Ramsar
Technical
Reports

Ramsar Technical Report No. 5
CBD Technical Series No. 57

A Framework for assessing the vulnerability of wetlands to climate change

Habiba Gitay, C. Max Finlayson, and
Nick Davidson

05

Ramsar Technical Report No. 5
CBD Technical Series No. 57

A Framework for assessing the vulnerability of wetlands to climate change

Habiba Gitay[1], C. Max Finlayson[2] & Nick Davidson[3]

[1] Senior Environmental Specialist, The World Bank, Washington DC, USA

[2] Professor for Ecology and Biodiversity, Institute for Land, Water and Society, Charles Sturt University, Albury, Australia

[3] Deputy Secretary General, Ramsar Convention Secretariat, Gland, Switzerland

Ramsar Convention Secretariat

Gland, Switzerland

June 2011

Published jointly by the Secretariat of the Convention on Wetlands (Ramsar, Iran, 1971) and the Secretariat of the Convention on Biological Diversity.

This report should be cited as: Gitay, H., Finlayson, C.M. & Davidson, N.C. 2011. *A Framework for assessing the vulnerability of wetlands to climate change*. Ramsar Technical Report No. 5/CBD Technical Series No. 57. Ramsar Convention Secretariat, Gland, Switzerland & Secretariat of the Convention on Biological Diversity, Montreal, Canada. ISBN 92-9225-361-1 (print); 92-9225-362-X (web).

Series editors: Heather MacKay (Chair of Ramsar Scientific & Technical Review Panel), Max Finlayson (former Chair of Ramsar Scientific & Technical Review Panel), and Nick Davidson (Deputy Secretary General, Ramsar Convention Secretariat).

Design & layout: Dwight Peck (Ramsar Convention Secretariat). Cover photo: Laguna Brava Ramsar Site, Argentina (Horacio de la Fuente)

Ramsar Technical Reports are designed to publish, chiefly through electronic media, technical notes, reviews and reports on wetland ecology, conservation, wise use and management, as an information support service to Contracting Parties and the wider wetland community in support of implementation of the Ramsar Convention.

In particular, the series includes the technical background reviews and reports prepared by the Convention's Scientific and Technical Review Panel (STRP) at the request of Contracting Parties, which would previously have been made available in most instances only as "Information Papers" for a Conference of the Parties (COP), in order to ensure increased and longer-term accessibility of such documents. Other reports not originating from COP requests to the STRP, but which are considered by the STRP to provide information relevant to supporting implementation of the Convention, may be proposed for inclusion in the series. All Ramsar Technical Reports are peer-reviewed by the members and observers appointed to the STRP and independent experts.

Ramsar Technical Reports are published in English in electronic (PDF) format. When resources permit, they are also published in French and Spanish, the other official languages of the Ramsar Convention.

For further information please contact:

Ramsar Convention Secretariat
Rue Mauverney 28
CH-1196 Gland
Switzerland
Fax: +41 (22) 999 0169
E-mail: ramsar@ramsar.org
Web: www.ramsar.org

Secretariat of the Convention on Biological Diversity
413, Saint Jacques Street, suite 800
Montreal, Quebec, Canada H2Y 1N9
Tel: +1 (514) 288-2220
Fax: +1 (514) 288-6588
E-mail: secretariat@biodiv.org
Web: www.biodiv.org

Ramsar Technical Report No. 5
CBD Technical Series No. 57

A Framework for assessing the vulnerability of wetlands to climate change

Habiba Gitay, C. Max Finlayson, & Nick Davidson

Contents

Foreword iv

Acknowledgements iv

Executive summary vi

1. Introduction 1
2. Vulnerability and assessment 1
   - 2.1 A definition of vulnerability 3
   - 2.2 Vulnerability assessment and risk assessment 3
3. Overview of methods and approaches for vulnerability assessment 4
   - 3.1 Different available approaches to assessing vulnerability 4
   - 3.2 Frameworks incorporating risks of climate change into development planning and projects 8
4. A framework for wetland vulnerability assessment 9
5. Challenges and information gaps 13
6. References 14

Foreword

Over the past four decades the Ramsar Convention on Wetlands has sought advice and adopted guidance on a suite of approaches and methods for wetland inventory, assessment and monitoring (see Ramsar Wise Use Handbook 13, 4th edition, 2010). As part of this guidance, the need to apply methods for assessing the vulnerability of wetlands, particularly in relation to the implications of global climate change, has become a focus of increasing attention. This report, providing a framework and methods for wetland vulnerability assessment, has been prepared in response to a request from the Ramsar Convention's Contracting Parties to the Convention's Scientific & Technical Review Panel (STRP) in Action 1.2.4 of the Ramsar Strategic Plan 2003-2008.

The work was initiated through a specific task in the STRP's 2003-2005 Work Plan, for the Panel's Expert Working Group 1 on wetland inventory and assessment, to "Develop methodologies for vulnerability assessment of wetlands to change in ecological character (including to impacts of climate change, alien species invasion and agricultural practices)". The guidance on vulnerability assessment forms part of a body of materials to support the Convention's *Integrated Framework for wetland inventory, assessment and monitoring*, which was adopted by the 9th meeting of the Conference of the Contracting Parties (in Resolution IX.1 Annex E, 2005, with additional material supplied by Information Paper COP9 DOC. 24) and subsequently updated periodically, most recently by the incorporation of the outcomes of COP10 in 2008 (Ramsar Wise Use Handbook 13).

The report draws upon, and as necessary elaborates and updates, information provided on vulnerability assessment presented to the Convention in 2002 (in Resolution VIII.3 and Information Paper COP8 DOC. 11, *Climate change and wetlands: impacts, adaptations and mitigation*), and complements the guidance on risk assessment and early warning systems adopted by the Convention in 1999 (Resolution VII.10, *Wetland Risk Assessment Framework*).

Acknowledgements

The Ramsar Secretariat and the STRP are very grateful for funding support from the Swedish International Development Agency (SIDA) for the preparation of this report.

The authors appreciate the review comments provided on a draft version of this report by members of the Scientific and Technical Review Panel and by Dr Rick van Dam from the Environmental Research Institute of the Supervising Scientist (Darwin, Australia). We are also indebted to earlier development of the concepts of vulnerability assessment undertaken by many contributors to the IPCC over many years, and to Ian Noble and the World Bank's Climate Change Team for sharing their risk assessment tools.

Executive summary

1. Wetland vulnerability refers to the relationship between exposure to a particular risk event, the impact of that event on a wetland, and the ability of the wetland to cope with the impacts or the efforts needed to minimize the impacts. The concepts of coping capacity or resilience and sensitivity are included as part of vulnerability, and they are especially important in the context of changes in the ecological character of a wetland due to climate change.

2. In the 1990s, methods were developed to assess the vulnerability of wetlands to climate change, especially sea level rise and extreme climate-related events such as floods and droughts. These methods generally identified the characteristics and present condition of the wetland, projected changes and management (or adaptation) options, and resulted in maps of vulnerable zones or lists of wetlands vulnerable to climate change.

3. Although it has been useful to develop methods that concentrate on the vulnerability of a wetland to climate change, vulnerability can also be considered in a broader concept because climate change is often an added or cumulative pressure on many wetlands. Vulnerability assessments should therefore address the ability of a wetland to cope with any impacts from externally driven forces.

4. By bringing together various methods and approaches, a general framework for wetland vulnerability assessment has been developed and is presented in this report. The framework has the following elements:

   i) establishing present status and recent trends: description of the wetland (biophysical and social), the present and recent pressures that exist, and the present condition. Due to limited data for many wetlands, local/expert knowledge is used where available to complement that collected through contemporary scientific means;

   ii) determining the wetland's sensitivity and adaptive capacity to multiple pressures: description of the pressures on the wetland and the development of plausible future changes in order to assess the sensitivity and adaptive capacity of the wetland to multiple pressures;

   iii) developing responses: determining the likely impacts of these changes on the wetland and the desired outcomes for it, as well as the responses that must be developed and implemented given its sensitivity and resilience; and

   iv) monitoring and adaptive management: determining the necessary steps to ensure the path to the desired outcomes.

5. The vulnerability assessment framework has much in common with the risk assessment and risk management methods that have been developed in the last decade. It is recommended that such assessments will be conducted within an adaptive management planning process that outlines the overall management goals or targets for the wetland.

6. Given the degraded status of many wetlands around the world, the approach presented here emphasizes the need for developing and implementing responses that will help reduce the wetland's vulnerability. It also incorporates the wise use concept and builds on Ramsar's risk assessment framework.

7. There still remain many challenges with wetland vulnerability assessment that will have to be addressed in order to provide the level of information required for management purposes. These include:

   i) the lack of spatial and temporal data, at appropriate scales, as a time series to determine the present condition and trends in the condition of a wetland, its natural dynamics, the sensitivity to past and present pressures, and potential thresholds, inertia or lag effects. These are all important when considering changes in the ecological character of a wetland;

   ii) an understanding of the complexity of the multiple, interactive pressures that often affect wetlands (e.g., land use and land cover change, pollution, climate change, etc.);

   iii) the need for developing appropriate metrics that can be used to measure the vulnerability of a wetland to multiple pressures; and

iv) the limited data and understanding of the sensitivity and adaptive capacity of wetlands

8. In many instances the assessment may be based on qualitative or subjective information. In this respect the assessment process should be seen as an iterative rather than a definitive process.

A Framework for assessing the vulnerability of wetlands to climate change

1. Introduction

The Ramsar Convention on Wetlands has paid considerable attention to the importance of wetland inventory, assessment and monitoring as tools for the conservation and wise use of wetlands, as well as to their value, through management planning processes, in maintaining and enhancing the ecological character of Ramsar Sites and other wetlands. This has led to the adoption of a substantial number of guidelines and other technical guidance by the Conference of the Parties to the Convention, materials which have been designed to assist Contracting Parties and others in implementing these key Convention processes. Guidance provided by the Convention has been compiled into the Ramsar Wise Use Handbooks (4th edition, 2010; www.ramsar.org/handbooks4), which are regularly updated and provide a substantial technical resource for wetland managers and decision makers. In the present report, in response to the Convention's Strategic Plan, guidance has been prepared for assessing the vulnerability of wetlands to climate change.

"Vulnerability" as a term has been used in various disciplines, for example in social sciences when referring to poverty, in human health when referring to disease outbreaks, and in environmental sciences when referring to climate change (Alwang et al. 2001; Brooks 2003; Harvey and Woodroffe 2008; Romieu et al. 2010). In this report, "vulnerability assessment" refers to the relationship between a particular climate-related event's impact on a wetland, the risk associated with that impact, and the efforts to manage that risk. Various frameworks that incorporate vulnerability to climate change have been devised over the past 15 years; amongst the first developed was one for coastal zones by the Intergovernmental Panel on Climate Change, IPCC (IPCC CZMS 1990), which still forms the basis of many other vulnerability assessment frameworks (see Downing and Doherty 2004).

The disaster risk reduction and climate change communities have independently developed concepts of vulnerability assessment with a focus on a physical, natural science-based approach that was later widened to incorporate human-related social-science approaches (Renaud and Perez 2010; Romieu et al. 2010). The source of divergence was connected with the initial purpose of the assessment, with the former focused on reducing the risk of disasters and the latter on climate change adaptation pathways.

This report presents a framework for determining the biophysical vulnerability of wetlands to climate change (*sensu* Brooks 2003). We include, but do not specifically elaborate on, the associated concept of social vulnerability, which is often used to describe the set of socio-economic factors that determine people's ability to cope with stress or change (see discussion in Brooks 2003). The concepts and specific information required for determining the vulnerability of a wetland to climate change (and other pressures) are presented in a framework that can be used for quantitative and qualitative assessments for which the user needs to determine the extent of specific information required for different biophysical and social situations.

2. Vulnerability and assessment

The term "assessment", as with "vulnerability", is used in various ways. In 2002 the Ramsar Convention adopted a definition of "assessment" (Resolution VIII.7; Finlayson et al. 1999) whereby *wetland assessment* is the identification of the status of, and threats to, wetlands as a basis for the collection of more specific information through monitoring activities. This places assessment within the context of the related concepts of inventory and monitoring as outlined in the Convention's *Integrated Framework for Wetland Inventory, Assessment and Monitoring (IF-WIAM)* adopted in 2005 (Resolution IX.1 Annex E; Finlayson et al. 2005; Davidson & Finlayson 2007). The IF-WIAM contains a suite of technical methods or tools, including a range of tools for assessing the condition of wetlands, namely, risk assessment, environmental impact assessment, strategic environmental assessment, and rapid biological assessment (Figure 1). In developing the IF-WIAM it was anticipated that other tools would be added progressively, and that many of the existing tools would be adjusted to better suit specific or local needs. This vulnerability assessment framework is one such additional tool.

As shown in Figure 1, this framework for vulnerability assessment forms a component of the IF-WIAM within the Convention's focus on the wise use of wetlands and maintenance of their ecological character. Wise use of wetlands was defined at the 9th meeting of the Conference of the Parties (Resolution IX.1 Annex A, 2005) as "the maintenance of their ecological character, achieved through the implementation of ecosystem approaches, within the context of sustainable development." At the same time, ecological character was defined as "the combination of the ecosystem components, processes and benefits/serv-

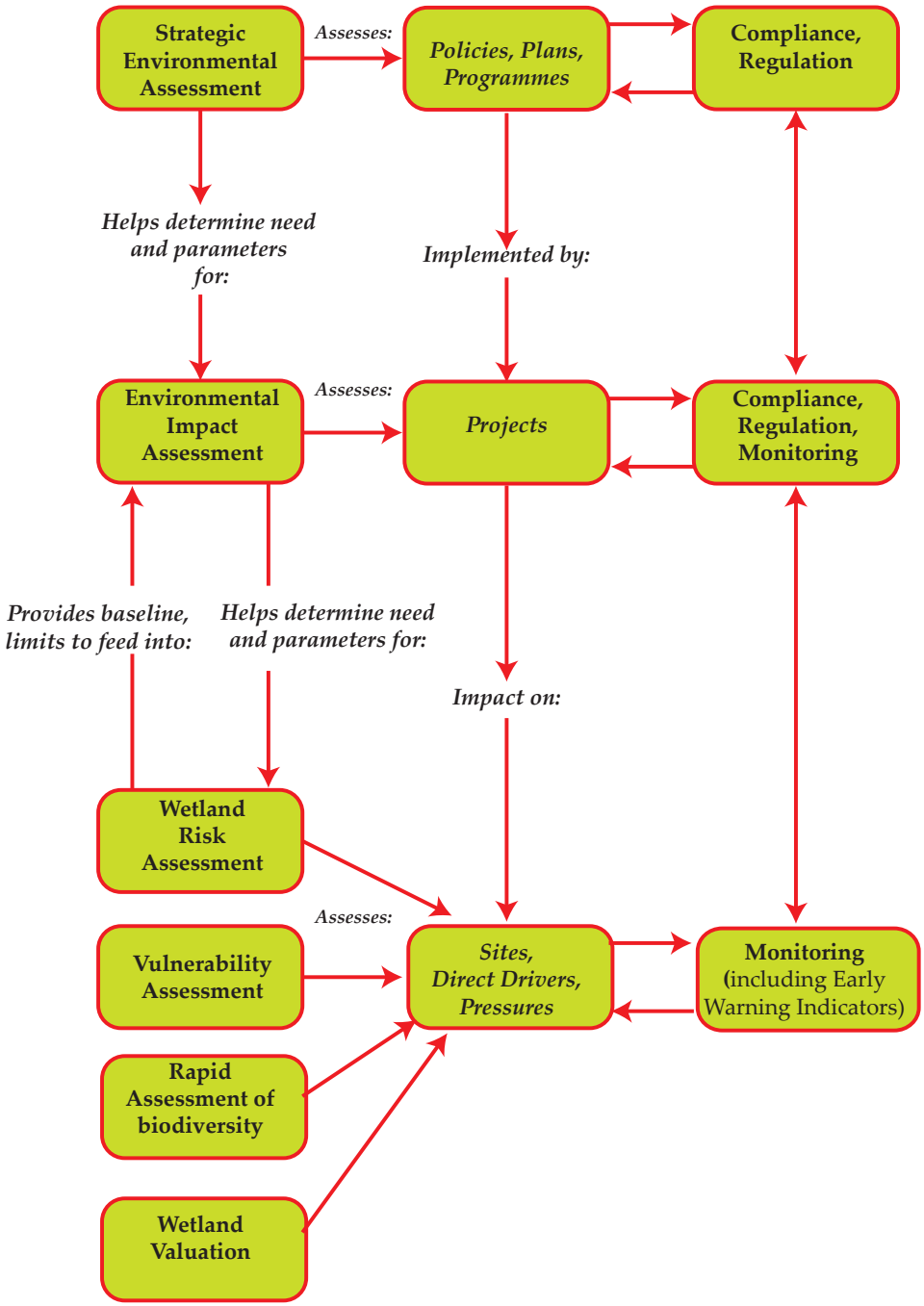


Figure 1: Integrated framework for wetland inventory, assessment and monitoring (from Ramsar COP9 Resolution IX.1 Annex E)

ices that characterise the wetland at a given point in time." Since maintaining the ecological character of a wetland involves maintaining the ecosystem services it provides, it is necessary to include a social component to ensure that the benefits to people are identified and, where required, quantified and valued using appropriate economic tools (see de Groot et al. 2006).

There are many approaches to vulnerability assessment (Winter 2000; Brooks 2003; Harvey and Woodroffe 2008; Nichols et al. 2008; Acreman et al. 2009). Here, vulnerability assessment is presented as an approach that can provide information and guidance for maintaining the ecological character of wetlands which are subject to adverse change as a consequence of climate change (including sea level rise), whilst recognising that climate change will interact with the many other anthropocentric pressures on

wetlands: for example, see Finlayson et al. (2006) for a discussion about climate change and other pressures on wetlands and waterbirds and Nicholls et al. (2008) for a discussion about sea level rise and coastal vulnerability.

2.1 A definition of vulnerability

There is no single widely-accepted definition of "vulnerability" – in fact, there is an array of terms that may be used very differently by different authors (Brooks 2003; Nichols et al. 2008). In this report we use the terms proposed by Brooks (2003) and refer to biophysical vulnerability as the vulnerability of a wetland to a specified hazard or range of hazards, where the term "hazard" refers specifically to the physical manifestations of climate change (for example, droughts, floods, storms, heavy rainfall, long-term changes in the mean values of climatic variables, etc.). Biophysical vulnerability is concerned with the ultimate impacts of a hazard (for example, a climate event) and is often viewed in terms of the amount of damage that occurs. One of the determinants of biophysical vulnerability is social vulnerability that is determined by factors such as poverty, inequality, and marginalisation (see Brooks 2003).

The work of the IPCC (IPCC 2001) and the review by Alwang et al. (2001) is used as a basis to propose a definition for vulnerability and to outline the characteristics that need to be considered in wetland vulnerability assessment. Taking a climate change impact perspective, the IPCC (2001) described biophysical vulnerability as a function of particular climatic variables and considered the vulnerability of any system to have two major components: i) the sensitivity of the system and ii) its adaptive capacity or resilience. Generalizing from the IPCC, these terms are defined for wetlands as follows:

> ***Sensitivity*** is the degree to which a wetland is affected, either adversely or beneficially, by climate-related stimuli, including the following elements of climate change: mean climate characteristics, climate variability, and the frequency and magnitude of extremes.
>
> ***Adaptive capacity*** is the ability of a wetland to adjust to climate change, to take advantage of opportunities, or to cope with or moderate the consequences.

Wetlands, like many other ecosystems, are also affected by many pressures due to human activity. So generalizing from the IPCC definition:

> ***Vulnerability*** is the degree to which a wetland is sensitive to and unable to adapt to or moderate the consequences of climate change and other (anthropocentric) pressures on its ecological character.

Vulnerability is determined at specific spatial and temporal scales and is a dynamic property that changes depending on the local conditions, such as the size of the wetland and the stability and diversity of the vegetation, as well as the adaptive capacity of relevant communities and institutions. A wetland may also be vulnerable at a particular time (e.g., when exposed to extreme climatic events) but not be vulnerable at other times. Thus the present condition of a wetland may not be a good indicator of its vulnerability over the long term.

2.2 Vulnerability assessment and risk assessment

Vulnerability assessment is presented as an approach that can provide information and guidance for maintaining the ecological character of wetlands subject to adverse change as a consequence of climate change (including sea level rise). As vulnerability is very dependent on context and scale, it is necessary to describe clearly its derivation and meaning and to address the uncertainties inherent in any assessments.

Biophysical vulnerability is closely associated with risk assessment and risk management (Alwang et al. 2001). (Note: the IPCC describes biophysical vulnerability as a function of particular climatic variables). Risk assessment is based on determining the extent of a particular hazard and its potential effect or impact on the system and may be expressed qualitatively or quantitatively as a probability (Burgman 2004); risk is generally described in terms of the probability of the extent and effect of a hazard impacting on a system. Thus, the determinants of both biophysical vulnerability and risk are essentially the same – hazard and social vulnerability.

The Ramsar Convention has developed a conceptual framework for wetland risk assessment, including guidance on predicting and assessing change in the ecological character of wetlands and the usefulness of early warning systems (Resolution VII.10; Ramsar Wise Use Handbook 18, 4th edition, 2010). It embodies a series of steps, which can be iterative and include (see also Figure 2):

- *Problem formulation*: Identification of the problem (includes site specific information and the multiple pressures that exist at the site)

- *Issue or hazard identification*: Identification of the hazard or risk and the extent of the problem
- *Risk assessment:* Analysis of the probability of the risk event and the likely impact of the event (at this stage, alternative scenarios can also be incorporated)
- *Developing risk management or risk minimisation options*: These vary depending on the risk; there may also be a prioritisation of the options, especially if multiple wetlands with different ecological character are affected and/or different drivers of change are included
- *Monitoring and adaptive management*: use of early warning systems, rapid assessment indicators, and/or GIS-based approaches for detecting changes and the effect of the risk management options. Depending on the results from the monitoring studies, adaptive management actions would be taken to modify any of the above steps.

The inclusion of alternative scenarios in the risk assessment framework (Figure 2) recognises that decision makers may require information on more than one management option. In this manner the iterative nature of the process is emphasised and strengthened. The importance of feedback loops in the risk assessment and management processes cannot be over-emphasised. Scenarios are increasingly being used in the assessment of complex biophysical and social issues, including climate change, biodiversity, agriculture, and energy (Peterson et al. 2003; Gordon et al. 2010). Together with site specific/local level information, contrasting plausible futures/storylines/narratives have been used to articulate interactions in complex systems and outcomes and also help with learning and preparing for change.

3. Overview of methods and approaches for vulnerability assessment

3.1 Different available approaches to assessing vulnerability

Given the wide but varied use of the term "vulnerability" (Brooks 2003; Nichols et al. 2008), we look at different approaches to assessing vulnerability and risk in different disciplines and the interpretation of three common concepts: risk, response and outcomes (Table 1). Some disciplines have treated risk implicitly whilst others have done so explicitly. For example, food security and disaster risk management have considered the risk from individual extreme climatic events explicitly. Vulnerability assessment within the climate change context, however, has to incorporate the slow changes in climate as well as the risk from extreme climatic events. Importantly, the additional and critical step in vulnerability assessment for wetlands is not to just consider the risk from climate change, but also to factor in the multiple other pressures (drivers of change) on them when developing management responses (see, e.g., Bayliss et al. 1997; IPCC 2002; Finlayson and D'Cruz 2005). An example of an approach for vulner-

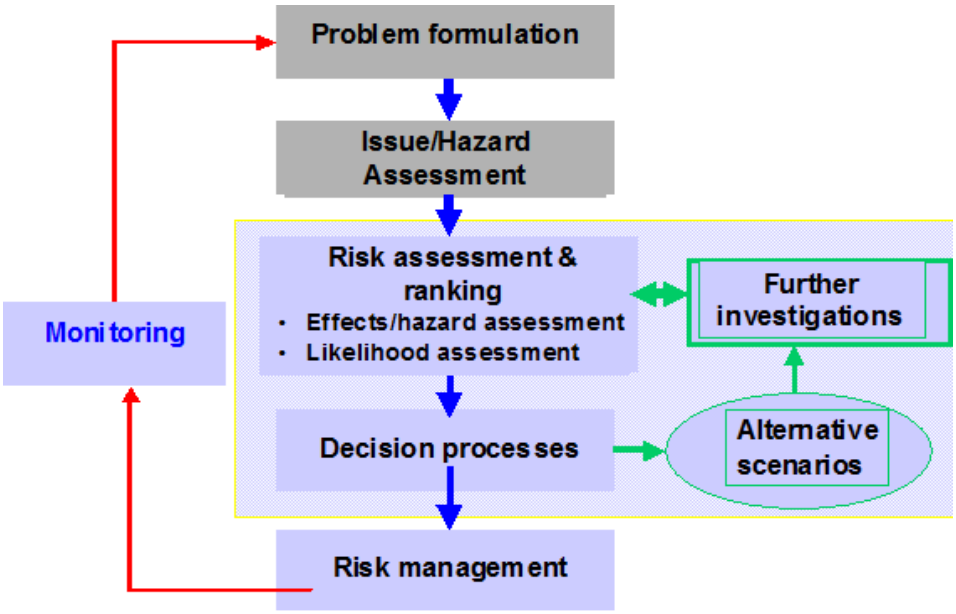


Figure 2: Making risk management decisions
(derived from van Dam et al. 1999)

Table 1: Examples of different approaches to vulnerability and risk from different disciplines and interpretation of risk, response and outcomes

Approaches	Risk	Response	Outcome
Sociology & anthropology	Implicit; usually focus on single source of risk	Often a key focus of this literature: how social and other assets are affected	Main focus: outcomes other than "income" poverty
Poverty alleviation	Implicit	Response clearly determines outcome but specific response mechanisms are rarely identified	Main focus: probability of being poor; transitions in and out of poverty
Asset-based approaches	Mostly implicit; sometimes includes value of assets at risk	Main focus: but often does not describe specific mechanisms	Not often explicit; sometimes use variability in outcomes as motivation
Sustainable livelihoods	Sometimes explicit; concept of sensitivity is related to exposure to risky events	Mostly explicit: concept of resilience is related to response. Key focus of this literature is household response mechanisms	Literature recognizes that vulnerability is an ongoing and forward-looking process
Food security	Sometimes explicit, e.g., poor rainfall, price changes. Focus on single source of risk	Sometimes explicit	Main focus: probability of not meeting food needs; consequences of inadequate food intake
Environmental management	Usually explicit; identifies risks and thresholds	Implicit; species and ecosystems can respond, but mechanism of response is not made explicit. Can incorporate autonomous adaptation or adaptive capacity	Explicit focus: species survival, decreased habitat loss, etc. Tends to be long term and forward looking (e.g., sustainability)
Disaster management	Explicit; focus on single source risk (*ex poste*)	Sometimes explicit, not well delineated	Explicit, but not always well delineated
Climate change	Explicit	Explicit – adaptation	Decreased effects of adverse impacts, improved coping capacity and resiliency of both ecosystems and human societies

Modified from Alwang et al. (2001)

ability assessment in complex wetland management situations is shown in Box 1.

Downing and Doherty (2004), drawing together many approaches used for climate vulnerability and adaptation, have suggested a vulnerability assessment framework in which the steps and methods can be modified to include ecosystems such as wetlands and maintenance of their ecological character. They emphasise that the approach should be seen as an iterative process, and although they do not explicitly incorporate monitoring and adaptive management, this is implicitly part of the process. Their framework is essentially a conceptual approach centred on stakeholder engagement and empowerment to better cope with climate variability and to develop responses for projected changes. It can also be viewed as an awareness-raising exercise. Downing and Doherty's framework and the associated methods can be summarised as follows (see also Table 2):

- *Examination of the present ecological and social system*. The methods concentrate on the knowledge obtained from stakeholders.
- *Stakeholder analysis and engagement*. This can include an inventory of stakeholders, analysis of their organisational capacity (e.g., focus, legal structure, resources) and a mapping of stakeholders that form the basis of social institutions.
- *Understanding current vulnerability to multiple stresses*. This can be done using a series of matrices to show the relative vulnerability of different groups and activities to climatic hazards (e.g., droughts, floods, extremely high temperature events). In this matrix, the columns can be the present climatic threats (or opportunities) and trends that are important for the vulnerable components of the system (specific ecological characters). Other pressures can be added. The matrix can be filled in with relative scores (e.g., from 1 to 5) for the degree to which each climatic hazard affects each ecological component or livelihood.
- *Evaluating narratives (scenarios) of future vulnerability*. Understanding future vulnerability requires an extension of the current vulnerability methods with some sort of scenario analysis. They can

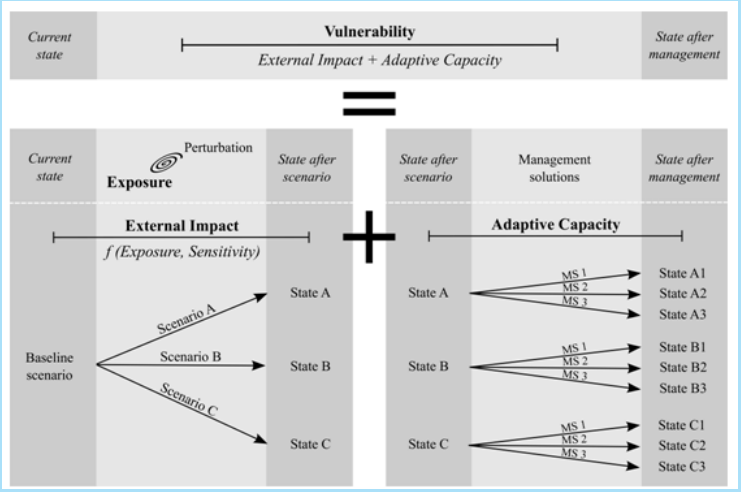
Box 1. WETwin vulnerability assessment case study

Inner Niger Delta, Mali

Food production within the Inner Niger Delta is strongly related to the intensity (extent and duration) of the seasonal inundation of its floodplain (Zwarts et al. 2005, 2006; Kuper et al. 2003). However, changing river flows (here defined as inflow) into the Inner Niger Delta, as a consequence of climate change, climate variability and upstream water and land management, is reducing the flood intensity and threatens the livelihoods of approximately one million people and their livestock in the Delta.

There is little quantitative data for the area, and thus it provides a case study for methods of undertaking vulnerability assessment in data-scarce situations. The vulnerability assessment approach applies simulations and expert judgment using qualitative data to assess impacts on different aspects of the system under different management options.

Downscaled global change scenarios were applied to the current system condition, in which the system was exposed to different perturbations. The reaction of the system to a perturbation is the difference between the current condition and the scenario conditions. The impact on the system was defined as a combination of exposure and system sensitivity.



Vulnerability Assessment Process as developed under the WETwin project

A range of management options were then applied to the scenarios. The adaptive capacity of the system was determined by comparing the system state with and without application of each of the management options. The resulting change in vulnerability was assessed from the combination of the impact of each management option (adaptive capacity), the system's sensitivity, and its exposure to a perturbation. The effectiveness of each management option was assessed for each scenario by comparing the change in vulnerability for each scenario and management option.

		Impact on:		
Management option	**Season**	**Human health & water related disease**	**Ecosystem functions**	**Water retention & purification**
Maximise Irrigation	Wet	0	-	0
	Dry	- -	- -	-
Maximise energy production	Wet	- -	-	-
	Dry	- -	+ / -	+
Maintain minimum flows	Wet	0	0	0
	Dry	- -	+ + / - -	+ +

Vulnerability assessment for the Inner Niger Delta, Mali.

Trends show the assessed qualitative impact of each management option on three aspects of the system for the wet season and the dry season.

++ (dark green): highly positive; + (green): positive; 0 (white): neutral; - (amber): negative; and – (red): highly negative.

Since change in inflows to the Delta is the dominant driver for change, three inflow-related management options were assessed, in which the inflow was optimized: 1) for maximised upstream irrigation; 2) for maximised hydropower energy production; and 3) for maintaining at least a minimum flow in the Delta.

The impact of each of these management options was assessed for three different aspects of the system: 1) human health and water-related diseases; 2) ecosystem functions; and 3) water retention and purification. Because there is major seasonality in river flows in

the Delta, there are different implications for the application of different management options between seasons. Vulnerability was therefore assessed separately for the wet and dry seasons. Results are summarized in Table 1.

References

Kuper, M., Mullon, C., Poncet, Y. & Benga, E. 2003. Integrated modelling of the ecosystem of the Niger river inland delta in Mali. *Ecological Modelling* 164: 83-102.

Zwarts, L., van Beukering, P., Kone, B., Wymenga, E. 2005. *The Niger, a lifeline. Effective water management of the Upper Niger Basin*. ISBN 90-807150-6-9.

Zwarts, L., van Beukering, P., Kone, B., Wymenga, E., and Taylor, D. 2006. The Economic and Ecological Effects of Water Management Choices in the Upper Niger River: Development of Decision Support Methods. *Water Resources Development* 2(1): 135-156.

[WETwin is a project funded under the European 7th Framework Programme and is coordinated by Istvan Zsuffa (VITUKI, Hungary) and Jan Cools (ANTEA Group, Belgium). More info at www.wetwin.net.]

include back-casting or time-dependent projections; note, though, that this has limitations, as the system behaviour may not remain the same in the future. Stakeholders can categorise the risks to particular components (e.g., of ecological character or their livelihood).

- *Identifying and evaluating potential adaptive strategies and measures*. The analysis can include financial, technical capacities, data requirements, time required to plan and implement the options, stakeholder commitment and involvement that would be needed and over what time period, who/what would be losers and who/what the beneficiaries and thus the potential conflicts that would need to be managed. Techniques to evaluate adaptation options range from qualitative checklists to full cost-benefit analysis. In most cases, some sort of multi-criteria analysis is essential.
- *Communication and integrations.* This would include testing potential responses and policy options. Rule-based and multi-agent modeling and/or formal models of environmental stresses, the responses of individual actors, and social networks can provide a means to test a wide range of scenarios. Simple rule-based approaches can be readily implemented, for instance in an expert system or decision framework. Role playing and policy exercises can be used to provide insight into the dynamics and processes driving future vulnerability, while the potential usefulness of adaptive options can be gleaned from stakeholder-driven exercises. For instance, a drought crisis could be 'played' for the present and then for a future scenario, perhaps with greater economic trade and an early warning system.

Bayliss et al. (1997), as part of preparing guidance for vulnerability assessment, developed a framework that specifically considered vulnerability to climate change in wetlands, using the framework for a large river and floodplain system in northern Australia, the Alligator Rivers. Their steps included:

- *Delineation of affected areas*: All wetlands in the region below 4 meters in elevation separated into different types (e.g., mangroves, salt flats and freshwater floodplains, lowland monsoonal forests), but treated as interconnected habitats. Major rivers and creeks were identified from maps and remote imagery. The vulnerability of these habitats to climate change was not assessed in isolation from other impacts and/or threats that were changing, or could change, the ecological character of the wetlands.
- *Stakeholder identification*: Those holding or having access to the information (e.g., research institutions, national parks, mining company) or major land holders. Local community interests, particularly landholders adjacent to the park and representatives of traditional Aboriginal people, were also involved.
- *Responses developed*: An integrated coastal zone management plan, given that the wetlands within the region are part of a broader biophysical region. Thus, responses to change, including sea level rise, need to be addressed by policies at the catchment and coastal zone level and not in isolation of adjacent jurisdictions or communities. Local associations, and all spheres of government, should be encouraged to participate actively in the planning, implementation and appraisal of management activities. Management policies that can respond to change are required and should proactively address the major or prime change scenario. Vulnerability assessment

Table 2. Some key objectives and methods for vulnerability assessment
(from Downing & Doherty 2004)

Step:	Examination of the present ecological and social system	Stakeholder analysis and engagement	Understanding current vulnerability to multiple stresses	Evaluating narratives (scenarios) of future vulnerability	Identifying and evaluating potential adaptive strategies and measures	Communication and integration
Objectives:	To describe the ecological and socio-economic system & actors	To identify actors and their motivations for climate adaptation	To identify vulnerable groups and current exposure to climatic and other stresses	To describe pathways of future vulnerability and adaptive capacity	To identify the range of choice and potential effectiveness of adaptive responses	To link the elements of the assessment together To communicate with stakeholders and support greater awareness and effective decision making
Analysis:	To define pathways through the analysis	Inventory & typology Networks & regimes	Attributes of vulnerable groups (e.g., livelihoods) Prevalence & location	Same analysis, with: changing prevalence, location, attributes	Inventory of adaptation options for sectors and stakeholders, including vulnerable groups	Pathways and narratives for core scenarios Visualisation of results Risk assessment
Key methods:	Workshops Mental mapping	Interviews Analysis of secondary material Knowledge elicitation	Sensitivity matrix Vulnerability indicators & profiles Sectoral impact models Geographic information system Rule-based dynamic modeling	Overlays of future risks (climate, socio-economic) Scenario generation Scenarios in dynamic models Probabilistic climate forecasts	Checklist of attributes of adaptation options Typology of adaptation measures, strategies and capacity Multi-criteria analysis Dynamic simulation Cost-benefit analysis	Formal risk assessment with expert and stakeholder judgement Policy exercises Role playing and gaming
Synthesis:	Elements (dimensions) of a risk analysis	Trends and transformations underway that shape vulnerable groups and stakeholders	Target vulnerable groups and risks Scales of risk Narratives, case histories, self reporting News stories, photography, video	Same as for current vulnerability, with: projections, backcasting, visions of future conditions	Identify high priority responses	Press release and news stories Video CD and decision support

should be integrated into the management processes for the coastal wetlands.

- *Information gaps identified*: For the long-term application of vulnerability assessment, more precise information on areas likely to be impacted is required. Delineation at a more detailed scale would be useful, but only if complemented with more accurate meteorological and hydrological information, including tidal records and water movements in the adjacent seas. Ecological information is very site specific and thus limited in space and time, and it generally does not include information on ecological processes. The absence of a time series of reference data hinders the vulnerability assessment. The ecological character of the region is partially described, but data upon which changes to this character can be identified are, at the best, cursory. The ecological character of the wetlands has undergone major change and is changing further, but the extent of change has not been widely determined.

This was amongst the early work on climate change vulnerability assessment and identified some issues that need to be addressed: issues of hazard and risk, governance, strategic planning, acquisition and custodianship of information, and further research and monitoring. Bayliss et al. (1997) also concluded that the human perceptions of risk covered natural, cultural and socio-economic values. The latter are analogous to the ideas of ecosystem services, especially regulatory and cultural services (MA 2003) and should be incorporated in the management plans. In addition, they recognised the need to raise public awareness for the responses to be implemented at multiple layers, e.g., community, regional and national (see also Eliot et al. 1999).

Acreman et al. (2009) present a framework for evaluating the eco-hydrological responses of wetlands to climate change. It is a multi-stepped approach with an emphasis on a regional scale that enables the broad issues to be highlighted with a general conceptual understanding of wetland processes and a minimal amount of data. Applying the framework yields a generic and quantitative assessment that can be used by decision makers to recognize and evaluate the risks to wetlands from climate.

This framework is based on the use of eco-hydrological models that combine climate changes, hydrological processes, and ecological responses to estimate what might happen to particular types of wetlands and their characteristic plant communities or species in the future. The step-by-step approach is outlined in Figure 3 and includes determining the objectives and the baseline species/wetland conditions, then developing and running appropriate climate and eco-hydrological models to determine the likely changes. Conceptual models are used to describe the hydrological processes within constraints derived from the availability of data.

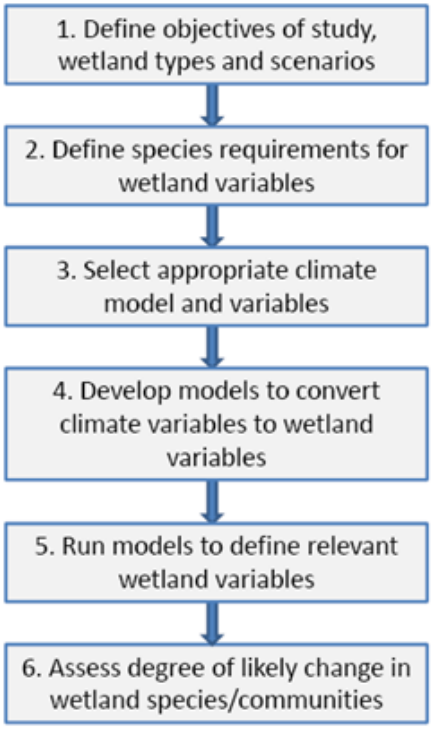


Figure 3: Framework for assessing ecohydrological responses of wetlands to climate change
(adapted from Acreman et al. 2009)

Accepting the importance of climate change, the need for it to be incorporated into development agenda, and the limited climate change expertise, the World Bank and other agencies have developed screening tools to help incorporate the risks that climate change poses to development projects and guide the users to minimising those risks. Those tools most relevant to assessing the vulnerability of wetlands include ADAPT and CRiSTAL and their features are summarised below. Their target users are different but both essentially aim to help the users incorporate climate considerations into their activities (IISD/WB/IDS 2007), particularly at the design stage, and both emphasise risk management. One of the other challenges of managing climate risk is the access to up-to-date and easily usable information and knowledge. Working with various partners, the World Bank has developed the Climate Knowledge Portal that makes many of these tools and much of this information and knowledge available from one platform (http://sdwebx.worldbank.org/climateportal/).

3.2 Frameworks incorporating risks of climate change into development planning and projects

ADAPT

The World Bank's screening tool (ADAPT) is designed to bring together climate databases and expert assessment of the threats and opportunities arising from climate variability and change (World Bank 2008). Through a series of questions it identifies the main climate characteristics of a project location and identifies components of the project that might be subject to climate risk, explains the nature of the risk, and provides guidance to appropriate resources (knowledge documents and experts to help follow up on any identified risks). Essentially, the tool mimics an initial consultation with a climate change expert. It is intended for project team members who have limited knowledge of climate change and is currently limited to agriculture and biodiversity-related projects.

The assessment is qualitative in that the risks and opportunities are coded into five categories: 1) climate change poses significant risk, 2) it poses some risk, 3) there is not enough information to make an assessment, 4) there is no risk from climate change, and 5) activities would reduce climate risk. A report generator delivers the results of the analyses and relevant documents to the user, based on the activities identified to be at risk on screen or in printed form.

This tool can form part of Environmental Impact Assessment (EIA) if project developers take climate change as an added risk. In addition, it would be possible to incorporate the various other pressures as part of the knowledge base within ADAPT if the data are available. (More information and access to the tool: http://go.worldbank.org/AWJKT60300.)

CRiSTAL - Community-based Risk Screening Tool – Adaptation and Livelihoods

CRiSTAL has been developed by several organisations including IISD, IUCN and SEI. It is aimed at planners and managers of community-level projects, and it helps the users to consider climate risk reduction and incorporate adaptation options in ecosystem management and restoration and/or sustainable livelihood projects It also helps users to understand the links between local livelihoods and climate change and ways to minimise the risk from climate change. It is intended to enhance local adaptative capacity through a better understanding of:

- how current climate hazards and climate change affect a project area and local livelihoods;
- how people cope, looking specifically at the resources needed to cope with climate stress;
- how project activities affect livelihood resources that are vulnerable to climate stress and/or important to local coping strategies; and
- how project activities can be adjusted so that they enhance adaptive capacity.

CRiSTAL is available in multiple formats (e.g., Excel, hardcopy) and multiple languages (English, French, and others to come). Detailed project inputs and vulnerability data are required and the outputs include vulnerability and livelihood profiles with suggestions for project modification. More information is available from www.iisd.org/cristaltool.

Other web-based resources to help with climate risk management

There are also additional web-based resources that can be used to provide climate- or vegetation-related information to help with vulnerability assessment. These include:

- *"Providing Regional Climates for Impacts Studies" – PRECIS* (www.metoffice.gov.uk/precis/). This has been developed by the Hadley Centre of the UK Meteorological Office. It provides grid-scale (50*50km) projections for climatic, soil, hydrological and vegetation information based on Global Circulation Models.
- *Statistical Down Scaling Model (SDSM) – Environment Agency, UK* (www.sdsm.org). The tool provides daily, transient, climate risk information for impact assessment over the 1961-2100 time horizon and has been primarily used for water resource management, though it is applicable to multiple sectors. After calibration of data, the tool provides rapid assessments to assist impacts and adaptation analysis.
- SERVIR – recognising the need for real-time weather information, a USAID/NASA led initiative provides this service for MesoAmerica and is being expanded to cover parts of Africa (www.servir.net/).

There are also knowledge sharing and other resources – many of which can be accessed from the Climate Change Knowledge Portal – that would be useful for wetland vulnerability assessments and include:

- **Adaptation Learning Mechanism** (www.adaptationlearning.net) is a collaborative, global learning process with leadership, facilitation and strong participation by developing countries. It is a platform for sharing knowledge and also acts as

a community of practice for adaptation practitioners.The UK Climate Impacts Programme (UKCIP-www.ukcip.org.uk) is aimed at UK organisations and is helping them adapt to impacts of climate change by providing methodologies and experiences of others who have taken action.

- **wikiADAPT** is a collaborate wiki project aimed at the climate adaptation community, now integrated into the weADAPT Knowledge Base (www.weadapt.org/knowledge-base/guidance/knowledge-base).

4. A framework for wetland vulnerability assessment

From all the methodologies and approaches, it is clear that vulnerability assessment should be seen as an iterative process that includes the following steps:

- determining a probability of a risk event occurring and the effect of this on the system, given its sensitivity and adaptive capacity;
- developing possible options that could reduce the adverse impacts from that event; and
- formulating the desired outcomes for the system within an adaptive management framework to ensure that the response options being implemented are achieving the desired outcomes.

Given the absence of specific data, it may often be necessary to make subjective judgements, particularly when dealing with risk assessment and risk perception. Changes in the information available for these steps would normally be expected to be addressed through an adaptive management approach that encouraged learning and the development of new knowledge that would feed back into management decisions and the assessment.

In recent years, vulnerability assessment has increasingly been linked with disaster management and adaptation to climate change. Adaptation to climate change deals with reducing the vulnerability to climate change through specific options. Although it is labeled as adaptation to climate change, in reality, given the linkages, it is adaptation to the multiple drivers of change and deals with present risks as well; thus it is sometimes included in national sustainable development planning. Most disaster management studies are based upon some version of the following relationship between vulnerability and risk and coping (Alwang et al. 2001):

Vulnerability = risk - coping

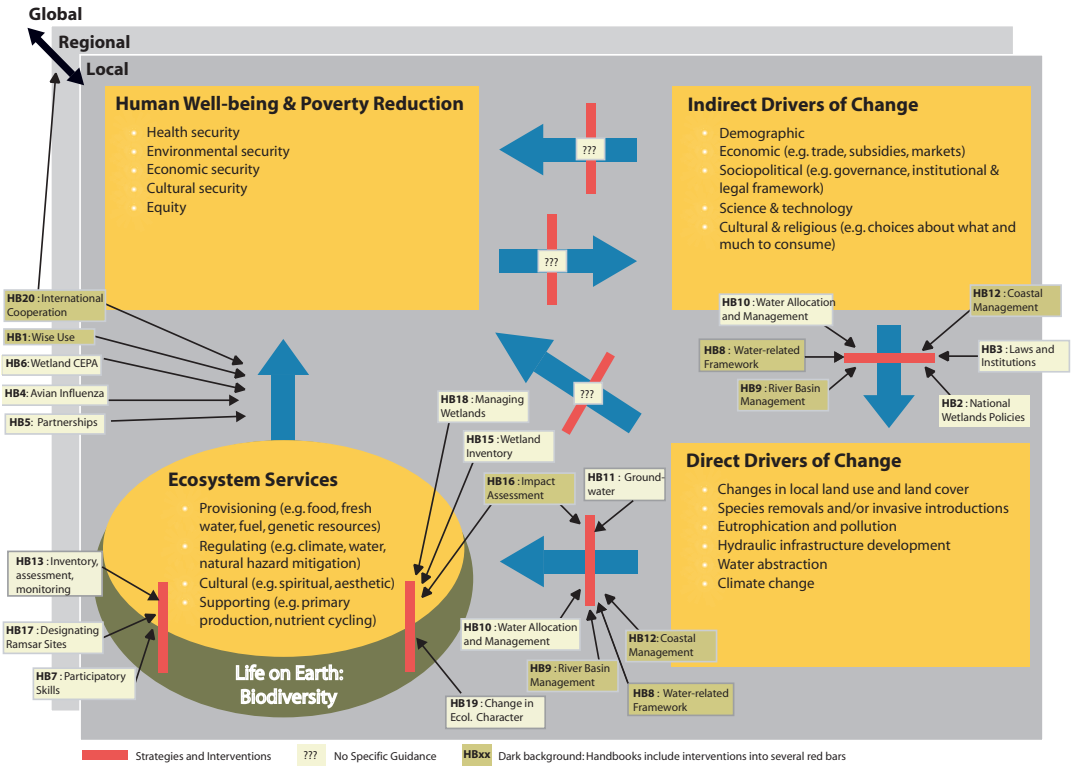


Figure 4. A framework for the wise use of wetlands. This framework illustrates the main guidelines contained in the Ramsar Wise Use Handbooks, vol. 1, 4th edition.

Risk here is defined as a function of: probability; primacy (shock value based on time elapsed since previous occurrence); predictability (degree of warning available); prevalence (the extent and duration of hazard impacts); and pressure (the intensity of impact).

Coping is a function of: perceptions (of risk and potential avenues of action – the ability to cope is information contingent); possibilities (options ranging from avoidance and insurance, prevention, mitigation, coping); private action (degree to which social capital can be invoked); and public action.

The wetland vulnerability assessment framework provided below is based on the OECD state-pressure-impact-response model that was the basis of the Millennium Ecosystem Assessment conceptual framework (MA 2003), and draws on the sources summarised above. The Millennium Ecosystem Assessment framework has also been used to outline the technical and policy guidance provided by the Ramsar Convention for managing wetlands (MA 2005) (see Figure 4) and can be used to support management responses to the vulnerability assessments.

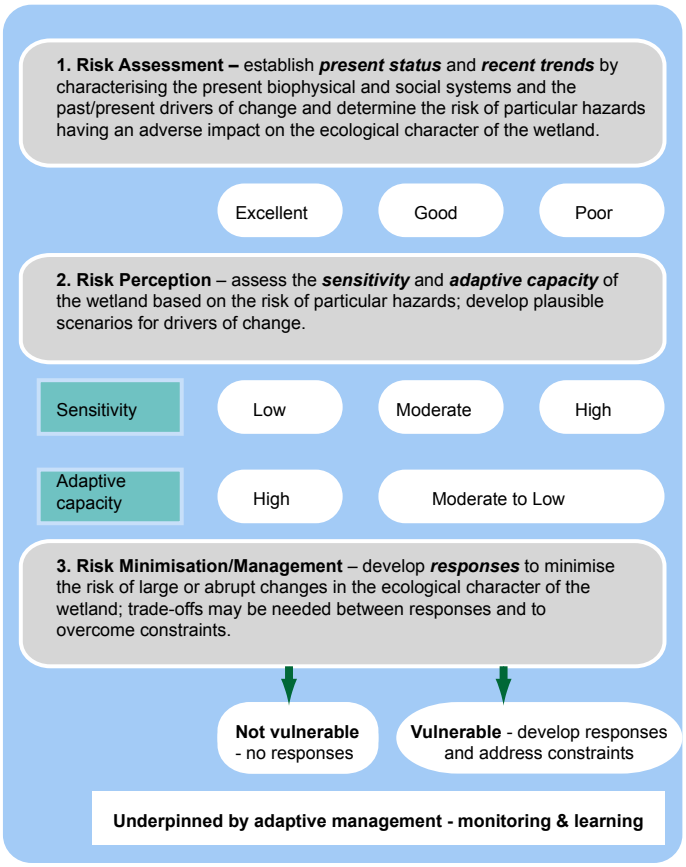


Figure 5. Vulnerability assessment framework for wetlands

Building on the methods and approaches already developed (as described above), the framework incorporates risk assessment (including risk perception by stakeholders) and risk management (Figure 5). It incorporates components of the concept of ecological character as a basis for developing indicators for assessing the condition and trends as well as for monitoring in support of the wise use of wetlands.

The framework is derived from that outlined in summary form by Finlayson (2006) and includes the following:

1) Risk assessment & 2) Risk perception

- *Delimiting the boundaries* of the social and biophysical system to be considered and including spatial and temporal boundaries, such as those associated with hydrology of the wetland;
- *Identifying the past and present drivers of change and existing hazards,* possibly through the use of a state-pressure-impact-response model;
- *Assessing the present condition and recent trends* in the ecological character of the wetlands, including the social/economic importance of the ecosystem services that the wetlands provide;
- *Conducting a stakeholders analysis* of the people involved in evaluating the potential responses and those affected by the potential changes in the system;
- *Determining the sensitivity and resilience* including adaptive capacity of the system and the surrounding social system;
- *Identifying the wetlands and groups of people* that are particularly sensitive to different pressures; and
- *Developing scenarios and storylines* with the involvement of the stakeholders to the risk of possible drivers of change and the interactions between them that could lead to future changes.

3) Risk minimisation/management

- *Identifying the wetlands and groups of people* that would not have the ability to cope with the (often adverse) changes, given their low present adaptive capacity and/or sensitivity;
- *Developing response options or coping strategies* that could minimise the risk of abrupt and/or large changes in the ecological character of wetlands (thus maintaining their ability to provide the ecosystem services that humans depend on). These can include interventions that directly reduce

vulnerability (or bolster biophysical resilience) as well as those that change people's behaviour: regulations, strategic environmental planning, infrastructure/engineering works, rehabilitation/restoration, developing education material, improving community awareness, developing integrated management plans, and taking account of local responses to climate variability. In some case, large adaptive capacity, high resiliency, and low sensitivity of the system could mean that no further management response is needed;

- *Conducting a trade-off analysis* to choose between potential response options given constraints such as institutional capacity, information/data availability, and, often, financial capacity; and
- *Specifying the desired outcomes* for the wetland based on maintaining the ecological character and determining measurable indicators. The manner in which the outcomes are determined is important and would preferably include all stakeholders and be done in a transparent manner.

4) **Monitoring and adaptive management** throughout the process. This includes a means of measuring the path to the desired outcomes.

One useful concept (borrowing the idea from the poverty alleviation literature) is that of *transitory vulnerability* and *chronic vulnerability*. For wetlands, given their inherently dynamic nature, this concept can bring together the time frame for responses with the nature of the system. In terms of developing responses, it would thus be useful to consider whether they are responses to transitory vulnerability (which in many cases may mean that no response is needed) or rather to a chronic vulnerability.

The vulnerability assessment framework set out here is very much a conceptual framework, and adjustments will need to be made as it is implemented and feedback on individual steps is obtained. It can be anticipated that practical considerations in individual assessments will result in adjustments to the framework. Hence the framework is provided as a guide for assessment and does not provide a tightly prescriptive approach – flexibility and responsiveness to local circumstances will be required. Whilst is it largely derived from the Convention's risk assessment framework (see section 2.2), there is a greater emphasis here on relating the present status and trends in the wetland to the sensitivity and adaptive capacity as a way of determining response options.

The qualitative relationship between sensitivity and adaptive capacity is presented in Figure 6 (a quantitative model for vulnerability assessment is not available). The matrix is adapted from the qualitative approach often used to express the extent of risk through a formal risk assessment (Burgman 2004). The constraints on these matrices are well known – they depend on expert opinion and relative judgements, but they do provide a means of comparing vulnerability within and between wetlands within a range of stated assumptions and uncertainties about the quantitative relationships that may exist, but which have not been otherwise determined.

Sensitivity	Adaptive capacity		
	High	Medium	Low
High			Highly vulnerable
Medium		Vulnerable	
Low	Not vulnerable		

Figure 6. Vulnerability assessment as a function of sensitivity and adaptive capacity

5. Challenges and information gaps

There are a number of challenges that have arisen in various works on vulnerability assessment. These are:

Challenges in dealing with "multiple" vulnerabilities in a system

- As vulnerability can be applied to particular drivers of change or hazard, any system can have "multiple vulnerabilities", and how these can be combined or prioritised is an issue that needs to be addressed. The value of the OECD state-pressure-impact-response model could be investigated further.
- As vulnerability is location-specific, for a wetland different habitats in the system can have different vulnerabilities and thus make it difficult to put these together and identify and implement responses. Scenario setting may provide a way of establishing plausible futures and engaging with stakeholders to identify response options.
- Frequently the mismatch between ecosystem/catchment boundaries and institutional (management) jurisdictions needs to be addressed to

implement responses and support the adaptive capacity of local communities.

Data, information and scenario development

- Reliable data is needed on present land use and land cover and any changes in these values, including data on distribution and extent of wetlands for particular ecosystems and the surrounding area (catchment or zones).
- Long-term monitoring of key biophysical parameters in the wetlands and their catchments and adjacent seas is needed to provide time series data for developing bench marks or baselines.
- Integration of data collection (inventory) for risk assessment, risk management and monitoring is needed, as well as identification of shortfalls in some of these.
- There are many challenges in downscaling climate and other models.
- It can be difficult to develop scenarios that outline likely future changes in drivers, status and condition of the system, given the lack of knowledge at the present time.
- Cost/benefit analyses using multiple criteria assessment approaches are needed for deciding between different options that may provide different ecological and socioeconomic benefits.

Perceptions of the need to address the vulnerability of wetlands

- There can be many differences among the decision makers' and society's views of the system's importance and hence the need to address vulnerability.
- There is often a perception that a system is able to cope with slow changes (e.g., slow increases in temperature, precipitation) and less able to deal with abrupt changes, such as storm surges or large-scale alterations in land use that affect the hydrology.
- There is a need for case studies of the coping strategies (or autonomous adaptations) for systems and human societies, taking the present climate variability as a surrogate for some changes likely to occur in the future.

The manner in which these gaps are addressed will greatly affect the extent and usefulness of a vulnerability assessment of wetlands, especially if management responses are dependent on quantitative rather than qualitative data, or if institutional structures are unable to effectively undertake or implement the outcomes of an assessment.

Successful vulnerability assessment is dependent on many factors – data and information being some of them, but also capacity and capability both during an assessment and when responding and communicating the outcomes and responses. The above considerations provide technical guidance for conducting an assessment: further advice on communication, community involvement, and managing wetlands is available in the Ramsar Wise Use Handbooks (www.ramsar.org/handbooks4)

6. References

Acreman, M.C., Blake, J.R., Booker, D.J., Harding, R.J., Reynard, N., Mountford, J.O. and Stratford, C.J. 2009. A simple framework for evaluating regional wetland ecohydrological response to climate change with case studies from Great Britain. *Ecohydrology* 2, 1–17.

Alwang, J., Siegel, P.B. and Jorgensen, S.L. 2001. *Vulnerability: A View From Different Disciplines*. Social Protection Discussion Paper Series No. 0115, The World Bank, Washington D.C. At www.worldbank.org/sp

Bayliss, B., Brennan, K., Eliot, I., Finlayson, M., Hall, R., House, T., Pidgeon, B., Walden, D. and Waterman, P., 1997. *Vulnerability assessment of predicted climate change and sea level rise in the Alligator Rivers Region, Northern Territory Australia*. Supervising Scientist Report 123, Supervising Scientist, Canberra. At www.environment.gov.au/ssd/publications/ssr/123.html

Brooks, N. 2003. *Vulnerability, risk and adaptation: a conceptual framework*. Tyndall Centre for Climate Change Research Working Paper 38, Tyndall Centre for Climate Change Research and Centre for Social and Economic Research on the Global Environment (CSERGE), School of Environmental Sciences, University of East Anglia, Norwich, U.K. 16 pp. At www.tyndall.ac.uk/sites/default/files/wp38.pdf

Burgman, M. A. 2004. *Environmental Risk and Decision Analysis: For Conservation and Natural Resource Management*, Cambridge University Press, London.

Davidson, N.C. and Finlayson, C.M. 2007. Developing tools for wetland management: inventory, assessment and monitoring – gaps and the application of satellite-based radar. *Aquatic Conservation: Marine and Freshwater Ecosystems* 17, 219-228.

De Groot, R.S., Stuip, M.A.M., Finlayson, C.M. and Davidson, N. 2006. *Valuing wetlands: guidance for valuing the benefits derived from wetland ecosystem services*, Ramsar Technical Report No. 3/CBD Technical Series No. 27. Ramsar Convention Secretariat, Gland, Switzerland & Secretariat of the Convention on Biological Diversity, Montreal, Canada. At www.ramsar.org/pdf/lib/lib_rtr03.pdf

Downing, T. and Dougherty, B. 2004. *Toward a core methodology for climate vulnerability and adaptation.* Stockholm Environment Institute, Stockholm.At www.vulnerabilitynet.org

Eliot, I. Finlayson, C.M. and Waterman, P. 1999. Predicted climate change, sea level rise and wetland management in the Australian wet-dry tropics. *Wetlands Ecology and Management* 7, 63-81.

Finlayson, C.M. 2006. Vulnerability assessment of important habitats for migratory species; examples from eastern Asia and northern Australia. In: *Migratory Species and Climate Change – Impacts of a Changing Environment on Wild Animals*. UNEP / Convention on Migratory Species, Bonn, Germany, pp. 18-25. At www.cms.int/publications/pdf/CMS_CimateChange.pdf (sic)

Finlayson, C.M. and D'Cruz, R. (coordinating lead authors) 2005. Inland Water Systems. In: *Ecosystems and Human well-being: current state and trends: findings of the Conditions and Trends Working Group*. R. Hassan, R. Scholes and N. Ash (eds). Pp. 551-583. Island Press, Washington D.C. At www.maweb.org/documents/document.289.aspx.pdf

Finlayson, C.M., Bellio, M.G. and Lowry, J.B. 2005. A conceptual basis for the wise use of wetlands in northern Australia – linking information needs, integrated analyses, drivers of change and human well-being. *Marine & Freshwater Research* 56, 269-277.

Finlayson, C.M., Davidson, N.C., Spiers, A.G. and Stevenson, N.J. 1999. Global wetland inventory – status and priorities. *Marine and Freshwater Research* 50, 717-727.

Finlayson, C.M., Gitay, H., Bellio, M., van Dam, R.A. and Taylor, I. 2006. Climate variability and change and other pressures on wetlands and waterbirds – impacts and adaptation. In: Boere, G., Gailbraith, C. and Stroud, D. (eds), *Water Birds Around the World*, Scottish Natural Heritage, Edinburgh, U.K. Pp. 88-89. At www.jncc.gov.uk/PDF/pub07_waterbirds_part2.2.6.pdf

Gordon, L., Finlayson, C.M. and Falkenmark, M. 2009. Managing water in agriculture to deal with trade-offs and find synergies among food production and other ecosystem services. *Agricultural Water Management* 97, 512–519.

Harvey, N. and Woodroffe, C.D. 2008. Australian approaches to coastal vulnerability assessment. *Sustainability Science* 3, 67–87.

IPCC CZMS, 1990: *Strategies for Adaptation to Sea Level Rise*. Report of the Coastal Zone Management Subgroup, Response Strategies Working Group of the Intergovernmental Panel on Climate Change, Ministry of Transport, Public Works and Water Management, The Hague, The Netherlands, 122 pp. At http://unfccc.int/files/adaptation/methodologies_for/vulnerability_and_adaptation/application/pdf/ipcc_common_methodology.pdf

IPCC 2001. *Climate Change 2001: Synthesis Report. A Contribution of Working Groups I, II, and III to the Third Assessment Report of the Intergovernmental Panel on Climate Change* [Watson, R.T. and the Core Writing Team (eds.)]. Cambridge University Press, Cambridge, United Kingdom, and New York, USA, 398 pp. Also at www.ipcc.ch/pub/syreng.htm

IPCC 2002. *Climate Change and Biodiversity*. Gitay, H. Suarez, A. Watson, R. T. and Dokken, D (eds.). *IPCC Technical Paper V*. WMO/UNEP, Geneva. Also at www.ipcc.ch/pub/tpbiodiv.pdf

IISD/WB/IDS 2007. *Sharing Climate Adaptation Tools: Improving decision-making for development*. Geneva Workshop, 11-12 April 2007. At www.linkingclimateadaptation.org/

MA 2003 – Millennium Ecosystem Assessment, 2003. *Ecosystems and Human Well-being: A Framework for Assessment*. Island Press, Washington, D.C., 245 pp. At www.maweb.org/en/Framework.aspx

MA 2005 – Millennium Ecosystem Assessment 2005. *Ecosystems and human well-being: wetlands and water synthesis*. World Resources Institute, Washington, DC. At www.maweb.org/documents/document.358.aspx.pdf

Nicholls, R.J., Poh Poh Wong, Burkett, V., Woodroffe, C.D. and Hay, J. 2008. Climate change and coastal vulnerability assessment: scenarios for integrated assessment. *Sustainability Science* 3, 89–102.

Peterson, G.D., D. Beard, B. Beisner, E. Bennett, S. Carpenter, G. Cumming, L. Dent, and T. Havlicek. 2003. Assessing future ecosystem services: a case study of the northern highland lake

district, Wisconsin. *Conservation Ecology* 7 [online] At www.consecol.org/vol7/iss3/art1

Ramsar Convention Secretariat 2007. *Wise use of wetlands: A Conceptual Framework for the wise use of wetlands.* Ramsar handbooks for the wise use of wetlands, 3rd edition, vol. 1. Ramsar Convention Secretariat, Gland, Switzerland. At www.ramsar.org/pdf/lib/hbk4-01.pdf

Ramsar Convention Secretariat 2010. *Ramsar Handbooks for the Wise Use of Wetlands*. 4th edition. 21 volumes. Ramsar Convention Secretariat, Gland, Switzerland. At www.ramsar.org/handbooks4

Renaud, F. and Perez, R. 2010. Climate change vulnerability and adaptation assessments. *Sustainability Science* 5, 155–157.

Romieu, E., Welle, T., Schneiderbauer, S., Pelling, M., Vinchon, C. 2010. Vulnerability assessment within climate change and natural hazard contexts: revealing gaps and synergies through coastal applications. *Sustainability Science* 5, 159-170

van Dam, R.A., Finlayson, C.M. and Humphrey, C.L. 1999. Wetland risk assessment: a framework and methods for predicting and assessing change in ecological character. In: C.M. Finlayson and A.G. Spiers (eds), *Techniques for Enhanced Wetland Inventory, Assessment and Monitoring*. Supervising Scientist Report 147, Supervising Scientist Group, Canberra. Pp. 83-118. At www.environment.gov.au/ssd/publications/ssr/pubs/ssr147-web.pdf

Winter, T.C. 2000. The vulnerability of wetlands to climate change: a hydrological landscape perspective. *Journal of the American water Resources* Association 36, 305-311.

World Bank 2008: *Resources for Managing Adaptation to Climate Change – ADAPT*. At http://sdwebx.worldbank.org/climateportal/.

Ramsar Technical Reports

Ramsar Technical Reports are designed to publish, chiefly through electronic media, technical notes, reviews and reports on wetland ecology, conservation, wise use and management, as an information support service to Contracting Parties and the wider wetland community in support of implementation of the Ramsar Convention.

In particular, the series includes the technical background reviews and reports prepared by the Convention's Scientific and Technical Review Panel (STRP) at the request of the Contracting Parties, which would previously have been made available in most instances only as "Information Papers" for a Conference of the Parties (COP), in order to ensure increased and longer-term accessibility of such documents. Other reports not originating from COP requests to the STRP, but which are considered by the STRP to provide information relevant to supporting implementation of the Convention, may be proposed for inclusion in the series. All Ramsar Technical Reports are peer-reviewed by the members, observers and invited experts appointed to the STRP.

Ramsar Technical Reports

No. 1.	2006	Guidelines for the rapid assessment of inland, coastal and marine wetland biodiversity (CBD Technical Series No. 22)
	2010	Lignes directrices sur l'évaluation écologique rapide de la diversité biologique dans les eaux intérieures, côtières et marines (Série des publications techniques de la CBD nº 22)
	2010	Directrices para la evaluación ecológica rápida de la biodiversidad de las zonas costeras, marinas y de aguas continentales (Serie de publicaciones técnicas del CDB núm. 22)
No. 2.	2006	Low-cost GIS software and data for wetland inventory, assessment and monitoring
	2007	La utilización de programas y datos de SIG de bajo costo para el inventario, la evaluación y el monitoreo de humedales
No. 3.	2006	Valuing wetlands: guidelines for valuing the benefits derived from wetland ecosystem services (CBD Technical Series No. 27)
	2007	Évaluation des zones humides: Orientations sur l'estimation des avantages issus des services écosystémiques des zones humides (Série des publications techniques de la CBD nº 27)
	2007	Valoración de humedales: Lineamientos para valorar los beneficios derivados de los servicios de los ecosistemas de humedales (Serie de publicaciones técnicas del CDB núm. 27)
No. 4.	2010	A Framework for a wetland inventory metadatabase
No. 5.	2011	A Framework for assessing the vulnerability of wetlands to climate change (CBD Technical Series No. 57)

Secretariat of the Ramsar Convention
rue Mauverney, 28
1196 Gland, Switzerland
ramsar@ramsar.org