FOUNDATIONS FOR THE FUTURE

A long-term plan for Australian ecosystem science

Ecosystem Science
Long-Term Plan

Acknowledgements

This document arises from activities undertaken by the Australian ecosystem science community over more than a year. More than 600 people across the country took part in surveys, workshops, and working groups that contributed to the final product.

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TERN
Terrestrial Ecosystem Research Network

ESA

National Committee for Ecology, Evolution and Conservation
A COMMITTEE OF THE AUSTRALIAN ACADEMY OF SCIENCE

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Cover image: composite of Australia from NASA's Terra-MODIS sensor, with 500m pixels, sourced from NASA

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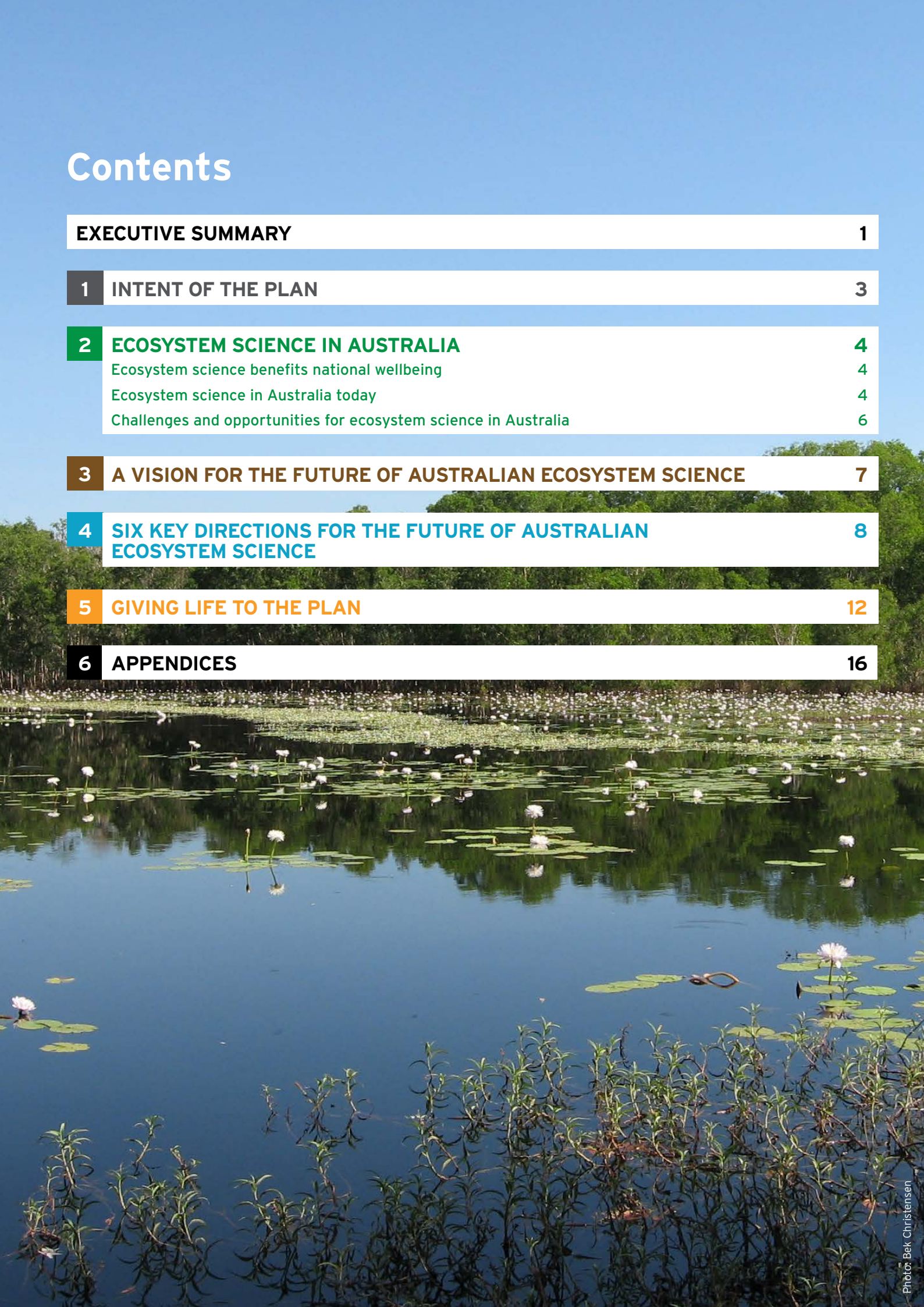


Photo: Bek Christensen

Executive Summary

Our natural and managed ecosystems form the world we live, play and work in; the settings for our industry; and the distinctive natural heritage that characterises the Australian nation. They are the basis of our current and future prosperity, and our national wellbeing.

However, growing human populations, continuing habitat loss, moving climate zones and increasing global competition for resources are applying unprecedented and cumulative pressures to Australian ecosystems. A strong and sustainable Australian ecosystem science enterprise is vital for understanding and securing these ecosystems in the face of current and future challenges. This Plan defines the vision and key directions for a national ecosystem science capability that will enable Australia to understand and effectively manage its ecosystems for decades to come.

The Plan's underlying theme is that **excellent science** supports a range of activities, including **public engagement**, that enable us to understand and maintain **healthy ecosystems**. Those healthy ecosystems are the cornerstone of our social and economic wellbeing.

The vision guiding the development of this Plan is that in twenty years' time the status of Australian ecosystems and how they change will be widely reported and understood, and the prosperity and wellbeing they provide will be secure. To enable this, Australia's national ecosystem science capability will be coordinated, collaborative, and connected. Knowledge from ecosystem science will be available and essential to government, industry, the general public, and for research and educational institutions.

The Plan grows from extensive engagement across the diverse ecosystem science community, and expresses its collective voice for the first time. It is based on an extensive set of collaboratively generated proposals from national town hall meetings that also form the basis for its implementation. The strong connections fostered through the development of this Plan have brought us to the threshold of a new era of collaborative effort in ecosystem science across the country.

Some directions within the Plan are for the Australian ecosystem science community itself to implement, others will involve the users of ecosystem science and the groups that fund ecosystem science.

We identify six equal priority areas for action to achieve our vision:

Delivering maximum impact for Australia: enhancing relationships between scientists and end-users

Improved communication and collaboration between ecosystem scientists, and people who can use the knowledge and other outputs generated by ecosystem science.

Supporting long-term research

Dedicated funding for long-term (a decade or longer) ecosystem research, complementing existing support for short-term research.

Enabling ecosystem surveillance

Development of systematic, continental-scale monitoring of essential ecosystem variables that reflect the health of our ecosystems.

Making the most of data resources

Sustained infrastructure and capacity for consistent collection, publication and archiving of ecosystem science data sets and meta-data in standard, easily accessible formats in publicly accessible websites.

Inspiring a generation: empowering the public with knowledge and opportunities

A general public that is inspired, informed and empowered with knowledge and understanding of Australian ecosystems.

Facilitating coordination, collaboration and leadership

A more collaborative and coordinated ecosystem science community including the formation of an 'Ecosystem Science Council' to offer leadership to implement the Plan, working with all relevant discipline areas, organisations, societies, and professions.

This shared vision will enable us to consolidate our current successes, overcome remaining barriers, and establish the foundations to ensure Australian ecosystem science delivers for the future needs of Australia. In doing this, we can put in place today the strategies and actions that will ensure we have the evidence, knowledge and skills to meet the needs of the Australian community tomorrow, and for years to come.

Photo: Glenda Wardle

1 Intent of the Plan

This Plan sets out the vision, key directions and priorities for Australian ecosystem science over the coming decades. This time scale is required to effect the cultural change required to implement the Plan. It recognises the need for long-term (more than 10 years) commitment to supporting activities that study ecosystem dynamics due to the time scales over which our ecosystems change.

The Plan's underlying theme is that excellent science supports a range of activities, including public engagement, that enable us to understand and maintain healthy ecosystems. Those healthy ecosystems are the cornerstone of our social and economic wellbeing.

The Plan was developed to:

- **Establish a basis for improved and continuing leadership**, coordination and collaboration across the ecosystem science community;
- **Establish an enduring process** that provides a cohesive, nationally representative 'voice' from the ecosystem science community;
- **Collaboratively identify clear priorities and directions** for the future, and the actions needed to support those; and
- **Produce a 'live' resource** that can be used to advise and direct activities in ecosystem science and management, and enable its long-term use in policy and decision making in government and industry.

The Plan has been developed through extensive consultation and engagement with the wide diversity of people who make up the Australian ecosystem science community (see Appendix 1). It represents their concerns, priorities, and hopes for the future of ecosystem science, of Australia's ecosystems and of the country's national wellbeing. The collaborative development of this Plan in itself is a significant achievement for Australian ecosystem science, as it is the first time the collective 'voice' of this diverse community – which encompasses all science that contributes to the understanding of ecosystems – has been achieved, captured and shared.

This Plan is intended to inspire and direct the efforts of the Australian ecosystem science community for years to come. It is also intended to provide insight for the key groups that enable and influence ecosystem science – the private sector, the Commonwealth, our State agencies, and our universities. Many of the goals and recommendations outlined in this document will require the engagement and support of these bodies over the coming decades.

Looking forward to 2035 the Plan sets broad long-term priorities, but also identifies the first short-term steps that will be needed to make meaningful progress towards these priorities. More detailed planning will be undertaken by the ecosystem science community to ensure successful implementation of actions in both the short (1-5 years) and long (more than 10 years) term.

"Healthy ecosystems are the cornerstone of our social and economic wellbeing."

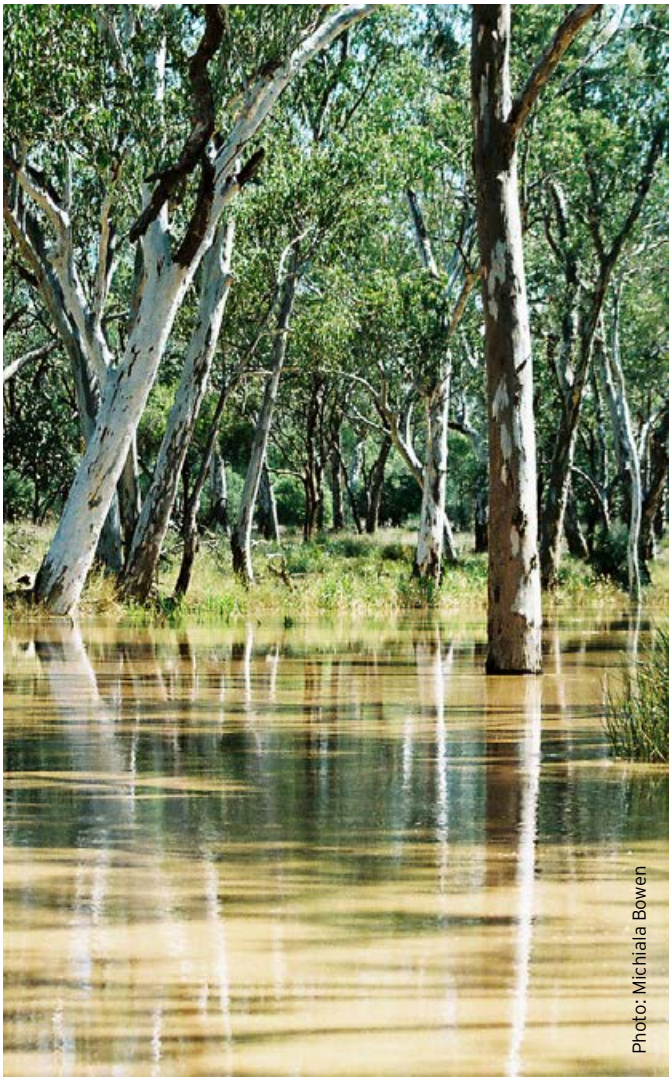


Photo: Michiala Bowen

2 Ecosystem science in Australia

ECOSYSTEM SCIENCE BENEFITS NATIONAL WELLBEING

Australian ecosystems encompass landscapes, coasts and marine areas, the living things that occupy them, their water, soils and atmosphere, and the dynamic interactions among all of these parts. Ecosystems occupy natural, agricultural and urban settings. They provide the environments where we live, play and work; the settings for our industry, agriculture, fisheries, tourism and resource extraction; and the distinctive flora and fauna that characterise the Australian continent.

Globally, the benefit from ecosystem services has been valued at approximately $125 trillion per year compared to a global GDP of $75 trillion[1]. This means that if we assess how natural capital is used in conjunction with built capital, social capital and human capital, ecosystem services make a contribution to human wellbeing that is at least as great as the contribution from traded goods and services. Australian governments over the past two decades have recognised ecosystems and their sustainability as high research priorities.

Many disciplines contribute to ecosystem science (Figure 1). Our national capability combines four types of activity: (i) observations and data acquisition; (ii) analysis of processes and mechanisms, including manipulative field experiments; (iii) synthesis across multiple processes and space-time scales, often by modelling; and (iv) support for decision-making. These four scientific activities reinforce each other and integrate across all activities required to ensure ecosystem health.

Ecosystem science delivers benefits for Australia in a range of contexts. For example, ecophysiology informs production of food crops, fibre and timber. Population dynamics underpins programs for pest control, fisheries, wildlife management and conservation. Biogeochemistry is a basis for tracking carbon storage, managing wildfire fuel, maintaining soil health, food security and water yields, and reducing erosion, nutrient runoff and algal blooms.

ECOSYSTEM SCIENCE IN AUSTRALIA TODAY

Australia has a proud history in ecosystem science. Australia was the fifth-ranked nation worldwide in Ecology and Environment for total citation influence 2003-13[2]. Eight Australian universities were rated 'well above world standard' in ecology, ecological applications, or environmental science and management through the national research excellence assessment (ERA) in 2012. Within the Commonwealth Scientific and Industrial Research Organisation (CSIRO), environment and ecology is one of the four highest-ranked areas of publication impact[3].

A wide range of groups undertake ecosystem research in Australia. Almost all Australian universities have ecosystem research activity. There are public research agencies at both State/Territory and Commonwealth[4] levels, and also bodies responsible for particular environments that have research arms as well as management arms[5]. Traditional owners contribute indigenous knowledge and are involved in environmental management. Private firms, for example in the resources industry, may conduct some research internally as well as contracting with universities or agencies for research. Similarly, regional natural resource management groups, catchment management authorities, non-government organisations[6] and community groups may involve themselves in research directly as well as by sponsoring research.

Most research involves some form of partnership with stakeholders and end-users, and much also involves financial contribution from industry. In recent years the level of ecosystem science activity in the Higher Education sector has been roughly equal to the level of ecosystem science activity in Commonwealth and State governments combined[7]. Total ecosystem science expenditure is a comparatively small fraction of the value of ecosystems and the services they provide.

Photo: Nicholas Webb

"Ecosystem science delivers benefits for Australia in a range of contexts"

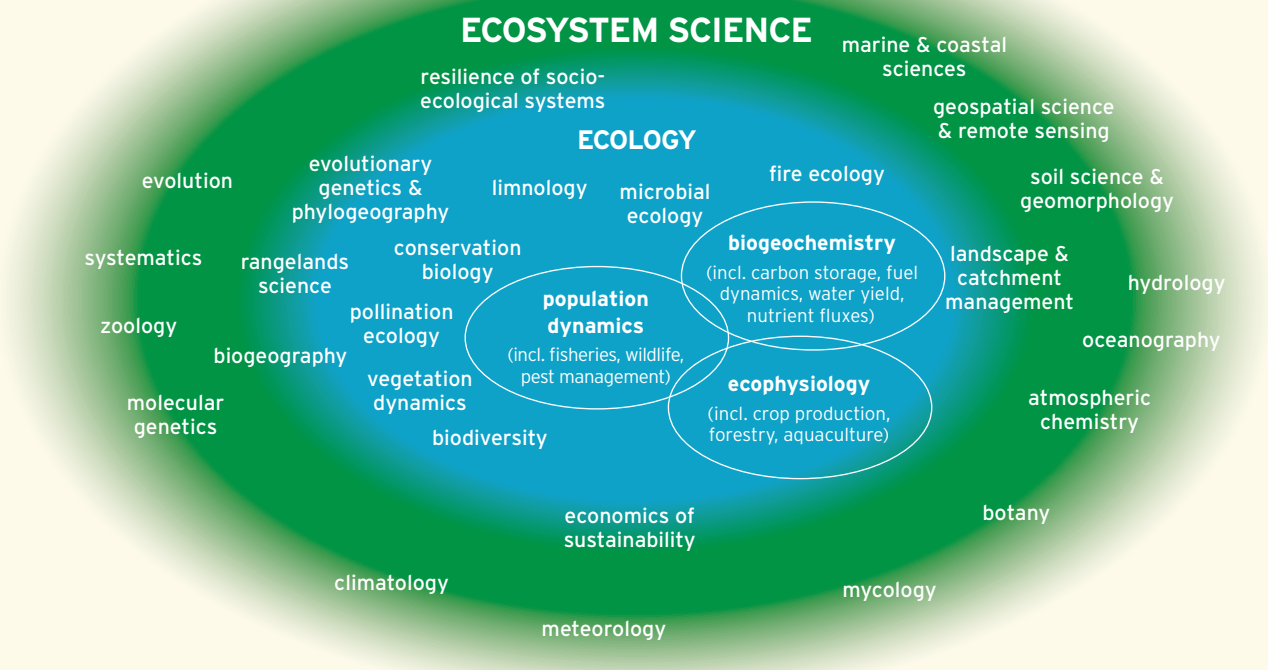


FIGURE 1: Ecosystem science draws on a large number of disciplines, some of which are shown here. Some are applied and others are basic sciences. They work across terrestrial, marine, freshwater, coastal and atmospheric domains. They study plants, animals and microorganisms in each of these settings. They can link together via ecology, including its three main sectors of population dynamics, biogeochemistry and ecophysiology.

SNAPSHOT

Understanding reef condition in the Great Barrier Reef

Australia's Great Barrier Reef is one of the seven wonders of the natural world, globally recognised as an Australian icon, and makes an economic contribution of over $5 billion annually[i]*. Ongoing monitoring of the reef and its condition by ecosystem scientists plays a vital role in understanding pressures and informing the development of management strategies. Annual surveys to measure coral cover across the Great Barrier Reef since 1985 have built the world's most extensive time series data on reef condition across 214 reefs. Researchers have used this long-term data to assess patterns of change and to determine the causes of change such as tropical cyclones, coral bleaching events, and disturbances due to Crown of Thorns Starfish*[ii]*. Understanding the causes of change helps management agencies like the Great Barrier Reef Marine Park Authority to develop targeted strategies to respond to threats to the reef. They can also use this knowledge to evaluate and adjust management actions over time, ultimately enhancing the long-term protection of the reef.*

[i] http://www.environment.gov.au/system/files/resources/a3ef2e3f-37fc-4c6f-ab1b-3b54ffc3f449/files/gbr-economic-contribution.pdf

[ii] More information: De'ath G, Fabricius KE, Sweatman H, and Puotinen M. (2013) The 27-year decline of coral cover on the Great Barrier Reef and its causes. Proceedings of the National Academy of Science, 2013: 1208909109v1-201308909. doi:10.1073/pnas.1208909109

CHALLENGES AND OPPORTUNITIES FOR ECOSYSTEM SCIENCE IN AUSTRALIA

Growing human populations, continuing habitat loss, moving climate zones and increased global competition for resources are applying unprecedented and cumulative pressures to Australian ecosystems. The future will demand new depth of understanding to manage faster-changing systems sustainably. Although Australian ecosystem science is already successful within Australia and influential on the world stage, we can do better than the status quo, and we will need to.

Long-term perspective is a key ingredient missing from the Australian research mix. Many ecosystem processes play out over decades to centuries. So for ecosystem science it is especially important to take a long view, with some projects providing consistency and continuity over very long time scales. Yet long-term projects should be only one component within an overall research strategy, and by no means the majority. Ecosystem science should remain agile to respond to new knowledge and circumstances. Fresh ideas about mechanisms, fresh models or fresh management priorities can replace older ideas within 3-5 year time scales.

Science culture worldwide is moving towards 'open access' data management. Benefits include reduced duplication, increased opportunities for re-use, new insights from cross-discipline collaboration, a better-organised evidence base for end-users and a more transparent research process. The Australian ecosystem science community similarly is taking steps toward increased data sharing. Continued steps along this path will be important.

New capacities are emerging from areas like genomics, environmental sensing both from satellites and at close quarters, machine learning and data synthesis, and from citizen-science initiatives where anyone with a mobile device can collect and contribute some types of ecosystem data. Through facilities[8] within Australia's National Collaborative Research Infrastructure Strategy (NCRIS) open access infrastructure is being established including continuing field sites, environmental monitoring systems, informatics facilities, and mechanisms for knowledge exchange across science and policy arenas. These community-wide activities work in powerful synergy with the mainstream of individual research projects pursued by individuals and small teams. They make each project more efficient by providing background data. They strengthen application of the nation's ecosystem evidence base to wider spatial scales and longer time scales, and link it more strongly to end-users. If these community-wide resources can develop a dependable continuing presence, their adoption will accelerate and benefits from them will flow faster.

In summary, there is opportunity to add specific new strands to Australia's ecosystem science research mix that can work together with established strengths and build stronger capability for tomorrow.

SNAPSHOT

Managing fire in the Australian landscape

Wildfires impact almost every facet of life in Australia, and activities in ecosystem science help us better understand how fires behave in Australian ecosystems and to develop fire management strategies. These activities range from the use of satellite image data to map and monitor fire at landscape scales, to direct field observations and experiments, to modelling of the ways that fires interact with different ecosystems. Alongside this, historic information and indigenous knowledge are integrated with new knowledge to expand our understanding of fire.

Environmental managers and agencies can use this knowledge to develop fire management strategies that help to protect ecosystems and public safety. Just one example is the Landscape Conservation Initiative[i] in Western Australia's iconic Kimberley region, where large wildfires can threaten the natural qualities of the area. Using improved knowledge of the interaction between ecosystems and wildfire, a number of management initiatives have been implemented to reduce the damaging effects of late season wildfires.

[i] http://www.dpaw.wa.gov.au/management/kimberley-strategy/conserving-the-unique-kimberley-environment/164-the-landscape-conservation-initiative

[1] Costanza R, de Groot R, Sutton P, van der Ploeg S, Anderson S, Kubiszewski I, Farber S, Turner RK (2014) Changes in the global value of ecosystem services. Global Environmental Change 26: 152-158. http://dx.doi.org/10.1016/j.gloenvcha.2014.04.002. Amounts are USD.

[2] Thompson-ISI Essential Science Indicators 14 Feb 2014

[3] CSIRO's Science Health and Excellence: summary of key findings 2012-13. CSIRO 2014

[4] For example the CSIRO, Australian Institute of Marine Science, Geoscience Australia, Bureau of Meteorology, Australian Nuclear Science and Technology Organisation, and the various state herbaria and natural history museums.

[5] For example at Commonwealth level the Great Barrier Reef Marine Park Authority, Murray-Darling Basin Authority, Australian Antarctic Division, and Parks Australia; at state level all the agencies responsible for lands, water, forestry and fisheries.

[6] For example Birdlife Australia, Landcare, Australian Conservation Foundation, Australian Wildlife Conservancy, Greening Australia, Earthwatch, Bush Heritage

[7] Based on best available data from the Australian Bureau of Statistics for 2011-2012 (Government) and 2010 (Higher Education) using Field of Research (FOR) Codes '05 Environmental Sciences' and '0602 Ecology', research activity in Higher Education sector valued at $339M, Commonwealth Government $239M, and State and Territory governments $105M. Other FORs encompass activity relevant to ecosystem science (e.g. oceanography), however were excluded as we are not in a position to estimate what share of their expenditure should be attributed to ecosystem science. At the time of writing data were not available for research conducted with private non-profits, private enterprise and consultancy firms. Total research expenditure across all FORs in Government and Higher Education sectors for these years was $11 000 – 12000 M per year.

[8] Notably the Terrestrial Ecosystem Research Network, the Integrated Marine Observing System, the Atlas of Living Australia, BioPlatforms Australia and the Australian National Data Service

3 A vision for the future of Australian ecosystem science

VISION STATEMENT

Our aspiration is that by 2035, the status of Australian ecosystems and how they change will be widely reported and understood, and the prosperity and wellbeing they provide will be secure. To enable this, Australia's national ecosystem science capability will be coordinated, collaborative, and connected. Knowledge from ecosystem science will be available and essential to government, industry, the general public, and for research and educational institutions.

Our vision for Australia 20 years from now is a society with a wide-ranging appreciation of terrestrial, marine and freshwater ecosystems. Scientific knowledge provides the basis for an increased public understanding about ecosystems - how they operate, what goods and services they provide, what threatens them. Just as medical science is used to inform the community and protect the health of people in our society, ecosystem science provides the basis for protecting the health of our ecosystems and supporting national wellbeing and prosperity.

Decisions about how ecosystems are used and managed will flow from effective policies to ensure we support current human populations and secure future community prosperity. Realisation of the vision will benefit Australian society through sustaining the essential environmental services we rely upon (Figure 2).

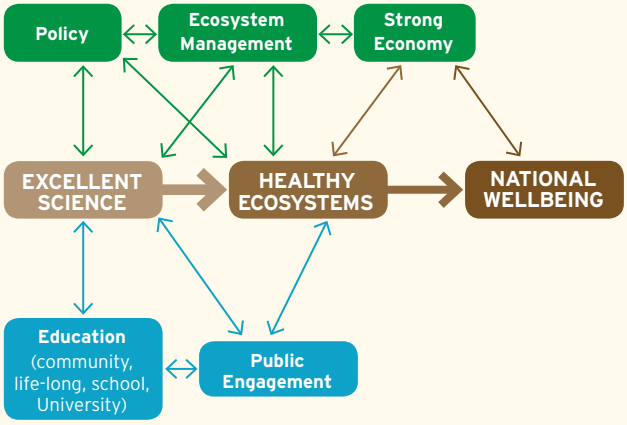


FIGURE 2: This diagram outlines the relationships among the components that form the basis for our vision. This Plan identifies priorities for building excellent science that supports a range of activities, including public engagement, that collectively enable us to understand and maintain healthy ecosystems. A range of other activities link with these components, ultimately influencing national wellbeing.

"By 2035 the status of Australian ecosystems will be widely understood"


Photo: Suzanne Long

4 Six key directions for the future of Australian ecosystem science

Australian ecosystem science has a strong history, and exciting opportunities lie ahead. The need has never been greater for ecosystem science to deliver the evidence, knowledge and tools to respond to the current issues and future trials facing the protection and sustainable use of Australia's ecosystems.

The six key directions outlined below have been identified through extensive consultation with the Australian ecosystem science community through surveys, town hall workshops, and online contributions (see Appendix 1). The directions connect with the three key themes of the vision: excellent science, public engagement, and healthy ecosystems.

All directions deserve equal attention as an integrated package. Recommended actions to be taken in support of these directions are outlined in Section 5 'Giving Life to the Plan'.

DELIVERING MAXIMUM IMPACT FOR AUSTRALIA: ENHANCING RELATIONSHIPS BETWEEN SCIENTISTS AND END-USERS

PRIORITY

Improved communication and collaboration between ecosystem scientists, and people who can use the knowledge and other outputs generated by ecosystem science.

An ongoing challenge in the implementation of ecosystem science has been the delivery of relevant scientific output in ways that are meaningful and useful for end-users of science, such as environmental managers and policy-makers. There is often a lack of effective communication between researchers and end-users, with the consequence that business, management and policy decisions are often not based on the best science, and science is not focussed on priorities for end-users. Stakeholder input throughout the development of this Plan indicated that both scientists and end-users often have limited understanding of the context and limitations that each party works within. Despite these challenges, some projects have had great success in delivering useful science in ways that have impact and meaning for end-users.

Ecosystem science needs to deliver meaningful outcomes and impact to ensure that it contributes to healthy ecosystems and national wellbeing. There are no easy solutions, and effective interactions between researchers and end-users are essential in achieving this goal.

SUPPORTING LONG-TERM RESEARCH

PRIORITY

Dedicated funding for long-term (a decade or longer) ecosystem research, complementing existing support for short-term research.

Many ecosystem processes operate over decades to centuries, yet so far the nature of ecosystem research in Australia has been overwhelmingly short-term and focussed on questions that can be answered by single projects in the context of 3-5 year or shorter funding cycles. The relatively few long-term research projects have been especially valuable in advancing our understanding of Australian ecosystems in ways that were not previously possible[9].

Long-term studies can be particularly important for distinguishing impacts of human activities from the impacts of natural variability. This is especially important for Australia, given that our climate is so highly variable.

The existing 3-5 year research funding schemes should be continued. Indeed, work funded through such schemes has already put Australia at the leading edge of research in this area. But there is also a pressing need to support longer term studies that give perspective to the short-term projects. There are successful international examples of long-term funding programs for ecosystem research that could serve as models for Australia.

[9] An excellent example of this is a 27-year study of coral cover in the Great Barrier Reef: De'ath G, Fabricius KE, Sweatman H, and Puotinen M. (2013) The 27–year decline of coral cover on the Great Barrier Reef and its causes. Proceedings of the National Academy of Science 2013: 1208909109v1-201308909. DOI:10.1073/pnas.1208909109

Photo: Bek Christensen

ENABLING ECOSYSTEM SURVEILLANCE

PRIORITY

Development of systematic, continental-scale monitoring of essential ecosystem variables that reflect the health of our ecosystems.

Our ecosystems are vital national assets, and can only be effectively managed if we have an ongoing capacity to track and monitor their status. Future generations of Australians will need access to this information to understand patterns of change and ongoing ecosystem processes, and to make informed decisions about the use and management of land- and sea-scapes. Australia has many ecosystem monitoring programs focussed on particular management issues. However, we have very few long-term ecosystem data sets collected over areas larger than catchments or states, at regular time periods, and in a standardised manner in the context of long-term surveillance. We have no national system for the analysis, evaluation and reporting of ecosystem measurements. Indeed, there is currently no consensus on what aspects of ecosystems should be measured, or on what methods to employ for measuring ecosystem health. This is in stark contrast to our well-established weather-station network, our census of households and our reporting of economic indicators.

MAKING THE MOST OF DATA RESOURCES

PRIORITY

Sustained infrastructure and capacity for consistent collection, publication and archiving of ecosystem science data sets and meta-data in standard, easily accessible formats in publicly accessible websites.

Australia needs sustained infrastructure and capacity-building to maintain and facilitate the publication of and access to ecosystem science data. We can get better value from our collective data resources by properly describing and storing data in ways that enable discovery, access and re-use. Significant gains have been made in recent years, but there is currently no coordinated national strategy for collecting, storing and accessing core ecosystem science data across terrestrial, aquatic and atmospheric domains. Moving Australian ecosystem science to a position of open access to both historical and current data can enable research communities to build time series at a scale well beyond that which they could achieve individually. Synthesis, analysis and modelling of collective data will help to deliver essential outputs for government, industry and society.

INSPIRING A GENERATION: EMPOWERING THE PUBLIC WITH KNOWLEDGE AND OPPORTUNITIES

PRIORITY

A general public that is inspired, informed and empowered with knowledge and understanding of Australian ecosystems.

Healthy ecosystems play a key role in the production and delivery of food, clean air and water, as well as the survival of our iconic plants and animals. Indigenous Australians recognise this value through their deep connection with country. However, many people do not fully appreciate the link between ecosystems and the goods and services they provide, nor do they understand the threats that ecosystems face.

To put the Australian community in a position to make judgements and decisions about the use and management of their ecosystems, they need to be engaged with and informed about these ecosystems. Better engagement of the Australian community with ecosystems and ecosystem science requires a fresh effort to develop and harness talent in the ecosystem science community to inspire, inform and empower the wider community with knowledge and understanding of their world, and their role in it. Integration of indigenous and western knowledge will ensure a broad approach to understanding ecosystems.

FACILITATING COORDINATION, COLLABORATION AND LEADERSHIP

PRIORITY

A more collaborative and coordinated ecosystem science community including the formation of an 'Ecosystem Science Council' to offer leadership to implement the Plan, working with all relevant discipline areas, organisations, societies, and professions.

Australia's ecosystem science research is conducted by many organisations operating at spatial scales ranging from local to global. The ecosystem science community includes many professional societies and bodies for specific disciplines and areas of interest. A range of government agencies in the states, territories and Commonwealth undertake ecosystem science activities, and make decisions concerning ecosystem science and management. This diverse community offers a wealth of knowledge and perspectives for ecosystem science and management.

Enhanced integration across previously silo-ed disciplines and organisations would bring significant national benefit. A new body is needed to facilitate this, acting as a forum where different disciplines and organisations can determine how best to collaborate, as a national voice that can speak for ecosystem science as a whole, and to coordinate the many specific initiatives that will arise from this Plan.

The development of this Plan was grounded in collaboration, with an open and transparent consultation process that engaged the full diversity of the Australian ecosystem science community (see Appendix 1). Continuing to build this collaborative approach to ecosystem science and the coordination of ecosystem science in Australia will be important to implement the key directions highlighted here, and to make the most of the talent and resources available to Australian ecosystem science.

Photo: Bek Christensen

5 Giving life to the Plan

This section presents the guiding process for the implementation of the Plan (Figure 3), the interconnections and major activities needed across the six directions (Figure 4), and the key actions for implementation in the first five-year period.

The key principles guiding the development of this Plan have been openness, inclusivity and transparency through clear communication. These are essential for cohesion and shared vision across the community of researchers, empowering active involvement and collaboration. By pulling in the same direction towards our shared vision, we establish foundations to address challenges and sustain ecosystem science into the future.

The implementation phase of the Plan will remain a consultative and collaborative process, shaped by the agreed content of this Plan, but responsive to new input and circumstances. The invitation to participate will be disseminated widely as part of ongoing communication with the ecosystem science community. This open and transparent communication will ensure our collective vision stays focused into the future.

Implementation of the Plan requires its activities to be staged over shorter time intervals with set milestones to monitor progress. Some of the key actions are for the research community itself to carry forward; others will need input and involvement of government(s) and other groups. An overview of the proposed actions is provided in Figure 4, with further detail and outcomes listed in Table 1.

FIGURE 3: Guiding process for implementation, monitoring and review of the Plan. The strategy for delivering the outcomes of the Plan reflects the consultation and leadership process followed to establish the basis for the plan.

SNAPSHOT
Improving liveability of Australian cities

More than 70% of Australians live in major cities[i]. Ecosystem scientists measure temperature and other climatic properties within cities to understand where high and low temperatures occur and where stormwater run-off is highest. This information is used to examine the affects that increasing urban tree cover and 'green spaces' have on temperature extremes and runoff.

Knowledge from these monitoring and modelling programs is used in several major Australian capital cities to implement tree planting or green roof/wall programs that increase shade, reduce temperature extremes, reduce run-off, and increase habitat and biodiversity[ii]. This results in cities with reduced temperature extremes, increased visual amenity of streetscapes, increased biodiversity and urban wildlife habitat, decreased stormwater runoff, and reduced energy consumption. And at the end of the day that means cities that are more healthy and easy for us all to live in.

[i] As at June 2013, Australian Bureau of Statistics

[ii] For example: http://www.brisbane.qld.gov.au/environment-waste/natural-environment/plants-trees-gardens/brisbanes-trees/brisbanes-urban-forest and http://watersensitivecities.org.au/resource-library/publication-download/

FIGURE 4: Some of the major, interconnected activities needed to implement the key directions identified in this Plan. One of the priorities that will support all other achievements is to establish coordination, collaboration and leadership, and this is shown by the overarching link to all other priorities.

During the Plan's development there were clear directives from the ecosystem science community for making fresh efforts towards long-standing challenges. For each priority there will be an assessment or review of current capabilities in each area followed by a process that develops recommendations and seeks appropriate resources. As these priorities will be progressed in parallel in an open and inclusive manner there is scope for wide participation and collaboration with existing programs and groups.

Alongside the wealth of ideas and proposals submitted through the consultation for this Plan, the next steps outlined in Table 1 set a course for changing the future of Australian ecosystem science. These actions will be first steps toward outcomes to be achieved over a twenty-year time period and beyond.

After the initial five years, this Plan and progress towards the key directions will be reviewed in consultation with the ecosystem science community, to enable us to adjust as needed and continue working towards our shared vision.

"The implementation phase of the Plan will remain a consultative and collaborative process"

TABLE 1: Key directions, priorities, long-term outcomes and key actions arising from this Plan

KEY DIRECTION AND PRIORITY	LONG-TERM OUTCOME (BY 2035)	KEY ACTIONS FOR FIRST 5 YEARS
Delivering maximum impact for Australia: enhancing relationships between scientists and end-users **Priority** Improved communication and collaboration between ecosystem scientists, and people who can use the knowledge and other outputs generated by ecosystem science	Improved interactions and knowledge exchange between producers and users of ecosystem science to strengthen management and policy.	1. **Identify elements of success, and pitfalls** to avoid, from previous interactions and experiences in knowledge exchange between researchers, practitioners and policy-makers working in ecosystem science and management. 2. **Generate advice and guidelines** for designing and implementing science activities that enhance mutual understanding and knowledge exchange between researchers, practitioners and policy-makers in the context of ecosystem science. 3. **Implement targeted projects** to enhance synthesis and integration across groups working on critical ecosystem issues. 4. **Advocate for improved training** in science communication at undergraduate and postgraduate levels. 5. **Develop new models** for identifying research priorities across universities, government and industry.
Supporting long-term research **Priority** Dedicated funding for long-term (a decade or longer) ecosystem research, complementing existing support for short-term research	Mechanisms to support long-term studies of processes and dynamics in Australian ecosystems.	1. **Review funding models from around the world**, alongside current Australian arrangements, and develop recommendations about how selected long-term ecosystem research can be dependably supported in Australia. 2. **Advocate recommendations** to appropriate government and other relevant parties.
Enabling ecosystem surveillance **Priority** Development of systematic, continental-scale monitoring of essential ecosystem variables that reflect the health of our ecosystems	Systematic, continental-scale monitoring of essential ecosystem variables that reflect the health of our environments.	1. **Catalogue and assess existing ecosystem monitoring programs** that have potential for contributing to ecosystem surveillance. This assessment is to be collaborative across local, state and national agencies and organisations, across different disciplines, and across terrestrial, freshwater, atmospheric and marine domains. 2. **Discuss widely the options and priorities**. Consistency and continuity of monitoring will be the priority as the aim is for future generations to be in a position to look back objectively over past changes. To achieve continuity over 100 years or more, proposals need to be modest enough that sustained bipartisan government commitment can be forthcoming. Alternatives could be developed adapted to different levels of resourcing. Our commitment is to resolve internal debates about what to measure, and to bring forward agreed proposals. 3. **Advocate to relevant parties** for implementation and long-term support of proposed surveillance program.
Making the most of data resources **Priority** Sustained infrastructure and capacity for consistent collection, publication and archiving of ecosystem science data sets and meta-data in standard, easily accessible formats in publicly accessible websites.	National infrastructure facilitates consistent collection, publication and archiving of ecosystem science data sets and meta-data in standard, easily accessible formats in publicly accessible websites. Active programs to synthesise the evidence base and apply it to policy and management.	1. **Assess current national capability** for ecosystem data publishing, archiving and management, identifying existing infrastructure, training programs, and other activities. 2. **Specify requirements for the future** including infrastructure, support personnel, and training activities needed. 3. **Develop a proposal to bridge gaps** to desired future capability, using current infrastructure, programs and people as a foundation. 4. **Advocate for implementation and long-term support** of proposed infrastructure, programs and people.

TABLE 1: Key directions, priorities, long-term outcomes and key actions arising from this Plan *(cont.)*

KEY DIRECTION AND PRIORITY	LONG-TERM OUTCOME (BY 2035)	KEY ACTIONS FOR FIRST 5 YEARS
Inspiring a generation: empowering the public with knowledge and opportunities **Priority** A general public that is inspired, informed and empowered with knowledge and understanding of Australian ecosystems	The value of healthy ecosystems, and the science underpinning that, is recognised by society at large. This understanding secures a long-term foundation for healthy ecosystems and national wellbeing.	1. **Identify elements of success, and pitfalls** to avoid, from past experiences of informing, inspiring and engaging the general public about ecosystems and/or ecosystem science. 2. **Across the country, assess the way that ecosystem science is addressed in schools** (primary and secondary) and develop recommendations for strengthening both curriculum and delivery, drawing upon the many ideas included in the proposals produced during development of this Plan. 3. **Implement targeted projects** identified amongst the proposals produced during the development of this Plan. 4. **Advocate for improved training** in science communication at undergraduate and postgraduate levels.
Facilitating coordination, collaboration and leadership **Priority** A more collaborative and coordinated ecosystem science community including the formation of an 'Ecosystem Science Council' to offer leadership to implement the Plan, working with all relevant discipline areas, organisations, societies, and professions	Australia's national ecosystem science capability will be coordinated, collaborative and connected across all relevant discipline areas, organisations, societies, and professions. Through open communication and collaboration the ecosystem science community will tackle challenges and implement activities to deliver excellent science and engage the public to maintain healthy ecosystems.	1. **Maintain the Plan's website** (www.ecosystemscienceplan.org.au) to enable open communication, engagement and sharing of ideas and information. 2. **Approach relevant professional societies**, organisations and agencies to discuss the Plan's key recommendations, and opportunities for ongoing input and involvement from these groups. 3. **The existing Steering Committee will oversee formation of a National Ecosystem Science Council** to lead implementation of priorities and actions outlined in this document. Similar organisations in other science communities include Astronomy Australia Ltd., the Australian Earth Observation Coordination Group, and the Ocean Policy Science Advisory Group. The Steering Committee will draft Terms of Reference, Council Composition, Operating Guidelines, and an Annual Review process for the Council, which will start operating in January 2015. 4. **The newly formed Ecosystem Science Council will establish action plans** and expert working groups to deliver on the priorities and actions outlined here. 5. **Every five years the Ecosystem Science Council will implement a review of the Plan** and evaluation of progress to date, leading to a revised plan of activities for the following 5 years.

SNAPSHOT
Informing the kangaroo harvest

Kangaroos are harvested across Western Australia, South Australia, New South Wales and Queensland as a means of pest control and for sale of skins and meat. Working in both Commonwealth and State Government agencies, ecosystem scientists use population models together with annual aerial surveys of kangaroos to predict expected numbers of kangaroos year-to-year across Australia. This knowledge is used to establish a harvest quota for each state in each year that maintains kangaroo populations within sustainable limits and provides a viable harvest for Australia's commercial kangaroo harvest export industry[i]. The use of ecosystem science to monitor and model kangaroo populations underpins the sustainability and continuity of the kangaroo harvest, and is part of the reason that the Australian kangaroo harvest is viewed globally as a leading example of wild harvest operations.

[i] For more information see http://www.environment.gov.au/system/files/resources/11b7d7c8-7a25-45fc-81ea-f672e14d1fec/files/kangaroo-harvest-factsheet.pdf

6 Appendices

6.1 CONSULTATION BEHIND THE PLAN

The process to develop this Plan was designed to capture the full breadth of views and ideas from across the ecosystem science community in Australia. It was grounded on principles of openness, inclusivity and transparency. A range of opportunities were provided for any interested person or group to have input, and care was taken to ensure that the final product reflected the combined input and contributions from across the community.

Leadership for the development of the Plan stemmed originally from a small group of like-minded individuals from across the Terrestrial Ecosystem Research Network (TERN), Ecological Society of Australia (ESA), and the Australian Academy of Science's National Committee for Ecology, Evolution and Conservation (NCEEC). These three bodies, with majority of resourcing provided by TERN, took responsibility for delivering the project, and provided the support needed to enable this.

The process used to develop the Plan was guided by a Steering Committee made up of people working in Australian ecosystem science and management across universities and research Institutions, and in State and Commonwealth organisations. Throughout the course of the project the Steering Committee membership included: Prof Stuart Phinn (Committee chair, University of Queensland, TERN Associate Science Director), A/Prof Glenda Wardle (University of Sydney), Prof Mark Westoby (Macquarie University, Chair of the NCEEC), Prof Kris French (University of Wollongong, Past President of the ESA, NCEEC member), Dr Margaret Byrne (WA Department of Parks and Wildlife, NCEEC member), Prof Andrew Lowe (University of Adelaide, TERN Associate Science Director), Prof Jason Beringer (University of Western Australia), Dr Helen Cleugh (CSIRO Marine and Atmospheric Research), Prof Peter Fairweather (Flinders University), and Dr Bek Christensen (Project coordinator, TERN). The Steering Committee developed and implemented the process to collaboratively develop this Plan (Figure A.1).

The activities undertaken to consult throughout the development of the Plan are outlined below, and fall into two broad categories: (1) Activities to share information, and (2) Activities to seek input. All outputs (e.g. survey responses, workshop reports) generated throughout the consultation and development of the Plan have been made available on the website *http://www.ecosystemscienceplan.org.au* to ensure openness and transparency.

Activities to share information

Engaging relevant organisations, professional societies, key leaders and other groups

Prior to publicly launching the process to develop the Plan, and throughout the development of the Plan, the Steering Committee approached a number of relevant professional societies, key leaders, and other groups in ecosystem science. The purpose of these communications activities was to inform these groups of progress towards the Plan, and to invite the ongoing involvement of their members as the process unfolded.

The full list of groups approached includes:

- Atlas of Living Australia
- Australasian Society for Phycology and Aquatic Botany

Figure A.1 The process used to engage Australia's ecosystem science community in developing Foundations for the future: A long-term plan for Australian ecosystem science.

- Australasian Wildlife Management Society
- Australian Antarctic Division
- Australian Coral Reef Society
- Australian Council of Environmental Deans and Directors
- Australian Entomological Society
- Australian Institute of Marine Science
- Australian Mammal Society
- Australian Marine Sciences Association
- Australian Meteorological and Oceanographic Society
- Australian Network for Plant Conservation
- Australian Rangelands Society
- Australian Society for Fish Biology
- Australian Society for Limnology
- Australian Society of Herpetologists
- Australian Wetlands, Rivers and Landscapes Centre
- Birdlife Australia
- Bureau of Meteorology
- CSIRO
- Environmental Research Institute of the Supervising Scientist
- Federal Government departments across portfolios of science, environment, industry, agriculture, forestries, fisheries
- Genetics Society of Australasia
- Geoscience Australia
- Great Barrier Reef Marine Park Authority
- Institute of Australian Geographers
- Institute of Foresters of Australia

- Integrated Marine Observing System
- Murray-Darling Basin Authority
- Office of the Chief Scientist of Australia, along with Chief Scientists for individual states and territories
- Science and Technology Australia
- Soil Science Australia
- Wet Tropics Management Authority

Public communication: website, social media and eNewsletter

To ensure easy access to information about the Plan and its development, a website was established and regularly updated at *http://www.ecosystemscienceplan.org.au.* This website remains the enduring source of information about all aspects of the Plan and its development.

Alongside this, an eNewsletter was regularly sent to subscribers to provide updates about progress towards the Plan. Twitter (@AESLTP) and Facebook (facebook.com/AESLTP) were also used to broadcast information about the Plan, and in some cases to respond to comments or enquiries from people.

An enquiry form was available on the website, along with a direct contact email, to ensure that people were able to contact the Steering Committee to ask questions or make contributions to the Plan.

Activities to seek input

Pilot workshop

Twenty-five people representing the breadth of Australian ecosystem science were invited to a pilot workshop in September 2013. The aims of this workshop were to:

1. Build a shared understanding of the open consultative process for developing this Plan; and
2. Generate the first contributions of content for the Plan to feed into this consultative process.

Participants were engaged in a series of discussions and activities to identify their key concerns for the future of Australian ecosystem science, and recommendations for priority areas of action. They also endorsed the proposed process for developing the Plan, providing advice and input on specific elements including:

- The design of the online survey
- Town hall organisation
- Formation of working groups to progress specific tasks for the Plan
- Key stakeholders and end-users to engage.

This input and feedback was used to refine the further development and consultation on the Plan.

The full report from this workshop is available at: *http://ecosystemscienceplan.org.au/Starter-workshop-report-pg27123.html*

Online survey

As a first step in gathering input for the Plan, an open online survey was conducted from November 2013 to January 2014. The purpose of this survey was to gather ideas and suggestions for ways to sustain and strengthen the future of ecosystem science in Australia in the long-term. The two principal questions asked were:

1. Why do you think ecosystem science is important for Australia?
2. What are your top three (or less) ideas for growing and strengthening ecosystem science in Australia over the next 20 years or longer?

Over 300 people from a range of organisations and all states and territories took the survey and collectively submitted over 700 ideas for the future of ecosystem science (NB - all responses were anonymous). These ideas covered a diversity of topics and approaches at a range of scales. A small working group reviewed all survey responses, and identified commonalities across the submissions. These were distilled into seven key themes for further consideration at town hall workshops:

- Data access and availability
- Ecosystem science governance
- Funding and investment
- Research agenda
- Linkage with end-users
- Education
- Other (items not clearly associated with other themes or crossing multiple themes)

The survey respondents came from a range of professional and organisational contexts (see demographic summary below). The full survey report is available at: *http://ecosystemscienceplan.org.au/Survey-pg27274.html*

Town hall workshops

A series of 'town hall' style workshops were hosted across the country to enable the ecosystem science community to contribute, discuss and refine ideas for developing the future of Australian ecosystem science. The workshops were designed to enable people to contribute their ideas, and connect these with the existing framework of themes identified through the survey. Small group activities then enabled attendees to work collaboratively in refining these ideas and developing more detailed proposals about clear actions that could be implemented to strengthen the foundations of Australian ecosystem science.

Workshops were held in:

- Auckland (EcoTas conference), 29 November 2013
- Melbourne, 4 February 2014
- Hobart, 6 February 2014
- Brisbane, 12 February 2014
- Townsville, 14 February 2014
- Adelaide, 18 February 2014
- Darwin, 21 February 2014
- Perth, 11 March 2014
- Sydney, 14 March 2014
- Canberra, 27 March 2014

A total of 293 people attended these workshops across the country, and came from a range of professional and organisational contexts (see demographic summary below). As a result of the town hall workshops, 87 proposals for future activities to strengthen Australian ecosystem science were developed. These proposals, and full details of the workshops are available at: *http://ecosystemscienceplan.org.au/Events-pg26776.html*

Online submissions

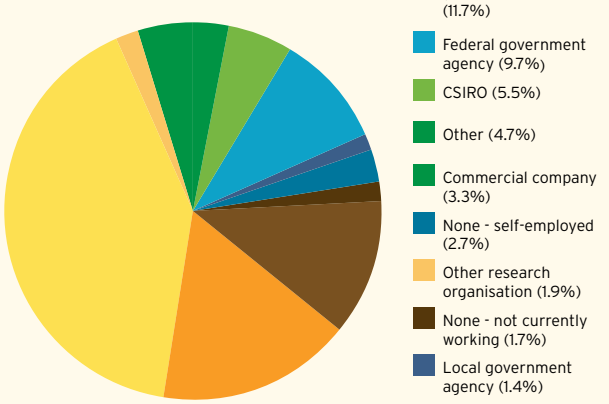
In addition to the town hall workshops, online materials and tools were published to enable individuals and groups to facilitate their own workshops and/or submit proposals online. This opportunity was given to ensure that people who could not attend the scheduled town halls were still able to share their ideas and submit input to the Plan.

Three proposals were received through this process, and are included in the full list of proposals that underpin the Plan's development. Further details on the online materials and tools are available at: *http://ecosystemscienceplan.org.au/Hold-your-own-town-hall-submit-proposals-pg28122.html*

Demographic summary

All survey and town hall registrants were given the option to provide some basic information about their work and connection with ecosystem science and management in Australia. From these data, we are able to see that people engaged in the development of the Plan covered a wide range of professional affiliations, with the majority coming from University (40.5%), State/Territory government agencies (16.6%), or non-government groups or associations (11.6%) (Figure A.2).

Figure A.2
Professional affiliations of people who participated in the online survey or town hall workshops for the Plan (n=639).



Similarly, this group of people also represent a variety of categories of work, with the majority working in research (33.7%), academia (19.1%), or natural resource management (17.2%) (Figure A.3).

Figure A.3
Categories of work of people who participated in the online survey or town hall workshops for the Plan (n=638).

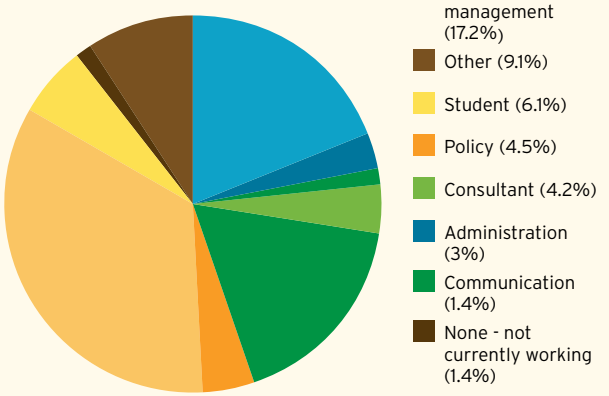



Photo: Aaron Greenville

Writing and peer review of the Plan

Parallel to the main consultation activities, a working group was formed to take responsibility for writing the Plan. The working group included: Dr Alan Andersen (CSIRO), Prof Jason Beringer (University of Western Australia), Prof Mike Bull (Flinders University), Dr Margaret Byrne (WA Department of Parks and Wildlife), Dr Helen Cleugh (CSIRO), Prof Bronwyn Harch (Queensland University of Technology), Prof Ary Hoffmann (University of Melbourne), Prof Andrew Lowe (University of Adelaide), Tim Moltmann (Integrated Marine Observing System), A/Prof Adrienne Nicotra (Australian National University), Prof Andy Pitman (University of New South Wales), Prof Stuart Phinn (University of Queensland), A/Prof Glenda Wardle (University of Sydney), and Prof Mark Westoby (Macquarie University).

The working group was tasked with monitoring the outputs from consultation activities and reviewing these to synthesise the future priorities; and was also given responsibility for writing the document itself. This group's activities commenced in December 2013, preparing a draft outline for the document and drafting background material. The group was able to monitor and in some cases participate in consultation activities across the country. On 7-8 April 2014 the group convened for a workshop to identify the future priorities, and to commence writing the Plan. The group continued their work throughout April 2014, and on 7 May submitted a draft document for peer review.

The draft document was formally reviewed by: Prof Jason Beringer (University of Western Australia), Prof Mark Burgman (University of Melbourne), Dr Margaret Byrne (WA Department of Parks and Wildlife), Prof Kris French (University of Wollongong), Prof Ove Hoegh-Guldberg (University of Queensland), Prof Lesley Hughes (Macquarie University), Assoc Prof Will Howard (University of Melbourne), Prof David Keith (University of New South Wales), Paul Lawrence (QLD Department of Science, Information Technology, Innovation and the Arts), Tim Moltmann (Integrated Marine Observing System), Dr Steve Morton (CSIRO), Prof Elaine Sadler (University of Sydney), Dr Ayesha Tulloch (University of Queensland), and Dr Brian Walker (CSIRO). The reviewers were asked for feedback on a range of criteria to assess how well the document met its aims and communicated the key messages in a clear and convincing manner. A number of other people provided informal feedback on the document, which was collated as part of the overall review. The Steering Committee and writing group considered all feedback, and incorporated this into a revision of the document that became the final version.

Photo: Forestry Tasmania