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CSIRO

Our Ref: 11/417

Committee Secretary
House of Representatives Standing Committee on
Climate Change, Environment and the Arts
PO Box 6021
Parliament House
CANBERRA ACT 2600
AUSTRALIA

28 July 2011

Dear Secretary

Re: Inquiry into Australia's biodiversity in a changing climate

We thank you for the opportunity to provide comments on the above inquiry. Our detailed responses to the Terms of Reference can be found in the attached submission.

If you have any queries regarding the content of our submission or would like any further information, please do not hesitate to contact Dr Sandra Oliver at CSIRO Ministerial and Parliamentary Liaison).

Yours sincerely

Andrew Johnson
CSIRO Group Executive - Environment

Submission 023
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CSIRO

CSIRO Submission 11/417

Australia's biodiversity in a changing climate

House Standing Committee on Climate Change, Environment and the Arts

July 2011

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Acronyms Used

CSIRO	Commonwealth Scientific and Industrial Research Organisation
IPCC	Intergovernmental Panel on Climate Change
NARP	National adaptation research plan
NRM	Natural resource management
R&D	Research and Development

Key points

- Climate change trends, and more frequent and intense extreme events, are predicted to have large effects on Australian biodiversity which will in turn affect the services we derive from species and ecosystems.
- By the end of the century, biodiversity changes are likely to be dramatic. The predicted changes include species loss, species movement, changes to ecosystem composition and character, and landscape transformation. The high likelihood of change leads to the overriding need to engage in a society-wide debate about what future conservation objectives should be and how changes in these should be included in future policy and management plans.
- Drivers for biodiversity changes include the direct effects of climate change (trends and extremes) such as temperature (air and water), rainfall, sea level rise, water acidification, storm event frequency and intensity, ground water levels, river stream and lake levels and salinity. Indirect drivers of change include altered fire regimes, new species interactions, new invasive species and adaptive planning for future human land uses.
- Currently, the social and economic values of ecosystem services are relatively poorly understood. As the quality of services change under climate change (as many of them are likely to do), and lost value is appreciated, adaptive solutions will be needed.
- Governance arrangements for dealing with biodiversity in a changing climate need to: consider the geographic scale at which change is being driven and manage at that scale; anticipate complex system interactions and ensure cross-sectoral coordination (especially at larger scales); and entrench adaptive management approaches for successful and rapid adaptation to change.
- Communities need to be engaged in the debate about how the species, ecosystems and landscapes around them will be changing and how they can react and adapt to those changes for a variety of purposes such as biodiversity retention and livelihood maintenance.

Introduction

CSIRO and climate change impacts on biodiversity

CSIRO is an internationally recognised research and development (R&D) provider in the field of climate change and biodiversity. CSIRO has conducted research relevant to this inquiry in areas including climate modelling, climate forecasting, biodiversity conservation and management, as well as adaptation to climate change.

This submission has been prepared by a team of scientists from across CSIRO with experience and international recognition in many facets of biodiversity research. In this submission, we review the issues concerned with climate change and biodiversity, and bring to the Committee's attention relevant conclusions based on past and current research. We describe some of the impacts of climate change on biodiversity, and also appropriate adaptation actions that people can take to maintain the ecosystem services, ecological integrity and evolutionary potential of Australian animal and plant life.

The need for climate adaptation research and CSIRO's response

In recent times (within the last decade), large parts of Australia have experienced the worst drought in recorded history, some parts have had bushfires associated with extreme weather conditions, while other areas have experienced extreme flooding. These recent experiences are examples of the type of extreme events that are likely to become more frequent and more severe over the coming decades due to climate change. These events have brought to the public mind appreciation of the reality of global climate change, of the impacts that it is likely to have upon our continent, and of the opportunities and challenges stemming from those impacts. While the impacts of extreme events on human social, financial and built environments are dramatic, these events are also extreme for biodiversity. They also remind us how dependant we are on biodiversity for a range of services, such as flood and storm surge protection (e.g., mangroves protect estuarine and coastal infrastructure), and how much more impact extreme events will have if the services provided by natural ecosystems are degraded.

The Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC 2007) reinforced the evidence that most of the global warming observed in the past 50 years is attributable to human activities, that there will be considerably more warming in the 21st Century, and that this warming will be accompanied by many other changes in the global climate system, including changes in wind, precipitation and weather extremes. The changes in climate factors are also likely to interact with other global environmental changes (such as changes in the water and nitrogen cycles globally) as well as global changes outside the environmental sphere (such as the effects of changing consumption patterns and population on demand for resources, changing global demography and urbanisation, and new technologies in energy, communications and many other sectors).

The international scientific congress, '*Climate Change: Global Risks, Challenges & Decisions*' in Copenhagen in March 2009, attended by more than 2,500 delegates from nearly 80 countries, reviewed some of the more recent evidence, including some dedicated biodiversity sessions. Recent observations indicate that, given high rates of observed emissions, the worst-case IPCC scenario trajectories (or even worse) are being realised (see Steffen 2011). While the global economic recession has caused some temporary slowing in the rate of increase of greenhouse gases in the atmosphere, their influence on climate change will continue even if emissions are reduced because some emissions have long lifetimes in the atmosphere. On her return to Australia from the Copenhagen conference, Australia's then Chief Scientist delivered the blunt message that "if we do not act, and act quickly and decisively, the effects will be devastating" (Sackett 2009). The particular importance of the possible impacts of climate change on biodiversity is reflected in the vision for Australia's draft Biodiversity Conservation Strategy 2010-2020, which aims to ensure that 'Australia's biodiversity is healthy, resilient to climate change and valued for its essential contribution to our existence' (National Biodiversity Strategy Review Task Group 2009). The scale of climate change is such that R&D must be marshalled to assist in the national response if this vision is to become reality. Science can add significant value to how we adapt to climate change through informing responses and management plans.

CSIRO's National Research Flagships Program delivers scientific solutions to advance Australia's most vital national objectives. Flagships are partnerships of leading Australian scientists, research institutions, commercial companies, CSIRO and selected international partners. The CSIRO Climate Adaptation Flagship became fully operational in July 2008. It is developing adaptation options to minimise the economic, social and environmental impacts of climate change, as well as to maximise new opportunities in response to climate change and variability. One of the Flagship's four Themes entitled 'Managing species and natural ecosystems', focuses particularly on developing adaptation options to reduce the future impacts of climate change on biodiversity.

General concepts and challenges in managing biodiversity adaptively in the face of climate change

The science of adaptation to climate change is still in a developmental stage. In the long run, it would be hoped that adaptation is considered during the development and implementation of all policy and practice so that no separate effort labelled 'climate adaptation' is needed. However, at present the future impacts of climate change for many areas of decision-making are poorly understood and a consolidated focus on adaptation is needed. In the absence of this, many responses to mitigate the future effects of climate change so far have been incremental and short term. Considerable inefficiencies are liable to arise from short term approaches, inadequate information, delaying action, failing to take sufficiently collective action, failing to recognise the significant insurance value of actions, or failing to realise synergies and efficiencies among actions.

There is a very wide range of potential impacts of climate change on biodiversity and ecosystems, and consequently on their management, as outlined in the following sections. In the absence of a well-structured approach to identifying and prioritising adaptation options, the result can be an overwhelming complexity of possible decisions. However, not all decisions are equal – some have shorter and other longer term consequences, such that some interact with relatively more certain changes than others. Additionally, different components of climate change (e.g. changes in mean and extreme temperatures, atmospheric and ocean chemistry, changes in rainfall, extreme events, etc) have different forms and levels of uncertainty into the future, leading to different forms of risk management being appropriate. A better framing of these issues is emerging from our research at present; this framing is only now being documented, but is a vital need for better decision-making in future.

These issues are universal to climate change adaptation in most sectors. For biodiversity and ecosystem management, however, further complications arise from the range of values encompassed by these concepts, and the diverse systems being managed. These issues are canvassed in a variety of general sources which we recommend to the Committee, including Dunlop and Brown (2008a, b), Hobday and Poloczanska (2008), Steffen et al. (2009a, b), the Marine Report Card (www.oceanclimatechange.org.au), Prober and Dunlop (2011) and Stafford Smith et al. (2011). It is also worth noting the generic value of longitudinal data sources from past to present in the form of programs such as the *Atlas of Living Australia* (http://www.ala.org.au) in determining how change has occurred and to provide the basis for modelling possible responses into the future.

It is worth noting that much thinking about adaptation at this point in time tends to be limited to impacts and vulnerability; to focus on responses, however, it is important to base thinking around adaptation options, and to take a decision-centric rather than impacts or methods-centred approach to the analysis. The remainder of this submission will identify different implications of climate change for terrestrial, freshwater and marine systems, and will canvass some different values.

CSIRO's response to the Terms of Reference

1. [Effects of climate change on] Terrestrial, marine and freshwater biodiversity in Australia and its territories

- Climate change will have major, systemic effects on almost all aspects of biodiversity in all types of environments, with significant regional differences.
- These impacts will affect current measures to conserve biodiversity and change the goods and services we derive from biodiversity.
- Many impacts have already been detected.
- In general, human, land and resource uses will interact with climate change to exacerbate impacts.

Observations and modelling over the last decades have provided compelling evidence that the impacts of climate change on the world's biodiversity are likely to be significant. Many impacts have been observed or hypothesised, including: upward and poleward shifts in species ranges, changes in the timing of many critical life history stages, changes in plant and animal physiology, changes in sex ratios, changes in ecosystem net primary production, nutrient cycling, and water relations, changes in disturbance regimes, changes in ecosystem structure and function, and changes in competition, parasitism, predation, dispersal, habitat provision and other interactions between species.

There are now many independent studies that have predicted potential impacts of climate change on biodiversity over the remainder of this century in different regions based on modelling and which have concluded that a significant fraction of terrestrial and marine species are likely to experience major changes in their populations sizes and geographic distributions. Studies have predicted that while some species will flourish in their current locations or in new locations that they will soon be able to occupy under new environmental and ecosystem conditions (i.e. the species around them will also be changing leading to different interactions with potentially less competition for resources), other species will not. The ways in which species can potentially be disadvantaged by climate change are numerous but essentially many plant and animal extinctions are highly likely. While these studies are necessarily based on a range of assumptions, the consensus results suggest that climate change is highly likely to have a significant impact on biodiversity, possibly similar in magnitude to the changes to biodiversity that have resulted from habitat loss and modification. Australian studies have found similar potential impacts to others around the world (as documented in Steffen et al. 2009a).

Terrestrial

Dunlop and Brown (2008a, b) have reviewed the likely impacts of climate change on terrestrial biodiversity in Australia in a report focussing particularly on the implications for Australia's National Reserve System, which is Australia's network of protected areas. Species and ecosystems are very likely to be affected directly by impacts cascading from individuals to populations to ecosystems and indirectly via changes to the interactions between species, provision of habitat, regulation of ecosystem processes and feedbacks on the climate. Given the range of impacts, climate change should not be seen as a singular additional threat to biodiversity, rather it is a systemic issue predicted to affect almost all aspects of biodiversity conservation. In particular, it is likely that impacts from climate change will amplify and further complicate the management of existing threats to biodiversity, including:

- changed availability and use of water;
- spread of native and exotic species into new areas;
- changes in land use; and
- altered fire regimes.

For example, a CSIRO-led report has been prepared by experts on the potential impacts of climate change on fire and biodiversity (Williams et al. 2009). The report considers how climate change may affect fire weather and fuels, how fire regimes may alter, and how this might then affect the dynamics of Australian ecosystems and the management of their biodiversity. Changes in fire regimes will differ in different regions: in southern Australia where a warmer and drier climate is expected, it is likely that there will be increased fire frequencies and the high intensity fires such as occurred in Victoria in 2009 and in the ACT in 2003, are likely to be more common. There are complicated and poorly understood interactions amongst variables associated with fire activity. For example, changes in water availability (affecting ground water) and fire regimes may threaten the persistence of globally significant eucalypt woodlands in south-western Australia (Prober et al. 2011). Other interactions such as fuel accumulation rates, fuel moisture, fire weather day frequencies, fire propagation rates in different vegetation structures, are the subject of research looking to quantify variations in risk to different assets across the landscape.

Importantly, Dunlop and Brown (2008a) concluded that observation and modelling studies consistently report that the details of the impacts of climate change vary considerably between species, ecosystems and regions. While it is likely that we can expect many types of changes (including changes in abundance, distribution, interactions, ecosystem processes and threats), the details cannot yet be predicted at the level of specific species and ecosystems due to the many complex interactions in ecosystems. This has important strategic implications for how biodiversity conservation can effectively respond to this challenge.

In Australia, different impacts may predominate in different regions, but it is difficult to say which regions' biodiversity will be more affected or less able to cope with climate change. In NSW, different studies have identified significant potential impacts in the rangelands, highly fragmented areas, the alpine zone, rivers and wetlands, coasts (near-shore through to salt marshes), the western slopes and the south eastern region (Pittock 2003, IPCC 2007, Stokes and Howden 2008, Dunlop and Brown 2008a). Most studies have focussed on how species may respond directly to changes in temperature and rainfall (e.g. through shifts in geographic range), ignoring important changes in how species interactions, ecosystem processes and threats to biodiversity may change. Focussing on the latter can identify a different range of impacts, implications and priority regions (see Dunlop and Brown 2008a,b; Prober et al. 2011).

Marine

Australian waters contain ecosystems that are of international importance and their biodiversity is of comparable global significance to that of terrestrial ecosystems. One of the most iconic marine biodiversity treasures is the World Heritage-listed Great Barrier Reef. The off-shore marine waters contain unique and relatively unknown habitats that range from abyssal plains to emergent corals reefs. Seamounts and extensive ocean plateaux provide habitats for a multitude of benthic[1] fauna and flora, much of it undescribed. The pelagic environment[2] supports large populations of marine mammals, and commercially-valuable fish species.

Australia has highly diverse and unique marine flora and fauna, ranging from spectacular coral reefs in the tropics to giant kelp forests in Tasmanian waters. The species diversity in Australia's

[1] Living on top of the sediment on the surface of the seafloor.
[2] Oceanic, far from land.

northern waters is very high because it is a continuation of the Indo-Pacific biodiversity hot spot. Although Australian temperate waters have lower species diversity than northern tropical waters, they harbour more endemic species due to their long history of geographic isolation (over geological time) from other temperate regions.

Marine, coastal and estuarine biodiversity is already, or highly likely to be, affected by sea level rise, increased ocean storm intensity, ocean acidification, increasing sea surface temperatures, the southern penetration of the East Australia Current (see the *Marine Report Card* at www.oceanclimatechange.org.au). These effects are expected to cascade throughout food chains with flow-on effects that cannot be fully anticipated. In combination with other climate and ocean change driven environmental stressors, changes are likely to include:

(i) changes and variations on phenology[3] of marine biota[4];

(ii) changes in the distribution and abundance of species;

(iii) changes in the extent and variation of ecological habitats;

(iv) varying effects on the physiology, life history events and environmental tolerances of individual species;

(v) changes in species interactions leading to different community composition, structure and function; and

(vi) overall changes in whole-of-ecosystem processes and functions resulting in as yet unknown or novel ecosystems.

Human, land and resource use pressures are likely to interact with climate change to exacerbate the impacts on marine systems: poor water quality (e.g. due to terrestrial runoff at the coast) increases coral bleaching risk; coastal development may limit landward migration of estuarine habitats as sea levels rise; fishing pressures may limit the capacity of species to repopulate habitats following disturbance events.

Marine biodiversity directly supplies ecosystem services such as: food, income and leisure activities through commercial and recreational fisheries; income and cultural services through marine tourism; and “option use value” through future unknown and speculative benefits, such as novel pharmaceuticals. These uses are likely to change in various ways as the ocean environment changes.

Freshwater

Freshwater aquatic biodiversity is predicted to be altered by climate change via direct and indirect pathways. The direct pathways that are predicted to affect water quality and quantity are:

(i) changes in global air and sea temperature are reflected in equivalent changes in water temperatures of streams, lakes, wetlands, etc;

(ii) an increase in air temperature will result in increased water temperature, longer stratification periods in reservoirs and lakes, as well as advances in spring events and delays in autumn events;

(iii) intensification of coastal winds mainly due to higher cyclonic activity increase shore erosion, alter mixing patterns, and lead to changed salinity conditions in coastal lakes and estuaries;

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[3] The influence of climate on annual events e.g. bird migration.
[4] Living organisms.

(iv) changes in precipitation and evaporation will result in changes of hydrological cycles, river flow regimes, sediment and nutrient transport, and can promote salinisation;

(v) changes of flow regime classes due to decrease in precipitation;

(vi) reduction of water availability in large parts of Australia;

(vii) sea level rise will result in inundation of coastal freshwater ecosystems, saltwater intrusion in coastal groundwater systems, and upstream movement of the tidal influence; and

(viii) increased CO_2 absorption will result in fresh water becoming more acidic, in some cases an increase in phytoplankton productivity or a decrease in, for example molluscs, is possible.

Indirect pathways by which freshwater biodiversity is predicted to be affected include:

(i) levels of dissolved oxygen tend to decrease due to increasing temperature, possibly decreasing wind speeds, and possible increase in eutrophication[5]; and

(ii) changes in air temperature will lead to changes in evaporation impacting mainly shallow water bodies and wetlands by reducing water levels.

The net effect of these factors is that freshwater ecosystems are likely to be significantly affected by climate change; however, in general the research base here is poorer than in other environments.

2. Connectivity between ecosystems and across landscapes that may contribute to biodiversity conservation [in a changing climate]

- Connectivity is a complex concept: more connectivity may be desirable to facilitate dispersal of some species to new geographic locations that are better suited to their survival under climate change, but connectivity is also undesirable where those species are invasive species. It is better to talk of managing for *appropriate* (rather than maximal) levels of connectivity.
- Appropriate connectivity needs to be managed in conjunction with other aspects of landscapes, including the national reserve system and off-reserve lands, both public and private.

'Connectivity' aims to conceptualise the ability of species to move around the landscape at both short and evolutionary timescales. There is a tendency to assume that more connectivity is a good thing in the face of climate change, in order to facilitate the movement of organisms to stay in balance with changing environments. However, there is a need to define 'connectivity for what', and a need to determine why and where increased connectivity will be needed. In some cases, increasing connectivity may be counterproductive – for example, both exotic and native invasive species will generally move more easily than some species which are most likely to be under threat, so a reduction in connectivity (as occurs when conservation managers isolate endangered species on islands or protect sensitive habitats from weed invasion) will be appropriate at times. Similarly connected forest cover may allow undesirable spread of wildfires into critical refuge habitats. It is therefore better to speak of managing for 'appropriate connectivity' rather than universally seeking to increase it. Appropriate connectivity may consist

[5] Shift in water status towards harbouring more plant life

of the National Reserve System and combined with enhanced off-reserve biodiversity management, building on specific strategies to integrate these approaches (e.g. Steffen et al. 2009b, p.44). Recent national discussions of 'corridors' may be a better framing of the connectivity issue, implying coordinated management of large tracts of both private and public, reserve and non-reserve land, including *appropriate* connectivity.

Considering connectivity in this broader context, the Dunlop and Brown (2008a,b) reports considered many of the important issues relevant to helping species and ecosystems survive climate change. While the report concentrated mainly on the formally protected conservation areas within the National Reserve System many of the conclusions are generally applicable to enhancing the ability of species and ecosystems to survive in all environments.

Climate change impacts will vary considerably between species and will be very difficult to predict. Therefore, probably the best approach to minimise loss will be to make sure many different types of habitat are protected. This way even if the ecosystems and habitats change, a wide range of environmental conditions will be available to help native species survive as they respond in many different ways over time. Larger areas of habitat, and more of them, will also be required to help species adapt to changing conditions. It is important that the protection focus on habitats that would otherwise be altered, rather than on habitats under no threat from local activities.

The National Reserve System has been built based on a 'bioregional framework'. It is designed to protect habitats across the continent that helps our biodiversity adapt to a broad range of environmental conditions. The key to a successful National Reserve System is the underlying planning principles of Comprehensive, Adequate, and Representative (CAR) where comprehensiveness means that the full range of ecosystems are captured in reserves; adequacy means that the areas reserved are large enough to maintain viable populations and ecological functions; and representativeness means that reserves capture good examples of habitats and ecosystems. These principles have been developed through 40 years of scientific theory development and practical testing under the assumption that climatic regimes were relatively static or at least slow to change over human management timeframes and therefore species were more affected by human land uses and other stresses than shifting environmental envelopes. Current estimates of the rate of increase in CO_2, warming, sea-level rise, etc. suggest that rates of change that species and ecosystems will experience by the mid to late parts of this century will be more rapid than most of the measured rates of climate change in geological history. Such profound rates of change bring into question whether the current reserve systems are going to be functionally adequate or representative.

The National Reserve System currently covers nearly 13 per cent of the continent and it contains many areas that are vital for the survival of Australia's plants and animals. Some of the native ecosystems only occur inside parks and reserves, or are limited elsewhere. The National Reserve System includes core habitats for many native species of high conservation value. Many of Australia's ecosystems, in NSW as elsewhere, are not yet adequately protected. As a result of climate change it is likely that more key habitats are added to the National Reserve System in order to protect their biodiversity. New additions need to target a diversity of ecosystems across poorly protected environment types, with a particular focus on minimising loss of key species.

Systematically providing as much diversity of habitat types as possible for native species through a Comprehensive, Adequate and Representative National Reserve System will assist the adaptation of Australia's biodiversity to the predicted impacts of climate change. The developing National Representative System of Marine Protected Areas will have similar benefits for the marine environment.

As climate change takes effect, there are likely to be changes in the abundance, diversity and distribution of species and ecosystems. There have already been important changes to native ecosystems and species in some areas (e.g. tropical marine species living further south). The challenge now is to more effectively manage threats such as fire, weeds and feral animals in protected areas, to help native species respond and adapt to changing environmental conditions, so we minimise the loss of key species and their habitat. In addition, we will need to manage the relative connectivity between ecosystems and landscapes to encourage the migration of native species and the containment of invasive exotic species.

Assisted relocation is being explored as a mechanism to ensure the persistence of wild population of iconic species that are so highly valued by society that their extinction is unthinkable. In assisted relocation, large numbers of individuals (tens to hundreds) are released into geographic locations that they have previously not occupied (in recorded history) in the hope that they will create a viable natural population that thrives under the new climatic and environmental conditions of the release location. These techniques are reserved for species which have low dispersal ability and the likelihood of a high extinction risk. Recent research has explored at what time in relation to the shrinking population size of critically endangered species, such action should be undertaken (McDonald-Madden et al. 2011).

In the ocean, connectivity is higher than on land, and corridor implementation is less of an issue. Marine reserve design should consider potential impacts of climate change, by establishing networks of protected areas. Off the fast-warming east coast, the goal of conservation planning should be to create marine reserves as 'stepping stones' to assist the southward movement of marine species. Increasing connectivity between separate regions via shipping (introduction of alien species) is also likely to be a future concern for coastal biodiversity. As on land, reducing connectivity may sometimes be an appropriate management strategy.

3. How climate change impacts on biodiversity may flow on to affect human communities and the economy

- Biodiversity provides ecosystem goods and services of great significance to human well-being and livelihoods.
- Many of these ecosystem goods and services will be affected by climate change, with far-reaching effects on the economy, though these are not well-documented and hence probably underestimated.

The world's ecosystems can be conceptualised as a form of capital asset (similar to manufactured and human capital) which, when properly managed, yield flows of goods such as food, fuel and fibre and services such as pollination, water purification, beauty, and genetic diversity important to the wellbeing of humans. The Millennium Ecosystem Assessment (http://www.maweb.org/en/index.aspx) has categorised these ecosystem goods and services into four types: provisioning, regulating, and cultural services that directly affect people, and the supporting services needed to maintain other services. The concept of nature as a stock of capital from which ecosystem services are produced and benefits derived is becoming widely used in environmental assessment reporting.

The link between natural capital and social and economic sectors include:

- The extensive areas of natural and modified pastures in which rangeland grazing is the main land use over 60% of Australia;
- Native forests that account for jobs in many sectors;
- Intact (remnant) terrestrial native vegetation (including forests and native pastures) that provide clean water and mitigate the adverse impact of natural hazards such as erosion and flooding;
- Biodiversity that provides important pollinators, seed dispersers, and pest control agents on which agriculture and forestry depend;
- Riparian and littoral vegetation[6] are special cases of native vegetation that occur at complex interfaces between terrestrial and aquatic systems, where they protect areas from erosion, filter sediments, nutrients and pollutants, mitigate the effects of flooding and storm events, and provide supporting habitats for aquatic biodiversity;
- Marine life that acts in coastal defence against damaging waves and storms, processing of pollution, oxygen production and greenhouse gas regulation;
- Biodiversity that directly supplies ecosystem services such as: food, income and leisure activities through commercial and recreational uses (especially fishing), and income and cultural services through tourism; and finally,
- The deep link between land, sea and biodiversity that is a part of the culture and identity of Aboriginal and Torres Strait Islander people (e.g. Green et al. 2009).

The estimated value of natural capital and ecosystem services has been calculated in several studies. For example:

I. In Queensland, fisheries are likely worth more than $200 million per year, mainly through the Great Barrier Reef system (Access Economics, 2007) and tourism is estimated to contribute $9.2 billion and employs 222,000 people (Tourism Queensland, 2006).

II. Australia’s marine biodiversity underpins considerable economic wealth for fisheries and aquaculture amounting to a gross value of approximately $A2.1 billion annually (based on figures from 2009-10; ABARE 2009).

III. The ecosystem services product (estimated commercial value of ecosystem services) of Australian coastal marine waters have been valued at US$222,762 million (roughly equivalent to Aus$205,000 million; Martíneza et al. 2007).

It is likely that some valuable natural assets will change in ways that cannot be prevented but it is not yet clear how these changes will affect the complex interactions among social and economic systems.

Damage to marine biodiversity will have far reaching consequences, such as for tourism. Some potentially negative impacts are, for example: loss of coral diversity due to acidification and bleaching of the Great Barrier Reef may result in a less-desirable tourism destination; and inundation of near-coastal freshwater systems with sea water at the floodplains in Kakadu National Park may change the Park’s current appearance (Director of National Parks 2010).

Generally, we are better able to predict a change from a current ecosystem state to a future lower value ecosystem state (even if we are not clear what exactly that ecosystem state is) than we are able to foresee future ecosystem states that have higher social and economic values than they do today.

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[6] Vegetation on seashores, lake shores and riverbanks.

4. Strategies to enhance climate change adaptation, including promoting resilience in ecosystems and human communities

- Numerous strategies to enhance conservation-related adaptation have been proposed, but there has been limited systematic exploration and prioritisation of these to date; this is now a fast moving area of research.
- The simplest, 'no regrets' strategies aim to maintain natural attributes of land and seascape resilience, and reduce threatening processes.
- Good approaches to adaptive management and adaptive governance are needed to promote learning in a rapidly changing environment.
- Coastal habitats are at particular risk of being squeezed between sea level rise and urban development.

Strategies for protecting climate-sensitive biodiversity and ecosystems will become increasingly important for management because the impacts resulting from changing environmental conditions due to changing climates and weather patterns are already evident and will persist into the future regardless of emissions mitigation (e.g. Julius et al. 2008). Climate is one of the determinants of species' distributions, of ecosystem structure, function and composition and of the services provided by species and ecosystems that benefit people. Species and ecosystems have the capacity to adapt autonomously to climate change, but the current rate of change interacting with stresses is likely to be beyond the unassisted adaptive potential of many species.

A wide range of options for adapting biodiversity management to climate change have been proposed and recently a number of reports have drawn on international experience and synthesised options for Australia (Buckley et al., 2007; Dunlop & Brown, 2008a; Steffen et al., 2009a). One finding that is common to these reviews is that the majority of suggested adaptation actions tend to be either broad principles, or very situation-specific proscriptions. Currently, there are few Australian case studies to guide implementation or support assessment of the likely costs, risks and effectiveness of different adaptation management actions (Heller & Zavaleta, 2009). Key messages from these sources indicate that options for adapting biodiversity management to climate change are likely to vary in their effectiveness and the contexts in which they might be useful: some adaptation will happen autonomously; some adaptation responses are more uncertain, and will carry more risks than others; some adaptation responses may be urgent and require policies driven by Government, while others can wait and responses follow monitoring. To date there has been has been little systematic analysis of adaptation management options for biodiversity conservation, and so while there currently exists no "best practice" guidelines, the science community is rapidly building this capability.

The simplest and lowest risk interventions to facilitate climate adaptation in intact land and sea-scapes aim to maintain natural attributes of resilience such as appropriate connectivity, large population sizes, genetic diversity and optimal ecosystem functions. Such options are likely to be beneficial for biodiversity regardless of future climate scenarios. They will not necessarily prevent transformational ecosystem change but will facilitate adaptation. In fragmented land and sea-scapes where these ideal attributes are not possible, restoration of degraded processes or attributes of resistance and resilience are likely to offer the highest priority, lowest risk adaptation options.

The range of policy and management options for enhancing the conservation of biodiversity under climate change and in the face of uncertainty about the details of impacts involve:

- ensuring that a wide range of possible changes resulting from climate change (including changing abundances and distributions and changing threats) are considered in policy and management plans;
- aiming to conserve a high diversity of native habitats, as well as a large area of habitat, especially that threatened by local activities;
- anticipating how the action and impact of various threats to biodiversity may change in order to be better prepared to respond to them in ways that minimise losses to biodiversity;
- anticipating how the action and impact of threats to biodiversity, including altered fire regimes, changed land uses (habitat loss and degradation), establishment of new exotic and native species, overharvesting and altered hydrological regimes, may change; and
- increasing coordination of different conservation and natural resource management programs to enable improved management at landscape and regional scales, and ensuring that natural resource management governance processes are adaptive (cf. Nelson et al. 2008).

There are also systemic issues for society concerning the objectives of conservation, which lead to higher order strategic needs. It is likely that objectives that implicitly or explicitly aim at *'no species loss'* will need to be replaced with objectives such as minimising loss and maintaining ecological processes. The definitions of invasive species will need re-visiting in environments where the aggressive establishment of native species in new places may be regarded as either successful adaptation or dangerous competition with species that cannot disperse so well (Webber et al. 2011). The arrival of some species in Australia from islands to the north may need to be accepted as part of their adaptation. Novel ecosystems that emerge will need to come to be valued in their own right even as those we have valued in the past may be vanishing. In short, these and other systemic effects mean that continued debate is needed in society about what we will value in the future, what conservation objectives should therefore be prioritised and how these should be implemented in policy and practice.

Processes that threaten biodiversity

Biosecurity risk assessments for invasive species, both exotic and native (Webber et al. 2011), terrestrial and marine, will need to be developed to take into account climate change. Identification of sleeper species (species currently with low abundance that could invade widely in the future) is needed early, so that appropriate adaptation response (e.g. eradication) can be put into place before they become a problem. While species distribution modelling is a critical initial step (Webber et al. 2011), further development is needed for this component of risk assessment to relate distribution to the biotic (living), abiotic (non-living) and dispersal attributes of species.

There is strong evidence that climate change will increase the annual area burnt and incidence of severe fire weather for many regions across Australia (Williams et al. 2009). As a consequence, inter-fire intervals may decrease. This may not necessarily be a problem for biomes[7] where fire frequency is naturally high (e.g. in tropical savannas), where climate change may not radically alter a regime characterised by frequent fire (i.e. annual-biennial), and where the fire regime is not limited by weather. However, it may be a specific problem for those elements of biodiversity where maintenance of longer-unburnt patches is a requirement for their

[7] Regions of similar climatic conditions with similar dominant plant species.

persistence (e.g. obligate seeding plants, and some mammals). Shortened intervals may be a general problem in the temperate sclerophyll systems of the south-east and south-west of Australia, where there are high proportions of fire-interval-sensitive species, and where climate change may cause increases in functional types that are sensitive to shortening inter-fire intervals. Moreover, if rainfall declines, as predicted in south-east and south-west Australia, the length of time required for flora and fauna to recover post-fire may increase. Changed fire regimes are predicted to drive ecosystem-level changes.

Marine ecosystems

Reducing vulnerability to the challenges of climate change of marine ecosystems, as for land systems, requires proactive management and rapid institutional learning. Governance and management strategies and practices need to be regularly tested and adjusted. Adaptive management has been advocated for several decades as an approach to natural resource management that maximises the rate of learning and progressive improvement in management responses to problems. Adaptive management strategies use information derived from targeted interventions to revise successive interventions and improve policy. 'Whole of system' strategies such as catchment-scale management and ecosystem-based management are likely to increase the prospect that marine systems will build increased resilience to unexpected 'shocks' or cumulative impacts of multiple stresses.

Adaptation options are highly dependent on specific geographical, biological and climatic risk factors, and are subject to institutional, political and financial constraints. Improvement of coastal development and planning regimes with specific attention on the predicted impacts of climate change on marine biodiversity is likely to help with conservation of coastal wetland habitats under changing climate. Two options for revision of planning guidelines are: provision of buffer zones between development and coastal habitats; and set-back provisions to allow for retreat and re-establishment of coastal habitats as sea levels rise. However, there is little evidence that such measures are being implemented except to protect built infrastructure or to diminish legal liability of local governments for damage to built environments. Recognition of the need for more consistent, integrated and ecologically sensitive coastal planning and development rules may result in protection of coastal habitats or accommodation of their retreat as sea level rises. The development of more consistent and proactive development and planning instruments is at an early stage and many surviving coastal ecosystems are already either compromised or constrained by surrounding development (e.g. Abel et al. 2011).

Fishing and aquaculture

Hobday and Poloczanska (2008) reviewed the impacts of climate change on fisheries and aquaculture. The East Australian Current, which runs down the NSW coast bringing warm waters from the north, is predicted to change the distribution of species targeted in wild fisheries and modify the locations of suitable environments for aquaculture species. Consideration of changes in distributions may allow fisheries management to facilitate adaptation to climate change. Selective breeding of aquaculture species may allow adaptation to warmer conditions, although changes in location may be inevitable for some operations.

Focused regional studies on the relationship between climate variables and the species of interest are one way to improve understanding of the potential impacts of climate change. However, the level of information available for many fisheries and aquaculture species is poor, so the adaptation options recommended by Hobday and Poloczanska (2008) focused largely on improving knowledge of species requirements. These adaptation options include:

- undertaking research on how fisheries and aquaculture management and policy can facilitate flexibility by operators seeking to adapt to climate change – are current management approaches suited to a changing climate?

- collecting and analysing data on the impacts of climate variability and trends on marine biology to give insight into the impacts of climate change on fisheries and aquaculture;
- developing methods for assessing the vulnerability of fished and aquaculture species to environmental variables under climate change, including means, extremes, and cumulative impacts;
- developing robust genetic strains for aquaculture species that are predicted to perform well in future environments, and examine industry locations and opportunities under future climate scenarios;
- developing predictive models for the occurrence of extreme events, and the thresholds for the biology (particularly for aquaculture);
- delivering these warnings at a time in the production cycle that is useful to operators and build the capacity of these operators to integrate this information into their management plans; and
- investigating regional case studies for the impacts of climate change on the biological, social and economic relationships in fisheries and aquaculture.

5. Mechanisms to promote the sustainable use of natural resources and ecosystem services in a changing climate

- Policy and practice need to accept and plan for significant change, which raises profound issues to do with re-negotiating desired conservation goals.
- Current and future land use changes which are not driven directly by climate change will interact with climate change to affect the biodiversity outcomes of policy and management.
- There is a key need for adaptive management supported by effective, targeted monitoring to respond to these complex changes.
- Promoting strategic coordination of natural resource management at regional scales is likely to be a vital strategy, with differentiated interventions tailored to different regions.

Current and future landuse changes, driven by the changing viability of grazing and cropping enterprises, urbanization, and emergence of new markets for carbon and biofuels, could either ameliorate or magnify climate change impacts. Opportunities for restoring habitat for native species are likely where agricultural productivity decreases, or with shifts from annual to perennial farming systems for carbon sequestration. However, many anticipated land use changes, especially increased cropping on the wetter fringes of the temperate grassy ecosystems or shifts to irrigated agriculture, are likely to add considerably to pressures on biodiversity. Hence, policy approaches to climate change and adaptation should consider how landuse changes interact with biodiversity outcomes. These interactions are likely to be of a different nature to those that have been considered in the past in the following ways:

- Accept and plan for significant and continuous changes in the distribution of species and ecosystems rather than attempt to prevent change. For example, pre-European vegetation types will not be suitable long term benchmarks for vegetation; ecological communities will change, some will disappear and new ones will form as different species respond in different ways; and observed declines in species' abundances and distribution will not necessarily indicate a threat to their viability, especially at the local scale.

- Monitoring in the short-term to build up the knowledge base on management and response necessary to succeed in the long term. The overarching strategy for biodiversity conservation should increasingly focus on developing management approaches that are adaptive and approaches that can cope with changes in species and ecosystems that will be difficult to predict.
- Analyse how climate change will interact with existing pressures on biodiversity. In particular, changed availability and use of water, spread of native and exotic species into new areas, changed land use (habitat loss and degradation), and altered fire regimes will interact with climate change. Managing for how these effects interact will be more important than managing separately for climate change as a threat.
- Many ecosystem processes and many of the changes that occur to biodiversity will do so at large scales. Increased coordination of different conservation and natural resource management programs would enable improved management at landscape and regional scales. In some situations increasing the connectivity of native habitat will increase the ability of species to adapt to climate change. However, increasing connectivity may add pressures for some species by facilitating colonisation of competitors, pathogens, predators and fire. Hence, isolated habitat patches will also be of conservation value, especially if they add to the diversity of habitats protected.

Steffen et al. (2009a,b) raise the idea of a regional integrated approach to understanding how different baskets of public and private investment partnerships, education and capacity building activities, policy approaches and appropriate instruments might be tailored to suit different types of regions in the light not only of changes in the climate but also other biophysical and social trends. This approach has not been tested in Australia but a small proof of concept analysis was carried out for Vietnam (see pp.5-12 in Miller et al. 2009). There is considerable recent work on market-based instruments which can be drawn on to consider what instruments are useful in different contexts, once the different contexts are clearly defined.

6. An assessment of whether current governance arrangements are well placed to deal with the challenges of conserving biodiversity in a changing climate

- Governance arrangements need to cope with issues of scale, interactions and feedbacks, and to support adaptive management.
- Adaptive governance principles are likely to become increasingly important under climate change.

Managing the effects of climate change on biodiversity will be a significant issue – the predicted loss of species and reduced efficacy of invaluable ecosystem services are considerable challenges. Governance arrangements need to be able to deal with the challenges outlined elsewhere in this submission and particular attention should be paid to:

- Scale: To accommodate ecological and evolutionary processes that occur at regional to sub-continental scales, whole of landscape plans in which biodiversity and its associated ecosystem services are valued alongside agriculture and other land uses will be critical. This implies that governance arrangements should be established at scales to cope with scale of dynamic change, which may be challenging under existing frameworks of governance. For example, the current state by state legislation relating to moving native species may be inadequate if assisted translocation of iconic species is considered the only way to save a species from extinction.

- Interactions and feedbacks: Ecosystems are complex adaptive systems. Approaching the management of such a system with an insular or siloed intervention often leads to unexpected consequences, perverse outcomes, and negative feedbacks. It will be even more essential for governance arrangements to be linked across sectors to minimise the unintended consequences. The various land uses, including agriculture, carbon farming, nature reserves, livestock grazing, corridors etc., are implemented across terrestrial landscapes. Several of these land uses interact in counter productive ways. Under climate change, unintended interactions could intensify the loss of biodiversity through mechanisms already described (e.g. invasive species using corridors; changed fire regimes).
- Adaptive management: Attempting to manage biodiversity (and other species-based systems such as agriculture) when there is uncertainty and complexity associated with how species and ecosystems will respond requires an adaptive management approach. If there is uncertainty about what the consequence of management interventions will be it is better to attempt a series of different interventions in a way in which the results can be compared robustly, than it is to try one intervention that might yield unexpected results. 'Learning by doing' (adaptive) management will need to become an accepted method of adapting to ever changing environmental conditions.

Other issues around adaptive governance in natural resource management, which will become increasingly important in the face of the uncertainties associated with climate change, have been considerably canvassed recently (e.g. Nelson et al. 2007; Marshall and Stafford Smith 2010 and references therein).

7. Mechanisms to enhance community engagement

- Communities will need support to debate and come to accept major changes in how they interact with biodiversity. Steps include awareness raising, demonstrating the value of biodiversity, and wide engagement with these values.

People engage with Australian biodiversity in very different ways. Three dimensions of "appreciation" have been proposed (Dunlop and Brown 2008a) – they are quite different from each other ecologically and represent very different ways to engage people:

- *Species* are noticed and appreciated by people bird watching or fishing, by naturalists with an interest in plants, overseas tourists who want to see koalas, kangaroos and crocodiles, or Aboriginal people harvesting traditional food sources.
- *Ecosystems* are enjoyed by people while picnicking, canoeing or bushwalking and are the focus of much eco-tourism and leisure activities.
- *Sea and Landscapes* are appreciated from a hill-top, lookout, headland or aeroplane and are the dimension that most people connect with Australian biodiversity as they travel through or live in non-urban areas.

The Australian community will be challenged by climate change in many ways. With respect to the effects of climate change on biodiversity, people will notice substantial changes in all three dimensions of appreciation noted above. It is unquestionable that drought, flood and fire have large direct impacts on the physical and mental stresses of communities and society. Indirectly these events also impact people by changing the biodiversity at species, ecosystem and landscape levels. Widespread drought reduces the visible signs of many species and reduces the appeal of whole landscapes. Fire impacts all three dimensions but whereas the effects of drought on biodiversity can be overturned relatively quickly (weeks to months), the effects of fires on biodiversity can be very long lasting as feedback loops maintain entirely new vegetation structures and species compositions (e.g. permanent conversion of woodlands and shrublands to grasslands in arid and semi-arid regions; and conversion of rainforest to eucalypt-dominated forest).

Climate change is predicted to bring with it species, ecosystem and sea and landscape changes through direct and indirect effects and interactions among variables. Most people will probably find it hard not to notice a change in one dimension or another of biodiversity, if not all three. These changes will already be evident to avid naturalists and become obvious to the least observant people within a couple of decades. Practically that means people will be observing changes in their surrounding natural environment that are the accumulation of slow inexorable climate change trends (such as gradual warming and gradual rainfall decline) and also increased frequency and intensity of extreme events

The natural environment around where people live may change: some familiar species are likely to disappear while unfamiliar ones appear; ecosystems that are favoured places for recreation will have a different look and feel; landscapes may start to look different. While there is little research on how changes in natural surroundings may affect communities, analogies with the effects of drought on rural communities suggest that severe changes may bring about community distress. Preparing people to acknowledge that change is likely and to understand the trajectory of that change is important because this will help people see the possibility of adaptation choices that open up new opportunities and positive outlooks.

People will need to be engaged with biodiversity loss to improve management strategies. The management strategies that are recommended to halt biodiversity loss are likely to impact on people's livelihoods and lifestyles. Unless people support and comply with the recommended strategies, biodiversity goals are unlikely to be achieved. Enforcement of socially unpalatable strategies can be prohibitively costly, and the transaction costs associated with implementing them may mean that biodiversity remains unprotected. Designing and delivering strategies that are socially acceptable will be a critical component in protecting Australia's biodiversity.

Three steps to engaging the community in accepting and mitigating changes to species, ecosystems and landscapes are:

- raising government and community awareness of the state of Australia's biodiversity (e.g. consistent quantification of biodiversity outcomes) and how it is changing;
- demonstrating the importance of biodiversity to the wellbeing of all Australians, and linking pressures on biodiversity from the investment and consumption choices society makes (e.g. including biodiversity in key national accounts); and
- creating a community-wide engagement in decision-making about biodiversity and participation in the practical conservation of biodiversity. This includes a dialogue about how ecosystems will be changing, information about how species are going extinct and including considerations that strategies may impact upon people. This dialogue differs from the 'preservationist' dialogue that pervades the conservation ethos currently.

Research by Gardner et al. (2009) provides the following recommendations for best practice for climate adaptation engagement.

- Prior to engagement: Set goals and plan; contextualise the issue; define the stakeholders; and manage expectations.
- Engagement processes: Use group discussion, and varied presentation formats; allow mutual influence and foster trust, respect and ownership.
- Climate change issues: Address gaps in knowledge; acknowledge uncertainty; address scepticism; and address emotional reactions.
- Engagement follow-up and evaluation: Maintain contact and feedback; plan evaluation from the outset; evaluate both process and outcomes; and acknowledge other impacts.

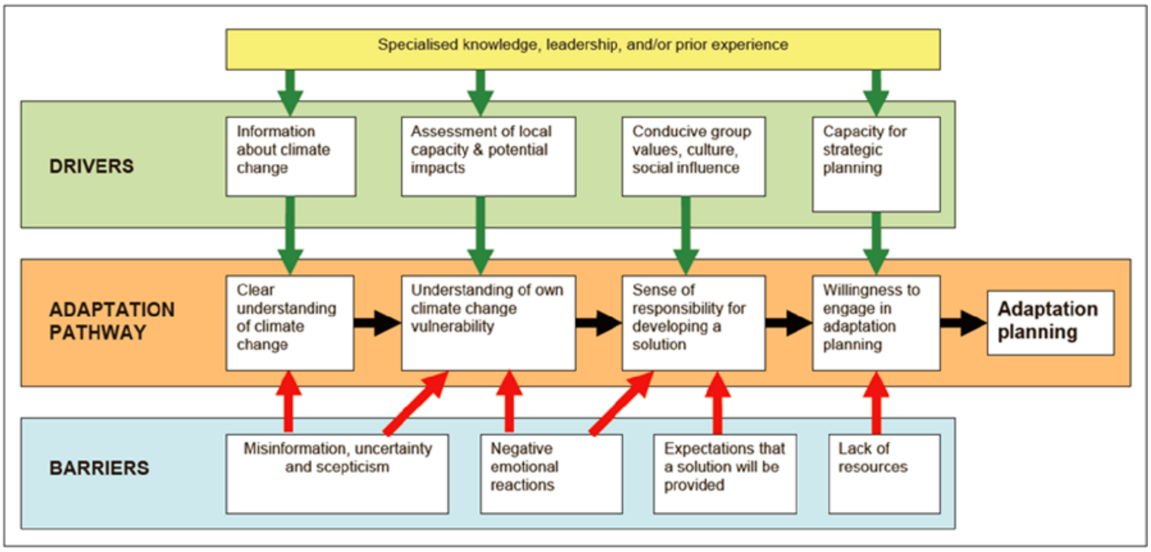

Figure 1. A pathway for adaptation engagement with associated drivers and barriers.

Source: Gardner et al. (2009)

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