Australian Academy of Science

STRESSED ECOSYSTEMS

BETTER DECISIONS FOR AUSTRALIA'S FUTURE

RECOMMENDATIONS

THEO MURPHY HIGH FLYERS

THINK TANK 2011

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BRISBANE, 29–30 SEPTEMBER

STRESSED ECOSYSTEMS

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Australian Academy of Science

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EXECUTIVE SUMMARY

The management of finite natural resources presents complex challenges for Australia. Many activities affect Australia's diverse ecosystems including mining, agriculture, urbanisation, invasive species, tourism, changed disturbance regimes as well as natural events such as flood and drought. As the demand for natural resources grows we face difficult trade-offs between what sea or land use should occur where and at what cost.

Decision making is the process of choosing between actions and therefore requires a prediction of the consequence of those actions. Hence robust decision making for Australia's stressed ecosystems depends on reliable models of ecosystems built on credible scientific, economic and social data, and an understanding of the uncertainties in these predictions. 'Models' (quantitative or qualitative) are important for understanding the interplay between human activities and ecological effects, identifying methods to foreshadow and mitigate negative impacts on ecological systems, and making plans for preserving and sustaining ecosystems.

The 2011 Theo Murphy High Flyers Think Tank brought together about 60 early career scientists and social scientists with diverse backgrounds, to discuss new approaches to understanding the effects of stress on complex ecological systems. Four Australian ecosystems were utilised as case studies for discussion:

a Queensland's Bowen and Surat Basins

b Ningaloo Marine Park, Western Australia

c Melbourne's peri-urban grasslands

d the Murray-Darling Basin.

In each of these regions there is a tension between different potential uses and users of the ecosystem. The issues surrounding natural resource use in each of these ecosystems are diverse and these regions have been subject to very different stresses for varying lengths of time. For instance, while the Murray-Darling Basin has been subject to extensive change and stress as a result of water use over a long period, Ningaloo Marine Park is relatively untouched. It is only in the past decade that Ningaloo has seen an increase in tourism and resource extraction interest, which has raised concerns about potential impacts on the region. Due to these differences, the four groups developed recommendations that were specific to their ecosystem and these are detailed in the subsequent sections of this document. We identified four over-arching recommendations from a synthesis of the work of the four groups. We believe that the implementation of these recommendations will help us to more effectively manage Australia's remarkable natural endowment.

1. **Collect more data on Australia's ecosystems and make it freely available.**

   All predictions of the future, whether they be based on models or informed expert opinion, require information. Each of the Think Tank discussion groups lamented the relative lack of freely available, credible data describing their stressed ecosystem. In some cases, the data has not been collected, sometimes it is collected but in inconsistent ways that defy analysis or verification, and too often data has been collected but is not publicly available. We must renew investment in, and incentives for, making credible environmental, economic and social data freely available for researchers to inform ecosystem modelling. This data curation must be stable, independent and long term, regardless of which agency is responsible for managing it.

2. **Engage the community in data collection.**

   One of the best ways to engage the community in charting a course for their region is by involving them in the data collection process, and in some cases reviewing the consequences of their own management actions. Simple citizen science methods can be developed that take advantage of the proliferation of hand-held communication devices to deliver credible data that can also be understood and visualised by the data collectors in real time. Such initiatives would not only engage stakeholders and the community in the scientific process (an essential part of policy development) in a constructive way, but would also significantly increase the scale of data collection for an ecosystem.

3. **Develop methods to determine the consequences of ecosystem decisions and make these accessible to all stakeholders.**

   Decision makers would benefit from an enhanced capacity to predict the consequences of alternative policies and management actions. Ideally, decision making should enable all people, from politicians to stakeholders with varying technical knowledge, to visualise the consequences of decisions. In order to achieve this, accurate and transparent models are required. In aspects of the environment where more formal modelling is impossible, processes such as horizon-scanning and foresighting workshops that envisage the possible futures for Australian ecosystems resulting from particular actions should be utilised. Such processes could also be used to identify ecosystems that are likely to become critically stressed in the future so that we can anticipate and mitigate adverse outcomes rather than relying on reactionary science that may be too late to contribute meaningfully to the management of ecological stress.

4. **Involve all stakeholders in ecosystem planning and decision making.**

   Participatory decision making is where stakeholders and communities can co-develop their future aspirations and determine, via an informed process, the future of their local environment. The different levels of Australian government need approaches to elicit the aspirations, capacities and desires of its people in the context of how they see the future of their landscapes. Such objective setting should involve all stakeholders and communities – education and decision making allows them to take ownership of the policies and decisions relevant to them.

A response to these recommendations would inform and provide a scientific basis for two current trans-government initiatives:

1. the establishment of a unit or taskforce devoted to foresighting to identify and guide management responses to emerging threats (Recommendation 23.3 of The Independent Review of the Environment Protection and Biodiversity Conservation ACT by Dr Allan Hawke AC which was agreed to by Government in its August 2011 response to the Review).
2. the New National Reform Agenda for Environmental Regulation (Council of Australian Governments, August 2011). This agenda acknowledges the need for major reform of environmental regulation across all levels of government to reduce regulatory burden and duplication for business and to deliver better environmental outcomes, including through greater use of regional planning and strategic assessments.

There are significant opportunities for policymakers to engage with researchers and stakeholders to implement the recommendations described here and produce local, regional, state and national level management plans for Australia's stressed ecosystems. To prevent, mitigate and manage the impacts of natural events and human activities on ecosystems requires a whole-of-government approach. The Academy believes that the recommendations from the 2011 Theo Murphy High Flyers Think Tank provide a roadmap for better ecosystem decision making. Furthermore, the Academy foresees the facilitation of an implementation process to progress these recommendations that engages federal, state and local government officials, and community, regional and industry representatives.

BOWEN AND SURAT BASINS, QUEENSLAND

INTRODUCTION

The Great Artesian Basin is one of the largest artesian basins in the world, containing an estimated 64.9 million gigalitres of water, and is the main source of fresh water for agriculture and other human use in inland Queensland. The Great Artesian Basin is defined on hydrogeological grounds, so its boundaries are different from the constituent sedimentary basins. Within Queensland, most of the extracted groundwater is sourced from the Surat and Eromanga Basins, but groundwater is also extracted and recharged from the upper part of the Bowen and Galilee Basins (Figure 1).

Springs in the Great Artesian Basin support a unique range of groundwater-dependent ecosystems, which

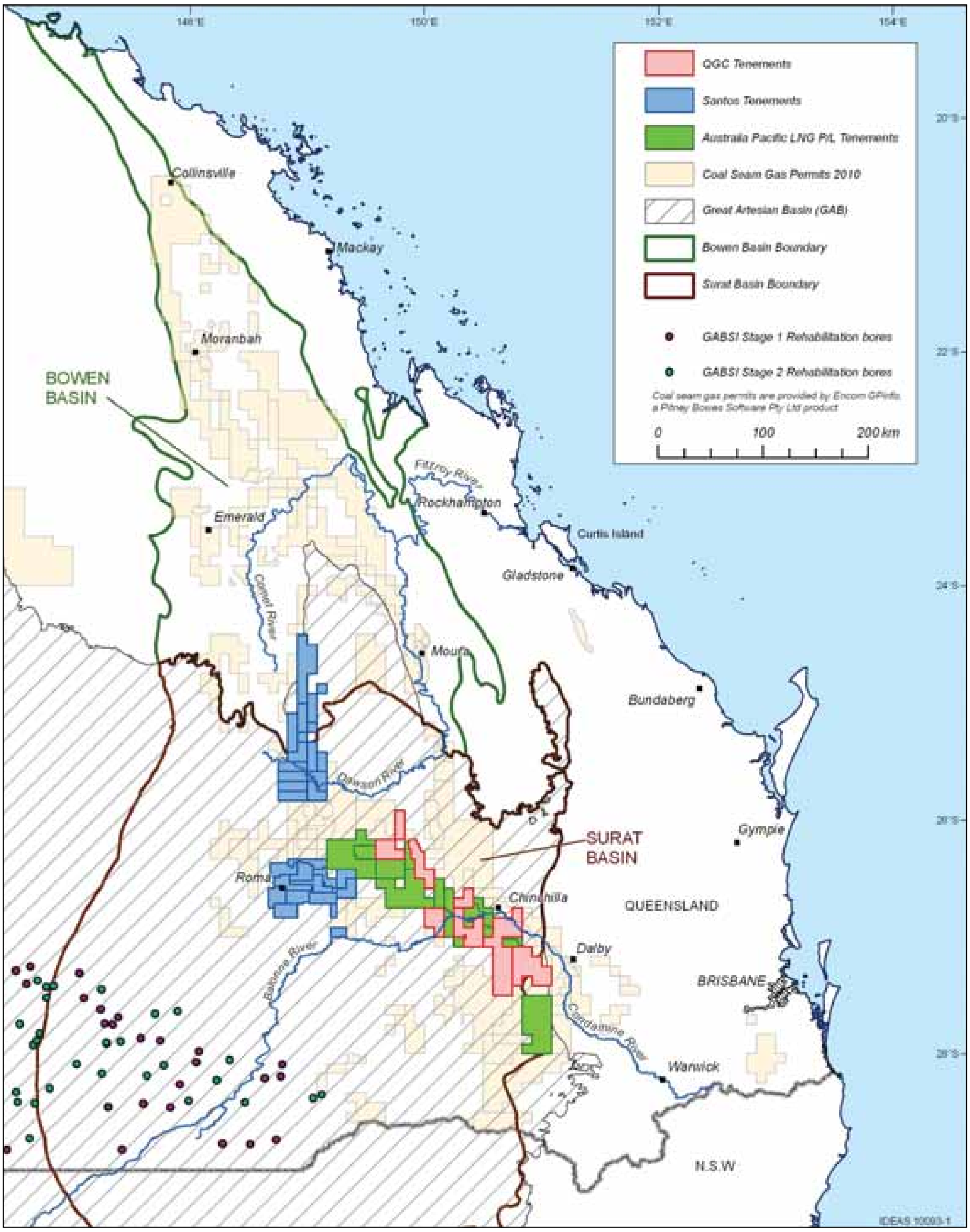

Figure 1: Map showing the boundaries of the Surat, Bowen and Great Artesian basins and the locations of existing and proposed coal seam gas permits. (© Commonwealth of Australia (Geoscience Australia) Geoscience Australia and Habermehl, MA (2010) Summary of Advice in relation to the potential impacts of coal seam gas extraction in the Surat and Bowen Basins, Queensland, Phase 1 Report Summary for Australian Government, Department of Sustainability, Environment, Water, Population and Communities)

contain rare and relic endemic flora and fauna listed under the *Environment Protection and Biodiversity Conservation Act 1999*. The springs are of national and international importance for their ecological, scientific and economic value, and are culturally significant to Indigenous Australians.

Queensland's Great Artesian Basin has a long agricultural history. Pulses, cotton and many grains are grown on the better soils. Livestock, particularly cattle, are a mainstay of the region. Its constituent basins are rich in coal at varying depths, although development to date has focused on the Bowen Basin and, more recently, the Surat Basin. Since 2004, the Bowen and Surat Basins have experienced a boom in traditional open-cut and longwall mining, and coal seam gas drilling. Commercial production of coal seam gas was initiated in the Bowen Basin in 1996 and the Surat Basin in 2006 and production has increased steadily each year to 212 petajoules in 2009–10. Figure 1 shows coal seam gas permits and the three major coal seam gas developments approved to 2010. The proven and probable reserves of coal seam gas in the Bowen and Surat Basins were 27 992 petajoules as of June 2010, making the region the most coal seam gas rich in the country. To put these reserves in context, the Queensland power grid utilises some 192 petajoules a year.

Farmers and pastoralists in the region are concerned about the effect of coal mining and gas extraction on their land and livelihoods. Several environmental and economic concerns have been raised in relation to coal seam gas and other mining activity, including possible contamination of ground and surface water and reduced artesian pressures in the Great Artesian Basin aquifers above and below the coal seams in the Surat and Southern Bowen Basins. There is a high level of uncertainty about the potential regional-scale impacts on land use, communities and the environment, particularly from coal seam gas extraction (Figure 2).

The speed of coal seam gas development necessitates an urgent understanding of what data, models and time are required in order to generate sufficient understanding of the systems involved. What are the political, environmental and economic costs of a suspension on coal seam gas approvals? In light of such costs, would an all-encompassing, complex model of these systems be achievable and worthwhile to reduce negative environmental and social impacts? Considering these questions, our group's discussions at the Think Tank identified three key research areas to address: i) regulatory frameworks, ii) land-use planning; and iii) environmental and human health impacts.

RECOMMENDATIONS

1. Review and improve the current regulatory frameworks governing the assessment and approval of coal seam gas development.

The agencies and arrangements that govern the exploration and development of the basins do so through single tenement-based environmental and social impact assessments (established under state-based legislation), which guide and coordinate the assessment and approval of mining developments, and are used to set up management and monitoring regimes. The pace and scale of coal seam gas development is likely to test the capacity of the current systems. While there have been some attempts at reform, there is currently limited coordinated or strategic assessment. Assessment processes that trigger data collection and collation have been managed in an *ad hoc* manner across government and private sectors with minimal focus on broader, long-term environmental assessment and adaptive management.

a) Regulatory review

The regulatory frameworks for coal seam gas exploration and exploitation need to be reviewed to determine where efficiencies may be gained and where gaps in knowledge exist. The adequacy of current efforts to monitor fugitive emissions should also be examined. The review should attempt to identify opportunities for a strategic whole-of-region framework that is capable of monitoring the cumulative and long-term impacts of multiple operations.

b) Mandatory monitoring and adaptive management frameworks

Regulatory frameworks should include triggers for the collection, reporting and management of appropriate datasets. Sampling regimes need to be of an appropriate quality and frequency to inform predictive models and decision support tools. Different funding arrangements for data collection and management should be explored, including participatory monitoring and assessment regimes. The development of a framework that is sensitive to the results of performance monitoring against specific agreed criteria should be considered. This means that if an operator fails to comply with performance criteria it will be forced to improve its operations.

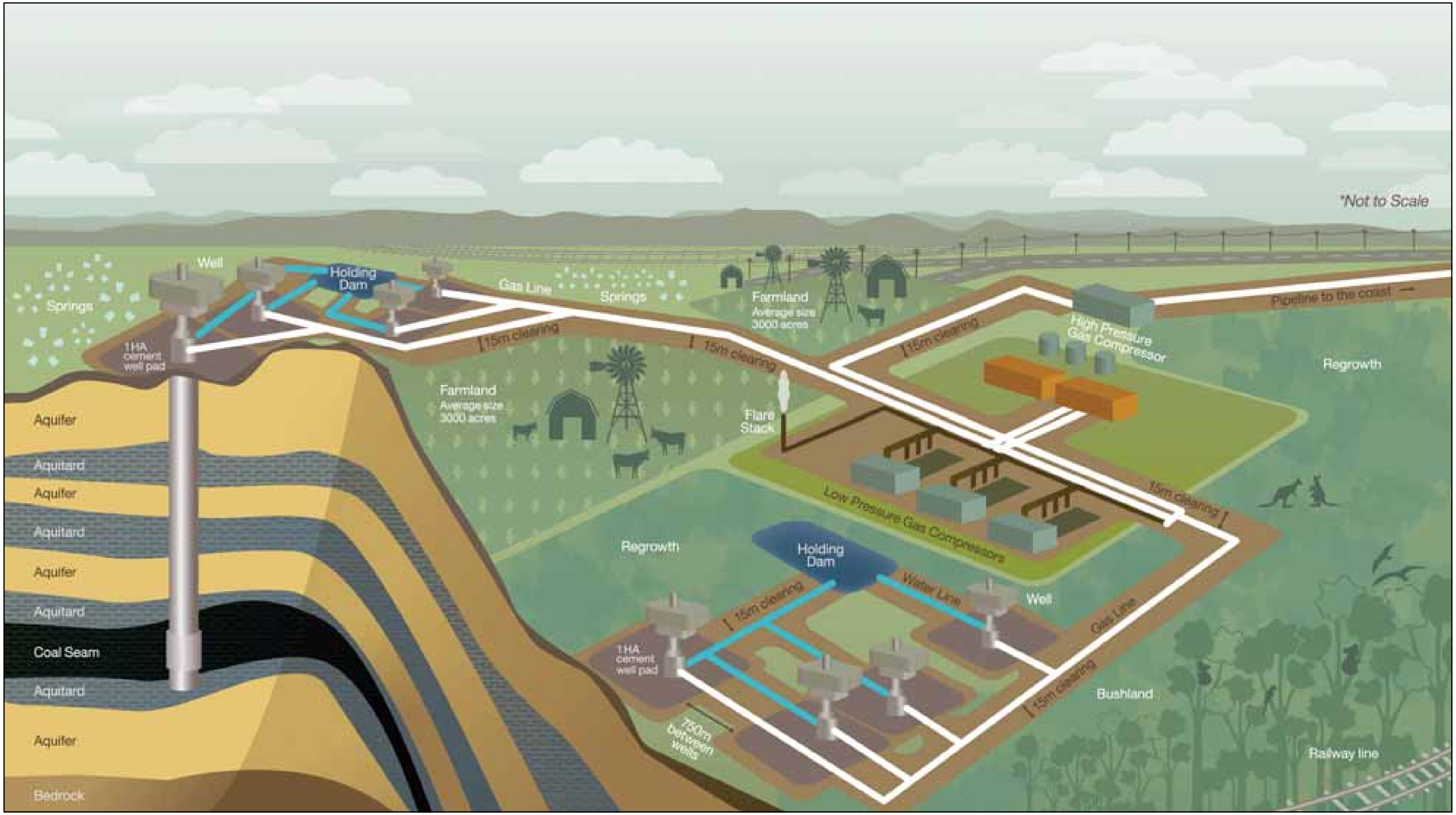

Figure 2: Conceptualised landscape and groundwater impacts of coal seam gas extraction in Queensland. (Tiffany Morrison, University of Queensland)

2. **Develop models that assess the impact of land-use change to inform planning and management decisions.**

The temporal and spatial scale of development approvals for coal seam gas in Queensland has challenged broader planning for the management of regional impacts. The impacts on land use, water and natural resources need to be understood in the context of food and water security and the future of Queensland communities. The land clearing required for each coal seam gas well pad and all associated infrastructure (pipelines, roads, etc.) can be extensive, with the potential for loss of prime agricultural land and natural ecosystems, and associated impacts on biodiversity and food security. Some pioneering social and economic research has already been undertaken on the impacts of land clearing, and planning has commenced as a result, but there are gaps in the data informing our understanding of change across the regions that must be addressed.

A gap analysis of existing models and data collection methods is essential. New models of land-use change incorporating tenure, natural resources, agricultural resources, infrastructure, demographics and other social indicators, Indigenous interests and biodiversity are needed. Remote sensing, data visualisation and scenario building should be used to present a range of alternative futures using spatially explicit land-use models. These will require cross-disciplinary research to reach cohesive conclusions. The impacts of the coal seam gas industry outside the Bowen and Surat Basins (for example in adjacent coastal communities, and in the wider Great Artesian Basin) should also be considered. Such land-use models have the potential for broader application beyond this particular region.

Carbon dynamics and economic modelling are also crucial for informing land-use decisions. Environmental data streams and modelling need to be linked with simple economics models to facilitate cost benefit analysis. The results can be used to underpin planning processes to reflect broader national and global interests.

A broadly accepted strategic land-use plan for the basins is needed that incorporates and considers existing and future use and is informed by the data and models described above. Community, government, industry and scientific participation should be encouraged so that the aspirations of all stakeholders may be considered during land-use planning. The land-use plan should be statutory so that it has the power to guide future development.

3. **Develop models and monitoring processes to comprehensively assess the impact of coal seam gas development on ground and surface waters.**

The existing models of current conditions in the Great Artesian Basin are primarily geological and hydrogeological. These models have been used to predict the impacts of coal seam gas extraction on groundwater systems but provide only an initial assessment of the possible wider impacts. The Queensland Water Commission is developing a regional groundwater model to assess the cumulative impacts of multiple coal seam gas developments but there is limited understanding and monitoring of both groundwater and surface water conditions and processes. More baseline data is needed before further development occurs, in order to understand and accurately model possible environmental impacts. For example, regional reductions in groundwater pressure and artesian groundwater flow have occurred since extraction began in the late 1800s. Increasing extraction of groundwater may result in further reductions in groundwater level and pressure in parts of the Great Artesian Basin. A long-term balance must be achieved between present and future environmental water needs and those of agriculture and the coal seam gas industry. Some of the necessary data may already exist with industry; however, this is yet to be made accessible for use in impact assessment.

a) Modelling impact pathways

A conceptual model should be developed to identify potential environmental impact pathways and key knowledge gaps within those pathways. Each impact pathway can be assessed for risk (i.e. assigned a likelihood and consequence) and associated uncertainty, based on dataset quality. The model can be used to identify data gaps and to determine research priorities. It can also be used as a tool to inform and engage stakeholders, and draw on local knowledge.

Data and process model integration is needed to reduce the uncertainty in surface and groundwater models. Some of the data that is needed to inform these models may already exist with industry and access could be achieved through greater cooperation between industry, academia and government.

b) Strategic water monitoring

Strategic monitoring of surface and ground waters is essential to determine current environmental conditions in order to assess any

Figure 3: Coal seam gas wells south of Chinchilla in south-west Queensland. (Photo: ABC 2011)

future environmental degradation. Sampling of surface waters should be both systematic and event-based, in view of the high degree of climate variability across the Surat and Bowen Basins. Parameters should include groundwater pressures, volumes, chemistry, toxicology and biology, and monitoring should be used to determine the environmental fate of hydraulic fracturing chemicals.

c) *Early warning indicators*

Early warning indicators of the impacts of coal seam gas developments on ecosystems need to be developed, encompassing physical, chemical and biological parameters. These must provide sufficient time for comprehensive investigation and for remedial measures to be implemented. Some physical and chemical results could be monitored continuously and reported in real-time where possible (e.g. via wireless data transfer). Significant changes in physical and chemical parameters of ground and surface waters could trigger more detailed sampling. Biological tests that measure the health of groundwater-dependent ecosystems on a regular basis should be developed. The inclusion of online data with participatory monitoring schemes would serve to educate as well as increase community confidence in results.

d) *Toxicology risk assessments*

Ecotoxicological and human health risk assessments of produced water, treated produced water and hydraulic fracturing chemicals should be conducted to predict the potential impacts of contaminants on receiving environments and to determine 'safe' dilution rates. Both surface water and groundwater exposure pathways need to be addressed.

In order to achieve this, concentration response data is required for the various effluent types and possibly for their constituent components.

SUMMARY

Due to the rapid development of the coal seam gas industry in the Bowen and Surat Basins, we urgently need to understand the implications of this activity on ecological, hydrological and agricultural systems and on human communities. This requires a coordinated, multidisciplinary approach. Assessment of groundwater and surface water environmental impacts and processes is critically needed. We do not have a comprehensive understanding of the past volumes of groundwater extraction for farming and human use, and are therefore uncertain of the consequences of coal seam gas water use in the region. We rely heavily on expert judgement in our understanding of the system but we also need good data, models and frameworks that seek to understand and balance key indicators of ecological, economic and social interests. Innovations in socioeconomic data collection, remote sensing and spatial analysis, data visualisation, scenario building and participatory assessment should be utilised. Funding and data-sharing agreements are needed to implement reform. Any reforms should consider the establishment of adaptive management regimes whereby monitoring of performance according to specific evaluation criteria feeds back into the development of implementation options for governments. These models and reforms can be based upon pre-existing models and would have broader use outside this particular region. It may be possible to bring together multiple databases hosted by different agencies and environments to develop a model that deals not only with water quality and production data but also with key socioeconomic and land-use planning data for the Surat and Bowen Basins (e.g. an improved version of the healthy waterways report card framework **www.health-e-waterways.org**/).

Much of the debate around coal seam gas is fuelled by social and political as much as scientific factors. However, the social and political issues cannot be resolved until we obtain a better scientific understanding of the impacts of coal seam gas extraction on environments and communities. Addressing the significant knowledge gaps that exist should help enable those local communities affected to participate more actively and effectively in planning their futures.

NINGALOO MARINE PARK, WESTERN AUSTRALIA

INTRODUCTION

Ningaloo Marine Park encompasses a remote 300 kilometre coastal reef system and covers approximately 243 600 hectares (Figure 4). Already iconic to the people of Western Australia, the Ningaloo coast (including the state-managed marine park) was recently accorded United Nations World Heritage status. The region has a resident population of just 7000 people but receives more than 200 000 visitors annually. Its main drawcards are marine recreational activities including snorkelling, SCUBA diving, recreational fishing and the opportunity to swim with whale sharks (Figure 5). Unlike the Great Barrier Reef, World Heritage listed in 1981, activities in the marine park are mostly close to shore or coastal and concentrated in both space and time at camping areas and towns during the winter months. This concentration of activities has prompted suggestions that Ningaloo might be in danger of being 'loved to death'.

The past five years have seen significant investment in biological, physical and tourism research at Ningaloo, to obtain important baseline information. It is critical to maintain the focus on Ningaloo and capitalise on this research impetus and the positive profile garnered by World Heritage listing, given the expected regional rise in tourism and in oil and gas activities in the near future. The tasks of synthesising current datasets and increasing understanding of this important system to a level equivalent to the Great Barrier Reef are all the more urgent given that future state government funding is now primarily focused further north, on the Kimberley.

RECOMMENDATIONS

1. **Increase the focus on process-oriented research of ecosystem function at Ningaloo and promote data-sharing between industry and the research community to aid such studies.**

   Over the past four years, there has been a notable increase in research activities concentrating on Ningaloo Marine Park, in part due to a period of increased Western Australian Government funding for the region. This has led to the acquisition of a large number of baseline datasets, which provide an excellent foundation for new multidisciplinary research programs devoted to investigating the complex interactions between physical and biological processes within Ningaloo waters, and ultimately how this contributes to the region's unique ecology. However, with this funding now at an end, there is a risk that recent growth in research activities at Ningaloo will decline. Resources are required to maintain research momentum and effort at Ningaloo, to promote activities that will build on existing knowledge and encourage new researchers with unique scientific perspectives. These resources may include external research funding or ongoing investment in research infrastructure in the region, for example in the form of a well-equipped research station.

   A significant amount of scientific and environmental information about the Ningaloo region is not publicly available. Open access to these datasets would greatly aid research and industry in the region, particularly given the expense associated with data collection in remote regions. Data-sharing between industry, the research community and non-government organisations will foster collaborations, reduce duplication, and thereby make efficient use of limited research resources. The research and industrial development permit process provides a framework to ensure information gathered during projects is made publicly available. However, it is important that such information is appropriately curated to ensure data reporting is in a functionally accessible and interpretable format, and that its access is managed to support research.

2. **Assess connectivity between reefs within Western Australia and investigate the impacts of climate change in the region.**

   a) *Assess the fine-scale pathways of connectivity between coral reefs within Ningaloo Marine Park, regionally in WA and beyond.*

      The coral communities of the Pilbara and Kimberley coast appear relatively tolerant to extreme environmental conditions, which could confer genetic or epigenetic advantages to reefs in the region, if Ningaloo is indeed a sink recruiting from these northerly populations. These advantages could increase resilience to perturbations including extreme climatic events. The regional ocean current systems surrounding Ningaloo Reef and the broader North West Shelf of Australia are not well understood compared with other shelf regions of Australia. Despite clear evidence of the southward flowing Leeuwin current, quantification of genetic connectivity between reef organisms within

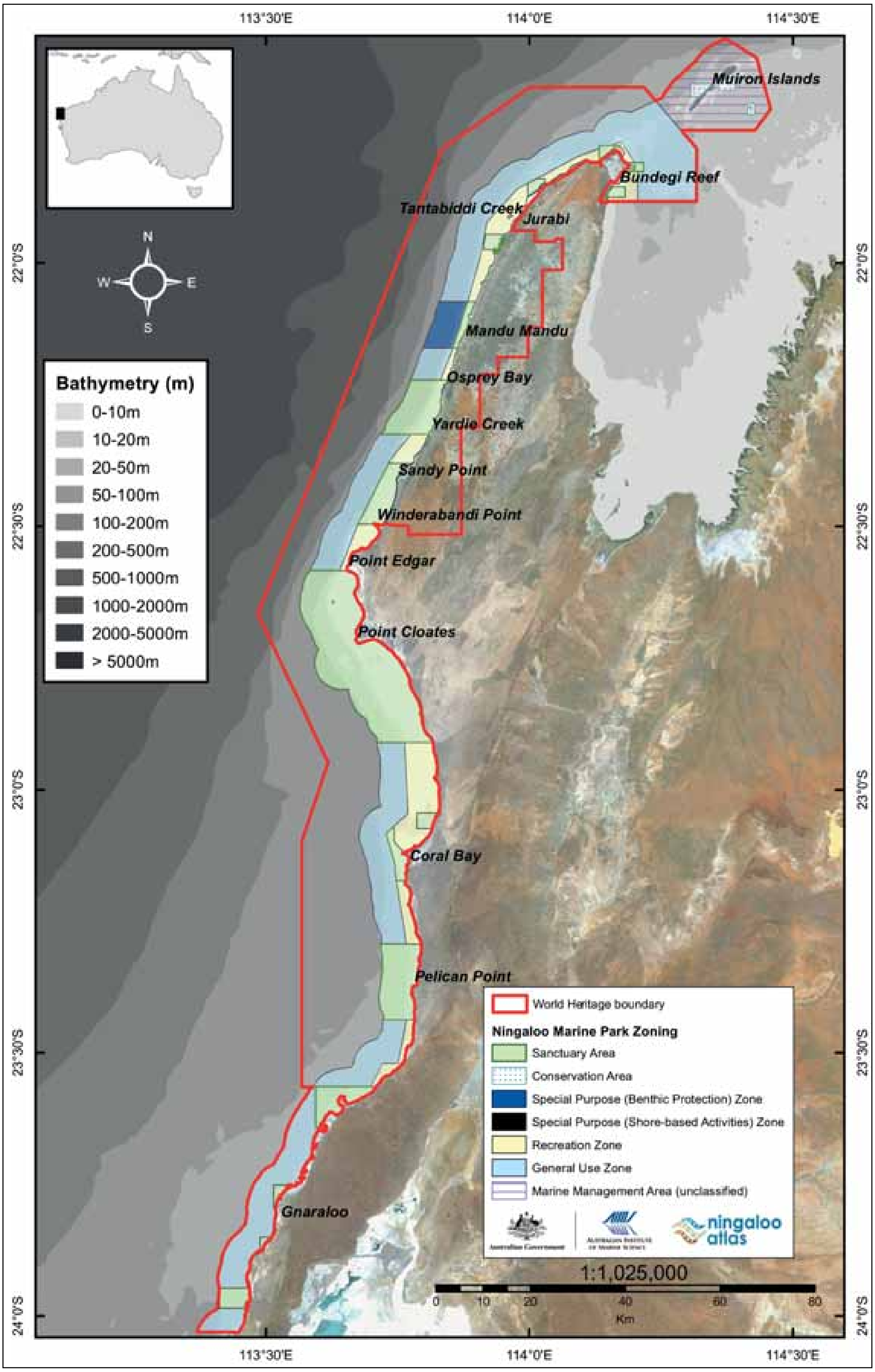

Figure 4: Ningaloo Marine Park location, zoning plan, and World Heritage boundary.
(Dr Ben Radford, Australian Institute of Marine Science)

Figure 5: Many picturesque locations and a diverse range of human-use activities contribute to the 'wilderness experience' of the Ningaloo Coast. (Photos: Prof. Lynnath Beckley, Murdoch University; Dr Claire Smallwood, Murdoch University; Dr Tyrone Ridgway, Australian Institute of Marine Science)

Ningaloo, between different management zones in the marine park, and other tropical reef systems to the north remains largely unstudied. Ecological connectivity (exchange of recruits and/or food resources) among components of the marine park is equally poorly understood. Knowledge of oceanographic, ecological and genetic connectivity on all scales is vital to management, and to facilitate understanding of the sources and sinks for larvae (e.g. corals, fish) supporting the ecology and biodiversity of the region.

b) *Investigate how reef and shelf processes in Ningaloo will respond to climate change, and estimate flow-on socioeconomic effects.*

Global climate change is affecting coral reef ecosystems worldwide through processes such as ocean warming and acidification. There is some evidence that reef-building corals at Ningaloo are tolerant to local temperature fluctuations. However, in 2011, the first recorded warm water-related coral bleaching event occurred at Ningaloo, suggesting that these corals are not immune to pressures associated with increasing water temperatures. Such events add urgency to the need to investigate how regional ocean processes control water temperatures at Ningaloo, how organisms are adapted to this dynamic environment, how ocean acidification will alter coral growth and the balance between accretion and erosion of the reef matrix, and how these phenomena will translate into changes in habitat. In addition, there is a critical need to identify the complex feedbacks between potential changes in reef structure and other ecosystem components such as fisheries.

Changing environmental conditions are also likely to affect the productivity of phytoplankton and zooplankton in oceanic and nearshore waters, with flow-on effects to the productivity of the reef ecosystem. At present, there is very little information predicting how patterns of pelagic production may change in the future, let alone what the predicted impacts are for ecosystem function, fisheries management and tourism enterprises. Such effects may have socioeconomic implications which complicate attempts to mitigate ecosystem damage. Identifying patterns of nearshore/open ocean coupling at Ningaloo, and quantifying whether and how bottom-up effects of oceanic productivity influence fluxes of carbon and nutrients within the reef complex should be a focus of future research.

3. Assess the impacts of activities including fishing, industry and tourism.

a) Measure and understand fishing impacts.

Fishing is recognised globally as a pervasive activity that can influence fish communities and have broad ecosystem consequences. Fishing is an important recreational activity at Ningaloo and it is imperative that managers understand the behaviour of both fishers and fish, with respect to target species, effort, location and compliance with local regulations. In particular, it is unknown whether location-focused versus diffuse fishing activity is more or less damaging to the reef ecosystem, and whether the activity of recreational fishers is likely to change under altered management regimes. Temporal and spatial shifts across the vast Ningaloo coastline can have serious ecological ramifications, and accurate assessments of fishing activities and their effects on the system should be regularly collected.

b) Improving understanding of risks from industrial spills and responses.

There has been a rapid and accelerating expansion of offshore oil and gas infrastructure along the northwest coast of Australia, including as close as 20 kilometres from the eastern border of Ningaloo Marine Park. Recent research has improved our understanding of local currents, and (with detailed habitat maps) has facilitated a better understanding of risks from spills from both offshore structures and increased marine transport activities. Development of advanced hydrodynamic models will improve our ability to predict seasons and areas of the marine park that are most at risk from oil spill. However, we must also improve our understanding of impacts from management responses, particularly the use of dispersants and the ecological consequences of these chemicals. Moreover, the socioeconomic ramifications of a major oil spill in a newly listed World Heritage area may be severe and mechanisms for mitigating these impacts requires investigation. Insights from these models, and from the experience of oil spills in other regions, will enhance our ability to understand the impacts of a major contaminant spill and improve responses to such an event.

c) Forecast the impacts of changing tourism demographics on recreational activities and regional infrastructure demands.

Ningaloo's recent World Heritage listing offers many opportunities, but may also confer additional pressure. Foremost among both is a likely shift in the tourism demographic away from local/state visitors towards high-end tourists travelling on the World Heritage brand, part of a group targeted by Tourism Australia as the global 'experience seeker'. A focus on non-extractive activities like 'adventure tours', snorkelling and diving, whale and whale shark tourism, as well as terrestrial activities involving the Cape Range National Park, may result in a move away from traditional regional activities that use existing infrastructure, like recreational fishing, or have low-infrastructure requirements, like wilderness camping. The projected expansion of the experience seeker market may in turn be compromised by industrial and commercial growth in population centres. The infrastructure requirements of the offshore oil and gas industry, associated population growth and development of a fly-in fly-out workforce, will affect the so-called 'wilderness experience' that has come to define the Ningaloo coast in tourist literature and imagination. This influx of occasional residents will exacerbate existing pressure on accommodation for people servicing the tourist industry. Understanding and balancing the changing demographics and motivation of tourists and residents is important to ensure that management keeps pace with changing attitudes and can plan ahead in an informed way.

4. Promote science communication incentives, including those within funded research initiatives, to achieve more effective science-based management.

Successful transfer of scientific knowledge requires effective communication among researchers, managers and the public. This requires that managers and researchers work together to identify and achieve common objectives. Communication plans addressing this link should be a requirement of funding.

The presence of active scientists within management agencies can facilitate the translation of scientific knowledge into policy and planning. This may involve producing collaborative management publications that allow managers to be more involved in the acquisition and analysis of scientific data while rewarding researchers with peer reviewed papers, the basis of academic merit.

In addition, there is an increased need to communicate the scientific outcomes of research to the public via media and communication channels designed to reach the general public target audience. This may involve funding to researchers and managers to outsource public outreach and engagement activities, and through continued support of initiatives such as the Ningaloo Atlas (http://ningaloo-atlas.org.au).

SUMMARY

Ningaloo Marine Park has many unique attributes that contribute to its potential as a research hotspot:

- It is a longitudinally compact nearshore ecosystem, featuring a close coupling between oceanic and coastal waters, providing research opportunities for a range of scientific disciplines and therefore increased capacity for cross-disciplinary collaborations.
- It is geographically situated in a transition zone between temperate and tropical climates, making it unique as a location for research on the differential biodiversity of zones, including research into the effects of climate change. The big impacts of climate change will be seen in transition zones because this is where organisms are at the limit of their tolerances, and where minor shifts could lead to large shifts in ecosystem structure and function.
- Its waters are comparatively pristine due to its geographic isolation, small resident population, low rainfall, and the filtering capacity of the terrestrial karst system of the Cape Range.
- It is set against a backdrop of good management practices and there are no commercial fishing activities to confound linkages between biota. This situation provides a relatively clean slate from which to study how a natural coral reef ecosystem operates and responds to change.

Ningaloo offers a diverse combination of tourism experiences unlike any other. The arresting, arid beauty of its land contrasts strikingly with its underwater mosaics of colourful reefs and associated biodiversity. The 'megafauna highway' provided by the nearshore/open ocean coupling provides one of the few places in the world where you can easily see migratory species such as turtles, whales and the world's biggest fish, the whale shark. The recommendations outlined above highlight the most pressing issues identified by the group of scientists that discussed the region at the Think Tank. Although currently in good shape, now is the time for scientists, managers and industry to be especially vigilant. Ningaloo has seen intense, sustained and increasing activity recently and now that it has been accorded World Heritage status, the eyes of Australia and the world are upon it. The very attributes that make Ningaloo such an inspiring, interesting and unusual ecosystem also place pressure on it. Considering the global issues that will have a direct impact on Ningaloo, including climate change and transnational migration of significant species, the role of scientists as ecosystem advisors has never been more important. It is our responsibility to ensure that decisions on the future of Ningaloo are made with the best science achievable.

MELBOURNE'S PERI-URBAN GRASSLANDS, VICTORIA

INTRODUCTION

The temperate native grasslands of the Victorian Volcanic Plain bioregion are considered one of Australia's 15 national biodiversity hotspots (Figure 6). They were the most dominant ecosystem in the Melbourne metropolitan area (Figure 7), but are now one of the most endangered ecosystems in Victoria. *Today, approximately 0.2% of the original extent of temperate grassland in Victoria remains*, with only half of that in good condition. Historically, vast areas of grasslands, including most of the Victorian Volcanic Plain bioregion, have been destroyed or substantially altered by agricultural practices such as grazing and cropping. As a consequence, some of the largest and most intact grassland remnants in Victoria occur on the western and northern fringes of Melbourne, where they are now vulnerable to urban expansion. Approximately 75% of the remaining area is privately owned, complicating efforts to protect and manage extant grasslands as Melbourne continues to rapidly expand.

Natural Temperate Grasslands of the Victorian Volcanic Plain are listed as critically endangered under the *Environment Protection and Biodiversity Conservation Act (EPBC) 1999*, and as threatened under the *Flora and Fauna Guarantee Act 1988*. Ongoing loss of habitat has resulted in the classification of many plant and animal species as nationally threatened and endangered (Figure 8).

Existing ecological models of this system include:

1. Statistical models demonstrating that the probability of a patch of grassland being degraded or destroyed is much higher if it is on private land, is close to the CBD and/or is close to a major road.
2. Population models showing that the probability that populations of grassland plants will be extirpated is a function of life-history characteristics or traits, encroaching urbanisation and changing disturbance regimes.
3. Models of the mean time to extinction for grassland plants showing that small patches of grassland (e.g. 10–20 ha) are sufficient to support populations for at least 100 years.
4. An algorithm identifying the optimal size of nature reserves to protect multiple species of grassland plants, which shows that many small reserves would be more efficient than fewer, larger reserves.
5. Metapopulation models of the growling grass frog in northern Melbourne, indicating the importance of both habitat quality and connectivity for this species.
6. A variety of land-use modelling tools that integrate conservation planning and land-use planning on the urban fringe.

RECOMMENDATIONS

The following recommendations are provided to prevent the future loss of this ecosystem.

1. Coordinate the efforts of local, state and federal governments to strengthen legislative measures (including compliance) to ensure there is no further loss of temperate native grassland.

To halt the ongoing loss of biodiversity and avoid the risk of extinction, it is critical that remaining areas of Victoria's temperate grasslands are managed effectively, and there is no further loss of this community. Despite existing legislation, protection of Melbourne's peri-urban grasslands is failing. The structure of the legislation has historically facilitated incremental loss of grassland, or 'death by a thousand cuts' because the cumulative impacts of habitat loss have not been considered. Further, despite the intention for offsets to be employed only after more effective mitigation strategies (e.g. avoid, minimise further degradation) have been attempted, offsets are commonly the primary option considered during environmental impact assessments (EIAs). Presently, our ability to achieve meaningful (large-scale) restoration of functioning native grasslands is uncertain and undemonstrated, and there are inadequate legislative measures in place to ensure compliance with offset targets. Therefore, offsetting should not be employed until: i) clear and measurable restoration goals are specified; ii) there is a framework in place to measure progress toward these goal; iii) compliance with goals is enforced and the consequences for not doing so are clear; and iv) we can be confident in our ability to restore and create resilient and viable grassland communities.

Figure 6: Melbourne's peri-urban native temperate grassland community. (Photos: Ryan Chisholm; Libby Rumpff)

2. Reimagining Melbourne: Employ foresight methods to develop alternative scenarios that represent preferred visions of a city for different stakeholders, and investigate the preferred scenario to fulfil social, economic *and* ecological values.

There is a need to develop a more productive, responsive, efficient and sustainable city landscape in which people recognise and take ownership of their shared vision for Melbourne. Effective planning depends on eliciting from citizens what they want their cities to look like and provide. People value different things but acceptable solutions will be determined by a range of fundamental criteria, including requirements for housing, education, transport, health, employment and the environment. The environment is often a low priority despite underpinning many of the other criteria.

There are two components to this recommendation. First, we propose the use of foresight methods to identify different planning visions for Melbourne, and second, we recommend that a structured process should be adopted when deciding which vision is preferred in relation to multiple (and potentially competing) social, economic and environmental values.

a) The alternative visions

Foresight is the practice of using a range of methods including horizon scanning, forecasting, emerging issues analysis, and action planning. It can be used to develop a suite of alternative scenarios that represent preferred visions for a city for different stakeholders. 'Foresighting' challenges ideas and assumptions, providing a means of reimagining the future of a city by providing options, while providing the opportunity for broad community engagement.

Foresight activities operate through a series of inclusive, deliberative workshops in which stakeholders, scientists and technical experts explore the past, present and future potential of a city. When people imagine different future scenarios, it is much easier to develop resilient designs and contingency plans that are based on a democratic process and that foster a culture of shared responsibility.

b) Identifying the preferred alternative

Good decisions emerge from structured, deliberate and inclusive consideration of a suite of alternative scenarios, and incorporate social, economic and environmental objectives. Preferences that individual stakeholders express

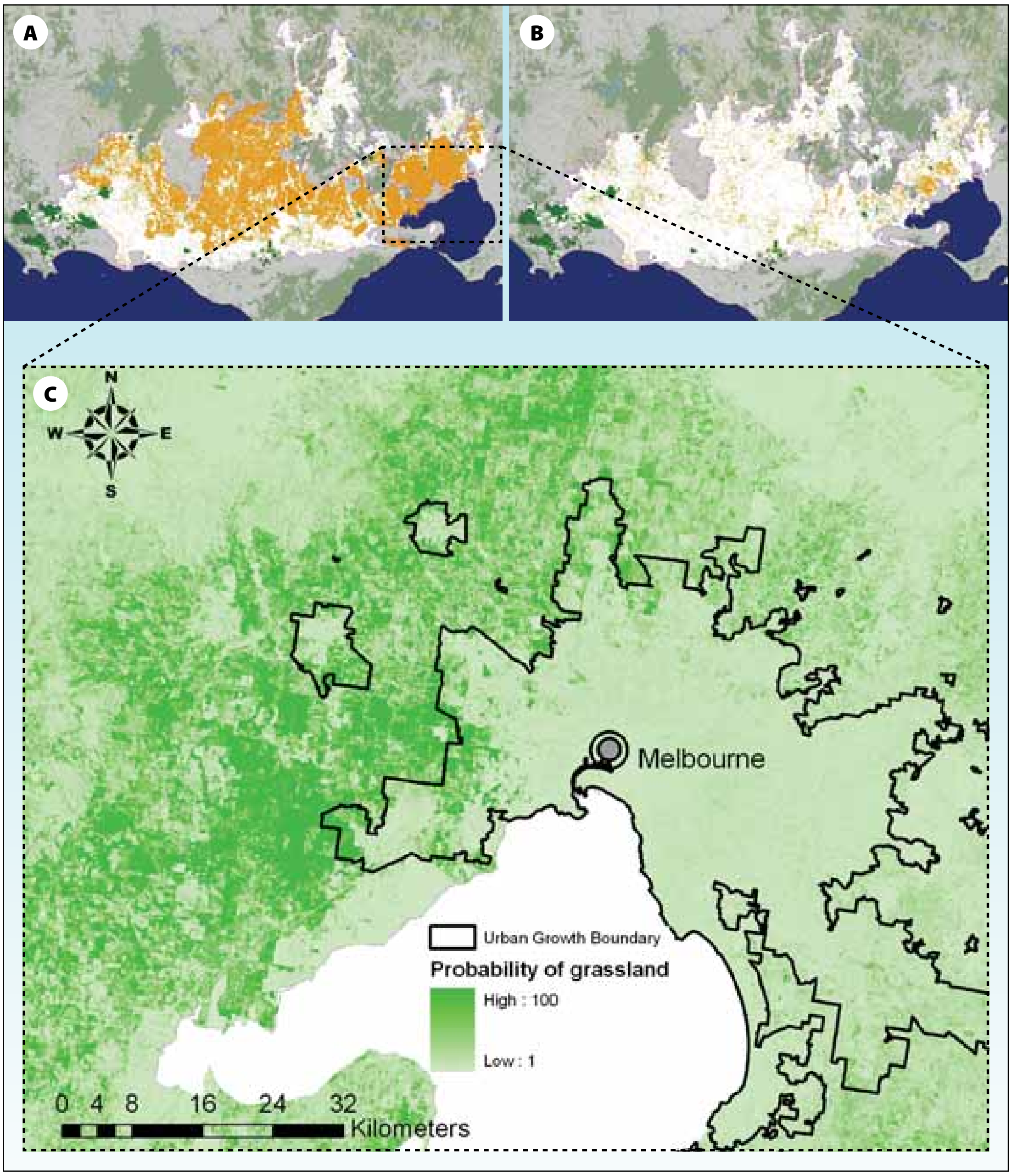

Figure 7: a) Modelled pre-settlement extent of native grassland vegetation (orange shaded area) across the Victorian Volcanic Plain bioregion (Department of Sustainability and Environment Victoria, 2005, unpublished data) b) Modelled current extent of native grassland vegetation (orange shaded area) across the Victorian Volcanic Plain Bioregion (Department of Sustainability and Environment, 2005, unpublished data). The larger blocks of remnant native grasslands are mostly on Melbourne's western fringe c) Probable occurrence of remnant native grasslands around Melbourne as modelled by the Department of Sustainability and Environment. Darker shades of green represent areas where there is a higher likelihood of remnant native grasslands. This is a dynamic region, and it is likely that grassland extent has been reduced since these data were generated (Garrard, GE (2009) Dealing with imperfect detectability in biological surveys for native grassland management. School of Global Studies, Social Science and Planning. PhD thesis, RMIT University, Melbourne).

for a scenario reflect individual values, and so are inherently subjective. It is the role of technical and scientific experts to estimate the expected outcome for each objective under each planning scenario. Structured decisions also emerge from facilitated workshops in which stakeholders consider the expected outcomes and risks for fundamental objectives under each set of possible planning scenarios. Stakeholders identify mutually acceptable alternatives, and think creatively about new alternatives that may satisfy the minimum requirements of all affected groups.

From the perspective of ecologically sustainable development, scenario planning and structured decision making provide the frameworks to evaluate biodiversity conservation as a fundamental consideration in the initial stages

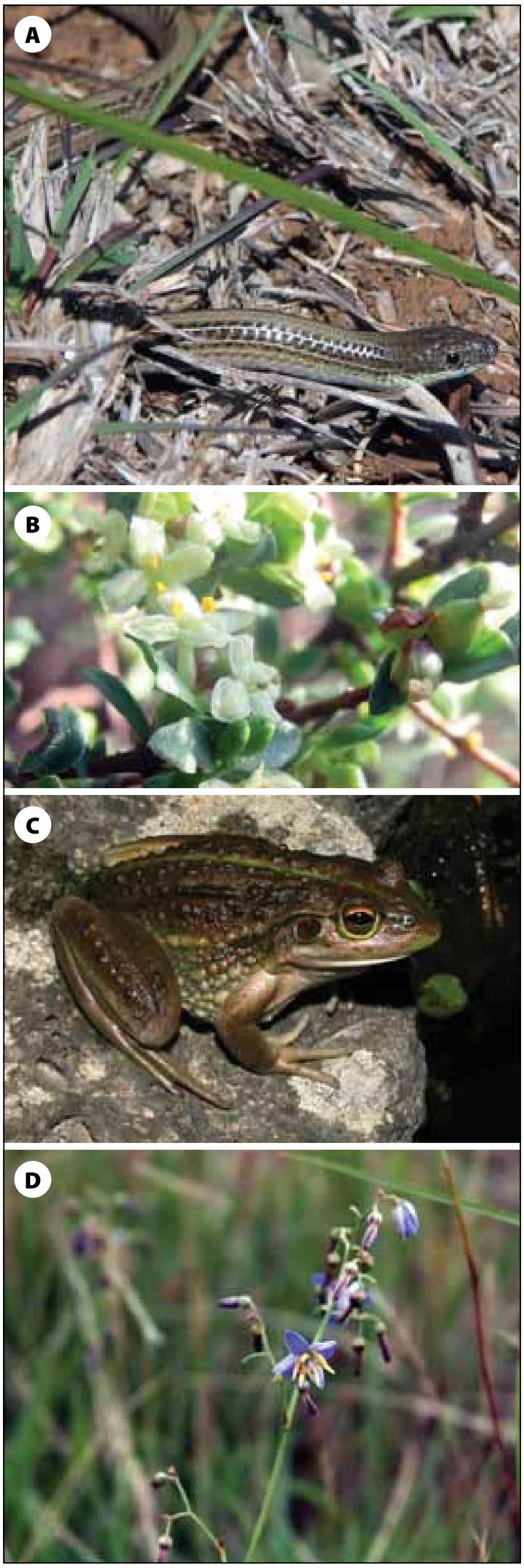

Figure 8: Threatened flora and fauna (EPBC classifications) of Melbourne's peri-urban grasslands including a) the vulnerable striped legless lizard *Delma impar* (Photo: Megan O'Shea); b) the critically endangered spiny rice-flower *Pimelea spinescens* subsp. *spinescens* (Photo: Megan O'Shea); c) the vulnerable growling grass frog *Litoria raniformis* (Photo: Geoff Heard); and d) the endangered matted flax-lily *Dianella amoena* (Photo: Georgia Garrard).

of urban planning at both city and suburb scales. Trade-offs are inevitable, but this approach enables the biodiversity trade-offs to be clearly expressed and considered alongside economic and social criteria. We recommend these approaches be used when reimagining Melbourne to identify the optimal blueprint for its future.

3. **Promote biodiversity-sensitive urban design by developing principles for biodiversity-sensitive planning at the local scale to be incorporated into planning legislation.**

   There is currently little consideration of remnant biodiversity in the design of housing estates. Over time, clearing of remnant vegetation, fragmentation of the landscape, introduction of pests and weeds, increased roads and traffic, and disturbance from intensive recreation inevitably result in decline of grassland flora and fauna species. These impacts can be controlled and substantially better outcomes achieved with ecologically-sensitive, evidence-based urban design that meets the needs of species, considers water and soil conservation, and encourages community use and perception.

   A new paradigm of 'biodiversity-sensitive urban design' is needed such that principles for considering biodiversity in housing developments are established. By establishing guiding principles for urban design, possibilities for maintaining and improving grasslands within urban development may be highlighted. Just as water-sensitive design principles are now considered best practice in urban design, this new concept should have broad uptake, with the potential for adoption in policy and legislation. Application of biodiversity-sensitive urban design principles need not be restricted to grassland ecosystems but could be applied in other regions of Australia where there is conflict between urban development and biodiversity. To apply biodiversity-sensitive urban design in regions previously home to grassland ecosystems, several key questions need to be addressed:

   - How should grasslands be incorporated within a housing development? For example, how can conservation planning tools be used to identify appropriate location of housing stock and conservation zones?
   - What degree of social acceptability exists for the implementation of biodiversity-sensitive urban design?
   - How can conflicts with other objectives for open space, such as recreation, be resolved? For example, can a hierarchy of reserves with differing public access be established?

- Can win-win situations be created with other planning objectives such as storm water retention?
- Can viable populations of vulnerable flora and fauna species be maintained within a housing development? Possibilities include the development of planning guidelines for augmenting existing grassland habitat (e.g. via green roofs/laneways and indigenous species on nature strips and gardens), and incorporation of 'habitat' star ratings for houses (i.e. similar to energy ratings).
- Can better principles for construction be developed to facilitate restoration of disturbed areas (e.g. the promotion of sensitive site preparation)?

4. **Implement a research program and education campaign to investigate and demonstrate the social and ecological benefits of temperate grasslands in Melbourne.**

   Grasslands are currently a public relations disaster. There is poor awareness of the integrative social, economic and ecological benefits that they provide. Due to the small size of plants, the short flowering season and the typically degraded state in which they exist, grasslands are not seen as having the aesthetic appeal of other habitats. As such they are undervalued, and there is very little imperative to consider grasslands in planning policy.

   Implementing biodiversity-sensitive urban design principles can have benefits beyond those directly related to biodiversity. Research has demonstrated that human interaction with the natural environment has a number of broader social benefits, including an increased sense of wellbeing, identity and community, increased social interaction, increased cognitive functioning in children, and reduced rates of crime and aggressive behaviour. Local plants, animals and ecosystems often provide the only encounters with nature that people living on the urban fringe experience. Therefore, Melbourne's peri-urban grasslands offer a significant opportunity for urban dwellers to interact with nature now and into the future.

   There is an opportunity to strengthen the identity of new and existing communities established near grasslands by creating a sense of ownership of their uniquely Melbourne biodiversity. We propose four approaches to encourage community interest and participation in conservation of grasslands:

   - Undertake a research program to investigate the values and perceptions of grasslands held by people living in Melbourne and how these values translate into willingness to engage in their conservation. We recommend that the Victorian Government work with local councils, community and environment groups, scientists and the broader community to achieve the goal of this research program.
   - Establish ways to promote positive interactions with grassland areas, such as 'cues to care' (see J Nassauer (1995) 'Messy ecosystems, orderly frames', *Landscape Journal* 14(2): 161–70).
   - Promote a public education and interpretation campaign, including education centres and school programs.
   - Promote and fund the establishment and activities of local community groups to support activities that encourage communities to be involved in grassland conservation.

SUMMARY

Temperate native grasslands are one of the most endangered ecosystems in Victoria, as recognised under state and federal legislation. Melbourne's peri-urban areas contain a large proportion of the remaining areas of native grassland, but these areas are under increasing threat from urban expansion. Protecting the remaining areas is a multidimensional problem of overlapping political, social, economic and environmental values. However, it is critical that there is no further loss of this community. At present, state and federal legislation is not adequately protecting these communities and species, there is poor integration of ecological values into local and state planning, and there is a poor public perception of grasslands.

By implementing the recommendations put forward here, we believe it is possible to halt further loss of temperate native grasslands and potentially enhance grassland ecosystems in the peri-urban region of Melbourne. However, action needs to be taken now to protect these important ecosystems for future generations.

MURRAY-DARLING BASIN

INTRODUCTION

The Murray-Darling Basin is the 'food basket' of Australia, generating approximately $15 billion a year in agricultural production, a third of which is produced using irrigation. Irrigation (including conveyance) uses about 11 000 gigalitres of water a year, representing 90% of the surface water consumed. On average, these extractions reduce annual flows in the lower Murray by approximately 60%, and in dry periods, flows are reduced by as much as 96%.

This level of water use has contributed to wide decline in the aquatic ecosystems of the basin. Evidence of this degradation led to the capping of surface water extractions in the mid-1990s. This was followed by the 2004 National Water Initiative and the *Water Act 2007* in which governments agreed to 'complete the return of all currently over-allocated or overused systems to environmentally sustainable levels of extraction'. The imperative for change was heightened by the millennium drought which further contributed to environmental decline and involved a level of water scarcity previously unforeseen for many consumers.

The *Water Act 2007* established the Murray-Darling Basin Authority and tasked the Authority with preparing a Basin Plan to set sustainable diversion limits. The Basin Plan is likely to recommend significant reductions in extractions. Any reductions will have considerable socioeconomic impact while a failure to significantly reduce extractions may result in further environmental decline.

A robust understanding of the relationships between water resource use, ecology and socioeconomic impact is important in making key policies and communicating the basis of these decisions to stakeholders. Over many years, the government and research institutions have developed an array of models that can assist decision making. These include:

- hydrological river system models
- hydraulic and ecosystem response models
- economic models of water trade and water resource use.

The application of these models to support whole-of-basin policy is challenging due to the different spatial and/or temporal timescales, and baselines of the models, as well as their extension beyond the purpose for which they were developed.

Planning a future for the Murray-Darling Basin epitomises the concept of a 'wicked problem', entailing lashings of ecological, socioeconomic and political complexity, uncertainty and, at present, controversy. From this web of diverse and conflicting demands, information sources and decisions, science provides the potential to link disparate interests and to guide the planning process. However, where scientific models and evidence-based decision making have been perceived as opaque (or worse – 'rubbish in, rubbish out'), scientific knowledge has presented a substantial stumbling block.

During the Think Tank, our group, comprising a diverse mix of scientists from the social and natural sciences, focused on future challenges and opportunities for science in the Murray-Darling Basin planning process. During our discussions, three broad but closely related themes emerged in which the role of science was seen as pivotal (Figure 9):

1. identifying values and developing objectives
2. investigating scenarios and identifying appropriate management 'levers' (actions) and their consequences, and
3. developing interactive processes of integrated and adaptive learning.

While we acknowledged that much scientific research is still required across the Murray-Darling Basin in all disciplines, the overwhelming idea emerging from our deliberations was that such scientific knowledge might do little to improve management unless it is more widely understood, accepted and discussed among the community. Better integration across scientific disciplines was also recognised as being highly important. Consequently, we identified the development of increased stakeholder education and involvement in the scientific process as the crucial challenge for scientists. Fortunately, this goal also emerged as a major opportunity!

The large spatial and temporal scales involved, as well as considerable socioecological variability across the Basin, present further challenges for traditional approaches to collecting, analysing and interpreting data to generate scientific knowledge that can support decision making. The following recommendations to government, policymakers and managers, address such issues of scale while enabling stakeholder engagement in the scientific process.

RECOMMENDATIONS

1. **Develop and promote an interactive, basin-scale ecological monitoring network linked to simple simulation models of the Murray-Darling Basin.**

   We recommend that the Murray-Darling Basin Authority leads the development of a public ecological database, which would include observations and monitoring data from basin ecosystems. This could be coupled to simulation models of the basin, including a participatory simulation 'multi-player game' that enables players to make a range of decisions about the management of the Murray-Darling Basin Authority from the perspective of different stakeholders (e.g. farmers, water managers). This would enable the public to see what the consequences of specific actions might be for the future of the basin. The rules governing these consequences would need to be made transparent to players and the uncertainties involved explicitly expressed so that players were made aware of the 'model' structure. Preferably, users could alter some of the assumptions (e.g. climate change scenarios) used in the model. The emphasis should be on demonstrating to players how land and water management choices at certain scales or within particular arenas (e.g. grazing, irrigation, environment, community) interact to produce effects at other scales or in other arenas. Developed in consultation with representatives of different stakeholder groups, made available online, and integrated with social networks, such a simulation game would promote awareness of and enthusiasm for scientific models among stakeholder groups across the basin, and promote an appreciation of the connectivity of the basin, e.g. between upstream and downstream users. Existing participatory, simulative games, such as Australia's Catchment Detox game (www.catchmentdetox.net.au), have been well received and widely used.

2. **Design and commence an ongoing and iterative participatory process at a local level across the Murray-Darling Basin to identify values and objectives for managing the basin.**

   There is a clear need for an inclusive and iterative process to develop objectives for the management of the Murray-Darling Basin that are linked to the values of all stakeholders in a transparent fashion. Drawing on current social science methods (e.g. see box: *The Group Process*), a localised, collaborative process could be developed and implemented basin-wide by which consensual targets for management could be identified based on a shared understanding of the knowledge and values of participants. Local workshops could be carried out by catchment management authorities, supported by professional facilitators and collaborative process designers, with the results amalgamated and discussed at regional, state and basin scales. Scientists from a range of disciplines with direct local knowledge, as well as those working at larger scales, could participate in such workshops as stakeholders themselves. A specific aim of these workshops would be to identify where seemingly conflicting values and fundamental objectives might align so that management targets reflect 'win-win' situations (e.g. reduction of acidification in waterways via environmental flows with additional biodiversity and food production benefits).

3. **Develop integrated whole-of-basin scenarios and analysis of potential management 'levers' to identify potential consequences and trade-offs associated with particular future paths of action.**

   A logical extension of the process described in the preceding recommendation is to conduct local, collaborative workshops to identify scenarios and preferred visions of the future, as well as the available and potential management actions or 'levers' and the probable consequences associated with following particular courses of action. Stakeholder participation in the development of such scenarios, coupled with the development of preferred visions for the future of the basin would promote understanding among different groups, of connectivity within the basin. It would also provide a basis for identifying no-regret, low risk or 'win-win' actions and the trade-offs that may be required to meet certain management objectives. A critical element of this process would be to explore management options available to the range of stakeholder groups across multiple scales and domains (land management, economic settings, community development) rather than limiting management choices to those associated with water allocation.

4. **Develop collaborative partnerships among community groups, scientific organisations and government agencies to design, implement and maintain monitoring programs for the collection, analysis, interpretation and sharing of ecological and socioeconomic information of relevance to basin management.**

   Long-term monitoring of ecological, social and economic indicators across the basin is needed to aid strategic adaptive management into the future. However, the scale, variability and complexity of the basin make this an immense task. Collaborative partnerships between scientists and a range of other stakeholder groups have the potential to vastly increase the spatial and temporal coverage of data at a local scale. This data could feed into basin-wide databases and be used to improve conceptual models, objective setting and scenario development in an iterative process. Novel methods for data capture might also be implemented more broadly across the basin, e.g. smart phone community monitoring applications and web-cams feeding real-time images of breeding events on floodplains to the Internet. Processes of data collection, collation and presentation of such monitoring data would need to be well designed to ensure ease of use by community members and access to information across the community. A governing body would need to regularly audit monitoring of the various groups to ensure consistent data across the basin. A further and important benefit of such collaborative monitoring processes would be increased understanding and engagement of stakeholders in the scientific process.

5. Use environmental water to experiment and learn.

Sustainable management of the Murray-Darling Basin requires increased understanding of the responses of environmental attributes that people value, to watering across multiple spatial and temporal scales. The acquisition of large volumes of environmental water by the Commonwealth and states provides an unprecedented opportunity to learn about ecological and socioeconomic responses (and their interactions) to watering, in a relatively controlled experimental setting at large spatial scales. A further recommendation is that a greater proportion of the Federal government funds currently allocated to improving water infrastructure could be more effectively used to support improvements in environmental water allocations if the funds were used to directly purchase environmental water (both temporary and permanent water). Based on the principles of strategic adaptive management, such environmental watering 'experiments' should be based on current conceptual models and management objectives so they have the double benefit of providing environmental water for management goals and increasing knowledge

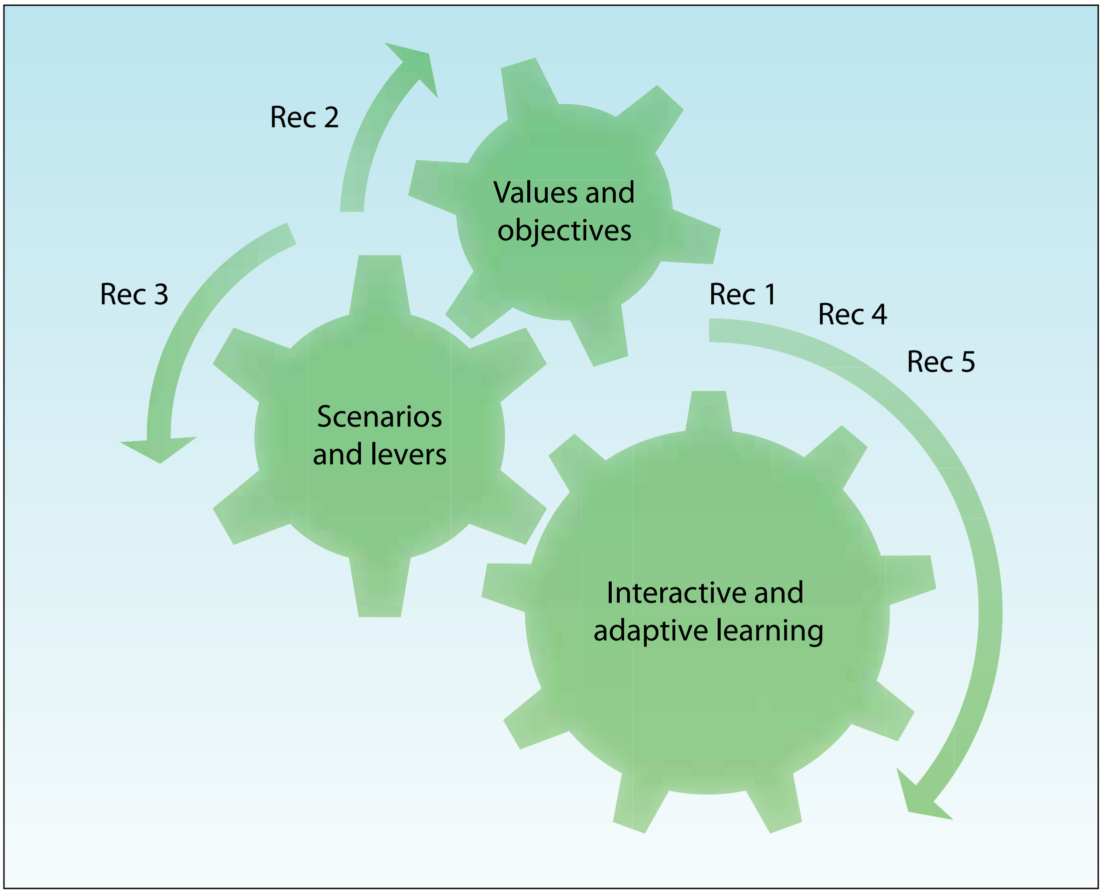

Figure 9: Recommendations for the Murray-Darling Basin are linked by three broad themes.

of responses to watering. Set within an inclusive, collaborative and participatory process of objective setting and monitoring, as described in the preceding recommendations, large-scale environmental watering experiments would also promote stakeholder engagement in the scientific process.

SUMMARY

Overall, the recommendations that emerged from our group's discussions highlight a need for scientists to contribute to a participatory, transparent and iterative process of developing interconnected values, management objectives and scenarios to inform decisions on actions in the Murray-Darling Basin. Stakeholder participation was identified as a key requirement for the acceptance of such a process. To this end, Participatory Adaptive Learning and Management ('PALM') may be a more appropriate moniker for the approach we propose – one that emphasises that the future of the Murray-Darling Basin is in everyone's hands.

THE GROUP PROCESS

Ongoing reforms in the basin are necessarily science-intensive, including the setting of a basin-wide limit for sustainable use of water. However, because of the 'wicked' nature of the situation, science cannot lead such reforms but only inform them. During the Think Tank, our group considered how we, as scientists, can effectively support reform in the Murray-Darling Basin. Group discussions were informed by Ian Burns of the Murray-Darling Basin Authority, the federal agency responsible for developing a basin-wide water resources plan. Ian provided an overview of the historical hydrological context in which basin water resources have been allocated. A discussion of the current condition of the basin and the methods used to determine this formed a useful starting point for the day. The process used by our group to structure our discussion was informed by the social sciences (soft systems methodology) in order to elicit our different (and diverse) perspectives on the situation. Early in the discussion, the 17 participants split into three conversation groups. Conversation mapping – essentially a process of facilitating and capturing a 'map' of a conversation – was useful for appreciating the diversity of perspectives across the group. By recording conversations in this way, group members were able to reflect on their own thinking and elicit the values and assumptions behind their individual points of view. As a result of this process, we identified emergent themes from the conversations – both challenges and opportunities to support basin reform.

BACKGROUND TO THE THINK TANK

PURPOSE OF THINK TANKS

The purpose of the Theo Murphy High Flyers Think Tank series is to bring together early and mid-career researchers from a broad range of relevant scientific disciplines to think about novel applications of existing science (including social science) and technology to issues of national significance, and to identify gaps in knowledge that should be addressed. These events are a unique opportunity for career development and networking among the nation's next generation of research leaders and their institutions.

Think Tanks are one of the premier events of the Academy's calendar. This Think Tank is the tenth that the Academy has held since 2002.

PREVIOUS THINK TANKS

Previous Think Tanks have culminated in reports to government that have been timely, well received and instrumental in influencing policy development. Past Think Tank topics (available at **www.science.org.au/events/thinktank/**) have been:

2002 Australia's national research priorities

2003 Safeguarding the nation

2004 Emerging diseases – ready and waiting?

2005 Biotechnology and the future of Australian agriculture

2006 Innovative technical solutions for water management in Australia

2007 Extreme natural hazards in Australia

2008 Preventative health: science and technology in the prevention and early detection of disease

2009 Agricultural productivity and climate change

2010 Searching the deep earth: the future of Australian resource discovery and utilisation

THE PROCESS

On Day One of the Think Tank, the theme – *Stressed ecosystems: better decisions for Australia's future* – was introduced with four brief presentations. These presentations were aimed at stimulating lateral thought in the discussions that formed the remainder of the Think Tank, rather than providing comprehensive coverage of the theme or any of the four particular ecosystems.

The afternoon session of Day One was dedicated to discussions in small breakout groups. Each participant was assigned to one of four breakout groups, each of which also comprised a chair, and an 'expert' who provided background information and answered specific questions arising during discussion of the group's ecosystem case study. Each group comprised a mix of skills and experience in order to stimulate lateral thinking and to challenge participants to extend themselves and think dynamically. Each chair had two participants preselected to act as the group's rapporteurs. The role of the rapporteurs was to collate the group's discussions and distil the discourse into a 15 minute presentation. Breakout groups were asked to examine and address their group's discussion questions but were also encouraged to move beyond these questions to other topics identified during the discourse.

On Day Two of the Think Tank, after a final review by the breakout group, the rapporteurs presented the findings of their breakout group. There was an opportunity for questions and discussion following each presentation, during the general discussion and in response to the final summing up.

SUPPLEMENTARY MATERIAL

Supplementary material, including the event program, is available at **www.science.org.au/events/thinktank/thinktank2011/index.html**

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EXPERT

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Dr Bernd Gruber

Dr Libby Rumpff

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Dr Remko Duursma

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THE ROYAL SOCIETY

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