SYNTHESIS SUMMARY 6

Terrestrial ecosystems

Increasing temperatures, more frequent and severe extreme weather events and declining rainfall have already resulted in observable shifts in the behaviour of terrestrial plants and animals, and more widespread impacts are evident on all terrestrial ecosystems.

NCCARF
National Climate Change Adaptation Research Facility

About this summary

This summary addresses adaptation actions to support terrestrial ecosystem conservation and function in a changing climate. The opening pages provide the context including the nature and impacts of climate change ('Why we need to adapt') followed by a synthesis of research findings around the impacts and adaptation response in terrestrial ecosystems ('The research base …'). It concludes with a summary of how this new research knowledge might help address key adaptation policy challenges. This final section is informed by a workshop held with practitioners ('Evidence-based policy implications').

This brief was developed by members and staff of NCCARF's National Adaptation Network for Natural Ecosystems, with input on the policy challenges developed in workshops held in Hobart (Tasmania) and Canberra (ACT) in March 2016. The workshops were attended by practitioners, policymakers and managers from within local, state and federal government organisations, community service organisations, not-for-profit organisations and universities.

The key research reports used to develop this summary are highlighted in Section 4. To see all reports from the ARG Program, please visit **www.nccarf.edu.au/adaptation-library.**

This Brief was prepared by Nadiah Roslan and members of the Natural Ecosystems Adaptation Network, and Sarah Boulter, Jean Palutikof and Ana Perez from NCCARF. Please cite as: NCCARF (2016) Terrestrial ecosystems. Synthesis Summary 6, National Climate Change Adaptation Research Facility, Gold Coast.

About this series

Between 2008 and 2013, the Australian Government funded a large nationwide Adaptation Research Grant Program (the ARG Program) in climate change adaptation. The Program was managed by the National Climate Change Adaptation Research Facility (NCCARF). It resulted in over 100 research reports that delivered new knowledge on every aspect of adaptation. The aim of the Program was to help build a nation more resilient to the effects of climate change and better placed to take advantage of the opportunities.

This series of Synthesis Summaries is based on research findings from the ARG Program, augmented by relevant new literature and evidence from practitioners. The series seeks to deliver some of the policy-relevant research evidence to support decision-making for climate change adaptation in Australia in a short summary. It takes an approach identified through consultation with relevant stakeholders about the needs of the intended audience of policymakers, decision-makers and managers in the public and private sectors.

Key findings

Five principal adaptation challenges emerge from the research evidence:

1. Identify key adaptation pathways and principles for managing ecosystems: Existing approaches to managing terrestrial ecosystems come from a history of significant investment in a particular conservation philosophy: managing in place, using pre-European settlement as a conservation benchmark and focusing on rare and threatened species (e.g. the Environment Protection Biodiversity Conservation Act 1999, reserve systems). Climate change has altered the current view of how to prioritise values of conservation, and it is clear that more nimble and flexible approaches will be needed (see Section 2.3).

2. Work across jurisdictions and tenure and identify roles and responsibilities: Climate change will mean many species and ecosystems can no longer survive in their current locations. Planning is likely to be most effective when undertaken at a landscape scale and where greater flexibility in management is encouraged. Working at the landscape scale will require greater cooperation and collaboration across jurisdictions and tenures.

3. Define new social, economic and ideological values to drive land management and policy arrangements: Climate change will mean prioritising new environmental and social values, and this will change what we are managing for, for example, individual species, ecosystem function or ecosystem resilience.

4. Use new tools to make decisions: New decision support tools and decision frameworks are becoming available to help incorporate the new principles and values of land management that are emerging under climate change into decision-making. The use of quantitative techniques to demonstrate effectiveness, such as cost–benefit analysis, and the search for co-benefits, for example through carbon sequestration, are likely to become important in decision-making.

5. Collaborate to manage new challenges, conflicting goals and inherited problems: Land managers may be faced not only with new challenges, but interaction and escalation of existing problems and conflicting management goals. For example, will movement corridors create new fire risks? These new challenges highlight the need for collaborative approaches between a range of experts. Existing approaches (e.g. assessing species vulnerability, identifying the costs and benefits of a management option, assessing the potential invasiveness of a species) will need to draw on existing knowledge and expertise but will also need to incorporate new time and geographical scales.

1. Why we need to adapt

1.1 The climate context

The Australian average surface air temperature has risen by 0.9 °C since 1910 and the number of extremely hot days increased (Figure 1), and if greenhouse gas emissions continue under a business-as-usual scenario, Australia's temperatures are projected to increase a further 2.8–5.1 °C by the end of the century (Figure 2). Current and predicted changes in temperature and rainfall are expected to cause major shifts in climatic zones and result in hotter, drier conditions across the majority of Australia. Along with an increase in extreme weather events – including drought, fire, heat waves and flooding – these changes are already having significant impacts on biodiversity, including changes in species distributions, timing of biological behaviours and changed ecological interactions.

Much of Australia's terrestrial biodiversity is adapted to the specific conditions found in its current range, but predictions indicate that species will experience substantially different local environments in the near future from those they experience now (Figure 3). Increases in warm weather, heat extremes and a decline in rainfall will force species to adjust to those environmental changes, through shifts in range and/or behaviour and physiology, or become extinct.

More information on the climate context is available in:

- NCCARF Terrestrial Biodiveristy Report Card[24] CSIRO and
- Bureau of Meterology Climate Change in Australia[4]
- AdaptNRM - Implications of Climate Change for Biodiversity Guide[45]

1.2 Key risks

Natural ecosystems have been identified as one of the most vulnerable sectors to climate change in Australia. Key risks include:

- Extinction of some species, particularly those with restricted or fragmented geographic distributions and/or specialised ecological requirements, including narrow climatic tolerances. While some species are likely to move or disperse into more suitable climate conditions, for some species moving to a more suitable climate is limited by dispersal capabilities and/ or geographical barriers.
- Population losses are also expected due to climatic shifts, extreme heat or drought events or fire. Heat-related mass mortality in individual animal

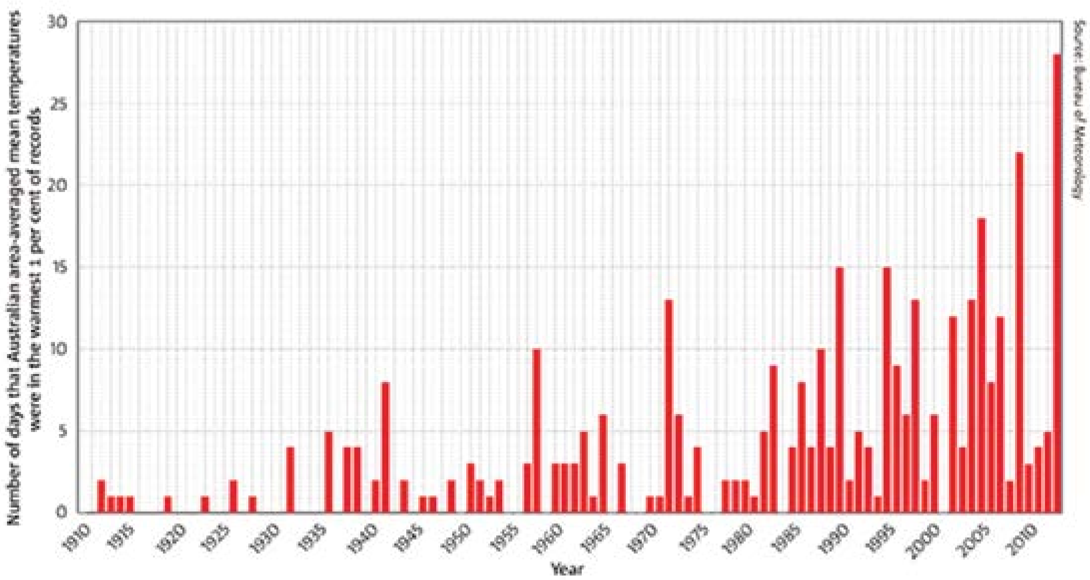
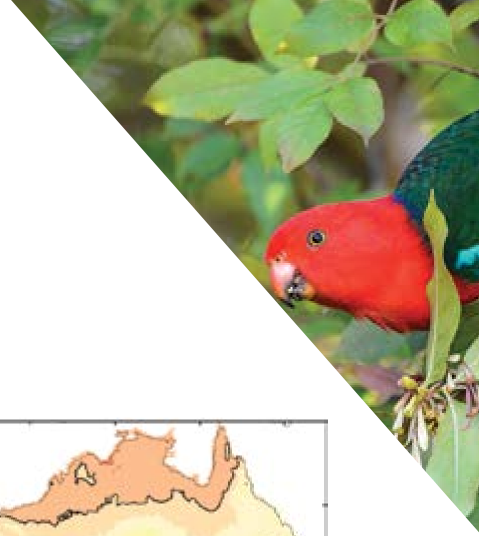


Figure 1 Number of extremely hot days (the Australian area-averaged daily mean temperature is above the 99th percentile) in each year for the period 1910–2013. Half of these extremely hot days have occurred in the past twenty years. Source: Bureau of Meteorology.[2]



species (e.g. flying foxes) has been recorded for some time. Plants can likewise die following extreme heat events, with some species more vulnerable than others.

- Changes in species assemblages are likely to be the long-term outcome of extinctions, losses and migration.
- Other risks include loss of ecosystem services and changed species interactions (for example, seasonal mismatch), including pollinator services and predator–prey interactions.

Climate change will also interact with other threats, including habitat loss and invasive species. For example, human-induced land-use changes such as urbanisation and farming can produce barriers to distributional shifts. There is also evidence that climate change will increase the geographic range and impact of invasive species such as weeds, disease and pests. Removing or minimising existing human stressors such as habitat loss and invasive species will continue to be important; however, climate change will be an additional as well as an exacerbating stressor on top of existing threats. It will become even more important to remove or minimise existing stressors, especially those that may benefit from climate change (e.g. the invasive cane toad may benefit from climate change more than native frogs). Climate change will also have a variety of flow-on effects on biodiversity; for instance, increased CO_2 concentrations lower the nutritional quality of foliage, which in turn reduces its digestibility by herbivores.[15]

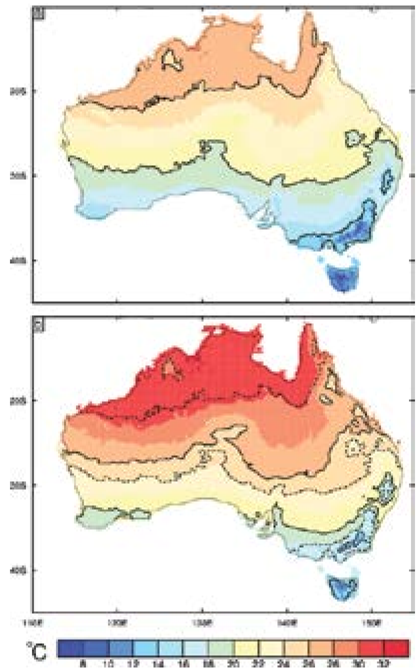


Figure 2 Annual mean temperature for present (a) and for late 21st century (b). Annual mean temperature is projected to increase by 2.8–5.1 °C across the continent. Source: © Commonwealth of Australia 2015, Bureau of Meteorology.[4]

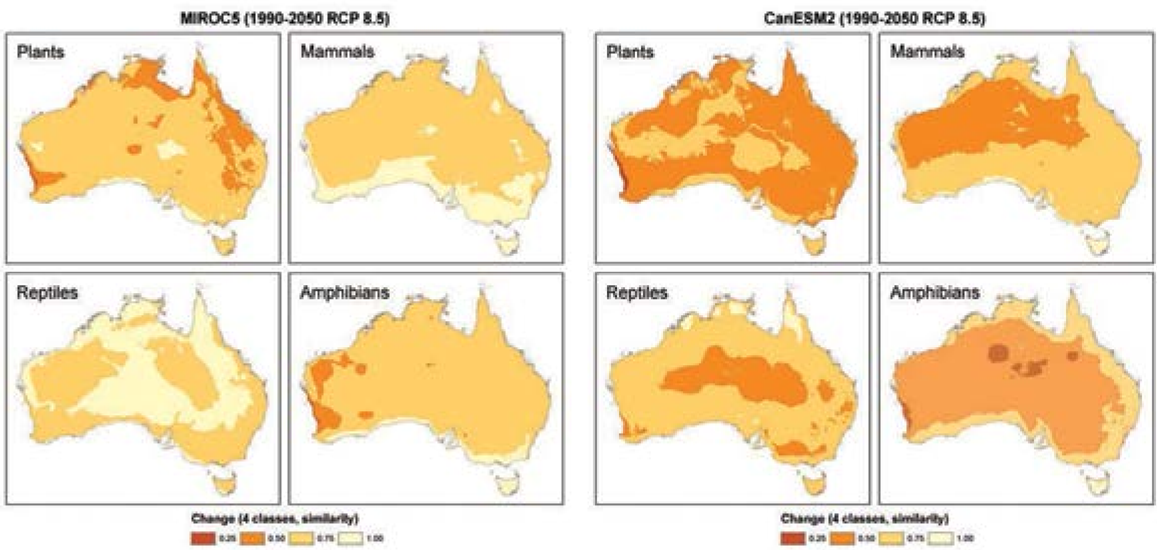


Figure 3 An example of the amount of change in ecological communities we might see under climate change by 2050. The darker the colour, the greater the change in the ecosystem from its composition in 1990. The scenarios on the left uses a 'mild' climate scenario, while the one on the right is for a 'hot' climate scenario. The four categories of similarity represented in the legend from dark (greatest change) to light (least change) from left to right are 0.25, 0.50, 0.75 and 1.00.[45]

2. The research base informing biodiversity and ecosystems under climate

2.1 Impacts are already happening

The impacts of climate change on Australian biodiversity are already being seen in a variety of habitats, communities and taxa. For example, researchers have noted changes in the timing of life-cycle events such as bird migration and breeding[3], and population declines as a result of heat stress and droughts in koalas, wetland birds and platypus have been detected.[16,17,31] Some species have already shifted their geographical ranges[3], and there is evidence of climate space having shifted in previous decades for many birds[37] and fish[13]. Mass die-off events have been recorded in flying foxes and the endangered Carnaby's cockatoo during days of extreme heat.[30,41] In reptiles, a change in the offspring sex ratio has been related to increasing temperatures.[39] At the ecosystem level, woody-thickening is threatening a variety of grassland habitats across Australia[22], while drought and reduced rainfall have resulted in increased tree mortality and shifts in species composition in some woodlands.[8] In alpine regions, there has been a significant decline in depth and duration of snow cover, and there have been tree-line shifts of 30–40 m in altitude during a 25-year period.[12,40]

Predicted future impacts may include a decline in specialist alpine ecosystems, such as snow patch herbfields and cushion plants[7], a contraction of ferns and bogs[42], and feral mammals may move to higher elevations.[25] In wetland areas, there is predicted to be degradation and drying of peatlands and wetlands and the loss of seasonal and ephemeral ponds.[46] Rainforest habitats are expected to see changes to the structure of the rainforest canopy[35], damage to some species due to high intensity cyclones[10] and increased growth of vines associated with increasing CO_2, leading to tree mortality.[11]

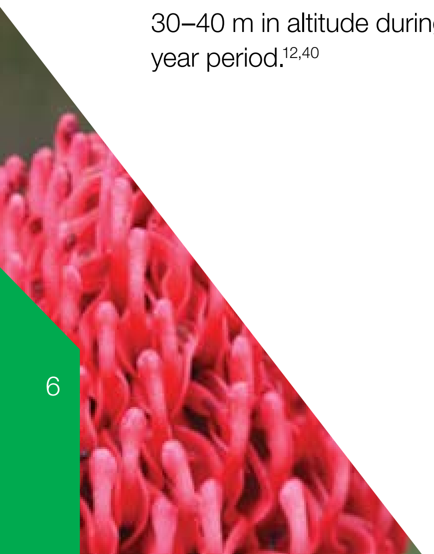
A number of other studies have projected the biological impacts of climate change with negative results: Reside and colleagues[29] applied a vulnerability assessment framework to 243 bird species inhabiting northern Australia and found that climate change will have substantial impacts on tropical savanna birds, with Cape York species being particularly vulnerable.[26,29] Dramatic changes to species assemblage and species richness are predicted for Australian rainforest vertebrates, with particular impacts to be felt among endemic, regionally endemic and restricted species that will need to move up-slope to track suitable habitat and respond to increased lowland biotic pressures.[1,43] Flightless ground insects are also identified as vulnerable taxa. The distribution models by Staunton and colleagues[34] for ground beetles (Carabidae) within the wet tropics of Australia suggest reductions in range size, population size and species richness will occur under all future climate change scenarios. They found 88% of the modelled Carabid species experience a population decline by over 80%, suggesting that flightless ground beetles are the most vulnerable taxa to climate change impacts in our wet tropics World Heritage rainforests.[34]

The observed and predicted impacts of climate change on terrestrial systems were summarised in the Phase 1 Report Card.[24]

2.2 Protected areas are not enough – we need a climate-ready conservation approach

In the past, Australia has taken a static approach to conservation, preserving key species and areas of biodiversity through the protected areas system. Dunlop and colleagues[6] maintain that this approach is not sufficient to preserve biodiversity under climate change – successful adaptation measures need to take a dynamic approach. Essentially, we can no longer focus on maintaining biodiversity as it was pre-European settlement but need to recognise and accept that communities and species will change and shift as the climate changes and plan accordingly.[6] We also need to first identify the sources of uncertainty and then make plans that are flexible enough to deal with this uncertainty.

There is evidence that the current reserve and protected areas system is not sufficiently climate-ready. Lukasiewicz and colleagues[19] state that the current



fragmentation of protected areas in Australia poses a problem for migration, especially for species with poor mobility or those that face human-made barriers to dispersal.

Maggini and colleagues[21] and Reside and colleagues[27] modelled specific locations likely to provide refugia – the habitat that species can retreat to under climate change. These studies found that the current reserve system and protected areas are not sufficient to allow species to move into identified refugia areas, and for some vertebrate species there appear to be no natural refugial areas for them to move to. Habitat connectivity will be a necessary component of providing climate refugia if species change their migration patterns due to climatic changes.[19]

The results of modelling the spatial distribution of climate change refugia areas[27] in Queensland have since been adopted by the Queensland Government in the Nature Refuges Program. This relatively new initiative is an excellent example of research rapidly informing policy and management to produce positive outcomes in on-the-ground environmental management.[38]

2.3 New approaches for the way forward

An *ecosystem-based approach* has been identified as the best approach to build resilience and adaptation to climate change in terrestrial systems. Doerr and colleagues[5] explored how landscapes can be best designed to promote ecosystem-based adaptation and resilience in order to benefit the greatest number of species and communities. They found that current landscape design approaches fall short in protecting species from future population declines. At very large spatial scales, they showed that the best option is to restore habitats to at least 30% native vegetation cover. Other studies have demonstrated that ecosystem resilience can also be improved by increasing landscape diversity and by protecting ecosystem services such as pollination.[18]

Approaches to managing natural landscapes will need to be 'recalibrated' to accommodate significant changes in the future. Dunlop and colleagues[6] provide three adaptation propositions as the basis of a climate-ready framing for conservation management:

1. *Conservation strategies accommodate large amounts of ecological change and the likelihood of significant climate change–induced loss in biodiversity.* For example, strategies might manage inevitable changes in the landscape to ensure more preferable outcomes than undesirable ones.
2. *Strategies remain relevant and feasible under a range of possible future trajectories of ecological change.* The uncertainties of predicting future responses mean strategies should be effective under a wide range of different types or scenarios of ecological change.
3. *Strategies seek to conserve the multiple different dimensions of biodiversity that are experienced and valued by society.* The way society experiences and values biodiversity differs among individuals, sectors and locations. Narrow ideas of what we value in natural systems will be difficult to achieve under climate change. In particular, threatened species and ecological communities are likely to become less effective as tools. New approaches will need to look to protect a wider range of values.

A range of tools and decision frameworks have been developed that can help land managers and policymakers incorporate climate change into natural resource management (NRM) plans (Box 1). These approaches focus on a number of key principles that will make up new approaches to land management under climate change:

1. *Identifying and prioritising refugia.* The effect of climate change will be felt differently in different places in the landscape. Refugia are those places regionally where we expect many species can avoid the worst impacts of climate change. Identifying refugia can help minimise biodiversity loss. Criteria that help identify what makes a suitable refuge and case studies of assessments are available in Reside and colleagues.[27,28]

2. *Designing and managing landscapes to increase ecosystem resilience.* As discussed above, looking more broadly at ecosystems and the whole landscape will build greater resilience and help ecosystems deal with shocks and changes. Doerr and colleagues[5] outline five principles for the landscape approach that can be easily adopted. They include acting locally but thinking regionally, considering alien species when undertaking restoration work, investing much more in restoration (but acknowledging there will be losers) and considering all land types in regional spatial planning.

3. *Incorporating climate-ready conservation planning.* As discussed above, the approach advocated by Dunlop and colleagues[6] is a climate-ready approach. It is about recalibrating what we think of as conservation planning to include managing change to get the best outcome, keeping options open and considering new values in conservation – ones that reflect a broad section of the community.

4. *Identifying the costs and benefits of adaptation actions.* This approach is as applicable to natural systems as it is to infrastructure and other adaptation responses. Adaptation actions can require significant initial investment (e.g. the Queensland Government is investing $5 million in purchasing land of high climate change refuge status).[33] A business case can be built that shows longer term savings from actions such as translocation of species, weed control, rebuilding or re-engineering ecosystem services. Some tools to help undertake these analyses are available in CATLoG and the *Systems Thinking Tools for Climate Change Adaptation*[36] (see Box 1). CATLoG can also assist in analyses of costs due to changes in climatic extremes – a threat that will drive more significant responses from biological systems than gradual increases in climatic averages.

5. *Assessing species vulnerability.* While assessing species vulnerability is not new, it will require an additional understanding of how climate change may impact on a species. Techniques include species distribution modelling, understanding behaviour and physiology of species and knowledge of habitat suitability across the landscape. A number of tools and examples of species vulnerability assessments are available (e.g. Box 1; [9,44]).

6. *Assessing potential of invasive species to spread.* In the same way that the vulnerability of species must be evaluated, assessment of the potential for invasive species to spread (or retract) is needed, and this can be done through species modelling and tools. For example, Weed Futures[14] provides a method to assess the future of invasive species.

7. *The potential of fire and fire-weather to impact biodiversity.* Restoration of vegetation, including the development of vegetation corridors, while facilitating greater mobility for species, can also create new bushfire risks that may be exacerbated by worsening fire-weather. Ongoing fire management and assessment will need to be considered in planning restoration and tree planting.

8. *Considering co-benefits.* Within land planning, there may be opportunities to derive biodiversity or conservation benefits through other land uses. For example, funding and policies of carbon sequestration, if carefully planned, can provide additional species habitat, movement corridors and sustainable land management (e.g. through soil carbon sequestration if management practices are changed).

Box 1 A number of examples of decision frameworks and tools that have been developed to help land managers and policymakers incorporate climate change into natural resource management plans.

CATLoG – Climate Adaptation Decision Support Tool for Local Governments[36]

Agency: NCCARF **Date:** 2013

Link: https://www.nccarf.edu.au/publications/climate-adaptation-decision-support-tool-local-governments

Description: Designed for local governments to compare and prioritise investment in climate change adaptation. Using an Excel based tool, the framework steps users through first an economic analysis and then a multi-criteria analysis. In this second step the analysis can incorporate economic, environmental, social and co-benefit values.

Weed Futures[14]

Agency: Macquarie University, NCCARF **Date:** 2013
Link: http://weedfutures.net/

Description: An online decision support tool that allows users to interrogate individual profiles for 500 non-native invasive or naturalised plant species to determine their weed threat for a specific region now and in the future.

Landscapes Future Analysis Tool[23]

Agency: NCCARF **Date:** 2013

Link: http://www.lfat.org.au/lfat/

Description: Web-based visualisation and decision support tool designed to help natural resource managers. The software supports spatial planning for remnant vegetation management and the establishment of corridors, considering the benefits for biodiversity and economic trade-offs. It is currently developed for SA Murray Darling Basin and Eyre Peninsula, but the tool can be adapted to other regions if the required information is input. Some of the approaches (e.g. engaging with stakeholders) can be used without climate change.

Systems Thinking Tools for Climate Change Adaptation[20]

Agency: NCCARF **Date:** 2013

Link: https://www.nccarf.edu.au/sites/default/files/attached_files_publications/Maani_2013_Decision-making_for_climate_change_adaptation.pdf

Description: A guide to the selection of adaptation tools that take a systems thinking and adaptive management approach, that is, decision-making that is iterative and considers the system as a whole (e.g. the landscape). The tool selection guide has the tools in the following groups: Problem framing and scoping tools, Qualitative/conceptual tools, Quantitative/probabilistic tools, Scenario thinking/planning tools and Organisational learning.

Making decisions to conserve species under climate change[32]

Authors: Shoo and colleagues
Date: 2013

Link: http://link.springer.com/article/10.1007/s10584-013-0699-2

Description: A simple decision framework (Figure 4) to assist managers and policymakers to prioritise decisions around climate change adaptation.
The framework gives decision-makers actions to consider under different scenarios.

CliMAS

Agency: James Cook University
Date: 2013
Link: http://climas.hpc.jcu.edu.au/

Description: This online tool allows users to produce maps and reports of species distributions for the present and climate projections each decade up to 2085 and for two greenhouse gas scenarios. Users can compare maps to see changes in distribution. This tool is useful to help stakeholders visualise projected changes.

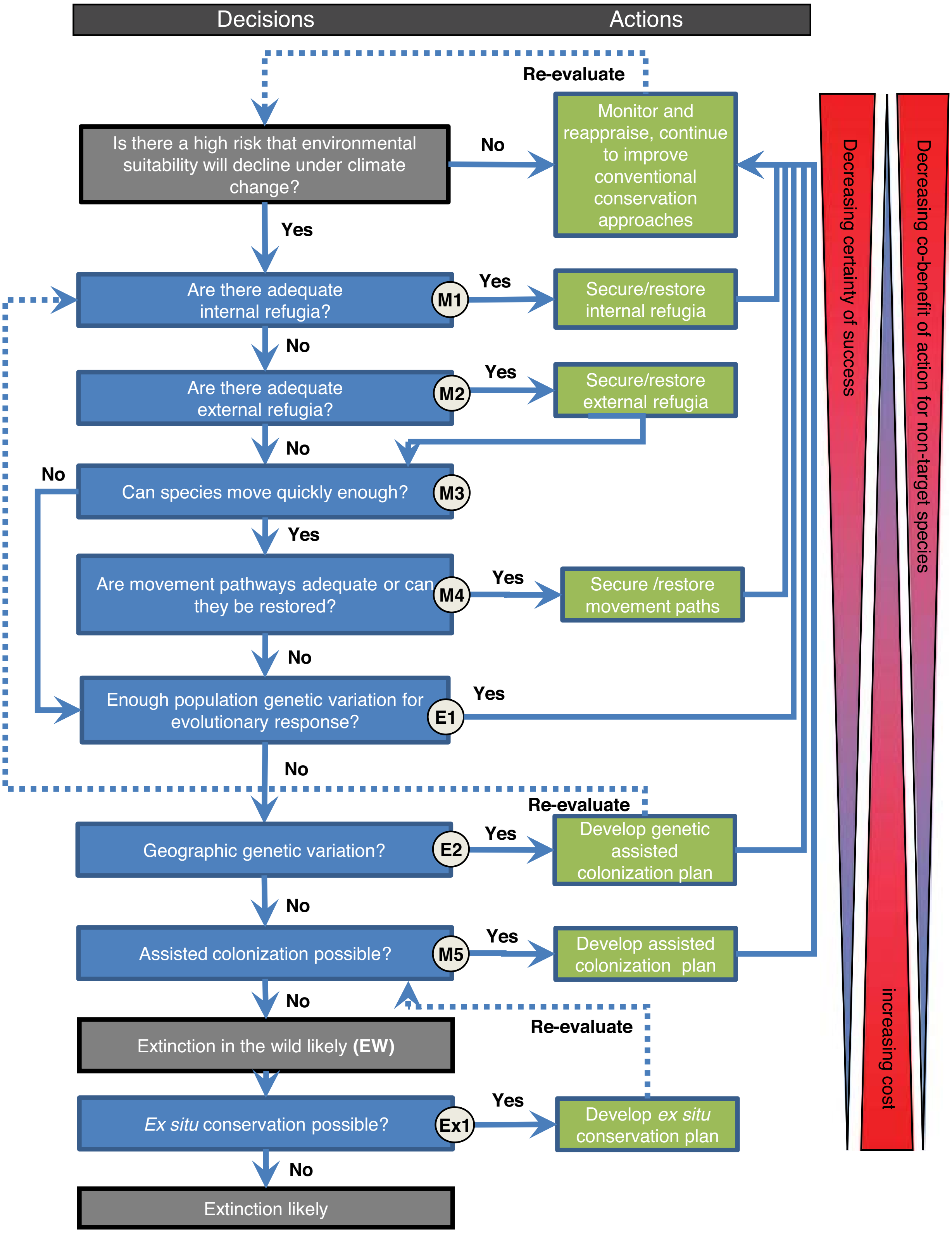


Figure 4 A decision framework for management actions focused on reducing the impacts of climate change.[32]

3. Evidence-based policy implications

ADAPTATION CHALLENGE 1:

Identify key adaptation pathways and principles for managing ecosystems

Existing approaches to managing terrestrial ecosystems come from a history of significant investment in a particular conservation philosophy: managing in place, using pre-European settlement as a conservation benchmark and focusing on rare and threatened species (e.g. the Environment Protection Biodiversity Conservation Act 1999, reserve systems). Climate change has altered the current view of how to prioritise values of conservation, and it is clear that more nimble and flexible approaches will be needed.

New research and modelling has identified that most species and ecosystems will need to migrate or change behaviour in order to find a climate that they can survive in. This means that many existing conservation areas will not support current ecosystems and species into the future. Policy, planning and management must allow for these changes. Future habitats that may provide suitable habitat or conditions (including refugia) are likely to be identified through modelling.

Focus may need to shift to consider concepts of resilience, ecosystem function, migration and refugia rather than conservation and preservation of existing ecosystems and species. Planning will need to consider longer time frames as well as addressing current changes and impacts. It will also need to address different spatial scales more effectively. The fundamental purpose of reserves or protected areas may need to be reconsidered to ensure management options will be more compatible with inevitable changes. This is likely to focus on a broader concept of land management for multiple purposes and include identification of opportunities for conservation as well as impacts and threats. Long-term planning timelines are likely to be more successful if they are accompanied by the appropriate policy framework, financial mechanisms and resourcing.

It is also clear that the approach to planning for ecosystems will need to be more proactive than reactive. There is a need for more lead time and research to make some important decisions, such as the relocation of species and the testing of the adequacy of identified refugia.

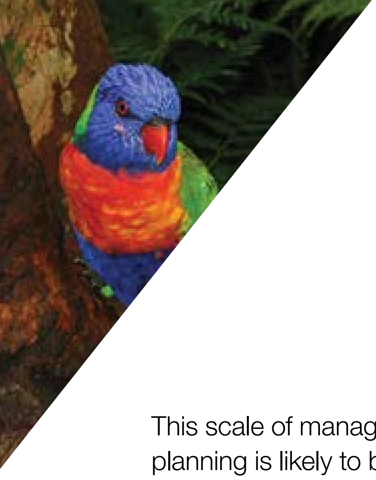
ADAPTATION CHALLENGE 2:

Work across jurisdictions and tenure and identify roles and responsibilities

Climate change will mean many species and ecosystems can no longer survive in their current locations. Planning is likely to be most effective when undertaken at a landscape scale and where greater flexibility in management is encouraged. Working at the landscape scale will require greater cooperation and collaboration across jurisdictions and tenures.

Climate change means new challenges in new places and across scales beyond existing jurisdictions – including on private land. New management approaches must navigate and negotiate with various land managers. Clarification of new roles and responsibilities may be needed to help improve the effectiveness of adaptation planning.

Decisions that affect ecosystems can be the responsibility of numerous individuals, organisations and levels of government – from private landholders (including Indigenous land owners), local government, state and federal government, to different branches of government, including those responsible for roads, conservation reserves, protected areas and defence lands.



This scale of management and planning is likely to best suit a landscape approach. This will require assembling information about where species might migrate or retreat to and their chances of surviving in-situ; and identifying potential refugia and corridors or connections between ecosystems. By working at the landscape scale, it may be possible to engage with wider audiences that consider themselves to be land managers but do not necessarily consider themselves to be responsible for biodiversity. Current examples of decisions that have been made using these approaches include those by Australia's network of NRM groups. They are already building adaptation plans at a landscape scale that lessons can be learned from and built upon.

In a practical sense, this requires aligning policies and regulations across jurisdictions and tenure. In order to do this, there is likely to be the need for a broader focus on a range of issues (e.g. sediment planning, water sensitive urban design, water quality issues) at a landscape scale. Each vested interest will have its own set of values or priorities for land management. For example, one of Australia's largest land managers, the Australia Defence Force, has a clear legislative obligation as to how they should manage their land.

Groups such as NRM groups and Catchment Management Authorities act as knowledge brokers and provide advice, but a gap in access to information may emerge as state governments move away from extension work. Close and trusted relationships can mean communities and individuals look to local governments and industry bodies for guidance. These organisations will benefit from understanding higher level (landscape) planning to make appropriate local decisions and provide appropriate advice.

Tensions between public and private interests and between conflicting policies (e.g. development versus conservation) are likely to persist. However, there are potential opportunities to build partnerships that can assess appropriate trade-offs and co-benefits. For example, a new development could be strategically located to allow for a future habitat refuge based on species modelling.

ADAPTATION CHALLENGE 3:

Define social, economic and ideological values to drive land management and policy arrangements

Climate change will mean prioritising new environmental and social values, and this will change what we are managing for, for example, individual species, ecosystem function or ecosystem resilience.

While much of the research and policy to support ecosystem management has focused on the natural environment, in reality social and economic values drive management and policies. Climate change will challenge existing social values (e.g. the desire to preserve pre-European species diversity and ecosystems), and new social values are likely to need to be identified, negotiated and agreed to.

New principles of ecosystem management may include values such as preservation of individual species, maintenance of specific ecosystems (including flow-on effects and intersections, such as clean water, flood mitigation), facilitating species movement or acceptance of new species composition of existing reserves.

New management actions required for species conservation and their viability in the face of climate change can be supported by good science (e.g. species modelling), but the selection of management principles needs to have support from stakeholders. Personal interests and values, industry values and competing values will all influence social ideals, for example, whether to prioritise development or bushfire safety over conservation. It is important that any shifts to a new set of ecosystem management principles are accompanied by education and guidance. Simple and digestible messages will be needed to help community and other stakeholders understand the rationale for any new values; this is why engagement on decision-making is important.

ADAPTATION CHALLENGE 4:

Use new tools to make decisions

New decision support tools and decision frameworks are becoming available to help incorporate the new principles and values of land management that are emerging under climate change into decision-making.

Climate change means that there will be 'winners' and 'losers' in the natural environment. Some species and ecosystems have a greater capacity to adapt and are likely to be more successful, while others might perish. For decision-makers, the challenge is to identify and prioritise strategies that have high likelihood of ongoing success. This may mean *not* investing in species with a very low chance of persistence and building strategies to deal with the uncertainty associated with managing for the future.

Decision support frameworks are beginning to emerge for planning and managing terrestrial ecosystems for climate change (e.g. Figure 4). While they cannot produce a single answer, they can help narrow the available options by identifying benefits, costs, trade-offs and feasibility of a given course of action. Adaptive management approaches will become more important than ever, and decisions are likely to be shaped with options to test and adjust management as responses and outcomes are better understood.

Where change is likely to be substantial, planning approaches will need to consider adopting transformative solutions that are a major change in direction away from traditional approaches or outcomes. Decisions are also likely to need to consider a number of values, including social values and economic values.

Ongoing monitoring of species survival and prospects, ecosystem health and adequacy and success of management approaches will be important to feed back into decision-making for ongoing adjustment and response.

ADAPTATION CHALLENGE 5:

Collaborate to manage new challenges, conflicting goals and inherited problems

Land managers may be faced not only with new challenges, but interaction and escalation of existing problems and conflicting management goal. For example, will movement corridors create new fire risks? These new challenges highlight the need for collaborative approaches with a range of experts.

Climate change will bring new challenges for land managers, for example new fire threats in previously wet vegetation types (e.g. sphagnum bogs, rainforest) or new invasive species. These new challenges must be addressed in systems that are already under stress from existing pressures, and management approaches need to account for thresholds of multiple pressures.

New challenges of climate change might create conflicting management issues. For example, development of species movement corridors could potentially create a new fire threat. Existing pressures may be worsened by climate change (e.g. water stress, heat stress, dieback). Where existing resources do not adequately address current pressures, adaptation will need to work with inherited problems and new pressures associated with a changing climate.

Competition for adaptation resources will also mean competing against large and powerful sectors (e.g. infrastructure), and it is likely that landscape management will need to work with these competing interests to incorporate an ecosystem-based approach into new sectors (see Section 2.3).

4. Key information and references

NCCARF-supported research is marked with an asterisk*

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