Queensland Wetlands and Waterways:

Assessing climate change risks and identifying adaptation priorities

WORKSHOP REPORT

(Photo: Lana Heydon - Mossman Gorge)

Christie Conference Centre, Brisbane QLD

17 & 18 April 2012

Acknowledgements

Thank you to all the participants of the workshop for sharing your skills and knowledge. We would like to thank Mike Ronan for facilitating the workshop.

Contents

Introduction

This report presents the findings of a workshop focusing on climate change risks and adaptation priorities for Queensland's wetlands and waterways, held in Brisbane on April 17 and 18, 2012. This workshop represented a collaboration between the Water Resources and Freshwater Biodiversity Adaptation Research Network of the National Climate Change Adaptation Research Facility (NCCARF), the Australian Rivers Institute (ARI) at Griffith University, and Queensland's former Department of Environment and Resource Management (DERM).

The Water Resources and Freshwater Biodiversity Adaptation Research Network has nodes in each State and Territory and conducts activities with the broad aims of i) synthesising and communicating existing knowledge, ii) promoting interdisciplinary and cross-institutional collaborations and iii) building capacity for future research and improved management.

The former DERM conserved, protected and managed Queensland's environment and natural resources and its management responsibilities included meeting the challenge of managing the environment in a changing climate and the protection of the state's aquatic ecosystems. A Biodiversity Strategy for Queensland, released by the previous Queensland Government, aims to build resilience to the anticipated effects of climate change and reverse biodiversity decline. The Strategy focuses on 'whole of landscape', allowing for greater consideration of the interdependencies and connections to allow ecosystems like wetlands to maintain the ability to be adaptive and resilient in a changing climate and acknowledges the importance of the protection of wetlands as habitation for biodiversity.

Population growth is placing pressure on Queensland's freshwater resources and it is expected that climate change will exacerbate this problem. As a result, the former DERM has released a document, *Water in Queensland*, which outlines key initiatives and direction for achieving: integrated adaptive and inclusive water management; safe sustainable, equitable and efficient provision and use of water; knowledge and capacity to support adaptive and evidence-based decision making and practice; a community that is informed and engaged in wise water management and use and; healthy and resilient water resources and aquatic ecosystems.

Workshop objectives

- To develop a common understanding of Queensland's freshwater wetland assets (i.e. what and where are Queensland's freshwater wetlands? What mapping exists? Etc.)
- To identify and agree on current threats to freshwater wetlands and waterways
- To share knowledge of climate change scenarios and climate science relevant to Queensland's wetlands and waterways
- To review and synthesise information on the implications of climate change for the structure and function of Queensland's freshwater wetlands and waterways
- To share information and experience and agree on current approaches to assessing climate change risk at the catchment scale
- To identify appropriate approaches to adaptation for Queensland's freshwater wetlands and waterways
- To identify strengths, weaknesses and opportunities to build capacity for future research, management and policy development relevant to climate change adaptation for Queensland's wetlands and waterways

Workshop design

The workshop was designed and conducted as a facilitator-led, interactive process with most of the sessions conducted in three groups, each focusing on a different geographic region: 1.) South East Queensland 2.) the Drylands (Lake Eyre and Bulloo) and 3.) the Wet Tropics. Participants chose their group based on their expertise and interests. Each group shared and discussed their ideas with the other participants at the end of every session.

Recording of outcomes

Outcomes were recorded using notes from the group discussions. The notes were put into this report, which was sent to the presenters for a preliminary review, then to all participants for a final review and to get feedback.

Forum participants

Twenty-three people participated in the workshop, representing numerous research organisations (Australian Rivers Institute, NCCARF, University of Adelaide, CSIRO, University of the Sunshine Coast, James Cook University) as well as a range of State, Commonwealth and regional Government agencies (former DERM, QCCCE, National Water Commission, GBRMPA and Condamine Alliance).

Workshop outputs

- The development of a Wetland*Info* page describing the impacts of anthropogenic climate change on Queensland's wetlands and the role these ecosystems can play in climate change mitigation
- Guidelines describing current approaches to assessing climate change risk at a catchment scale
- Provision of opportunities for attendees to actively participate in emerging approaches from the Queensland Wetland Program

Day one - Key features, threats, climate change scenarios and impacts

Welcome and introduction: presented by Dave Rissik

Objectives, scope, expectations and introductions

Session 1 – Queensland's Freshwater Wetlands and Waterways

Aquatic Ecosystems (wetlands) in Queensland: presented by Mike Ronan

Overview of QLD Wetlands & Wetlands Program: wetland assets - typology, mapping; wetlands connectivity (4D connectivity project) and threats.

For the purposes of the Queensland Wetlands Program the following wetlands definition, from the *Wetland Mapping and Classification Methodology*, applies:

Wetlands are areas of permanent or periodic/intermittent inundation, with water that is static or flowing fresh, brackish or salt, including areas of marine water, the depth of which at low tide does not exceed 6 metres. To be classified as a wetland, the area must have one or more of the following attributes:

i. *at least periodically, the land supports plants or animals that are adapted to and dependent on living in wet conditions for at least part of their life cycle, or*
ii. *the substratum is predominantly undrained soils that are saturated, flooded or ponded long enough to develop anaerobic conditions in the upper layers, or*
iii. *the substratum is not soil and is saturated with water, or covered by water at some time.*

Wetlands include:

- Rivers and Creeks
- Artificial Wetlands e.g. Dams

- Springs
- Subterranean / Groundwater
- Lakes, lagoons, billabongs
- Swamps
- Bays and Marine Areas
- Estuaries
- Not floodplains (specifically, floodplains that are intermittently covered by flowing water but do not meet the hydrophytes and soil criteria)

Queensland has over 68,000 square kilometres of wetlands (an area slightly smaller than Tasmania).

Wetlands mapping- 3 layers:

1. Drainage lines (streams)
2. Wetland areas
3. Wetland points (springs, waterholes)

Classes of GDEs

- Terrestrial
- Surface expression (wetlands, base flow)
- Subterranean (Aquifer, Karst)

Wetlands habitat typology attributes:

- Wetland System – Lacustrine (lake) / Palustrine (swamp)
- Climate regions – Coastal and Sub-Coastal/ Arid and Semi Arid
- Water Type – Fresh/ Salt
- Water Regime – Commonly wet/ Periodically inundated
- Substrate – Peat/ Soil/ Rock/ Sand
- Topography – Floodplain/ Non-floodplain
- Vegetation – Tree/ Shrub (Wet Heath) / Grass, Sedge, Herb

4D – connectivity project

- There needs to be a purpose for connectivity linked to the overall management objectives
- Potential and realised connectivity needs to be understood for decision making
- Components and connectivity MUST BOTH be addressed for long term systems resilience
- Connectivity is a mechanism that supports ecological processes
- Conceptual models of underlying processes are essential precursors to addressing connectivity
- Knowledge gaps and uncertainty must be acknowledged, but not limit decision making
- The process determines the ecological relevance of the spatial and temporal scale
- Connectivity must occur through the physical environment (air, water, land)
- Adaptive management allows for decisions to be refined

Queensland Wetlands Program

A joint initiative of the Australian and Queensland Governments which aims to support projects and programs that will result in long-term benefits to the sustainable use, management, conservation and protection of Queensland wetlands

- 70 Projects
- Address all aspects of wetlands management

Monitoring changes in extent:

1. Clearing of vegetation
2. Additional water-bodies
3. Loss of water bodies
4. Modification to existing water bodies

Queensland Flow Regimes, Aquatic Ecosystems, Climate Change Threats: presented by Angela Arthington

Hydro-Ecological Relationships and Thresholds to Inform Environmental Flow Management and River Restoration - a test of the ELOHA Framework

ELOHA Concepts

1. *"Rivers of a chosen region can be grouped into distinctive flow regime classes on the basis of ecologically relevant flow metrics - measures of magnitude, seasonal timing, frequency, duration and variability of particular flows."*
2. *"Ecological characteristics of rivers within each flow regime class will be relatively similar compared to those of other classes. Therefore class members may be managed in similar ways in terms of environmental flows."*
3. *"Rivers within each flow regime class that are 'regulated' (or supplemented) in the same way by dams or other infrastructure will show similar ecological responses to flow regime change."*
4. *"Increasing degrees of flow regime change will have increasing impacts on ecological response variables."*

Implications for Climate Change

- ELOHA flow classifications help to reveal natural and altered flow regime characteristics, and prominent gradients
- Biodiversity patterns for riparian vegetation, aquatic vegetation and fish track natural gradients in climatic and hydrologic characteristics of SEQ
- Changes in flow regime below dams are reflected in biodiversity and biomass shifts, Some of these changes are positive (e.g increased aquatic plant cover below dams with elevated, more stable low flows) and some are negative (e.g. low abundances of native fish vs alien abundance in streams with increased number of zero flow days)
- ELOHA study provides signals for the possible impacts of:
    i. warmer or cooler regimes
    ii. drier or wetter regimes
    iii. more or less variable regimes - daily, dry season, annual

Group Discussion - Key features of Queensland's freshwater wetlands and waterways

In three working groups, participants discussed the key features in their climate region (South East Queensland, Wet Tropics and Drylands- Lake Eyre and Bulloo). Maps of the regions were used, which included the four wetland types that were focused on in the workshop (estuarine, lacustrine, palustrine and riverine) as well as springs. Information sheets with a short summary of the region were also used.

South East Queensland – Key features

South East Queensland runs from the NSW border to South of Gladstone, is dry in the west and wet in the south and includes several large dams, regulated rivers and farm dams. Groundwater Dependent Ecosystems (GDEs) are not well represented. Fraser Island has some rain water dependent perched lakes as well as window lakes arising from seepage from main water table "streams" in natural depressions. ICOLLs (Intermittently Closed and Open Lakes and Lagoons) are present on the edges of estuarine areas. There are large permanent rivers with bordering lakes (eg. Noosa) that are different to mainland streams. Rivers in the west driven by groundwater are vulnerable.

Drylands (Lake Eyre and Bulloo) – Key features

The Drylands are characterised by highly episodic, variable water regimes with highly dynamic (boom and bust) wetland populations and communities, with the exception of springs. When water is not flowing, waterholes are contracted and can dry out. There are internal drainage basins and extensive areas of flow with lateral and longitudinal connectivity. Different species are found within each catchment, and some fish and bug species are endemic to the springs that lack the natural capacity to cope with variance. Vegetation in the Drylands is sparse and related to the water systems. There are many bores in the region. The large bores are capped but some smaller properties have their own bores that can be unregulated. Most internal palustrine systems in the region are saline and even some springs are saline.

Wet Tropics – Key features

The Wet Tropics have generally steep relief and high stream slopes, resulting in steeper catchments where run-off is generally faster, leading to more peaked discharges, greater erosive power and a higher disturbance intensity of spates in the province. Water turbidity is generally very low and ephemeral waterbodies exist in the dry tropics area. The principal land use in the Wet Tropics is agriculture (sugar cane, bananas) and grazing.

Session 2 – Threats to Queensland's Freshwater Wetlands

Threats to Queensland Wetlands and Waterways: presented by Peter Negus

- A threat is the change in biophysical and chemical conditions of an ecosystem that produces an adverse ecological response

List of generic threats – SEAP (stream and estuary assessment program)

- Acid soil runoff
- Pathogens
- Climate change
- Riparian disturbance
- Direct biota removal or disturbance
- Introduced or translocated terrestrial species (flora / fauna)
- Flow management
- Sediments (suspended / deposited)
- Aquatic disturbance
- Salinity
- Introduced or translocated aquatic species (flora / fauna)
- Thermal alteration
- Nutrients
- Toxicants
- Organic matter

The list covers most threats, however is flexible to add others. The SEAP approach can:

- Prioritise monitoring
- Prioritise research
- Prioritise management
- Be applied at any scale – bioregion to individual wetland
- Applied to any ecosystem type

Group Discussion- Anthropogenic activities currently impacting on Queensland's freshwater wetlands and waterways

South East Queensland - Anthropogenic activities

Anthropogenic activities currently impacting rivers in South East Queensland include direct biota removal, flow management, landuse change, aquatic disturbances, dredging, engineering (corridors etc.), introduced species, nutrients, toxicants, organic matter (OM), pathogens, sediments, riparian disturbance and fire. Threats impacting palustrine wetlands include increased water extraction, fires, vegetation change, sandmining, forestry, tourism, landuse changes, acid sulphate soils (Wallum), ground water draw down, oil spills (toxicants) and development and sensitive subterranean ecosystems. Lacustrine systems are impacted by dams.

South East Queensland Group Discussion Notes

- **Rivers**
  - Direct biota removal
  - Flow management
  - Landuse change
  - Aquatic disturbances
    - Dredging
    - Engineering
    - Corridors etc.
  - Introduced species
  - Nutrients
  - Toxicants
  - Organic matter (OM)
  - Pathogens
  - Sediments
  - Riparian disturbance
  - Fire
- **Palustrine**
  - Increased water extraction
  - Fires
  - Vegetation change
  - Sandmining
  - Forestry
  - Tourism
  - Landuse changes
  - Acid sulphate soils (Wallum)
  - Ground water draw down
  - Oil spills (toxicants)
  - Development
  - Sensitive subterranean ecosystems
- **Lacustrine**
  - Dams

Drylands – Anthropogenic activities

Anthropogenic activities currently impacting on the Drylands include grazing pressure and feral and pest animals. Toads are eating large amounts of native macroinvertebrates from the springs. There are massive numbers of goldfish in the southern area that are very large in size. Camels in the far west can drink small waterholes completely dry, and then move on, leaving native animals with no water. Pigs eat native vegetation around waterbodies, erode banks and rip up mussels to eat (which are important filters). Red Claw is also a threat in the area.

Drylands Group Discussion Notes

- **Feral and pest animals**
  - Toads are eating large amounts of native macroinvertebrates from the springs
  - Goldfish in the southern area- large in size and massive amounts
  - Red Claw
  - Camels in the far west can drink small waterholes completely dry, then move on, leaving native animals with no water
  - Pigs
    - Rip up and eat mussels (important filter)
    - Eat native vegetation around waterbodies
    - Erode banks
- **Grazing pressure**
- **Rock holes**
  - Many are ephemeral

Wet Tropics – Anthropogenic activities

Anthropogenic activities currently impacting on the Wet Tropics include sandmining, feral/ exotic animals, grazing pressure, coastal development, tourism (unsealed roads and sedimentation), hydroelectric stations, instream works, riparian clearing, herbicides and pest vegetation/ weeds such as Pond apple, Hymenachne and Para grass.

Wet Tropics Group Discussion Notes

- Sandmining
- Feral/ exotic animals
- Pest vegetation/ weeds
  - Pond apple
  - Hymenachne
  - Para grass
- Grazing pressure
- Coastal development
- Tourism
  - Unsealed roads
  - Sedimentation
- Hydroelectric stations
- Instream works
- Riparian clearing
- Herbicides

Session 3 – Climate Change Scenarios for QLD Wetlands and Waterways

Climate change projections for Queensland: presented by David Robinson

- What's certain:
    - CO_2 will rise (how much depends on us)
    - Temperatures will rise (+0.6 - 1.5°C: 2030; 1 - 5°C: 2070)
- What's likely but with direction of change varying across Queensland:
    - Rainfall will probably change (drier S & E)
    - Storms / cyclones will probably intensify
    - 'High end' extremes will be more likely (and may co-occur and be more pronounced and of longer duration
    - 'Low end' extremes will generally decline (e.g. frosts)

Overall estimate of impacts for the risk averse:

- Reduction in pasture growth
- Decrease in surface cover
- Decrease in plant available water capacity
- Increased wind erosion
- Decrease in human health and increase in welfare related issues
- General negative long-term effects on ecosystem function

- What the climate data may mean for river flows:
    - For each 1°C rise in temperature, we can expect around a 5% change in flows

Group Discussion- Climate change impacts that have occurred or are likely to occur in the future

South East Queensland – Climate change impacts

Swamps

Low lying palustrine may convert to marine and estuarine in the event of a sea level rise. The Noosa everglades may become an estuary. There would be nowhere for palustrine wetlands to retreat. Significant species from Flinders beach near Amity may become extinct unless managed and significant loss of wetland habitat is likely to occur. The likelihood and intensity of fires would increase, leading to decreased plant resilience and making it harder for wetlands to bounce back. Increased evaporation and decreased rainfall could lead to lower water levels and increased temperature could lead to stronger stratification and decreased dissolved oxygen below thermocline. Climate change could possibly result in less acid sulphate issues.

South East Queensland Group Discussion Notes

- **Swamps**
  - Low lying palustrine may convert to marine & estuarine with sea level rise. Noosa everglades may become an estuary
  - Nowhere for palustrine wetlands to retreat
  - Significant species from Flinders beach near Amity may become extinct unless managed
  - Significant loss of wetland habitat
  - People may protect important values
  - Increased likelihood and intensity of fires- decreased plant resilience, harder for wetlands to bounce back
  - Increased evaporation and decreased rainfall could lead to lower water levels
  - Increased temperature may lead to stronger stratification and decreased dissolved oxygen below thermocline
  - Less acid sulphate issues?
- **Rivers**
  - More dams and infrastructure
  - More interbasin transfer due to increased water reuse- artificial connectivity
    - Spread of exotics with higher connectivity
  - Headwater flows decrease and become a series of pools
    - fish communities could alter
    - decreased genetic transfer
    - potentially lead to loss of fish species
  - Refuge waterholes smaller and warmer- increase in organic matter
  - More direct impacts (socio-economic), more planting
  - Increased sedimentation
  - More thermal alien species moving from north to south
  - Decreased breeding in some species (eg. pig-nosed turtles)
- **More intensive events**
  - Faster delivery of pollutants, nutrients?
  - Water-borne diseases
  - Increase in mosquito population- Ross River Virus, Dengue Fever)

Rivers

More dams, infrastructure and water reuse could result in more interbasin transfers and artificial connectivity, spreading exotics due to the higher connectivity. Headwater flows could decrease; becoming a series of pools and altering fish communities, decreasing genetic transfer and potentially lead to loss of fish species. Refuge waterholes could become smaller and warmer, increasing organic matter. Sedimentation could also increase and more thermal alien species may begin moving from north to south. Climate change could impact breeding in some species, for example the pig-nosed turtles, which lay their eggs late in the dry season and offspring develop fully in the eggs and then stay in hibernation until conditions are suitable i.e. when they are flooded with water or by a sudden drop in air pressure, signalling an approaching storm. Regardless of how late the wet season is, they will not hatch until is has started to rain.

More intensive events

More intensive events could lead to faster delivery of pollutants and nutrients, water-borne diseases and an increase in mosquito population (and potentially an increase in the outbreaks of Ross River Virus, Dengue Fever etc).

Drylands (Lake Eyre and Bulloo) – Climate change impacts

We need to know species temperature parameters in order to make specific inferences, but generally, dryer dry periods may lead to decreased vegetation cover. In the northern savannas the relationship between strength of drought and tree density is pronounced. Other impacts include a reduction in the number of species that can survive “busts” and a decrease in the quality and number of refuges. Springs are probably less likely to be affected compared with other types of waterbodies.

Increased evaporation and decreasing quality of waterholes and wetlands may mean less livestock, perhaps leading to an increase in feral animals. Feral animals compete with native animals for resources and less water could lead to an increase in water temperature (due to smaller areas of water) and an increase in algal blooms. Some species that live on the surface of waterholes are very sensitive to temperature (eg. rainbowfish).

More intense, less frequent rainfall would mean wetlands would probably fill up quickly and dry up quickly and this could lead to a decline in birds that use the wetlands for breeding. A decline in big rainfall events may lead to a very slow decline in species that seed in the dry wetland beds, and less surface water may lead to more bores and more pressure on existing bores.

Increased CO_2 levels could change the composition of vegetation, changing the composition of leaf litter. The likelihood and intensity of fires could increase.

Drylands (Lake Eyre and Bulloo) Group Discussion Notes

- Dryer dry periods may lead to decreased vegetation cover
  - In the northern savannas the relationship between strength of drought and tree density is pronounced
- Reduction in the number of species that can survive "busts"
- Decrease in the quality and number of refuges
- Springs probably less likely to be affected compared with other types
- Increased evaporation and decreasing quality of waterholes and wetlands may mean
  - Less livestock, perhaps leading to an increase in feral animals?
  - Feral animals compete with native animals for resources
  - Less water could lead to an increase in water temperature (due to smaller areas of water) and an increase in algal blooms
    - Some species that live on the surface of waterholes are very sensitive to temperature (eg. Rainbowfish)
- More intense, less frequent rainfall affects wetlands
  - Fill up quickly and dry up quickly
  - Could lead to a decline in birds that use the wetlands for breeding
- A decline in big rainfall events may lead to a very slow decline in species that seed in the dry wetland beds
- Increased CO_2 levels can change composition of vegetation, changing the composition of leaf litter
- Increased likelihood and intensity of fires
- Less surface water may lead to more bores and more pressure on existing bores

Wet Tropics – Climate change impacts

Climate change may alter the frequency and duration of cloud interaction with mountains along the east wet tropics escarpment. Reduced rainfall may cause loss of perennial stream flow and refuge waterholes may dry-up during the dry season. Floristics could change, as well as run-off and streamflow.

Aquatic ecosystems (streams) on mountain tops provide thermal refuges, and the thermal tolerance threshold may be

Wet Tropics Group Discussion Notes

- **Cloud Capture**
  - Climate change may alter the frequency and duration of cloud interaction with mountains along the east wet tropics escarpment
- **Spells between rainfall events**
  - Reduced rainfall may cause loss of perennial stream flow
  - Refuge waterholes may dry-up during the dry season (riverflow and groundwater?)
  - Changed floristics
  - Changed run-off and streamflow
- **Maximum temperatures**
  - Aquatic ecosystems (streams) on mountain tops provide thermal refuges
  - The thermal tolerance threshold may be surpassed
- **Temperature regime**
  - Reproductive cues
  - Sex selection
  - Shifting distributions

surpassed as a result of rising temperatures due to climate change. A new temperature regime could also change reproductive cues, sex selection and shifting distributions.

Session 4 – Climate Change Impacts in QLD Wetlands and Waterways

Climate Variability and Queensland's Wetlands: presented by Jon Marshall

Some wetlands have been going though various phases over thousands of years (eg. wet, dry, wet or riverine planktonic, benthic, riverine planktonic).

- The climate of Queensland has varied dramatically in the past
- In response, wetland biota have adapted, persisted in climate refuges, or been forced to extinction
- Human induced degradation of wetland ecosystems, landscapes fragmentation, and more rapid fluctuation in climate than in the past, are all likely to reduce our capacity to predict wetland ecosystem responses to future climate variability

To maintain the ability of wetland ecosystems and the species they support to adapt to future climate variability we should:

1. Protect or restore climate refuges such as mound-springs and coastal-dune wetlands
2. Protect or restore connectivity between wetlands to allow recolonisation processes to proceed following extreme climate events
3. Protect or restore degraded wetlands to improve their resistance and resilience to climate variability

The history of the wetlands of North Stradbroke Island (Defining natural climate variability in South East Queensland and improving ecosystem management): presented by Cameron Barr

- The inland wetlands appear to have been persistent features of the landscape over very long timeframes. The coastal wetlands are significantly younger than anticipated.
- The persistence of the inland systems indicates a resilience to even extreme climate perturbations.
    - Groundwater levels are key to this persistence.
- The coastal wetlands are clearly vulnerable to sea-level rise.

Day two – Climate change risk assessment, adaptation options and research priorities

Session 1 – Climate Change Risk Assessment for Freshwater Wetlands and Waterways

Informing Outlook for Great Barrier Reef Coastal Ecosystems: presented by Donna Audas

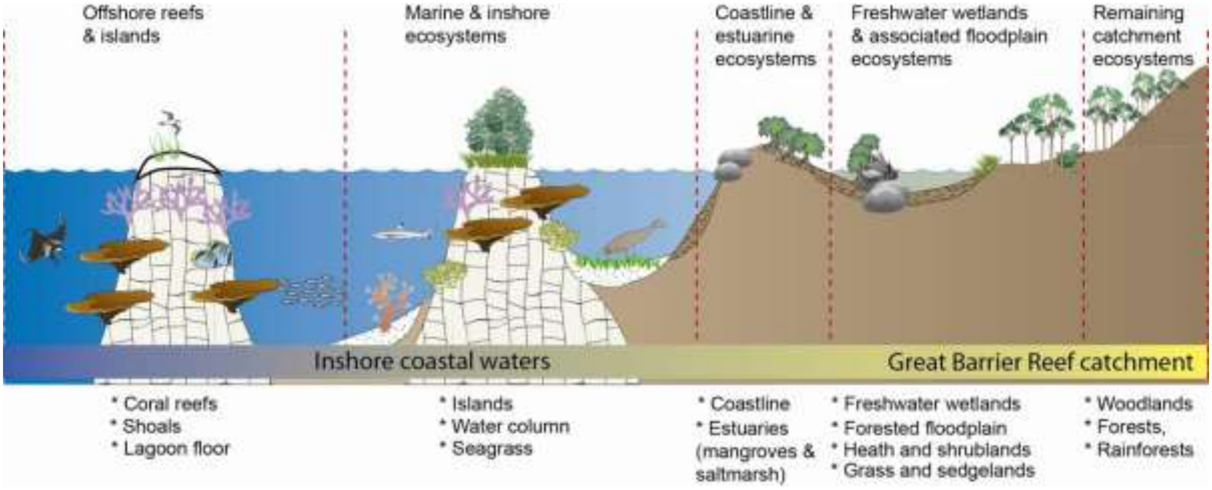
Coastal ecosystems connect the land the sea. The report being developed assesses the coastal ecosystems which connect the 35 basins forming the Great Barrier Reef catchment (the catchment) to the Great Barrier Reef World Heritage Area (the World Heritage Area). This provides an understanding of the coastal ecosystems that have the potential to influence its health and resilience. The Report identifies changes to the coastal and inshore ecosystems since European settlement, and assesses the implications for the Great Barrier Reef.

The Report being developed will provide further detail necessary to inform the future management of the World Heritage Area, catchment and the inshore species reliant on a healthy environment and in particular the management of Great Barrier Reef. It will describe how the inshore marine, coastal and catchment ecosystems are interconnected and how they are reliant on one another for their functions, illustrating how species that form part of the amazing biodiversity of the World Heritage Area live in and move between these ecosystems throughout their life cycles.

Natural coastal ecosystems with connections to the Great Barrier Reef:

- Coral Reefs
- Lagoon floor
- Islands
- Water column
- Seagrasses
- Beaches
- Estuaries
- Freshwater wetlands
- Forest floodplain
- Heath & shrublands

- Grasslands
- Woodlands
- Forests
- Rainforests



While these ecosystems can be categorised into many different groupings, this review focussed on understanding the functions and the services of these ecosystems from the perspective of the health and resilience of the Great Barrier Reef.

Examples of some of the pressures on coastal ecosystem and their functions

- Instream structures / bunds
- Ponded pastures
- Recruitment
- Sediment trapping
- Potential acid sulphate soils
- Temperature regulation
- Blackwater

Key ideas from workshop session 1

The functions coastal ecosystems provide for the Great Barrier Reef include: physical processes such as sediment and water distribution and cycling; biogeochemical processes such as nutrient and chemical cycling and biological processes such as habitat and food provisioning.

Coastal ecosystems are functional ecosystems that range from those with strong and direct links for the functions they provide to the Great Barrier Reef (for example river discharges of freshwater) to systems that are more remote with less direct but nevertheless critical links (for example highland rainforests preventing hill slope soil loss). There are three broad groupings based upon their level of influence on reef health. Those ecosystems with greatest influence are located on the Great Barrier Reef coast (coastline and estuarine ecosystems), that form the boundary between terrestrial and marine ecosystems. The second group of ecosystems are those that are part of the coastal floodplain adjacent to and linked to the Great Barrier Reef coast (freshwater wetlands and associated floodplain ecosystems). These are ecosystems that are directly linked to the marine environment permanently or intermittently by water. Lastly the ecosystems that make up the bulk of the catchment but have less direct links to and thus less influence on the health on, the Great Barrier Reef make, up the last group (remaining catchment ecosystems).

One of the main reasons inshore species are particularly vulnerable is that they often have life history traits and behaviours which predispose them to exposure to human-related threats. Many have relatively long lives with a reliance on a small home range. This report will seek to assess the extent of changes, the implications for the World Heritage Area, and the management strategies in place or required to halt and reverse the declines in inshore biodiversity.

Climate change will exacerbate the pressures on coastal ecosystems over the coming decades. Severe cyclones and increased sea surface temperature anomalies are predicted to occur more frequently as the climate warms, bringing a future where the recovery potential of coral reefs and seagrass meadows becomes increasingly important. Chronic stresses from reduced water quality can hinder recovery of damaged seabed communities. Therefore, the combined effect of increased flooding, increased temperatures and more severe storms means efforts to restore the natural resilience of important habitats such as coral reefs and seagrass meadows are more important than ever before.

Session 2 – Adaptation Options for Freshwater Wetlands and Waterways

Assessing biodiversity management strategies for a changing climate: presented by Michael Dunlop

Key issues for adaptation:

1. **Magnitude** of climate change and its ecological impacts
    - Shifting baselines, changing objectives
    - Magnitude of loss
2. Many different **types** of change
    - Not a singular ecological phenomenon
3. Multiple **values** associated with native species and ecosystems
    - Existing surrogates may not be sufficient
4. Considerable **uncertainty**
    - Types of decisions
    - Information base
    - People and institutions
5. Adaptation in undertaken by **people** in agencies with multiple (conflicting) incentives and mandates
    - Build capacity, not blue prints

Adaptation Framework:

1. Reassess biodiversity policy **goals**
    - Be explicit about biodiversity values
    - Desired outcomes for species, ecosystem health and landscapes
2. Develop **management objectives** to contribute to different outcomes
    - Ecological requirements to achieve goals
3. Plan for different types of **ecological change**
    - Ecological change scenarios under climate change

4. Systematically identify **management actions** for objectives x scenarios
    - Evaluate effectiveness of existing actions
    - Identify knowledge gaps
5. Identify **priorities** for adaptation pathways
    - Uncertainty, risks, timing, decision lifetime

Moving from impacts to adaptation in the coastal zone: presented by Wade Hadwen

The ten questions for adaptation actions:

1. What are the goals of the action?
2. What climate change driver or ecological consequence does the action address?
3. What type of adaptation action is it? Engineered, resilience building etc.
4. What are the spatial and temporal scales for implementation?
5. What are the likely intended ecological consequences?
6. What are the unintended ecological consequences, both within the target and non-target habitat?
7. What are the unintended human consequences, including local and regional impacts on settlements, infrastructure and communities?
8. What are the likelihoods and impacts of the unintended consequences?
9. What are the costs (social and economic) and efficacy associated with the action?
10. What are biophysical and socioeconomic constraints that might inhibit uptake and implementation?

Seven principles of climate change adaptation

1. ***Climate change adaptation needs clearly defined goals***. 'keep the system as it is', 'significantly improve the condition of the system' or, 'move the system to a new alternative state'
2. ***Climate change adaptation decision making must include stakeholders from environmental, social and economic realms***
3. ***Climate change adaptation decision making requires data to be easily available and shared***
4. ***Climate change adaptation demands a drastic re-think of existing policy and planning constraints.*** We need to be more flexible and dynamic (spatially and temporally)
5. ***Climate change adaptation in the coastal zone requires a thorough understanding of connectivity, both within ecosystems and between them***
6. ***Adapt at local/regional scales, but don't lose sight of the bigger picture.*** Climate change adaptation actions at the local/regional scales must not impinge upon the capacity of species or communities to persist at the larger scale.
7. ***Climate change adaptation should not be considered in isolation of the many non-climatic threats that coastal environments already face***

Climate change is multi-parameter (includes temperature, rainfall etc.) and there are important trend (increasing temperature etc.) and variability (extreme events) issues to contend with.

When looking anywhere near the coast, sea level rise is a massive issue that may swamp (literally and figuratively) the other changes in climate we might expect to see.

Group Discussion – Adaptation options and impediments to implementing them

South East Queensland – Adaptation options

Adaptations for sea level rise

Likely impacts of sea level rise are seawater intrusion and conversion from freshwater to marine/estuarine. Can the Wallum swamps move to new areas? Wallum habitat moves much slower than mangrove habitat (thousands of years). There is a possibility to transplant habitat and species mechanically (eg. the heathland behind Sunshine Coast University)

We could identify opportunities and potential sites that could support the ecosystem (filling in the gaps), for example, buy back schemes, land zoning, farmland (eg. Unused sugar cane fields)- revert existing land regime back to what it was previously (old Wallum areas).

When not appropriate to move naturally or transplant, seed banks could be considered, as well as captive breeding programs. Engineering options were also considered, such as building a sea wall in front of 18 mile swamp to keep it freshwater, but this may not be cost effective, and that area has already been estuarine in the past. There is an emphasis on maintaining corridors South-North and establishing East-West ones.

South East Queensland Group Discussion Notes

Adaptations for sea level rise:

- Likely impacts are seawater intrusion and conversion from freshwater to marine/estuarine
- Can the Wallum swamps move to new areas?
- Wallum habitat moves much slower than mangrove habitat (thousands of years)
- Could possibly transplant habitat and species mechanically (eg. the heathland behind Sunshine Coast University)
- Identify opportunities and potential sites that could support the ecosystem (filling in the gaps)
  - Buy back schemes
  - Land zoning
  - Farmland (eg. Unused sugar cane fields)- revert existing land regime back to what it was previously (old Wallum areas)
- When not appropriate to move naturally or transplant:
  - Consider seed banks
  - Captive breeding program
  - Engineering options- could build a sea wall in front of 18 mile swamp to keep it freshwater
    - May not be cost effective
    - That area had already been estuarine in the past
- Maintaining corridors South-North and establishing East-West ones

Drylands (Lake Eyre and Bulloo) – Adaptation options

Adaptation ideas for the drylands included recognising recharge zones, decreasing grazing, and maintaining infiltration back into the aquifer. To mitigate tourism impacts we could identify the big, main waterholes and provide infrastructure to lessen environmental impact from tourists/ campers. Boring and extraction need to be managed; at the moment there is a set volume allowed to be extracted from each bore hole, but perhaps implementing a sliding scale allowance to respond to changing water levels would be useful.

Camels need to be managed before they move further east and become a bigger problem and refugia needs to be maintained, perhaps by fencing riparian areas- keeping vegetation and bigger trees in place as thermal regulation.

Drylands (Lake Eyre and Bulloo) Group Discussion Notes

- Recognise recharge zones
  - Decrease grazing
  - Maintain infiltration back into the aquifer
- Mitigate tourism impacts
  - Identify the big, main waterholes and provide infrastructure to lessen environmental impact from tourists/ campers
- Manage boring and extraction
  - At the moment there is a set volume allowed to be extracted from each bore)hole
  - Perhaps implementing a sliding scale allowance to respond to changing water levels would be useful
- Feral control
  - Camels need to be managed before they move further east and become a bigger problem
- Maintain Refugia
  - Fence riparian areas- keeping vegetation and bigger trees in place as thermal regulation

Wet Tropics – Adaptation options

Three general principles were agreed upon, including restoring condition (management of threats), restoring "appropriate" connectivity and protecting refuge sites. Key refuge sites need to be identified, perhaps artificially adding water into water holes (similar to what was done in Victoria). A captive breeding program could also be considered (When threshold for temperature is reached). Where is the threshold? A point was raised- we need to strike a balance between defining thresholds and taking action. If we spend years trying to define thresholds for every single species, we may find we have passed the thresholds already, so proactive management is encouraged

Wet Tropics Group Discussion Notes

- General principles
  - Restore condition- management of threats
  - Restore "appropriate" connectivity
  - Protect refuge site
- Identify key refuge sites
- Artificially add water into water holes (similar to what was done in VIC)
- Captive breeding program (When threshold for temperature is reached)
  - Where is the threshold?
  - Point was raised- we need to strike a balance between defining thresholds and taking action. If we spend years trying to define thresholds for every single species, we may find we have passed the thresholds already, so proactive management is encouraged

Session 3 – Synthesis: Research priorities and where to next?

Research Priorities

- Process understanding of systems and landscapes
- Related to values that are agreed/ captured for an area/ system
- Better framework for thinking of the values to be considered for an area (socio-economic research)
  - Ecosystem services approach (spatially)
  - Separate values from type and state (eg. Have values on species and ecosystems as well as land)
  - Identify values that persist through change and that aren't fixed to type only
- Waterholes- roles in landscape, behaviour under climate change, abundance of waterholes in landscape, where are they? Connection to groundwater? **Process understanding**
- What are key indicators of change? What do we need to know to manage the system?
- Dealing with extreme events- are they a higher priority than slow change?
  - Ranges, maximums and frequency etc. to enable planning for extremes
  - Impacts of higher frequency of extreme events?
- Better understanding of meta population and meta community dynamics
- What are the implications of CC at the level of hydrology?
- Improving data acquisition systems- climate, weather and local scenarios and responses; combining bottom-up and top-down data
- Communication- do a better job of communicating what we **are** sure about (characterise things we know/ don't know) and communication uncertainty better- associated with risk and severity
- What do we know about current threats and "condition"/ monitoring to ID change and enable response
- Coastal models to determine impacts on coastal / fresh/ estuarine wetlands
  - Adapt existing USA models to Australian conditions
  - More **tools** to help managers anticipate change (what it will be) and responses

    - Models need to establish what data we need to collect and where from
- Objectives (how to unpack) more work/ teasing out
    - Eg. Switch from threatened species focus
- Analyse effectiveness and cost/ benefit of management options

Where to next?

- Symposium? Include climate change but link into other areas too

Appendix A – Workshop Agenda

Queensland Wetlands and Waterways: assessing climate change risks and identifying adaptation priorities

Date: 17 - 18 April 2012

Venue: Christie Conference Centre, 320 Adelaide Street, Brisbane CDB

Facilitator: Mike Ronan

<table>
<tr><th colspan="3">DAY 1 - Tuesday April 17</th></tr>
<tr><td>Time</td><td>Activity</td><td>Presenter</td></tr>
<tr><td>9:00 am</td><td>Welcome and Introduction
- Objectives, scope, expectations and introductions</td><td>David Rissik</td></tr>
<tr><td colspan="3">Session 1 – Queensland’s Freshwater Wetlands and Waterways</td></tr>
<tr><td></td><td>Presentation
- Overview of QLD Wetlands & Wetlands Program: wetland assets - typology, mapping; wetlands connectivity and threats.
- “Aquatic ecosystems (wetlands) in Queensland”

Presentation
- Overview of QLD Waterways: SEQ ELOHA trial, SW Qld etc
- “Queensland Flow Regimes, Aquatic Ecosystems, Climate Change Threats”

Discussion:
Form break-out groups:
1. SEQ
2. Drylands
3. Tropical North

Q1 What are key features of Queensland’s freshwater wetlands and waterways in each climate region?

Whole group synthesis</td><td>Mike Ronan

Dr Angela Arthington</td></tr>
<tr><td></td><td>Morning Tea</td><td></td></tr>
<tr><td colspan="3">Session 2 – Threats to Queensland’s Freshwater Wetlands</td></tr>
<tr><td></td><td>Presentation
Threats to Queensland Wetlands and Waterways

Discussion in break-out groups:
Q1. What anthropogenic (non-climate change related) activities are currently impacting on Queensland’s freshwater wetlands and waterways in your climate region?
Q2. How are these activities impacting on wetland ecosystems?</td><td>Peter Negus</td></tr>
</table>

	Whole group synthesis	
	Lunch	
Session 3 – Climate Change Scenarios for QLD Wetlands and Waterways		
	Presentation Climate change projections for Queensland **Discussion in break-out groups:** Q1. What climatic changes have occurred already or are currently occurring in your climate region of relevance to wetlands and waterways? Q2. What climatic changes of relevance to wetlands and waterways are projected in your climate region? Whole group synthesis	David Robinson
	Afternoon Tea	
Session 4 – Climate Change Impacts in QLD Wetlands and Waterways		
	Presentation - Climate variability and Queensland's wetlands	Jon Marshall
	Presentation - The history of the wetlands of North Stradbroke Island - "Defining natural climate variability in South East Queensland and improving ecosystem management" **Discussion in break-out groups:** Q1. What climate change impacts have occurred already or are currently occurring in wetlands and waterways of your climate region? Q2. What climate change impacts are likely to occur in wetlands and waterways of your climate region in the future? Whole group synthesis	Cameron Barr
4:50	Close of Day 1	

<table>
<tr><th colspan="3">DAY 2 - Wednesday April 18</th></tr>
<tr><td>Time</td><td>Activity</td><td>Presenter</td></tr>
<tr><td>9:00 am</td><td>Recap of Day 1</td><td>Mike Ronan</td></tr>
<tr><td colspan="3">Session 1 – Climate Change Risk Assessment for Freshwater Wetlands and Waterways</td></tr>
<tr><td></td><td>Presentation
- The Great Barrier Reef Marin Park Authority has developed a basin assessment framework for coastal ecosystems that incorporates climate change risk and vulnerability of freshwater wetlands and waterways
- “Informing outlook for Great Barrier Reef Coastal Ecosystems”

Discussion in break-out groups:
Q1 How can climate change risks to wetlands and waterways in your climate region be assessed and what are the major risks likely to be?
Q2. How can vulnerability of wetlands and waterways in your climate region be assessed? i.e. what factors influence vulnerability and which wetlands/waterways are likely to be most vulnerable?

Whole group synthesis</td><td>Donna Audas</td></tr>
<tr><td></td><td>Morning Tea</td><td></td></tr>
<tr><td colspan="3">Session 2 – Adaptation Options for Freshwater Wetlands and Waterways</td></tr>
<tr><td></td><td>Presentation
- Assessing biodiversity management strategies for a changing climate

Presentation
- Management principles for climate change adaptation for aquatic ecosystems
- Moving from impacts to adaptation in the coastal zone

Discussion in break-out groups:
Q1. What are appropriate adaptation options for freshwater wetlands and waterways in your climate region?
Q2. What are the impediments to implementing these adaptation options?</td><td>Michael Dunlop (CSIRO)

Wade Hadwen</td></tr>
</table>

	Whole group synthesis	
12:40 pm	***Lunch***	
Session 3 – Synthesis: Priorities for risk assessment and adaptation		
1:40 pm	**Whole Group Discussion :** Q1. What are the research priorities for informing climate change risk assessment for QLD wetlands and waterways? Q2. What are the priorities for adaptation for QLD wetlands and waterways within each climate region at local and catchment / regional scales? Q3. What are the priorities for adaptation for QLD wetlands and waterways at State scale?	
	Afternoon Tea	
Session 4 – Where to next?		
	Whole Group Discussion: Q1. What are the current risk assessment and adaptation strategies in QLD relevant to climate change risk assessment and adaptation for freshwater wetlands and waterways? *Compile preliminary list.* Q2. What are the current research projects in QLD relevant to climate change risk assessment and adaptation for freshwater wetlands and waterways? *Compile preliminary list.* Q3. Where to next? - WetlandInfo page? - Symposium? - Report card?	
4:50	Thanks and Close of Day 2	

Appendix B: Workshop Attendance list

Attendee Name	Organisation/Contact email
Professor Angela Arthington	Emeritus Professor, Australian Rivers Institute, Griffith University Email: A.Arthington@griffith.edu.au
Donna Audas	A/Manager Coastal Ecosystems, Great Barrier Reef Marine Park Authority Email: Donna-Marie.Audas@gbrmpa.gov.au
Dr. Cameron Barr	Post-doctoral Research Associate, Geography, Environment and population, University of Adelaide Email: cameron.barr@adelaide.edu.au
Anthea Brecknell	Project Officer,WDE, National Water Commission Email: Anthea.Brecknell@nwc.gov.au
Suzanne Burow	Senior Hydrologist, (former) DERM Email: Suzanne.Burow@derm.qld.gov.au
Dr. Michael Dunlop	Land, Water, Biodiversity & Climate Analyst, CSIRO Email: Michael.Dunlop@csiro.au
Cheree Fenton	Senior Environmental Scientist, , Aquatic Ecosystem Health, (former) DERM Email: Cheree.Fenton@derm.qld.gov.au
Dr. Wade Hadwen	Research fellow, Australian Rivers Institute, Griffith University Email:W.Hadwen@griffith.edu.au
Sam Mackay	Senior Policy Officer, (former) DERM Email: Sam.Mackay@derm.qld.gov.au
Jon Marshall	Principle Scientist, Water Planning Ecology, (former) DERM Email: Jonathan.Marshall@derm.qld.gov.au
Carl Mitchell	Water Leader, Condamine Alliance Email: Carl.Mitchell@condaminealliance.com.au
Glen Moller	Team Leader, Aquatic Ecosystem Report- Healthy Waters Policy, (former) DERM Email: Glen.Moller@derm.qld.gov.au
Shauna Naron	Team Leader, Wetlands, (former) DERM Email: Shauna.Naron@derm.qld.gov.au
Peter Negus	Senior Scientist (Team manager), Water Planning Ecology, DERM Email: Peter.Negus@derm.qld.gov.au
Dr. David Rissik	Deputy Director (General Manager) NCCARF, Griffith University Email: D.Rissik@griffith.edu.au
David Robinson	General Manager, Qld Centre of Climate Change Excellence Email:David.Robinson@derm.qld.gov.au
Mike Ronan	Manager, Wetlands, (former) DERM Email: Mike.Ronan@derm.qld.gov.au
Dr. Fran Sheldon	Senior Lecturer, Australian Rivers Institute, Griffith University Email: F.Sheldon@griffith.edu.au
Gill Smith	Principal Policy Officer, (former) DERM Email: Gill.Smith@derm.qld.gov.au
Dr. Neil Tindale	Senior Lecturer in Environmental Chemistry, University of the Sunshine Coast Email: NTindale@usc.edu.au
Maria VanderGragt	Principal Environmental Scientist, Aquatic Ecosystem Health, (former DERM) Email: Maria.Vandergragt@derm.qld.gov.au
Dr. Jeremy VanDerWal	Senior Research Fellow, Centre for Tropical Biodiversity & Climate Change, James Cook University Email: JJVanDerWal@gmail.com
Doug Ward	Senior Research Fellow, Australian Rivers Institute, Griffith University Email: Doug.Ward@griffith.edu.au

Appendix C

See attached files for detailed information sheets for each climate region used in the workshop.