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Knowledge Bank of Management Effectiveness

Learning from Australia's actions to improve the environment

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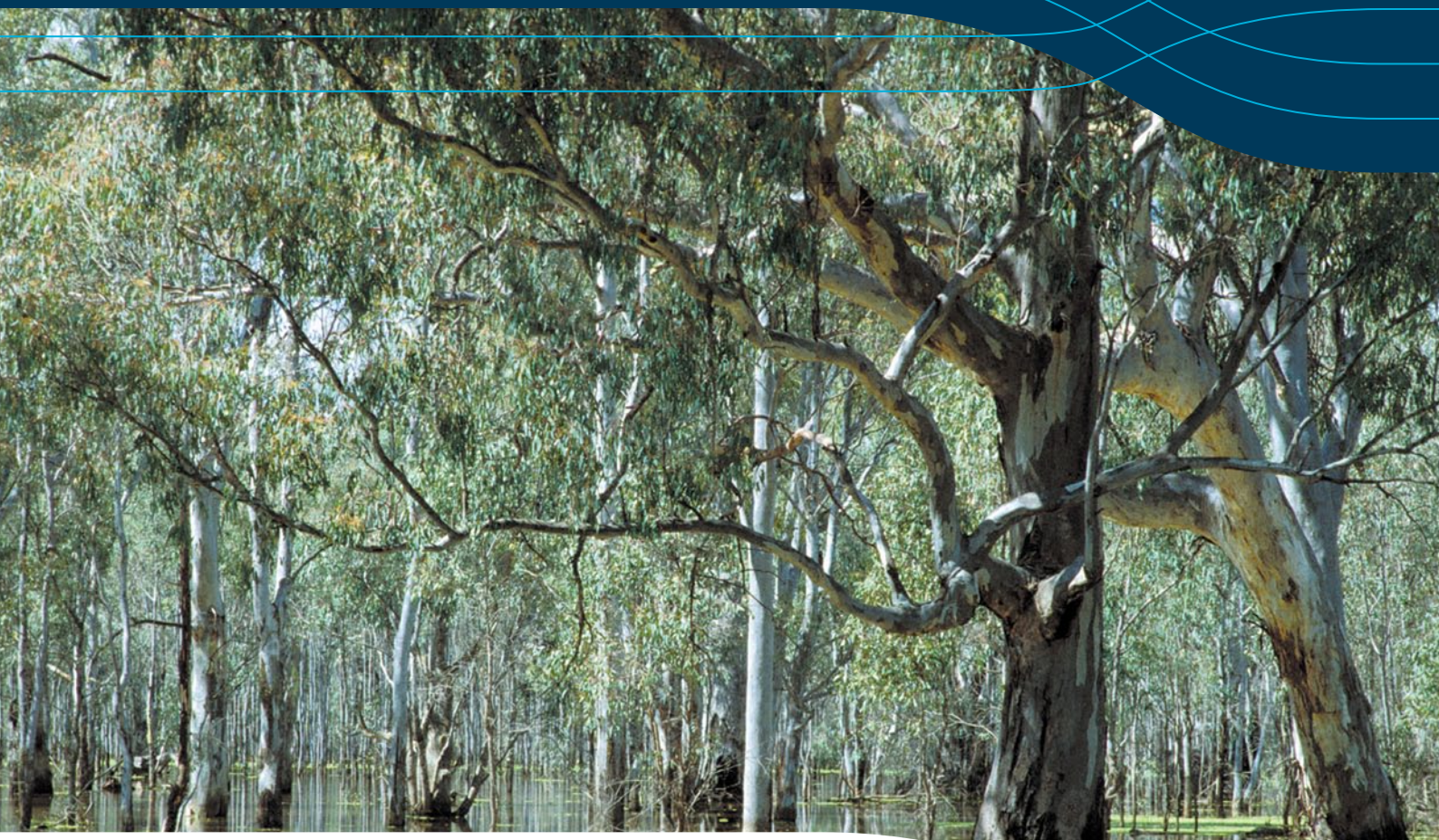

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Acknowledgements

To our knowledge, the Knowledge Bank of Management Effectiveness is the broadest systematic map (a classification of studies of management effectiveness across a broad domain) yet attempted globally. To be tractable yet still provide useful insights, we knew it would have to remain true to scope, strike the right balance between sufficient depth to be meaningful but sufficient breadth to provide confidence, and require the cooperation of many researchers, practitioners, and policy and program managers in Australia. We are very grateful to the many people who contributed to achieving these goals. In addition to the project team, multiple CSIRO librarians provided invaluable assistance with understanding recent changes to searchable databases like Trove and communicating with Thompson Reuters when Web of Science appeared to be functioning incorrectly. Several researchers across Australia responded to our requests for grey literature to include in the Knowledge Bank, and it was gratifying to see the spirit of collective learning alive through that process.

Finally and most importantly, our thanks for so many useful conversations, both formal and informal, with many people who implement the actions to improve our environment on ground, researchers who study interventions, and particularly program and policy offers in government who help to design and administer intervention programs as well as monitoring and research programs. Particular thanks to the Working Group within the Department of the Environment and Energy organised and convened by Fiona Dickson to provide on-going advice for this project. The insights we have been able to derive about key barriers to learning from our actions in Australia, as well as positive suggestions for how to create a better culture of and process for adaptive learning, would not have been nearly as rich, insightful, or practical without that full breadth of generous input.

Boxes provided as "penguin homes" along the cliff face (which is under restoration) at Nepean Bay on Kangaroo Island. Copyright shared (Department of the Environment and the creator) for unlimited time. Baker, John.

Executive Summary

MAKING MANAGEMENT MORE EFFECTIVE

Australia invests significantly in trying to improve the environment. From grazing management to revegetation to controlling exotic invasive species, there are many actions or 'interventions' taken that are intended to improve or restore native ecosystems and the diverse species they sustain. Funding is not limitless, so it is important to target investments in on-ground action toward the interventions that are most likely to be effective, and to target monitoring and research to improve our understanding of effectiveness where it may be lacking.

In practice, it has been challenging to understand the effectiveness of interventions aimed at improving degraded environments. Society is well-practised at extracting *benefit from the environment*, and expert at quantifying and measuring the success of extractive activities, for example in amounts of raw materials produced. By contrast, *benefits to the environment* gained through human activity (i.e. natural resource management interventions) and the flow-on services that improved environments provide to society are relatively under-measured and poorly understood, in part because of the complexity and variety of desired outcomes and resulting under-investment in developing measurement systems to understand drivers of success.

Yet in order to support a secure and prosperous society, particularly under global climate change, there is a need to significantly improve our understanding and measurement of the effectiveness of different natural resource management interventions. Without this, we will not know how to adaptively manage the critical ecosystem services on which our future prosperity relies. Thus, the time is ripe to synthesise the evidence currently available on the effectiveness of natural resource management (NRM) interventions in Australia, and use such a synthesis to guide adaptive management, and secure more effective and efficient outcomes for society.

An initiative of the Australian Government's Department of the Environment and Energy (DoEE) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Knowledge Bank of Management Effectiveness for NRM aims to fulfil that purpose. The Knowledge Bank project sourced direct studies of the effectiveness of NRM interventions across Australia produced through to 2016, collected them in an updatable repository, and drew initial insights into what we have learnt thus far and where key knowledge gaps remain. The Bank itself – currently a Microsoft Excel database and associated reference library – will remain a living resource that can receive 'deposits' as more sources of evidence become available and facilitate 'withdrawals' as governments, planners and land managers seek to explore the evidence overall or for their individual regions and interests.

This report provides a short overview of the development of the Bank and the volume of and patterns in the sources discovered. Its main aim is to explore the insights drawn from the total evidence available to date. Key questions about some of the methodological details are included in pull-out boxes, but full explanations of the methods used and the results obtained can be found in the companion technical guide (Doerr et al. 2018).

MEASURING EFFECTIVENESS

To assess effectiveness, the aim of the intervention must be clear – there must be a desired outcome to measure. While high-level goals are often clear, like maintaining or improving the viability or persistence of species, species' adaptive capacity, or the ability of ecosystems to provide critical services, these high-level goals may be virtually impossible to measure directly. Instead, they must be associated with lower-level measurable outcomes that are expected to lead to higher-order goals, either over time or with additional intervention. Thus, before building the Bank, the relationships between high-level goals and a wide range of potential lower-level outcomes that might be actually measured needed to be constructed.

Even when desired measurable outcomes are clear, evidence for effectiveness can come from a variety of sources. Before building the Bank, it was important to decide which types of evidence to include. Evidence can come from ecological theory, modelling to predict effectiveness (a more structured form of using ecological theory), controlled experiments in the laboratory or at smaller scales, and direct measurement in the field (either through monitoring or more formal scientific research). Theory, models and experiments help reveal which interventions *should* work, but direct measurement at scale in the field confirms which interventions actually *do* work. While the latter evidence can be harder to obtain, it best reflects the aim of the Knowledge Bank. Thus, the Bank focused on collating and synthesising direct empirical evidence of effectiveness from monitoring and research in the field, at the scale of on-ground management intervention.

BUILDING THE BANK

The Bank was built using a technique called 'systematic mapping', which is related to 'systematic reviewing' and is derived from medical research, where rigorous, transparent, repeatable synthesis about the effectiveness of interventions is critical. Following formal guidelines for the conduct of systematic maps and reviews in environmental science and management, specific search techniques and search terms were developed and tested to cast a broad net and find all relevant sources of information, including in the 'grey literature' (unpublished theses, brochures, websites, etc.). Thousands of potential sources were then filtered using predetermined inclusion and exclusion criteria until only sources that actually report on NRM intervention effectiveness in Australia remained. Data were extracted from those sources, including information on whether the authors concluded that the intervention studied was effective or not, or was partially effective. Partial effectiveness included situations in which desired outcomes were only partially achieved (e.g. managing livestock grazing led to an increase in the number of native plant species but not fully back to desired reference condition numbers). It also included situations in which the effectiveness of the intervention was context-dependent – in which the intervention studied sometimes achieved desired outcomes and sometimes did not (e.g. controlling weeds led to increased nativeness at some sites but not others).

INITIAL INSIGHTS FROM THE KNOWLEDGE BANK

Limited Evidence Exists

The key result from the initial building of the Knowledge Bank was that relatively little direct, empirical evidence has been documented and is available about NRM management effectiveness in Australia. Interventions were grouped into ten Themes based on the type of threat or damage they are intended to reverse, and fewer than 20 sources of evidence were available for six of those Themes (Proliferation of Weeds, Predation/Damage by Feral Vertebrates, Damage by Pest Invertebrates, Excessive Nutrients and Pollutants, Loss of Keystone Species, and Loss of Key Structures and Functions). For the remaining four Themes (Excessive Grazing, Clearing of Native Vegetation, Changed Hydrological Conditions, and Changed Fire Regimes), evidence came from between 37 and 78 studies and presented a mixed picture of effectiveness, though partial effectiveness was the most common conclusion. In these four Themes where greater evidence was available, studies were so diverse in terms of the details of the interventions, the types of outcomes measured, and the other interventions employed at the same time that more nuanced insights could not be discerned.

Partial Effectiveness is Common

Aside from an overall lack of evidence, another clear pattern was that interventions were most commonly reported to be only partially effective. In the cases of managing excessive grazing and revegetation, there was some evidence to suggest that full recovery to a 'reference' or 'benchmark' state or condition only rarely occurs, even following many decades of investment in conservation management. This may reflect the challenge of restoring Australia's fragile environment. The degree and permanency of ecosystem modification that has occurred to date, including the legacy effects of anthropogenic land uses, poses a challenge if desired outcomes focus on restoration. Restoration to full ecosystem health may require significant time and resources which are rarely available.

More Novel Interventions & Systems Approaches May Be Needed

The results suggested that systems approaches, which identify and manage key drivers, as well as more novel 'engineering' approaches that focus on restoring key processes rather than specific ecosystem compositions and structures may be a more effective approach to management, and more capable of creating significant change rather than just incremental improvement. Though more rarely applied, the more novel 'engineering' approaches to NRM intervention were more likely to be considered effective.

BARRIERS TO LEARNING FROM ON-GROUND ACTIONS

Overwhelmingly, the main insight from the Knowledge Bank is actually that we aren't currently learning enough about effectiveness from on-ground actions. Given the large number of on-ground interventions, the extreme paucity of direct studies of effectiveness was surprising. Combined with the insight that partial effectiveness is common and thus desired outcomes are not being achieved, it suggests that the most important action to take is to make some fundamental changes in how we learn to be more effective.

To develop a set of options or 'building blocks' that could be employed to accelerate learning and innovation in environmental management, we gathered expert opinion from our project staff, staff involved in various programs within the Department of the Environment and Energy, and other researchers and NRM practitioners (the managers and implementers who negotiate with private land managers to implement interventions on the ground). We also qualitatively analysed patterns in the sources that were excluded from the Knowledge Bank as well as those that were included.

Drawing on these diverse sources of input, we first articulated what appeared to be the most critical barriers to effective learning from on-ground actions. These were: •

- Lack of meaningful articulation of desired, measurable outcomes, including
  - current approaches used to set NRM targets, which tend to be either highly generalised or focused on outputs, neither of which lend themselves to clarity about desired outcomes
  - desired outcomes based on incremental improvement rather than focusing on the drivers of substantial change in the system
  - lack of long-haul investment plans which would make it more worthwhile to articulate more substantial systems outcomes
- Different drivers of success for program designers, researchers, and land managers/implementers which tend to inadvertently prevent effective collaboration for learning
- The flow-on consequences of the above for program design, which thus tends to focus on single practice rather than learning itself as a goal
- Recent emphasis on activity reporting and trend or surveillance monitoring, each of which have important purposes but neither of which help answer questions about effectiveness
- Lack of consistent discoverability and accessibility of information in part because of the preferred channels and the types of communications resourced (e.g. web-based)

CREATING A CULTURE AND MECHANISMS OF ADAPTIVE LEARNING

We worked with our broad group of experts to explore building blocks for learning and developed options for each building block that could be implemented in different programs and contexts over time to overcome these barriers and build a coherent system for learning about the effectiveness of on-ground management interventions. This report provides short descriptions of potential options to serve as conversation-starters. Options may need to be implemented for all five building blocks, which address both structural change and increased collaborative relationships and governance:

Structural Changes in NRM

- Build physical research infrastructure to support learning
- Build information infrastructure to support learning
- Improve NRM program design

Relationships and Collaborative Governance

- Develop the structural changes above collaboratively with program designers, researchers, and practitioners
- Manage the disparate drivers of program designers, researchers, and practitioners/implementers through structures for long-term collaborative governance

For example in terms of structural change, NRM program design may need to allow for the comparison of multiple interventions intended to achieve the same outcomes to facilitate more rapid learning. A national set of sentinel sites (an option for building physical research infrastructure) could provide dynamic reference or benchmark comparisons for these multiple interventions. Additionally, a consistent categorisation of desired outcomes (an option for building information infrastructure) could allow multiple practitioners and researchers to monitor outcomes in comparable ways, facilitating national scale learning. These pieces of infrastructure would then make it possible for program designers to build programs that can implement, monitor and compare interventions in terms of their effectiveness.

To design such structural change, deliberate collaboration between program designers, researchers and practitioners would be essential – collaboration that extends beyond advice, consultation or serving on steering committees. For example, the disparate drivers of these three different disciplines mean that unless the categorisation of desired outcomes noted above was built with their diverse needs specifically in mind, researchers would not use it consistently and practitioners might not strive to achieve the outcomes if they didn't align with values of regional land managers. Specific collaborative projects, more formal partnerships or possibly brokered relationships between these different disciplinary cultures would also help in the long term to deliberatively counter the drivers that may push program designers, researchers and practitioners apart. This collaborative governance would help to ensure that many of the other building blocks for improving learning can fulfil their potential for significant and long-lasting reform.

Without any change in the environment management and restoration sector in Australia, we are likely to continue to learn very slowly. Without change, the Knowledge Bank will only grow incrementally and remained constrained by limited evidence to help build confidence and better target environmental investment. Yet there are clear options to accelerate and innovate. We hope the synthesis and ideas presented here can serve as a catalyst to stimulate that positive change.

Introduction to the Knowledge Bank

Natural Resource Management (NRM) and Landcare activities are fundamental to the ongoing health and prosperity of Australia's environment. Over the past three decades, many on-ground actions have been implemented to reduce threats to our environment, improve the condition of native systems, and even re-establish native ecosystems where they have been heavily modified.

Ideally, this investment in on-ground interventions would have been accompanied by systematic monitoring and research in order to build a body of evidence regarding the observed effectiveness of these on-ground management activities. Yet this is not the case. Of the evidence that does exist, much of it is published in scientific journals to which government and management practitioners do not have direct access. Internal government reports, public research summaries and factsheets, and unpublished student work are valuable sources of information on effectiveness that can be difficult to find as they are not systematically documented and often not securely stored or accessible. As a result, there is a lack of understanding about how much direct evidence exists. Most importantly, the lack of synthesis means that the question still remains:

How much have we learned about what works best to achieve our goals?

It was this question that motivated the development of the Knowledge Bank of NRM Management Effectiveness – an initiative of the Australian Government's Department of the Environment and Energy (DoEE) and the Commonwealth Scientific and Industrial Research Organisation (CSIRO). The initiative aimed to discover existing direct studies of the effectiveness of NRM interventions (activities to improve the environment) across Australia, collect them in an updatable repository, draw initial insights and identify where key knowledge gaps remain. These insights were intended to help direct and lend confidence to investment in NRM, particularly through development of confidence ratings for different on-ground actions based on a rigorously framed system of inference, taking into account volume, consistency and quality of evidence as well as transferability of inference across ecosystem types. Results were also intended to help focus future monitoring and research efforts toward the most critical knowledge gaps, to ensure learning is most cost-effective and can more rapidly contribute to improved outcomes.

This report provides a brief overview of the methods used to find evidence of management effectiveness and a summary of the immediate insights that can be drawn. Effectiveness was defined based on achievement of high-level desired outcomes articulated throughout Australian environmental planning and, more commonly, achievement of more directly measurable short-term or intermediate outcomes that are expected to lead to those high-level desired outcomes. The Bank focused on collating and synthesising direct empirical measurement of effectiveness at scales relevant to real-world on-ground application, rather than controlled experiments at smaller scales or modelling studies, as the latter enrich our understanding of which interventions should be effective rather than confirm actual effectiveness on ground. Throughout this report, pull-out boxes are provided as optional reading where more explanation may be required, and full details are available in the companion technical report (Doerr et al. 2018). The Bank itself is a Microsoft Excel database and associated reference library held by DoEE.

In the process of producing the Bank, it became clear that the volume and comparability of the evidence were both relatively low, suggesting that learning about management effectiveness is still at an early stage. Thus, the original intent to provide confidence ratings was unachievable and focus was shifted to maximising insights about how best to focus monitoring, research, and learning more broadly. Patterns were explored in the studies available and broad consultation was undertaken to identify key barriers to learning from on-ground actions. Experts were also consulted on options for how to accelerate efforts to learn and thus more quickly improve on-ground investment – reducing investment risks and increasing cost-effectiveness. Implementing some of these options to build an ***adaptive learning infrastructure*** into NRM activities is likely to provide the most effective way to reduce investment risk and build confidence in Australia's actions to protect and improve our environment for the benefit of society.

Overview of How the Bank was Developed

The approach used to construct the Bank – to find direct empirical studies of the effects of on-ground NRM interventions and extract consistent, comparable data from them – is known as 'systematic mapping' (James et al. 2016). Systematic maps use transparent, consistent and repeatable methods to search for relevant studies and describe the total volume and nature of the evidence available across a suite of interventions. Systematic maps are thus particularly suitable for the initial stages of addressing broad questions (like the effectiveness of NRM interventions). They frequently lead on to 'systematic reviews' of specific interventions where sufficient volume of evidence exists to permit more detailed analyses and quantitative synthesis. The Knowledge Bank provides a systematic map of NRM intervention evaluations in Australia with the intent to support future development of systematic reviews where possible.

Following international guidelines for systematic review and mapping (Collaboration for Environmental Evidence 2013), a detailed protocol was developed and executed. The value of a protocol is that it provides a process to identify as many existing sources of information as possible (given the time and resources available) in an unbiased way. It also provides a specific written methodology that can be followed again in the future to update the Bank. The process involved the following main steps:

1. **Develop a draft search strategy** specifying exactly which databases to search (Web of Science, Google, Trove, and NRM Knowledge Online), which search strings to use, and any other approaches needed to search the grey literature (unpublished theses, brochures, booklets, factsheets, etc.)

2. **Test the search strategy** to see if it identifies papers the research team already knew about that report on effectiveness to test whether the searches are adequate

3. **Modify the search strategy** to ensure test papers are identified and that the first 50 sources identified appear moderately relevant

4. **Filter sources** to exclude those that aren't relevant based first on title, then abstract, then full text

5. **Extract basic data** from each remaining relevant study into the Knowledge Bank database

Interventions

Interventions included in the Bank were drawn from Management Recommendations contained in the profiles of Conservation Management Zones (CMZs) within Australia, supplemented with project team knowledge of on-ground work currently occurring. The CMZ Management Recommendations were derived from *Environment Protection and Biodiversity Conservation Act 1999* threatened species and ecological community recovery plans, conservation advices, scientific literature, biodiversity and vegetation management policies, local government environmental planning documents, environmental Non-Governmental Organisations planning and restoration literature (e.g. Greening Australia), as well as Natural Resource Management (NRM) regional plans and national, state and local NRM programs. They are therefore representative (though not necessarily comprehensively exhaustive) of the suite of actions currently invested in or recommended by governments and organisations across Australia (Table 1).

To target our searches more effectively, these NRM interventions were grouped into 10 Themes based on the type of damage or threat to natural ecosystems each intervention is intended to halt or reverse (Table 1). Thus, the five broad steps involved in systematic mapping noted above were followed separately for each of the 10 Themes.

Table 1. Management interventions included in the Knowledge Bank, organised according to 10 Themes, expressed as types of damage done to natural ecosystems in Australia which interventions are intended to halt or reverse. Further information and clarification on some interventions are available in the box 'Advantages and disadvantages of classifying interventions and outcomes'.

Theme	Interventions
Excessive Grazing	• Manage timing of grazing • Reduce total grazing pressure (livestock, feral herbivores, natives)
Clearing of Native Vegetation (whether recent or legacy)	• Encourage natural regeneration • Revegetate, matching local composition & structure • Revegetate, engineering new composition • Revegetate, engineering new structure • Manage fire regimes to restore native system
Changed Hydrological Conditions	• Create structures that reduce erosion • Manage release of water from dams & weirs • Manage water for floodplains & wetlands via regulators • Reduce extraction of surface and ground waters • Reduce populations of predatory, parasitic & competing pests (fish)
Changed Fire Regimes	• Change fire extent and/or intensity • Change fire intervals and/or seasonality • Protect sensitive habitats from fire
Proliferation of Weeds	• Control weeds in revegetation & remnants • Control outlying populations of weeds • Reduce weeds next to native vegetation and waterways • Control transformer weed species (including flammable grasses) • Clean vehicles & footwear between sites
Predation/Direct Damage by Feral Vertebrates	• Kill introduced predators/other vertebrates that cause direct damage • Remove habitat for introduced predators/other vertebrates that cause direct damage • Control access by introduced predators/other vertebrates that cause direct damage • Support natives that compete with introduced predators/other vertebrates that cause direct damage
Damage by Pest Invertebrates	• Reduce populations of plant-feeding pests • Reduce populations of predatory, parasitic & competing pest invertebrates
Excessive Nutrients and Pollutants	• Avoid chemical application in and next to native vegetation • Plant or maintain densely rooted vegetation next to native vegetation and waterways • Plant or maintain scattered trees next to wooded native vegetation • Reduce movement of livestock into native vegetation
Loss of Keystone Species	• Reintroduce keystone species (animals, plants, micro-organisms) (captive breed if necessary) • Revegetate, engineering composition to cater for a keystone sp. • Revegetate, engineering structure to cater for a keystone sp.
Loss of Key Structures and Functions	• Create and/or manage movement 'corridors' • Protect and manage refugia • Protect, manage & restore keystone habitat structures (mature trees, logs, snags in water, etc.) • Control overabundant native species

Outcomes

To design the search strings to identify sources that assess *outcomes*, not just report on actions, and to specify outcomes in a consistent way in order to evaluate effectiveness, we developed a 'Program Logic' (Roughley 2009) for each Theme. Program Logics trace the relationships between interventions and their expected immediate outcomes, as well as which intermediate and ultimate outcomes might be expected to follow-on over time due to ongoing ecological processes. We focused on the high-level ultimate outcomes commonly articulated in Australia across governmental and non-governmental programs:

- maintaining native species diversity
- maintaining or improving the long-term persistence of species and reducing extinction
- maintaining representative diversity of healthy ecosystems
- maintaining or improving long-term adaptation potential
- maintaining or improving ecosystem services

We then traced how interventions might be expected to deliver those outcomes – which immediate and intermediate outcomes need to be achieved first, like improved ecosystem condition or the recovery of threatened species. For example, reducing total grazing pressure may be used as an intervention to maintain or increase native species diversity, but the process by which that outcome could be achieved needs to be more explicit. To be able to achieve such a long-term outcome, reducing grazing pressure (the intervention) might first need to result in an increase in ground cover through allowing existing plants to grow bigger (and immediate outcome), which may then lead to improved soil conditions for seedling establishment through the creation of more protected inter-tussock spaces (and intermediate outcome). This in turn might result in better germination rates for a greater diversity of seeds in the seedbank, particularly forbs (a long-term outcome), resulting in increased plant diversity (an ultimate outcome). Any or all of these outcomes could be measured and could constitute evidence of effectiveness.

Note that we used this Program Logic approach specifically to define a broad suite of measurable desirable outcomes from NRM interventions which then allowed us to construct search strings that would more precisely target studies that actually measured outcomes while still casting the net wide in terms of the types of outcomes measured. The Program Logics thus served a specific methodological purpose and were not intended to be definitive national management and outcomes typologies, which could only be usefully developed with more broad-based input.

Assessing effectiveness

Data extracted from sources in systematic maps do not generally include information about effectiveness – the map is purely intended to assess the relative volume of evidence available for different interventions or other conditions. Effectiveness is then assessed through more detailed systematic reviews where evidence is of a sufficient volume. However, we wanted to draw some initial inference from the Bank as a whole. So we took it one step further than a traditional systematic map and extracted data on effectiveness using a 'vote counting' procedure. This means we simply classified each source based on whether the authors concluded the intervention was effective or not, or whether it was 'partly' effective (i.e. only under some conditions, or outcomes were only partially achieved). We were then able to assess broad patterns in effectiveness across Themes, across interventions, or within interventions based on other sources of variation (like type of outcome measured, geographic location, etc.).

Common questions about these methods are addressed in the following pull-out boxes, and more complete information can be found in the companion technical guide (Doerr et al. 2018).

Advantages and disadvantages of classifying interventions and outcomes

In reality, no two interventions or outcomes assessments are exactly the same. Because of this, some degree of classification is required. But there will always be some limitations with classifications like Table 1 and the Program Logics developed to consider outcomes (see the technical guide, Doerr et al. 2017). For example, the interventions described may be too broad for some uses, it may be unclear where some specific approaches fit, rarer interventions may seem to be absent, and/or classifications won't include the combinations of interventions that are common on the ground (e.g. controlling foxes alongside rabbits).

However, classifications also permit broad comparisons to be made, trends to be identified, and general principles to be extracted. Thus, classifications will never be perfect but as long as they are sufficiently robust given their intended purpose, and representative (rather than necessarily fully comprehensive), they can be a valuable aid in learning about effectiveness. In this case, the purpose of the classifications was to assist with developing effective strategies to search for evidence of effectiveness. Further work would be required to generate classifications or typologies of interventions and outcomes that could be used cross-jurisdictionally to support a system of national learning.

Some points of clarification about the classifications we used may help illustrate their representativeness and robustness (and inform interpretation of the results):

- Many specific actions are possible under each of the interventions (e.g. controlling weeds can be done in many different ways) so the focus here is on the higher-level effort, not the fine details.
- Control of feral herbivores does not specifically appear because it is part of 'Reduce total grazing pressure' – it has the same intended outcomes as managing livestock grazing.
- 'Managing release of water from dams & weirs' can include details of dam and weir construction like the provision of fishways.
- Seemingly similar interventions like 'Control weeds in revegetation & remnants' and 'Reduce weeds next to native vegetation and waterways' are separate because the desired immediate outcomes are different (i.e. controlling a resident weed vs. preventing invasion in the first place).
- Fire can be used as an action under a variety of interventions (like 'Control weeds in revegetation & remnants' as well as 'Encourage natural regeneration'). Changed Fire Regimes as a Theme thus involves managing fire with the aim of restoring natural regimes of fire frequency and intensity, not using fire as a specific management tool to achieve other aims.
- One key class of interventions not included at this stage were those under the Theme of Proliferation of Disease. Because of the diverse nature of diseases for both plants and animals, and thus the special challenge of designing search terms that would be comprehensive enough without picking up far too many irrelevant sources, this Theme was beyond the scope of this project. However, this remains an important category for further analysis.
- Some interventions may have co-benefits. For example, 'Revegetate, engineering new structure' could involve mixed environmental plantings with high densities of shrubs aimed at achieving carbon sequestration which may also contribute to reversing problems associated with vegetation clearing albeit with an 'engineered' vegetation structure.

What about novel interventions?

Some of the interventions we assessed included novel approaches to environmental management and restoration. For example, 'Protect and manage refugia' and 'Revegetate, engineering new composition' are both frequently suggested as ways to support nature conservation under climate change but may not yet be commonly applied let alone assessed for actual on-ground effectiveness.

These types of interventions were included in the Knowledge Bank for two reasons. First, they emerged from the standard process used to determine which interventions to include in the Bank. They are mentioned in recovery plans, conservation advices, scientific literature, policies, and/or planning documents. Even if these interventions aren't commonly applied, they are at least recommended, and including them ensured our methods were transparent and repeatable.

Second, it seemed worthwhile to gain some data on whether novel interventions are actually being applied and assessed. Trialling a diversity of approaches at once is arguably one of the best and fastest ways to learn about effectiveness (rather than trialling approaches one at a time, only testing novel ones once existing ones are proven ineffective). So even if we anticipated a relative lack of evidence associated with these interventions, quantifying that lack provides information about important gaps in our ability to learn about effectiveness.

The inclusion of these novel interventions means we need to be cautious about interpretation of a lack of evidence about their effectiveness. Lack of evidence could be due to a lack of monitoring, a lack of reporting in discoverable and accessible ways, or a lack of trialling the interventions to begin with. Distinguishing between these causes required more qualitative interpretation across the studies included and excluded from the Bank as well as the gathering of expert opinion, performed to identify key barriers to learning.

Parks and Wildlife Ranger alongside the predator fence in the Venus Bay Conservation Reserve that was erected to keep out foxes and rabbits. Copyright Department of the Environment (taken by staff). Markovic, Dragi.

Summary of Results

Overall Evidence

We initially identified 15,653 peer-reviewed and grey literature sources across the 10 Themes through our searches. However, relatively few sources of information about effectiveness remained after these thousands were examined for relevance (Table 2). Six of the Themes ended up with just 20 or fewer sources for the whole Theme and fewer than 10 sources for almost all of the interventions within these Themes. This included Themes where interventions are commonly applied on-ground such as 'Proliferation of Weeds'.

Even where more substantial numbers of sources were identified (Excessive Grazing, regeneration and revegetation to combat Clearing of Native Vegetation, Changed Hydrological Conditions, and potentially Changed Fire Regimes), the ability to draw insights about effectiveness was limited by high levels of diversity among the sources. For example, 71 sources examined the outcomes of reducing total grazing pressure. Overall, reducing total grazing pressure was generally found to be partially effective – it partially but not fully restored sites to reference or benchmark condition. Seventy-one sources would normally be sufficient to explore in detail and conduct a systematic review. However, these studies varied widely in the outcomes measured, the details of the interventions applied (including the combination of interventions used), and the starting conditions of the sites. This meant that of 71 sources, no more than four were similar enough to be roughly comparable (i.e., similar intervention, outcomes measured, and historical management of sites). This diversity means that many more sources would be required to draw clearer conclusions about what influences or limits the effectiveness of reducing total grazing pressure.

Thus, results from the construction of the Knowledge Bank indicate that:

- Sources of evidence about on-ground management effectiveness are lacking across all types of interventions. This is despite the large opportunity to evaluate effectiveness that exists as a result of numerous interventions being applied on the ground.
- Even where more sources of evidence are available, there is so much diversity in the application of interventions as well as the assessment of effectiveness that few general conclusions can be drawn.
- We found no evidence to assess effectiveness for approximately one-third of all interventions. This lack of evidence may have a variety of causes but it appears that many of the more novel interventions are not being formally trialled and evaluated (e.g. supporting native species that compete with introduced predators, managing livestock movements into native vegetation to limit nutrient transfer, and protecting and managing refugia). Many others are perhaps assumed to be useful and virtually never assessed or assessments aren't shared in a discoverable way (e.g. cleaning vehicles between sites to minimise transfer of weed seeds, and reducing carp populations).

Table 2. Number of sources of evidence about effectiveness identified for each intervention under each Theme.

Theme	Interventions	# Sources
Excessive Grazing	• Manage timing of grazing	16
	• Reduce total grazing pressure (livestock, feral herbivores, natives)	71
Clearing of Native Vegetation (whether recent or legacy)	• Encourage natural regeneration	16
	• Revegetate, matching local composition & structure	46
	• Revegetate, engineering new composition	4
	• Revegetate, engineering new structure	4
	• Manage fire regimes to restore native system	2
Changed Hydrological Conditions	• Create structures that reduce erosion	1
	• Manage release of water from dams & weirs	40
	• Manage water for floodplains & wetlands via regulators	13
	• Reduce extraction of surface and ground waters	0
	• Reduce populations of predatory, parasitic & competing pests (fish)	0
Changed Fire Regimes	• Change fire extent and/or intensity	7
	• Change fire intervals and/or seasonality	29
	• Protect sensitive habitats from fire	0
Proliferation of Weeds	• Control weeds in revegetation & remnants	4
	• Control outlying populations of weeds	0
	• Reduce weeds next to native vegetation and waterways	9
	• Control transformer weed species (including flammable grasses)	2
	• Clean vehicles & footwear between sites	0
Predation/Direct Damage by Feral Vertebrates	• Kill introduced predators/other vertebrates that cause direct damage	10
	• Remove habitat for introduced predators/other vertebrates that cause direct damage	0
	• Control access by introduced predators/other vertebrates that cause direct damage	2
	• Support natives that compete with introduced predators/other vertebrates that cause direct damage	0
Damage by Pest Invertebrates	• Reduce populations of plant-feeding pests	0
	• Reduce populations of predatory, parasitic & competing pest invertebrates	3
Excessive Nutrients and Pollutants	• Avoid chemical application in and next to native vegetation	0
	• Plant or maintain densely rooted vegetation next to native vegetation and waterways	7
	• Plant or maintain scattered trees next to wooded native vegetation	0
	• Reduce movement of livestock into native vegetation	0
Loss of Keystone Species	• Reintroduce keystone species (animals, plants, micro-organisms) (captive breed if necessary)	4
	• Revegetate, engineering composition to cater for a keystone sp.	2
	• Revegetate, engineering structure to cater for a keystone sp.	0
Loss of Key Structures and Functions	• Create and/or manage movement 'corridors'	1
	• Protect and manage refugia	0
	• Protect, manage & restore keystone habitat structures (mature trees, logs, snags in water, etc.)	15
	• Control overabundant native species	0

Insights by Theme

The original aim of drawing inference or insights from the initial development of the Knowledge Bank was to be able to articulate for each Theme which interventions we can most confidently invest in, how generalised their effectiveness is and thus how widely we could confidently apply them across landscapes, and which still require some monitoring or research to have full confidence in implementing. However, the paucity and diversity of sources discovered meant that such detailed insights are not yet possible to derive. As a result, most of the remainder of this report is devoted to understanding broader cross-Theme patterns, particularly some additional qualitative analysis about why so little evidence is available (or discoverable) as well as what could be done to more rapidly and cost-effectively build confidence in management interventions.

However, these broader strategic and programmatic insights and options will not be relevant for all audiences. Some people interested in this work will largely have influence at more detailed levels and will still want some Theme-based recommendations. Thus, the following box provides the most robust suggestions we can offer from the evidence currently available about what to invest in and how to monitor.

Recommendations for implementing and monitoring by Theme

Excessive Grazing

Grazing management is usually partially effective at restoring ecosystems to reference or benchmark condition. However, the degree to which grazing management is successful is likely to depend on many different local and historical factors as well as other interventions it is combined with. Active experimentation at local scales – trialling a few different approaches and comparing them – is recommended, as it is likely to lead to rapid learning and improvement at the most relevant scales.

Clearing of Native Vegetation

Regeneration and revegetation to combat past or current clearing are also usually only partially effective at restoring reference or benchmark condition, even after long time periods of recovery. Both on-ground actions and monitoring efforts could be switched from restoration of local composition to exploring more 'engineering' or process-driven restoration options, where specific elements of the system are restored because they are thought to encourage key processes of recovery. Conceptual models of ecosystem dynamics would help to identify components of ecosystems that can drive process-based recovery and enable this approach.

Changed Hydrological Conditions

Research and monitoring effort may be best applied to deliberate testing of broader conceptual systems models rather than studying effectiveness of specific management events as management in these situations is more focused on shifting a regime over the long term than once-off management intervention. Interventions can then be planned based on the conceptual models but not individually empirically tested.

Changed Fire Regimes

Research and monitoring effort may be best applied to deliberate building and testing of broader systems models, including taking advantage of data collection from burns conducted for reasons other than nature conservation. Interventions can then be planned to manipulate key drivers in rigorous, empirically tested systems models and not individually monitored.

Proliferation of Weeds

Shift away from monitoring the removal of weeds themselves and toward monitoring the broader environmental benefits of controlling weeds as these impacts are still not well-established. A special focus on transformer weeds, preventing weed spread/dispersal, and the conditions under which interventions may not need to be on-going would be useful.

Predation/Direct Damage by Feral Vertebrates

Immediate biodiversity outcomes are beginning to be established for controlling these species but the outcomes assessed are usually quite limited and often involve benefits to only a single species. Some monitoring resources could be effectively re-directed toward assessing broader environmental outcomes rather than simply reductions in the feral predators themselves. Long-term studies of predator-prey dynamics could also be used more effectively by introducing control interventions.

Damage by Pest Invertebrates
Virtually no evidence exists of the environmental benefits of interventions to reduce damage by pest invertebrates, so investment in the interventions should always be coupled with investment in monitoring the resulting outcomes. Cross-sector research that assesses both the agricultural and environmental benefits of interventions to reduce the damage done by pest invertebrates would dramatically increase the knowledge base as interventions are performed much more frequently for agricultural benefit.

Excessive Nutrients & Pollutants
Grassy riparian buffers are effective at reducing nutrient transfer and sedimentation in many circumstances and may not need further monitoring. However, monitoring of other types of buffers should happen more frequently. Terrestrial buffers (e.g. those adjacent to terrestrial native vegetation that may reduce 'edge effects' and wind and water transfer of nutrients) should be implemented and monitored more frequently to assess their effectiveness.

Loss of Keystone Species
Reintroductions of keystone species or 'ecosystem engineers' may be particularly likely to generate broader ecological benefits but these are new and relatively rare interventions. It may be worth concentrating on keystone plants, rather than charismatic fauna, and pairing on-ground interventions quite tightly with research. Most monitoring will be fairly complex if it aims to assess the broader environmental benefits and not just the establishment of the species itself.

Loss of Key Structure & Functions
Restoration of important habitat structures is likely to benefit wildlife species, including some threatened species. However, more novel interventions like protecting refugia remain to be evaluated. Monitoring of effectiveness should move away from simple immediate measures of success such as 'use' or 'occupancy' and focus instead on whether or not proper ecological function (e.g. dispersal) is restored as well as evaluation of more novel approaches.

Inspecting monitoring site for Bridal Creeper control near Kingscote on Kangaroo Island. Copyright shared (Department of the Environment and the creator) for unlimited time. Baker, John.

Cross-Theme Patterns

Partial Effectiveness

Six of the ten Themes involved interventions that were most commonly reported to be only partially effective (Figure 1). These included the most commonly applied interventions of managing grazing, regeneration and revegetation, managing environmental water, and controlling weeds. These were also the Themes in which interventions tend to be targeted at broad ecosystem benefits. In contrast, restoring key habitat structures for specific fauna species or species groups was more likely to be reported as definitely effective, though not necessarily at generating ecosystem-wide benefits beyond the specific species involved.

Although this demonstrates we can be successful at putting back some specific elements of ecosystems that have been lost, there are challenges in restoring whole systems. We currently do not know how to do it. Given that many of the studies reporting partial effectiveness measured outcomes at sites many decades after initial intervention, achieving effectiveness is not simply a matter of allowing sufficient time. This is not necessarily unexpected, but a strong pattern and thus an overall striking result, particularly given increasing reliance on restoration to offset impacts of clearing.

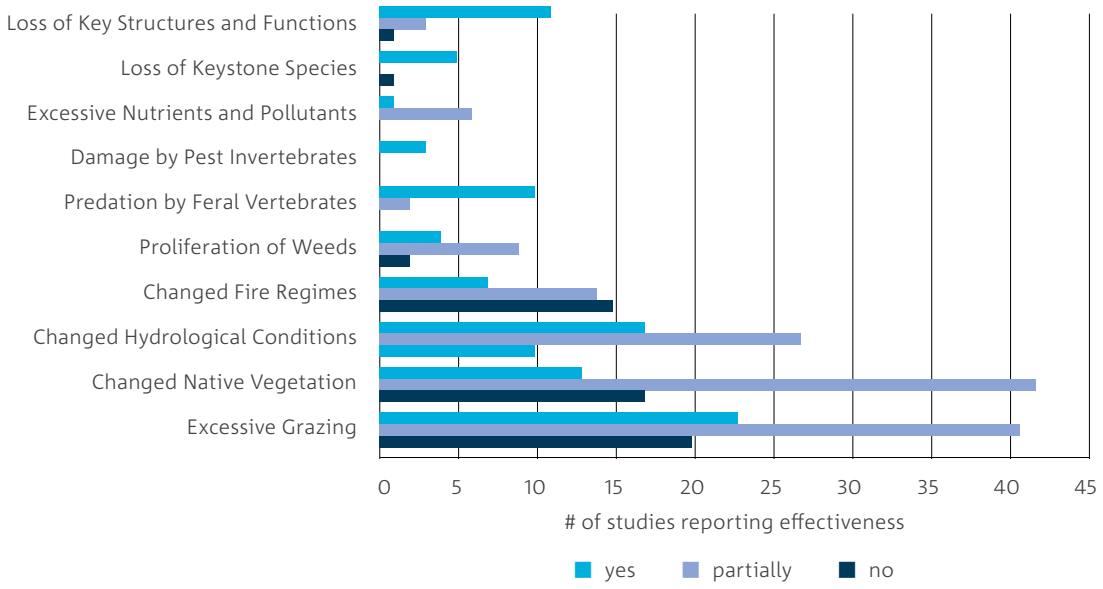

Figure 1. Cross-theme patterns in effectiveness – number of studies reporting that interventions were definitely effective (yes), partially effective (partially), or not effective (no) across each of the 10 Themes.

Systems Drivers vs. Interventions

For several of the Themes, one of the conclusions that emerged was that individual interventions may not be the most appropriate way to design management or monitoring, particularly in ecosystems that depend on natural disruptive processes like fire or flooding. Instead, management that focuses on changing key systems drivers – changing the disturbance *regime* – through multiple interventions over time may be more likely to succeed. This is partly because in these systems, single interventions create change but it may be varied and temporary, and only multiple interventions are capable of driving significant change in desired directions.

For example, a single application of environmental water will create immediate change in floodplain ecosystems, but that change may only be temporary and the nature of the change will differ substantially in systems with previous watering histories (and a range of other variables). Achieving desired outcomes like improvements in the health of floodplain ecosystems requires a plan to shift the watering regime over time, not just the application of individual watering events. As such, the 'intervention' is actually about long-term regime change and assessing effectiveness through monitoring and research needs to be done by assessing the consequences of that regime change, not the effects of individual watering events.

This approach thus also requires us to be clear about the desired state (or set of dynamic states) we want an ecosystem to be in. Disturbance regimes drive ecosystems into different states which may not inherently be 'good' or 'bad', just different. For example, reduced fire frequency can lead dry sub-tropical sclerophyll woodlands to transition toward sub-tropical rainforest. In this case, fire management is only 'effective' if we have explicitly decided that rainforest is preferred in that location over dry woodland.

This need to define the desired state or states (not just the direction of improvement) is most obviously true for interventions that focus on shifting disturbance regimes, like ecological management of fire and environmental water. Yet it is worth considering whether this approach is more generally applicable. All ecosystems are dynamic to some degree and thus can be conceptualised as existing in multiple different states, with key drivers that govern shifts between states. Interventions that target those key drivers may be capable of creating a step-change in desired outcomes, instead of just gradual incremental improvement. With limited funds to invest in environmental recovery, it could make sense to preferentially invest in interventions that can create these threshold changes, thus creating a more cost-effective outcome.

This cross-Theme pattern thus suggests that an important alternative way to think about confidence in investment and learning about effectiveness may not necessarily involve monitoring or empirical research on specific interventions and their consequences. Instead, it may be more productive to construct dynamic systems models that articulate key drivers of system change and the different system states they produce, and base on-ground investment decisions on these models. Empirical research could then focus on testing elements of the models (rather than specifically monitoring individual interventions). As the models improve, so too will confidence in on-ground investment decisions based on them even if 'effectiveness' is never directly assessed.

The Australian Ecosystem Models Framework is progressing development of a national set of dynamic ecosystem models which describe ecosystems in multiple natural and non-natural condition states, and the natural and non-natural drivers which transition ecosystems between states. These models may provide the conceptual underpinning for taking the systems drivers approach described above to defining desired outcomes, planning interventions, and monitoring and reporting on effectiveness.

Engineering Restoration?

One more cross-Theme pattern worth highlighting was the potential value of increasing investment in more novel, 'engineering'-type approaches to restoration. Note that in Figure 1, restoring keystone species to engineer follow-on changes in the ecosystem and restoring key structures and functions were both considered effective by the majority of studies available. In contrast, interventions in most other Themes were most commonly considered to be only partially effective. In addition, revegetation techniques that engineered a particular composition or structure to boost key ecosystem processes were more likely to be effective, though the number of studies was small. These interventions were often designed to use plantings to stimulate a particular ecological process that may be critical for recovery, rather than necessarily replace the species that might be expected to be there in the absence of clearing/modification. For example, revegetating using essentially a monoculture of *Themeda* grass (an 'engineered' composition) could be used as part of a process to reduce artificially-elevated soil nutrients (Prober and Lunt 2009). Similarly, Colloff et al. (2010) found that certain vegetation structures created through revegetation were particularly useful at improving water infiltration in the soil because they encouraged greater soil invertebrate diversity. Engineering structure or composition to stimulate certain soil processes and/or recruitment of other plant species may be particularly effective.

These results suggest that refocusing restoration on reinstating key processes rather than specific ecosystems *per se*, including through more interventionist 'engineering' approaches, could be worthy of much deeper exploration and experimentation. Trialling these more novel interventions, not just in controlled experiments but as real on-ground NRM interventions at scale may provide an important way to move beyond the trend toward only partial effectiveness.

In summary, we are regularly intervening in the environment, but we do not yet have the appropriately structured mechanisms, and the culture of testing and experimentation, that supports building a knowledge base about which interventions are actually working to deliver desired outcomes. This result meant that some of our aims in the Knowledge Bank project were not achievable – we cannot yet derive nuanced insights about which interventions are reliably effective in which circumstances.

Key Barriers to Learning

Perhaps the best way to improve confidence in the effectiveness of NRM is through a much more systematic, programmatic approach which embeds a culture of adaptive learning into environmental management. This must also include developing the necessary mechanisms to support such a learning culture. The Knowledge Bank results suggest that a lack of learning is pervasive across NRM interventions, particularly given the scale and frequency with which on-ground interventions are applied compared to the scale and frequency with which effectiveness is assessed. Such pervasiveness suggests that a lack of learning results at least in part from key, potentially systemic barriers.

To explore what systemic changes might be needed to create a culture of adaptive learning and its associated mechanisms, we thus first articulated what we found to be the current key barriers to learning. These were developed by:

- qualitatively examining the types of studies that both were and were not included in the Knowledge Bank
- drawing on the project team's own experiences working with environmental management programs in Australia (from the program development side as well as the practitioner and monitoring sides)
- gathering expert opinion from staff involved in various programs within the Department of Environment and Energy
- gathering expert opinion from other researchers and NRM practitioners

Informal processes were used, but there was generally widespread consensus about the barriers noted below as well as suggestions for how to overcome them (presented in the following section). Barriers most commonly related to:

- the way we specify targets and outcomes desired
- different drivers of success for program designers, researchers, and land managers/ implementers
- flow-on consequences for NRM program design, and
- disproportionate emphasis on only certain aspects of monitoring, reporting, and information sharing.

Approaches used to set NRM program targets

National NRM program targets have tended to oscillate between two modalities of target setting – a high level of generalisation versus fairly specific output (rather than outcome) targets. Both of these modalities make it difficult to identify the intended outcomes of the interventions and to achieve adequate replication of interventions within the landscape – both of which are critical for learning about effectiveness. Output targets tend to aim at the short-term with a focus on activities more than what they are intended to achieve. Over-generalised targets may be aimed at longer-time frame delivery but are rarely directly measurable. These two modes of target-setting are rarely presented within a coherent program logic that articulates the step-by-step pathway to the achievement of the higher-order, longer-time frame objectives. Yet it is the intermediate stages in this pathway where achievement can be measured and effectiveness can be evaluated. Thus, the lack of contextualisation of these target-setting modalities poses a higher level barrier for assessing the effectiveness of NRM. Changes in focus on the different modalities over time and across programs also provide a barrier to learning about effectiveness. Cross-program effort is likely to be crucial to building enough volume of comparable evidence but when different programs articulate targets quite differently, it can be very difficult if not possible to monitor effectiveness across them. It is worth considering the slightly different nature of the barriers posed by each of these modalities, as well as the overall barrier presented by the lack of consistent approach.

Highly generalised targets

Often the objectives and desired outcomes of NRM programs are expressed at a very high level, such as 'conserving the environment' or 'improving biodiversity', not as things that are directly measurable. Targets that are highly generalised do not provide adequate guidance to practitioners or decision-makers as to where, what and why NRM investment is necessary. Lack of consistent statements about the where, what and why (including measurable outcomes desired) mean that interventions to achieve the objective can be overly diverse and uncoordinated, and people doing monitoring and research are free to decide which outcomes they assess. It then becomes difficult or even impossible to draw consistent insights across interventions/studies because so many different interventions are used and so many different outcomes are measured.

For example, the Caring for our Country Biodiversity and Natural Icons target was to *"Increase by at least [400,000 / 600,000 /1,000,000] hectares… the area of native habitat and vegetation that is managed to reduce critical threats to biodiversity…by 2013"*. This target did not link the number of hectares chosen to any specific ecological need, and the 'where', 'why', 'how' and 'when' was unidentified. In particular, not describing what was meant by "managed" in the Biodiversity and Natural Icons target resulted in varying interpretation by stakeholders on the ground, and thus a wide variety of bespoke interventions (including even public-awareness campaigns and data modelling). The knock-on impact is that the interventions employed to achieve this target may be too diverse to assess effectiveness in anything but an anecdotal way. Even if they could be grouped into similar categories to assess effectiveness, the lack of consistent reporting on the approaches used meant there was no way to identify proposals that used similar interventions, and to strategically invest to achieve coordination, consistency and sufficient replication of efforts in the landscape to enable subsequent learning.

Output-focused targets

Output targets are intended to be short-term ways to work toward more significant outcomes. They have a tendency to focus on the volume of activity, but often fail to logically link how a particular volume (or sometimes even a particular activity) contributes to the achievement of higher order environmental outcomes. Thus, they too pose a barrier to monitoring and evaluating effectiveness.

Output targets can also have a tendency to focus on restoring the most 'visible' elements of a system – rather than prioritising interventions that remedy some of the most challenging but necessary aspects of an ecosystem. For example, the long-term modification of native soils through agricultural land uses may limit the success of revegetation efforts unless significant investment is first applied to restoring soil function. Currently, such investment is rarely the focus of government NRM programs, which have a tendency to aim for generation of above-ground visible change, and thus measure success in terms of the volume of immediately visible output (e.g. number of trees planted) rather than the realised benefit.

For example, the Caring for Our Country Biodiversity and Natural Icons target, "to undertake 1500 days of volunteer cane toad control" resulted in approximately 8360 volunteer days of activity between 2008 and 2013. At face value, the target was more than exceeded and thus success was achieved. However, was an actual environmental outcome truly achieved? Assuming that a single volunteer can clear up to 2 hectares of cane toads in a single day, over the entire five year effort, this may have equated to approximately 167 square kilometres of 'volunteer cane toad control'. However, only 1433 days were targeted at the cane toad 'front line' near the Western Australian border, and this subset of effort may have resulted in approximately 30 square kilometres of cane toad control, if targeted all at the same time. As cane toads occupy over 1 million square kilometres and their populations are expanding by > 55 square kilometres per annum, this output-focused target could not be effective at delivering an outcome for "biodiversity and natural icons" beyond perhaps slightly temporarily slowing the expansion of cane toads.

While this didn't come up regularly in our informal data collection on barriers to learning, it is worth noting that another issue with output focussed targets is that they often create an administrative burden for governments and practitioners without the commensurate environmental benefit. The volume of effort put into administrating these sorts of targets within government (communication materials, grant assessment, contracting, contract management) and for grantees and practitioners (grant application, marshalling volunteers, on-ground activity, reporting to government) may significantly sap resources from other projects. Thus, the value proposition of output targets without a clear link to intended immediate and intermediate outcomes intended is worthy of close examination, not just in terms of whether they support learning about effectiveness but in terms of whether they support efficient resourcing of environmental improvement.

Lack of measurable desired outcomes in a systems context

Under the Knowledge Bank Themes of Changed Hydrological Conditions, Changed Fire Regimes, and potentially also Excessive Grazing, a lack of articulation of whole-of-system impacts posed a barrier to learning Water (floods and flows), fire and grazing are often key drivers in ecosystem dynamics. The aim of interventions is often not just to intervene and have an immediate effect but rather to intervene many times to change the overall regime of the driver and thereby create a step change in the whole system. In this case, if most studies focus on the immediate outcomes of a single intervention, they may be missing the opportunity to learn about how a regime of intervention can create outcomes for the whole system. For example, many studies of the effects of environmental watering events suggested that environmental water is only partially effective because some species benefited whereas others did not. But that's not a surprising conclusion – that's how systems drivers work, through repeated changes that create winners and losers and shift the ecosystem into a different state. Until desired outcomes are articulated as major shifts in the system, not just incremental change, there may be many outcomes measured without any clear sense of whether they constitute improvements or not.

Given ongoing global declines in biodiversity (Butchart et al. 2010, Johnson et al. 2017), it is important to learn more about these major ecosystem levers which may have potential to drive step changes in the restoration of the environment.

Different motivations for program designers, researchers, and implementers

Assessing the outcomes of interventions – effectiveness monitoring – is what Lindenmayer and Likens (2010) refer to as 'question-driven monitoring' – something that deliberately extends beyond trend monitoring toward more formal scientific comparisons but using real-world interventions as the 'treatments'. We found some evidence that this kind of approach may consistently fall through the cracks between the three disciplines involved in making it work – NRM program design, research, and the implementers of land management actions. There is no doubt that some individuals have the capability to look across these domains. The barrier may be that the key drivers of success in these professions – the way people are judged, rewarded and promoted – inadvertently work at cross purposes, resulting in systemic barriers to a shared adaptive learning system despite individuals' capabilities.

For example, we found that even among the studies included in the Knowledge Bank, probably less than half of them were actually studies of on-ground interventions and what they had achieved in terms of environmental outcomes. Instead, researchers were often applying the interventions themselves, in more controlled experimental conditions and at smaller scales, rather than in partnership with land managers at scale. In addition, many researchers focused on exploring the 'natural' ecosystem dynamics rather than the consequences of management interventions in the system. For example, there were impressive long-term studies by researchers of the population dynamics of feral predators linked with their prey species, but these did not involve assessing the outcomes of interventions to limit feral predator populations (e.g., Hone 2002). In contrast, many managers monitored their own interventions of controlling feral predators like foxes, but only by assessing the number of baits taken or foxes killed, not the broader ecological benefits achieved by doing so (e.g., Dexter and Meek 1998, Carter et al. 2011). While both of these approaches are valid and useful, they are each limited in and of themselves and the separation of activities and approaches between managers and researchers means they cannot leverage each other's strengths.

We explored some of the reasons for this separation of approaches and found a number of drivers of success in these different disciplines that may actively work to keep them apart (Figure 2). This includes NRM program design as a discipline, as well as the disciplines of research and management implementation. Many of these particular barriers to learning may be difficult to address, but acknowledging them is likely to be helpful:

- To study effectiveness of interventions in the real world, researchers often need to collaborate with multiple practitioners to gain sufficient sample size for research. This can be a complex brokering challenge with many transaction costs not normally factored into research funding. Thus, researchers who pursue this approach may accomplish less research and publish less per project or dollar of funding, limiting their visibility and career progress.
- Researchers are under pressure to always do novel research (apply *new* methods, measure *new* outcomes not measured by anyone else, etc.) in order to publish in high-impact journals, which makes it difficult to do research in ways that build understanding across multiple similar studies.

- Implementers often feel they need to demonstrate best-practice and continual success as those that appear more successful gain further funding. This no-fail culture makes it difficult for implementers to experiment with multiple approaches, which is what researchers fundamentally require in order to make effective comparisons.
- Implementers often work for implementing agencies or organisations which often do not have stable long-term funding. Individuals must therefore build their careers by moving frequently between different employers, creating relatively high turnover and making it difficult to form longer-term relationships with researchers.
- Implementing organisations frequently work with individual land managers to apply interventions on private properties, and the more work done, the better (both in terms of outcomes and reputation for the organisation and thus more funding – drivers created by the world of program design and funding). As a result, implementers often negotiate bespoke interventions on each property to fit in with what the private manager wants to do. While this helps to create a sufficient volume of activity, it make it virtually impossible to have the replication of relatively consistent interventions required for assessing effectiveness in anything but an anecdotal sense.
- NRM program designers may wish for outcomes to be assessed, but are fundamentally only directly responsible for overseeing monitoring and reporting during the life cycle of a program, which is usually too short to allow any meaningful environmental outcomes to accrue. And there has been a lack of in-built contractual and management mechanisms track the post-investment life of sites and thus to counter this driver to focus short term. For example, programs such as the Biodiversity Fund favourably treated grant applicants who committed to 10-year management and maintenance of their revegetation sites (post their six-year investment), but upon receiving these grants, recipients were not contractually bound to demonstrate this ongoing management and the government had no way in which to determine compliance or evaluate the outcomes. Even if program designers form collaborative links with researchers and research funders, the mismatch in time scales means that it is very difficult to link investment in on-ground actions with investment in research/monitoring on effectiveness, which may need to be completed by researchers or implementers decades into the future.
- NRM program designers are also under pressure to produce 'new' approaches from one investment cycle to the next, in part driven by the need to respond to different interests and priorities of ministers and/or senior public servants. However, this driver for program designers also means that implementers are forced to focus on different environmental challenges from one short-term funding cycle to another and cannot effectively build a portfolio of consistent, repeated actions which is what would be needed for learning about effectiveness.

Greg and Matthew Johnson's property near Yeoval, NSW is part of the Environmental stewardship program to protect box gum grassy woodland. Copyright Department of the Environment (taken by staff). Tatnell, Andrew.

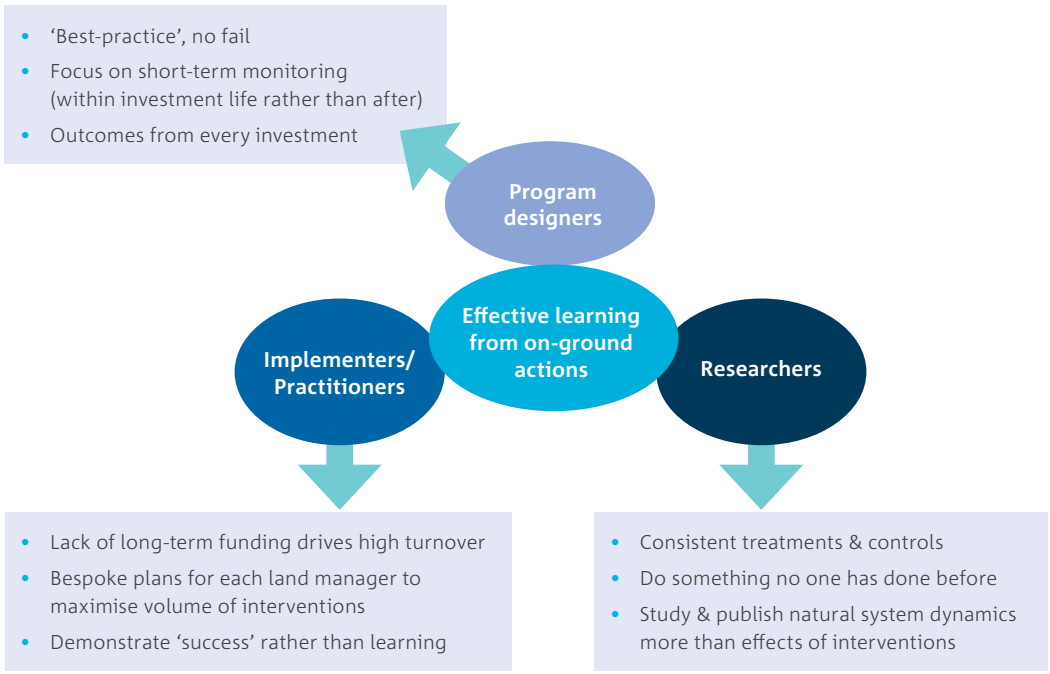

Figure 2. Schematic illustrating some of the different drivers for program designers, implementers/practitioners and researchers that actively work to pull them away from effective collaboration to learn about effectiveness when implementing on-ground actions.

It has certainly been recognised that better links across these disciplines (especially between research and land management) would be useful. Yet to date, that has largely been tackled not by addressing the disparate drivers keeping them from effective collaboration, but rather by simply trying to provide opportunities for them to talk with each other. For example, federal funds increasingly preferentially go to cross-discipline partnerships (including via the current NESP model) and new types of conferences are emerging that focus on shared approaches to solutions rather than disciplines (e.g. Restore, Regenerate, Revegetate 2017 in Armidale, New South Wales). These structured opportunities for shared discussion are certainly valuable, but will have limited success unless the underlying drivers that continually push the disciplines apart (or at least limit collaboration) are also addressed.

Program design which does not include learning and building evidence as an integral objective

Even if researchers were widely connected with practitioners and attempting to research the outcomes of real on-ground interventions, there would still be limited opportunities to do so because of the way programs that fund on-ground interventions are often structured. Those program structures may have arisen in part because of the disparate drivers among program designers, practitioners/implementers and researchers, but it means that structurally, programs themselves currently serve as barriers to learning. Learning about outcomes involves making comparisons, preferably using statistical analysis, which provides the potential to reveal general principles as well as the specific contexts in which actions are more vs. less effective, and fundamentally requires the following:

- Comparing the outcomes of interventions to some sort of control or benchmark
- Replication (or many applications of the same intervention) within similar local/regional contexts (e.g. within the same vegetation type and catchment)
- Replication is also desirable across local/regional contexts but not at the expense of replication within local contexts

Thus, when program designs include targets that are highly generalised and desired measurable outcomes are not articulated, the drivers for implementers to apply bespoke interventions

on individual properties and for researchers to measure new and different outcomes in new and different ways will dominate. As a result, the inability to have replication and to assess effectiveness across many applications of an intervention will essentially be structurally entrained by the program design.

At the other end of the targets spectrum, learning will be particularly slow if we only trial one intervention (or set of interventions) at a time. When program designs are based on output-focused targets, there is usually a pre-determined single intervention applied. (This could include a single consistent *set* of interventions, like excluding livestock grazing with weed and rabbit control, applied everywhere.) Even if that consistency can be achieved by implementers, assessing effectiveness requires comparison to control sites, particularly in the absence of measurable, desired outcomes. Unfortunately, control sites can be difficult to find and there is often an unwillingness to spend monitoring funds on monitoring control sites. Outcomes may not be assessable for a long time to come, meaning we don't get the opportunity to learn about effectiveness and try a different approach until well into the future.

Similarly, replication within a local/regional context can be severely limited not just because of the individual tailoring of interventions to each site (including to land manager preferences) but also because there may be a desire to spread funding across many regions for 'equity'. This in itself wouldn't be a problem if funding were consistently available each year for the same types of interventions (as part of a long-term investment strategy), and thus multiple sites with the same interventions could build up in a region over years. But drivers of success for program designers mean there has been a tendency to shift priorities every few years rather than take this long view. This combination of spreading investment over larger geographic areas and lack of a long-term investment strategy means that appropriate replication is not only not planned but may be structurally constrained from ever developing.

We emphasise that this is a particularly important barrier to consider ways to overcome, in part because it is a complex problem. Programs need to be designed to minimise risk when spending public funds, federal programs need to provide benefit across Australia not just in particular regions, tailoring interventions to each site is often critical to gain the support of private land owners to undertake the interventions, and actively experimenting with multiple interventions and learning for future benefit is sorely lacking and desperately needed. It is challenging to design programs that can sufficiently satisfy these diverse needs and that don't inadvertently create perverse incentives and outcomes, particularly given the diverse drivers for the many people and disciplines involved. Current program designs prioritise some if these needs at the expense of learning about effectiveness, and it may be challenging but ultimately highly beneficial to wrestle with the complexity and reform approaches to program design.

Emphasis on activity reporting and trend monitoring which do not address effectiveness

Activity reporting

Much 'monitoring' and reporting on interventions in the environment in Australia currently involves the most immediate type – essentially just reporting on activity and outputs. For example, program designers often require reporting on how many kilometres of fencing were constructed, how many fox baits were laid, how many land managers were reached through workshops, etc. Activity reporting is essential as without it we would lack even the most basic data on what we have done where. As such, it forms a critical foundation for assessing effectiveness, particularly where outcomes may not be anticipated for many decades and thus assessment of effectiveness may have to occur well into the future. However, as discussed above, activity reporting in and of itself is inadequate to build a picture of the effectiveness of NRM interventions.

Changes in NRM program design over multiple investment cycles may have inadvertently placed greater emphasis on activity reporting than monitoring effectiveness. For example, in the former Caring for our Country program, approximately 10% of total project budgets could be allocated to monitoring (including of effectiveness) and administration. However, in the subsequent Biodiversity Fund, it was stipulated that no more than 5% of the project budget could be used for administration, monitoring and activity reporting – a value that for most projects restricted the work to activity reporting alone and precluded any meaningful effectiveness monitoring. While it is certainly reasonable to expect that basic activity reporting should be part of all on-ground projects, structured assessments of effectiveness to learn most efficiently are also required. The arbitrary % maximum allocation of budget to monitoring

may not always be appropriate. A well designed, small-scale project that has explicitly built in experimental design and substantial effectiveness monitoring may deliver more public benefit and value for money than a broader-scale project without effectiveness monitoring.

Emphasis on activity reporting may have also driven changes in capability in different sectors, creating a self-reinforcing loop in which only some types of monitoring and reporting are achieved and thus learning is limited. The last two decades have seen a shift in stable financial support and governance arrangements for many practitioner/implementer organisations (such as regional natural resource management groups) such that their ability to retain capability fluctuates depending on the results of competitive funding rounds – rounds in which activity reporting has been emphasised. As a result, many NRM regions only have the ability to undertake activity reporting, and the capability and capacity to assess ecological outcomes has often been lost.

Trend or surveillance monitoring

The other common type of monitoring is 'trend' monitoring – noting overall changes at a variety of scales in things like tree cover, population estimates, etc. without directly assessing whether or not interventions were responsible for driving the changes. In most trend monitoring, the scales involved (usually regional to national) and the general lack of comparisons (e.g. not deliberately comparing areas where interventions are and are not applied) generally preclude learning about effectiveness of specific interventions and are intended more as an overall status check. Particularly where trend monitoring suggests we are not reversing overall declines in environmental condition, complementary approaches more specifically targeted at assessing effectiveness of interventions (even at just a subset of sites/scales) are crucial for learning how to change those trends.

However, the two approaches are sometimes confused as interchangeable with apparently more emphasis on trend monitoring because of the larger scales over which it can be applied. Again, the intent may not be to actually emphasise trend monitoring, but it is often funded and administered quite separately from the research streams that are more likely to produce effectiveness monitoring, so there may be little line-of-sight across the whole integrated system of investment in different types of monitoring. There is certainly a perception that concerted efforts have been made to improve our approaches to both activity reporting and trend monitoring over the past decade, but this hasn't been matched with equal investment in effectiveness monitoring.

For example, consistent 'typologies' or categories of management activities and their immediate outputs have been developed to collect useful national-scale data on activities. In addition, investments in surveillance monitoring, through new technologies such as remote sensing, have taken precedence over on-ground monitoring investment. This is because such products offer the promise of an efficient way of building national scale insight into the environment (to satisfy regulatory reporting responsibilities, such as State of the Environment reporting) that could not realistically be achieved through on-ground effort. But on-ground *effectiveness* monitoring is different than on-ground trend/surveillance monitoring and serves a different purpose. Remote techniques may indeed be the most efficient way to report on trends, but they don't help us learn how to shift those trends, and thus are limited in policy and programmatic application. Emphasising just one or two aspects of an overall monitoring system thus serves as a barrier to our ability to learn.

Information not discoverable or accessible

Lastly, while it is clear that we are not learning about the effectiveness of our interventions mostly because of a lack of information generation, the process of developing the Knowledge Bank also suggested that more information has been generated than we are currently able to discover and access. In the last decade or so, there has been a substantial shift in the way scientific information is shared. Managers and policy-makers have extremely limited (if any) access to the formal published scientific literature. So factsheets, brochures, booklets, videos and webpages (the 'grey literature') are being used much more to convey research results that may be relevant to managers and policy-makers. The intent is usually for research to produce both types of outputs. But with increasingly limited research funding, it is often the manager-friendly grey literature that is produced first, and the intention to publish later may not be fully realised, particularly given that it may take significantly more than a year to progress a manuscript through the publication process. Much work is also undertaken via honours theses which also often remain unpublished.

So additional information on effectiveness of interventions is likely to lie only in the grey literature. The problem is that as the grey literature burgeons in sheer volume, it becomes increasingly difficult to discover electronically and much of it has never been easily accessible particularly in electronic form. Standard protocols for systematic maps and reviews suggest using search engines for the grey literature like Google, but because the search functionality is much more limited compared to databases of journal articles like Web of Science, the suggestion is usually to scan just the first 100 hits for relevance. Given that the material available is growing at something close to an exponential rate, this approach is clearly going to miss relevant sources. But search strings cannot be further refined given the limited functionality of these engines (like Trove), and it is simply not cost-effective to attempt to screen many thousands of grey literature sources which often must be tracked to the source to allow examination beyond a simple title.

For example, one of our Google searches revealed an excellent brochure that provided a summary of multiple research projects undertaken by the Cooperative Research Centre (CRC) for Catchment Hydrology examining the effectiveness of riparian buffers, particularly at limiting sedimentation and nutrient transfer (Hairsine 1997). The work was included in the Knowledge Bank based on this grey literature source because no journal articles were found that presented the results of these multiple studies. This source was also not considered highly relevant according to the Google search algorithms as it appeared more than halfway through the first 100 hits that were screened. We were left with the distinct impression that it was almost luck that led us to discover this source, that there are likely others in the grey literature like this one, and that the researchers (many of who continue to have distinguished careers to this day) simply ran out of time during the course of the CRC funding to complete journal publications. Unfortunately, these excellent grey literature sources are likely to be mostly lost to future science.

Erosion control methods that have been undertaken as part of the Matthews Creek Restoration project at Deans Marsh. Copyright shared (Department of the Environment and the creator) for unlimited time. Baker, John.

Building Blocks for Accelerating Learning and Innovation

The barriers discussed above were explored in some detail specifically so we could begin to develop a set of building blocks that could be implemented over time to better embed a culture of adaptive learning into on-ground environmental management and associated applied science in Australia. If we treated the barriers too simplistically, the options we might suggest to achieve each building block could be too simplistic or naïve to actually help accelerate learning and innovation.

Thus, to develop ideas for solutions, we drew on the same broad set of expertise that we used to elucidate the barriers (our experienced project team, expert opinion of program staff within the Department of Environment and Energy, and expert opinion from other researchers and NRM practitioners). We paid particular attention to developing options that could link with or build on existing Australian initiatives like the Atlas of Living Australia (ALA) or the Terrestrial Ecosystem Research Network (TERN) to make these solutions easier to implement. However, it was well beyond the scope of this project to develop a *full* set of solutions. So each suggested option is described only briefly, as they are intended to be conversation starters, and there could be many possible ways to implement them. They are grouped under five building blocks which in turn fall under two main themes. Each building block is required for an effective learning system based on on-ground actions. In other words, we believe that some positive action is likely to be needed for *all five building blocks* – pursuing only one or two may lead to a perpetuation or even intensification of some of the barriers to learning currently experienced. The building blocks are:

Structural Changes in NRM

- Build physical research infrastructure to support learning
- Build information infrastructure to support learning
- Improve NRM program design

Relationships and Collaborative Governance

- Develop the structural changes above collaboratively with program designers, researchers, and practitioners
- Manage the disparate drivers of program designers, researchers, and practitioners/ implementers through structures for long-term collaborative governance

The following sections describe options for how to create positive change in each of these areas.

Structural Changes in NRM

Options for Building Physical Research Infrastructure to Support Learning

Create a national system of reference/sentinel sites for comparisons, building off TERN infrastructure

Fundamental to learning is the ability to compare interventions not just to each other but also to sites where no interventions are occurring. These 'control' sites (in the language of researchers) also need to be replicated as the purpose is to be able to distinguish change as a result of intervention from background seasonal or regional change. While this is ideally done by having roughly matched local control sites in a similar number to intervention sites, in practice this can be difficult to achieve both logistically and financially.

To overcome this and support an integrated intervention monitoring system, a national network of monitoring sites could be set up across Australia, potentially building off existing TERN infrastructure. The challenge would be to choose the most appropriate sites from a 'control' vs. intervention perspective. The Australian Ecosystems Model Framework, a collaborative project between the Australian Government and the CSIRO, may provide a conceptually consistent way of designing the system and choosing sites to represent a range of ecosystem types (see below).

Such a system would include 'reference' sites – sites that are representative of ecosystems in their most natural states (i.e. ecosystems in a range of growth stages, and pre- and post- natural disturbance states). It would also include 'sentinel' sites which would be representative of ecosystems in the range of anthropogenically disturbed condition states that are indicative of the sites where NRM interventions are likely to be applied.

The sentinel sites would represent where an intervention is required, but not occurring, and the reference sites would represent an ideal outcome state. This would allow projects that are monitoring actual interventions to make comparisons against these national 'book ends', without having to resource monitoring at control sites separately for every intervention program.

Develop a set of national experimental sites for exploring novel interventions

In the Knowledge Bank, novel interventions showed some particular promise to achieve full rather than partial recovery but were rarely tested. One way to test novel interventions more commonly without increasing risk would be to create specific experimental sites as part of our national physical research infrastructure. This would take novel interventions partially or completely out of NRM programs, at least at the early stages of exploration, but could provide a better test-bed for new ideas. Those that appear to have promise of effectiveness based on early data could then be incorporated into direct on-ground intervention programs. While this would take some significant effort and resourcing, it is worth mentioning in part because it focuses on much-needed innovation and because it too could build off our existing national research infrastructure like TERN and thus could be more cost-effective to develop than might appear at first glance.

It also may be possible to partner with other organisations to set aside some of their intervention sites to experiment and build the evidence-base. For example, the Ecological Engineering for Biodiversity Adaptation to Climate Change project has begun to set up low-cost efficient research infrastructure in collaboration with restoration practitioners in order to test the success of different plant material provenancing strategies under climate change. With good information and design, such an approach can potentially be replicated for other intervention types.

Options for Building Information Infrastructure to Support Learning

Continue to build and test dynamic conceptual systems models under the Australian Ecosystem Models Framework

One of the most critical pieces of underpinning information infrastructure is a set of systems models that articulate the science community's understanding and assumptions about the key drivers and varying states of ecosystems. Australian ecosystems are dynamic and can exist in many different states before even considering issues of degradation. For example, savanna woodlands can still be high-quality savanna woodlands both before and after fire – what's critical to their health is the nature and timing of that shifting dynamic. Thus, there are 'natural' drivers of major system fluctuation (as well as anthropogenic ones) and change itself isn't necessarily a threat. In NRM intervention, we want to ensure we are intervening to ameliorate the major anthropogenic drivers of change, and to assess the effectiveness of that. NRM interventions should not unwittingly limit natural processes or change. Conceptual systems models (like state-and-transition models) can bring together our current knowledge and help us focus on key drivers and the more significant outcomes that might be expected from intervening in ecosystems. They therefore provide a conceptual underpinning for effectiveness monitoring.

In addition, for many types of intervention, assessing effectiveness from individual interventions may not be appropriate as the intent of intervening is to create a certain regime of a key driver to manage overall and long-term systems dynamics (e.g. when applying environmental water to restore key flood regimes or when managing fire in fire-dependent ecosystems). In these situations, the best way to learn about effectiveness is likely to involve more controlled, experimental tests of dynamic systems models rather than direct assessment of the outcomes of individual on-ground interventions.

Thus, a set of dynamic conceptual systems models of Australian ecosystems would fill multiple roles in accelerating learning and innovation in environmental management. The process of developing such a set of conceptual models has commenced. The Australian Ecosystem Models Framework is providing Australia with its first nationally consistently set of dynamic ecosystem models which can be deployed to support monitoring and reporting of NRM investments. These models will characterise and classify ecosystems based on their 'natural dynamics'. The models will describe the dynamics and attributes of Australian

ecosystems in 'unmodified' states, as well as the attributes of ecosystems in modified condition states, and the anthropogenic disturbances and management interventions that we currently believe/assume can transition ecosystems between condition states. Ongoing monitoring and research will be required to test if the assumptions articulated in the models about ecosystem drivers and interventions hold true *in situ*, as well as how these dynamics alter and adapt under rapid climate change.

Agree on consistent typologies or classifications of interventions and outcomes desired over different time scales

As noted by the new National Restoration Standards produced by the Society for Ecological Restoration Australasia, restoration depends on clear targets, goals and objectives (Standards Reference Group SERA 2016). While Australia has several different ways to classify management actions, it does not have an agreed national set nor is there an agreed set of desired outcomes except at the very highest, unmeasurable level. Yet consistent typologies or classifications of both interventions and desired outcomes would facilitate consistent monitoring, layered monitoring over time, and comparison across studies to learn general principles of effectiveness. The Program Logics developed in this project could represent a start, but would need further elaboration and workshopping to enable their integration and acceptance by NRM program managers, researchers, and practitioners. The reality is that there will be no such thing as a 'perfect' set of classifications because the specific needs of all three of these groups differ. The aim here is rather to put learning as the purpose at the forefront and ensure the classifications are sufficient to allow all three of these stakeholder groups to participate in learning – in gathering and organising information that can be consistently redeployed to build our evidence-base.

Use classifications to help pool monitoring data by building them into MERIT and resources from state, territory, regional and local jurisdictions

Once consistent typologies or classifications are built and agreed collaboratively with multiple jurisdictions, researchers and practitioners, they could be incorporated into multiple NRM data capture systems to make it useful and relatively easy to pool monitoring information captured by those different systems to maximise re-use for learning. For example, building the classifications into the Monitoring Evaluation Reporting and Improvement Tool (MERIT) would enable it to extend to outcomes assessment. To avoid substantial increases in reporting requirements, data capture processes could be further streamlined at the same time, and the classifications should be developed with that use (and the ability to streamline) in mind. If the same classifications were also used by state, territory, regional NRM and local monitoring programs, the ability to aggregate data would dramatically increase, making it possible to test effectiveness in a way that is simply not currently possible.

Ensure that research funding resources both journal publication and grey literature production, storage, and metadata

Grey literature has become critical for connecting science with those who might use it, but we are still far from any reliable mechanism to store and, most importantly, adequately search the grey literature so that it can remain discoverable and accessible in perpetuity. Thus, for the moment, it is critical for all studies of management effectiveness to be communicated through both grey literature and journal publications (which *are* readily discoverable and accessible via Web of Knowledge). At the moment, resourcing is often only adequate to focus on one of these forms of communication. Extra time should also be devoted to considering where to store grey literature electronically and how to specify appropriate metadata to maximise its discoverability. One way to help ensure this happens would be to make it part of research funding contracts and deliverables and ensure the time to communicate in these multiple forms is adequately resourced.

Grow the Knowledge Bank as a 'self-service' platform for participatory learning, and mandate inclusion of relevant government-funded research in the Bank

The Knowledge Bank was always intended to be permanent information infrastructure, available for a wide diversity of users to contribute to and ask questions of, and it is arguably imperative to establish it as permanent infrastructure in order to build our understanding and knowledge base. Public accessibility for self-service 'withdrawals' of information and insights from the Bank will be important in the long term. In the near term, priorities could include:

- Formalising long-term ownership and governance of the Bank, including how new entries will be vetted and included
- Establishing processes to ensure that all relevant government-funded research (e.g. through the National Environmental Science Programme (NESP) and similar initiatives) is included in the Bank
- Commencing a broader initiative to source existing grey literature from a wide set of stakeholders (including practitioners as well as researchers) and evaluate it for inclusion into the Bank. Note that the Knowledge Bank included an effort to source grey literature from researchers, but a more involved social process may be required to gain sufficient levels of participation.

Once more information is actually available in the Bank on studies of effectiveness, future work to ensure the optimal value of the Knowledge Bank would be to develop confidence ratings around evidence and build a system of extrapolation to identify how 'generalised' the management approaches identified in the Knowledge Bank can be applied within Australia's diverse geographies.

Options for Improving NRM Program Design

Build long-term, adequate replication of interventions both within and across investment cycles through strategic target setting

As clearly seen in the work we did to elucidate barriers to learning, variability as a result of targets and priorities being highly generalised or too focused on outputs (as well as current levels of investment within a given investment cycle) limits the degree to which sufficient replication is occurring to permit comparisons and analyses of effectiveness. In other words, the resulting 'thin' spread of specific interventions across the landscape substantially limits the ability to learn about their effectiveness. In some ways, the most straightforward way to address this barrier is to design longer-term (perhaps decadal or more) NRM objectives and targets, focused on measurable outcomes, both within and especially across investment cycles. Such strategic objectives would provide essential architecture for the development of long-term monitoring and evaluation frameworks and allow monitoring efforts to be coordinated across projects. In practical terms, the same interventions would be funded over at least a few investment cycles rather than redeveloping investment priorities each cycle, building greater replication of sites with approximately the same interventions over the right time scales to assess effectiveness.

Potential objections to or perverse consequences from this approach include various constraints that may arise from longer-term nationally-driven priorities as well as the possibility that new priorities will be needed frequently as conditions change. To overcome those potential issues, the Australian Government developed the Conservation Management Zones of Australia (CMZs). This project was designed to provide long-term, stable planning architecture for national NRM programs by identifying regional boundaries within which threats, management needs, and even patterns of change as a result of climate change might be expected to be largely consistent. These boundaries and the resources that have been and might yet be developed to support planning within them, could allow longer-term strategic outcomes and targets to be developed and acted on collaboratively, providing sufficient consistency while still allowing for regional variation. Progressing toward implementation of the CMZs (or similar long-term planning architecture) would provide sufficient consistency and replication of interventions over the time scales needed to assess effectiveness without being too constraining or top-down.

Coordinate program interventions with the implementation of other policy, regulatory and financial instruments across landscapes to achieve more consistency (replication) across sites

Strategic, coordinated delivery of interventions, as well as the mix of financial, policy and regulatory mechanisms being applied across NRM and resource use domains is essential in order to ensure that on-ground activities do not cancel each other out. Although this seems axiomatic, within Australia's complex environment and mixed land use contexts, the potential for on-ground land and resource use activities to counteract the effectiveness of management interventions (and thus cloud the ability to assess if individual

interventions are effective) is high. For example, protecting and managing a remnant patch of grassland to improve habitat for grassland fauna which is adjacent to a grassland remnant that has been approved for clearing may result in population declines even if interventions in the protected remnant were actually effective. At present, many additional uncoordinated actions may occur that impact any given intervention. This presents a significant challenge for the design and implementation of management effectiveness monitoring, as it makes it difficult to identify which additional factors need to be monitored to unpick effectiveness and demands even larger numbers of sites monitored to allow for analysis of those additional variables. Coordination of existing mechanisms would go some way toward alleviating these sources of variability across sites. Important for learning, the resulting increase in consistency would help to counteract some of the drivers of high variability in interventions and outcome assessment that were identified as barriers to learning but which may be difficult to address because they arise from differing drivers for researchers and practitioners/implementers.

Design and deliver programs which deliberately compare interventions, including novel ones, and compare them to sentinel and reference sites

As noted in the discussion of barriers above, rapid learning is hampered when we only examine one intervention at a time, particularly given the length of time that might need to pass before we can expect outcomes to be achieved and measurable. More effective learning can occur if we actively compare a few different interventions that are designed to achieve the same outcome, making it more likely that more effective approaches will be found within one round of application and assessment (Figure 3). More rapid learning would result, quickly increasing the cost-effectiveness of NRM investment and minimising risk of investment in the future. This approach requires a fundamentally different program structure – one that does not accord with current approaches to setting targets, specifying desired outcomes, and satisfying some of the current drivers around program design.

Figure 3. Benefit of trialling multiple interventions intended to achieve the same outcome simultaneously within a single program rather than sequentially. In this schematic, imagine that A, B and C are all different grazing regimes intended to assist recovery of native grasslands, and that effectiveness can only be reasonably assessed after 10 years of management. If C is the one that is fully effective but only a single intervention is trialled per on-ground funding program, it may not be discovered and more widely implemented until 2050. In contrast, if multiple interventions are trialled and compared in a single program, C could be identified as the most effective and more widely implemented 20 years sooner.

To facilitate this, NRM programs could be designed such that instead of either specifying one fully prescribed intervention (or set of interventions) or specifying a general type of intervention and allowing complete local tailoring (common approaches at the moment), it may be possible to design programs where two or more specific interventions intended to achieve the same outcome are *both* applied so their outcomes can be compared. For example, riparian buffering programs intended to improve water quality by reducing transfer of nutrients and sediments into waterways could deliberately restore grassy vegetation along some stretches of a river and mixed woody/grassy vegetation along other stretches of the same river

to see which type of restoration planting is more effective at buffering. Both interventions would still need to be applied consistently to develop replication, but comparing their effectiveness within the same NRM program allows learning to occur much faster.

Another potential learning benefit from implementing this kind of comparative intervention testing is that it could provide the framework for more frequent trialling of novel interventions. One of the clear conclusions from the Knowledge Bank was that our current interventions are not sufficient to fully restore ecosystems, so there is an imperative to still be trialling fundamentally new and different approaches. Yet as revealed in our exploration of barriers, novel interventions are rarely trialled at scale, perhaps because of a perception of high risk. Incorporating just a few sites with really novel interventions into a broader program in which multiple interventions are being compared can both minimise the risk and maximise the learning.

Finally, particularly where cost-effectiveness is important, programs must also be designed so that comparisons can be made with 'control' sites (reference and sentinel sites, as above) to unpick the influence of interventions versus other drivers within a system (e.g. weather). This is important because interventions can appear effective even if the outcomes would have been achieved anyway, without an investment. For example, weediness of many sites in a region may decline (and nativeness increase) due to climate change or changes in regional land uses, regardless of costly weed management. Monitoring only the intervention sites would suggest the costly intervention was effective, leading to further unnecessary investment. Monitoring additional control sites would identify that the change was occurring regionally, regardless of investment. Yet the inclusion of controls within NRM program monitoring is currently rare. If a national system of reference/sentinel sites is not available or suitable to provide comparisons (see Options for Building Physical Research Infrastructure above), they need to be built into NRM program monitoring.

To some extent, this may require a cultural / focus shift within government. Most NRM program success is still quantified by outputs (e.g. x hectares of management, x kilometres of fencing, x number of trees planted). These statistics can provide media headlines and a sense of program achievement which can be useful for government in the short-term (i.e. within their term of government). However, as we do not know whether such outputs are achieving environmental outcomes, measuring control sites is more likely to beneficial over the longer-term, particularly with respect to understanding the true value of investment. However, it is a less palatable approach as it requires governments to sacrifice some direct investment into interventions and the resulting 'volume' of output in media-friendly statistics, in favour of investment into measuring what happens when interventions are not applied. This is harder to explain and justify in fast-cycle media.

Finally, it should be noted that not all intervention types lend themselves to being monitored with formal comparisons and controls. For example, it is relatively challenging to set up comparisons and controls for environmental watering interventions. In this case, clear articulation of the anticipated system change that will occur through interventions over time is essential using conceptual systems models (see Options for Building Information Infrastructure above) and monitoring and learning about effectiveness should focus on testing those conceptual models.

Develop strategic, tiered monitoring systems to apply different scales, types of data collection, and types of expertise to most efficiently accomplish the multiple aims of monitoring

Monitoring to learn about the effectiveness of interventions is not the only purpose of monitoring. Yet as noted in the barriers section above, monitoring to detect trends or report on patterns at a national scale – the types monitoring most common at the moment – involve collecting data that simply cannot be repurposed to learn about effectiveness. The multiple aims of monitoring require different approaches to collecting different data. Given the relatively limited amount of funding available for monitoring relative to the funds being placed into interventions, funds need to be allocated as strategically as possible in order to achieve the multiple purposes of monitoring. A well-designed and delivered NRM monitoring program has the potential to do just that by facilitating strategic integration of data from a range of scales and expertise. Coordinating the design across the different purposes of monitoring would make it possible to build systems of inference and extrapolation.

For example, Figure 4 presents a schematic of a possible three-tiered monitoring system designed to match the scale of data collection, type of data collected, and type of expertise required to the three most common purposes of monitoring. The size of circles represents the relative scale of data collection (not relative investment or importance). Effectiveness monitoring could be implemented at a *subset* of sites where intervention is occurring, to generate targeted learning about effectiveness. Tracking outcomes at intervention sites serves a different purpose focused on accountability and program reporting and thus might need to be done at all intervention sites but could utilise simpler data collected by ecological

generalists (including practitioners and even citizen scientists). Reporting on overall trends (for example to build State of the Environment reports or report on Australia's international biodiversity commitments) does not require comparisons but does need to cover status and trends at a national scale and is thus best suited to remotely sensed data. Designing all three tiers in a systematic way could allow coarse national-scale data on trends to be linked with more detailed information from effectiveness monitoring to make robust inferences about why particular trends are being detected and to begin extrapolating to how trends might change with more or different intervention.

Figure 4. An example of a tiered monitoring system designed to monitor for the three most common purposes of monitoring – learning about effectiveness, tracking outcomes at sites where intervention has occurred, and gathering status and trend information at larger scales for state and national reporting. Note that the size and nestedness of the circles represents the relative number of sites and/or spatial scales over which the monitoring needs to be conducted. See the main text for more information.

One advantage of such a targeted tiered approach is that it could take much more strategic advantage of the different types of expertise available to help with monitoring, guided by careful selection of variables and methods to suit the intended purpose. For example, with good guidance and methods, measurement of over-storey flora recruitment may be able to be carried out by citizen scientists, whereas only scientists or long-experienced practitioners may be in a position to measure species richness and diversity. Identifying when and where monitoring can be carried out reliably by non-experts as part of the standard obligations of receiving government funding (in addition to activity reporting), can mean that funds can be saved and directed towards the more complex ecological monitoring. The advantages could be that the partnership between practitioners, citizen scientists and ecologists is well-defined within a system of monitoring, and could lead to the most efficient use of that diverse capability.

To decide how much effort to dedicate to the three different tiers, it should be recognised that effectiveness monitoring is fundamentally about learning in order to change and improve approaches in the future, while the other tiers are more about assessment than learning. To decide how best to allocate monitoring resources across these tiers, it may be useful to explore a structured expansion of the definitions of value for money to incorporate valuation of the learning that may be generated through effectiveness monitoring. Such a valuation could also help clarify which interventions to target for effectiveness monitoring given constrained funding, as the value of learning may differ depending on the level of prior information and other variables.

Finally, the idea of integrating different types of data into a more comprehensive monitoring system is not new, but it is often driven from the data end, starting by looking at the types of data available and finding ways to integrate them. However, such an approach often overlooks effectiveness monitoring as that can rarely been done with existing standard data sources and datasets. Such an approach may also inadvertently result in reduced efficiency in delivering against some of the other monitoring purposes. Thus, what is critical in designing a tiered monitoring system to more effectively learn is to focus on the different purposes of monitoring as the starting point and the anchor for all decisions, letting choices about data sources, variables, and types of expertise to utilise be guided by those different things we need to learn (effectiveness, overall outcomes from intervention, and large-scale trends).

Pool monitoring resources across a program of effort and contract a single monitoring project

As above, monitoring to learn requires many sites to be consistently assessed. Yet within a given investment round, many different implementers/practitioners are contracted and each are often expected to do their own monitoring. By pooling monitoring resources and contracting a single separate monitoring project, the resulting learning would be much more significant than if every site (or every few sites) was monitored separately by different practitioners. It also provides the opportunity to decouple the time frames for monitoring from the time period over which the interventions are implemented, allowing the monitoring project to be funded and conducted years after the interventions, which can be important as many outcomes will take a long time to be achieved. Longer-term planning is required to enable the ability to follow through on monitoring a decade or more after intervention. The Conservation Management Zones of Australia is designed to be the architecture within which to support consistent longer-term target-setting and delivery of NRM. It is therefore a framework that can support more of this coordinated programmatic monitoring.

Judge applications for funding based on the quality of the plan to learn about effectiveness, not the assertion of confidence that outcomes will be achieved

One of the most direct ways to counter the barrier that learning itself is not an explicit objective is to make it one. This might be most evident – and extend a culture of learning to implementers/practitioners as well – if competitive funding to deliver interventions was dependent on a plan to learn, structuring the interventions in a way to support this (i.e. with replication, a degree of consistency, etc.). At the moment, applications for on-ground works (e.g. through devolved grant programs) usually require practitioners to make the case that their proposed actions are definitely going to lead to desired outcomes. A substantial change would be to require practitioners to design their on-ground works with *learning about outcomes* in mind and make the case that their proposed approach *to learning* will definitely allow them to increase their understanding of which on-ground works are actually effective, permitting them to deliver better outcomes in the future. Contracts and reporting would then focus not just on completion of activities for on-ground works but also completion of activities for learning.

This option forces the more detailed outcomes monitoring (or at least planning of it) back into the hands of practitioners who may not really have the capability or capacity, so may not be ideal in every circumstance and may not be the first option pursued. But it does have the potential to take advantage of the natural experimentation and ingenuity that many land managers have and it is also less risky than trying to judge applications based on confidence that outcomes will be achieved, given that the results of the Knowledge Bank thus far suggest such confidence may always be limited. It may also be one of the best ways to make learning an explicit goal and kick off a self-reinforcing system of collaborative learning across NRM program designers and implementers/practitioners.

Relationships and Collaborative Governance

Many of the barriers to learning arise specifically because the disciplines of NRM program design, ecological research, and on-ground NRM practice and implementation each have an inherently limited understanding of the drivers and constraints of the others. This is natural as NRM intervention relies on specialist knowledge within these three areas. But it can easily result in programs designed without comparisons for learning, practitioners who negotiate bespoke projects with each landowner and thus no replication, and researchers who avoid studying real-world interventions because they don't readily fit into a proper experimental design. Thus, a fundamental building block to accelerate learning and innovation is to implement one or more options that help transcend these common barriers and create cross-domain collaboration. While many of the options above attempt to provide structural solutions to this integration challenge, some attention to relationships and collaborative governance is also required (i.e. the people and cultures in addition to the structures and mechanisms).

Options for developing the structural changes collaboratively with program designers, researchers, and practitioners

Many of the suggestions for structural change may not achieve what they are intended to achieve if they don't adequately link the different domains and cultures of program designers, practitioners, and researchers. To ensure effective compromises are made and that structural changes are planned and executed in ways that work with and for each of these cultures, it would be most useful to develop the structural changes through active collaboration across the disciplines. This will also help to ensure any structural changes are actively adopted and used by these different groups, which is important given the limits and often undesirability of mandating adoption. To that end, it would be useful to also consider state, territory and regional jurisdictions. Collaboration across the disciplines (and jurisdictions) to create and implement structural change could take a variety of forms, but all would need to go beyond the provision of advice or consultation. Options include but are not limited to:

- **Projects to develop structural changes led by one discipline** (e.g. NRM program designers) but with an active working group formed by individuals from other disciplines (and jurisdictions) to provide early and frequent review and suggestions (least collaborative)
- **Project to develop structural changes jointly led by one or two people from each discipline**, with early and frequent review sought from each of their networks
- **Projects to develop structural changes led by an independent entity/broker** committed to using knowledge co-production processes to equally involve a broad range of stakeholders from all three disciplines and multiple jurisdictions (most collaborative)

Options for collaborative governance to deliberately manage the disparate drivers of program designers, researchers, and practitioners/implementers

In the set of options above, the focus is on setting up individual collaborative projects to build structural changes that better link and meet the needs of the different disciplines and jurisdictions involved. But it is likely that unless additional options are implemented to link these disciplines *in the longer term* and attempt to counter the drivers that sometimes pull them away from effective collaboration, any structural changes will struggle with long-term adoption and positive impact. To date, there have been a range of approaches and efforts to help these different disciplines talk with each other, but those efforts appear to be insufficient to counter the drivers and/or explicitly develop mutual understanding of each other's disciplinary cultures in a way that enables learning from on-ground actions. We therefore suggest that more formal mechanisms for collaborative governance may be required. These could take a variety of forms, each of which may have different advantages and challenges or risks:

- **An independent brokering entity (or 'backbone organisation') to guide program design, implementation and monitoring** – To date, Australia has experimented with knowledge brokering but increasingly, it is actually partnership or relationship brokering globally that is thought to drive better cross-domain collaboration. In this model, an independent brokering or backbone entity applies best-available social science about what works to help people understand and work with collaborators in other domains (i.e. cross-disciplinary or even transdisciplinary practice (Wilby 2011, Cundill et al. 2015)). In this model, formal brokered partnerships could be established either regionally or nationally and the broker would be responsible (and have some authority) for ensuring that programs were designed, implemented and monitored collaboratively across the three disciplines (and potentially across jurisdictions as well).

- **Regional collaborative planning partnerships** – The Conservation Management Zones (CMZs) were originally developed to provide the architecture that would allow collaborative planning to take place in a way that could be regionally driven and managed. Full implementation of the model might see more formal partnerships established within each CMZ (with or without a 'backbone organisation') to link jurisdictions and disciplines and engage them in collaborative long-term planning of priorities, targets, and learning approaches.
- **Encouraging self-organisation of collaborative governance by providing the enabling conditions** – The least formal option could involve simply placing a strong focus on building the physical and information infrastructure that can enable collaborative governance, then simply encouraging such governance to develop more 'organically' by sharing the infrastructure and articulating the benefits of collaborative governance across disciplines and jurisdictions.

In all these options, collaborations might be better identified and encouraged if the physical research infrastructure was in place (e.g. national or regional reference and sentinel sites existed, consistent classifications/typologies of interventions and outcomes were co-developed, etc.). The options largely differ in terms of how intensively collaborative governance is facilitated to address the barriers posed by the different motivations of program designers, researchers, and implementers.

It is also worth noting that all of the options discussed above for strengthening relationships and collaborative governance are themselves interventions – they are just social interventions rather than on-ground management interventions. It is thus worthwhile considering 'experimenting' with them – applying multiple options at smaller scales and comparing which work best before considering something that might be applied nationally.

River restoration project to help support the Trout Cod population in the Seven Creeks area near Euroa. Copyright shared (Department of the Environment and the creator) for unlimited time. Baker, John.

Building Blocks for Accelerating Learning and Innovation – A Summary

Structural Changes in NRM

- **Options for Building Physical Research Infrastructure to Support Learning**
  - Create a national system of reference/sentinel sites for comparisons, building off TERN infrastructure
  - Develop a set of national experimental sites for exploring novel interventions
- **Options for Building Information Infrastructure to Support Learning**
  - Continue to build and test dynamic conceptual systems models under the Australian Ecosystem Models Framework
  - Agree on consistent typologies or classifications of interventions and outcomes desired over different time scales
  - Use classifications to help pool monitoring data by building them into MERIT and resources from state, territory, regional and local jurisdictions
  - Ensure that research funding resources both journal publication and grey literature production, storage, and metadata
  - Grow the Knowledge Bank as a 'self-service' platform for participatory learning, and mandate inclusion of relevant government-funded research in the Bank
- **Options for Improving NRM Program Design**
  - Build long-term, adequate replication of interventions both within and across investment cycles through strategic target setting
  - Coordinate program interventions with the implementation of other policy, regulatory and financial instruments across landscapes to achieve more consistency (replication) across sites
  - Design and deliver programs which deliberately compare interventions, including novel ones, and compare them to sentinel and reference sites
  - Develop strategic, tiered monitoring systems to apply different scales, types of data collection, and types of expertise to most efficiently accomplish the multiple aims of monitoring
  - Pool monitoring resources across a program of effort and contract a single monitoring project
  - Judge applications for funding based on the quality of the plan to learn about effectiveness, not the assertion of confidence that outcomes will be achieved

Relationships and Collaborative Governance

- **Options for developing the structural changes collaboratively with program designers, researchers, and practitioners**
- **Options for collaborative governance to deliberately manage the disparate drivers of program designers, researchers, and practitioners/implementers**

WORKING IN A COORDINATED WAY ACROSS THESE BUILDING BLOCKS AND OPTIONS

It is worth noting that there are benefits to be gained from exploring the implementation of many options at once in a deliberate, coordinated way, both in terms of resource efficiencies as well as better outcomes. Thus, while it may be tempting to progress one thing at a time and slowly grow an accelerated learning culture, there is a potential argument to be made for more comprehensive change to happen early.

For example, the Australian Ecosystem Models Framework has been mentioned multiple times in the options above. Further developing it and then aligning the selection of national reference and sentinel sites to the types of ecosystems and their state dynamics in the Framework would ensure that physical infrastructure and information infrastructure could work in concert to support learning from on-ground interventions. Adopting a tiered monitoring framework linked to key drivers of change in the Australian Ecosystem Models Framework would then clarify what might need to be measured and how at sentinel and reference sites to use them as effective comparisons.

Coordination with other areas of government policy and programs would also be desirable. For example, significant investment has been made in bringing climate adapted approaches to NRM at a national scale. One of the clearest messages from research into the impact of climate change on biodiversity is that a great deal of dynamic change will occur as species and ecosystems naturally adapt to changing climates. The dynamic nature of the environment becomes particularly obvious and salient. Yet at present, many monitoring systems are based on measurement against 'static' benchmarks consisting of vegetation structure and composition. The Australian Ecosystem Models Framework may provide a sound basis for designing monitoring systems that take into account long-term ecological change in response to environmental and climate change, and thus bring learning about NRM interventions into alignment with prior investment and capacity-building in adaptation.

Finally, while coordination may not always achieve substantial additional benefit, it is possible that a lack of coordination may create additional risks. For example, pooling monitoring effort across a whole program of investment may only deliver substantial benefit if the program was designed with deliberate comparisons built into it in the first place. Risks of lack of coordination across the different options would be worth assessing to identify a minimum package of work that might be most cost-effective to implement as a first step.

CO-BENEFITS FOR IMMEDIATE NRM PROGRAM EFFECTIVENESS

Finally, while the focus of barriers and options was specifically on the ability to learn and thus make interventions more effective into the future, there are potential co-benefits that could be achieved in terms of NRM program effectiveness right now. For example, coordinating interventions and other instruments across landscapes could help ensure that the positive benefits of investment are not undone or outweighed by other actions. Setting longer-term outcomes-based targets would not only provide the architecture to support sufficiently replicated interventions, it would also avoid spreading investment too thinly across the landscape and provide confidence and certainty for stakeholders on the ground about what NRM investment is attempting to achieve. This would be particularly true if those targets were developed collaboratively with practitioners within something like the Conservation Management Zones of Australia.

Longer-term targets would also allow NRM programs to match the temporal scale of change in program priorities with the actual temporal scale of change in environmental needs. Targets are most effective if they reflect the distribution of environmental assets and threats. These environmental characteristics rarely change their boundaries across investment cycles (potentially even with the onset of rapid climate change). Likewise, although government may allocate some NRM investment through electoral commitments, managing environmental health and ecosystem services is inherently driven by environmental, not electoral, needs. These needs do not change across investment cycles. The majority of NRM targets would therefore be most effective if they were designed as long-term targets (perhaps decadal or more), intended to focus investment and drive replication, and were holistically formulated to generate landscape-scale, as well as species specific outcomes – many of which are the very same traits of targets that best support learning.

Concluding Remarks

It would be easy to view this synthesis with a sense of dismay that we don't have more clear evidence of the effectiveness of our many efforts to improve Australia's environment. Indeed, many people we have spoken to are unsurprised by the nature of the results – that limited evidence exists – but *are* surprised by the comprehensiveness of the results across all aspects of NRM. Given the scope of the problem, the message isn't so much that we aren't learning enough from on-ground interventions but rather that the problem is so systemic – that we appear to lack a *system* that encourages us to learn.

However, rather than being dismayed, it is also possible to view this as a positive call to action to change the system. Some of the options suggested are not necessarily new and have been discussed before. Some are even in the early stages of being implemented. Many of the options are imminently achievable. What may be different as a result of the Knowledge Bank work is the realisation that a systems solution is required – that changes need to be implemented as part of a more systemic effort to shift toward a culture of and supporting architecture for learning. Learning itself needs to be an explicit goal, driven by a variety of very practical needs including the need to manage risk to government investments, to have confidence Australia will be able to report on its international commitments, to ensure we are doing so in as cost-effective a way as possible, and of course to try to achieve the best environmental outcomes we can. This doesn't necessarily mean that a systemic change needs to be daunting or require an immediate and comprehensive overhaul. It probably does mean that a longer-term blueprint is worthwhile to guide the choice and implementation of immediate options toward more systemic improvements in our ability to learn about effectiveness.

Without any change in the environmental management and restoration system in Australia, we are likely to continue to learn very slowly. Yet there are clear innovations and options which are beginning to drive potential for a step change in our approaches to environmental management and monitoring – beginning to accelerate our ability to have an effective system for learning from on-ground actions. We hope the synthesis and recommendations presented here can serve as a catalyst to stimulate that positive systemic change.

Collecting Prickly Tree plants for revegetation in a forestry corridor near Millicent (after acclimatisation in school hot houses). Copyright Department of the Environment (taken by staff). Markovic, Dragi.

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