RESEARCH PRIORITIES PLAN

REVIEWED 2018

THE WESTERN AUSTRALIAN BIODIVERSITY SCIENCE INSTITUTE

The Western Australian Biodiversity Science Institute

ACKNOWLEDGEMENTS

A comprehensive review of The Western Australian Biodiversity Science Institute (WABSI) Research Plan 2017-2020 was undertaken in the latter part of 2018 in consultation with diverse stakeholders. We would like to thank the multiple people and organisations that assisted in this process.

The review incorporated what we have learned from our achievements to date and an analysis of Western Australia's biodiversity issues and priorities. The revised Plan will continue to enable us to address biodiversity knowledge gaps and meet end user needs.

OUR SUPPORTERS

Professor Michael Poole, AM
BOARD CHAIR, THE WESTERN AUSTRALIAN BIODIVERSITY SCIENCE INSTITUTE

"This Research Priorities Plan was developed as a result of extensive consultation with industry partners, not-for-profit organisations, government and representatives from the research community. It reflects the priorities and challenges they see that need to be addressed through building scientific knowledge about terrestrial biodiversity in Western Australia. WABSI has a unique role to play as we bring diverse stakeholders together to identify and fill the gaps in our collective biodiversity knowledge and share scientific information, as well as reduce duplication. This Research Priorities Plan will help deliver benefits for decades to come."

Hon. Dave Kelly, MLA
MINISTER FOR WATER; FISHERIES; FORESTRY; INNOVATION AND ICT; SCIENCE

"The Research Priority Plan aligns with Western Australia's new Science and Innovation Framework and will address our most critical biodiversity knowledge issues. By bringing together the State's leading research expertise, it will help deliver robust science whilst reducing duplication of effort."

Hon. Stephen Dawson, MLC
MINISTER FOR ENVIRONMENT; DISABILITY SERVICES

"The Research Priorities Plan 2017-2020 identifies gaps in our understanding of important biodiversity issues. The plan will guide delivery of high-quality science through collaboration and build capacity for improved decision-making, so we can achieve a balance between conservation and sustainable economic development."

Professor Peter Klinken, AC
CHIEF SCIENTIST OF WESTERN AUSTRALIA

"This Plan will contribute greatly towards building scientific knowledge as a critical asset for Western Australia. High quality information that is relevant and easily accessible will help attract investment, encourage innovation and deliver benefits for years to come."

Dr Tom Hatton
CHAIRMAN, ENVIRONMENTAL PROTECTION AUTHORITY

"This Plan will enhance Western Australia's collective biodiversity knowledge to provide a greater understanding of potential impacts. This will contribute significantly to a sound and more robust environmental impact assessment process whilst enabling the development of better policies to protect our unique biodiversity."

Gavin Price
HEAD OF ENVIRONMENT – ANALYSIS AND IMPROVEMENT, BHP

"Industry needs relevant and high quality biodiversity research to help address key challenges and deliver greater certainty for investments. The WABSI Research Priority Plan will bring together Western Australia's leading scientific capability to facilitate critical research and enable efficient access to information. It will assist us to better manage impacts and make decisions with more certainty whilst advancing societal knowledge of our State's unique biodiversity."

Vern Newton
DEVELOPMENT MANAGER, HANSON

"The Plan will deliver high quality, independent science through programs that directly address industry's most pressing knowledge needs. It will enable us to make more informed management decisions to ensure we are delivering better environmental outcomes."

Dr Blair Parsons
SCIENCE AND PROGRAMS LEADER, WESTERN REGION, GREENING AUSTRALIA

"WABSI research programs will bring leading expertise together to build and share scientific knowledge. It will not only help inform our conservation and restoration work but will also enable community to achieve more effective environmental outcomes through incorporating the values and perspectives of diverse stakeholders."

Hon. Kerry Sanderson, AC
EX-GOVERNOR OF WESTERN AUSTRALIA

"While a lot of effort is being expended to protect the State's world-renowned native plants and animals, we need to do more. Having the community and business become key partners as well as advocates, means it is a challenge I feel confident we can meet. We're very supportive of WABSI helping us better understand biodiversity across our State and building a shared resource. It will mean that our conservation areas continue as part of our heritage and contribute to our quality of life."

Colin Barnett
EX-PREMIER OF WESTERN AUSTRALIA

"Science is crucial to ensuring our rich and unique biodiversity assets are here for future generations to enjoy. At the same time, the main drivers of our economy - mineral exploration and processing, broadacre agriculture and tourism - intersect with the State's biodiversity, as does urban development."

CONTENTS

INTRODUCTION

The Western Australian Biodiversity Science Institute (WABSI) was established by the Western Australian State Government (to December 2020) to:

- Shape strategic priorities for acquiring and applying new knowledge for the management of WA's terrestrial biodiversity.
- Deliver excellence in biodiversity research by fostering active collaboration across sectors and amongst researchers.
- Ensure information is available in a form that is useful, relevant and accessible to government policy makers, industry, land managers and other relevant stakeholders.
- Act as an honest broker, linking the research capability to the needs of end users.

THE WABSI RESEARCH PRIORITIES PLAN

This document identifies key biodiversity research and translation priorities within Western Australia and the process through which this comprehensive portfolio of WABSI research was developed to address those priorities.

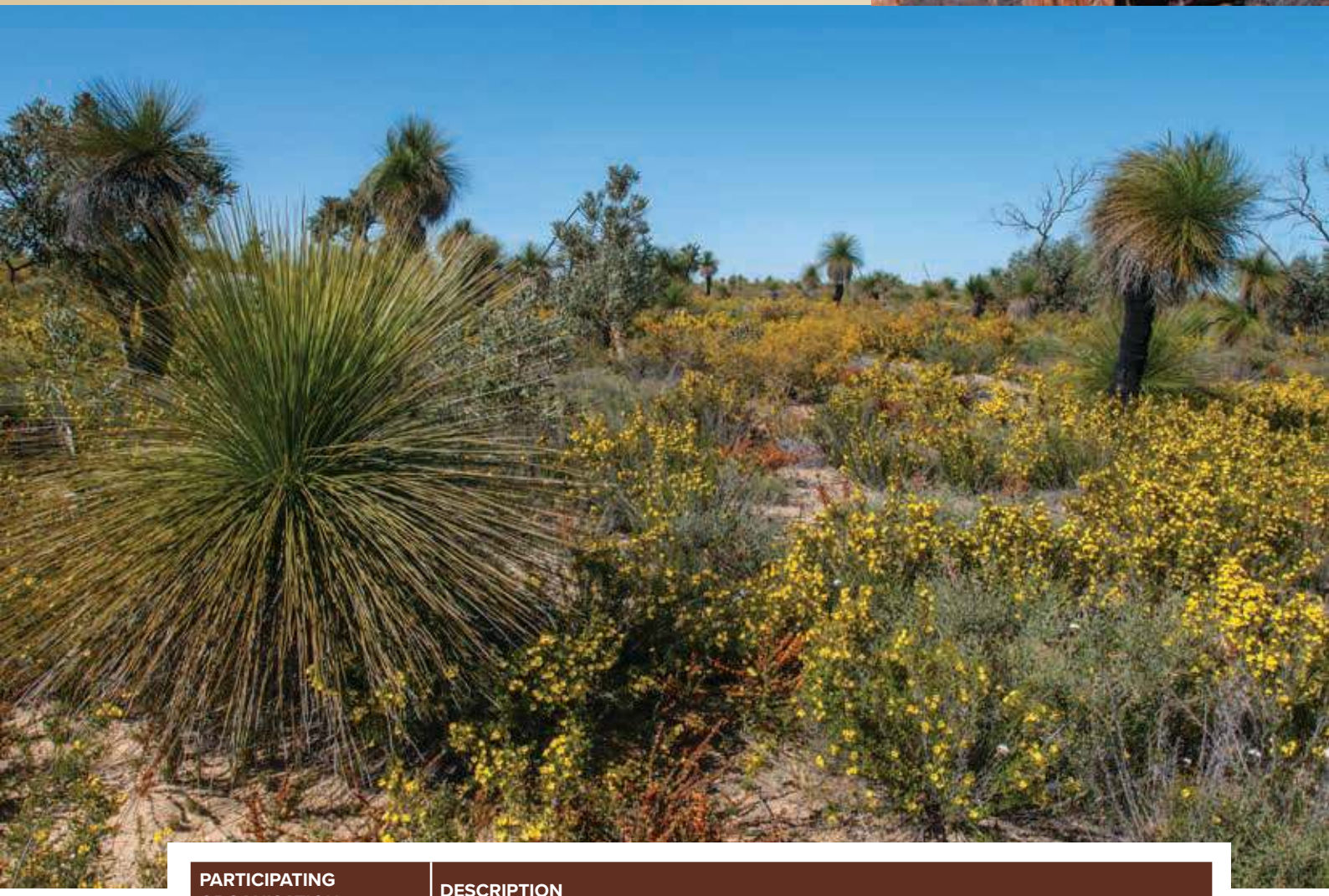
The Research Priorities Plan should be considered in conjunction with the following documents:

- The Joint Venture Agreement of WABSI which sets out the principles, rules and processes through which the participating organisations collaborate and undertake research and research translation.
- The Strategic Plan
- The Annual Operating Plan
- The Pathways Document (2015)

PARTICIPATING ORGANISATIONS

The Western Australian Biodiversity Science Institute (WABSI) is a formal collaboration amongst a number of scientific institutions operating in Western Australia, several Western Australian government agencies and authorities with research and management interests pertaining to the State's terrestrial biodiversity. With these Participating Organisations, WABSI represents the science capability within the State and undertakes a role to broker the capability of partner organisations to respond to end user needs.

PARTICIPATING ORGANISATION	DESCRIPTION
Botanic Gardens and Parks Authority (BGPA)	BGPA is an agency of the Department of Biodiversity, Conservation and Attractions that manages Kings Park and Bold Park. The research they primarily undertake is in native plant ecology.
Commonwealth Scientific and Industrial Research Organisation (CSIRO)	The CSIRO is Australia's national science agency. Research pertaining to Western Australia's terrestrial biodiversity is undertaken at the CSIRO primarily within its Land and Water Business Unit.
Curtin University	Curtin University is Western Australia's largest university in terms of student numbers and is a member of the Australian Technology Network of Universities. Research pertaining to Western Australia's terrestrial biodiversity is undertaken primarily within the School of Science at the Faculty of Science and Engineering.
Department of Biodiversity, Conservation and Attractions (DBCA)	DBCA is a Western Australian Government department charged with conserving biodiversity and managing the State's national and marine parks. Researchers at DBCA, including Kings Park Science, study, describe, monitor and map species and ecological communities in Western Australia; the outputs of which underpin strategies to protect, conserve, manage and restore WA's biodiversity.
Department of Mines, Industry Regulation and Safety (DMIRS)	DMIRS is a Western Australian Government department charged with attracting private investment in resources exploration and development through the provision of geoscientific information on minerals and energy resources, as well as the management of equitable and secure titles systems for the mining, petroleum and geothermal industries.
Department of Water and Environmental Regulation (DWER)	DWER supports Western Australia's community, economy and environment by managing and regulating the state's environment and water resources. The department is responsible for environment and water regulation, serving as a 'one stop shop' for industry and developers, with the aim of streamlining and simplifying regulation.
Murdoch University (Murdoch)	Murdoch is a Western Australian university and a member of the Innovation Research University group in Western Australia. It undertakes research pertaining to Western Australia's terrestrial biodiversity. The new Harry Butler Institute provides a focus for Murdoch's biodiversity research and training.



PARTICIPATING ORGANISATION	DESCRIPTION
The University of Western Australia (UWA)	UWA is a member of Australia's Group of Eight research intensive universities. Research pertaining to Western Australia's terrestrial biodiversity is undertaken primarily within the Faculty of Science. Regionally based research centres, including the Centre of Excellence in Natural Resource Management located in Albany, focuses research on the South West global biodiversity hotspot.
Western Australian Museum (WA Museum)	WA Museum is a Western Australian State Government authority formed to manage the State's museum and associated collections. Researchers at the WA Museum maintain and conduct research on the museum's arachnid and myriapod, entomology, mammalogy, ornithology and subterranean biology collections. The WA Museum also performs an important vouchering service for biological surveys conducted in WA.
Edith Cowan University (ECU)	ECU is a young, progressive university with recognised strengths (in the recent ARC Excellence in Research Australia: ERA assessment) in: ecology, environmental science, terrestrial biodiversity and mine-site rehabilitation.
Department of Primary Industries and Regional Development (DPIRD)	The recent amalgamation of the departments of Agriculture and Food, Fisheries and Regional Development and the Regional Development Commissions provides a focus for Western Australia's primary industries and their regional settings.

THE WESTERN AUSTRALIAN CONTEXT

By virtue of its geographical expanse, climatic diversity, areas of relative wilderness, vast regions with extremely nutrient-impoverished soils, and the fact that significant areas of the State have not been covered by sea or glaciated over geological time, Western Australia has a globally unique biodiversity that is characterised by significant endemism. By way of example, there are more species of flowering plants in the Fitzgerald River National Park than in all the United Kingdom, contributing to the South West of Western Australia being one of only 36 (as of 2017) 'Global Biodiversity Hotspots' which are defined as geographical regions that have at least 1,500 vascular plant species and where at least 70% of their original habitat has been lost.

In contrast with many other developed countries, Western Australia is relatively early in its development. Significant urban, industrial, resources and agricultural development has taken place in Western Australia only over the last 150 years. Consequently, there remain significant and important opportunities for development and wealth generation within the State.

The challenge is to integrate the future social and economic development of the State with strategies for the effective management of biodiversity. Complex issues and trade-offs are typically involved, the resolution of which requires a robust and rigorous scientific information-base.

A major task confronting policy-makers, industry leaders and land managers' is therefore to find strategies for the optimal management of biodiversity that are compatible with the ongoing imperative for the State's development underpinned by current population trajectories.

At a fundamental level, the case for a biodiversity institute is to address these questions in a way that addresses the core objectives of responsible economic development and the conservation of the globally-recognised biodiversity of Western Australia.

A biodiversity institute contributes by providing information and knowledge to facilitate greater certainty around decision-making processes. Greater knowledge enables efficient decisions that take account of the needs of stakeholders, substantially improving both productivity and environmental protection.

PRINCIPLES FOR SETTING BIODIVERSITY RESEARCH PRIORITIES

The purpose of the Research Priorities Plan is to identify key biodiversity research priorities within Western Australia. It focuses on supporting the needs of end users including business, mining and industrial interests such as the mineral resources sector and urban developers, land managers, conservation managers, government agencies, regulator, consultants, land-care groups and other science leaders.

Enhanced information and knowledge is consequently sought to:

1. Help inform effective biodiversity conservation; and
2. Facilitate sustainable development.

DRIVERS OF VALUE

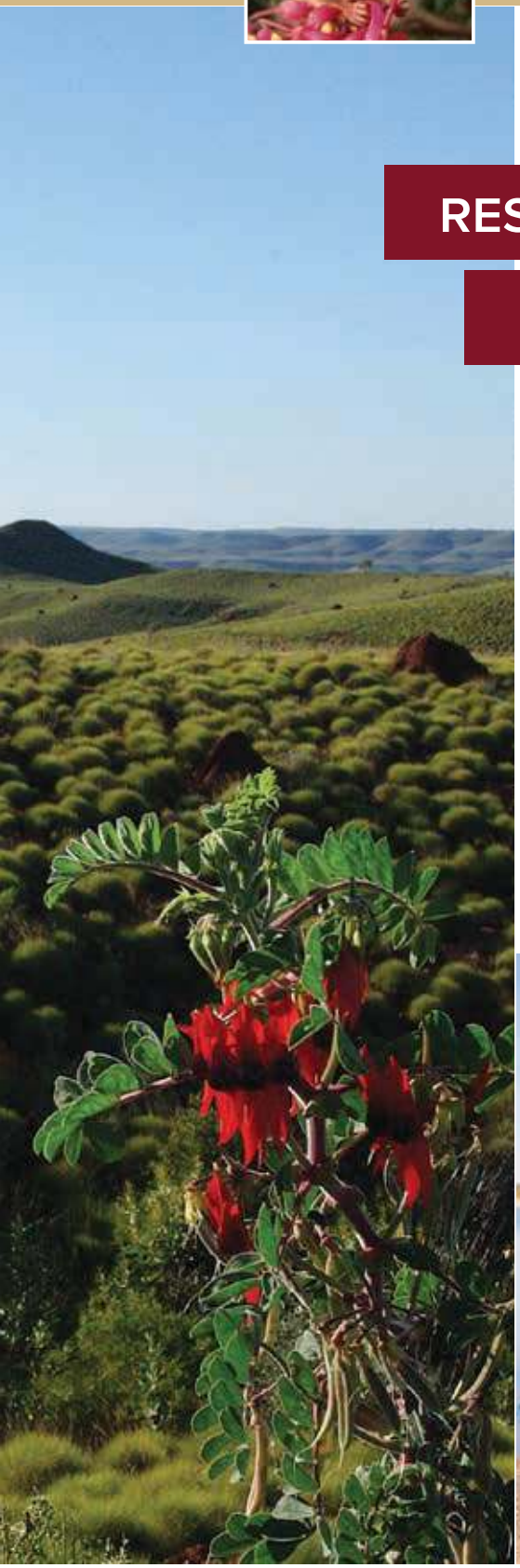
Building upon these two primary outcomes, the following drivers of value have been identified to assess research priorities:

- **Improved access to knowledge** including knowledge of species, populations and communities, geographic distribution, management needs and values.
- **Excellence in science** including positioning Western Australian research institutions at the forefront of state, national and international biodiversity research.
- **Informed decision making** to provide independent and objective advice to decision makers.

To achieve these objectives, WABSI engages early with end users to allow the nexus of research and end user requirements to occur. It does this by working with both communities often at the prefeasibility stage. WABSI engages with end users to clearly identify the research needs that will result in outcomes that end users can readily adopt.

The WA State Government identified a need to fund an institute to address the issues of obtaining stronger levels of engagement between industry and the research community and funded the establishment and ongoing operations of WABSI until the end of 2020. It also established WABSI to:

- Help support the broad ‘economics’ of projects.
- Bring new research funds into the State (such as from Commonwealth programs) to address current knowledge gaps.
- Leverage the collective intellectual capital and research capability of partners.
- Reduce duplication by merging similar projects or sharing knowledge across projects.
- Deliver the primary aim of improved biodiversity conservation and industry/facilitation of sustainable development.
- Potentially deliver materially improved products and services for end user application.
- Place Western Australia at the leading edge of global biodiversity research with the potential to deliver transformational insights potentially within a decade.



RESEARCH PLANNING HIERARCHY

The WABSI Research Planning Hierarchy includes up to three tiers of research planning and prioritisation (Figure 1). This Plan is the overarching tool for research development.

Programs of Work, grouped into higher level initiatives where necessary, are developed by WABSI to enable the development and implementation of more detailed research program plans.

Program plans are developed after extensive end-user engagement and scientific consultation typically around a broader issue. Within these programs, proposed activities are prioritised largely by the level of engagement or contextual significance of the knowledge gaps being addressed.

Projects developed to support the delivery of the programs are led by the WABSI joint venture or other relevant research partners and are supported by program planning, communication and governance structures established at the Program level (Figure 1).

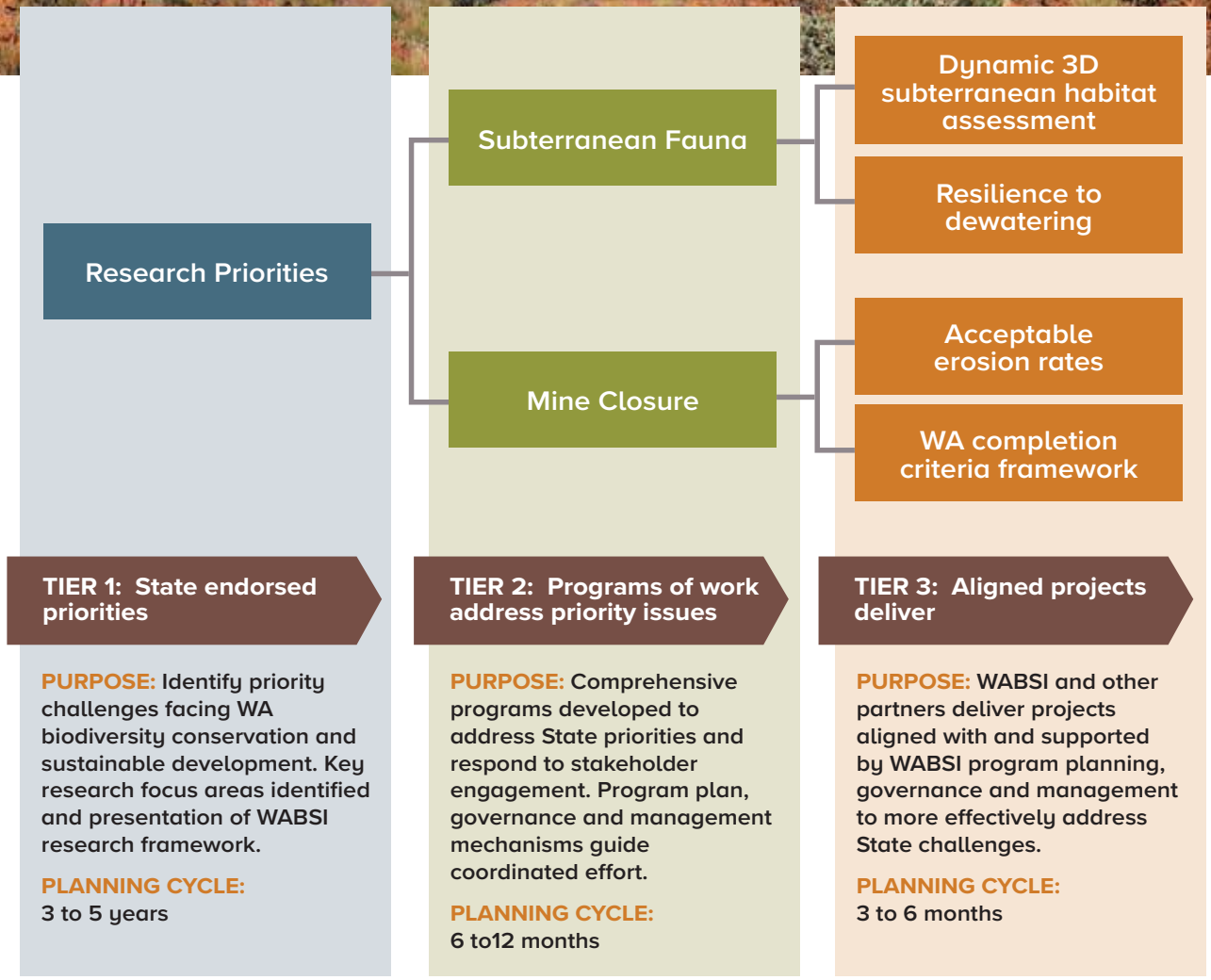


FIGURE 1 WABSI research planning hierarchy with example Programs of Work and associated projects

RESEARCH FRAMEWORK

CROSS-CUTTING PRINCIPLES

The cross-cutting principles set the context within which all research conducted by WABSI will be undertaken. All work commissioned is directed by clearly defined outcomes by end-users.

The major cross-cutting principles include:

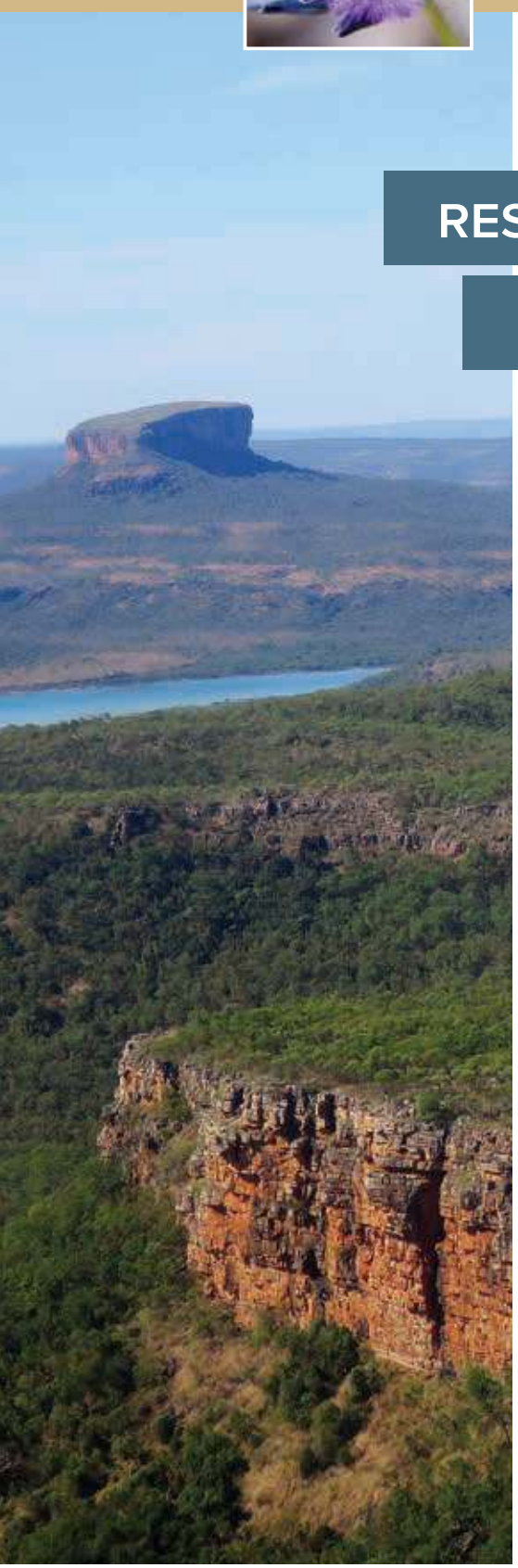
- **Stakeholder engagement** — Research, using best science, should address the questions posed by end-users, both conservation and regulatory, to ensure that the research outcomes are relevant to their needs with clear pathways to adoption.
- **Transdisciplinary research** — All research proposals must contain explicit reference to how the outcomes of individual research projects will be integrated with the other complementary research required across plant, animal, soil, climate and biological sciences and underpinned by interrelated social and economic disciplines.
- **Social and economic analysis** — Research proposals assist in building knowledge that will improve the effectiveness and/or reduce costs associated with managing biodiversity. Research should, wherever practicable, assess the relative costs and benefits of alternative approaches in delivering conservation outcomes in a regional and landscape context.
- **Indigenous knowledge** — Researchers should, wherever possible, engage and develop strong collaborative relationships with Aboriginal land managers. Indigenous knowledge systems should be considered alongside Western-science-focused data systems to respect and recognise the value of traditional ecological knowledge, empower two-way participation in biodiversity and land management information collection, management and access, support intergenerational transmission of traditional ecological knowledge as well as encourage equitable sharing of benefits arising from access to traditional ecological knowledge.
- **Communication and adoption** — Ensure that the outcomes of WABSI research programs are effectively communicated with a particular focus on building the understanding of key decision makers and the general public on the value of biodiversity and ensuring clear plans are established to promote the adoption of findings that are relevant to biodiversity managers and other decision makers.

To ensure that these principles are incorporated in research program development and delivery, WABSI guidelines and protocols have been developed and adopted.

PROGRAMS OF WORK

To achieve project alignment with WABSI strategic priorities in the Research Priority Plan, while facilitating project initiation and development, research program plans (Plans) are detailed. Plans are developed using the WABSI Research Framework (Figure 2), providing an opportunity to embed the cross-cutting themes, integrate across the research programs and deliver across relevant geographies to best address prioritised issues and knowledge gaps relating to biodiversity outcomes and sustainable development across the State. Plans identify end users and stakeholders, guide needs analyses, specify outcomes, and describe research transfer and adoption.

FIGURE 2 The process of developing Programs of Work, led by WABSI



RESEARCH THEMES (NODES)

The WABSI Research Framework is organised across a core set of themes (nodes) that are coordinated and led by a Program Director.

- **Biodiversity Survey**
  Western Australia is characterised by a significant diversity in the range of plant and animal species across varied landscapes and ecological communities. A comprehensive understanding of the State's biological resources, their distribution and processes that influence them can only be delivered through a more coordinated and focused effort across agencies and industry.
- **Ecosystem Processes and Threat Mitigation**
  An understanding of the distribution of plant and animal species alone is not sufficient for effective management of biodiversity. Continued investment will build the capacity of land managers to understand and manage the processes that maintain or threaten ecosystems such as fire regimes, water availability and management, climate, exotic species, disease and fragmentation through land clearing.
- **Information Management Systems**
  A substantial amount of information on the State's biodiversity has already been collected and variously interpreted by research agencies and the related industry. An improved knowledge management system will be developed to facilitate further aggregation, interpretation and access to the existing data held by government, industry and research agencies. Information Management is a foundational program that supports the collection, analysis and reporting of information derived from the other WABSI research programs.
- **Restoration and *ex-situ* Conservation**
  Collaboration between industry and researchers has developed restoration technologies for many regions of the State, notably within the alumina industry in the Darling Ranges. These capabilities will be extended across other land use systems and ecological communities, including developing technologies for *ex-situ* conservation and mechanisms for the translocations of plants and animals.

BIODIVERSITY SURVEY

Introduction and context

Government, community and industry require the capability to undertake biodiversity assessments that inform land use planning and decisions on natural resource management. A core need in order to do this, whether for research, conservation planning or environmental impact assessment, is to characterise the biodiversity that occurs at a site, how this biodiversity is distributed across the landscape and assess its current and projected condition. Biodiversity to be assessed runs the gamut from genes, to species (taxa), to ecological communities.

Comparison of the biodiversity of a site with other sites allows an evaluation of distinctiveness and significance including the degree to which elements of biodiversity at the site require protection or can be lost without a significant negative impact on overall biodiversity. This core need drives four subsidiary requirements:

1. **Capacity to identify biological elements** — Users need the efficient, accurate and readily available identification tools in order to determine with confidence which elements of biodiversity (i.e. from genetic variation within a population to ecological communities).
2. **What elements of biodiversity exist where** — For decision makers, users need well-documented evaluation of what elements of biodiversity occur where and what factors influence distribution.
3. **Capacity to determine significance** — For decision-making, users need to be able to determine the significance of all identified elements of biodiversity by establishing a context for an observation (of a species, ecological community or gene) at a given site.
4. **Standardisation** — In order to ensure rigour and comparability, users need assurance that data quality and appropriate methodological standards are properly in place.

At the **species level**, a maintained census and identification methodologies for different taxonomic groups of all taxa that occur in Western Australia are required, backed by sufficient taxonomic expertise to underpin the scientific validity of the census. Foundational taxonomic work is particularly important in a State such as WA where biodiversity is only partially known and new taxa are regularly discovered. Species-level censuses are currently maintained by the WA Herbarium (plants, algae and fungi) and WA Museum (animals). To determine significance, sufficient spatial records are required to estimate the area of occupancy, extent and abundance of species. For some groups such as birds, large datasets exist in accessible repositories. However, for other groups such as many invertebrates, the record set is relatively sparse and many collections in existing institutions (e.g. WA Museum) are yet to be adequately digitised and so are not readily 'discoverable'.

At the **ecological community level**, vegetation maps that are both structural and floristic are required at different hierarchical scales, to be able to assess the area of occupancy and distribution of each vegetation community and its current and projected condition through time. In contrast to other Australian States, protocols for vegetation mapping at all relevant scales are yet to be developed in Western Australia. New methodologies that could be deployed include classifications based on hyperspectral time-series satellite imagery, or community classifications based on genomic sampling.

At the **gene level**, a characterisation and catalogue of Operational Taxonomic Units (OTUs) or genetic units and assemblages are required. Sufficient spatial density of samples is also required to understand the distribution of resolved genetic units. For taxonomic groups which are well-characterised at the species level, gene diversity can be estimated from taxon diversity. However, phylogeographic patterns and patterns of genetic structure for many species are unknown, limiting the validity of taxon surrogacy for gene diversity. In taxonomic groups that are poorly understood at the species level, such as many invertebrates, it may be more efficient, for example, to measure gene patterns directly, without fully resolving species-level structure.

At all scales, appropriate standards for the collection of data need to be developed and, where available, they need to be more widely employed, including standard operating procedures, guidelines and manuals that promote consistency in sampling effort, and better collection and management of biodiversity data.

Objective

Develop a thorough and robust understanding of the full range of species and ecological communities in Western Australia, their geographic distribution and their current and projected condition through time.

End user outcomes

1. Capacity to accurately identify elements of biodiversity including robust data methodological, collection and quality assurance standards.
2. Understand the geographic distribution of species, ecological communities and genetic diversity.
3. Capacity to prioritise conservation effort against agreed criteria, such as comprehensiveness, adequacy and representativeness, biodiversity condition and trends for the purposes of environmental assessment and conservation planning.
4. Simple, efficient and effective guidelines for environmental impact assessments associated with regulatory processes.

Focus area 1: Standards, identification tools and information systems

Rationale

End users need confidence that species and ecological communities have been robustly surveyed, correctly identified and that their geographic distributions are properly understood. A key priority is the development of identification tools, robust methodologies and minimum standards for data collection that can be used in multiple contexts. End users are seeking greater confidence in the capacity to reliably and efficiently identify species, ecological communities and interpret genetic data and information.

Priority areas for commissioned work

WABSI supports research for developing tools, systems and standard processes to allow for consistent and efficient collection and interpretation of biodiversity data. Examples of key resources that would support the identified needs of end users include:

- **eFlora of Western Australia** — An online electronic version of a Flora, or an eFlora, provides contemporary and integrated taxonomic and descriptive information in a single resource that is readily accessible to a wide audience, including industry, government and the community. It will have built-in keys and other tools to identify species occurring in any given area such as a reserve or bioregion; vast and comprehensive information about species that can be searched, filtered and packaged in different formats for different audiences, and is easy to maintain and keep up-to-date in the face of growing and changing knowledge, with links to other online resources.
- **Western Australian Vegetation Information System** — This assists the establishment of protocols and procedures, deploys innovative technologies and maintains data and analysis methods to deliver fit-for-purpose derived products such as vegetation maps suitable for biodiversity assessment and site-based plot data to inform on trends in habitat condition.

Focus area 2: Identify and trial new technologies

Rationale

Given the scale of the task in understanding the elements of biodiversity, their geographic distribution and condition, new technologies and approaches are required to drive faster and more cost-effective biodiversity assessment.

A key priority is to develop, identify and trial innovative new technologies and systems for the collection, collation and analysis of biological survey data that enables the taxonomic resolution of species, informs the definition of ecosystems and biological communities, and enables distribution of species across Western Australia to be predicted. A main driver for new technologies relates to the lack of adequate biodiversity data across large areas of the State to inform land management decisions, and generally the current high cost of traditional approaches to biodiversity survey.

Priority areas for commissioned work

There is an opportunity to not only investigate the utility of new technologies singularly, but also to identify the most effective ways of integrating their deployment to deliver more robust and comprehensive biodiversity assessments. A further opportunity comes from the need to identify solutions to managing the enormous quantities of data arising from these approaches.

Examples of technologies applicable to biodiversity survey and assessment include:

- **Molecular and genomic technologies**
  - **DNA barcoding** — identification of species using this approach has become increasingly popular and more cost-effective in recent years. DNA sequencing is particularly useful for separating cryptic taxa and those groups where there are few taxonomic specialists.
  - **Environmental DNA (eDNA)** – DNA captured from an environmental sample, such as water or soil, can be used to detect single species, communities or even describe entire ecosystems. Multispecies detection (eDNA metabarcoding) combined with high throughput sequencing is emerging as a powerful tool that has multiple applications for biodiversity survey and monitoring.
- **Remotely sensed technologies**
  - **Satellite platforms (geospatial and temporal coverage)** – the increasing availability (including for free) of higher spatial and broader spectral resolution imagery has increased the utility of satellite imagery for many applications. In addition, archive and search platforms enhance the capacity to undertake advanced analyses of imagery at no added cost.
  - **Airborne platforms (UAVs to aircraft)** – the increased availability of even higher resolution imagery, in combination with sensors such as hyperspectral, radar, laser and passive thermal, makes the utility of these platforms considerable.
- **Automated detection tools and mobile apps**
  - Remotely operated camera traps and audio recording units have significantly increased the capacity to detect species, particularly those that are difficult to detect using more traditional approaches.
  - The development of automated visual and sound recognition software will increase the efficiency and accuracy of the above tools.
  - Mobile device ‘apps’ coupled with citizen scientist programs have dramatically increased the ability to target data collection and increase coverage, with in-built functions to help improve data quality.
  - Use of machine learning and artificial intelligence particularly for the analysis of ‘big data’.

Focus area 3: Understanding pattern and significance

Rationale

Informed decision making by end users requires data on the biodiversity at a site to be placed in the context of the broader geographic area (e.g. biogeographic region), as well as the projected trajectory of biodiversity condition over time.

Determining conservation significance and status is critical for both targeting conservation efforts and also informing environmental assessment, including prioritising conservation actions, identifying management and threat mitigation strategies, and targeting offsets.

Western Australia has been covered by an extensive network of biological surveys from which considerable data has been collected. This data can be utilised for the assessment of biodiversity patterns across the landscape that is critical for land management decisions, such as evaluation of cumulative impacts. As there also remains a significant gap in biodiversity data across large areas of the State, strategically filling these gaps is important for more informed decisions. Traditional field surveys are unlikely to be completely replaced by emerging survey technologies, however when used in combination, they are likely to provide a more powerful approach to cost-effectively identifying and monitoring biodiversity patterns.

Priority areas for commissioned work

WABSI facilitates collaborative research that increases the capacity to synthesise a comprehensive view of the status of biodiversity at varying scales within WA. Outputs will support the informed evaluation of the potential impacts of future trends and developments on biodiversity including those required for regulatory processes. Key priorities include:

- **Spatial modelling and decision-support tools**
  - Collating and using existing biological, spatial and environmental data to develop predictive models of the patterns in biodiversity across Western Australia's landscapes; across all levels of diversity from genes to ecological communities. This includes developing refined spatial layers for key environmental variables that currently lack adequate resolution or coverage, and identifying gaps in survey coverage.
  - Biological surveys to fill priority gaps in data coverage, taking maximum advantage of advances in survey technologies.
  - Investigating and developing conservation planning tools that use patterns of biodiversity to address status and significance.
  - Developing decision-support tools that integrate the modelled biodiversity patterns with information on ecosystem threats and processes so that the cumulative impact of proposed developments and/or conservation actions can be evaluated.
  - Designing and implementing optimal monitoring strategies to track changes to biodiversity condition and status over time.

ECOSYSTEM PROCESSES AND THREAT MITIGATION

Introduction and context

Successful management of Western Australia's biodiversity demands more than an understanding of the geographic distribution and conservation significance of species and communities. Biodiversity management encapsulates the challenge of understanding ecosystem processes that are dynamic, adaptive and exhibit cyclical patterns and global change trajectories associated with the impact of a wide range of biotic and abiotic drivers. These include natural processes such as fire, climate, nutrient cycling, pollination, predation and water cycling as well as impacts driven by human interaction, such as anthropogenic climate change, the introduction of non-native species, disease, altered water flows and land use change. These critical ecosystem shaping factors can interact synergistically, and can impact both directly and indirectly, on biodiversity outcomes.

Conservation managers face the practical issue of how to maximise triple-bottom line outcomes for biodiversity outcomes over time. This involves consideration of:

- Diverse, and at times competing, views on the value of biodiversity relative to other societal outcomes;
- The interdependencies that exist between environmental, economic and social outcomes for biodiversity; and
- The allocation and prioritisation of limited resources to areas, issues and activities most likely to produce sustainable outcomes for biodiversity conservation.

Optimising management outcomes is not a simple task and requires a systems-based view. Research may include both foundational knowledge and the development of creative and innovative solutions and tools for integrated management. Given the focus of the Research Program in meeting the needs of end users and the breadth of potential research topics, some elements of research under this program are defined by geographic regions, while other elements are focused across the State.

Objective

Continuously build the capacity of stakeholders to understand and adaptively manage ecosystem processes and develop more integrated cost-effective strategies for mitigating threats to biodiversity conservation.

End user outcomes

WABSI invests in research that addresses knowledge gaps and develops tools for decision makers, with a particular focus on understanding trade-offs and improving management outcomes to better balance biodiversity conservation and sustainable development. This includes:

1. The development of effective adaptive management strategies that identify and integrate ecosystem processes into producing more resilient biodiversity outcomes through time; and
2. Setting priorities and addressing knowledge gaps for the effective management and mitigation of threats to species and communities.

Focus area 1: Integrating ecosystem processes into adaptive management

Rationale

Tools for the management of biodiversity are required based on a robust understanding of the key processes that drive and determine the persistence of species and communities, and the ongoing condition, viability and resilience of Western Australia's ecosystems and to build understanding of how the environment is likely to change through time.

Managers are seeking capacity to define and understand the key ecological drivers and evolutionary processes, and the interactions between them, for priority regions and ecological communities. Tools are needed to enable researchers and managers to integrate dominant processes into management plans that will assist in targeting conservation and restoration efforts.

The future evolution of the environment is likely to be significantly influenced by our ability to predict and manage fire regimes, develop adaptation and mitigation

solutions for the impacts of climate change and implement more effective management of our fragile and ancient soils.

Considerable research is required to understand the knowledge gaps that exist for these interactions, and identify management solutions that factor in direct and indirect interactions is even more challenging. Successful outcomes require interdisciplinary approaches to identify social and economic drivers and options for policy responses.

Priority areas for commissioned work

Examples of research that may be supported include:

- **Fire management** including implications of climate change and asset protection in the South West, management of fuel loads and re-introduction of Aboriginal burning practices in northern and arid environments.
- **Soil nutrients and nutrient cycling** including tools for managing soil chemistry and reintroducing critical soil biota.
- **Climate change and altered water flows** including capacity to model impacts and identify cost effective solutions for managing water regimes, guidelines for identifying and managing climate resilient ecological communities.

Focus area 2: Identifying and mitigating key threats

Rationale

Capacity is required to identify the key threats to species and communities in order to prioritise research that will improve management outcomes. Methodologies are required to help understand the potential impact of threats on species and landscapes. Examples of key issues include the capacity to determine thresholds for land disturbance and thresholds for local population extinction (minimum viable population size), develop pest and weed management strategies, predict the resilience of ecosystems to a rapidly changing climate, and the management of disease. For example, whilst a landscape planning and prioritisation process may identify the management of predation as a critical issue, the effectiveness of existing techniques and tools for managing feral cat and fox predation are limited. Foundational research is required to understand the underlying mechanisms and processes taking place and how they may be more effectively controlled and managed.

Priority areas for commissioned work

Examples of research that may be supported include:

- **Identification of key threats to species and communities** including an understanding of global environmental change impacts on biological processes involved in species persistence, and how to improve the management of disease impacts (e.g. *Phytophthora*) at the landscape scale.
- **Risk assessment and prioritisation** including tools for assessing the potential impacts of key threats and develop appropriate mitigation and management plans, and identifying dominant threats and ranking for management based on agreed criteria such as likelihood, impact and reversibility.
- **Invasive alien species management** including new and improved techniques for tracking and controlling pests (foxes, cats, cane toads etc.), weeds and diseases, including effective, efficient and humane culling and baiting, biological control and gene editing approaches.
- **Land use change threats and opportunities** including options and methodologies to identify and respond to changes in land use, and land use planning for existing and new uses such as irrigated agriculture, and developing an understanding of grazing pressure impacts in arid systems.
- **Landscape fragmentation** including determining population viability and thresholds for loss of small populations, managing species and communities in fragmented landscapes.

INFORMATION MANAGEMENT SYSTEMS

Introduction and context

A great deal of information on the State's biodiversity has been collected and interpreted by research agencies and industry. However, the existing knowledge base is fragmented and difficult to access. All stakeholders agree that an enhanced information base that can be readily accessed and easily interpreted will improve decision-making.

The benefits of improved information management are significant and include:

- **Improved access to knowledge** to make better informed decisions and improve conservation management and research outcomes.
- **Better informed planning processes**, creating greater certainty and reduced compliance requirements for land managers.
- **A capacity to support** the streamlining of environment impact assessment and regulatory processes, thereby reducing duplication, costs and delays in decision making.
- **Support future digital environmental impact assessment**, monitoring and prediction systems.

The concept of an authoritative source of biodiversity information and data is attractive. However, it is a goal that has proven elusive to government, industry and other stakeholders due to complexity and the timeframes involved.

Objective

WABSI is working with industry, regulators, researchers and the community to build a data sharing and access culture that enables us to better understand 'the cumulative environmental impacts, of an action, on a region, overtime'. This can be achieved by focusing on five strategic objectives:

1. Create and lead a culture of shared expertise, common data standards, policies and incentives for data sharing and support a system for persistent storage and archiving of data.
2. Mobilise biodiversity data from all available sources (Environmental Impact Assessment, government agencies, Natural Resource Management groups, the research community, community groups etc.) to make the data promptly and routinely available to the entire biodiversity community.
3. Curate and manage surveys into data layers that give individual surveys context and meaning, enabling this data to be used as evidence.
4. Deliver (or enable) informed, trusted analytical and assurance outcomes using shared solutions and technologies.
5. Support optimised policy and decision making, transparent, efficient assessment and assurance processes as well as informed environmental adaptive management frameworks to provide investment confidence and an informed community.

The issues associated with biodiversity information management will not be resolved quickly or easily. A concerted and disciplined approach over several years is required across government, industry and research agencies to ensure that information is made accessible by establishing clear policy frameworks and investing in supporting infrastructure as well as in information technology.

End user outcomes

1. Capacity to efficiently secure electronic access (web-based) to available biodiversity data of known quality and origin to support better planning and decision-making processes.
2. User-friendly interface and tools to discover, interpret and analyse data using accredited methodologies.
3. Streamlined processes including data standards and quality guidelines that improve data quality, avoid duplication in collection of environmental data and therefore reduce costs and delays associated with both development and conservation planning.
4. Improved collaboration and knowledge-sharing leading to enhanced conservation management and research outcomes.

Focus area 1: Policy commitment and foundations

Rationale

A number of foundational activities are required to underpin and facilitate a culture of data sharing across government agencies, industry and research organisations. Improved information management requires a high level commitment from the key organisations involved, a willingness to be guided by a coordinating agent and a capacity to contribute to a common infrastructure and standard.

Each stakeholder that collects biodiversity information must be recognised and have their right to store and manage data for their own purposes reaffirmed. However, an obligation to share information, including in a format that complies with common standards, is normative in many industries – including disciplines such as medical research, accounting and engineering.

Priority areas for commissioned work

WABSI will seek to develop an agreed framework and approach for the management of biodiversity information including:

- **Organisational commitment** — a commitment from all participating organisations to a common vision, objectives, principles and a road map. It would include early initiatives for biodiversity information management to establish a governance mechanism through WABSI in order to coordinate organisational efforts so as to invest in common standards and infrastructure over time. For example, key business analysis and project management for organisational consultation, together with mapping and understanding of user needs, priorities and barriers.
- **Policy incentives** — that facilitate open access to data and its reuse including storage and access associated with government environmental approvals and licensing and strengthened incentives for sharing of data collected for research and academic publication.
- **Data standards** — that establish minimum requirements for data collected for different purposes such as vouchered collections, biological survey and so on.
- **Data collection workflows** — that map, standardise and streamline workflows for the collection and storage of data, including processes for lodgment of data associated with government approvals and licensing arrangements used for environmental impact assessment.
- **Knowledge networks** — that establish and recognise data custodians and providers, as well as the tools for annotation and validation of different data types.

Focus area 2: Data collection and access

Rationale

To achieve the objective of simplifying access to biodiversity information, a considerable investment needs be made in infrastructure. This would help enable biodiversity data to be mobilised, organised and aggregated from a variety of sources in a web-based platform to support end user access and use.

The benefits of a capacity to aggregate biodiversity information from multiple sources onto a shared platform are compelling. However, this in turn requires each agency and stakeholder to commit to investing in the common infrastructure and also ensuring that their own data management systems and standards are interoperable with the requirements of the shared platform.

Priority areas for commissioned work

Developing improved organisational practices, policies and knowledge management systems to facilitate integrated access, aggregation, sharing and interpretation of the biodiversity related data gathered and held by government, industry and research agencies (contributing to the State's commitment to establishing a State Environment Data Library through the Department of Mines and Petroleum).

Key activities include:

- **Data storage and quality assurance** — develop a data storage, curation and quality assurance capability to ensure biological datasets are visible, accessible, managed according to best practice, as accurate as possible and able to be aggregated.
- **Data collection** — evaluate and provide data collection tools that enforce data and collection standard agreed in focus area 1.
- **Data service** — establish criteria and select a provider or system for data aggregation service development (IT platform) and support with agreed specifications for data repository, aggregation and interpretation and progressively building the capability of the information management system.
- **Data types** — identify different data types and understand the needs of different end users for different data types and their application.
- **Data mobilisation** — establish agreed priorities for the mobilisation of strategic data types into the data service or platform so as to progressively address knowledge gaps or development pressure points for Western Australia.

Focus area 3: Data interpretation and re-use

Rationale

Access to raw data is necessary but not sufficient to meet the needs of users of biodiversity information.

A key requirement is to develop tools, methodologies and interfaces that stakeholders and the general community can use to build an understanding of the nature and value of Western Australia's biodiversity.

Priority areas for commissioned work

WABSI will invest in and support research and development of tools, methodologies and interfaces for improved access and interpretation of biodiversity information:

- **Tools for data access and interpretation** — ensure data users have access to tools to visualise and interpret data in ways that meet their needs.
- **Examples and tools supporting additional data re-use** — provide best practice examples, especially as they connect to data being generated and made available through WABSI.

RESTORATION AND *EX-SITU* CONSERVATION

Introduction and context

This program seeks to progressively build upon Western Australia's capacity to restore and rehabilitate key disturbed ecosystems, establish new populations of threatened species through translocations and protect species through *ex-situ* collections. Successful reconciliation of the ongoing development of the State, with the objective of biodiversity conservation, requires a proven capability to understand and restore species and ecological communities.

A key goal of the process of ecological restoration is recovering historic ecological continuity that was interrupted by ecosystem impairment. Historic continuity is not necessarily the recovery of what occurred in the past but rather the continuity or persistence of an intact ecosystem in response to an ever-changing environment, which can lead to new expressions of that ecosystem in the future. This recognises the value of activities occurring across the restorative continuum for biodiversity conservation within Western Australia where they move the trajectory of broad ecological recovery in a positive direction.

This research node seeks to address the significant task of progressively building the capacity of land managers across the State to understand and develop successful strategies for the restoration of ecological communities and the reintroduction of species.

Challenges include:

- Limits to our understanding of how to undertake restoration or reintroduce key animal and plant species across the vast majority of Western Australian ecosystems.
- The need to establish criteria for success in different environments to inform decision making.
- Building capacity to set standards for, and undertake restoration of, ecosystems when key environmental attributes such as climate, soil chemistry or groundwater levels have changed.
- Developing an understanding of the socio-economic drivers of restoration, including identifying markets and supply chains within which restoration programs operate, relative costs and benefits of restoration and expectations of restoration outcomes.

These challenges manifest differently across the regions of the State when considered in conjunction with the needs of land users and the degree of ecological change within which restoration is to proceed.

Objective

Develop and facilitate the adoption of cost effective and scalable strategies and tools for the restoration and reconstruction of Western Australian ecosystems and, where appropriate, the reintroduction of threatened plants and animals.

End user outcomes

To build the capacity of land managers across the State to understand and develop successful strategies to restore ecological communities and to reintroduce species is critical. This would support the conservation of our biodiversity and facilitate sustainable development.

Key outcomes being sought include:

- Guidelines and policy frameworks through which standards for restoration, including closure standards, can be identified and set for different sites. This will require the development of robust approaches to define and evaluate criteria for restoration and translocation success.
- Proven low cost, scalable technologies for the restoration of ecological communities and translocation of plants and animals.
- Mechanisms to advance the restoration economy and development of relevant supply chains to deliver high quality restoration outcomes.
- Capacity to house, store, breed, release and successfully establish (translocate) a representative range of Western Australia's plant and animal species.

To achieve these outcomes across landscapes and industry challenges in Western Australia, requires the delivery and integration of research across three focus areas.

Focus area 1: Identifying goals and evaluating restoration success

Rationale

Given the large range of activities, costs and contexts within which ecological restoration takes place, it is important for the conservation of Western Australia's biodiversity to be able to clearly identify goals and evaluate the success of restoration and reintroduction programs. Evaluation requires the development of early and predictive indicators of restoration and translocation success that are robust, meaningful and measurable. Opportunities presented by practitioner-research partnerships in restoration and reintroduction programs should be developed to support more effective identification of goals and success measures.

Priority areas for commissioned research

- Techniques for determining the targets for species richness and community composition appropriate to each restoration site.
- Improved methods for net benefit analysis to better evaluate and optimise investments in restorative activities to underpin restoration planning and overarching goal setting.
- Investigation and development of systems for improved restoration monitoring and shared learning.
- Development of early indicators and measures of long term restoration successes for key species and communities.
- Risk analyses of restoration approaches — understanding climate variability/change, provenance (local vs non-local), and use of surrogate species and ecosystems threat mitigation.
- Adequate genetically representative germplasm in *ex-situ* collections including seed orchards and captive animal colonies.
- Developing appropriate, robust monitoring techniques and methods for assessing long-term translocation and reintroduction success.

Focus area 2: Restoration technologies

Rationale

The future demands for restoration are significant, ranging from rehabilitation of mine sites, through the restoration of areas within conservation parks that have suffered degradation, the protection of remnant vegetation, to the restoration of fundamental ecological functions (such as ground water balances).

To address these challenges, contemporary restoration programs will aim to restore biodiverse plant and animal communities, often at a large scale. In practice, this means the return of tens to hundreds of species in many ecosystems, potentially across thousands of hectares. Scale and cost are key drivers of research priorities for restoration – there is a clear need to develop proven, cost effective and scalable restoration.

Priority areas for commissioned research

- Understanding physical, chemical, hydrological and biotic attributes of re-made soils and substrates to enable seedling establishment and plant growth and inform landform stability and erosion management.
- Understanding and capitalising on the role of soil biotic processes in the restoration process.
- Techniques for restoring recalcitrant and manage threatened species within restored communities.
- Development of seed technology for effective seed use, delivery, improved germination and survivability.
- Creating native seed production farming enterprises to generate high quality seed and to reduce the impact of seed collection on wild sources.
- Development of surrogate species and ecosystems.
- Landscape scale analysis of the cumulative impact of ecological restoration activities.
- Restoration of areas impacted on by *Phytophthora* dieback and invasive plants to restore important ecosystem services and functions.

Focus area 3: Reintroduction technologies

Rationale

Many WA native animal and plant populations are still declining and captive breeding, translocation strategies and the management of threatening processes need to be improved to prevent extinction of certain WA animals. The technology required to successfully translocate animal and plant populations mirrors the requirements of restoration technologies including landform and soil attributes, seed/animal sourcing, propagation and distribution. However, translocations of rare and threatened species require additional focus on the management of endangered source populations. The ecosystem benefits of translocations also need to be explored, such as the impact of re-introduced 'ecosystem engineers'. Integrated translocation of plants and animals to support enhanced ecosystem restoration programs should also be examined.

Priority areas for commissioned research

- Innovative techniques for captive breeding and appropriate *ex-situ* captive breeding protocols.
- Sourcing and storage of plant propagules, development of technologies to better deliver plants for translocations and improve seedling establishment.
- Understanding biotic and abiotic attributes that both enable and optimise plant establishment, growth, survival and recruitment of subsequent generations.
- Assessing the value(s) of fauna translocations to broader ecosystem restoration practices.
- Creating *ex-situ* production enterprises (seed orchards and captive breeding) to generate high quality offspring to reduce pressure on wild populations.
- *Ex-situ* management of source material ('insurance populations'), seed banks/orchards and the use of islands for animals.
- Developing appropriate protocols for *ex-situ* captive breeding.

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NEXT REVIEW

WABSI is currently funded until 2020. It is anticipated that this Research Priorities Plan will be reviewed at that time to ensure continuity of program delivery to address gaps in Western Australia's collective biodiversity knowledge and to meet the needs of end users.

The Western Australian Biodiversity Science Institute

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