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Inquiry into Australia's Biodiversity in a Changing Climate

Submission by the Water Resources and Freshwater Biodiversity Adaptation Research Network

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Executive Summary

- "Water and its availability and quality will be one of the main pressures on, and issues for societies and the environment under climate change" (IPCC, 2008, Climate Change and Water technical paper). "Water will also be the fundamental medium for climate change adaptation in all sectors" (GPNN, IUCN, WWC & IWA, 2009 submission to IPCC).
- Impacts on freshwater biodiversity from climate change will arise particularly from altered thermal regimes, altered precipitation patterns and river flow regimes and, in the case of coastal wetlands, sea level rise.
- The Australian continent and its freshwater species and ecosystems have a number of unique characteristics that need to be considered in planning for climate change.
- Climate change policy needs to recognise freshwater ecosystems as water users and critical to human society. There is high potential for maladaptation from other sectors in responding to climate change (i.e. unintended consequences on freshwater biodiversity).
- For freshwater biodiversity robust water planning arrangements that incorporate provisions for environmental flows is a key adaptation strategy. Uncertainty is unavoidable, but adaptation decisions need to consider a range of climate projections, not just the median.
- Australia's protected area network has an important role to play in conserving freshwater biodiversity. Within this framework refugia need to be managed in a broader landscape context, in conjunction with other high conservation value aquatic ecosystems. A sophisticated approach is required to spread risk, to identify and manage different types of refugia, and to maintain and increase connectivity for refugia.
- To enhance climate change adaptation and resilience in social-ecological systems, strategies need to be implemented that break down the divisions (or silos) between different government agencies, mono-functional land uses, and single-issue responses to climate threats. Strategies that shorten the planning cycle and implement a continuous planning performance are needed to improve adaptive capacity.
- Community engagement is crucial. There is a need to facilitate public awareness about climate change and its impact, communicate with the public and stakeholders regarding water allocation and management decisions, and to identify pathways for individuals to be active participants in sustainable water management.

- The holder of government environmental water entitlements could be given greater freedom to trade in water markets and to have capacity and flexibility in delivering water to achieve the best environmental outcome for which they are mandated.
- A partnership model of research delivery could be an effective mechanism to provide the knowledge needs for adaptive management of climate change. Such models already exist where consortia of research institutions pool resources and expertise to deliver large coordinated research programs.
- Regional natural resource management has developed significantly as a means of coordinating catchment management activities, and provides a good basis for managing climate change adaptation.

1 Introduction

The Water Resources and Freshwater Biodiversity Adaptation Research Network, convened by the Australian Rivers Institute at Griffith University, brings together Australia's top water scientists with interests and skills in water resources and freshwater biodiversity and the implications for these of climate change. The Network has a regional node in each State and Territory and is supported by over 20 partner research institutions. Network activities are conducted under three broad themes (water scenarios and resources, freshwater biodiversity and water governance) with the aim of facilitating collaborative, cross-disciplinary research at the national scale, building research capacity through supporting and mentoring early career scientists and synthesising and communicating relevant knowledge to give Australian water and biodiversity managers the best chance of coping with an uncertain climate future.

The Network is funded by the National Climate Change Adaptation Research Facility (NCCARF), whose role is to lead the Australian research community to generate the biophysical, social and economic information needed by policy and decision-makers in government, and in vulnerable sectors and communities, to manage the risks of climate change impacts.

A key activity in this role is the development of National Climate Change Adaptation Research Plans (NARPs). In December 2010 the Freshwater Biodiversity National Adaptation Research Plan was completed, which focused on the identification of climate adaptation research priorities for freshwater species and ecosystems. This Research Plan proposes four principles to guide climate change adaptation research for freshwater biodiversity:

1. an emphasis on end user engagement
2. participatory research and adaptive learning
3. building on national and international research, and
4. dealing with uncertainty.

A copy of the plan is available at http://www.nccarf.edu.au/national-adaptation-research-plans.

2 Response to Terms of Reference

2.1 Terrestrial, marine and freshwater biodiversity in Australia and its territories

Freshwater systems are already considered to be the most threatened ecosystems on the planet from human activities (Dudgeon et al. 2006; Vörösmarty et al. 2010). Freshwater systems have the highest rates of extinction of any ecosystem, with estimates of at least 10,000-20,000 freshwater species extinct or at risk. This is particularly significant considering that, although they cover less than 1% of the earth's surface, freshwater habitats support 6% of all described species, including approximately 40% of fish diversity and a third of the vertebrate diversity (Dudgeon et al., 2006; Strayer and Dudgeon, 2010).

Most of the world's larger river systems have also been moderately or heavily fragmented by dams and flow regulation (Nilsson et al., 2005), with major impacts on aquatic biota, especially migratory species (Pringle, 2001). Floodplains have been transformed for intensive urban and agricultural land use to the extent that many are functionally extinct from their rivers (Tockner et al., 2008). Increases in nutrient loading and other pollutants from cities and agriculture have resulted in declines in water quality and loss of ecosystem services.

In addition to these existing stresses, freshwater biota and ecosystems are expected to be more specifically affected by climate change in several ways:

- by changes in hydrologic regime (i.e. changes in the timing, magnitude and frequency of low and high stream flows, groundwater recharge and discharge, and the magnitude and distribution of hyporheic (stream bed) exchanges). Climate induced changes in precipitation will significant alter ecologically important attributes of hydrologic regimes in rivers and wetlands, and exacerbate impacts from human water use in developed river basins. . Adaptive responses from humans to climate change (e.g. increased water use and diversions) will exacerbate these changes.
- by the thermally-induced changes of global warming. Rising temperatures resulting in rising stream and river temperatures has been linked to shifts in invertebrate community composition and changes in the composition of river fish communities.
- by sea level rise. Sea level rise will likely lead to direct losses of coastal wetlands with associated impacts on waterbirds and other wildlife species dependent on fresh water. River deltas and associated wetlands are particularly vulnerable to rising sea levels.
- by changes in aquatic chemistry both directly and through groundwater and hyporheic exchange (e.g. dissolved oxygen, pH, nutrients, salinity and turbidity).

Features of the Australian continent and its freshwater species and ecosystems that have specific relevance to considering climate change impacts and adaptation responses are outlined below:

- *Biogeographic history and degree of endemism*: The Australian continent has been isolated from other land masses for over 45 million years. Today, Australia is home to 7 to 10 per cent of all species on Earth, and a significant portion of these species occur nowhere else. For example, more than 90 per cent of Australia's reptiles, frogs and vascular plants are endemic. Many endemic species are already considered threatened and/or have small geographic and climatic ranges – factors that indicate high vulnerability to rapid climate change. Many of Australia's freshwater biota are more diverse and endemic than elsewhere in the world (e.g. galaxiid fish, parastacid crayfish, phreatoicid isopods and candonine seed shrimps and diving beetles in groundwater), and include relicts of ancient life forms of Pangaean and Gondwanan origin (e.g. syncarid shrimps, petalurid dragonflies, lungfish, salamander fish and Spelaeogriphacea) and Tethyan origin (e.g. in groundwater, Thermosbaenacea, Remipedia). Although fish diversity is relatively low (~200 spp) by world standards, the fauna has a high degree of endemicity.

- *Aridity and rainfall variability:* Australia's climate spans a very wide gradient and is highly variable, with extremes in temperature and precipitation (droughts, floods and storms). These episodic climate events are important in terms of driving the structure and function of Australian freshwater ecosystems. If Australia's climate becomes drier, the pre-adaptation of some species to climate variability could bestow a degree of resilience not found in many other parts of the world suffering similar drying conditions. However, many species may already be operating close to their physiological limits, and even small changes could therefore have large impacts.
- *Flat topography*: Australia has limited topographic relief with less than 5 per cent of the land more than 600 metres above sea level. Lack of topographic variability can increase the spatial impact of climate extremes, such as heavy rainfall, flooding and droughts and sea level rise. It also reduces altitudinal options for species migration in response to changed climate conditions.
- *Tectonic stability*: Over several geological periods, much of Australia has been free of major mountain-building processes and glaciation, and has been emergent, resulting in deep regolith and a mosaic of different types of soils and vegetation, with landscape dominated by palaeovalleys. Where ecological community mosaics are significantly influenced by soil characteristics, there may be special challenges to adaptation.
- *Role of fire*: The combination of aridity, high temperatures and an abundance of sclerophyllous vegetation means that fire plays an important role in determining ecological community composition, distribution and function. Fire directly affects the boundaries and health of ecosystems sensitive to fire, including wetlands and bogs. Climate-associated change in fire regimes may be one of the most significant drivers of ecosystem change in many regions.
- *Nature of human impacts:* Intensive farming, widespread grazing and trampling by ungulates, and extensive mining are relatively recent phenomena in Australia compared with most other continents. Australia's biodiversity is still responding and possibly adapting to these relatively recent land use changes.
- *Invasibility of Australian ecosystems:* Nutrient enrichment of Australia's water systems from agricultural and urban development has had negative consequences for many freshwater ecosystems, including the establishment of many alien plant species. Introduction of vertebrates and invertebrates has also had devastating consequences for native biodiversity.
- *Limited data and mapping:* For large parts of Australia (e.g. about 75 per cent of Western Australia) there is limited mapping of freshwater ecosystems or information about freshwater system values, typology, hydrology or variability. Even less knowledge exists about groundwater-dependent ecosystems in Australia.

2.2 Connectivity between ecosystems and across landscapes that may contribute to biodiversity conservation

Connectivity is one of the key concepts behind biodiversity conservation, although not the only one. National environmental goals and policies have key roles to play in protecting Australia's biodiversity at all scales from national to local, landscapes to species or even individual organisms. The overall goals of conservation in Australia include: (1) maintaining well functioning ecosystems; (2) protecting a representative array of ecosystems; (3) removing or reducing existing stressors; (4) building and restoring habitat connectivity; (5) identifying and protecting current refugia; and (6) minimising the loss of species. Climate change poses challenges for the more traditional 'preservationist' approach to conservation policy, with more recent moves toward approaches that seek to manage change in ways that minimise loss of biodiversity and maintain evolutionary processes, ecosystem functions and the delivery of ecosystem services. This would mean, for instance, anticipating or identifying refugia that develop as climate change impacts occur, and protecting them through reservation, management agreements or other mechanisms.

Climate change is likely to test the utility of the criteria of comprehensiveness, adequacy and representativeness (CAR) that currently underpin the protected area estate (National Reserve System) and inform national approaches to conservation. Resolving the meaning and utility of CAR and other criteria for conservation planning and reserve programs will become more pressing under climate change, to ensure Australia's protected area system can meet the challenges of climate change. For freshwater biodiversity, this will include a focus on maintaining the utility of functionally critical freshwater habitats.

The role of Australia's protected area network for freshwater biodiversity is further complicated by the relatively limited protection currently afforded freshwater species and ecosystems. While protected areas comprised around 89.5 million hectares (11.5 per cent) of Australia's landmass in 1998, the proportion of certain types of ecosystems in protected areas can vary considerably, as shown in *Australia's Strategy for the National Reserve System 2009–2030* (National Research System Task Group 2009). This situation is common globally, as 13 per cent of land areas, 6 per cent of coastal areas but less than 1 per cent of the planet's ocean areas are currently protected (Nellemann & Corcoran 2010).

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

Developing and assessing the potential effectiveness of climate change adaptation responses for freshwater biodiversity is complicated by the need to consider activities and processes in other sectors. These may operate across catchments and in upstream drainage networks, the surrounding land, between surface and groundwater, in the riparian zone and, in the case of migratory species, in downstream reaches of rivers and wetlands (**Dudgeon et al. 2006**).

Freshwater biodiversity can be detrimentally or beneficially affected by actions in virtually all other sectors, including terrestrial biodiversity, primary industry, water resource management, and urban and infrastructure development. Climate change policy responses that could affect freshwater biodiversity include afforestation, biochar and biofuel production, solar thermal operations, pumped storage hydropower, carbon capture and storage, coal seam gas, interbasin water transfers, new agricultural production areas and greater water storage.

Freshwater biodiversity is significantly affected by actions taken in primary industries, water management and use, infrastructure, and settlement development and use, as well as many other aspects of society and the economy. Achieving successful adaptation initiatives and programs for freshwater biodiversity will require effective collaboration between all of these sectors. Integrated approaches to adaptation responses that take account of economic and social factors will also be required to ensure investments are well directed and to avoid maladaptation or perverse outcomes. For example climate adaptation responses in other sectors are also very likely to exacerbate these threats, for example as societies attempt to drought-proof or flood-protect agriculture and cities with increased investments in infrastructure (Malmqvist et al., 2008; Tockner et al. 2008).

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

Recognising the interconnections between humans and the ecosystems that support them, the Resilience Alliance (www.resalliance.org) has coined the term 'social-ecological system' to describe how resource use and social structures are coupled. In this way, promoting the resilience of ecosystems and/or human communities is done via governance arrangements that 'govern' interactions at this interface.

Governance arrangements, in this context, are anything that influences the way people interact with their environment and each other – including laws, rules, policies, strategies, organisations, practices and beliefs (see Ryan et al. 2010 for a comprehensive description).

In a climate changing world, the only certainties are change and uncertainty. Therefore, the most fit-for-purpose adaptation strategies will be both systemic (concerned with the whole system, not just parts of it) and adaptive (responsive to change). For example, the current conservation reserve system may not be fit-for-purpose for protecting the species and ecological communities they were designed to protect under changes to climatic conditions, and few current reserve systems adequately protect freshwater species at present (Turak et al. 2011).

To enhance climate change adaptation and resilience in social-ecological systems, strategies need to be implemented that break down the divisions (or silos) between different government agencies, mono-functional land uses, and single-issue responses to climate threats. Strategies that shorten the planning cycle, or do away with planning cycles and implement a continuous planning performance (Ison and Wallis 2011) are needed to improve adaptive capacity.

For freshwater biodiversity robust water planning arrangements that incorporate provisions for environmental flows is a key adaptation strategy. Refugia need to be managed in a broader landscape context, in conjunction with other high conservation value aquatic ecosystems. Connectivity is important for refugia management, weirs, farm dams and other barriers may prevent aquatic organisms dispersing to otherwise connected aquatic habitats and limit recolonisation when flows return. Climate change will exacerbate these impacts on existing refugia, either through changes to water regimes, or through changes to water management or abstraction. A sophisticated approach is required to spread risk, to identify and manage different types of refugia, and to maintain and increase connectivity.

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

Protection of Australia's freshwater biodiversity will be improved through activities already canvassed under the National Water Initiative, including a '*national imperative to ensure the health of river and groundwater systems*' (Clause 5) and an initiative that tasks all states and territories to '*identify and acknowledge surface and groundwater systems of high conservation value*' (Clause 25x). Several riverine and wetland freshwater ecosystems are currently being assessed under the *Environment Protection and Biodiversity Conservation Act 1999* as threatened ecological communities (e.g. the River Murray from the Darling to the sea, the wetlands of the Darling, and the Mary River of South-east Queensland). Such initiatives would provide alternative and complementary conservation benefits to the national reserve system.

To promote more sustainable natural resource use and ecosystem services, the government could investigate policies that would assist in a transition to a more diverse range of landscape values, including combinations of productive, protective and consumptive (lifestyle) uses (Holmes 2008).

Australia's productive landscapes range from areas of high agricultural productivity to marginal or retired land. Likewise, protective landscapes range from areas of high conservation value and protection (e.g. National Parks) to areas of lower protection (e.g. State Forests). A strong trend towards higher valuing of amenity landscapes, for tourism and 'tree-change' lifestyles, is emerging, particularly around regional centres.

These ways of valuing the landscape (production, protection, consumption/lifestyle) are not incompatible, and combinations of these co-exist. These include small farms that combine production and lifestyle uses, also marginal productive land with conservation value, and mixed-used forests that combine conservation and amenity (Holmes 2008).

Multifunctionality, which seeks to achieve all three of these landscape values, is a widely accepted agricultural policy in some parts of Europe, but is weak in Australia (Bjørkhaug and Richards 2008). In fact, many perceive multifunctionality as a form of trade protectionism: a concept unpopular in the neoliberal Australian policy discourse (Dibden and Cocklin 2009).

Recent developments in Australian policy, specifically the Climate Change Plan (Australian Government 2011) and the Murray-Darling Basin Plan (Murray-Darling Basin Authority 2010), tend towards a type of market-based multifunctionality (Cocklin et al. 2006) through payment for ecosystem services in the form of environmental water or carbon offsets linked to biodiversity. This mechanism could be extended to a wider range of ecosystem services and natural resource uses.

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

The ability to adapt to climate change has an important governance and institutional dimension, including the capacity of our social and economic systems to respond to the challenges of a changing climate. Australia has well functioning tiers of governance from the Federal to the State, Territory and local government levels, with a range of coordination structures in place to coordinate activities across jurisdictions. These include the Murray Darling Basin Authority and the Lake Eyre Basin Ministerial Council, which address the two major cross jurisdictional river basins in Australia. In addition to continuing to improve these institutional structures there are a number of initiatives that could be taken to improve governance arrangements as outlined below.

The holder of government environmental water entitlements could be given greater freedom to trade in water markets and to have capacity and flexibility in delivering water to achieve the best environmental outcome for which they are mandated. In recent times of severe drought external political and institutional factors have influenced the ability to provide water to aquatic ecosystems. For example in 2007 wetlands in the Murray system were disconnected from the river as a water saving measure. In South Australia, twenty-seven wetlands were closed in January 2007 and two additional wetlands (Ross and Jaeschke Lagoons) were disconnected in June 2007. Victoria and NSW similarly implemented wetland disconnections, in some cases building additional infrastructure to ensure flows could be regulated (MDB 2007). The manager of environmental water entitlements should be able to operate with the same freedom and constraints as other rural water users.

Regional natural resource management has developed significantly as a means of coordinating catchment management activities and delivery of government funding programs over the past two decades. In 2004 the Commonwealth reviewed arrangements for the regional delivery of natural resource management programs and found that there was consistent support for regional delivery as the best means for achieving integrated natural resource outcomes at a landscape scale.

A climate change primer for regional natural resource management bodies by Campbell (2008) concluded that climate change needs to be high on the agenda for Australian regional NRM bodies, and that risk management and current best practice natural resource management approaches provided a good basis for climate change adaptation. However the national commitment to regional natural resource management is structured around short term funding programs and is at continuing risk of loss of capability. Regional natural resource management needs to be placed on a sounder footing if it is going to be effective in delivering adaptive management outcomes.

Research capacity and achieving adaptive management for climate change are strongly related. There is currently no strong Commonwealth leadership in research coordination across the water sector in Australia. The closure of Land and Water Australia by the Commonwealth Government in 2009 saw the loss of a key research purchaser, an agency able to respond to government policy and program needs. Government Programs such as the National Water Initiative are reaching the end of their life and uncertainty surrounds any likely replacement.

In the absence of national institutions that operate as purchasers of research and managers of large coordinated research programs, a partnership model of research delivery could be an effective mechanism to provide the knowledge needs for adaptive management of climate change. Such models already exist where consortia of research institutions pool resources and expertise to deliver large coordinated research programs, in conjunction with targeted Government investment. Governance arrangements involving Boards of Management and agreements between the parties can ensure that research outcomes are directed to meeting the needs of managers.

2.7 Mechanisms to enhance community engagement

Adaptation to climate change must be driven by key sector groups, peak industry bodies and other organisations, natural resource-based industries, local government, local communities and regions, and private and not-for-profit organisations. Groups able to contribute to adaptation include those that traditionally have been concerned with freshwater biodiversity conservation, but also an increasing number of groups from other sectors, such as water management, agriculture, forestry, mining and tourism, whose activities affect or depend on freshwater biodiversity. (e.g. Barmuta et al. 2011)

An approach to defining adaptation needs in which end user engagement is a specific focus of the process brings a broad community of both practitioners and scholars to bear on the climate adaptation problem. Some of these stakeholders may not previously have been involved in climate change and its interaction with biodiversity conservation – for instance, water engineers, farmers, natural resource managers, regional planners, political scientists, lawyers, economists, sociologists, geographers, national park managers, foresters, conservation biologists, agricultural scientists, and so on. The approach needs to increases both the adaptation effort and commitment to research and its findings, with research scientists needing to develop better understandings of how to communicate research findings to potential users.

Many of the researchers, communities and organisations interested in freshwater biodiversity conservation operate at regional or local levels, and will rely on knowledge focused on the species/genetic, ecosystem/community and landscape scales to implement adaptation actions. Nevertheless, policy development at the larger regional scales (often across state borders) and at the national level is central to dealing with climate adaptation. Both an upwards and downwards exchange of information is required to deliver effective adaptation.

Mechanisms to enhance community engagement include facilitating public awareness about climate change and its impact on water resources, communicating and involving the public in water allocation and management decisions, and identifying pathways for individuals to be active participants in sustainable water management. This might involve asking questions to gain broader community acceptance of climate change goals such as *How do we want to use our water*? or *What do we want our future freshwater ecosystems to be like*?

3 Case Studies

The scope of the committee's inquiry sought to include some case studies of 'nationally important ecosystems', as defined by submissions to the inquiry. The Australian Government has identified high conservation value aquatic ecosystems (HCVAE) based on criteria relating to international recognition (such as the Ramsar Convention on Wetlands of International Importance, World Heritage Convention, and the East Asian – Australasian Flyway Site Network), diversity, distinctiveness, vital habitat, evolutionary history, naturalness and representativeness. High conservation value aquatic ecosystems include rivers, wetlands, floodplains, lakes, inland saline ecosystems, groundwater dependent ecosystems and estuaries.

In addition to Ramsar and World Heritage listed aquatic ecosystems the following 44 sites were identified as a priority for funding under recent Commonwealth Programs (Caring for our Country) using the HCVAE criteria, and would make a good candidate list from which to select case study locations.

- Paroo River System, Lake Wyara, Lake Numalla and the Eulo Artesian Springs Supergroup (NSW and QLD)
- Barwon-Darling River System and Northern Tributaries (NSW and QLD)
- Lowbidgee Floodplain (NSW)
- Cotter River (ACT)
- Lower Ovens River System (VIC)
- Lower Glenelg and Discovery Bay (VIC and SA)

- Lower Snowy and Brodribb River Systems (VIC)
- Derwent Estuary (TAS)
- Pike-Mundic Wetland Complex (SA)
- Chain of Bays (Streaky Bay to Venus Bay) (SA)
- Lake MacLeod (WA)
- Howard Sand Plains (NT)
- Anson Bay and associated coastal floodplains (NT)
- Lake Woods (NT)
- Barkly Lakes (Eva Downs Swamp, Lake Sylvester, Tarrabool Lake) (NT)
- Dulcie Ranges Springs (NT)
- Springs of the Treuer Range (NT)
- Pools of the Western Finke River Catchment (NT)
- Blue Mud Bay (NT)
- Northern Holroyd Plain Aggregation (QLD)
- Southern Gulf Aggregation (QLD)
- Lake Buchanan (QLD)
- Mitchell Springs (QLD)
- Lake Galilee (QLD)
- Bustard Bay Estuaries and Freshwater Wetlands (QLD)
- Bulloo River and Bulloo Lake (QLD)
- Richmond Floodplain Wetlands (NSW)
- Clarence Estuary and Floodplain Wetlands (NSW)
- Lower Lachlan River and Floodplain Wetlands (NSW)
- Tuross and Deua River Systems (NSW)
- Mitchell River System (VIC)
- Upper Thomson River System (VIC)
- Tamar Estuary (TAS)
- Limestone Coast Wetland Complex (SA)
- Pelican Lagoon Basin (SA)
- Fleurieu Peninsula Swamps Complex (SA)
- Coffin, Mt Dutton, Kellidie Bay Coastal Wetland System (SA)
- Cooper Creek Catchment (SA)
- Lower Blackwood River (WA)
- Fortescue Marshes (WA)
- Millstream Pools (WA)
- Lake Gregory (Paruku) System (WA)
- Prince Regent River System (WA)
- Mitchell River System (WA)

References

Australian Government (2011) Securing a clean energy future: The Australian Government's climate change plan. Department of Climate Change and Energy Efficiency, Canberra.

Barmuta, L.A., Linke, S., and Turak, E. (2011) Bridging the gap between 'planning' and 'doing' for biodiversity conservation in freshwaters. *Freshwater Biology* **56**(1), 180-195.

Bjørkhaug, H. and Richards, C.A. (2008) Multifunctional agriculture in policy and practice? A comparative analysis of Norway and Australia. *Journal of Rural Studies*, 24:98-111.

Campbell, A. 2008. Managing Australian Landscapes in a Changing Climate: A climate change primer for regional Natural Resource Management bodies. Report to the Department of Climate Change, Canberra, Australia.

Cocklin, C., Dibden, J. Mautner, N. (2006) From market to multifunctionality? Land stewardship in Australia. *The Geographical Journal*, 172: 197-205.

Dibden, J. and Cocklin, C. (2009) `Multifunctionality': trade protectionism or a new way forward? *Environment and Planning A*, 41:163-182.

Dudgeon, D., Arthington, A.H., Gessner, M.O., Kawabata, Z.I., Knowler, D.J., Lévêque, C., Naiman, R.J., Prieur-Richard, A.H., Soto, D., Stiassny, M.L.J. & Sullivan, C.A. 2006. Freshwater biodiversity: importance, threats, status, and conservation challenges. *Biological Reviews* **81**, 163-82.

Holmes, J. (2008) Impulses towards a Multifunctional Transition in Rural Australia: Interpreting Regional Dynamics in Landscapes, Lifestyles and Livelihoods. *Landscape Research*, 33:211-223.

Ison, R. and Wallis, P. (2011) Planning as Performance: The Murray–Darling Basin Plan. In Connell, D. and Grafton, R.Q. (Eds.), *Basin Futures: Water reform in the Murray-Darling Basin, Canberra.* ANU ePress; pp. 399-412.

Malmqvist, B., S.D. Rundle, A.P. Covich, A.G. Hildrew, C.T. Robinson, and C.R. Townsend 2008: Prospects for streams and rivers. pp 19-29. *In*: N.V.C. Polunin (ed). *Aquatic ecosystems*. *Trends and Global Prospects.* Cambridge Press.

Mac Nally, R., Bennett, A. F., Thomson, J. R., Radford, J. Q., Unmack, G., Horrocks, G. and Vesk, P. A. (2009), Collapse of an avifauna: climate change appears to exacerbate habitat loss and degradation. *Diversity and Distributions*, 15:720–730.

Murray Darling Basin Commission 2007. Dry Inflow Contingency Planning. Overview Report to First Ministers. September 2007. Canberra

Murray-Darling Basin Authority (2010) Guide to the proposed Basin Plan: overview. Murray-Darling Basin Authority, Canberra.

Nellemann, C., E. Corcoran (2010) Dead planet, living planet: Biodiversity and ecosystem restoration for sustainable development.

Nilsson, C., C.A. Reidy, M. Dynesius, and C. Revenga, 2005: Regulation of the world's large river systems. *Science*, 308, 405-408.

Pringle, C.M. 2001: Hydrologic connectivity and the management of biological reserves: A global perspective. *Ecol. Appl.,* 11, 981-998.

Ryan S, Broderick K, Sneddon Y, Andrews K (2010) Australia's NRM Governance System. Foundations and Principles for Meeting Future Challenges. Australian Regional NRM Chairs: Canberra. Available at: http://www.actnrmcouncil.org.au/publications

Strayer, D. L., and D. Dudgeon, 2010: Freshwater biodiversity conservation: Recent progress and future challenges. *J. Nth Am. Benthol. Soc.,* 29, 344-58.

Tockner, K., S.E. Bunn, C. Gordon, R.J. Naiman, G.P. Quinn, and J.A. Stanford, 2008: Floodplains: Critically threatened ecosystems. pp 45-61. *In*: N.V.C. Polunin (ed). *Aquatic ecosystems*. *Trends and Global Prospects.* Cambridge Press.

Turak, E., Ferrier, S., Barrett, T., Mesley, E., Drielsma, M., Manion, G., Doyle, G., Stein, J., and Gordon, G. (2011) Planning for the persistence of river biodiversity: Exploring alternative futures using process-based models. *Freshwater Biology* **56**(1), 39-56.). (see, for example, Mac Nally et al. 2009)

Vörösmarty, C.J., P.B. McIntyre, M.O. Gessner, D. Dudgeon, A. Prusevich, P.A. Green, S. Glidden, S.E. Bunn, C.A. Sullivan, C.A. Reidy, and P.M. Davies, 2010: Global threats to human water security and river biodiversity. *Nature,* 467, 555-561.