Implementing Adaptation to Climate Change in Terrestrial and Freshwater Natural Environments in Tasmania

Report on an **expert workshop** held in **Hobart, Tasmania** on **28 - 29 November, 2011**

Louise Gilfedder, Nicholas Macgregor,
Kerry Bridle, Oberon Carter and Daniel Sprod

Department of
Primary Industries, Parks, Water and Environment

Tasmanian Government

Photo Tom Bennett.

Citation: Gilfedder L, Macgregor N, Bridle K, Carter O and Sprod D (2012) *Implementing Adaptation to Climate Change in Terrestrial and Freshwater Natural Environments in Tasmania*. Report on an expert workshop held in Hobart, Tasmania on 28 - 29 November, 2011. Report to the Department of Primary Industries, Parks, Water & Environment, Hobart.

ISBN: 978-0-7246-7003-1 (Web)
ISBN: 978-0-7246-7004-8 (Print)

Front and back cover photo: West Coast Range. Photo Tom Bennett. Cover insets: Tree photo Tom Bennett. Sand photo Brett Littleton.

Contents

Overview and acknowledgements 4

Setting the scene 5

Workshop aims and structure 7

Conclusions 8

Common themes across ecosystems

1: How will a changing climate affect natural values? 9

2: Setting conservation goals in a changing climate 9

3: Adaptation actions 11

4: Information and monitoring requirements 14

Implementing adaptation:
common themes and differences across Natural Resource Management Regions

5: Perceived barriers and opportunities to adaptation 15

Recommendations for implementing adaptation 16

Results for each ecosystem 17

Coastal ecosystems 18

Freshwater and riparian ecosystems 26

Wet forests & rainforests 33

Dry forests and woodlands 39

Alpine and montane ecosystems 46

Lowland grasslands & extensive natural grazing systems 53

References 60

About the Authors 61

Overview and acknowledgements

In November 2011 the Tasmanian Department of Primary Industries, Parks, Water & Environment (DPIPWE) convened an expert workshop to explore how general adaptation principles could be translated into specific guidelines for different regions and ecosystems in Tasmania. This was intended to build on the evidence base provided by the recently published report *Vulnerability Assessment of Tasmania's Natural Environment to Climate Change* (Department of Primary Industries, Parks, Water and Environment 2010).

The workshop in 2011 also built on earlier workshops in Hobart on the impact of climate change on natural values. These included:

- *Tasmanian Terrestrial Biodiversity and Climate Change* road show in Tasmania on 7th June, 2011, hosted by the National Climate Change Adaptation Research Facility's Terrestrial Biodiversity Adaptation Research Network
- Workshop on *Prioritising monitoring programs in the Tasmanian Wilderness World Heritage Area* on October 8th 2009
- A one-day conference in October 2008 on *Managing Natural Values in a Changing Climate.* This event was run by DPIPWE in partnership with the Tasmanian Climate Change Office; around 160 people attended. (Workshop notes available on the DPIPWE website summarise the key discussion points)
- An earlier small workshop in May 2008 on *Potential Impacts of Climate Change on Tasmania's Terrestrial and Marine Biodiversity and Natural Systems* for staff in DPIPWE's Resource Management & Conservation Division.

The *Implementing Adaptation to Climate Change in Terrestrial and Freshwater Natural Environments in Tasmania* workshop was organised and facilitated by Nicholas Macgregor, an ecologist at Natural England and Louise Gilfedder of DPIPWE. The event was sponsored by the National Climate Change Adaptation Research Facility (NCCARF), the Tasmanian Climate Change Office and NRM South and NRM North. Nicholas Macgregor's visit to Australia was sponsored by NCCARF and also included giving lectures at NCCARF/Griffith University in Brisbane, at the Victorian Centre for Climate Change Adaptation Research in Melbourne, and at DPIPWE's office in Hobart. He also convened (with Alastair Hobday from the CSIRO Climate Adaptation Flagship) a symposium on *New approaches to conservation in a changing climate - translocation as an adaptation strategy* at the Ecological Society of Australia national conference in Hobart (ESA 2012). We are extremely grateful to all the organisations mentioned above for their support.

The workshop was attended by 65 participants working in conservation management of terrestrial and freshwater ecosystems. (Marine ecosystems were not covered as they had already been discussed in detail at a workshop in November 2011 conducted by the Institute for Marine and Antarctic Studies, Fisheries, Aquaculture and Coasts.) Participants included land managers, researchers, policy makers and conservation practitioners from government agencies, environmental NGOs, environmental consultancies and research institutions. We are grateful to all participants for their contributions. We would particularly like to thank Shona Prior for opening the workshop with an overview of the work of the adaptation unit at the Tasmanian Climate Change Office and Michael Grose for presenting downscaled projections for Tasmania from Climate Futures for Tasmania; Leon Barmuta, Magali Wright, John Harkin, Jill Pearson, Peter Davies and Jennie Whinam for helping to facilitate discussion groups during the workshop; and Felicity Faulkner for helping us prepare for the workshop. Tasmanian Institute of Agriculture assisted with the production of this report.

We gained much from the workshop. Participants' feedback identified that it was a very timely and useful exercise that generated and collated much useful information. It also provided valuable opportunities for networking and discussing future collaborations. This report summarises the key issues raised at the workshop and the adaptation goals and actions identified by participants, as well as knowledge gaps to be addressed by future research. We hope it will provide a starting point for developing adaptation strategies to conserve Tasmania's important natural heritage under a changing climate.

Setting the scene

Climate change is already affecting Tasmania's ecosystems. It is clear from the evidence collated in *Vulnerability Assessment of Tasmania's Natural Environment to Climate Change* (Department of Primary Industries, Parks, Water and Environment 2010) that further, potentially severe, effects on biodiversity and ecosystem function can be expected in the future. This presents great challenges for nature conservation, which needs to take appropriate action to help the natural environment adapt despite uncertainty about the timing and magnitude of possible climatic changes and their consequences for complex natural systems.

A range of good principles have been developed for adaptation in conservation, and these are starting to become established in conservation thinking and planning. For example, DPIPWE (2010) proposed the following principles for Tasmania:

- Maintain and protect well-functioning ecosystems
- Increase the protection of habitat
- Reduce the impacts of current threats
- Maintain viable, connected and genetically diverse populations
- Active interventions.

A more detailed set of principles were developed as part of the England Biodiversity Strategy (Smithers et al. 2008) (Box 1). Most or all of these principles are equally applicable to Tasmania.

We now need to increase our understanding of what these principles might involve in practice, for different biomes, ecosystems and species, and how action should best be implemented. The workshop was intended as a first step towards this.

The focus of the workshop was on natural values. This term includes the range of biodiversity and geodiversity values at a given site and in the broadest sense means the natural environment and the natural processes and ecosystem functions that it contains.

Box 1

England Biodiversity Strategy Climate Change Adaptation Principles

- **Take practical action now**
  - Conserve existing biodiversity
  - Conserve protected areas and all other high quality habitats
  - Reduce sources of harm not linked to climate
  - Use existing biodiversity legislation and international agreements

- **Maintain and increase ecological resilience**
  - Conserve range and ecological variability of species and habitats
  - Maintain existing ecological networks
  - Create buffer zones around high quality habitats
  - Take prompt action to control spread of invasive species

- **Accommodate change**
  - Understand change is inevitable
  - Make space for the natural development of rivers and coasts
  - Establish ecological networks through habitat restoration and creation
  - Aid gene flow
  - Consider the role of species translocation and ex-situ conservation
  - Develop the capacity of institutions and administrative arrangements to cope with change and learn from experience
  - Respond to changing conservation priorities

- **Integrate action across partners and sectors**
  - Integrate adaptation and mitigation measures
  - Integrate policy and practice across relevant economic sectors
  - Build and strengthen partnerships
  - Raise awareness of the benefits of the natural environment to society

- **Develop knowledge and plan strategically**
  - Undertake vulnerability assessments of biodiversity and associated ecosystem goods and services without delay
  - Undertake scenario planning and embrace no regrets actions
  - Pilot new approaches and monitor
  - Identify potential win-win solutions and ensure cross-sectoral knowledge transfer
  - Monitor actual impacts and research likely future impacts
  - Improve understanding of the role of biodiversity in ecosystem services
  - Research knowledge gaps with stakeholder participation

Workshop aims and structure

The principal aims of the workshop were to bring together people with expertise in climate change, ecology and conservation management to:

- Discuss in detail climate change issues and adaptation options for different Tasmanian ecosystems
- Develop some initial recommendations on how these options could be implemented
- Share information about adaptation research and conservation management that is already being done in Tasmania.

In addressing the second aim, we tried to take into account the fact that adaptation for the natural environment (as in all sectors) needs to be place-specific and that it needs to take into consideration not just ecology and climate but also factors such as administrative arrangements, available policy instruments, and the role of other sectors present in particular sites and regions. As Steffen *et al.* (2009) in *Australia's Biodiversity and Climate Change* put it, "on-the-ground application of general principles for biodiversity conservation under climate change requires consideration of the characteristics of particular areas or locales – a 'place-based approach'... adopting a regional approach, with the regions defined by common socio-economic characteristics and trends, existing biomes and climate change regimes".

The workshop was structured into two distinct parts, which between them covered five important topics.

In the first part of the workshop, separate groups each focused on a different biome/broad ecosystem type:

- lowland grasslands and extensive natural grazing systems
- coastal ecosystems
- freshwater and riparian ecosystems
- dry forests and woodlands
- wet forests and rainforest
- alpine and montane ecosystems.

Each of these groups discussed what should be done to assist that ecosystem to adapt to climate change, covering:

1. Climate impacts of concern

Which consequences of climate change are of greatest concern for conservation? (This drew on existing information and was intended to set the context for the workshop.)

2. Setting conservation goals in a changing climate

What sort of goals should be set for the ecosystem in question to facilitate adaptation?

Each ecosystem group identified goals that would address the following issues:

I. Making current populations and assemblages more able to cope with change

II. Facilitating/managing species movements

III. Managing interactions between species

IV. Reducing exposure to direct physical threats and protecting against extreme events

V. Reducing other pressures.

How might goals need to be modified and changed in future? How is adaptation being built into existing conservation projects?

3. Adaptation actions

How can adaptation goals be translated into actions? Which specific actions are needed in the ecosystem in question: a) in the short term vs long term and b) at different spatial scales? Are these actions new or already being used in conservation management?

4. Evidence and monitoring gaps

What do we need to know about future environmental changes, and about the effectiveness of different actions? What should be monitored? What options are there for testing and learning from new approaches?

In the second part of the workshop, participants were rearranged into three new groups, each focusing on one of Tasmania's Natural Resource Management regions. These groups discussed how action could be implemented, taking into account current policies and other sectors. These discussions addressed a fifth topic:

5. *Barriers to and opportunities for action*

What are the barriers to effective action? What opportunities are there, including synergies with other sectors, and opportunities to link conservation to provision of ecosystem services? What can be done to overcome barriers and take advantage of opportunities?

Barriers and opportunities were considered in the following categories:

- Inertia from past or current conservation approaches
- Policy and legislation
- Funding, land use and resource constraints
- Influence of other sectors
- Other/lack of knowledge.

And in relation to the following aspects of adaptation:

- Identifying appropriate adaptation objectives
- Taking action
- Monitoring change
- Testing new approaches
- Changing objectives and actions.

Conclusions

The remainder of this report summarises conclusions from the workshop. The first section summarises overall conclusions relating to climate impacts, adaptation goals, actions and knowledge gaps, bringing together common issues identified across the different ecosystems. The second section summarises the overall conclusions of discussions about implementing adaptation, highlighting common issues (and differences) across the three Tasmanian Natural Resource Management (NRM) regions. It concludes with a set of general recommendations for implementing adaptation in Tasmania that emerged from the final plenary discussion. The final section of the report contains summaries of results for each separate ecosystem type.

Common themes across ecosystems

1: How will a changing climate affect natural values?

Climate impacts identified as being of concern for conservation across most or all ecosystems included:

- Impacts on plant species:
  - o Changes to timing and success of germination, recruitment, and establishment processes
  - o Changes in native species composition (e.g. species re-sorting)
  - o Changes to species' habitat (e.g. changed fire regimes, changed soil hydrology, flooding)
  - o Changes in species' geographic distributions
  - o Increased pests that will prey on, or compete with, native plant species.

- Impacts on animal species:
  - o Thermal tolerance of some species being exceeded
  - o Changes to species' habitat (e.g. changed fire regimes) affecting breeding success and survival.

- Changes to species interactions and communities:
  - o Changes in extent of some communities (due to direct impacts of climate change as well as indirect impacts relating to changed land use)
  - o Reduced health/resilience of some communities
  - o Changes to disturbance regimes affecting component species and processes
  - o Release thresholds for some species being crossed, leading to changes to community type (e.g. buttongrass succession to dry forest)
  - o Changed timing of seasonal events (e.g. flooding, burning, fish spawning) and potential mismatches in timing between species
  - o Increased spread of pests and pathogens.

- Changes to ecosystem structure and function:
  - o Changes in nutrient status of soils or changes to nutrient cycling
  - o Decreased opportunities for recruitment events reducing long-term ecosystem persistence
  - o Changes to structural dominants
  - o Changes to hydrological processes
  - o Changes to perenniality/ephemerality
  - o Potential loss of key species, which may affect ecosystem processes.

Among the wide range of potential impacts identified as a major concern by the different groups, the four climate-related threats identified by Dunlop and Brown (2008) as being particularly hard to manage – invasive species, changed fire regimes, land use change and altered hydrology – were prominent.

2: Setting conservation goals in a changing climate

Adaptation goals

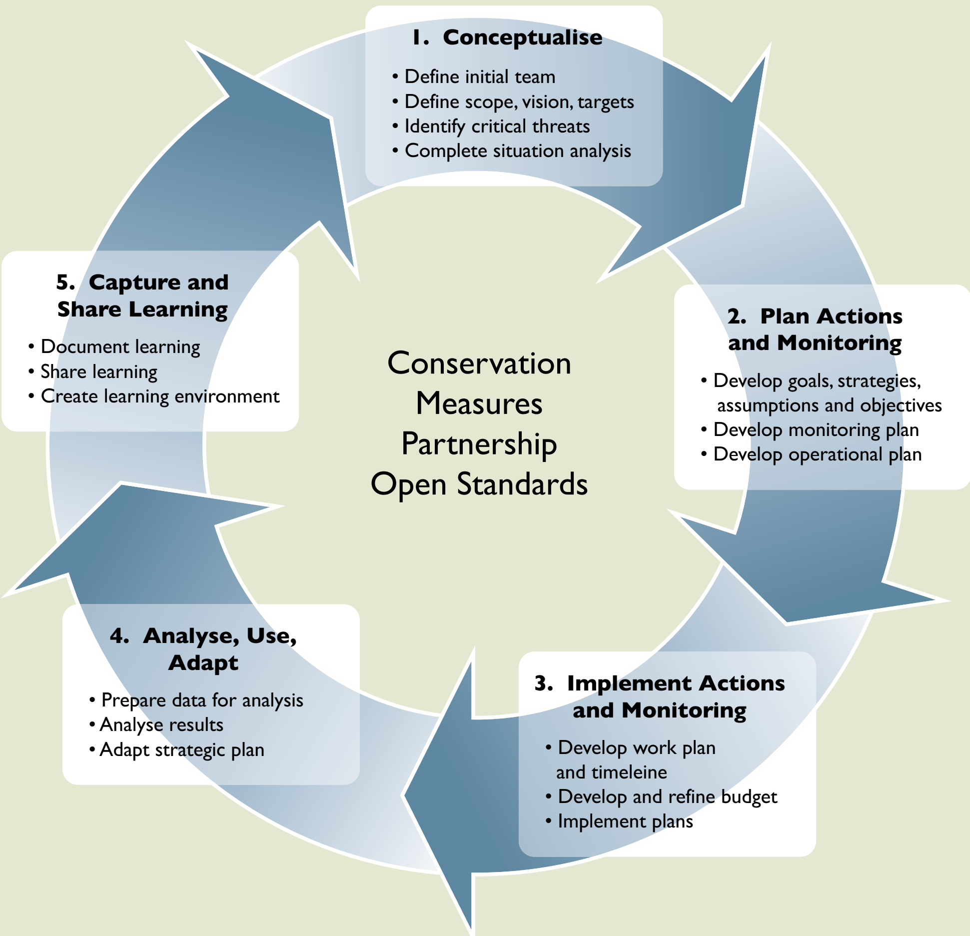
Minimising current threats and disturbances (e.g. from fire, pests, weeds, disease and inappropriate land management) was identified as a critical goal for providing the foundation for future adaptation in all ecosystems. In other words, future conservation must be based on good current conservation.

Other conservation adaptation goals identified for a number of ecosystems included:

- Protect and maintain connectivity (especially for species whose current location may become unsuitable)
- Maintain longitudinal/latitudinal and vertical/altitudinal connectivity
- Facilitate species movement
- Identify and protect contemporary and future refuges
- Minimise the impacts of current threats and landuse change

- Control the movement of invasive species already present, and reduce exposure to new invasive species
- Create and protect "no go" areas in which access needs to be controlled to protect particularly fragile and vulnerable species and ecosystems
- Maintain and enhance structural diversity and species diversity
- Maintain ecosystem function (especially hydrological regimes)
- Maintain natural disturbance regimes
- Reduce human-induced disturbances
- Protect, maintain and increase extent of habitat
- Protect keystone species
- Restore degraded habitat, especially after extreme events
- Identify and protect particularly important areas, including areas likely to remain stable and act as refugia, areas of high diversity and endemism, areas important for ecosystem function, and areas requiring active management to limit the impacts of climate change.

Box 2: Adaptive management framework of the Conservation Measures Partnership's *Open Standards for the Practice of Conservation* that are suitable for application to adaptation planing for climate change.



http://www.conservationmeasures.org/wp-content/uploads/2010/04/CMP_Open_Standards_Version_2.0.pdf

Adaptive management

Another issue identified by all groups was the need for a strong adaptive management approach. This should include the setting of measurable goals, clear program logic on how actions work towards the goals, maintenance of an accurate evidence base testing the effects of actions, and review and modification of strategies and actions based on evidence. This is necessary because it is likely that actions and strategies will need to be changed in the future. Ecologists use the term 'tipping point' to describe an irreversible shift from one state (e.g. forest) to another (e.g. grassland). Currently, we do not know what the tipping points may be in Tasmania's different ecosystems or when they might be reached. A crucial requirement, therefore, is to ensure that appropriate monitoring programmes are in place to be able to detect changes in the environment and determine the effects of our actions. This information will help to inform potential changes to policy, conservation goals and management plans. New management techniques might need to be tested. Supporting policy, legal and cultural changes might be required to support adaptive management. Box 2 (opposite) sets out a globally accepted approach to adaptive management developed by the Conservation Measures Partnership.

3: Adaption Actions

These lists summarise some of the broad actions identified for many or all of the different ecosystems. (More specific actions are listed in the individual ecosystem summaries in the final section of the report.)

Actions to take now that should be applied for biodiversity conservation even in the absence of climate change:

1. Prioritise areas for conservation using a risk-based decision-making process
2. Protect the biggest and the best remnants by good management of public land and providing conservation management agreements on private land
3. Use reservation, restoration, and planting to secure and connect areas
4. Take appropriate action – particularly management of weeds, pests and fire – to manage existing threats to natural values
5. Adopt an adaptive management approach in conservation planning and management at all scales
6. Develop reserve management plans that consider climate change
7. Identify and protect "no-regret" sites (ie low cost, low risk options)
8. Implement property management planning (and build in adaptation to climate change)
9. Better integrate conservation and production
10. Engage the community.

Actions to take now specifically to address climate change:

11. Identify key climate-related stressors to sites/ reserves
12. Implement improved monitoring to detect trends and rates of change in natural values under climate change
13. Build climate change adaptation into planning schemes, policy and legislation

14. Conduct community engagement and education about climate change
15. Conduct more research to understand impacts of climate change on natural values
16. Develop a climate change adaptation framework for natural values on all land tenures in Tasmania
17. Protect critical terrestrial and aquatic habitats under legislation
18. Identify sleeper-weeds under climate change and prepare management plans.

Additional actions to take in the medium-term (up to 2050):

19. Accept some resorting of species/vegetation re-structure (and modify conservation targets accordingly)
20. Provide/develop incentives to 'move' reserves to new, more appropriate locations
21. Implement appropriate strategies relating to land use planning and provision of information to manage possible changing human populations and patterns of development, and agricultural and recreational land use
22. Update climate change projections (and identify adaptation to suit)
23. Provide payment for ecological services (e.g. tax, environmental lotto)
24. Increase the emphasis in conservation policy and management on restoration, biosecurity and, potentially, translocation
25. Educate policy makers and the general public about the concept of 'mobile reserves'
26. Improve fire detection and response systems
27. Use vegetation management and strategic restoration to maintain and enhance habitat extent and connectivity.

Actions to take in the long-term (beyond 2050):

Few specific long-term actions were identified, which may reflect the difficulty in predicting long-term scenarios for native ecosystems, and the fact that, following an adaptive management approach as set out above, longer-term actions need to be based on the results of actions in the shorter term.

28. Identify 'do nothing' sites where change is allowed to take place
29. Introduce structural 'mimics' to take the place of current important species that cannot persist under changed conditions
30. Reconfigure the reserve system
31. Consider mobile reserves that move with the 'climate front'.

Synthesis of adaptation goals and actions identified

Drawing together information in the sections above, we can identify a series of over-arching adaptation goals for Tasmania, under which we can group more specific goals. The actions listed above can be mapped onto this structure. This is shown below, with relevant actions listed by their number. (NB. actions 1, 5, 9, 10, 12, 13, 14, 15, 16, 19, 21, 22, 23 and 30 apply to all goals below and are not shown).

Protection of habitat and key natural values

- Protect, maintain and increase extent of habitat – 2, 5, 8, 17, 20, 27, 31
- Maintain and enhance structural diversity and species diversity – 5, 8
- Maintain ecosystem function (especially hydrological regimes) – 2
- Protect keystone species – 5, 8
- Maintain natural disturbance regimes – 2, 4, 5, 8, 26.

Restoration of ecosystems & habitat

- Restore degraded habitat especially after extreme events – 3, 24, 29
- Protect, maintain and increase extent of habitat – 2, 5, 8, 17, 20, 27, 31.

Connectivity

- Protect and maintain connectivity (especially for species whose current location may become unsuitable) – 2, 3, 20, 25, 27, 31
- Maintain longitudinal/latitudinal and vertical/altitudinal connectivity – 2, 3, 27, 31
- Facilitate species movement – 3, 24, 25, 27, 31.

Refugia

- Identify and protect contemporary and future refuges – 17
- Identify and protect exclusion or "no go" areas – 17 .

Managing existing threats

- Minimise the impacts of current threats and landuse change – 4, 11, 18, 26
- Reduce human-induced disturbances – 2, 4, 5, 8, 26
- Control the movement of invasive species already present, and reduce exposure to new invasive species – 4, 18, 24.

4: Information and monitoring requirements

Common issues identified included the following:

- **What do we need to know about ecology, ecosystem function and about likely environmental change?** We need to:
  - Understand stressor thresholds and 'tipping points' – points at which ecosystems no longer support all current organisms
  - Identify factors of environmental change that accelerate pace towards tipping points
  - Better understand the recoverability of degraded systems
  - Identify environmental and physical barriers to dispersal of species
  - Understand recovery processes and trajectories (biotic and geomorphic)
  - Collate information on the disturbance requirements and life history traits of flora and fauna and make it publically available
  - Better understand ecosystem function and ecological processes in order to support recovery and restoration after disturbance and extreme events/disasters.

- **What do we need to know about the effectiveness of management actions?**
  - Whether appropriate actions are being implemented – we need some system of monitoring of implementation
  - The scales at which particular management actions are effective
  - How to set appropriate objectives and measure success
  - The management actions that should be taken over the long term at the landscape level
  - Better baseline measures of the condition of species, communities, and ecosystems.

- **What should we be monitoring?**
  - Changes in extent and condition (remote sensing)
  - Landscape processes and function (e.g. Landscape Function Analysis)
  - Threatened species and other species of concern
  - Spatial variation in community assemblages, including finer scale floristic community analyses
  - Threats such as grazing, fire, pests, weeds and pathogens, and changes in landuse
  - Vegetation and fauna dynamics
  - Effects of climate extremes
  - The condition and usefulness of refugia over time - are they degrading?
  - The effectiveness of corridors (e.g. streamside reserves and wildlife habitat strips) in facilitating movement of different taxa.

- **What options are there for testing and learning from new approaches?**
  - New decision-making frameworks that support a multiplicity of views, opinions and values
  - Expanding the use of citizen science
  - Better use of modern technologies e.g. remote sensing or genetic techniques
  - Translocation experiments, e.g. for cloudforest lichens
  - Investigating the effects of different grazing and fire regimes
  - Using structural mimics and other features to improve habitat structure
  - Investigating the practicality and ethics of translocations, to understand under what circumstances they work and when they should and shouldn't be used. For example, provenance trials for *E. obliqua* at different altitudes.

Implementing adaptation: common themes and differences across Natural Resource Management regions

5: Perceived barriers and opportunities

Common issues across all three NRM regions

- **Identifying appropriate adaptation objectives and then communicating them to the broader community** was an area in which all three NRM regions identified significant barriers to action. These included:
  - Lack of community awareness or knowledge (or even denial) makes it hard to set objectives or get "buy-in" from the community
  - Low levels of public trust in policy makers
  - Extreme events (fire, flood) change public opinion & perceptions of risks
  - Conflict between public pressures to manage iconic values at the expense of important conservation values, and demands from other sectors such as agriculture and tourism
  - Inconsistencies in policy at different spatial scales – e.g. focus on agricultural intensification in the Midlands will further affect landscape connectivity.

- **Taking action**
  - The short-term nature of most current incentive programs makes investment in adaption activities difficult
  - Clarification is needed of the roles of different spheres of government
  - There is over-reliance on voluntary conservation action on private land
  - Population pressures could create additional stress on the environment and hamper adaptation.

- **Monitoring change**
  - All regions identified the inadequacies of current monitoring systems, the need for integrated approaches across all tenures, and the poor funding base for monitoring
  - Improved technologies such as remote sensing could provide benefits
  - There is an important role for citizen science.

- **Testing new approaches, changing objectives and actions**
  - Deeply held belief systems in different parts of society can make change difficult, particularly where there is low acceptance & mistrust, but changing approaches to community consultation provide an opportunity
  - Policy/legislative change tends not to be dynamic; this could be a significant barrier to an adaptive management approach
  - New State policy/planning directives under the Land Use Planning Act (LUPA) present opportunities
  - It will be important to engage other sectors. The influence that Tasmania's few major industries have is both a barrier and opportunity. There could be marketing and economic benefits to both industry and conservation from a more collaborative approach.

Taking the regional context into consideration

As well as the common issues outlined above, some differences between NRM regions emerged, reflecting different administrative arrangements, available policy instruments, land use pressures and the role of other sectors.

Native vegetation extent in catchments across all three NRM regions ranges from fragmented to intact. Eight of the seventeen fragmented catchments identified by Michaels et al. (2010) occur in the Cradle Coast region, including the most highly fragmented catchment region. Coastal catchments in this region are dominated by intensive agricultural activities such as vegetable production and dairy farming. Land values for the highly productive volcanic soils are high and farm sizes are relatively small. Challenges in this region include the cost of increasing connectivity between native vegetation patches.

The NRM North region includes the Northern Midlands bioregion, a national biodiversity hotspot and the focus of national policy and program priorities including water development incentives. The Northern Midlands is also highly fragmented and includes a wide range of land uses from intensive to extensive agriculture, urban expansion, conservation and plantation forestry. The nationally listed lowland native grassland communities are primarily located on private land. The development of widespread irrigation infrastructure to provide more reliable water supplies to farmers places further pressure on the extant fragmented lowland ecosystems through both direct and indirect changes to land use (including native vegetation clearance).

The NRM South region includes the largest city in the State, with ribbon development settlements along the river and sprawling rural residential blocks into the surrounding hills. Expansion of housing developments on the urban fringe, particularly into bushland areas, affects local biodiversity values. Incorporating information about climate change into regional council planning frameworks will be necessary to optimise positive outcomes for beach nesting birds and saltmarsh communities with sea-level rise.

The three NRM regions focus on engagement with the community, from small to large landholders, across public and private land. Building community capacity to better manage natural resources is a necessary component of being able to adapt to a range of current and future pressures, including climate change. Cradle Coast NRM region has a successful engagement program with small-scale landholders, providing them with information on best practice management of natural assets. NRM North and South engage with primary producers in attempts to minimise the loss of natural assets on farms. NRM North has supported the development of property management planning modules, including a climate change module. NRM South has worked with stakeholders within catchments to determine best management outcomes for coastal communities, both plants (particularly saltmarshes) and shore birds.

To be most effective, the policies, plans and management actions implemented to facilitate adaptation should consider these regional issues and try to take advantage of any opportunities that exist.

Recommendations for implementing adaptation in Tasmania

In a final plenary discussion, participants at the workshop were invited to make recommendations about what needed to be done in Tasmania to support and enable all the issues and suggestions that had been identified as priorities in earlier workshop discussions. The following summarises some of the main points, grouped under four broad themes that emerged.

Workshop participants felt that, to successfully address adaptation for the natural environment, Tasmania needs:

Leadership and vision: A clear state-wide adaptation policy is required, with the inter-relationships between different sectors addressed. Detailed adaptation strategies for the natural environment will be needed in particular areas or for particular taxonomic groups (for example a coastal shorebirds strategy). Members of the conservation community need to take greater action on adaptation and to work together to develop a better and more extensive set of case studies to help guide future efforts. DPIPWE could produce updated guidelines for conservation management that explicitly address adaptation.

Effective policies, regulations and incentives (at multiple levels): Existing policies have an important role to play in adaptation but could be enforced more effectively. Cross-sectoral solutions are needed, with nature conservation incorporated into land use and development plans. State and local governments need to work together effectively, for example in planning the protection of climate change refugia. New approaches might be needed, particularly to accommodate change on the coast – rolling easements on titles and/or incentive programs to reserve private land in key locations might be needed to allow for landward movement of coastal ecosystems

Information, communication and engagement: It will be important to communicate effectively with local communities and engage them in the adaptation process. To do this, we need to understand people's preferences and interests in relation to conservation (including cultural and recreational interests), and seek to increase public engagement with the natural environment in ways that align with those interests. Communication about climate change needs to be targeted and appropriate to the relevant audiences. Making links with people outside the traditional conservation sector will be important, and will help to develop a vision for the future that has widespread support. There could be an important role for writers, artists, musicians and other creative people in helping to develop this vision.

Appropriate spatial prioritisation of conservation: It might not be possible to do everything everywhere. Places of particular importance need to be identified and prioritised for action, at a range of scales from the whole state to individual catchments. Specific aspects of this have already been covered earlier in the report – for example protecting areas of high diversity and endemism, potential refugia, areas crucial for ecosystem processes and services, and areas required for ecological connectivity. Other aspects could include mobile reserves that can be moved as climatic conditions change, and new protected areas (for example adjacent to existing conservation sites that are vulnerable to climate change) for species to move to. To support all of this, there is a need for reliable, spatially-explicit information to be made available in a useful form to those people who will need to make decisions about where to focus adaptation efforts.

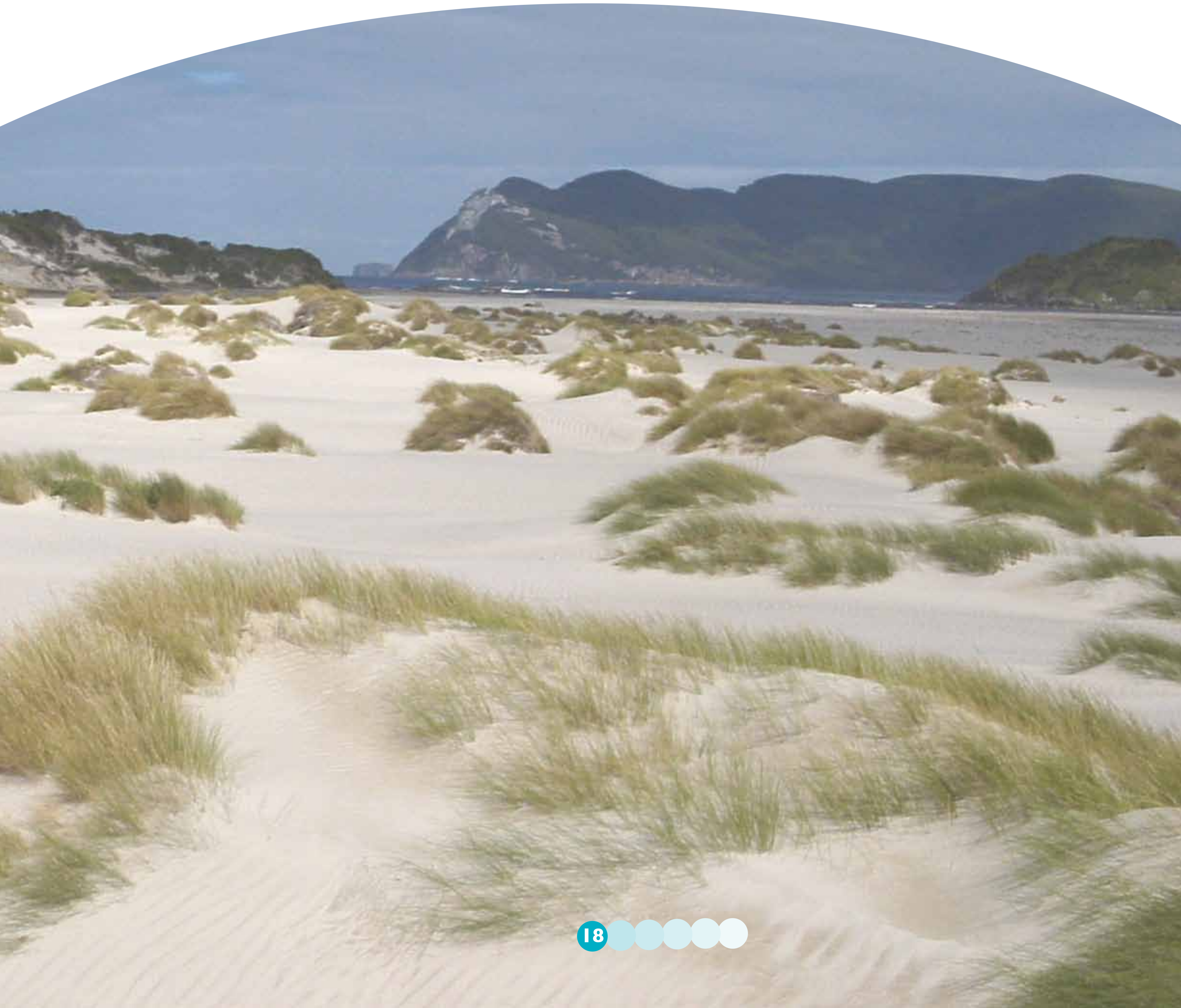
Results for each ecosystem

In the following section we present the results for the six ecosystems – coastal ecosystems; freshwater and riparian ecosystems; rainforests and wet forests; dry forests and woodlands; alpine and montane ecosystems; and lowland grasslands and extensive natural grazing systems. Each group considered the same four topics – impacts, adaptation goals, actions and knowledge gaps – but in some cases took slightly different approaches to exploring them, or focused on particular aspects.

Coastal ecosystems

Tasmania has a wide diversity of coastal landforms, reflecting complex lithology and geological structure, various discrete sediment sources, and variable nearshore submarine topography. It has a large extent of coastline relative to its land mass, with the highest ratio of coastline to land area of any Australian state. There are few undisturbed high-energy compartmentalised rocky and sandy coasts in the world's temperate zones that compare with those in Tasmania, especially on the west coast. Tasmania's offshore islands are important sea bird rookeries. The Tasmanian coastal environment contains a high proportion of the state's native plant species (about a third), with about 145 species (8% of the flora) largely confined to coastal areas.

Participants: John Harkin and Jill Pearson (facilitators), Kerry Wratten, Micah Visoiu, Russell Wise, Stewart Blackhall, Dick Shaw, Christine Crawford, Anne Kitchener, Emma Williams, Felicity Faulkner, Shannon Fox, Lynne Sparrow, John Sumby and Michael Comfort.



1a. Consequences of climate change in coastal ecosystems on the east coast

Changes and consequences	Level of conservation concern
Warming of marine environment and changing currents leading to: - Altered marine habitat, affecting crayfish, seagrass, establishment of mangroves - Increased incidence of marine pests (e.g. urchins, seastars)	High
Change in fresh water/salt water balance, caused by salt wedge affecting complex estuarine communities e.g. near Swansea, Apsley Marshes and Moulting Lagoon, Derwent River Estuary, Maria Island	High
Saltmarsh migration or shrinking area, with impacts on saltmarsh composition and loss of habitat for species and of ecosystem function such as nitrogen capture and filtration	High
Rising sea level causing loss of habitat for shorebirds, coastal raptors, migratory birds and water birds, potentially impacting on international responsibilities such as Ramsar sites	High
Storm surges, causing physical displacement of coastal and dune species, and loss of shore bird nesting sites	Medium
Flash-flooding, erosion and increased sediment flowing into coastal waters, with impacts on species such as seagrass, oysters and other molluscs and the spotted handfish	Medium – High
Changes to the timing of seasonal and flood events affecting shore nesting birds and fish spawning events	
Reduced buffering capacity against pests, with effects on species and community composition, and reduced resilience	High
Changes to soil structure, biodiversity and carbon content in coastal environments (including increased salt content) - increased incidence of acid sulfate soils, with wetting and drying events leading to soils containing iron sulfides producing sulfuric acid.	High

1b. Consequences of climate change in coastal ecosystems on the west coast

Changes and consequences	Level of conservation concern
Loss of shorebird, seabird and penguin habitat and breeding area and reduction of breeding success, as a result of sea level rise and storm surges	High
Loss of saltmarsh and samphire flats in the southwest, northwest and King Island as a result of sea level rise, reducing the habitat for orange-bellied parrot and reducing its breeding success	Medium
Increase in the presence and abundance of invasive pests and weeds, such as marram grass, sea spurge and sea urchin in currently relatively pest-free areas	High
Changes to suitable colony locations and predator-prey dynamics affecting seal populations	Medium
Drying out of coastal peatlands and loss of saltmarsh providing greater access to dune fields for four-wheel-drive vehicles and other recreational activities, leading to damage and spread of pests and pathogens such as Phytophthora and Chytrid fungus in frogs	Medium
Increase in stresses on coastal vegetation from factors such as increased frequency of drying and increased salt spray, storms and pests	High
Drying and changes to fire regimes in peatlands, leading to loss of peat and impacts on fluvial systems	High
Erosion, recession and increased mobility of coastal dune systems and reliant vegetation. Changes to, and loss of, shorebird habitat. The potential for natural responses, particularly regeneration, is unclear	High
Loss of fossil records and cultural values in coastal dunes as a result of erosion and recession	High
Coastal squeeze and inundation of coastal saltmarsh in the northwest. Loss of species habitat and ecosystem services	High
Salt water intrusion and resulting ecosystem change in coastal lagoons and freshwater systems; unknown potential for movement inland	High
Changes to marine ecosystems from rising water temperatures, changes in currents, storm surges and increased runoff of tannins and organic matter from land. Potential loss of kelp forest	High
Impacts on marsupial lawns in sheltered coastal estuaries such as Melaleuca and Bathurst Harbour from erosion and inundation.	Medium

2. Setting conservation goals in a changing climate for coastal ecosystems

2a. Adaptation goals for Tasmania's East Coast

Saltmarshes

- Ensure that viable areas of saltmarsh are maintained into the future
- Identify and ensure the long term protection of the highest priority areas to support retreat of coastal ecosystems and species assemblages (to provide the best chance of their long term survival)
- Protect saltmarsh from destructive processes such as grazing, vehicle damage, weeds, and earthworks
- Protect and enhance currently degraded areas
- Identify and plan for potential species movements along coasts, or between east and west coasts of Tasmania – for example by protecting locations suitable for the orange-bellied parrot to shift to in the future (refuges)
- Maintain or improve the quality of surface waters and substrate flow; maintain hydrological regimes – both freshwater and tidal flows.

Sandy beaches and dunes

- Protect current areas and species populations to maximise persistence and survival
- Identify key populations under pressure (e.g. breeding failure at specific sites) and manage appropriately
- Identify successful populations, understand reasons for success and attempt to retain
- Protect landward areas to allow movement of dunes and the vegetation they support
- Protect areas that are projected to be most stable in the future
- Manage and minimize pressures such as recreational vehicles and weeds.

2b. Adaptation goals for Tasmania's West Coast

- Identify and actively conserve threatened and priority coastal peatland areas
- Document the important values within geomorphological sites being lost to erosion and recession
- Understand, manage and ensure sufficient land for inland movement of saltmarsh; identify opportunities for restoration and conservation of saltmarsh in new areas in the future
- Understand and manage the inland movement of priority dune systems and the vegetation they support (including considering the implications for other ecosystems/vegetation types/species that may be affected)
- Identify freshwater species, assemblages and functions most at risk and prioritise conservation of potential refugia where active management can be targeted.

3. Adaptation actions at a range of spatial scales and timescales for coastal ecosystems

Individual site/reserve	
Actions to take now	Complete Parks and Wildlife Service general management plan, incorporating climate change
	Undertake short-term hazard reduction works for priority sites
	Manage and limit sources of nutrient input such as storm water, agricultural runoff, urban drainage
Additional actions in the longer term (to 2050 and beyond)	None identified
Catchment	
Actions to take now	Prioritise the development of water management plans for priority saltmarshes
	Implement climate change based monitoring systems
	Identify corridors on the ground – overlays under planning schemes
	Increase awareness among planners and other council staff, land managers, consultants etc
Additional actions in the longer term (to 2050 and beyond)	Maintain climate change based monitoring systems
Bioregion	
Actions to take now	For each bioregion, identify those saltmarshes/beaches that can be sustained in the long-term (i.e. in good condition, with a lack of threats or easily addressed threats, and capacity to move inland)
	Redefine "bioregion" for coastal area
	Use Smartline mapping to identify soft sediment versus hard shorelines, as these will be affected differently
Additional actions in the longer term (to 2050 and beyond)	Identify sites where a 'do nothing' approach is most appropriate and allow change to occur

State	
Actions to take now	Uphold *Water Resources Development Act* to ensure environmental flows
	Revise the Water Plan (for environmental flows). Speed up development of water plans for each catchment
	Improve and enforce legislation/schemes
	Use state legislation to protect current and projected future areas of range of valued species and ecosystems
	Raise the profile of climate change in local politics
	Identify and allocate resources to implement strategies and actions
	Review State policy –protection of natural assets vs protection of infrastructure and human assets
	Look at Commonwealth coastal framework to shape state policy
	Look at legislative/state policy changes (e.g. planning directives to accommodate refuges, migration, corridors etc.
	Develop strategic decision making framework so that there is a consistent approach to local decision making
	Consider the protection of coastal natural assets in the decision making system
	Incorporate climate change and sea level rise into State Coastal Policy
Additional actions in the longer term (to 2050 and beyond)	Identify and allocate additional resources to implement strategies and actions. e.g. introduce incentives for reservation of new areas to which coastal ecosystems are expected to move.
All spatial scales	
Actions to take now	Develop a land use planning strategy to manage possible changes in human populations and housing development. Use the full range of available management agreements, payments and other incentives to achieve appropriate management on priority areas of land
Additional actions in the longer term (to 2050 and beyond)	Develop a risk based decision making process to identify priority sites
	Undertake risk assessment of sites under greatest threat and identify those that can be recovered
	Prioritise sites and specify actions
	Identify "no regret" sites where action would be cheap and beneficial regardless of climate impacts
	Develop enabling strategy to encourage institutional and community behavioural change (incentives, engagement, education) and monitor results
	Aim for sustainable development as a community and political aim for Tasmania
	Build capacity for compliance, monitoring and enforcement.

4. Information and monitoring requirements in coastal ecosystems

What do we need to know about ecology, ecosystem function and about likely environmental change?

- A greater understanding of the ecology of coastal ecosystems, including sandy beaches
- 'Tipping points' at which ecosystems no longer support all current organisms
- Factors of environmental change that accelerate pace towards tipping point (e.g. impact of storm surges)
- More information about shorebirds – monitoring feeding, nesting, successful breeding and dispersal
- Recoverability of degraded systems
- A greater understanding of saltmarsh condition. Work out what a "healthy" saltmarsh is
- The potential benefits of a changing climate. Is there a chance that threatened species habitat will increase at the cost of non-threatened habitat?
- Recovery of disturbed dune communities after erosion or landward movement
- Potential for estuarine communities to move in response to changing salinity.

What do we need to know about the effectiveness of management actions?

- Which actions are most effective in addressing the impacts of greatest concern?

What should we be monitoring?

- Responses of organisms to current condition
- Shorebird populations (fecundity rates) over long term
- Extent and retreat of saltmarsh.

Which new management approaches should we test and experiment with?

- New decision-making frameworks that support a multiplicity of views, opinions and values
- Greater ownership of critical decision-making
- Sharing of resources among council areas combined
- Compulsory acquisition of land
- Legislative measures to support 'rolling easements'/migratory reserves/ebb-flow – flexibility.

Case study of adaptation research:

Shorebirds, terns and sea-level rise in Tasmania.
Dr Eric J Woehler, BirdLife Tasmania

BirdLife Tasmania (formerly Birds Tasmania) has been systematically surveying shorebirds and terns on Tasmania's sandy beaches since the early 1980s. Since 2000/01, these surveys have incorporated the collection of GPS data, and recognised an additional and cumulative threat to beach-nesting birds in Tasmania – that of predicted sea-level rises. Conceptually, sea-level rise acts as a habitat fragmentation process, identical to habitat fragmentation in the terrestrial landscape. Beach aspect, profile and geomorphology will determine how a beach responds to sea-level rise. Each beach will respond differently to sea-level rises, fragmenting the available nesting habitat for the beach-nesting birds, adding further pressure to these birds.

A project is presently using these shorebird and tern mapping data combined with LiDAR and inundation modelling to contribute to adaptation planning. The project seeks to identify sensitive areas and sensitive species likely to be threatened by predicted sea-level rises, and also resilient areas that may act as refuges for the birds where their habitat can retreat. To date, more than 200 sandy beaches have been surveyed and their nesting birds mapped, resulting in more than 3000 GPS data points for Hooded and Red-capped Plovers, Pied Oystercatchers, and Fairy and Little Terns.

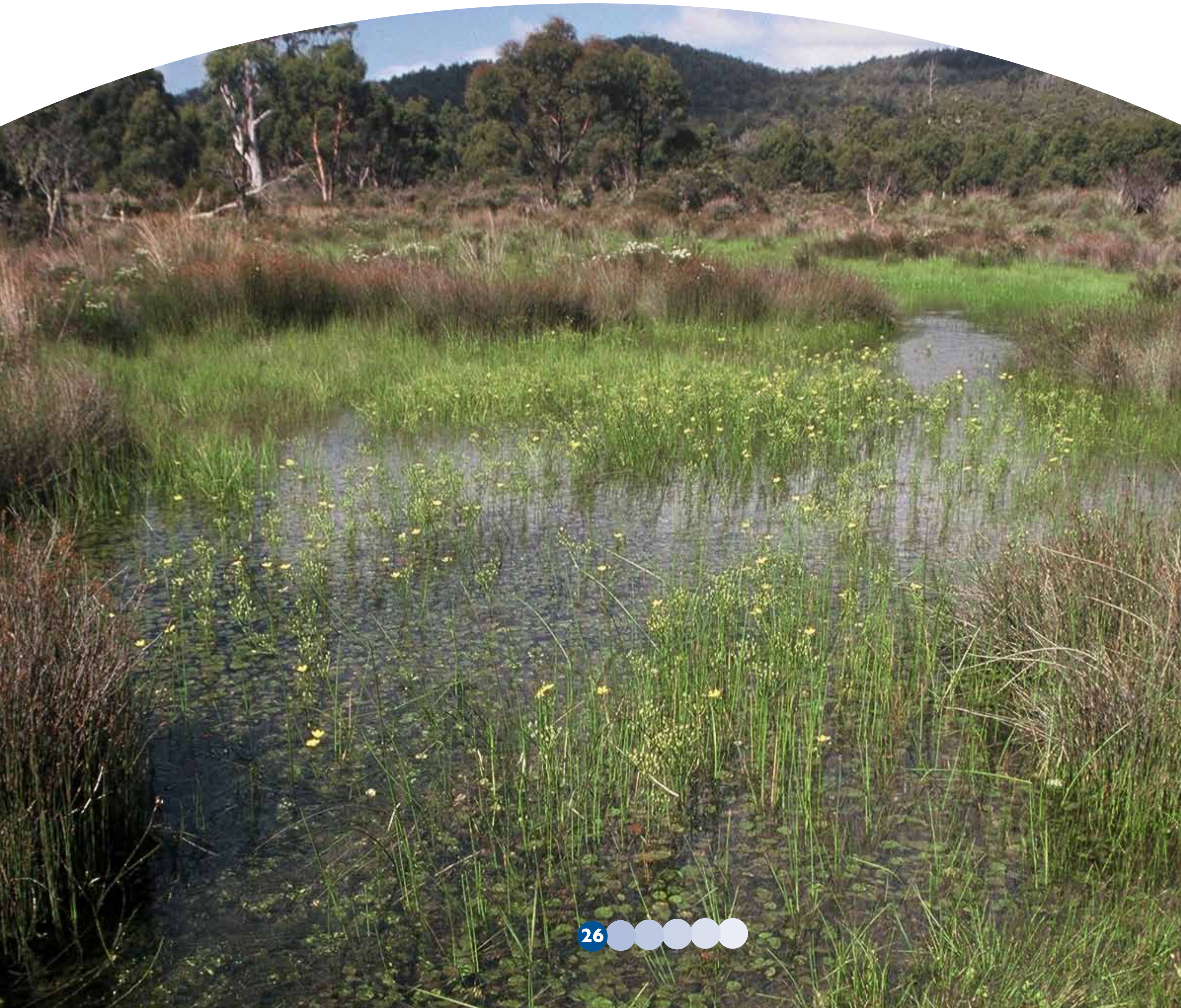
birdlife
TASMANIA

Photos Eric Woehler.

Freshwater & riparian ecosystems

Tasmania's freshwater ecosystems contain an extensive network of rivers, streams and wetland environments, which also include lakes, swamps and tarns. Many of these ecosystems have internationally and nationally significant scientific and biological values with 10 Ramsar and 86 wetlands listed on the national Directory of Important Wetlands. Tasmania's freshwater biophysical values have been compiled into the Conservation of Freshwater Ecosystem Values (CFEV) database. This provides a reference point from which priority-based management and conservation decisions on freshwater ecosystems can be developed.

Participants: Peter Davies and Leon Barmuta (facilitators), Carolyn Maxwell, Cindy Hull, Nicole Sherriff, Margaret Brock, Anne Watson, Janet Smith, Peter Nuttall, Annie Philips, Martin Read, Stuart Chilcott, Anita Wild, Helen Locher, Andrew Baldwin.



1. Consequences of climate change in freshwater and riparian ecosystems

The freshwater and riparian ecosystems group did not provide any ranking of the severity of the consequences of climate change.

Changes and consequences

Species and community changes

Change in species distributions - altitude, latitude, laterally within catchments

Loss of flow 'obligate' taxa

Increase and decrease in dispersal and recruitment (species-dependent)

Increase in distribution and dominance of some exotic and native species, e.g. fish, including through water transfers

Change in status of disturbance-dependent species

Decrease in spawning of fish

Change in species physiology and susceptibility to disease

Loss of and change to riparian vegetation communities including increased weed invasion and terrestrialisation

Change in phytoplankton and benthic algal production, biomass, and composition

Increase in barriers to dispersal

Increase in pathogen transmission and virulence

Decrease in condition and extent in highland tarns, bogs, temporary wetlands etc.

Decrease in condition and extent in peripheral lake-wetland communities

Temperature-induced change in reproduction and sex ratios

Decrease in species diversity and increase in opportunistic species

Increase in interruptions of life-cycles

Increase in plant species with flexible reproductive strategies

Increase in complexity of wetland community structure

Decrease in number of alpine species (frogs, stoneflies)

Increases and decreases in wetland extent and condition

Increase in the significance of Tasmanian habitats for migratory water birds at local to international level. Conservation opportunities but also increased pressure on wetland systems

Changes to perenniality/ephemerality of freshwater systems

Changes to interactions between groundwater and surface water

Changes in water regime

Change and increase in seasonality; increase in high flow events

Increase in duration and frequency of low flow events

Decrease in magnitude of low flow events

Increase in evaporation; wetland drying

Changes in connectivity (both increases and decreases)

Changes in ground water regimes and therefore wetland water regimes

Increase in vulnerability of peatlands

Change in sea levels

Changes in estuarine connectivity and hydrodynamics

Movement and loss and/or expansion of saltmarshes

Change in water quality

Increase in salinity, turbidity, acid sulfate soils

Changes in sedimentation and geomorphological regimes

Increase in erosion intensity

Erosion causing loss of riparian vegetation, leading to increase woody debris, CO2 emissions, reduced shading and increased water temperature. Erosion would also 'degrade' channels upstream, increasing sediment transport and 'aggrading' channels and wetlands downstream

Increase in hill slope sediment in aquatic systems

Channel widening, deepening and infilling

Wetland infilling

Increased fire frequency and oxidation leading to peat losses

Increase in woody debris in channel

Interaction between system response (ability) and land use context

Changes to temperature regime

Higher average, maximum and minimum water temperatures

Changes in human water use and development

More dams, inter-basin transfers and levees

More abstraction

Increased regulation of flow - fewer high flows; both increase and decrease in low flows

More groundwater extraction

Changes in landuse, leading to changes in nutrient regimes

Increase in intensification

Increase in regulation of lake levels

Increase in river channel 'management'(i.e. alteration)

Increase in conversion and drainage of wetlands

2. Setting adaptation goals in freshwater ecosystems

General adaptation principles

1. Prevent eutrophication
2. Limit spread of weeds and pathogens
3. Maintain interactions between riparian and aquatic systems
4. Manage movement/invasiveness of newly established (including Australian native) species
5. Maintain and enhance integrity of freshwater ecosystem to maximise resilience and capacity to adapt
6. Adopt integrated biophysical approaches to assessing freshwater ecosystem health.

Goals for upland freshwater ecosystems

- Maintain reservation status of existing protected areas
- Maintain longitudinal, latitudinal and vertical connectivity
- Maintain hydrological regimes
- Identify and protect freshwater refugia both in and out of reserves
- Protect headwaters of tributaries.

Goals for lowland freshwater ecosystems

- Maintain natural disturbance regimes
- Maintain longitudinal, lateral and vertical connectivity.
- Incorporate climate change adaptation into land use change development processes and assessments
- Protect, maintain and restore habitat
- Identify priorities for managing species most at risk that can be protected through refugia
- Maintain, enhance and create CAR reserve areas to protect freshwater ecosystems.

Changing goals over time

There are environmental tipping points that could force a change in approach. Possible required changes might include containment of species (e.g. carp) and more intensive treatment of problems (rehabilitation, engineering), and a focus on more intensively manages reserves or refuges. It will be important to consider ecosystem services to ensure buy-in by the community.

Changing objectives could be hard because we don't measure responses frequently or systematically enough. We have the tools but not the legal or policy framework. Lessons could be learned from the Murray Darling system, which provides a good case study of a conservation management area that has changed its original approach.

3. Adaptation actions at a range of spatial scales and timescales for freshwater ecosystems

Individual site/reserve	
Actions to take now	Design and implement place-based conservation
	Develop a strategy for appropriate use of fish barriers
	Implement appropriate monitoring
	Identify key stressors
	Identify species tolerances
	Prioritise outcomes
	Declare critical aquatic habitats under *Threatened Species Protection Act*
Additional actions in the longer term (to 2050 and beyond)	Update management plans based on new climate change projections and experience of past management
Catchment	
Actions to take now	Implement place-based conservation
	Manage fish passage and planning
	Undertake appropriate monitoring
	Assess the impact of population increase or decrease via more detailed assessment of impacts of climate change
	Assess geomorphic risks and constraints under climate change
	Protect the diversity of in-stream habitats e.g. riparian in channel management
Additional actions in the longer term (to 2050 and beyond)	Update new climate change projections and catchment management plans
Bioregion	
Actions to take now	Establish freshwater CAR reserve system built on Conservation of Freshwater Ecosystems (CFEV) database
	Improve groundwater/surfacewater knowledge
	Develop novel methods to enable mobility of aquatic systems in the landscape, e.g. mobile reserve
Additional actions in the longer term (to 2050 and beyond)	No actions identified

State	
Actions to take now	Implement scientifically-determined environmental flow requirements
	Assess Statewide water environmental allocations
	Identify freshwater refugia
	Improve knowledge about groundwater
	Develop a scheme for prioritising species based on resilience and threats
	Develop coherent policies for translocation and insurance populations and reintroductions
Additional actions in the longer term (to 2050 and beyond)	Integrate freshwater issues at project inception. For example, consider impacts of interbasin water transfers
	Design and implement a framework and principles for adaptation, including an appropriate process for risk assessment
	Update new climate change projections
	Develop payment for ecological services, e.g. tax, environmental lotto
All spatial scales	
Actions to take now	Increase community engagement and education
	Integrate freshwater and riparian connectivity with planning, policy items in train
	Collaborate with major water managers to set future directions that take climate change into consideration
	Undertake appropriate monitoring
	Promote ecological function and knowledge
	Fill knowledge gaps through research
Additional actions in the longer term (to 2050 and beyond)	None identified

4. Information and monitoring requirements in freshwater systems

What do we need to know about ecology, ecosystem function and about likely environmental change?

- Barriers to dispersal – environmental, physical
- Stressor thresholds
- Recovery processes and trajectories (biotic and geomorphic)
- Disturbance requirements for flora and fauna
- Wetlands and riparian seedbanks
- Habitat requirements for life stages at species level (both plants and animals)
- Groundwater-surface water interactions
- Ecology of lowland rivers – extreme floods with storm surges and extreme drought
- Thresholds and tipping points
- Species-specific triggers for breeding and reproduction.

What do we need to know about the effectiveness of management actions?

- Whether ecological indicators are met as a result of different actions
- How to implement adaptive management effectively
- Effectiveness of using precautionary higher benchmarks (e.g. flows) for managing climate change
- Implement adaptive management to determine effectiveness of management actions
- Are conflicts resolved, is there community acceptance?
- How to ensure robustness to 'surprises'.

What should we be monitoring?

- Variability
- Threats such as grazing, irrigation, dams etc
- Vegetation dynamics
- Fauna dynamics
- Effects of climate extremes
- Effects of landuse change
- Effectiveness of monitoring actions
- Whether refugia are remaining "refugia" or whether they are they degrading
- Presence and absence of pests, weeds and pathogens over time
- Geomorphic condition and indicators
- Basic water quality parameters – nutrients, salt, carbon, dissolved oxygen, E. coli etc
- Groundwater.

What new management approaches should we be testing and experimenting with?

- Selective breeding
- Protecting critical aquatic habitats under *Threatened Species Protection Act*
- Effect of water management on resilience
- Properly implementing existing management approaches
- Managing/controlling pests, weeds and diseases, with associated public education
- Remote sensing for freshwater environments
- Catchment-based management approaches using a robust aquatic ecosystem health program and database in the state.

Wet forests and rainforests

Tasmania has a large forested area (52% of the state), with a diversity of forest types including rainforests, eucalypt forests and woodlands, subalpine communities, coniferous forests, heathlands and a range of scrubs and woodlands dominated by species other than eucalypts such as wattles, tea-trees and banksias. Rainforests occur from sea level to subalpine environments and are largely in western Tasmania with its higher rainfall. Where fire is more frequent rainforest species become restricted and eucalypt forests predominate. Wet eucalypt forests are largely dominated by ash species and require catastrophic fire events for stand replacement. Understoreys may be shrubby or grassy, largely depending on soil fertility. Tasmania's temperate rainforest and related rainforest scrubs provide habitat for primitive relict genera of flora and fauna and exhibit high levels of endemism. Montane rainforests in particular, especially coniferous forests, are rich in primitive plant species, relict species and endemics.

Tasmania's tall eucalypt forests form some of the most pristine temperate forests in the world. These unique forests provide the world's best examples of distinctive evolutionary features that enable the dominant sclerophyll trees to survive in areas where the climatic climax vegetation is rainforest. Sclerophyll forests provide habitat for all five of Tasmania's endemic mammals. Several threatened raptors, such as the grey goshawk, wedge-tail eagle and the masked owl occur in these forest habitats, as well as the threatened spotted-tailed quoll and Tasmanian devil.

Participants: Magali Wright (facilitator), Oberon Carter, Steve Read, Jeremy Little, Peter McQuillan, Brad Potts, Sue Baker.

Photo Oberon Carter.

1. Consequences of climate change in wet forests & rainforests

This group only assigned high status to some consequences and did not rate the others.

Changes and consequences	Level of conservation concern
Fire (probably the major driver of change) – changes in fire frequency, size, intensity; likely to vary according to ecosystem - Synergy with drought: opening canopy, drier soils, greater flammability, leading to more even aged stands and reduced species richness - In the west, there could be bigger, more frequent and more intense fires, changing vegetation types towards grassy communities - In the east there could be lower intensity smaller fires – possible range expansion - The area of greatest concern is Mt Read	High
Decrease in bryophyte species richness and distribution	
Loss of mycorrhizal associations	
Range restriction of Huon pine due to changed fire regimes (e.g. Teepokana), and also saline intrusion in coastal rivers	High
Loss of ferns as a result of drought and fire	
Loss of key species (e.g. fungi), which may influence ecosystem processes	High
Net loss of old growth forest and associated habitat such as tree hollows	High
Loss of species with specific habitat needs	
Net loss of area of wet forests, leading to loss of structural connectivity, with possible consequences for other processes and for some species	High
Changes to decomposition, with less carbon stored	
Changes to structure of forest boundaries, e.g. loss of sharp boundaries as a result of increased fire and increased shrub cover	

2. Setting conservation goals in a changing climate for wet forests & rainforests

Key adaptation goals

- Manage fire
- Identify and protect long term refuges and hotspots of high endemism
- Protect keystone species such as seed dispersers
- Ensure appropriate connectivity, particularly for broad ranging species (e.g. dasyurids)
- Maintain forest across environmental gradients to provide a wide range of topographic and other habitat conditions
- Maintain hydrological cycles
- Minimise human-induced disturbance.

3. Adaptation actions at a range of spatial scales and timescales for wet forests & rainforests

Key:

* Limited experience of this action in this ecosystem

** Completely new action for this ecosystem

P Priority

Individual site/reserve	
Actions to take now	Restrict road building in remote areas
	Prevent additional fragmentation (e.g. roads/habitat conversion etc).
Additional actions in the longer term (to 2050 and beyond)	Protect iconic rainforest and wet eucalypt forest old-growth sites from fire **P**
Catchment	
Actions to take now	Implement ex situ protection of both plants and animals. Collect DNA and propagules of iconic species.
	Protect, maintain, and create middle aged (future old-growth) forest reserves **
Additional actions in the longer term (to 2050 and beyond)	Increase resources for fire detection - more staff and/or satellite-based detection
	Make strategic use of conservation covenants and reserve creation to ensure high priority areas are given protected area status *
	Make decisions about the appropriateness of salvage logging after wildfire & implement mitigation planning including no-take areas *

Bioregion	
Actions to take now	Assess protected area status to identify reserve priorities (eastern bioregions)
Additional actions in the longer term (to 2050 and beyond)	Prioritise protection of iconic sites/refugia (western bioregions)
	Extend protected area status to high conservation status areas threatened by roads and mining (western bioregions)
	Implement a focussed biosecurity effort (eastern bioregions)
	Maintain and enhance connectivity (eastern bioregions)
	Consider assisted translocation in fragmented landscapes as last resort (eastern bioregions)**
State	
Actions to take now	Manage anthropogenic ignitions by putting in place a legal framework and management on the ground *
	Support research on knowledge gaps – phenology, functional ecology, impact and benefits of control burning **P**
	Identify and prioritise protection of sites of refugia **
	Identify areas susceptible to pests and diseases
	Identify areas/genes/species that are more resistant
	Undertake bioclimatic niche modelling for ecosystems
	Undertake strategic planning exercises
	Develop a strategy for salvage harvesting following wildfire to minimize ecological impacts including refugia of unlogged burnt areas.
Additional actions in the longer term (to 2050 and beyond)	Protect refugia *
	Restore forests, particularly to enhance connectivity
	Increase resources for fire detection
All spatial scales	
Actions to take now	Manage anthropogenic ignitions * **P**
	Develop a legal framework for better fire control.
	Prioritise areas to protect from fire (populate GIS layers for different key attributes)
	Develop a process to implement protection for fire – is it possible to protect all areas?
	Undertake forest health monitoring to support biosecurity actions
Additional actions in the longer term (to 2050 and beyond)	Improve resources for and responses to fire detection and management *
	Consider mobile reserves that can move with the climate front - promote the idea to the public and policy makers
	** **P**

How might goals and management change over time?

An adaptive management approach is needed in order to manage currently unknown impacts of climate change (primarily fire?) on wet forests and rainforests. Any of the following could trigger revised management objectives in the future:

- Fire affecting the condition and/or extent of wet forests and rainforest, thereby increasing risk of further fires from dry lightning strike and potentially moving wet forests and rainforests beyond a threshold (loss of multiple age classes and changing structure, altered function and processes)
- Increased incidence of ignitions, and increased fire frequencies
- Reduction in extent, condition and/or function of ecosystem.

In response to these triggers, fire management options might, for example, change from controlling all fires (where possible) to allowing low intensity wild fires for fuel reduction purposes. An increased focus on protecting all potential fire refugia, rather than just the most important ones, might also be needed.

Changing objectives or management could be difficult. A management structure needs to be established that supports a flexible approach to setting and reviewing management objectives, and accommodating change.

Lessons from past conservation experiences include:

- Improving on the experience of Regional Forest Agreements to develop flexible management approaches
- The need to focus activity across land tenure (private land is important)
- Competition between stakeholders in the Murray Darling Basin
- Observations of, and management responses to, past drought experiences
- The need for policy and management to be informed by research
- The need to focus on the full range of ecosystem services rather than using a value-based approach (strategic, not specific).

Existing action relevant to adaptation

- Free Air Carbon Enrichment (FACE) experiments in forest ecosystems (none yet in Tasmania)
- Use of modelling tools to explore and map potential changes
- Pest management strategies (e.g. chytrid fungus in frogs)
- Supporting research on the impact of climate change fire in wet forest & rainforest (e.g. PWS/UTas research, Warra LTER)
- Supporting Private Land Conservation Program – focus on threatened forest types and old growth.

Photo Oberon Carter.

4. Information and monitoring requirements in wet forests & rainforests

What do we need to know about ecology, ecosystem function and about likely environmental change?

- Environmental envelope of particular species, for example *E. regnans* and *E. obliqua*
- What are the timeframes for changes?
- What will happen to soil biota with drying and changes in fire regimes in wet forests?
- In accepting re-sorting of species, what species/ interactions could we be losing?
- Where are these ecosystems going to move to? What new species/ecosystems might we gain?
- Dispersal abilities of different species
- What qualities create climate change refugia?
- Which places are priorities to protect? Where are they and how do we protect them? How resilient are they?
- Where are the areas of high endemism and areas with many threatened species? (These should be prioritised for reservation/fire management etc)
- The role of bats in forest ecology
- Better fire prediction and behaviour models are needed.

What do we need to know about the effectiveness of management actions?

- How well is fuel reduction burning working to reduce fire size and intensity?
- What biosecurity actions work to limit /restrict impacts of pests/diseases?
- Does creating structural connectivity improve functional connectivity?
- Can fire be used as a management tool to protect fire sensitive vegetation?
- Effectiveness of current local and landscape-level forestry reserves, e.g. wildlife habitat strips (currently biased towards riparian areas)
- What are the long-term landscape level impacts of current fire management? Are we increasing or decreasing the risk of mega fires?

What should we be monitoring?

- Altitudinal transects (as in Warra/BAMPS) to monitor movement/boundary shifts with increased focus on phenology, e.g. flowering, pollination, dispersal ability
- Biosecurity
- Effectiveness of corridors (e.g. streamside reserves/habitat strips) in facilitating movement of different taxa.

What new management approaches we should be testing and experimenting with?

- Practicality and ethics of translocations. Do they work? When should they be used? provenance trials for *E. obliqua* at different altitudes
- Managing the production matrix to maintain and improve resilience. Clarifying the importance of rotation lengths, aggregated retention forestry vs clearfelling
- Translocation experiments with cloud forest lichens
- Is there scope for remote-sensing to detect fires?

Dry Forest & Woodland Ecosystems

Dry eucalypt forests and woodlands cover much of the central and eastern parts of Tasmania. They are dominated by eucalypts and have a multi-layered understorey that may be grassy, shrubby, heathy or sedgy, depending on rainfall, soil fertility, fire frequency, grazing regimes and other environmental factors. They are very species-rich ecosystems, with most of Tasmania's *Eucalyptus* species and about half of its native flora occurring in these forests. Many community types are rare or threatened, particularly those communities that occur in environments that have been highly modified for agriculture or settlement. They are important habitat for many of the State's threatened plant and animal species.

Participants: Daniel Sprod (facilitator), Graham Green, Tim Rudman, Rod Knight, Neil Davidson, Sandra Whight, Stuart King, Louise Mendel

Photo Oberon Carter.

1. Consequences of climate change in dry forest & woodland ecosystems

Changes and consequences	Level of conservation concern
Change to disturbance regimes (frost, erosion, drought, fire) limiting capacity for and success of regeneration	High
Obligate species at risk from competition from generalist species and exotics favoured by changing conditions	Medium
Loss of foundation species as a result of climate impacts adding to current pressures	High
Added pressures on already threatened species e.g. from changes to herbivory (domestic or wild herbivores)	High
Changes in important symbiotic relationships affecting regeneration success	High
Changed envelope for *Phytophthora cinnamomi* in forests	
Changing land use in response to climate change, for example land clearance for irrigation infrastructure	High
East coast forests with their high levels of genetic diversity and richness are under increased pressure due to increased rainfall & temperature, and potentially increased frequency and intensity of fire and extreme fire events	High
Central Highland forests drier in all seasons, with lower frost frequency, increased tree decline, loss of hollow habitat, shifting species distributions and changing community composition.	High
Increased envelope for myrtle rust in northeast Tasmania	Medium
Buttongrass morphing into dry forest as a result of loss of tree death factors (frost, waterlogging)	
Potential for hotter, more frequent fires leading to loss of structure, diversity, transition zones, and ecosystem function	High
Reduction in nutrient status of plants (and consequent effects on herbivores) from increased CO2, increased fire and increased erosion	High
New habitat for exotics that are favoured by new conditions (greater water variability etc.)	Medium
Decreased potential for 'regeneration window' as a result of changes in micro climate	Medium
Disruption of connectivity (genes, organisms, species).	

Possible geographic trends

- Myrtle rust potential – King Island, northwest corner, Furneaux Group, Northeast coast, east coast to Freycinet Peninsula
- Changes in white gum (*E. viminalis*)/cabbage gum (*E. pauciflora*) distribution – north coast between Badger Head & Mussleroe Bay
- Loss of seasonal moisture, loss of frost frequency, strong drying signal with accelerated tree decline, loss of hollows, shift in species distribution, changes in vegetation community – Central Highlands
- High eucalypt species diversity at risk from changed intensity and seasonality of rainfall – southeast and east coast
- Pressures due to favourable conditions for intensive agriculture (grazing, pivots), with implications for invertebrates including birds and invertebrates – Midlands and western slopes of the Eastern Tiers.

2. Setting conservation goals in a changing climate for dry forest and woodland ecosystems

General principles

- Identify areas and values at highest risk of impacts of climate change
- Identify areas and values needing active management to control impacts of climate change
- Identify areas and values at minimal risk from climate change and therefore likely to function as refugia or source populations
- Identify areas and values needed to maintain functioning ecosystems under climate change.

Goals

- Isolate species and ecosystems likely to be at risk from climate-related invasions or changes from other areas, or whose effects may be deleterious to other species
- Ensure connectivity for species and ecosystems whose locations are likely to become unsuitable habitat under a changing climate
- Manage and control the movement of important current and new pests, weeds and diseases
- Maintain 'recruitment windows' for foundation species in these ecosystems (especially eucalypts)
- Maintain the matrix for wide-ranging species such as forester kangaroos and Tasmanian devils
- Increase our understanding of 'soil health' in order to maintain or increase functionality of soil ecosystems, storage of soil carbon, mycorrhizal function, bacterial and fungal diversity, and diversity of soil fauna
- Achieve better control of anthropogenic ignitions (currently the cause of 90% of fires)
- Accept "new" or novel ecosystems
- Ensure appropriate reservation and monitoring of reference sites to inform future management.

3. Adaptation actions at a range of spatial scales and timescales for dry forests & woodlands

Key:

* Limited experience of this action in this ecosystem

** Completely new action for this ecosystem

P Priority

Individual site/reserve	
Actions to take now	Collect better condition data * **P**
	Secure priority areas through reservation, restoration and planting **P**
	Implement planned burning
	Implement post-weed/disease management
	Undertake property management planning
	Manage grazing sympathetically to ensure recruitment 'windows' for foundation species such as eucalypts
	Encourage private landowners to maintain dry forest and woodlands on their property
Additional actions in the longer term (to 2050 and beyond)	Identify triggers for change (from objectives & monitoring)
	Review and change management objectives
	Manage vegetation to keep some sites and species populations isolated
	Use translocation if required **
	Use structural mimics to replace important species that cannot tolerate changed conditions **
	Use fire/disturbance to maintain a system that is evolving in a different direction under climate change
Catchment/landscape/bioregion	
Actions to take now	Develop adaptation objectives *
	Benchmark woodlands and forest
	Rank threats and strategies
	Undertake reserve management planning
	Identify areas important for connectivity & refugia* **P**
	Integrate conservation planning into land use and development control documents (local government planning schemes)
	Fire management planning Identify and implement tenure blind landscape scale burning to retain key assets and regime

Additional actions in the longer term (to 2050 and beyond)	Accommodate species arrivals (natural or human-facilitated) from elsewhere **
	Control movements of undesirable invasive species through use of fire, pesticide etc
	Use landscape-scale planning to facilitate appropriate levels of connectivity
State	
Actions to take now	Identify spatial priorities **P**
	Secure seedbank funding **P**
	Incorporate biodiversity into planning schemes and implement those schemes
	Use quarantine procedures to manage/control new threats – e.g. myrtle rust etc
Additional actions in the longer term (to 2050 and beyond)	Manage the risk from changing human populations, development and land use patterns and subsequent impacts on the environment **P**
	Reassess conservation management objectives and reconfigure the reserve system if necessary
All spatial scales	
Actions to take now	Develop and implement climate change adaptation framework
Additional actions in the longer term (to 2050 and beyond)	Integrate conservation planning into landuse and development control
	Create seedbanks to preserve genetic resource
	Transfer seed to new locations in anticipation of climate change
	Beyond 2050/under more extreme change: Reassess strategies and actions based on change in environmental conditions

Changing goals and management over time

Monitoring flowering, seeding and regeneration of trees will help to identify when 'tipping points might be approaching. If all of these indicators are absent, then the woodland will change to grassland, unless active intervention to bring in structural mimics is successful.

It could be very difficult to change objectives, particularly to accept major ecosystem changes. We may already have reached this point in the dry woodlands suffering from tree decline, yet no-one wants to admit defeat. Similarly the species that might be used as structural mimics to maintain woodland in the future might be today's weeds, or introduced species. It could be difficult to convince people of the benefits of tolerating these species while continuing to promote vigilance against invasive species.

To inform future management, we can learn from the results of past attempts to introduce complexity. Even fence posts and piles of rock may help, but structural mimics would be best.

Existing adaptation in Tasmania

Examples of existing woodland conservation projects whose objectives address climate change are:

- Tasmanian Land Conservancy permanent reserves have some adaptation objectives, though fewer actions at this stage
- Greening Australia Tasmania – genetics experiments for restoration and revegetation
- DPIPWE is doing work on refugia planning – Project Prioritisation Protocol (PPP) for threatened species
- DPIPWE also has a project on flora attributes and life history traits, which is looking at sensitivity of species to climate change
- Parks: climate change is being incorporated into risk assessment
- NRM North has a Property Management Plan (PMP) climate module (but presently unfunded)
- Note: Management of conservation covenants currently does not address climate change

4. Information and monitoring requirements in dry forest & woodland ecosystems

What do we need to know about ecology, ecosystem function and about likely environmental change?

- What are the most strongly interrelated ecosystems – i.e. affecting or being affected by other ecosystems?
- Influence of biogeographic history & interaction with species' climate envelopes
- Species-habitat models including reliability assessments
- Measures of ecosystem function
- "Trigger" events for rapid ecosystem change
- Life history traits andattributes (at species, population, community, and ecosystem level)
- Models used for fire behaviour (e.g. soil dryness index) are known to be poor, yet will be used to make decisions – these need to be improved (and current weaknesses highlighted)
- Where are the areas of greatest species richness that could provide reservoirs to improve or maintain adaptive potential?
- Susceptibility of species to change. Not existing threats, but what will be threatened in the future?
- The impacts of deer on vegetation
- Which genetic resources are required for resilience?

What do we need to know about the effectiveness of management actions?

- Whether the current suite of potential management actions helps to "buffer" dry forest ecosystems from the effects of climate change
- The scales at which different management actions are effective
- How do we measure success?
- Implications of management on carbon stores or sequestration.

What should we be monitoring?

- Status of assets (as we define them)
- Recruitment and recruitment windows
- Environmental changes that can be used in transition models to give us information about the reversibility of change
- Condition indices (preferably remotely) – these indices need first to be defined
- Automated identification of bird calls teamed with only recording and uploading.

What new management approaches should we be testing and experimenting with?

- Expanding the use of citizen science
- Manipulating disturbance regimes in woodlands for heterogeneity and regeneration
- Tenure blind landscape management
- Addressing human factors in making management-decisions
- Better use of modern technologies e.g. remote sensing
- Broadening participation in management to spread and reduce management costs
- Embedding research and monitoring into management actions
- Mobile reserves (validating the concept).

Restoration to protect biodiversity and carbon storage: an adaptation option for the Midlands

Protecting biodiversity and carbon storage in the Tasmanian Midlands is led by Greening Australia Tasmania, in partnership with the Tasmanian Land Conservancy, Bush Heritage Australia, NRM North, Tasmanian Farmers and Graziers Association, the University of Tasmania and the Tasmanian Government's Department of Primary Industries, Parks, Water and Environment. The $5 million project budget includes $2.2 million from the Australian Government's Biodiversity Fund.

The project aims to restore 1,000 hectares in the Tasmanian Midlands back to good ecological health, providing productivity benefits to landholders such as healthier soil and shade and shelter for livestock, as well as storing a significant amount of carbon. It aims to provide a template for broadscale restoration in fragmented landscapes.

The Midlands are the driest part of Tasmania, and have been severely fragmented and cleared for agriculture. Only about 3% of native grassland and 30% of native vegetation remain, making it one of 15 national Biodiversity Hotspots, and a priority area for restoration in Tasmania. One of the ecological aims of the project is to re-connect the Eastern tier with the Western tier across the dry valley floor, and to create protected habitats for vulnerable marsupials and woodland birds. Over 25 years, it is expected that at least 16,250 tonnes of carbon will be stored by the project's restoration activities.

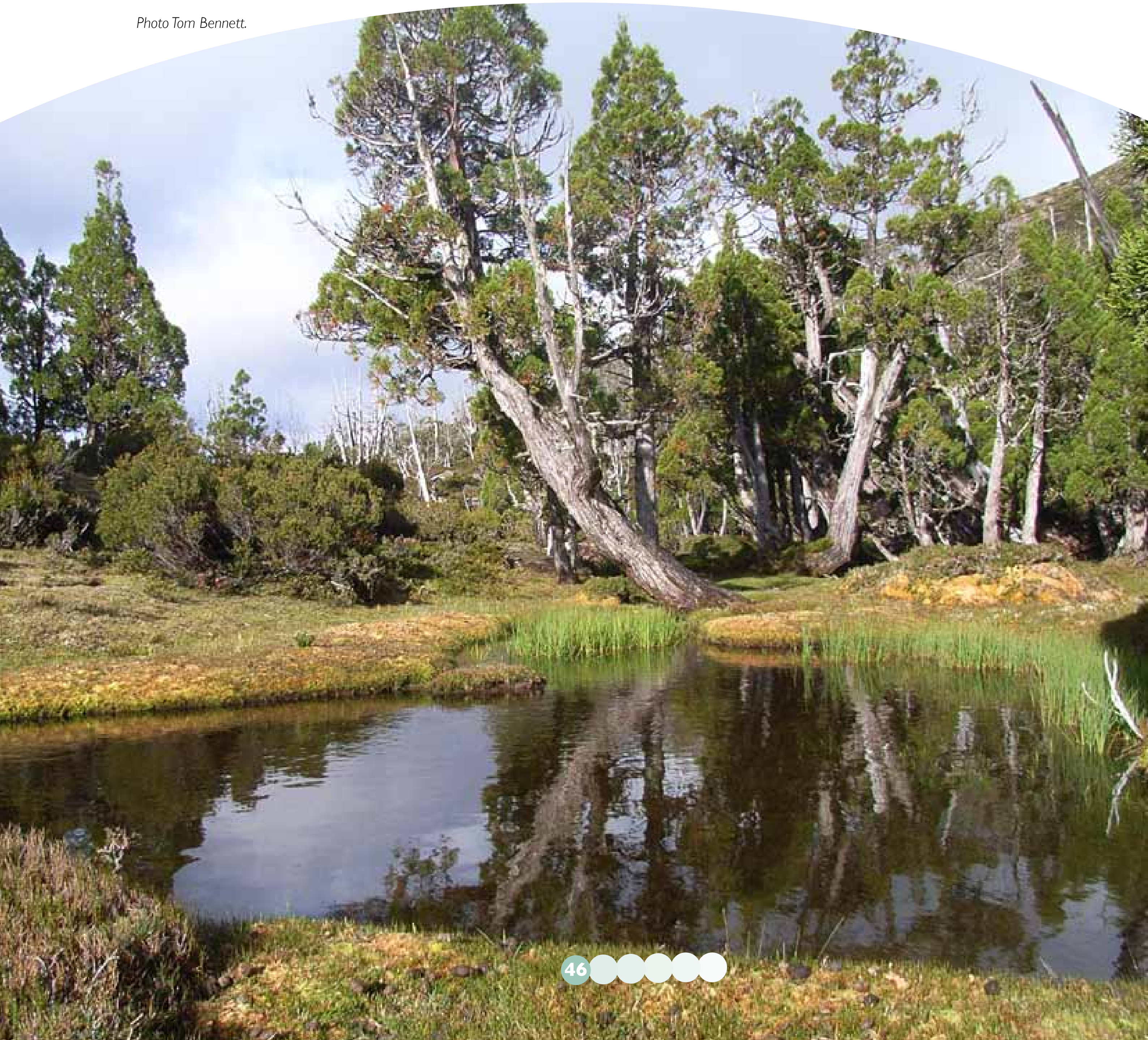
This project builds on a previous partnership project *Strategic restoration to conserve, buffer and link remnants in the threatened bioregion of the Northern Midlands*, which included funding from the Ian Potter Foundation. This project successfully restored 100 hectares of land and demonstrated good outcomes for carbon storage from the restoration of native vegetation.

Alpine and montane ecosystems

Alpine and montane ecosystems include the distinctive Tasmanian high country vegetation of conifer forests and coniferous heath, fjaeldmark, snowgum woodland, cushion plants, alpine shrubland, herbfields and montane grasslands. These communities occur within the alpine zone where the growth of trees is impeded by climatic factors. The altitude above which trees cannot survive varies between approximately 700 m in the south-west to over 1 400 m in the north-east highlands; its exact location depends on a number of factors. In many parts of Tasmania the boundary is not well defined. Sometimes tree lines are inverted due to exposure or frost hollows.

Participants: Jennie Whinam (facilitator), Matt Taylor, David Taylor, Mick Brown, Nick Fitzgerald and Mandy Caldwell.

Photo Tom Bennett.



1. Consequences of climate change in alpine and montane ecosystems

Changes and consequences	Level of conservation concern
Decrease in annual rainfall and potential increased risk of prolonged drought affecting: seedling establishment and germination; water availability/soil moisture in alpine peatlands, wetlands and streams; and fire frequency	High
Increased drought conditions	High
Changes in seedling establishment and germination – seedling germination and establishment may be enhanced with reduced frosts and longer growing seasons, but may also be inhibited by prolonged dry periods and increased grazing pressure from wild herbivores.	
Changes in soil properties- hydrology, peats, soil biota, change in freeze thaw cycles	
Physiological stress e.g. retraction in the range of the Miena cider gum with warmer, drier decades in recent times	
Higher temperatures and less rainfall will affect soil properties and hydrology: soil moisture, soil biota, organic contents, and length of the growing season (warmer soils = longer growing season)	
Increased fire frequency and intensity (not the same impact across all alpine areas; some communities are fire-killed but others can tolerate fire)	
Increase in grazers (feral and native), generalists and r species e.g. rabbits	High
Decrease in obligate seeders (e.g. epacrids) and specialists such as aquatic species, poorly-dispersing species and K species e.g. pencil pines	
Decreased extent of *Sphagnum*/peatlands communities, snowpatch/fjaeldmark, alpine wetlands/string bogs, coniferous vegetation, deciduous beech Nothofagus gunnii shrubberies and cloudforests	
Increased extent in some communities such as montane grassland, woody shrubs & trees invading grasslands, boulder fields with no vegetation	
Increases in species competition because of species moving up from the lowlands, and increased shrub and tree invasion above the treeline	
Increased impacts and risk of pests, weeds and diseases (e.g. root-rot fungus *Phytophthora cinnamomi*, crack willow)	
Deer are expected to expand in numbers and altitudinal range	
Reduced health and condition in alpine streams and riparian areas e.g. reduction in stream flows and soil moisture in alpine streams and riparian vegetation	High
Changes in ecological connectivity: loss of small isolated areas and increased gene mixing; large areas becoming fragmented	Medium
Increases in plant species competition with migration of species from lowland environments.	

2. Setting conservation goals in a changing climate for alpine and montane ecosystems

Key adaptation goals

- Manage non-climate pressures
- Identify and protect refugia
- Monitor, control and manage negative impacts of pests, weeds and disease (can't prevent all)
- Manage fire risk
- Take a strategic approach and consider the wider matrix in which the alpine 'archipelago' is situated
- Monitor change
- Consider ex-situ conservation and translocation – decide whether it is desirable to move species and under what circumstances.

3. Adaptation actions in alpine and montane ecosystems at a range of spatial scales and timescales

Key:

* Limited experience of this action in this ecosystem

** Completely new action for this ecosystem

P Priority

Individual site/reserve	
Actions to take now	Monitor restricted distribution communities and species.
	Identify priority species and communities with restricted distributions susceptible to *Phytophthora*, other pathogens, fire etc.
	Identify outlying provenances
	Carry out fire management, including maintaining appropriate fire regimes and fuel reduction burning – use strategically in surrounding landscape to prevent catastrophic fires entering alpine areas Integrate fire and weed management to prevent weed incursions
	Manage human access (e.g. no-go zones; use of fuel stoves only)
Additional actions in the longer term (to 2050 and beyond)	Management responses based on outcomes of research
	Investigate viability of preventing woody encroachment (e.g. use of fire to maintain montane grassland)
	Other actions based on ground research and the results of the adaptive management process

Catchment/landscape	
Actions to take now	Use species characterisation to identify those that are vulnerable and to prioritise/inform management (e.g. vagility, resilience)
	Manage fuel stove-only areas in fire-sensitive vegetation and high usage/high risk areas
	Identify contemporary/future refuges
	Quantify impacts and control non-native species (e.g. deer) which have an impact on native plant species in the alpine zone
	Take biosecurity measures to reduce risks of pests, weeds and diseases (prevention, barriers, protection, detection, prioritisation, extermination
Additional actions in the longer term (to 2050 and beyond)	Continue management of threats
Bioregion	
Actions to take now	Assess relative refugia qualities by bioregion **
	Identify actions to explore the desirability and viability of translocation, including defining situations where translocation may be desirable, candidate species, possible destinations for translocation and risks to existing wildlife
Additional actions in the longer term (to 2050 and beyond)	Continue to manage threats
	Implement ex situ conservation measures
State	
Actions to take now	Investigate existing conservation e.g. seed conservation and research at the Royal Tasmanian Botanical Gardens.
	Identify refugia
	Monitor conifer health
	Research ecosystems and functions *
	Identify threats from outside alpine zone **
	Debate the pros and cons of translocation *
Additional actions in the longer term (to 2050 and beyond)	Identify and establish no-go zones to prevent spread of disease
	Research pollination ecology

All spatial scales	
Actions to take now	Use strategic reserve design and private land conservation to manage the whole alpine area and surrounding matrix
	Monitor to inform management action
	Conduct analysis of management interventions
	Undertake more research to better understand alpine ecology
Additional actions in the longer term (to 2050 and beyond)	Use historical photos/plots to understand the significance of change
	Adopt a precautionary approach
	Implement an adaptive management approach
	Increase biosecurity *
	Develop and implement ongoing monitoring
	Undertake active fire management (fire management agencies - Parks & Wildlife Service, Forestry Tasmania and the Tasmania Fire Service) *

Changing goals and management actions over time

It is essential to put in place a strong adaptive management approach now, with flexible objectives and using monitoring to inform future reviews and changes to management arrangements. For example, it will be important to monitor recruitment of pencil pines.

Changing aims and objectives would be relatively achievable for some management actions, but could be very difficult overall as alpine areas are likely to be a lower priority for funding, limiting the potential for expensive interventions such as translocation.

Past changes in conservation and land use from which lessons could be learned for adaptation include:

- Weed behaviour in the alpine zone as a result of recreational activities
- Restoration of Sphagnum peatlands after harvesting.

Current action in Tasmania

There appears to be a fairly high level of climate change awareness among conservation managers in the alpine zone, and some new projects have been set up specifically to address climate change. Existing projects approaching climate change adaptation include:

- Modelling species responses to climate change
- Warra Long Term Ecological Research (LTER) site
- Tasmanian Wilderness World Heritage Climate Change project
- Fire refugia identification project
- Bushfire Risk Assessment Model System (BRAMS)
- Modelling species responses such as alpine-obligate skinks, and Bioclim modelling
- Ex situ populations (e.g. cider gum).

4. Information and monitoring requirements in alpine and montane ecosystems

What do we need to know about ecology, ecosystem function and about likely environmental change?

- The distribution of invertebrates and cryptogams in the alpine landscape
- More about ecosystem function (cushion plants, sphagnum, conifers)
- Bioclimatic envelope of species
- Flows of energy, carbon, water, nitrogen and nutrients
- Thresholds or tipping points for likely environmental change
- The role of soil seed banks; germination requirements and seedling establishment.

What do we need to know about the effectiveness of management actions?

- The pros and cons of translocation. Understanding the real imperative of the conditions under which a species needs to be considered for relocation (within Tasmania and at national/Australia-New Zealand scales)
- Baseline measures of condition are required to gauge changes to species, communities and ecosystems
- The potential role and effectiveness of ex-situ conservation.

What should we be monitoring?

- Restricted taxa and communities are the highest priority for monitoring, especially those susceptible to fire and disease
- Snow patch, fjeldmark and conifer communities are a priority
- Increased land use – there may be development pressures with climate change.

Which new management approaches we should be testing and experimenting with?

- Formalised adaptive management framework, with defined triggers and consequent actions, built into the policy/legislative framework
- Measurable targets.

Monitoring the effects of climate change in the Tasmanian Wilderness World Heritage Area

Jennie Whinam and her team at the Department of Primary Industries, Parks, Water and Environment are implementing a monitoring program to better understand the impacts of climate change on the natural values of the Tasmanian Wilderness World Heritage Area with a particular focus on alpine areas. Weather stations have been established at Mt Sprent and Cradle Mountain to assist with investigations into ecotone dynamics, as well as to assess whether the weather in high altitude alpine areas is changing in similar ways to changes being recorded at lower altitude weather stations.

Other projects include ongoing monitoring of the alpine treeline (to see whether tree species are moving upslope in response to warmer conditions), conifer health (to gain insight as to how Tasmania's primitive endemic conifers are coping as conditions change) and fjaeldmark extent and condition (areas of plant growth restricted due to extremes of cold and exposure to wind). An altitudinal transect has been established at Mt Weld-Warra as a component of the international Long Term Ecological Research (LTER) Network to record baseline biodiversity data against which future changes in the altitudinal distribution of flora and fauna can be measured in relation to climate change, succession due to fire or its absence, and other chance events.

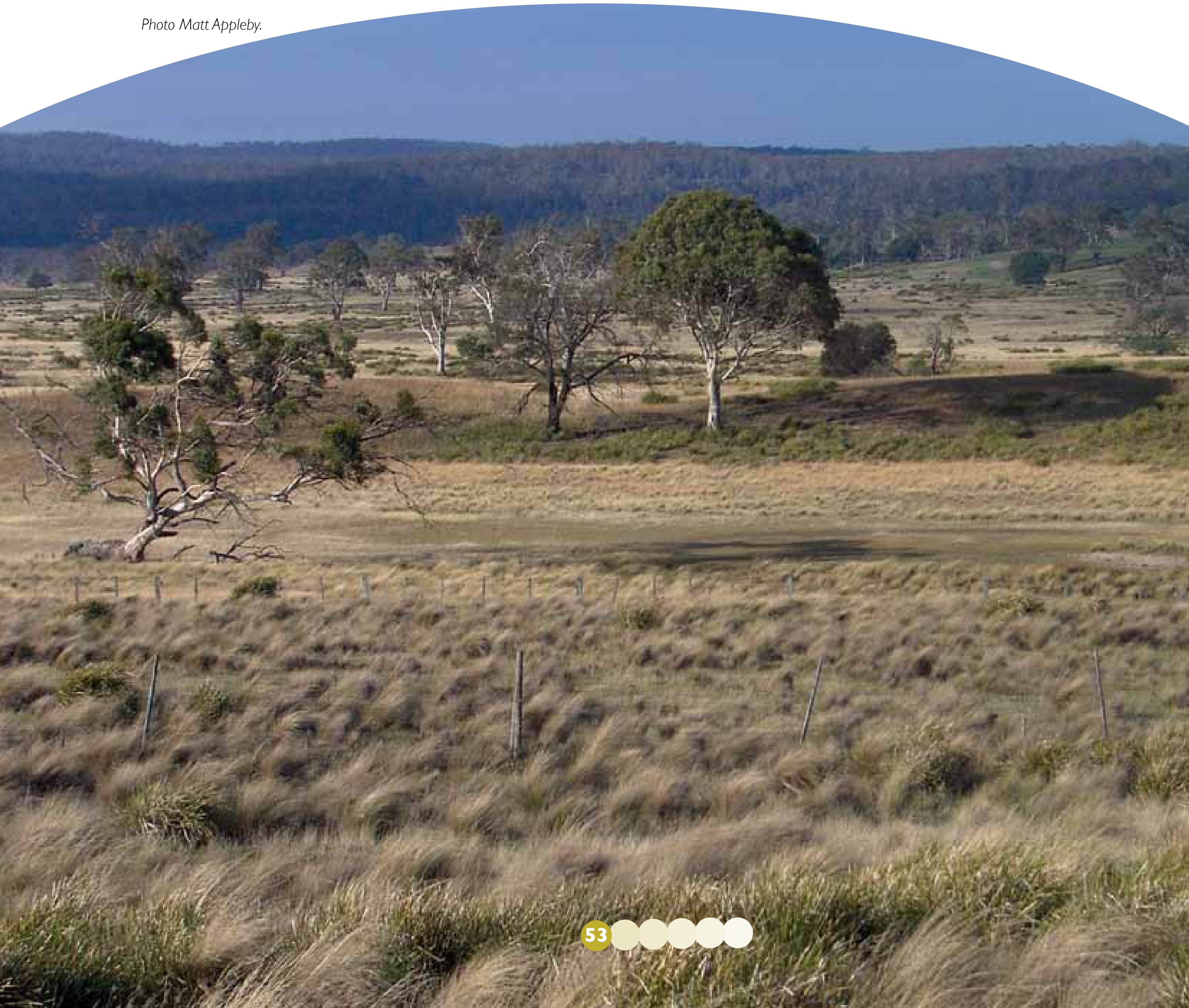
The results of these projects are used to inform management decisions relating to priorities for fire protection, weed and disease management, priorities for ex situ conservation of plant species and use of natural resources (such as dendrochronology research, where cores are extracted from old conifers to assess changes in climate over thousands of years), particularly in the world heritage area.

Lowland Grasslands & Extensive Natural Grazing Systems

Lowland native grasslands are areas of native grassland dominated by native grasses with lightly scattered or absent trees. The dominant grass species are tussock-forming and are a mix of perennial C3 genera (*Poa, Austrostipa* & *Austrodanthonia*) and the widespread C4 grass *Themeda triandra*. Lowland temperate grasslands form a floristic continuum with grassy woodlands. There are different types of grasslands that are found in a variety of habitats, including valley bottoms, dry slopes, rock plates and coastal foredunes. Grasslands can be natural or may be human-induced as a result of heavy burning, tree clearing or dieback. Temperate grasslands are a major conservation challenge at a global level and it is no different in Tasmania - some of the lowland temperate grassland types have been recognised as some of the most threatened vegetation communities in Australia.

Participants: Kerry Bridle (facilitator), Maria Weeding, Rebecca Harris, Matt Appleby, Louise Gilfedder, Leanne Sherriff

Photo Matt Appleby.



1. Consequences of climate change in lowland grasslands & extensive natural grazing systems

Changes and consequences	Level of conservation concern
Thermal tolerances of species exceeded (for example, ptunarra brown butterfly)	Medium-High
Increased invasion of weed species (current & novel) as a result of changing conditions and resulting species range changes and changing competitive relationships among plant species	High
Shift in grass competition/dominance e.g. from wallaby grass to kangaroo grass	Medium
Increased soil dryness – particularly Upper Derwent valley region/Central Highlands leading to drought death, changed phenology etc.	High
Changes to fire frequency and natural fire regimes	Medium
Changes in land use and management in extensive natural grazing systems, e.g.: - shift in grazing to south-facing slopes - changes in social values including reduced importance of conservation - intensification of grazing - shift to high value crops - shift from merino to dorper & meat sheep with different grazing impacts - abandonment of grazing and associated management strategies such as fire - changes in fire regimes.	High
Changes to seasonality, for example plant responses to changes in growing degree days – potential for mismatch with pollinators which may still be underground in larval stage	High
Invasion of grassland by trees and shrubs	High
Changes to nutrient cycling & microbial activity with changing temperatures (tree decline in run country)	High
Potential extinction debt not yet realised/identified due to fragmentation and potential increased risks of species	High
Changes in soil microbe flora and nutrient cycling in extensive natural grazing systems	
Carbon plantings (but possibly not in the Midlands where conditions may be too dry)	
Changing composition of assemblages (e.g. shift in dominance to C4 kangaroo grass, loss of species richness in herbs)	
Change to frequency and intensity of extreme events such as extreme temperatures, frosts, erosion and rainfall	High
Loss of grassland habitat if invaded by woody species	High

2. Setting conservation goals in a changing climate for lowland grasslands & extensive natural grazing systems

Some key adaptation goals

- Maintain existing management of areas in good condition, but increase monitoring of changes and ability to change management strategies in response to change
- Continue to minimise current threats such as pests, diseases and weeds
- Reduce impacts of changes to land use and land management; look for opportunities for changes that will benefit both farming and grassland ecosystems
- Ensure Tasmanian endemic grassland species are identified and retained
- Restore grasslands with moderate levels of past disturbance
- Maintain or create connectivity for grassland species
- Consider translocation for threatened species
- Maintain ground cover, structural diversity and species diversity
- Establish reference areas that can "move", otherwise they may be "lost" over time.

How might goals and management actions need to change over time?

Grazing strategies might need to be changed to fit with new 'pasture' composition which may include a higher proportion of woody vegetation (shrubs). Required connectivity thresholds might need to be reconsidered

At this stage we don't know at what point ecological tipping points might occur, but monitoring of the following will help to provide information to inform possible modifications to conservation goals and management approaches in the future:

- Shifts in competitive relationships among grass species
- Increases in woody vegetation
- Extensive grazing figures from landholders (one way of monitoring change is to look at changes in production in extensive grazing lands)
- Climate weather forecasts, including El Niño/La Niña (to provide information to advise farmers on appropriate stocking levels).

Changing conservation goals for this ecosystem could be difficult, not just because we might not recognise 'tipping points' but also because of current legislative requirements. Management actions specified by covenants on land titles might need to be made more flexible.

There are opportunities to learn lessons for adaptation from observations of, and management responses to, past drought experiences and extreme events. Drought can be a good time to provide incentives and support for conservation initiatives.

3. Adaptation actions at a range of spatial scales and timescales for lowland grasslands

Key:

* Limited experience of this action in this ecosystem

** Completely new action for this ecosystem

P Priority

Individual site/reserve	
Actions to take now	Engage and resource community groups *
	Actively manage threatened grassland species at site level*
	Protect "climatic spaces" - micro-refugia (management guidelines are needed) **
	Use active fire management at Township Lagoon NR – burning every 3-5 years *
	Control Weeds of National Significance (WONS) as a priority *
	Maintain or establish appropriate grazing
	Maintain or establish appropriate fire regimes
	Contain transformer weeds (e.g. buffers)
	Augment populations with better-adapted genetic stock
	Restore grasslands with moderate levels of past disturbance
	Identify priority species that may not cope with future climate predictions at that site
	Re-introduce species that have suffered local extinction
	Use grazing and fire to reduce shrubbiness, increase grassiness
	Maintain existing good management where it is working
	Manipulate structural components to provide diverse habitat (e.g manipulate tree cover to improve conditions for grassland species)
Additional actions in the longer term (to 2050 and beyond)	Restore habitat
	Implement flexible management to respond to change
Catchment/landscape	
Actions to take now	Allow dead whitegum (*E. viminalis*) forest to revert to grassland & accept its value as resilient community
	Explore use of structural enhancement (large coarse woody debris, rocks)**
	Use flexible grazing regimes & monitoring to determine effects of different cover
	Protect ecosystems such as grassy woodlands to help improve connectivity for grassland species
	Identify connectivity pathways and ensure they are protected
	Use strategic grazing & other control methods to reduce competitiveness of weeds

Additional actions in the longer term (to 2050 and beyond)	Increase use of low intensity fire to reduce fuel loads and prevent high intensity fire **
	Work with Tasmanian Fire Service to burn grassland to meet area targets for hazard reduction burning **
Bioregion	
Actions to take now	Work on protection of the biggest and the best remnants **P**
	Provide connectivity for genetic resources because of threat of loss **P**
	Establish Friends of Grasslands Groups (northwest & Midlands) **
	Identify sites that may be more biogeographically suitable for species thought unlikely to persist in their current range (translocate species if appropriate)
Additional actions in the longer term (to 2050 and beyond)	None identified
State/All spatial scales	
Actions to take now	Identify sleeper weeds under climate change **
	Work with industry and government so that conservation & production can co-exist
	Control hawkweed*
	Control serrated tussock *
	Identify Priority sites for management triage**
	Provide education resources*
	Plan for control of new weed threats**
	Establish connectivity for promoting perennial grazing systems between important grasslands **
	Increased vigilance for andquarantine and control of weeds
	Identify significant sites of endemic grasslands and record them on a register
	Increase public awareness/understanding and value of native grasslands.
	Minimise pest, disease and weed populations
	Work with farmers and other land managers to identify benefits for both farming and the environment
	Establish monitoring in grasslands
Additional actions in the longer term (to 2050 and beyond)	Monitor trends and rates of change **

4. Information and monitoring requirements in lowland grasslands & extensive natural grazing systems

What do we need to know about ecology, ecosystem function and about likely environmental change?

- Biological information about particular species, assemblages and communities
- Impacts on (plant and animal) species interactions
- Possible shifts in competitive advantages and species interactions
- Soil biology/microbial activities (shifts under different climate)
- Impact of extinction debt
- Grassland restoration & rehabilitation techniques
- Climate envelopes – now & future
- Plasticity of different species.

What do we need to know about the effectiveness of management actions?

- We need simple measurable objectives
- Clearer understanding of the links between action, outcome and conservation objective
- If private land management is the key to future success then we need to have well designed experiments to assess different management processes e.g. grazing systems for management of woody weeds, diverse habitats etc
- Monitoring across tenures
- Database of long-term plots
- Vegetation Condition Assessment (VCA) - could this be a surrogate for rapid monitoring or other quick techniques?
- Better understanding of practicalities and techniques of rehabilitation/ restoration to enable connectivity corridors/buffer
- Does creating buffers around grassland make a difference?

What should we be monitoring?

- Changes in extent and condition (remote sensing)
- Function (Landscape Function Analysis)
- Threatened species and other species of concern
- Spatial variation in community assemblage (with better finer floristic analysis)
- Changes in species presence and abundance.

Are there new management approaches we should be testing and experimenting with?

- Utilise Free Air Carbon Enrichment (FACE) research (Mark Hovenden at University of Tasmania - 10 years of data)
- Creating novel grassy ecosystems
- Wildlife-Friendly Farming (e.g. US Behave approaches)
- Shading of grasslands
- Different grass heights to create cooler microhabitat at ground level.

Case Study of research that has informed adaptation thinking: Free Air Carbon Enrichment (FACE) research by UTas

Carbon dioxide is expected to be 550 parts per million by mid-century and for the past 10 years at the University of Tasmania researcher Mark Hovenden and his team have been researching how this will affect plants. Plots of native grasslands were exposed to an atmosphere with elevated levels of carbon dioxide and a 2˚C increase in temperature. Despite plants requiring carbon dioxide for photosynthesis, the higher concentrations alone did not stimulate greater growth in the grassland plants. Growth is limited by nutrients and water, and any extra growth was small. Microbial activity also changes with higher carbon dioxide and elevated CO2 reduces the quality of the leaf litter, meaning that carbon accumulates as leaf litter, locking up nutrients. Flowering, seed production and seed mass were not significantly affected by FACE, warming or their interaction in most species. Some species, however, did respond significantly to simulated global changes, and these impacts are likely to have substantial implications for grassland community composition and structure.

The results of this research better informed our thinking of how grasslands may respond to climate change. Managing the existing threats to grasslands such as the potential impacts of landuse change and the risk of increased fragmentation is an important focus of adaptive management approaches rather than the climate per se.

Mark J. Hovenden et al (2007) Flowering, seed production and seed mass in a species-rich temperate grassland exposed to FACE and warming. *Australian Journal of Botany* 55(8) 780–794

Photos Mark Hovenden.

References

Department of Primary Industries, Parks, Water and Environment; Resource Management and Conservation Division (2010). *Vulnerability of Tasmania's natural environment to climate change; an overview.* Department of Primary Industries, Parks, Water and Environment. Hobart, Tasmania

Dunlop M & Brown PR (2008) *Implications of climate change for Australia's National Reserve System: a preliminary assessment*. Report to the Department of Climate Change, February 2008. Department of Climate Change, Canberra, Australia.

Hovenden MJ, Wills KE, Vander Schoor JK, Chaplin RE, Williams AL, Nolan MJ & Newton PCD (2007) Flowering, seed production and seed mass in a species-rich temperate grassland exposed to FACE and warming. *Australian Journal of Botany* 55(8) 780–794

Michaels K, Norton T, Lacey M, Williams J (2010) Spatial analysis of Tasmania's native vegetation cover and potential implications for biodiversity conservation. *Ecological Management and Restoration* 11, 194-200.

Smithers RJ, Cowan C, Harley M, Hopkins JJ, Pontier H & Watts O (2008) *England Biodiversity Strategy climate change adaptation principles: conserving biodiversity in a changing climate.* Department for Environment, Food and Rural Affairs. London, United Kingdom.

Steffen W, Burbidge AA, Hughes L, Kitching R, Lindenmayer D, Musgrave W, Stafford Smith M & Werner PA (2009) *Australia's biodiversity and climate change: a strategic assessment of the vulnerability of Australia's biodiversity to climate change.* A report to the Natural Resource Management Ministerial Council commissioned by the Australian Government. CSIRO Publishing

About the authors:

Louise Gilfedder is a senior conservation scientist at the Tasmanian Department of Primary Industries, Parks, Water & Environment, where she leads the *Natural Systems Resilient to Climate Change* project. She also works at the University of Tasmania where she focuses on ways to improve the sharing of knowledge between scientists and policy makers. Previously, she served for 10 years as a director of Bush Heritage Australia and as convener of a local Bushcare Group. She is currently involved with the Temperate Grasslands Conservation Initiative (an international specialist group of the IUCN) and is a member of the Science Council of the Tasmanian Land Conservancy.

Nicholas Macgregor is principal specialist in landscape ecology at Natural England (a UK government conservation agency). He is an ecologist who works on conservation strategies, with a particular focus on adaptation to climate change and on large-scale conservation management. His current research interests include ecological networks, climate change refugia, and how adaptation to climate change is being approached by conservation managers. He is chair of the cross-European ENCA Climate Change Group, which aims to share information among European nature conservation agencies and to facilitate the translation of climate change evidence into conservation management.

Kerry Bridle is a research fellow at the Tasmanian Institute of Agriculture. Her ecological research has covered impacts on private and public lands, focusing on grazing impacts in alpine and lowland grasslands. Previous ecological experience includes assessing recreational impacts across a range of Tasmanian ecosystems and the ecology of Tasmanian peatlands. Kerry is a Tasmanian representative on the NCCARF Terrestrial Biodiversity Steering Committee and regional councillor for the Ecological Society of Australia.

Oberon Carter is Conservation Management Officer at the Tasmanian Department of Primary Industries, Parks, Water & Environment. His work primarily involves developing spatial layers and tools to inform conservation planning in Tasmania as a major component of the work of the *Natural Systems Resilient to Climate Change* project. He has also worked extensively in south-eastern Australia on threatened species recovery, vegetation surveys and mapping and conservation covenanting. He also plays a mean guitar.

Daniel Sprod is Landscape Ecologist for the Tasmanian Land Conservancy with special interest in landscape scale conservation planning and prioritisation. Current research topics are modelling woodland bird distribution, carbon methodologies and modelling connectivity for vulnerable mammals and birds. He has developed landscape conservation plans for biodiversity and sustainability, from the farm level, through regional, catchment and State scales.

Resource Management and Conservation
Department of Primary Industries, Parks, Water and Environment
GPO Box 44
Hobart Tasmania 7001

Tasmania
Explore the possibilities