CSIRO LAND & WATER
www.csiro.au

CSIRO

Methodology for analysing the vulnerability to climate change of Ramsar wetlands sites

Prepared for the Australian Government Department of the Environment and Energy

Michael Dunlop and Nicola Grigg

Australian Government

Citation

Dunlop M and N Grigg (2019) Methodology for analysing the vulnerability to climate change of Ramsar wetlands sites. CSIRO. doi https://doi.org/10.25919/5f5fbdb711fab

Cover image

Straw-necked ibis, Macquarie Marshes Ramsar Site

© Heather McGinness

Contents

Tables

Acknowledgments

The authors are indebted to members of the Wetlands and Aquatic Ecosystem Sub Committee and the Wetlands team of the Australian Government Department of the Environment and Energy who contributed invaluably to the development of this methodology. We acknowledge their contributions through multiple meetings, phone hook ups, workshops and comments while this methodology was being scoped, prototyped and finalised.

Development of this methodology has drawn on a nuanced understanding of climate adaptation and how it intersects with the needs of decision makers that has been developed over the past decade by the 'adaptation pathways' community within CSIRO and the Transformational Adaptation Research Alliance internationally. We particularly acknowledge the wisdom and insights of Paul Ryan (Australian Resilience Centre) who has been especially invaluable in the hard work and art of translating new ideas about adaptation into effective engagement processes.

We would also like to thank Nicolás Marin from ANU and University of Pontificia Universidad Javeriana, Colombia, for his assistance, particularly in the design of the workshop used to test the prototype of the methodology, and for the facilitation hint included in Step 13. Thanks to Heather McGinness for providing photograph used on the cover.

This methodology was adapted from the *Climate-ready biodiversity management tool* developed for the Sydney Coastal Councils Group (Dunlop & Ryan 2016).

This project was funded by the Australian Government Department of the Environment and Energy and CSIRO.

1 Introduction

In Australia, multiple studies have shown the potential for climate change to lead to very significant impacts on wetlands over the coming century (Barmuta et al. 2013; Bino et al. 2013; Catford et al. 2013; James et al. 2013; Lester et al. 2013; Capon and Bunn 2015; James et al. 2017). In recognition of the sensitivity of wetlands to climate change there is a growing need by managers and policy makers to better understand the potential consequences of climate change for the wetlands they are seeking to conserve. CSIRO, in collaboration with the Wetlands and Aquatic Ecosystems Subcommittee, has developed this methodology for investigating the potential vulnerability to climate change of wetlands in Australia that have been designated under the Ramsar Convention on Wetlands of International Importance.

The Ramsar Convention was signed in 1971 to create an institution and guidance to facilitate the conservation of internationally significant wetlands and the wise use of all wetlands. Australia has 66 Ramsar sites covering an area of more than 8.3 million hectares, spanning marine, coastal and inland locations, including permanent and ephemeral wetlands, in all climatic zones and jurisdictions. While the Australian Government is responsible for administering Australia's obligations under the Convention and manages a number of sites, most sites are managed by State and Territory governments, with a small number of privately owned and managed sites.

Wetland sites are listed under the Ramsar Convention by reference to a set of criteria for recognising wetlands of international importance (DEWHA 2008). Once listed the intention is to maintain the 'ecological character' of wetlands. Ecological character is defined as: 'the combination of the ecosystem components, processes and benefits and services that characterise the wetland at a given point in time' (DEWHA 2008). Components include biological, chemical and physical features; processes cover hydrological, nutrient, energy, soil, primary production, species interactions, dispersal and migration; and services include provisioning, regulating, supporting and cultural. A Ramsar Information Sheet (RIS) is required, under the Ramsar Convention, to be prepared for each Ramsar wetland 'at a point in time', usually at the time of listing. The RIS is updated every 6 years. The ecological character of the Ramsar wetland, comprising its critical ecosystem components processes and services, is described in the RIS and establishes the baseline against which the site is managed and ecological change can be assessed. Information about a Ramsar site's ecological character may also be available in a management plan or in a separate ecological character description document.

Where wetlands experience an adverse change in their character, due to anthropogenic activities, parties to the Convention are obliged under Article 3.2 of the Convention to notify the Ramsar Secretariat about the change. There is also an expectation for parties to notify if a change in character is likely. A response strategy to address the change should also be developed, as set out in national guidance (DEWHA 2009).

The ecological character that is described need not represent a pristine or natural state, especially for wetlands that have resulted from human activities. The Convention also commits parties to the 'wise use' of all wetlands, not just those listed. Wise use is defined as 'maintaining their ecological character … within the context of sustainable development'.

The Ramsar Convention, aims to maintain wetlands according to their ecological character as described in the RIS, accommodating variation or alternative natural states. Ecological character has traditionally been interpreted as essentially a stationary[1] concept, with fixed boundaries, abundances of particular species, and classification of wetland types (DEWHA 2008; Finlayson et al. 2017). The prospect of widespread and

[1] Stationary is often used to describe systems that vary, but within fixed bounds, between given states or with a relatively static average condition. It contrasts to systems that are trending away from their historic conditions, even where there is variation around that trend.

significant ecological change, driven by climate change, presents challenges for the implementation of the Ramsar Convention and for the management of Ramsar site.

Over time, climate change has the potential to drive widespread ecological change in wetlands and it is likely that Ramsar wetland management will, in most situations, need to adapt to accommodate these changes (Pritchard 2014; Finlayson et al. 2017). As a result, to usefully inform decisions about management investments that are sustainable and effective in the long term (Adger 2006; Chapman 2011), analyses of the vulnerability of wetlands need to consider the future dynamics of wetlands, not just the potential for them to change.

Intent of the analysis

This methodology has been designed to guide managers in their exploration of the ecological changes that might occur at their sites as a result of climate change. It sets out to provide a standard method to help Ramsar site managers explore future changes to wetland sites, understand their vulnerabilities, and start considering the consequences for management and policy at various levels of governance. It provides a set of concepts to enable managers to think about the issues in their own wetlands and to document this process and share experiences of doing it with other managers. This will enable development of a collective knowledge base to underpin adaptation of wetland policy and management. It will help site managers communicate clearly and in a structured way with wetland stakeholders about maintaining values in the face of climate and ecological change.

The methodology helps managers identify the extent to which various ecological values of their sites could be managed to persist even in the face of ecological change (Dunlop et al. 2013). So, while facing change is challenging, identifying that many ecological values can potentially be preserved helps provide assurance and some indication of how management might be adapted to accommodate change. The methodology draws on the *Climate-ready biodiversity management tool* (Dunlop & Ryan 2016; case study in Dunlop et al. 2017; see also van Kerkhoff et al. 2018). The approach is consistent with the scan cycle described in *Climate Compass – A climate risk management framework of Commonwealth agencies* (CSIRO 2018).

We suggest the analyses conducted with this methodology be coupled with a *pathway approach* to planning future adaptation. Adaptation pathway approaches identify the changes in policy and management that might be required sometime in the future as climate change continues, and then scope the work that needs to be done by management and policy agencies, research organisations and civil society in the near term to lay the foundation for a considered, gradual and informed transition as and when the need arises (Stafford Smith et al. 2014; Wise et al. 2014; Finlayson et al. 2017). This near-term work could be implemented as part of an adaptive management cycle.

It is important to note that despite the prospect of significant ecological change in the future, the current intent of the Ramsar Convention, to maintain ecological character, and the mechanisms used to address current threats continue to be valid and effective.

Understanding the vulnerability of wetlands

This assessment process has been developed in the context that almost all wetlands are likely to be affected by climate change, and that these impacts have the potential to change the ecological character of many wetlands, over time, challenging the current objective of maintaining ecological character. The assessment process seeks to explore the potential future impacts on wetlands in a way that enables Ramsar managers and others in the wetland community to gain a new understanding of the impacts of climate change and develop new potential solutions. Specifically, this analysis focusses on unpacking two key dimensions: the *value* of wetlands and the *dynamics* of change to assess climate change vulnerability in the context of the prospect of future changes in ecological character. This could be used to identify adaptation responses, communicate the imperative for climate mitigation, explore sensitivity to water allocation, prioritise investment, design monitoring, suggest areas for further investigation, and engage with stakeholders.

Overview of the methodology

Logic

A key concept of the methodology is the idea that with almost all ecological change there will be something that persists, and that often there is considerable value in what persists, even if some value is lost through the change. For example, in a drying landscape a permanent wetland may become intermittent, in doing so there may be a change in the species it supports, its value as a refuge may decrease, but it may still be a wetland with many wetland species, functions and benefits, still be wetter than other parts of the landscape during dry periods, and continue to meet the criteria for international importance. The methodology steps users through the process of exploring change that can be anticipated at a site, analysing how this might affect the multiple values associated with the site, interpreting this in terms of vulnerability, then exploring the consequences.

The process is driven by consideration of hydrological and ecological change, but it intersects with social and institutional considerations, as these can contribute to vulnerability. The methodology uses the Ramsar Convention terminology of components, processes and services, ecological character, criteria for international importance of wetlands, but it also draws on broader expressions of value for wetland sites.

The methodology has three stages, with steps to guide the user through the analysis (Figure 1). A series of tables are provided as templates for recording the deliberations and results. It is expected the analysis will be done by a group of people, typically the site manager, some colleagues and some additional experts. The process works well when multiple perspectives and expertise are combined to deliberate on the steps. It could also be done by an individual or modified to use as a stakeholder engagement tool.

Stage 1. Understanding context is about developing a shared basis for the analysis. Much of the context will be familiar to site managers and documented in the RIS, the ecological character description if available, or the management plan. However, the methodology is a process of thinking differently about a site, and it helps to step back and explore the broader context, including the social and institutional setting and information from other stakeholders, to provide a foundation for the analysis. This step is relatively straightforward, ahead of the following steps that involve concepts and analysis that may be less familiar to participants.

Stage 2. Scoping future impacts starts with initial concerns and known sensitivities about hydrological and ecological impacts, brings in climate change projections for the site or region, constructs a scenario of 'greatest plausible change' for the site, then constructs a 'change-persistence table' for the site. The change-persistence table documents understanding about how different features of the site might change and persist. This is used to explore the consequences for Ramsar and other values associated with the site, and implications for future management and knowledge about the site. The idea behind greatest plausible change is explained in a section below.

Stage 3. Interpretation guides the users through exploration of the results of Stage 2. It starts with a series of questions designed to facilitate deliberation among participants about the data collected in the previous stage. Guidance is then provided to elicit and document some key messages and conclusions about the vulnerability of the site. Users are guided to document any insights or implications for policy or management that have been revealed, noting that structured adaptation analysis planning is beyond the scope of the methodology.

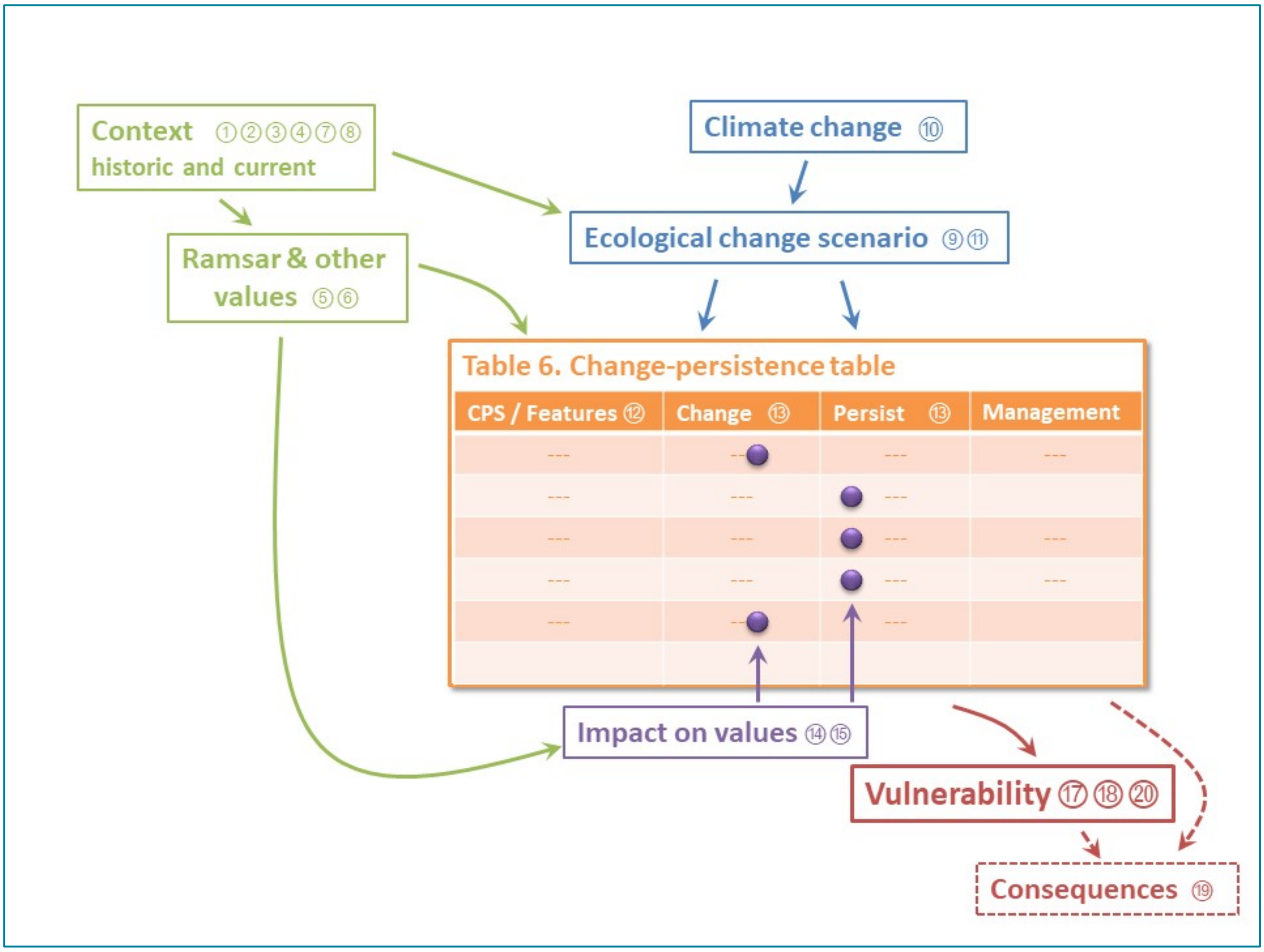

Figure 1 Workflow of the Ramsar site vulnerability assessment methodology
Circled numbers refer to the steps. CPS / features = the components, processes and services that are critical to the described ecological character of the site and other features valued by stakeholders. Step 19, Consequences, is dashed indicating comprehensive adaptation assessment is beyond the scope of this methodology.

Learning

Globally, protected area managers are still trying to work out how to make sense of and respond to the challenge of anticipated significant ecological change. The task is hard; significant impacts of climate change on wetlands are not yet widespread, so there is limited lived experience of vulnerability or adaptation, and many managers have had limited experience seriously assessing the implications of climate change at the site level (e.g. Colloff et al. 2017). Participants using this methodology cannot be expected to be expert at the task. Compounding this unfamiliarity, some participants may find consideration of future change personally challenging.

The process described here has been designed to help people engage with and use a range of concepts that they may not be familiar with. Some suggestions are included below to help make it easier for participants to both complete the process and learn more effectively about the core concepts and about climate adaptation more generally.

- Create a setting in which it is safe for participants to engage with ideas they may find challenging. Explicitly acknowledge any discomfort and dissonance participants may experience. Do not use this methodology in a high-stakes situation unless you are familiar with it.
- During the process and at the end, pause and reflect on the experience of doing the process and the concepts being used, in addition to the content.
- Provide feedback to the wetlands community and to the authors, to improve implementation of the methodology.
- When undertaking for the first time, it might be beneficial for users to seek advice from managers who have experience using the methodology.

Case studies

Two case studies were documented during the development of this methodology, to help trial a prototype of the process and to assist people wishing to use the process. The case studies illustrate the steps of the methodology and provide useful guidance in interpreting the analytical steps.

Note: However, ***they should not be regarded as definitive 'CSIRO assessments' of the vulnerability of the two sites.*** They were developed by the authors of the methodology, not by site managers. They used generalised knowledge of the impacts of climate change on wetlands and readily available information about the sites in the recent past (largely the ecological character descriptions, but also other material provided by the site managers), rather than drawing on a broad base of knowledge and local expertise or detailed studies of climate change impacts for the sites. They were also largely completed before final adjustments to the methodology were made so there may be some small inconsistencies.

Anticipating future ecological change

This methodology revolves around participants anticipating future ecological change. To do this the methodology uses a 'greatest plausible change' scenario and a qualitative assessment process. These decisions are based on over a decade of experience of adaptation analyses and are consistent with *Climate Compass: A climate risk management framework for Commonwealth agencies* (CSIRO 2018). This approach has proven effective for rapidly gaining an understanding of vulnerability and the nature of future adaptation decisions.

When considering vulnerability, there is little to be gained by concluding that a site is not vulnerable in the near term or under minimal change scenarios if there is a clear possibility of future significant change that would require concerted action to reduce the loss. In the face of a wide range of climate change projections and uncertainty about the impact of climate change on wetlands, use of a greatest plausible change scenario provides a balance between considering catastrophic changes (where everything is vulnerable and little adaptation action can be taken) and small changes. By considering greatest plausible change, there is no assumption that change will happen sooner than it will or that it will happen to the extent anticipated. Uncertainties associated with the rate and magnitude of change do need to be accommodated in the planning of adaptation responses, for example using an adaptation pathway approach. By understanding vulnerability to greatest plausible change and how to prepare for a possible transition to coping with it, society will be better prepared for large change (if and when it eventuates), and this preparation will help in dealing with smaller changes in the meantime, in particular by helping to prevent potentially maladaptive responses. Using a greatest plausible change scenario does work very well in practice, even in situations where managers are very reluctant to consider near-term changes in objectives or more than the smallest of near-term changes in management.

Similarly, this methodology can be undertaken with only qualitative information about hydrological and ecological impacts of climate change on a site. While quantification can be useful, it is not essential for identifying potential vulnerabilities or future adaptation actions, and where it is available it is not likely to be the most important information. Regional climate change projections of some climate variables are available for all Ramsar sites, however very few have modelling of hydrological or ecological responses. Experience has also shown that participants may focus on quantitative information at the expense of factors that are not so well understood but are likely to be more important in determining ecological outcomes and vulnerability, such as how climate change might affect ecosystem processes, species interactions and anthropogenic pressures. Once future potential vulnerabilities and management decisions have been identified, wetland managers can then carefully determine what quantitative data might be needed at what time and with what specification to help them make future decisions.

Further discussion of the use of greatest plausible change scenarios and doing assessments with minimal quantification of hydrological and ecological impacts is provided in the Appendix.

2 Climate-ready vulnerability assessment steps

In this methodology the term CPS, for components, processes and services, is used to refer to the hydrological and ecological values of the site that are identified as critical to its ecological character. These are described in the site's RIS or a separately published ecological character description. This methodology also includes other features of the site that correspond to the Ramsar criteria for which the site was listed and features that may be considered important to various stakeholders but that have not been described as critical to its ecological character.

Stage 1. Understanding context

This stage helps confirm the scope of the site being assessed as a guide to the information and understanding needed to do the analysis. It starts people thinking and talking about the site in a way that is possibly broader and more future-oriented than they may do for operational planning and management. Most of the information required for this section will be available in the RIS and a separate ecological character description of the site if available. Additional information can be provided from management plans, research reports, site managers, other experts and stakeholders.

Table 1 is a template for summarising the information prompted in the steps below. It provides a standardised way to collate information about the site to aid analysis, communication and comparison with other Ramsar sites.

There is a logical sequence to the steps in the assessment, but they do not have to be completed strictly in order. Reviewing documents and group deliberation can be expected to elicit information that will be relevant to several steps. For each step, ➢ indicates the task and ○ indicates guidance on the content.

Step 1. Physical description of the site

➢ Briefly describe the site:

- ○ Location, size
- ○ Number and type of wetlands and key functions
- ○ State it was in at time of listing
- ○ Underlying hydrology
- ○ Other uses, impinging uses and threats
- ○ Relationships with other sites (e.g. staging areas for migratory birds)
- ○ Include a map of the site and a conceptual model of the wetland system.

Step 2. Institutional context of the site

➢ Briefly describe the institutional context of the site:

- ○ Date of Ramsar listing
- ○ Current managers
- ○ Catchment water allocation processes
- ○ Other state or regional management frameworks that apply

    - Management and regulation of other activities in the catchment that might affect water quality or quantity.

Step 3. History of use and change

- How has the site historically been used?
    - Change in use of the site, over say the past 100 years
    - Groups that have used it in the past
- How has the ecological character of the site changed over the same time period?

Step 4. Current stakeholders and their relationships to the site (values at stake)

- Who values the site and why?
    - Groups that have some relationship with the site
    - Include managers (in their stewardship role)
    - Features of the site they relate to or value
    - *What's at stake?* The aspects of the site that different stakeholders would be upset about if they experienced change
    - Identify the specific physical or ecological attributes underpinning these values.

Step 5. Ramsar values

- What are the components, processes and services that are critical to the ecological character (as described) and support the criteria for which the site was listed as internationally important?
    - Components
    - Processes
    - Services
    - Ramsar criteria under which the site was listed.

Step 6. Current threats and changes

- What are the current threats to the site, and how has it changed in response?
    - Include direct anthropogenic threats and natural processes
    - Include possible lag effects and cumulative impacts
    - Altered hydrological processes
    - Recent ecological changes
    - Changes in character or other values
    - Timing of the threat: a short intense disturbance (either one off or regular), a threat that is increasing, or one that is persistent and steady
    - Level of natural recovery
    - What restoration has been applied, or might be required?

Step 7. Responses to past extremes

- How has the site responded to extreme events in the past?
    - Millennium drought
    - Fires
    - Storms and cyclones

  - Flooding
  - Paleo events
  - Did the site recover to its original condition or to a changed state?
  - Any active management that has been used, and its success in restoring the site.

Step 8. Current management activities and priorities

- How is the site managed?
  - Current management activities
  - Management that might be done if more resources were available
  - Conflicting objectives or trade-offs in the management.

Table 1 Key characteristics of the site

CHARACTERISTICS	SITE
Physical description	Physical Hydrology Ecology
Institutional context	
History of use and change	
Current stakeholders and their relationships to the site (values at stake)	
Ramsar values	Ecological character - critical components, processes and services Ramsar Criteria
Current threats and changes	
Responses to recent extremes	
Current management activities and priorities	

Stage 2. Scoping future impacts

- Note any uncertainties or contingencies that might affect how climate change affects the conservation issue. Record them in Table 2.

Table 2 Uncertainties

UNCERTAINTIES
For example: Will the site regularly become fire prone?

UNCERTAINTIES
Will some wetlands become completely terrestrialised, stop filling ever?
Will the same types of habitats be present but in different areas, or will the types of habitat change?

Step 9. Key climate change concerns for the site

- What are the hydrological and ecological impacts of climate change that are of most concern to managers and regulators?
  - Identify different *types* of change that are relevant, rather than just the amounts of change
  - Focus particularly on changes that might lead to significant changes in management
  - Include how threats might be affected by climate change, and the consequence of this for the site
  - Draw on current trends, responses to past events, specific knowledge about the dynamics of the site, modelling, general knowledge about ecological impacts of climate change. If necessary, draw on specific climate change projections (next step)
  - Summarise changes in Table 3. This does not need to be exhaustive as it will be expanded upon in Step 11.

Table 3 Future ecological changes anticipated to affect the site

FUTURE ECOLOGICAL CHANGES
For example: Ephemeral wetlands fill less often and for shorter periods
Increased competition for water resources
Water bird breeding less successful
Terrestrialisation of mudflats

Step 10. Projected climate change

- What are the relevant climate change trajectories for the site? What is the greatest plausible climate change for the site?
  - Record a summary of key findings from climate change projections in Table 4.
  - The steps below outline how to explore relevant change using Climate Change in Australia[2]. Many states have other climate change information, some including additional climate change projections.
  - *The intent is to gain a broad appreciation of the trajectories and magnitudes of climate change that might drive ecological changes that would be regarded as significant for the site in the long*

[2] https://www.climatechangeinaustralia.gov.au/en/
Registration will be required for some tools, but it only takes 1 minute.

term. There is no need to be probabilistic, or summarise all possible rates of change and timeframes.

  - Read the summary of projected climate change for the site's sub-regional NRM cluster in Climate Change in Australia: https://www.climatechangeinaustralia.gov.au/en/climate-projections/future-climate/regional-climate-change-explorer/sub-clusters/
  - Identify the greatest plausible changes for key climate variables using the Climate Futures Exploration Tool. Use scenario RCP 8.5, year 2090, choose variables of most interest to the site (from previous step, Table 3; e.g. Annual Rainfall, Annual Average Temperature, Time in Drought (you can only choose two at a time), then click on the region the site is in. From the results matrix, for each variable, identify the consensus maximum change (i.e. the change for the variable that is projected by at least 50% of climate models): https://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-futures-tool/projections/
  - Use the Climate Analogues tool to identify which locations currently have a climate similar to that projected for the site. Use scenario RCP 8.5, year 2090, and the 'maximum consensus' setting. On the map, click on the weather station closest to the site to see the identified analogues. Consider the environments and ecosystems currently found near those locations, and how similar or different they are to those at the site. You may need to choose 2050 *as well*, as analogues for 2090 may be so far away people are not familiar with them. This tool may be more effective for imagining future terrestrial ecosystems than wetlands, but it will enable users to gauge the magnitude of ecological change that might be associated with the projected climatic changes for the site: https://www.climatechangeinaustralia.gov.au/en/climate-projections/climate-analogues/analogues-explorer/

Table 4 Climate change at the site

CLIMATE CHANGE KEY MESSAGES
Example format *From Climate Change in Australia, XXXXX sub-cluster*
• Average temperatures will continue to increase in all seasons (XXX confidence). (Regionally, warming of XX°C by 2090 for a high emissions case RCP8.5). • More hot days and warm spells are projected (XXX confidence). • By late in the century, less rainfall is projected during the XXXX season (XXX confidence). Regionally, XX% decrease by 2090 for a high emissions case RCP8.5.
• Even though mean annual rainfall is projected to decline, heavy rainfall intensity is projected to increase, with XXX confidence.
• Potential evapotranspiration is projected to increase in all seasons as warming progresses (XXXX confidence). • Increases in radiation and decreases in relative humidity are projected later in the century (XXXX confidence).
• A XXXX fire-weather climate in the future (XXXXX confidence). • Locations that currently have a climate similar to that projected for the site (in 2090, RCP 8.5) include XXXX.

Step 11. Trajectories of future ecological change

- What are the most significant ecological changes that might occur at the site?
  - Record a summary of the key changes in Table 5.
  - Focus on a scenario of 'greatest plausible change'; don't get distracted with smaller, near-term change or catastrophic magnitudes of change.

- Record the elements you could draw on to provide an account of the changes. Consider: *How might you (or your successors) look back from 50 years hence and describe the ecological changes that have occurred?*
- Include the ecological and hydrological dynamics that lead to the changes.
- Include changes to threats and their impacts, and interacting and cascading impacts.
- Include key assumptions behind the changes, where necessary.
- Think about how the site (with its fixed location) might change, as well as how the mobile biotic components might change.
- Only develop multiple scenarios if different trajectories for the site are feasible and would be characterised by notably divergent ecological changes, or if the site has multiple wetlands that might have different trajectories.
- This scenario is to guide thinking; it will not be the only type of change that can be considered.
- You do not need to be excessively detailed; if necessary, you can come back to this step and record additional detail as you complete subsequent steps.

Table 5 Scenario of greatest plausible ecological change

SCENARIO OF GREATEST PLAUSIBLE ECOLOGICAL CHANGE
XXXXX and ZZZZZZ are the greatest concerns. This could manifest as:
Hydrologically
Ecologically
Interactions with other threats

Step 12. List key important or valued components, processes and services of the site

- Identify the critical components, processes and services (CPS) and other features that are valued and make the site important.
    - Draw on the features identified as important to stakeholders (Step 4), CPS listed in the RIS or separately published ecological character description if available (Step 5) and those potentially at risk due to climate change (Step 9).
    - List the CPS and other features that are valued in column 1 of Table 6.
    - Include hydrological and ecological components and processes.
    - Include CPS that are critical to the ecological character; highlight these (e.g. in bold text).
    - Include any additional features that correspond to Ramsar criteria under which the site was listed; highlight these (e.g. in bold text).
    - Include any additional features that correspond to other formally recognised values of the site that are valued more generally by different stakeholders. Some of these may relate to 'wise use'. These are included as they are part of the context within which the site is managed and may inform decisions about its future management and therefore affect its vulnerability.
    - Think broadly, for example include wilderness or naturalness of the site if they are important to stakeholders.
    - Include attributes of the whole ecosystem, as well as species-level components.

- Think about why the CPS / features are important and to whom.
- Where relevant, consider the fixed place *and* the components that might come and go from that place.
- Where climate change impacts vary between different wetlands at a site, create separate partitions in the table for the different wetlands and their CPS / features.
- To avoid an excessive number of rows, some CPS / features can be grouped into a single row initially, and then split into separate rows if different elements have different responses in Steps 14 and 15.

Step 13. Analysis of the impact of changes on key CPS and other valued features of the site (change-persistence table)

- Assess how the change might, and might not, affect the CPS and other valued features of the site:
  - Consider how each CPS / feature (rows in column 1, Table 6) might be affected under the identified ecological change scenario (Step 11); also consider other climate change impacts if they are likely to be important (Step 9).
  - List attributes that might change (column 2) and those that could feasibly persist despite the changes (column 3). These make a pair; there is always something that doesn't change.
  - In choosing these attributes assume realistic levels of good management of the site: i.e. changes that would be inevitable *despite good management* and attributes that might persist *with good management* despite the inevitable changes.
  - Note in column 4 where the management required to help attributes persist (column 3) is significantly different from current practice in magnitude, type or intent, or where changes in policy or resources might be required.
  - Add any additional key uncertainties in Table 2.
  - Note in column 5 any caveats or assumptions for specific rows. Comments with additional detail can also be included.
  - General assumptions about the dynamics of the ecological change trajectory for the site, including interactions and cascading impacts, can be captured in Step 11 (Table 5) and do not need to be repeated.
  - Additional rows can be added, if necessary, to document where different aspects of an identified CPS / feature vary in their patterns of change and persistence.

Facilitation hint: This part of the analysis can be difficult, it requires participants to think in a different way about the site. One way to facilitate completing the table is to have each participant complete columns 2 and 3 for a couple of rows on their own, then share and reflect on how they have interpreted the task. This reflection and group sense-making can foster better engagement with the task and learning from it. With that experience the group as a whole can work through constructing the rest of the table. A similar approach can be used for Steps 14 and 15. It may also help to consult the case studies.

Table 6 Change-persistence table

1. IMPORTANT CPS AND FEATURES OF THE SITE *	2. … ATTRIBUTES OF THIS CPS / FEATURE THAT MIGHT CHANGE	3. … ATTRIBUTES OF THIS CPS / FEATURE THAT COULD PERSIST	4. CHANGE IN MANAGEMENT OR DECISIONS REQUIRED FOR IDENTIFIED ATTRIBUTES IN COLUMN 3 TO PERSIST (OPTIONAL)	5. COMMENTS, OTHER CAVEATS OR ASSUMPTIONS (OPTIONAL)

* **CPS / features highlighted in bold** correspond to Ramsar values: components, process or services critical to the ecological character and other features corresponding to relevant Ramsar listing criteria.

Step 14. Analysis of the extent to which Ramsar values might be affected by change

- Assess the extent to which anticipated change would affect the ecological character as described and the Ramsar Criteria for which the site was listed:
  - For CPS that are critical to the ecological character (highlighted rows in column 1, Table 6), rate the extent to which the anticipated change could constitute a *change in described ecological character*
  - For CPS / features contributing to the Ramsar Criteria for which the site was nominated, rate the extent to which the anticipated change would *alter how the site meets each Ramsar criterion* including whether it *continues to meet each criterion*.
  - Icons or coloured dots could be used for each individual evaluation.
  - Additional rows can be added, if necessary, to document where Ramsar values associated with different ecological attributes of an identified CPS / feature vary in how they are affected by change.

Step 15. Analysis of the extent to which other values might be affected by change

- Assess how the values people associate with each feature might be affected:
  - For each feature (rows, Table 6), assess whether the stakeholder values related to that feature are associated with the changing or the persisting attributes of the feature. In other words, to what extent might the value of the feature persist in the face of the anticipated ecological change?
  - Annotate the table with icons to associate the value to stakeholders of the features with the attributes in columns 2 or 3.
  - Additional rows can be added, if necessary, to document where multiple values associated with different ecological attributes of an identified feature vary in how they are affected by change.
  - Summarise how the different values associated with the features are linked to attributes that are anticipated to change or persist (from Table 6 into Table 7).

Table 7 Summary of how values associated with CPS and other valued features are likely to change or persist with anticipated change to the CPS / features

1. IMPORTANT CPS AND OTHER VALUED FEATURES OF THE SITE	2 VALUES LIKELY TO BE AFFECTED BY CHANGED CPS / FEATURES	3. VALUES LIKELY TO PERSIST
Complex, unique hydrology supporting a wide diversity of types of lakes in an internally draining catchment	EC	Cons, Other
Habitat for migratory and endemic birds	EC	Ramsar, Cons, Other
Large, varied waterbird population	EC	Ramsar, Cons, Other
Refuge site, e.g. drought refuge	EC	Ramsar, Cons, Other
Bird observatory provides access to and information about the site, as well as scenic facilities for rest and nature appreciation	Cons	Cons, Other

Key
EC: The ecological character as described in the RIS or a separate ecological character description for the site.
Ramsar: The Ramsar listing criteria.
Cons: Other conservation values not included in the described ecological character or Ramsar listing criteria.
Other: Other non-conservation values associated with the site.

Step 16. Hydrological processes underpinning change in values

- Identify hydrological processes maintaining or driving change in key values:
  - For each Ramsar value, is the change (or persistence) of value associated with specific hydrological processes?
  - Across the site more broadly, are specific hydrological processes responsible for the general pattern of changes and persistence of values?

Stage 3. Interpretation

This stage is about interpreting the analysis conducted in Stage 2. The key steps in it involve having a conversation about the results and participants' impressions of the vulnerability of the site, documenting key patterns, and scoping key implications for the near term and longer term. The conversation is included to allow a free ranging exploration of the data, with the expectation that the results may include unexpected patterns and implications that need to be made sense of collectively.

This methodology is not intended to identify adaptation actions. However, it does include the opportunity to document any implications for planning or management that become apparent and to highlight examples where action might be warranted in the near term to enable better understanding of important change processes or to start preparing for timely responses in the future.

Finally, guidance is provided about how the elements above can be combined into a narrative that summarises the multiple dimensions of vulnerability explored in the analysis.

Step 17. Review the data

- Look for patterns in the data in Table 7 and have a conversation about the patterns, and their consequences. The following questions are to guide discussion to help participants collectively think about the results. Do take notes, but the key details will be elicited and documented in Step 18.
  - Are there CPS / features that stand out as particularly subject to change in character or values?
  - Are there CPS / features that stand out as likely to persist, i.e. retain character or values?
  - Particularly focus on CPS / features that may change ecologically but retain their Ramsar values or other conservation values.
  - For each row in the table, the CPS or feature with its changing and persisting attributes represent a trajectory of change. Are there particular trajectories that are different from the types of change that might result from current threats?
  - Are the drivers of the changes in the table similar to or different from the threats that are currently managed?
  - How important are interactions with other threats?
  - Are there key factors at the site that reduce vulnerability?
  - Look at the site as a whole. Is there general tendency for ecological character to change? Do Ramsar listing values or other conservation values tend to persist despite changes in particular components, processes or services?
  - When might these ecological changes occur? What observation, monitoring or modelling would be needed to detect or confirm that various changes were occurring or inevitable?
  - What change in management might be required to ensure values persist despite ecological changes anticipated in the table?
  - Has this analysis changed your understanding of vulnerability to climate change and how it might be represented?
  - Has this analysis provided insights about near-term adaptation actions (noting that specific adaptation stages have not been included)?

Step 18. Document the key patterns

- Identify and document key patterns in the data in Table 7. Draw on the conversation in Step 17.

  Looking at individual CPS / features:
  - Identify those CPS / features that stand out as either particularly vulnerable to change…
  - … and those that are particularly resilient.
  - Identify those CPS / features that stand out as either particularly vulnerable to loss of Ramsar values (e.g. stop meeting a criterion) or other conservation values …
  - … and those that may retain their values.

  Looking at the site as a whole:
  - Select the category below which best describes the general pattern for CPS / features for the site:
    - components persisting
    - changed components but persisting processes and services
    - changed processes but persisting services
    - changed components, processes and services.

- Note features that counter the general trend.
- Select the category below which best describes the general trend for the site:
    - retains ecological character as described
    - risks change in ecological character, but still meets Ramsar criteria
    - risks failing to meet Ramsar criteria but retains other conservation values identified by stakeholders
    - risks loss of all conservation value.
- Note features that counter the general trend.
- Select the dominant drivers of the anticipated change (more than one may apply):
    - direct temperature, rainfall or sea-level rise impacts on components
    - altered hydrology
    - changes in species interactions
    - climate change causing increased susceptibility to threats
    - climate change causing increase in threats.
- Describe the change processes causing the most significant change
- Describe any separate change processes that are also important
- Describe any key factors at the site that help reduce its vulnerability (e.g. size, heterogeneity, isolation/connectivity, landscape context, receives groundwater from regional/large aquifers).

Step 19. Consequences of the patterns

- Identify and document any consequences of the results for describing the vulnerability of the site:
    - Select the level of vulnerability of the site in the face of greatest plausible change:
        - Site likely to be minimally affected by climate change
        - Site could feasibly be managed to maintain its character
        - Some change in character is inevitable but with good management the site will retain status as an internationally important wetland
        - Site may lose status as an internationally important wetland, but with good management the site could retain conservation and other values to national and local stakeholders
        - Even with concerted management, the site faces losing most of its value to stakeholders.
    - Select the nature of the vulnerability of the site in the face of greatest plausible climate change, i.e. which factors are priorities for monitoring and future management or policy interventions:
        - Increases in current threats
        - Direct climate change impacts
        - Climate change interacting with other threats, including new threats
        - Need to change management, but may not have the resources, skills or enabling planning or policy framework (e.g. no process to update objectives)
        - Loss of status due to change in ecological character, even though the site is still worth conserving against Ramsar or other criteria

- Ecological outcomes in the site critically depend on how future water allocation processes across the catchment deal with reduced availability
- Cross-jurisdictional issues affect how climate change will affect the site
- Other.

➢ Identify and document consequences of the results for *long-term* management and policy. Note that this methodology has not specifically addressed adaptation responses. The questions below are intended as prompts to help capture any insights that did emerge.

  - Can you anticipate how new 'climate-ready objectives' could be formed, i.e. ones that are feasible and retain the values associated with the persisting attributes of the CPS / features of the site (column 3, in Table 6) as it undergoes change?
  - Can you anticipate when, on the trajectory of change, managers may need to switch from seeking to prevent ecological change to new objectives that accommodate change? Has this already occurred?
  - What change in management might be required to preserve values associated with persisting attributes of the CPS / features, while accommodating those aspects of ecological change that are inevitable?
  - Does the analysis provide insight about how to accommodate some inevitable ecological change due to climate change while effectively preventing inappropriate anthropogenic change?
  - Does the analysis provide insights about how change in character, for the purposes or Article 3.2 reporting, might be assessed in the face of climate change?
  - Does the analysis provide insights about how Ramsar values (ecological character, criteria) might be described in the face of climate change? Recognising that, for most sites, this is a *future* issue.

➢ Identify and document consequences for *near-term* management and policy. Note that this methodology has not specifically addressed adaptation responses. The questions below are intended to help capture any insights that did emerge.

  - What barriers can you foresee to changes in management that might be required in the near- or longer-term? Include technical (knowledge), social (values) and institutional (rules) barriers.
  - Does the analysis provide any insights into priority monitoring or research to better understand changes in CPS / features or to guide new management or objective setting?
  - What knowledge would be needed to help identify when changes in management or objectives were appropriate, including biophysical, social and institutional?

Step 20. Summary statement of vulnerability of the site

➢ Summarise the knowledge and insights about the site's vulnerability to climate change by developing a short narrative. This narrative could be tailored for different communication purposes, such as reporting or education.

  - The paragraphs below could be used to guide drafting of a summary statement about the site. Replace the text in square brackets with appropriate statements informed by the synthesis and analysis above.

The [name] Ramsar site is vulnerable to [main changes / change in character] in the face of significant climate change, but is likely to retain [main persisting features / (most) Ramsar criteria and other conservation values].

The major climatic changes of concern for this site are [reduced rainfall, increased temperature, sea-level rise, …], which would lead to [hydrological change] and [ecological change] at the site. In particular, climate change is likely to affect [components] by [how]. This in turn would affect [processes] and [services]. In addition [other valued features] could [change].

Despite these changes [some components] can be expected to persist. Similarly [process and services] are likely to persist, and the site can be expected to retain [other conservation values].

The site may cease to meet criteria [###], but would continue to meet criteria [zzz].

Threatening process at the site are expected to [interact / increase / new ones]. Overall, the site will be most threatened by [current anthropogenic threats amplified by climate change / emerging anthropogenic threats / direct climate change impacts in the catchment or on site / a combination of climate change and threats].

In order to retain values as it changes, [changes in management and policy] may be needed. The key processes driving change are [hydrological / ecological process / institutional] which [may need additional monitoring / research / has already begun being monitored] to understand their future dynamics.

3 References

Adger WN (2006) Vulnerability. *Global Environmental Change*, 16(3), 268–281.

Barmuta L, Davies P, Watson A, Lacey M, Graham B, Read M, Carter S and Warfe D (2013) *Joining the dots: Integrating climate and hydrological projections with freshwater ecosystem values to develop adaptation options for conserving freshwater biodiversity.* National Climate Change Adaptation Research Facility, Gold Coast, 190 pp.

Bino G, Jenkins K and Kingsford RT (2013) *Adaptive management of Ramsar wetlands*, National Climate Change Adaptation Research Facility, Gold Coast, 222 pp.

Capon S and Bunn S (2015) Assessing climate change risks and prioritising adaptation options using a water ecosystem services-based approach. In J Martin-Ortega, R Ferrier, I Gordon and S Khan (Eds.), *Water Ecosystem Services: A Global Perspective* (International Hydrology Series, pp. 17–25). Cambridge: Cambridge University Press. doi:10.1017/CBO9781316178904.004

Catford JA, Naiman RJ, Chambers LE, Roberts J, Douglas M and Davies P (2013) Predicting novel riparian ecosystems in a changing climate. *Ecosystems* 16(3), 382–400.

Chapman PM (2011) Global climate change means never going home again. *Marine Pollution Bulletin*, 62(11), 2269.

Colloff MJ, Lavorel S, van Kerkhoff,LE, Wyborn CA, Fazey I, Gorddard R, Mace GM, Foden WB, Dunlop M, Prentice IC and Crowley J (2017) Transforming conservation science and practice for a postnormal world. *Conservation Biology, 31*(5), 1008–1017.

CSIRO (2018) *Climate Compass: A climate risk management framework for Commonwealth agencies*. CSIRO, Australia. https://www.environment.gov.au/climate-change/adaptation/publications/climate-compass-climate-risk-management-framework

DEWHA (Department of the Environment, Water, Heritage and the Arts) (2008) *National Framework and Guidance for Describing the Ecological Character of Australia's Ramsar Wetlands. Module 2 of the National Guidelines for Ramsar Wetlands—Implementing the Ramsar Convention in Australia.* Australian Government Department of the Environment, Water, Heritage and the Arts, Canberra.

DEWHA (Department of the Environment, Water, Heritage and the Arts) (2009) *National Guidelines for Notifying Change in Ecological Character of Australian Ramsar Sites (Article 3.2). Module 3 of the National Guidelines for Ramsar Wetlands—Implementing the Ramsar Convention in Australia.* Australian Government Department of the Environment, Water, Heritage and the Arts, Canberra.

Dunlop M, Parris H, Ryan P and Kroon F (2013) *Climate-ready conservation objectives: a scoping study*. Gold Coast: National Climate Change Adaptation Research Facility.

Dunlop M and Ryan P (2016) *Climate-ready biodiversity management: a tool to help design biodiversity projects in the face of climate change*. CSIRO. https://doi.org/10.4225/08/5852daf3f234f

Dunlop M, Ryan P, McGuinness S and Glynn A (2017) *Scoping climate-ready management of Eastern Suburbs Banksia Scrub in Queens Park, Sydney*. CSIRO. https://doi.org/10.4225/08/5ac520bd3fbc7

Finlayson CM, Capon SJ, Rissik D, Pittock J, Fisk G, Davidson NC, Bodmin KA, Papas P, Robertson HA, Schallenberg M and Saintilan N (2017) Policy considerations for managing wetlands under a changing climate. *Marine and Freshwater Research, 68*(10), 1803–1815.

James CS, VanDerWal J, Capon SJ, Hodgson L, Waltham N, Ward DP, Anderson BJ and Pearson RG (2013) *Identifying climate refuges for freshwater biodiversity across Australia*, National Climate Change Adaptation Research Facility, Gold Coast, 424 pp.

James CS, Reside AE, VanDerWal J, Pearson RG, Burrows D, Capon SJ, Harwood TD, Hodgson L and Waltham NJ (2017) Sink or swim? Potential for high faunal turnover in Australian rivers under climate change. *Journal of Biogeography*, 44(3), 489–501.

Lester RE, Fairweather PG, Webster T and Quin RA (2013) Scenarios involving future climate and water extraction: ecosystem states in the estuary of Australia's largest river. *Ecological Applications, 23(*5), 984–998.

Pritchard D (2014) *Change in ecological character of wetland sites – a review of Ramsar guidance and mechanisms*. Consultant's Report for Ramsar Convention Secretariat, Gland, Switzerland.

Stafford Smith M, Horrocks L, Harvey A and Hamilton C (2011) Rethinking adaptation for a 4° C world. *Philosophical transactions. Series A, Mathematical, physical, and engineering sciences, 369*(1934), 196–216.

van Kerkhoff L, Munera C, Dudley N, Guevara O, Wyborn C, Figueroa C, Dunlop M, Hoyos MA, Castiblanco J and Becerra L (2018) Towards future-oriented conservation: managing protected areas in an era of climate change. *Ambio*, 1–15.

Wise RM, Fazey I, Stafford Smith M, Park SE, Eakin HC, Van Garderen EA and Campbell B (2014) Reconceptualising adaptation to climate change as part of pathways of change and response. *Global Environmental Change, 28,* 325–336.

Appendix

Greatest Plausible Change

Frequently people are uncomfortable with using a single scenario, especially when it involves considerable change that will probably occur at a time well beyond their planning horizon or even lifespan. It can feel like it is setting one up to fail, and not relevant; experience has shown that while a greatest plausible change scenario can be challenging, the approach is very effective.

A greatest plausible change scenario is a balance between considering catastrophic changes and small changes. A very large change scenario causes people to simply disengage, it's likely unrealistic and there is little that people can do to effectively prepare for it. Small, near-term change is appealing, but can be very misleading. It encourages people to believe they can act to resist climate change, which they may be able to for small levels or short timeframes. However, it prevents them engaging with the new challenges of climate change. Smaller changes will have different ecological dynamics and require different actions, which means people will not seek to understand the more complicated dynamics of larger changes, nor the significant challenges of managing them. In addition, there is an increasing understanding that near-term resistance actions can be maladaptive in the longer term by making adaptation to larger change much harder to achieve.

Greatest plausible change scenarios are often challenging. People can readily imagine the consequences, which typically include the loss of things that are valued, and they sense that there is not much they could do without infeasible amounts of intervention to prevent the change. At first appearance they undermine hope and agency. However, with a carefully designed process it is possible to identify how management can be applied to achieve good outcomes. This does call for participants to engage with changes in how wetlands are traditionally managed, which can be challenging. The process in this methodology is specifically designed to help people engage with greatest plausible change in an easy and safe way, to see all is not lost and they would have agency to influence the outcomes.

Using an adaptation pathway approach, identifying vulnerability to a greatest plausible change scenario will suggest that some responses to it might be required. Planning that response involves engaging with the trajectory through smaller levels of change to that large change. This will help managers decide when to start acting differently and on what basis they might do this, for example using observed change (what, by whom, with what process, and what confidence) or modelled change (of what, by whom, how far beforehand) or some other processes. A pathways approach also helps identify actions that are simultaneously suitable for smaller levels of change and lay a foundation for transitions in management to deal with more significant ecological change.

Using a greatest plausible change scenario, with pathways planning, does not aim to commit people to future action that is not needed. Rather, it helps avoid the situation where future managers are not able to respond effectively when they need to because of action taken or not taken in the near term. While future large change might be beyond the current planning horizon, preparing for large change needs to start as soon as possible given that it will likely take many decades to get ready, or the change may come sooner than anticipated. Long-term foresighting is a near-term planning tool.

Quantification

The use of a qualitative process to assess vulnerability may be unexpected or a challenge especially for participants who are used to using highly quantitative methods such as detailed hydrological modelling. Where quantification is available it can be used with this methodology, but it is not essential.

Quantification, especially mapping, can be very useful for helping participants engage with the magnitude of future change, and for helping to illustrate where future change may be beyond the bounds of variation or past experience. However, the availability of some quantified information can readily distract attention from the wide range of ecological and institutional processes that are not well quantified but may significantly affect how sites are affected by climate change. Importantly, focusing on quantification of impacts and uncertainty can distract focus away from decisions about wetland management and policy that may need to be made in the future. The approach used here is designed to fast track consideration of future vulnerability and decision-making challenges. The nature of the information needed to support those decisions can then be scoped, and monitoring, research and consultation processes can be designed to meet those future needs.

Quantification of future hydrological and ecological impacts depends on modelling which has uncertainties and assumptions. Some uncertainties can be characterised, such as emission trajectories, others are very hard to assess such as non-linear ecological responses, and assumptions about 'other things being equal'. Similarly, it is likely that new interactions between ecological phenomena and between biota will be significant, and as a rule these cannot be modelled. Hence quantification at best provides a partial description of future change.

The Climate Analogues tool in Climate Change in Australia highlights a useful hybrid approach. It uses extensive quantification of current and projected climate variables to identify locations that have a current climate similar to that projected under climate change for a chosen site. It is then left to the user to qualitatively assess the multiple similarities and differences between the analogue locations and the chosen site in terms of the factors of interest, such as the ecosystem types that are present.

Finally, whether quantitative data is available or not there will always be uncertainty in any vulnerability assessments and adaptation planning which must be accounted for in the design of adaptation planning processes. The adaptation pathways approach has been developed specifically to deal with such uncertainty.

If quantitative analyses are available, they can be used but with care to ensure the wider range of phenomena that will be important and are not quantified are also considered. Finally, lack of availability of quantitative data about current dynamics or future impacts should never be an excuse to delay undertaking a vulnerability or adaptation analysis.

CONTACT US

t 1300 363 400
+61 3 9545 2176
e enquiries@csiro.au
w www.csiro.au

FOR FURTHER INFORMATION

Land and water
Dr Michael Dunlop
t +61 2 6246 4102
e michael.dunlop@csiro.au
w www.csiro.au/landandwater