Science that matters

Evaluating research impact of the Arthur Rylah Institute for Environmental Research

A. F. Bennett

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Acknowledgment

We acknowledge and respect Victorian Traditional Owners as the original custodians of Victoria's land and waters, their unique ability to care for Country and deep spiritual connection to it. We honour Elders past and present whose knowledge and wisdom has ensured the continuation of culture and traditional practices.

We are committed to genuinely partner, and meaningfully engage, with Victoria's Traditional Owners and Aboriginal communities to support the protection of Country, the maintenance of spiritual and cultural practices and their broader aspirations in the 21st century and beyond.

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Science that matters

Evaluating research impact of the Arthur Rylah Institute for Environmental Research

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Context

Evaluating the impact of research is a challenge for all research organisations. Research outputs, by themselves, do not bring about change; they provide knowledge that can bring about more informed and effective policies, plans, on-ground actions and community involvement. Understanding the 'pathway to impact' is a key step in evaluating how research is used and the benefit it provides, in this case for the environment.

The Arthur Rylah Institute for Environmental Research (ARI) is the Victorian Government's biodiversity research institute, part of the Biodiversity Division within the Department of Environment, Land, Water & Planning, Victoria. With more than 80 research staff, ARI's focus is to carry out strategic research, disseminate knowledge and provide advice to enhance sustainable management and conservation of ecosystems, primarily in south-eastern Australia.

Aims

1. To develop an approach for evaluating the research impact of an environmental agency;
2. To use this approach to evaluate the impact of research undertaken by the Arthur Rylah Research Institute.

Approach

A systematic review of individual research projects is desirable, but not feasible for hundreds of projects. Rather, we developed a conceptual model of the pathway to impact, which links research outputs with processes that deliver beneficial environmental outcomes.

Research impact was hypothesised to depend on four 'enablers':

- quality of *engagement and relationships;*
- *credibility and reputation;*
- provision of *relevant and applicable knowledge;* and
- effective *communication and dissemination*.

Thus, if these enablers facilitate impact, and if there is evidence that they are operating effectively across research programs, then it is likely that the pathway to impact is operational and research is likely to be effective.

Evidence for impact

We selected seven case-study projects and retrospectively reviewed their outputs and impact and the factors contributing to impact. These case studies affirmed that the specified enablers were indeed a key element in research outcomes being translated to impact. To examine evidence for the extent to which these enablers are operating across ARI's projects, data from a variety of indicators were collated.

Engagement and relationships: There is strong evidence that engagement and relationships with clients are very positive based on data from annual client surveys seeking feedback on individual projects. Engagement with diverse stakeholders is also promoted through ARI's communication strategy.

Credibility and reputation: Data from refereed publications provide evidence of the collective credibility and reputation of scientists at ARI. There is a high level of external collaboration, an increasing publication output, a growing profile internationally, and recognisable contributions to new conceptual knowledge. Further, client surveys recognised the 'rigour and robustness' of science as applied in individual projects.

Relevant and applicable knowledge: ARI delivers relevant and applicable knowledge in four main ways: through provision of expert advice and knowledge to stakeholders (within DELWP and to other agencies); through specific research projects; by developing decision support tools and data sets; and by contributing to new conceptual knowledge. ARI spatial products profoundly underpin natural resource management across Victoria.

Communication and dissemination of research occurs at many levels, from individual projects to workshops and events, to seminar programs, to social media profiling of the Institute and research highlights. ARI has dedicated resources that support a comprehensive communication program.

Synthesis

The ‘pathway to impact’ approach provides a valuable framework for evaluating how ARIs research contributes to environmental outcomes. Rather than being a retrospective approach, it demonstrates how measures to enhance impact can be incorporated into current and upcoming activities in a pro-active way. These include mapping the perceived pathway to impact for major projects and programs and incorporating the relevant enablers into project design, delivery and review.

ARI has an established reputation for applied environmental research. It is distinctive as a research institute due to being embedded within Government. This offers unique opportunities to further build its role as an organisation that spans the knowledge-action boundary, and to work co-operatively within Government and with the wider scientific community to achieve environmental outcomes.

1 Introduction

Evaluating the impact of research is an important issue for research organisations worldwide. Whether stated explicitly or recognised implicitly, a common purpose for undertaking research is that generating new knowledge will benefit human society. Further, in many areas of research (including the environment), research institutions and programs are substantially supported by public funds and so it is a reasonable expectation that the benefits and impact of the research are evaluated. Ensuring that research is effective and has impact is especially important in environmental science and natural resource management, given the increasing impact on biodiversity of human use of land and water. However, despite concerns about the 'research-implementation gap' and the need to more effectively span the 'knowledge-action boundary' (e.g. Cash et al. 2003; Knight et al. 2008; Cook et al. 2013), assessment of research impact is seldom undertaken. It is complex, difficult and there are no standard methods for doing so. Here, we report on an approach to evaluating the research impact of an environmental research institute, operating within a government agency.

The Arthur Rylah Institute for Environmental Research (ARI) is the Victorian Government's biodiversity research institute. It forms part of the Biodiversity Division within the Environment and Climate Change Group of the Department of Environment, Land, Water & Planning (DELWP), Victoria. ARI's focus is to carry out strategic research, disseminate knowledge and provide advice to enhance the sustainable management and conservation of ecosystems in south-eastern Australia. The Institute comprises more than 80 research staff, who collectively have a wide range of scientific and technical skills in the flora, fauna and ecology of terrestrial, freshwater and estuarine ecosystems. This expertise encompasses ecological monitoring and evaluation, conservation of threatened species, population modelling, spatial analysis, landscape ecology, the development of decision support systems, and science communication.

Like other agencies and centres that have a strong applied focus, ARI is committed to 'science that matters' and 'research that has an impact'; and to activities which work towards positive change across terrestrial and aquatic ecosystems (DELWP 2017). This commitment is expressed in the daily and regular activities of staff as they carry out projects, interact with policy makers and managers, and provide advice and guidance. It is reflected in the program structure and activities of the Institute. However, evaluating exactly how, and to what extent, the research undertaken by a research institute like this has a positive impact is difficult and seldom done, yet it is essential in order to ensure research is effective and achieving its goal.

The aim of this exercise was twofold: i) to develop an approach for evaluating the research impact of an environmental agency; and ii) to use this approach to evaluate the impact of research undertaken by the Arthur Rylah Research Institute. Specific objectives were to:

1. Establish a framework for understanding *how* impact occurs, through the lens of the 'pathway to impact'
2. Synthesise key factors that influence the pathway to impact
3. Collate information on relevant outputs and indicators, and on selected case-study projects
4. Identify opportunities for ARI to enhance the benefits and impact of its research activities.

2 Approach to evaluating impact

Research impact from ecological and environmental research can be described as the effect on, change in, or benefit to, the environment arising from research (see Box 1). Essentially, it is the outcomes for the environment from the adoption or use of the knowledge generated by research.

Evaluating such research impact is inherently difficult. There are at least three key issues, each of which is especially relevant to environmental research.

Attribution – Typically it is difficult to directly link a specific piece of research, advice or knowledge product to an enhanced environmental outcome because there may be multiple factors involved. A research project does not directly produce an environmental outcome. Rather, research provides knowledge, techniques and advice which can justify and guide changes in policy and practice which, in turn, result in improved environmental outcomes. To bring about such positive change involves others – responsible agencies, community groups and individuals – who are part of a pathway to achieving impact (e.g. a change in policy to protect ecosystems).

Measuring benefits – The environmental benefit gained from a particular change in policy or practice as a result of research is difficult to measure in quantitative terms (e.g. as economic or social benefit). Further, an assessment of the level of benefit needs to take into account what would likely have occurred in the absence of the new knowledge from research (i.e. the counterfactual), which is often more difficult to measure.

Time lags – There may be a substantial period of time (years to a decade, or more) after research outputs are achieved and knowledge communicated, before changes in practice occur and benefits accrue. A shorter-term perspective (e.g. less than 1-2 years) is likely to substantially underestimate the impact and benefits of research.

Some organisations, especially universities, often have focused on measures of research quality or research excellence, but these are not the same as research impact. For example, measures based on evaluation of published research outputs and analysis of citations are an indicator of 'academic impact'. Such measures assume that a larger number of publications, in higher impact journals, gathering more citations, indicate that the research has influenced others and thereby has an impact on the development of scientific knowledge.

A widely used approach to assessing research impact is to evaluate case studies of research projects or themes, qualitatively review their performance, the kinds of outputs produced, their engagement with stakeholders and evidence for the types of change that have occurred as a consequence of the work. This approach has been used, for example, by development agencies; and is now also being used in the university sector. The Engagement and Impact Assessment (see ARC 2020) undertaken for the first time in Australian universities in 2018, involved universities documenting a narrative on engagement and impact for a selected case study in a particular research field (e.g. 05 Environmental Science). A single narrative was put forward for a research field by an institution, for review. The assessment of impact of the University in that field is valid only in so far as the selected case study is typical of all research undertaken in that field.

Box 1: What is research impact?

Australian Research Council (2015)

"*Research impact is the contribution that research makes to the economy, society, environment or culture, beyond the contribution to academic research*."

National Health and Medical Research Council (2020)

"*NHMRC defines the impact of research as the verifiable outcomes that research makes to knowledge, health, the economy and/or society. Impact is the effect of research after it has been adapted, adopted for use, or used to inform further research*."

2.1 Pathway to impact

The approach here is to focus on the concept of the 'pathway to impact', a mental model of the pathway (or sequence of steps) by which research and scientific knowledge are hypothesised to lead to changed outcomes.

Figure 1 outlines a model of the pathway to impact for science and research undertaken by ARI. This model assumes that work undertaken by ARI will have impact (i.e. lead to positive environmental outcomes) if each of the steps in the pathway operate effectively. It reflects the distinctive applied emphasis of ARI, which differs from that of a university or some other research centres. This model recognises four main pathways by which ARI's research can have impact, associated with different types of outputs (see Fig. 1):

A. Provision of expert knowledge and advice (e.g. the conservation status and requirements of a threatened species) can guide changes to policy, contribute to decision-support systems, or influence management practices that lead to positive changes to the environment. It can also inform the wider community and empower people to act for nature.

B. Results from research projects (e.g. evaluating a particular management practice) can affirm the benefits of management practices, guide changes to more effective practices, or catalyse changes in priorities for environmental actions.

C. Production of decision-support tools and data sets (e.g. spatial maps of vegetation types or fire severity) can directly guide in choosing amongst alternative options for environmental actions, in determining priorities and cost effectiveness, and in identifying the most effective locations to achieve benefits.

D. Development of new conceptual knowledge (e.g. new insights into cause and effect relationships, new analytical approaches) can have long-term benefits by identifying more effective ways of achieving environmental outcomes. Through publication, such new insights become available to other scientists and environmental managers worldwide and can have wide-ranging benefits.

How can the effectiveness of the steps in the pathway to impact be assessed? One way is to review each individual project to examine what happened at each step and to assess changes to policy or practice that may have occurred as a result. This approach would identify direct links between specific projects and their impacts. However, it is not feasible here because ARI has had hundreds of individual projects over the last 5 years. It is also a retrospective process – learning about impact primarily occurs (long) after the project has completed. Rather, we have taken a two-pronged approach in which we:

1. Examine a small number of selected case studies to assess what has been achieved, what has contributed to their individual pathways to impact, and to seek generalities in what contributes to (or hinders) an effective pathway to impact.
2. Collate a series of measures or indicators that give insight into the likely effectiveness of the steps in the pathway across the range of projects undertaken at ARI. That is, to make an Institute-wide (multi-project) assessment of the extent to which the pathway to impact is operating effectively.

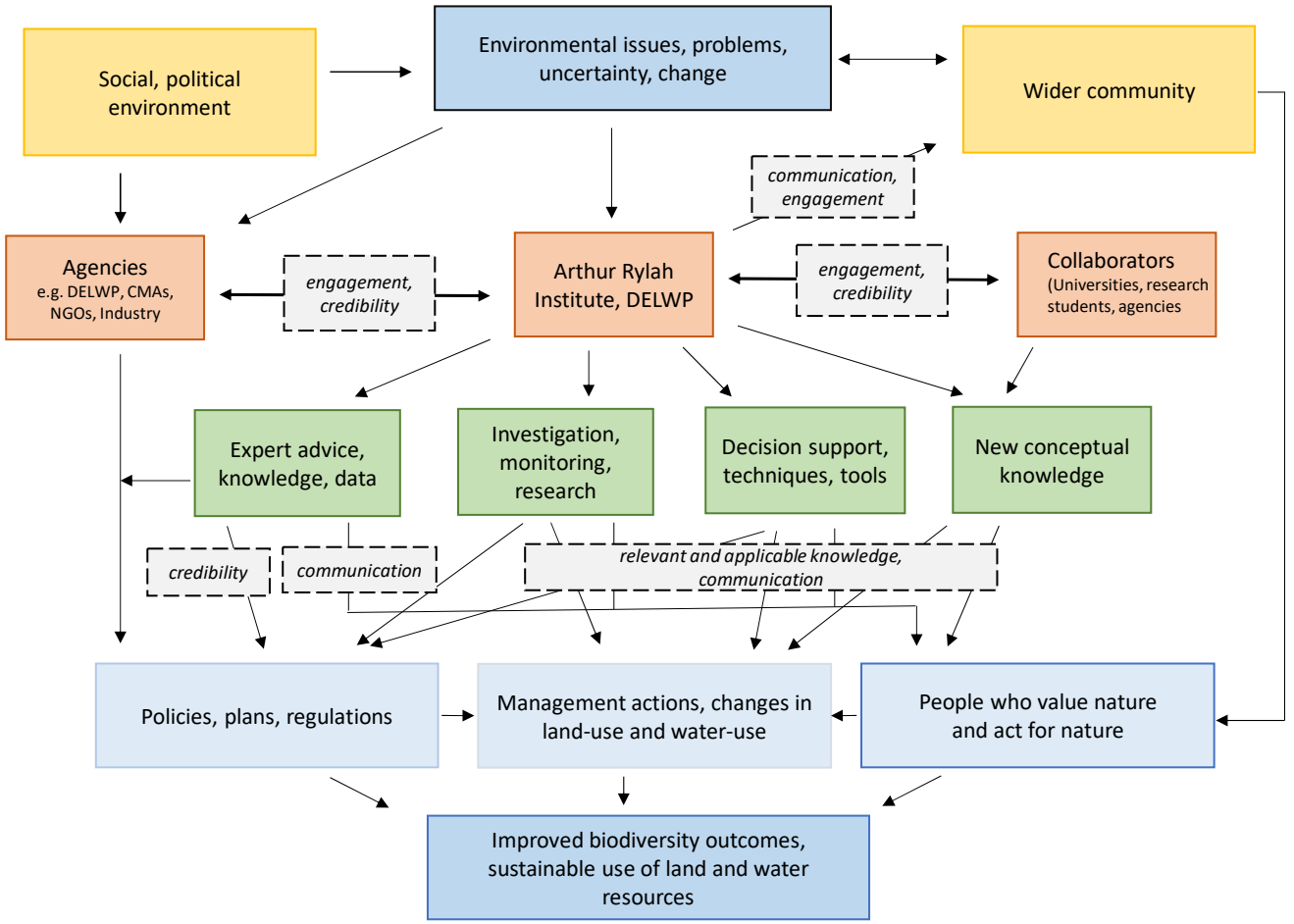


Figure 1. Model of a pathway to impact for research and knowledge generated by ARI.
The underpinning assumption is that impact will be achieved if these pathways are effective. Four 'enablers' (grey boxes) facilitate the pathway: engagement and relationships, credibility and reputation, relevant and applicable knowledge, communication and dissemination.

2.2 Enablers of impact

Based on the model in Fig. 1, we hypothesise that the likelihood of ARI's research leading to outcomes that enhance environmental benefits will be influenced by four key factors, here termed 'enablers', that influence steps in the pathway. [NB: The term 'client' is used below to collectively refer to those commissioning research by ARI, seeking advice, or using knowledge and decision support tools. Many are partners and collaborators.]

1. The quality of **engagement and relationships** between researchers and agencies, other collaborators and the wider community. Effective engagement and positive relationships are more likely to result in:
    - the objectives and design of a project being aligned with the client's requirements;
    - the outputs (results) of the project meeting the client's needs;
    - greater uptake and implementation of recommendations; and
    - ongoing and trusting relationships.
2. **Credibility and reputation** of ARI scientists as having knowledge and skills to provide high quality advice and recommendations. A high level of credibility is more likely to result in:
    - greater acceptance of advice and implementation of recommendations;
    - greater respect for the work of the agency that acts on that advice (i.e. a flow-on effect to the client);
    - greater opportunities for collaboration with other scientists; and
    - respect for individual scientists, for ARI, and for the Department (DELWP), in the community.
3. The delivery of **relevant and applicable knowledge**. High quality outputs that are relevant and applicable to end-user needs are more likely to result in:
    - clients having greater capacity to carry out their work effectively;
    - greater satisfaction by those who have commissioned the work; and
    - a positive ongoing relationship based on a good experience.
4. Effective **communication and dissemination** of knowledge to clients, partner agencies, collaborators and the wider community. Effective communication will result in:
    - clarity of message about results and recommendations to key stakeholders;
    - provision of new knowledge to a wider range of people and organisations; and
    - an enhanced profile for ARI and for the Department (DELWP).

Data for a range of indicators have been collated to provide insight into these enablers (Table 1, Section 3). The indicators serve as surrogate measures of whether the steps in the pathway to impact are effective. In selecting these indicators, independent and objective measures have been used wherever possible (to avoid conscious bias), largely derived from existing information sources at ARI.

This evaluation relates primarily to projects undertaken over a 5-year period, 2015-2019, recognising that:

A. research projects and knowledge-based activities often extend over several years;

B. there is a time-lag between outputs and associated outcomes and change occurring; and

C. a time-period of ~5 years provides a broader perspective on ARI's activities and allows some assessment of trends through time.

2.3 Case studies

Case studies are commonly used to explore more deeply how, and why, a particular body of research has (or has not) had impact, and the extent and type of that impact. Essentially, a case study seeks to understand the entire pathway to impact (Fig. 1) for a single project. Seven case studies were selected for a 'deeper dive' into research impact, and to seek generality concerning the factors that enhance success. They also provide a test of the relevance of the 'enablers' specified above (and see Table 1): if the enablers are catalysts for research impact, then they should emerge as important elements in individual projects.

The criteria for selecting case studies (by the ARI Senior Leadership Team) were that they:

A. are illustrative of the range of research undertaken at ARI (e.g. from both terrestrial and aquatic systems);
B. are relevant to the role of ARI in providing advice to Government agencies;
C. include both smaller and larger, and shorter- and longer-term projects; and
D. were considered *a priori* as likely to have had a positive impact and therefore offer lessons to be learned.

For each project, an interview was held with the project leader (ARI scientist) using a standard set of questions. An interview was also held with a stakeholder/client who either had commissioned the research or was closely familiar with it and involved in its application. This latter interview was by phone, using a standard set of questions circulated to the interviewee beforehand (Appendix 2). Based on these interviews, a draft summary of the case study was prepared using a similar structure for each (drawing on relevant reports or publications, as appropriate). The draft summary was circulated to both interviewees for review, to ensure that the synthesis of the interviews accurately represented their views.

Table 1. The relationship between 'enablers' of the pathway to research impact and indicators, measures and outputs of research that have been collated in this evaluation.
Case studies were examined to test whether enablers were important in achieving outcomes in selected projects. Various indicators and measures were collated to assess whether the enablers are operating effectively across ARI's programs.

Enablers	**Indicators, measures and outputs**					**Case studies**
	Client surveys	Publications	Decision support	Conceptual knowledge	Targeted communication	
Engagement and relationships	Yes	-	-	-	Yes	Yes
Credibility and reputation	Yes	Yes	Yes	Yes	-	Yes
Relevant and applicable knowledge	Yes	Yes	Yes	Yes	-	Yes
Communication and dissemination	-	Yes	-	-	Yes	Yes

3 Evaluating the pathway to impact

Research impact depends on successful operation of the steps in the pathway to impact. In turn, these steps are hypothesised to depend on four key enablers (Fig. 1). Here, data are collated from a range of indicators and research outputs to examine evidence for the strength and effectiveness of operation of the enablers.

3.1 Client surveys - how do our clients perceive ARI research?

Each year, ARI surveys a sample of clients seeking responses to a standard set of questions. Clients associated with the 100 projects of highest value ($ amount) are invited to respond to an online survey (using Survey Monkey) in relation to the project in which they invested. Surveys are not anonymous.

Responses were collated for relevant questions for the five most-recent surveys, financial years 2013/14 to 2017/18. These responses represent an independent assessment by clients of the performance of ARI in delivering projects, and in the relevance and applicability of the research and knowledge to the client. Sample sizes (number of respondents) for each year were: 2013/14 (n=41 responses), 2014/15 (n=36), 2015-16 (n=40), 2016-17 (n = 35) and 2017/18 (n= 50 responses).

Figure 2 summarises responses over 5 years to several questions relating to overall satisfaction and the level of influence the work has had (or will have), while Fig. 3 summarises responses to a series of more specific questions. The results indicate a high level of satisfaction with projects undertaken by ARI (Fig 2a; Fig 3a). Clients overwhelmingly reported that 'overall satisfaction with the work performed' was very good or excellent. This pattern was consistent across the five years surveyed, with some 90% being satisfied in 2017-18.

Box 2 summarises the relationship between responses from client surveys and the enablers of impact.

Box 2: Client surveys - relationship with 'enablers' of impact

Engagement and relationships

Evidence for positive engagement with clients was shown by responses to a question asking about ARI's understanding of the organisation's need in relation to the project (Fig. 3a). The trend for combined responses of 'very good' and 'excellent' increased from ~62% to ~90% across the five-year period. Likewise, ARI's communication with the client organisation in relation to specific projects (Fig. 3b) was consistently rated highly (>70% 'very good' or 'excellent' across all years).

Credibility and reputation

Clients consistently responded that 'the rigour and robustness of the science and thinking' was 'very good' or 'excellent' (~80% of responses annually) (Fig. 3c); while the 'quality of the outputs delivered' was assessed as 'very good' or 'excellent' from ~65-80% of respondents each year (Fig. 3d). These responses provide evidence of a high level of credibility for the science undertaken by ARI scientists.

Relevant and applicable knowledge

Annual responses from clients regarding 'the relevance of any recommendations made by ARI' (Fig. 3e) varied between years, with from 50-80% of responses being 'very good' or 'excellent'. Most other responses were 'good', although 'don't know' was reported in several years. While these are strong outcomes, there is scope for continued efforts to engage with clients to maximise the relevance of recommendations.

A

B

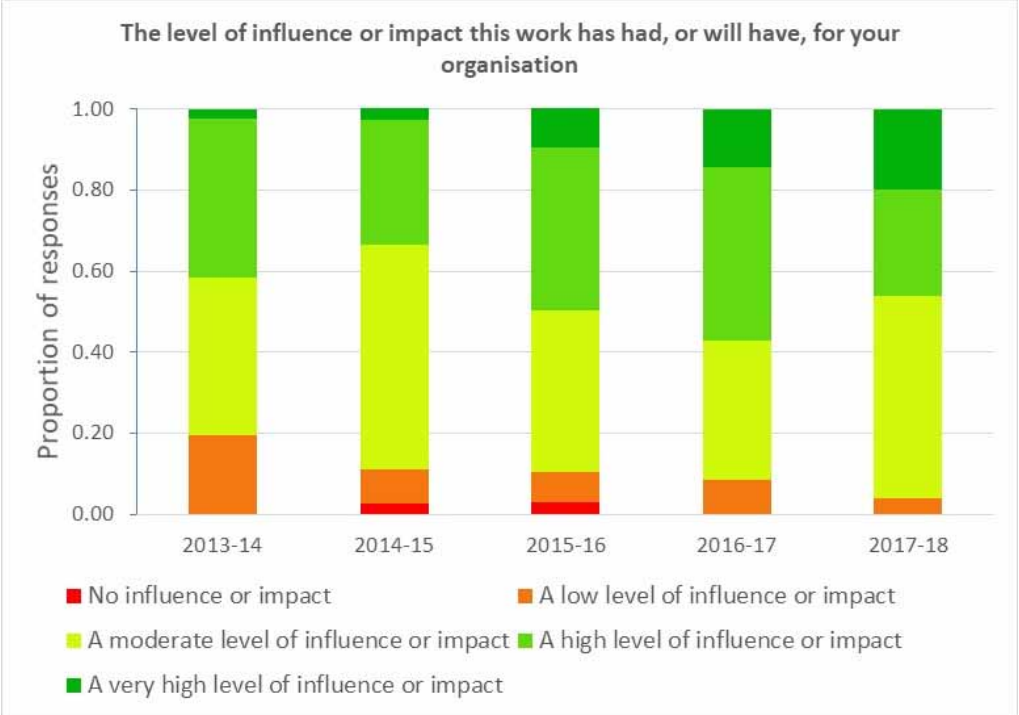
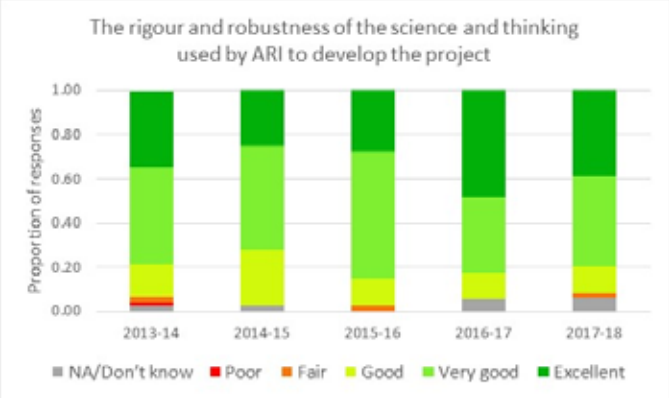


Figure 2. Summary of satisfaction and assessment of impact of ARI research in client surveys over a 5-year period. Responses are to the following standard questions: A) Based on your experience with ARI on this project, what is your overall satisfaction with the work performed? and B) What level of influence or impact this work has had, or will have, for your organisation?

A

B

C



D

E

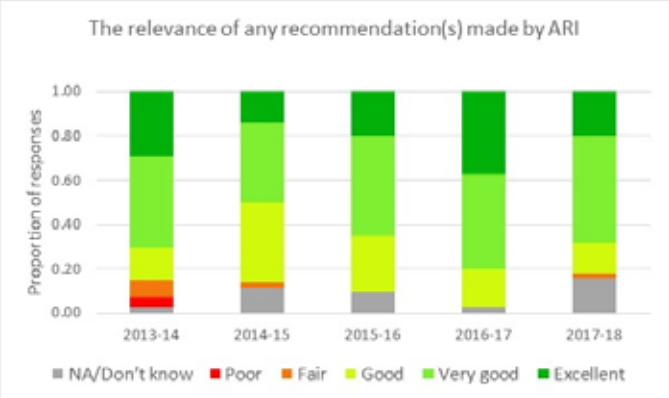


Figure 3. Summary of indicators of communications, effectiveness and quality of ARI research in client surveys over a 5-year period.
Responses are to standard questions as shown in titles. Sample sizes ranged from 35 to 50 responses per year.

3.2 Publications

3.2.1 Types of publication outputs

Publications – including reports, technical reports, peer-reviewed scientific papers and information sheets – are a major form of research output. ARI staff have consistently produced around 100 reports per year (Table 2). Most are specifically for the client who commissioned the work and therefore are not published documents available to others (unless approved by the client). Some reports, including ARI Technical Reports, are published documents also made available on the ARI website. Fact sheets are short summaries (typically 2-4 pages, colour) highlighting key findings from projects in an accessible form. The number of fact sheets has increased over the last 5 years. They are also made available online.

Table 2. The numbers of different types of research outputs generated by ARI, 2015-2019.

Output type	2015	2016	2017	2018	2019
Reports (clients)	92	98	99	94	92
ARI Technical Reports	3	10	8	11	10
Fact/info sheets	7	16	15	31	28
Journal papers (submitted)	55	92	63	58	104
Book chapters (submitted)	2	4	5	3	2
Presentations	93	96	101	123	102

3.2.2 Trends in refereed scientific papers

Publication in scientific journals is an essential part of the research process.

A. It makes research results and technical information available to a wider audience, nationally and internationally.

B. It is the primary means by which new concepts and syntheses are disseminated among the scientific community, and therefore a primary means of research impact.

C. It adds credibility to research because manuscripts are peer-reviewed before publication.

D. It is a responsible way of using limited resources wisely so that others can benefit from new knowledge. All environmental managers draw on published research, both local, national and international.

Figure 4 summarises trends in the number of scientific papers authored (or co-authored) by ARI scientists. Three trends are apparent:

1. The number of peer-reviewed scientific publications shows an increasing trend through time.
2. ARI scientists are collaborating widely with scientists from other organisations, with the majority of papers being collaborative and led by external scientists.
3. The number of ARI-led papers has remained roughly similar. However, a recent strategy to increase the numbers that are ARI-led is reflected in a potential upward trend from 2017 to 2019.

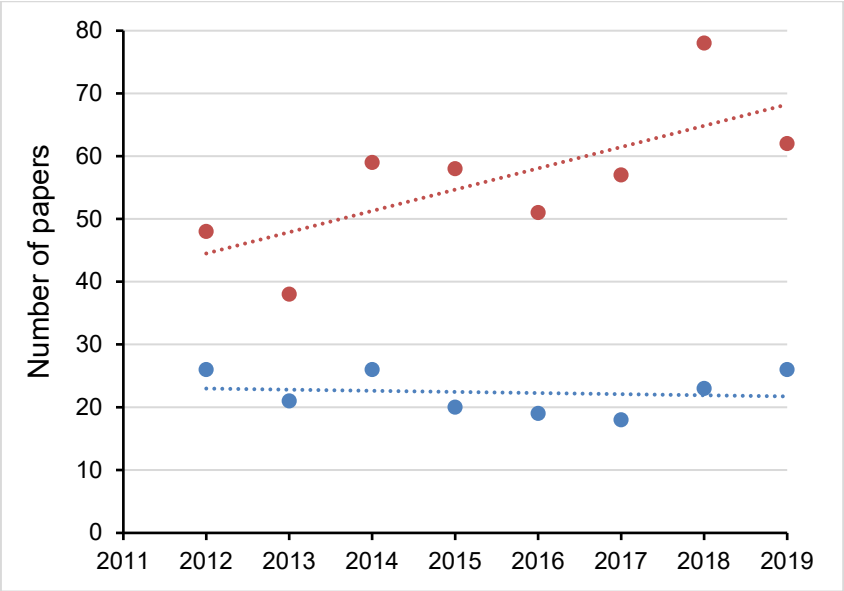


Figure 4. Trends in the number of papers published in scientific journals 2012-2019 which are (co-) authored by ARI staff.
Trends are shown for: a) the total number of papers (red) and b) those led by ARI staff (blue).

ARI research is published in a wide array of scientific journals, national and international. Table 3 presents the top 10 journals, by number of papers, in which ARI scientists published (2015-2019), together with the number led by ARI scientists and those involving collaborations led by external scientists. This list includes several of the most highly regarded international journals in conservation and applied ecology (e.g. *Journal of Applied Ecology, Biological Conservation, Ecological Applications*).

A common indicator of the 'esteem' of a journal is its Impact Factor (IF), based on the average number of citations per paper in that journal for the two years following the year of publication. While there are differing views on the value of this measure, it allows some comparison of publishing trends. Over the last 5 years (2015-2019), ARI publications (n=452 refereed papers) have been published in a range of journal types in terms of readership distribution and impact factor: this includes journals with more local distribution with IF typically < 1.0; those with national or southern hemisphere focus (e.g. *Austral Ecology, Emu:Austral Ornithology*) with IF typically 1-2; and those with strongly international focus (typically IF >2.0). Notably, ARI scientists have published in some of the most highly regarded international journals (e.g. *Conservation Biology, Journal of Applied Ecology, Fish and Fisheries, Global Change Biology*), including prestigious journals such as *Nature, Nature Climate Change, Trends in Ecology and Evolution*, and *Frontiers in Ecology and Environment* (IF >8.0) (Fig. 5).

There is a tendency for collaborative research with external partners to have a greater proportion of publications in higher ranked journals (Fig. 5b). This reflects ARI's primary research focus on applied management issues in Victoria and Australia, often published in more-local journals. However, it also clearly indicates that the knowledge, expertise and data held by ARI scientists are widely sought as part of multi-institutional researcher collaborations and make valuable contributions to publications of international relevance and quality.

There also is a trend for ARI-led papers to increasingly be published in journals of higher impact factor (Fig. 6). In the period 2016-2019, a relatively greater proportion of papers have been published in journals with impact factor >2.0, with a notable increase in those with IF 5.0 – 8.0 (highly regarded international journals).

Box 3 summarises the relationship between publication outputs and the relevant enablers of impact.

Table 3. The top ten journals for ARI publications (2015-2019), by number of papers in each

Journal	IF	Total papers	ARI led	Externally led
Marine & Freshwater Research	1.86	16	12	4
Biological Conservation	4.45	13	2	11
PLOS One	2.78	12	2	10
Journal of Applied Ecology	5.78	11	3	8
Ecological Management & Restoration	1.44	11	8	3
Austral Ecology	1.40	9	2	7
Diversity & Distributions	4.09	7	0	7
Ecological Applications	4.38	7	3	4
Ecology and Evolution	2.42	7	2	5
Wildlife Research	1.24	7	3	4

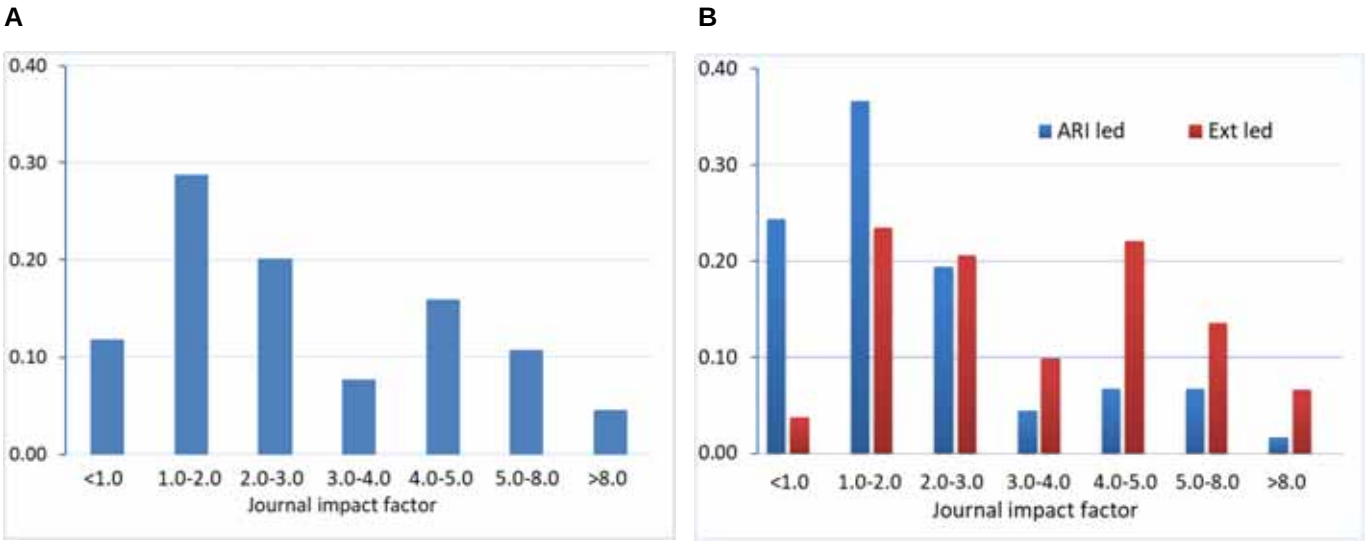


Figure 5. The proportions of ARI publications (2015-2019) in relation to the journal impact factor (ISI).
A) all publications; B) comparison of ARI-led publications vs those led by external collaborators. Note: for journals that do not have an impact factor, an arbitrary value of 0.50 was assigned.

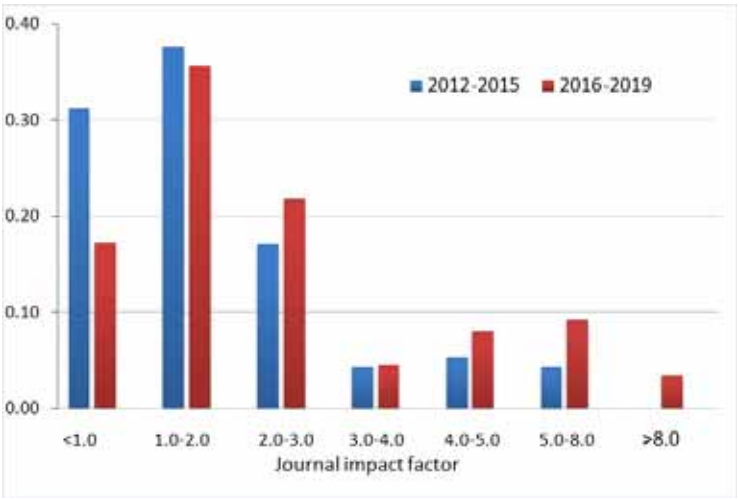


Figure 6. The relative proportion of ARI-led papers in relation to the impact factor of the journal for two four-year periods, 2012-2015 and 2016-2019.

Box 3: Publications – relationship with 'enablers' of impact

Credibility and reputation: Publications provide evidence of credibility and reputation in several ways. First, credibility with clients depends on delivering a timely and quality product, relevant to their needs. ARI produces a large volume of client reports and runs an internal peer-review process to enhance the quality of the product for the client. Second, and more important to the wider credibility and reputation of individual scientists and the Institute are published papers in the refereed scientific literature. These inform perceptions of reputation among peers in the scientific community. Evidence shows that:

A. As an Institute, ARI is an active participant in the wider scientific community with its scientists (co)authoring 50-80 papers per year (with numbers increasing, Fig. 4) across a wide range of environmental topics. These are published in the national and international literature, including leading international journals (Fig. 5). ARI has a recognisable profile, notable for an Institute funded primarily on a client-project basis for applied projects.

B. ARI scientists have extensive collaborations with scientists from many locations. These show that the knowledge, expertise and data held by ARI scientists are recognised and valued.

C. The relative proportion of papers led by collaborators (cf. ARI-led, Fig. 4)), particularly in journals of higher esteem (Fig. 5), suggests that collaborations have a large influence on the reputation of ARI (as indicated by publications). Promising signs are a trend for increasing numbers of ARI-led papers in journals of higher impact factor (Fig. 6).

D. The data assembled are for ARI as a whole and do not reveal patterns among individual scientists. There is wide variation among staff in the number and quality of outputs. A small number of staff contribute disproportionately to journal publications and the associated reputation of the Institute.

Relevant and applicable knowledge: A large proportion of ARI's research outputs are client reports (~100 per year) directly communicating knowledge on a matter of relevance to the client. Evidence from client responses (Figs 3e, d) indicate a high level of satisfaction with the quality of the outputs and relevance of recommendations. Evidence of the relevance of knowledge published in journal papers can be linked to citations, as a crude indicator of the extent to which the work influences the scientific field.

Communication and dissemination: Publications are evidence of communicating and disseminating knowledge as part of the pathway to impact in research. Their value in contributing to impact depends on the number, type and how well they are targeted. The breadth of types of publications – from fact sheets to client reports to papers in international journals – is evidence that ARI publications are contributing to multiple pathways to research impact (e.g. with specific clients, with the international scientific community).

3.3 Decision support and provision of expert advice

As a research institute embedded within state government (i.e. Department of Environment, Land, Water & PLanning), a key role for ARI is to provide advice and information to support government policy development and implementation. This takes numerous forms including: formal decision-support tools; spatial data layers that underpin planning processes; new technical processes for data collection; enhanced tools for data analysis; provision of technical expertise; advice on survey and study design; expert advice to committees and recovery teams; and day-to-day advice on specific plants, animals, ecosystems and conservation issues.

The provision of such information is a distinctive and notable element in the pathway to impact for ARI (see Fig. 1) compared, for example, with universities and other research-focused institutes. It requires having a body of staff that has a wide range of expertise (e.g. flora, fauna, ecosystems, spatial analysis, modelling) and can combine that expertise in a coordinated way, as required, to meet demands for information. This differs from a typical university model, where the focus is on having high-calibre staff with individual fields of expertise that may not necessarily be complementary.

3.3.1 Decision-support tools and data

Table 5 summarises a range of examples of decision-support tools and datasets for which ARI staff have taken a leading role. The pathway to impact of such tools (Fig. 1) is that they directly support those making decisions on priorities for conservation, those developing new policy, and those planning management actions to sustain natural resources – by enabling them to make more informed and more effective choices. To illustrate the pathway to impact, a descriptive summary is given in Table 4 of examples of *how* the tools are used and *who* uses them. These are indicative only – they do not capture the full breadth of use.

Box 4 summarises the relationship between decision-support tools, expert advice and the enablers of impact.

3.3.2 Provision of expert advice

Provision of expert advice by ARI staff to a wide range of people, agencies and organisations occurs on a daily basis. It is difficult to quantitatively summarise the extent and breadth of these activities, and the range of staff involved. As an indicative illustration, a small number of examples of the kinds of advice provided by ARI staff to other groups within DELWP and externally are shown in Table 5. These examples are from internal, monthly DELWP Sycle reports from a single, selected year (2018).

Box 4: Decision support and expert advice – relationship with 'enablers' of impact

Engagement and relationships: Provision of decision support and expert advice is a means by which ARI staff engage with a wide range of people involved in policy, planning and management – including in both regional settings and policy divisions of DELWP.

Credibility and reputation: The demand for, and use of, knowledge, advice and decision-support tools generated by ARI are both a consequence of the credibility and reputation of ARI staff, and a factor that further enhances such reputation. Many of these tools have placed Victoria at the forefront of natural resource planning in Australia. They also are based on advances in conceptual knowledge that are of international standing (e.g. methods for species distribution modelling) (see Table 8).

Relevant and applicable knowledge: The breadth of ways (Table 5) in which decision-support tools and data products provide a foundation for management of natural resources in Victoria – including through planning processes for fire management, forest management and statutory planning – point to the depth of their impact. Data sources, such as vegetation maps for Victoria, underpin planning process that are widely used across Victoria on a daily basis.

Table 4. Examples of decision-support tools and data provision by the Arthur Rylah Institute to enhance policy development and on-ground management.

Decision support/ software/ data	Description	How is it used	Who uses it
Habitat distribution models (HDMs) for species in Victoria	Predictive models (and spatial maps, GIS layers) of the state-wide distribution of habitat suitability for individual species of plants and animals. Models are available for ~450 animal and ~1700 plant species in Victoria. Model development is based on world-leading approaches in species distribution modelling.	Habitat distribution models underpin many tools and processes used for conservation management in Victoria. e.g. - threatened species management - survey design (e.g. forest pre-harvest surveys) - customised products (e.g. Koala habitat suitability) - Regional Forest Agreement processes - the Strategic Management Prospects (SMP) tool - determination of the nature of 'offsets' for clearing native vegetation (State section of the Vic Planning Scheme) - species overlays, such as the Giant Gippsland Earthworm habitat overlay (Baw Baw and South Gippsland Shires)	All agencies involved in land and conservation management use these HDM's either directly or indirectly. Also used by Universities and other researchers.
Native vegetation cover in Victoria	State-wide mapping of the distribution of native vegetation extent and landcover in Victoria	Underpins the Native Vegetation Retention controls (together with species models) and implementation through planning schemes. Used by various forms of environmental accounting, including carbon accounting, offsetting, and incentive schemes such as Bush Broker, Bush Tender. Bushfire risk modelling for the Bushfire management overlay. Input into 'Phoenix' and 'Frost' fire simulation models. Used in other models, such as SMP and new wetland species models	DELWP staff Local government
Vegetation types in Victoria	State-wide mapping (GIS layers) of Ecological Vegetation Classes (EVCs) for Victoria. (ARI is a major contributor over several decades). Combinations of EVCs have been used to map broader categories including Ecological Vegetation Divisions (EVDs) and Ecological Fire Groups (EFGs).	Underpins many planning and management processes, e.g. - conservation assessment of status of ecological communities - national vegetation mapping for Australia - fire management planning, metrics for ecosystem resilience to fire - research design and planning e.g. stratifying sampling) - fuel type and fuel accumulation rates for fire simulations (Frost and Phoenix)	All agencies involved in natural resource management, either directly or indirectly. Researchers.

Decision support/ software/ data	Description	How is it used	Who uses it
Strategic Management Prospects (SMP)	Decision-support tool for prioritising management actions to enhance nature conservation in Victoria. Based on optimising, across multiple plant and animal species, the locations and actions that are predicted to provide greatest overall benefit for conservation.	Underpins conservation planning in Biodiversity 2037: - biodiversity response planning - assessing priorities for allocation of resources - method for assessing gains in conservation outcomes - collecting new primary data through expert elicitation and capacity for expert model editing and species record entry.	Led by DELWP Biodiversity Division for working with DELWP regional staff, CMAs and other conservation agencies and groups
Mapping fire severity by remote sensing	Tool to enable rapid mapping of fire severity in shrublands, woodlands and forests using Landsat imagery. Novel approach that integrates machine learning, Landsat imagery and cloud computing (Google Earth Engine).	To map the severity of wildfires, for use in fire management planning (e.g. DELWP staff, Gippsland region and 2019-20 wildfires). Future use for routine mapping of wildfires and prescribed burns to feed into planned burning optimisation. To support research into effects of environmental variables on fire behaviour.	DELWP for fire mapping. Universities for research.
Fire Analysis Module for Ecological Values (FAME)	A web-based tool, the Fire Analysis Model for Ecological values (FAME), to analyse the ecological consequences of fire management, and an approach to analysing alternative options and trade-offs.	A decision framework guides decision makers and stakeholders on how to better conceive and apply ecological models and metrics to inform a strategic, fire planning process that transparently explores trade-offs between life and property and biodiversity values.	Fire managers (planning, evaluation, monitoring) in a range of organisations (DELWP, Parks Victoria, Country Fire Authority).
Population models for fish species in the Murray Darling Basin	Stochastic population models to calculate likely population growth (or decline) of a species based on demographic factors (e.g. birth and death rates), environmental factors and potential management influences. A user-friendly 'front-end' to the software allows a user to select options to test 'what if' scenarios for population management.	Used to test the likely consequences of - different management scenarios on persistence of a species - outcomes from re-stocking and re-establishing (e.g. threatened species such as Murray Cod, Macquarie Perch).	Primarily by researchers in collaboration with waterway managers (e.g. as commissioned work, or in collaborative workshops).
River rehabilitation decision support	A stand-alone tool for stream systems in Victoria that provides a spatial map at a 'reach' level on attributes such as instream woody habitat, overhanging vegetation, barriers to fish passage.	To identify priorities for habitat rehabilitation and stream restoration. Users select attributes (or add their own) and a spatially mapped index is generated to indicate priorities.	Primarily designed for Catchment Management Authorities (CMAs)

Decision support/ software/ data	Description	How is it used	Who uses it
Vegetation condition of floodplain forests of the Murray Darling Basin	Tool for spatial mapping of the condition of floodplain forests based on tree health, as assessed from satellite imagery. Annual updates can be made based on remote imagery.	Audit of the health of Murray Darling Basin floodplain vegetation, updated annually by agency staff. Provides means to report against targets for the Basin. To support decisions related to environmental watering	Murray Darling Basin Commission (MDBA) Water authorities (Victorian Environmental Water Holder, Commonwealth Environmental Water Office). CMAs
Prioritisation for reserve design	'Bespoke' conservation planning products to enhance design of the conservation reserve system. Based on identifying areas of highest value for representing all taxa, by optimising across species distributions.	To identify areas of highest priority to augment the existing reserve system, to enhance biodiversity conservation values.	Victorian Environmental Assessment Council
Modelling rainforest distribution in Victoria	Identification and spatial mapping of the distribution of rainforest in Victoria, based on remote sensing to provide a consistent, state-wide inventory and map.	For forest management planning To assess the impacts of wildfire Conservation planning Support revision of the EVC layer Regulation of timber harvesting	DELWP policy and regional staff, conservation agencies and community

Table 5. Selected examples of provision of expert advice (as documented in DELWP Sycle reports, 2018)

Theme of advice	To
Response to Forest Policy & Planning Division's 'Precautionary Principle Guidance' document, especially with respect to Greater Glider conservation in production forests	Biodiversity Division DELWP
Grey-headed Flying-fox camps in Victoria, Vic Gov submission to Commonwealth Parliamentary Inquiry, flying-fox management in eastern states	Biodiversity Division DELWP
Fish death event, Darling River, NSW	MDBA, Victorian Fisheries Authority, Water & Catchments Division DELWP
Natural values mapping of critically endangered aquatic fauna affected by wildfires.	Fire Forest and Regions Division (FFR) DELWP
Forest zoning for threatened species and how to interpret prescriptions and guidelines	FFR DELWP
Preliminary analysis to estimate density and abundance of feral cats on French Island	Port Philip & Westernport CMA
Baiting programs, approach for surveys, recent Spotted-tail Quoll record near Kinglake	Parks Victoria
Expert elicitation process, recent and projected population trends for Leadbeater's Possum, Threatened Species Commissioner's review of the federal Threatened Species Strategy	Dept Agriculture, Water & Environment
Setting of sustainable culling rates for eastern grey kangaroos for the Gippsland drought relief ATCW process.	Biodiversity Division DELWP
Further inclusion of threatened fishes in State Freshwater Fisheries Management Plan	Victorian Fisheries Authority
Southern Bent-wing Bat ecology and collision risk with turbines	FFR, DELWP
Threatened alpine lizards for PV Hawkweed control program, Bogong High Plains	Parks Victoria
Design of feral cat management activities	Parks Victoria, Alpine Resorts Commission
Methods & budget for estimating state-wide deer abundance to support deer strategy	Biodiversity Division DELWP
MOU to allow for timber cleared for roads to be utilised as instream fish habitat	VicRoads
Translocation Evaluation Panel processes for fish stocking and translocations	Scientific Advisory Committee
Darling River fish kill response in response to request from Minister for Water	Water & Catchments Division DELWP
Greater Glider management actions	Biodiversity Division and FFR DELWP
Leadbeater's Possum Recovery Plan revisions	Dept Agriculture, Water & the Environment
Scientific input on impacts of inter-valley transfers on the ecology of the Goulburn River	Expert Panel Workshop

Theme of advice	To
Southern Bent-wing Bat IUCN status assessments	Scientific Advisory Committee
Draft affidavit for use in court for wildlife poaching/smuggling case	DELWP
MDBA plan for a new Native Fish Strategy following the Darling River Fish Kill	Water & Catchments Division DELWP
Improving ecological planned burning management in Port Phillip region.	Port Phillip Region, FFR DELWP
Input to DELWP Data Strategy Review	DELWP
Advice to the media on spring snake emergence and human snake encounters	Media
New data collection protocols for the wild dog program	Biodiversity Division DELWP, Dept Economic Development, Jobs, Transport and Resources.
Management of key breeding cave for critically endangered bat	Trust for Nature
Regulating deer numbers in the Alpine National Park	Parks Victoria
Onsite advice, Leadbeaters Possum & Helmeted Honeyeater habitat management in the Yellingbo conservation area	Zoos Victoria

3.4 New conceptual knowledge

Research leads to new ways of thinking and new understanding, and also to new approaches and techniques. Such new knowledge underpins advances in science, including in natural resource management, and provides a foundation for improved conservation and management. Progress is incremental and builds on previous knowledge: "we see a little further, by standing on the shoulders of those who have gone before.". Examples of studies that have led to new conceptual knowledge are listed in Table 6.

Box 5 summarises the relationship between new conceptual knowledge and the enablers of impact.

Table 6. Examples of theme areas in which ARI scientists have led, or contributed to, new conceptual knowledge and advances in environmental management at an international level in the last 5 years.

Theme area and topic	Journal
Evaluating management actions	
Benefits of experimental restoration of woody debris in rivers for fish metapopulations	*Ecological Applications*
Provision of environmental flows promotes spawning of a threatened diadromous fish	*Marine & Freshwater Research*
Using abiotic drivers of fish spawning to inform environmental flow management	*Journal of Applied Ecology*
Priorities for management of chytridiomycosis in Australia: saving frogs from extinction	*Wildlife Research*
Disturbance regimes	
Relative influence of different disturbance regimes for a cryptic grassland reptile	*Landscape Ecology*
Wildfire refugia in forests: severe fire weather and drought mute topography and fuel age	*Global Change Biology*
Introduced deer and their potential role in disease transmission to livestock	*Mammal Review*
Flow magnitude & variability influence growth of fish species in a regulated floodplain river	*Hydrobiologia*
Assessing the distribution and changes of instream woody habitat in SE Australian rivers	*River Research & Applications*
Avifaunal disarray: models of occurrence and ecological effects of a despotic bird species	*Diversity & Distributions*
Century-scale effects of invasive deer and rodents on dynamics of forests	*Ecological Monographs*
Human disturbance in tropical forests can double biodiversity loss from deforestation	*Nature*
Do multiple fires interact to affect vegetation structure in temperate eucalypt forests?	*Ecological Applications*
Analytical techniques and development	
Detecting outliers in species distribution data	*J Biogeography*
On the selection of thresholds for predicting species occurrence with presence only data	*Ecology & Evolution*

Theme area and topic	Journal
A condition metric for Eucalyptus woodland derived from expert evaluations	*Conservation Biology*
Using propensity scores for causal inference in ecology	*Methods Ecology & Evolution*
Using remote sensing and Random Forests for wildfire severity mapping	*Remote Sensing of the Environment*
Quantifying ecosystem 'quality' by modelling multi-attribute expert opinion.	*Ecological Applications*
Estimating population density from presence-absence data using a spatially explicit model	*Journal of Wildlife Management*
Population ecology & dynamics	
Lifetime fitness costs of inbreeding and being inbred	*Current Biology*
Invasive prey does not control invasive predators: European Rabbit and Red Fox, SE Aust	*J Applied Ecology*
Polygenic adaptation associated with climate across the range of a threatened fish species	*Molecular Ecology*
Refugia and connectivity sustain amphibian metapopulations afflicted by disease	*Ecology Letters*
Enumerating a continental-scale threat: how many feral cats are in Australia?	*Biol Conservation*
Technical application	
Extending the effectiveness of electrofishing to estuarine habitats	*Transactions American Fisheries Society*
Detecting rare carnivores using scats: implications for monitoring fox incursion in Tasmania	*Ecology & Evolution*
Control of globally invasive common carp: an 11-year commercial trial of the Williams' cage	*North American Journal Fisheries Management*
The golf ball method for rapid assessment of grassland structure	*Ecological Management & Restoration*

Box 5: New conceptual knowledge – relationship with 'enablers' of impact

Credibility and reputation: Producing new conceptual knowledge and understanding that has wide 'generality' is the goal of science. Thus, research undertaken by ARI, published in the international literature, that gives new insights that scientists and managers in Australia and worldwide can use, adds to the credibility and reputation of the Institute. In selected areas, ARI scientists are among international leaders: for example, in technical methods for species distribution models; in modelling ecosystem condition and quality; in evaluating the benefits of environmental flows for fish populations; in fire severity mapping; and in using metapopulation models for amphibian conservation.

Relevant and applicable knowledge: Many advances in knowledge are directly applicable to improved conservation and management. For example, a new approach, using remote sensing and random forest models to rapidly map fire severity has direct benefits for fire management. Similarly, new approaches for eliciting expert judgements of potential management actions underpins the Strategic Management Prospects tool.

3.5 Communication

ARI has a commitment to targeted communication and engagement activities. This is guided by dedicated staffing and an annual ARI Engagement Action Plan. The aim of these activities is to communicate research outputs and knowledge to partners and stakeholders in natural resource management; to build the profile of ARI within DELWP) and with other agencies, and in the wider community in Victoria and nationally. Communication effort is also dedicated to ensuring and building connectedness within the Institute.

A wide range of communication activities is undertaken, targeted to different audiences and using different communication channels (Table 7). There are many opportunities, limited only by staff time available.

There has been growth in audience and 'reach' of communication messages in recent years. Email newsletters, for example, provide a means of communicating regular updates about ARI research generally, as well as more targeted messages to those with particular interest in aquatic or terrestrial research. The number of email contacts has increased substantially between 2017 and 2019 (Table 10). The audience for ARI email notices (Fig. 7) as at Nov 2019, is broad, with major groups being people in Government agencies, Catchment Management Authorities, Universities and personal subscriptions.

Use of technology, such as webinars for online attendance at seminars, has provided new opportunities previously not possible. As at Nov 2019, 733 registrations and online attendances have been recorded (a single registration may represent one or a group of people), including 458 in 2019. Registrants are able to ask questions online. Feedback (Feb-Nov 2019) from 76 respondents averaged 4.27 (i.e. agree/strongly agree) that the webinar met expectations.

Social media (Yammer within DELWP, Twitter and DELWP Facebook) are actively used to communicate topical stories (e.g. 73 posts on Yammer in 2019). The ARI website has been refreshed and now is managed by ARI staff. Regular updates of new research stories are made, and the site is a key repository for publications such as fact sheets, ARI Technical Reports and other published reports.

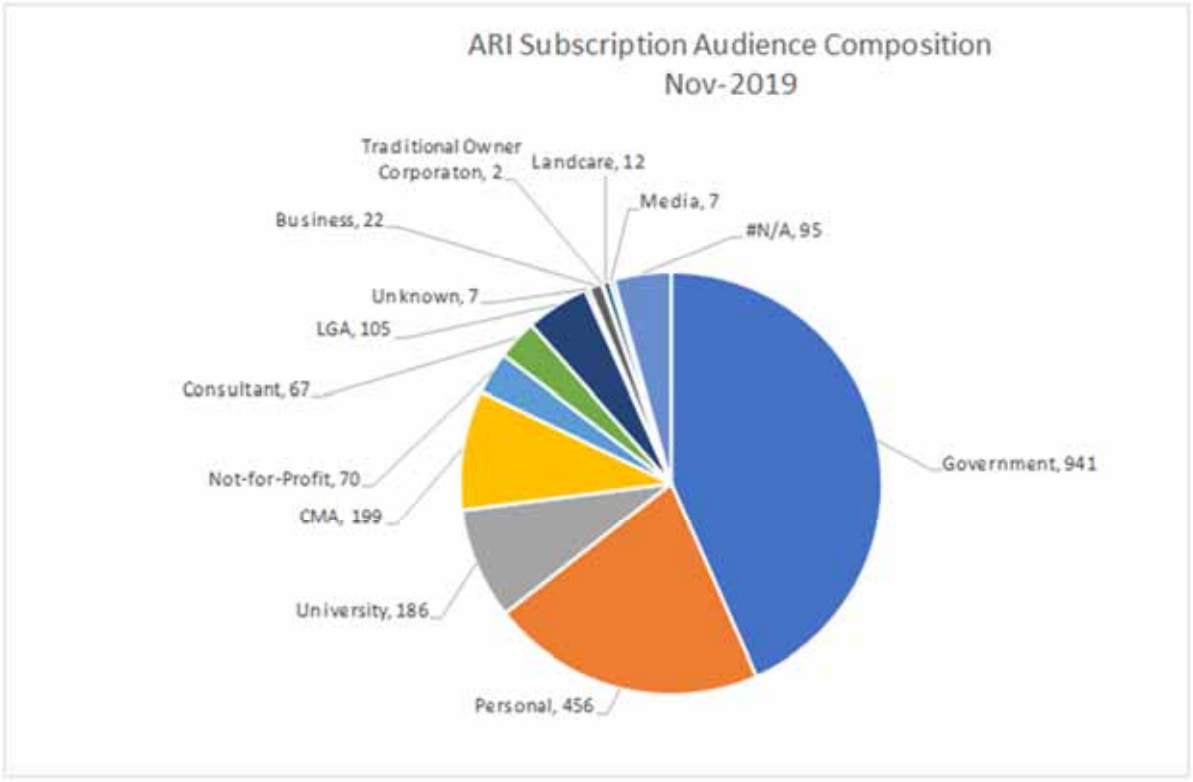


Figure 7. Composition of the subscription audience that receives email notifications from ARI as at Nov 2019.

Table 7. Overview of forms of communication, target audiences, and types of activities to communicate research outcomes (as at Nov 2019)

Form of communication	Target audience(s)	Activity and purpose
ARI Website	DELWP, wider scientific and stakeholder community	Information about ARI staff, projects, recent research findings and events. Access to published reports and fact sheets. Creating awareness and profile for ARI as part of DELWP, to the wider stakeholder community.
Seminar program (webinar)	ARI staff, DELWP staff, wider community	Seminars at ARI throughout the year (with webinar option) to communicate research findings. Includes ARI staff and invited speakers e.g. in 2019 – 14 seminars with 22 presenters; 30-80 people at ARI, up to 85 webinar registrations
Presentations	Clients and stakeholders, agencies, wider scientific community	Presentations by staff to present results from research, to contribute to workshops and symposia, and as part of scientific conferences. More than 100 presentations are made annually.
Email newsletters ARI eNews Aquatic quarterly update Aquatic quarterly 'influence' Terrestrial quarterly update	DELWP, Parks Vic, CMAs and other agencies and stakeholders, Universities, wider community, interested individuals	Email newsletters with updates on projects, items of interest, information about publications, research activities of ARI staff. Aims to ensure regular flow of information to stakeholders and interested people. Circulation lists vary depending on recipients interests (e.g. ARI eNews provides general information; Aquatic quarterly 'influence' has a focus on recent science for managers).
Social media Yammer, Twitter DELWP Facebook	DELWP (especially Yammer), other clients and stakeholders, wider community	Short stories, typically with images, to build awareness and profile of ARI science and scientists, news and events.
Science Week	Primarily within DELWP, but also circulated to wider community	Week-long program of activities, events and news, including special seminars, information sessions, social media and profiles. A key purpose is to enhance profile of ARI within DELWP, among senior managers and staff, through awareness of activities
Other – externally Information to Biodiversity Division and DELWP Exec	DELWP	Information and messages to share news, events and maintain profile of ARI
Other – within ARI Noticeboards Project communications Feedback on trial seminars	ARI staff	Maintaining communication among ARI staff. Guidance in developing specific strategies for project-level communication and engagement. Training and skills development in communication.

Table 8. Summary of the number of contacts receiving email newsletters and seminar information, 2017-19

Communication type	2017	2018	2019
ARI eNews	n/a	995	1395
Aquatic quarterly update	695	985	1190
Aquatic quarterly 'influence'	87	301	512
Terrestrial quarterly update	n/a	148	571
Seminar announcements	n/a	607	1007

Box 6: Communications – relationship with 'enablers' of impact

Engagement and relationships: Communication products are an important means for engagement with clients and stakeholders, and importantly for them to engage with ARI. For some products, the engagement is largely about raising awareness and promoting ARI's profile (e.g. Yammer, DELWP Facebook) while for others there is greater depth of engagement through specific communication of research outputs in meaningful ways (e.g. website, fact sheets, seminars and webinars). Communication *within* ARI, to share news, provide peer support, and promote a common sense of purpose, also contributes to communication as an enabler of impact.

Communication and dissemination: ARI's communication strategy, range of communication channels to target different audiences (Table 7), and breadth of audience (Fig. 7) are evidence that much attention is given to this enabler. Measures of success in terms of output reach can be gauged by growth in the number of people subscribing to email newsletters (a personal choice) (Table 8), and in the uptake of opportunities such as the webinar. It is more difficult to assess the effectiveness of communication activities in achieving ultimate impact.

4 Case studies

Seven case-study projects were investigated and documented (Appendix 1), based on interviews with the ARI lead scientist and a client from the organisation that commissioned the research. Case study projects provide an opportunity to consider the entire 'pathway to impact' for a particular project, to assess the nature of the impact, and to consider the relevance of 'enablers' identified as part of the pathway to impact (Fig. 1).

4.1 Kinds of impacts

Four general types of impact were identified from these research projects, broadly applicable to other research projects undertaken by ARI:

1. *Confidence to continue existing management practices*. Scientific evidence from the research supports a particular management practice or activity, such that managers have confidence to continue, improve and extend, the use of that practice. For example, re-snagging of rivers with woody debris (Appendix 1.6) confirmed this practice has benefits for native fish populations. This practice is increasingly being undertaken in a range of waterways and the research outcomes underpin new initiatives to extend it further (e.g. use of trees felled on roadsides by VicRoads as woody debris for waterways). Similarly, evaluation of a newly installed fishway at Dight's Falls (Appendix 1.3) confirmed that it was meeting its objective of facilitating fish passage past a barrier, but also identified limitations and ways in which it might be improved.
2. *Underpinning of new management programs*. Outcomes from research can set the foundation for a new management approach or program, that is based on the research outputs. For example, introduction of the new Kangaroo Management Program in Victoria fundamentally depends on research that determined, for the first time, a reliable estimate of the size of kangaroo populations in Victoria (Appendix 1.2).
3. *Improved conservation standing*. Where a research project is integrated with management actions, it can directly enhance the ecological outcomes or conservation status of one or more species. For example, the re-stocking and translocations of Macquarie Perch into the Ovens River (Appendix 1.1) have successfully re-established a population of this threatened species, extended its distribution and enhanced its national conservation status.
4. *Improved stakeholder relationships, more effective management*. A broader impact arises when research outputs provide greater confidence for managers and, in turn, facilitate better and stronger relationships between managers and stakeholder groups, resulting in more effective management. For example, demonstration that translocation of Koalas can be undertaken successfully (Appendix 1.4) has enhanced the credibility of this activity, given wildlife managers greater confidence, improved their relationships with stakeholders, and enhanced community perceptions of the overall Koala Management Program.

4.2 Enablers of impact

Interviewees were asked about their perception of factors that contributed to the pathway to impact for specific projects. The varied responses elicited (Appendix 1) align closely with, and affirm, the 'enablers' identified in the ARI model of pathway to impact (Fig. 1).

Engagement and relationships

This 'enabler' was identified as a key element in the pathway to impact in all case studies, variously expressed by phrases such as the value of 'effective engagement', 'strong partnerships … built on past experience, trust and respect', 'relationships and good will', 'close liaison', 'a sense of shared responsibility' and 'strong mutual relationship'. Particular mention was made of the value of a past history of relationships of successfully working together. For some projects (e.g. FAME, Appendix 1.7), engagement with stakeholders was a critical component of the structured decision-making process.

Positive engagement and relationships beyond those immediately involved in the project (i.e. researchers, managers) were also identified. For example, positive relationships with wider stakeholder groups and

community groups were identified in several case studies (e.g. Appendix 1.1, 1.6), recognising the benefit of their support and the associated 'social licence' for carrying out research and management leading to outcomes.

Engagement from the start of a project – to be clear about purpose of the research, to clearly understand the client's requirements, and to agree on objectives – was important. Engagement typically occurred throughout the project, from planning and project design to regular interaction and feedback through the life of the project. Recognition of the complementary roles that different parties may have, such as field research, managing wider engagement, and coordinating local communication in regional settings, was also recognised.

Credibility and reputation

Credibility was important to achieving research impact, primarily related to the credibility of individual researchers and the scientific quality of the project, rather than to ARI as an institute *per se* (though there was recognition of a strength of ARI being the diversity of skills available).

The credibility of researchers was recognised by their track record on other projects, technical capacity to carry out the work, and prior knowledge and experience on which the current project could be based. Personal elements were also important component of credibility, including a long-term relationship of working together and mutual respect, and the effort that researchers made to understand a manager's requirements. There was also recognition of the value of having complementary expertise within a team, and of calling on outside expertise or peer review to ensure high-quality science.

The scientific credibility of the research, including its design and rigour, was also recognised. This included publication in a peer-reviewed journal being a factor that was seen to enhance the credibility of the work (added authority) and contribute to the pathway to impact.

Relevant and applicable knowledge

The relevance and applicability of the research to addressing a real-world issue that managers, planners or policy makers were facing was repeatedly identified as a key contributor to impact. In particular, impact was likely to be realised where there was a specific demand for the research (e.g. community concern about wellbeing of Koalas Appendix 1.4; design of forest surveys Appendix 1.5), it related to a management intervention for which answers were sought (e.g. re-snagging in streams Appendix 1.6; incorporating biodiversity in strategic fire planning Appendix 1.7), or there was a process or program in place where it would be used (e.g. Kangaroo Management Program Appendix 1.2).

Other factors noted that contribute to relevance and applicability included the use of rigorous design to ensure that results would be meaningful, and a prior history or background knowledge that ensured that the current work was well focused.

Communication and dissemination

Communication between researchers and clients/stakeholders was a feature of all case studies, typically involving diverse forms of communication. Notably, it occurred throughout the project, rather than simply at the end; and was a means to ensure that the project was on track and likely to meet required needs.

Communication was seldom specifically identified as a factor contributing to the pathway to impact, but this likely was because communication was the focus of a separate question for each case study (Appendix 2).

5 Synthesis

The aims of this study were to develop an approach for evaluating research impact, and then to use this approach to evaluate the impact of research undertaken by the Arthur Rylah Institute. This has been undertaken through the lens of the 'pathway to impact' and the factors that enhance that pathway. The focus has been on the impact of the Arthur Rylah Institute as a whole, rather than particular programs, projects or individual scientists. It has also been an evaluation of impact for this institution, rather than a benchmarking exercise with other organisations or institutes. Wherever possible, it has been based on objective data.

5.1 Pathway to impact

The concept of pathway to impact is a useful framework for conceptualising how research impact occurs. The model in Fig. 1 highlights three key points. First, there are multiple pathways to impact, reflecting different types of research and knowledge products and different ways in which they will be used. Second, each pathway involves multiple steps that involve organisations and people external to ARI, and involve what has been termed the 'knowledge-action' boundary (Cook et al. 2013). Individual research scientists or ARI as a research institute, seldom have direct influence on the application of research and its subsequent impact; rather, their role is indirect through their influence on others. Third, achieving impact is more likely to occur when explicit attention is given to the factors that help to bridge the knowledge-action boundary, and make the impact pathway operational. Thus, a key element of the pathway to impact is to identify processes that facilitate spanning the boundary between research production and its implementation.

Case studies provided an opportunity to explore the pathway to impact for a range of projects, from a retrospective position of looking back to review outcomes. While each represents a single example (Appendix 1), collectively they affirm the model of the pathway to impact (Fig. 1).

5.2 Enablers of impact

The case study projects affirmed the hypotheses set out in Fig 1. (and Section 2.2) that the selected enablers are critical to effective operation of the pathway to research impact. These enablers are largely consistent with factors identified elsewhere as being critical to spanning the boundary between knowledge and action, including in sustainable international development (Cash *et al.* 2003) and conservation (Cook *et al*. 2013). As outlined by Cash *et al*. (2003) these factors are (with enablers in this report in brackets):

- Credibility – the scientific adequacy of the technical evidence and arguments [*credibility and reputation*]
- Salience – the relevance of the assessment to the needs of decision makers [*relevant and applicable knowledge*]
- Legitimacy – the perception that the production of information has been respectful of stakeholders' divergent values, unbiased in its conduct, and fair in treatment of opposing views [*engagement and relationships*].

The quality of **engagement** and **relationships** between researchers and clients / stakeholders was consistently identified in case studies as a critical enabler of research impact. Effective engagement is complex, multi-faceted and occurs at several levels – for individual projects, for programs and for the Institute as a whole. Feedback from client surveys relating to specific projects (Section 3.1) showed that ARIs understanding of a client's needs was perceived to be high and had increased over the last 5 years. At the level of the Institute, communication activities (Section 3.5) also highlight an increasing engagement with a wide range of stakeholders and clients. Effective engagement and the building of strong relationships must remain a high priority for ARI across all levels.

There was strong evidence for the **credibility and reputation** of ARI's research. Client surveys provided very positive feedback on the 'rigour and robustness' of individual projects (Section 3.1). For the Institute as a whole, publication records over the last 5 years show a high level of collaboration with external scientists and a growing contribution internationally (Section 3.2); together with a range of areas where ARI science is

contributing to new conceptual knowledge (Section 3.4). In addition, diverse data sets, spatial layers and decision-support tools generated by ARI (Section 3.3) are used regularly and widely in natural resource management and underpinned by research of international standing (e.g. species distribution modelling, decision theory).

The production of **relevant and applicable knowledge** was highlighted in case studies as important in research impact – that the research met the needs and answered the questions of stakeholders. Client survey responses to 'the relevance of any recommendations made by ARI', varied between years but predominantly were 'very good' or 'excellent'. For a research institute, the provision of relevant knowledge extends beyond immediate one-to-one client relationships. The demand for, and use of, direct advice and decision support tools generated by ARI is a major part of its pathway to impact. Many of these tools and data layers profoundly underpin daily decisions and actions in natural resource management across the state (e.g. species distribution models, vegetation mapping). Further, ARI is part of the wider scientific community and as such its contribution to new conceptual knowledge, disseminated through publication, contributes to wider scientific relevance.

Communication and dissemination is a key element in making research and knowledge available in appropriate form as part of the pathway to impact. The case studies revealed diverse forms of communication involved in projects. Client surveys found that across a large number of projects, stakeholders predominantly reported that ARI's communication was 'excellent' or 'very good'. ARI has an active and multi-dimensional communication strategy that facilitates knowledge exchange with a diverse and growing audience (Section 3.5), but quantifying the effectiveness of such communication is challenging.

By recognising the importance of these enablers in spanning the knowledge-action boundary and thereby facilitating research impact, they can be pro-actively embedded in individual projects and in the overall activity of the Institute. In this way, evaluating research impact can move from a largely retrospective activity, after completion of a project, to a pro-active part of carrying out current projects and developing new ones. Checking throughout the life of a project on the effectiveness of enabler activities is a positive way to maximise the likelihood of impact.

5.3 Opportunities to enhance future research impact

A) Give further attention to the pathway to impact – for projects, programs and as an Institute

Making an explicit effort to map a pathway to impact forces an individual, program or organisation to think deeply about the steps involved in the application of research outputs, who will use the outputs, how they might be used, and whether they are in a relevant form. It also stimulates recognition that there *is* a gap between knowledge and action, that knowledge does not implicitly lead to action, and that research will have impact only if this boundary is spanned.

A researcher, or research institute, does not have sole responsibility for ensuring the translation of research to action; effective knowledge exchange is a two-way process. However, by giving attention to the pathway to impact, recognising the need for boundary spanning activities and incorporating them as part of the research process, researchers are more likely to achieve research that has an impact (and personal satisfaction).

The selected case studies show that ARI can demonstrate an effective pathway to impact and effective operation of the key enablers along those pathways. However, there is potential for greater engagement with policy, planning and management actions within DELWP with regard to areas of research expertise. ARI scientists have much knowledge and experience to offer. There appears to be a lack of coordinated processes to foster engagement in a regular and systematic way.

B) Incorporate key 'enablers' in projects and programs in a more explicit way

Research projects and programs can pro-actively work towards greater impact by embedding enabler activities in the life of a project. This could be done by responding to a simple checklist.

Engagement and relationships:

- Who are the key players?
- How can they be involved in development and co-design of this project?
- What processes are in place for engagement throughout the project?

Credibility and reputation:

- Are the most appropriate people with high level skills involved in design and delivery?
- How will this project be used to further build credibility?

Relevant and applicable knowledge:

- Is it clear what the client wants from this project?
- Will the study design deliver relevant knowledge in a form the client can use?
- How will this project build wider understanding of this issue?

Communication and dissemination

- What are the most appropriate forms of communication?
- How will communication occur throughout the project?

C) Build expertise and profile as a boundary-spanning organisation

ARI is well placed, as a respected body of scientists embedded within government, to continue taking a leading role in spanning the boundary between knowledge (research) and action in conservation science (Enquist et al. 2017) – both in relation to ARI's own research and in the wider scientific community. Communication is a key element. ARI has a strong commitment to communication, and expertise in connecting with diverse audiences. It could develop further a 'boundary spanning' role in translation of knowledge, and by serving as a mediator able to communicate effectively with different groups. ARI's seminar program, and other means of 'leading by convening' (e.g. collaborative workshops and symposia) could serve this purpose.

D) Enhance strategic collaboration with other researchers and research institutions

ARI has much to offer as a research collaborator: it has scientists with diverse skills, a wealth of data including state-wide data sets, understanding of government policy and directions, and access to decision makers. In turn, ARI benefits from collaboration with other scientists and institutions by access to complementary expertise, research students (including as future employees), and deeper engagement with conceptual thinking. As shown in Fig. 1, collaboration with external collaborators contributes to a pathway to impact for ARI. Collaborations make up a large proportion of ARI's published papers and contribute significantly to its impact and reputation in the wider scientific community.

E) Set the agenda for research

ARI scientists, through their relationships with Government, agencies, collaborators and the community, are well placed to appreciate the pressures and changes likely to determine the future of biodiversity in Victoria and Australia. While ARI currently has a role in setting the research agenda, innovative ways are needed for researchers and policy makers to collectively look to the future, identify emerging issues, and plan for research that will ensure the knowledge base to respond to a changing world.

F) Recruit relevant skills for the future workforce

Research impact depends on having the right people with the right skills to deliver relevant knowledge products. For an Institute with a diverse research role there are several challenges:

- maintaining experts in disciplinary areas, able to offer sound advice based on personal expertise and experience

- recognising new skills to respond to changing directions (e.g. perspectives from social science, growing demands for spatial analysis and modelling, insights from genomics); and,
- being able to attract and retain high quality scientists and offer pathways for career development.

In recent years, ARI has been successful in attracting new, high calibre staff, and there has been a growing recognition that it is a good place to work. A successful future will depend on continuing to be able to do this.

G) Balance local and wider impact

An ongoing challenge for ARI is to achieve wider scientific benefits and impact from projects that may be local in nature and funded by a client for a specific purpose. Pathways for achieving wider benefit could include:

- rigorous design of the project in the context of wider questions and theory; and
- obtaining client approval for wider dissemination of outcomes (e.g. information sheets for wider distribution; conference presentations, publishable papers).

Converting a greater proportion of unpublished client reports into published scientific papers would have large benefits for the self-esteem and reputation of ARI's scientists, and overall scientific productivity.

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Appendix 1 – Case studies of research projects and impact

A1.1 Re-establishment of an endangered riverine fish, the Macquarie Perch, in the Ovens River

Interviewees: Zeb Tonkin (Project Leader, ARI), Glen Johnson (DELWP Hume region)

Context

The Macquarie Perch, a nationally endangered species, historically was abundant in the lower and mid-Ovens River, Victoria. Its status has declined dramatically throughout its range, populations have become fragmented and genetically depauperate, and overall abundance has declined. The species became locally extinct in the Ovens River in the 1970s.

This project to re-establish the species in the Ovens River was based on: a) significant on-ground work undertaken since 2008 to improve the health of the Ovens River, and b) a large body of research over a decade on the ecology of this species (distribution, population demography, habitat use), that provided a foundation of knowledge for management action. Re-establishment was carefully planned and involved translocation of sub-adult fish from a healthy population (Lake Dartmouth), and the release of hatchery-bred juvenile fish (fingerlings). The hatchery production involved breeding from broodstock from a single location (genotype), as well as crossing individuals from different locations (to mix genes).

The project was funded by several sources, including the National Landcare Program; DELWP (Threatened Species Initiative, Biodiversity On-ground Actions Regional Partnerships; and through an ARC Linkage (Monash University) (genetic components). Hatchery breeding and stocking was funded by the Victorian Fisheries Authority. The work was undertaken between 2013/14 and 2018: fingerling stocking is ongoing.

Aims

To assess the effectiveness of the stocking and translocation programs in re-establishing a self-sustaining population in the Oven River, through:

1. monitoring the distribution and abundance of the species at a series of sites in the Ovens River
2. using genetic techniques to assess the survival rates of translocated sub-adult fish, as well as offspring of the hatchery stock (both single and mixed genotypes).
3. using population modelling to estimate future population trajectories and likely success of the program.

Key results

- Monitoring (2016-2018) showed that Macquarie Perch were present at over 70% of sites monitored; that the species has dispersed well beyond the release sites (>22 km upstream including into the Buffalo River); and that there is evidence of natural recruitment of juveniles (i.e. successful breeding).
- Genetic analyses have shown that both translocated and stocked fish have survived, growing at similar rates to fish from existing populations and are contributing to natural recruitment. There is also a higher survival rate of stocked fish of mixed parentage (cf. single genotype). This provides

evidence of ‘genetic rescue’; that is, the value of introducing additional genetic diversity into a population.

- Based on the numbers and age structure of fish released, the population modelling predicted a growing population size, and high likelihood of a self-sustaining population in the river.

Communication

Ongoing communication occurred throughout the project between research scientists, regional DELWP staff and CMA staff. Extensive community engagement, social media and other communication, with community groups (including anglers, water authorities) and schools (e.g. events in association with translocation and stocking releases).

Research outcomes have been communicated in multiple ways including two fact sheets (hard copy and online), client report, community presentations (both by ARI and regional DELWP staff), several presentations at a national conference (ASFB), and submission of a journal paper. Aspects of the research will form part of a PhD thesis (Monash University). Further scientific publications are planned.

Impacts

The project provided evidence of successful re-establishment of a nationally endangered species. This has expanded its distribution, enhanced its conservation, and contributed to the national recovery program for this species.

It has contributed new technical knowledge and understanding of processes involved in population re-establishment, which will benefit future programs to re-establish the Macquarie Perch (e.g. as is being considered in NSW).

It has provided scientific evidence to support restocking programs (of Macquarie Perch and other species more broadly), including knowledge of the relative survival of stocked fish and of the value of genetic management in stocking programs.

Further contributions to scientific knowledge are expected related to:

- survival and fitness of stocked vs translocated fish; and
- impacts of translocation on donor populations (e.g. the relative effects of translocation of larger numbers of juveniles and sub-adults vs adults including breeding females).

The project has enhanced relationships among the local community through communication and engagement, including with key waterway conservation groups and anglers.

It has reinforced to the wider community the value of long-term conservation work on the lower Ovens River including riparian restoration, demonstration ‘reaches’, and the conservation value of the river.

Pathway to impact

Key aspects of the pathway to impact included the following.

A. A sound knowledge base from extensive prior research on this species provided a foundation for action. This included, for example, ecological knowledge relevant to selecting suitable sites for release; and knowledge of the status of the Lake Dartmouth population as a source of sub-adults to translocate.

B. A supportive context for the research arising from long-term, multi-agency and community involvement in restoring the Ovens River and its fish populations. There was a supportive local community (e.g. DELWP, CMAs, Wangaratta Sustainability Network, anglers, schools), fostered throughout the project by targeted communication and engagement activities that created a strong ‘social licence’ for the project. As Glen Johnson noted, “We have really good advocacy and interest in the community.”

C. Prior success with the re-establishment of the endangered Trout Cod *Maccullochella macquariensis* in the Ovens River ~1997-2006), provided confidence of a likelihood of success. Re-establishment of Macquarie Perch was a logical 'next step'.

D. Strong partnerships between ARI researchers and regional staff, built on past experience, trust and respect, and recognition of complementary roles in the project (research, engagement, communication).

E. Collaboration between scientists at ARI and Monash University in undertaking specific research components of the project.

A1.2 Estimating Victoria's kangaroo population

Interviewees: Dave Ramsey (Project Leader, ARI), Liz Colluccio (Biodiversity Division, DELWP)

Context

Victoria has three species of large kangaroos – the Eastern Grey Kangaroo (*Macropus giganteus*), Western Grey Kangaroo (*M. fuliginosus*) and Red Kangaroo (*Osphranter rufus*). Like other wildlife species, they are subject to legal culling in Victoria for damage mitigation purposes under the Authority to Control Wildlife (ATCW) provisions of the *Wildlife Act 1975* (Victoria). In recent years, a trial program was conducted that allowed kangaroo carcasses from authorised control activities to be processed into pet food. Participants in the trial were keen to sell the kangaroo skins into the overseas market, but such export requires approval under the national EPBC Act. To gain approval under the EPBC Act required knowledge of the abundance of these kangaroo species in Victoria and therefore the likely impact on populations. Consequently, a project was initiated to conduct state-wide aerial population surveys of these three species of kangaroo. The focus was on non-forested areas across the state (because aerial surveys are not effective in forested regions).

The pet-food trial program ended in Sept 2019. The Government of Victoria announced that from 1 Oct 2019, Eastern Grey and Western Grey Kangaroos can be harvested on private land for commercial pet food processing, under a Victorian Kangaroo Harvest Management Plan. A key element of the Plan is that the harvest be ecologically sustainable. Consequently, this project was also directly relevant to determining quotas consistent with an ecologically sustainable harvest.

This project was funded by the Biodiversity Division, DELWP. Aerial surveys were undertaken in 2017 and 2018, and population estimates were made for each year.

Aims

1. To develop and implement a rigorous, robust and repeatable method for assessing the distribution and abundance of kangaroos, that takes into account sources of uncertainty.
2. To estimate the distribution and abundance of three species of kangaroos (Eastern Grey, Western Grey, Red Kangaroo) in non-forested regions in Victoria as a whole, and for local government areas in Victoria.

Key results

- A state-wide estimate of the numbers of kangaroos was obtained for Victoria. In 2018, there were an estimated 1,251,000 (95%CI = 889,000 – 1,762,000) Eastern Grey Kangaroos, 130,000 (91,000 – 185,000) Western Grey Kangaroos and 44,000 (25,000 – 77,000) Red Kangaroos.
- Estimates were made for all local Government areas across Victoria.
- The results provided new and updated information on the distribution of these species in Victoria. It revealed, for example, that the overlap zone between the Eastern Grey and Western Grey Kangaroo has shifted further to the north-west.

Communication

A series of reports setting out the approach and methods used, and the outcomes of the population assessment in 2017 and 2018, were produced. These are publicly available on the DELWP website. There was regular engagement and communication between policy personnel and researchers to ensure the project met the required needs.

Impact of the research

It will allow better decisions about kangaroo management in Victoria, at present and into the future. The research provided, for the first time, a clear understanding of the size of kangaroo populations across Victoria. Previously state-wide decisions and planning were made in the absence of such knowledge; quantitative data were available only for local areas (e.g. some parks and reserves).

The research provided essential information to underpin the Victorian Kangaroo Harvest Management Plan and made possible the implementation of this new policy on kangaroo management. Rigorous, quantitative estimates of the abundance of kangaroos in Victoria are essential for setting quotas to ensure the program can meet its requirement for an ecologically sustainable harvest. This meets the requirements of both the Victorian Government and Commonwealth Government.

This work has set the foundation for further research including:

- Ongoing monitoring to align with the Plan and set annual harvest quotas.
- Development of a harvesting model to predict how kangaroo populations are likely to change in relation to harvesting and environmental factors (e.g. rainfall).
- Establishing the basis for a long-term data set on changes in kangaroo populations.

Pathway to impact

Key aspects of the pathway to impact included:

A. a specific need and purpose for the research, such that the outputs were aligned with that purpose and could be used immediately.

B. the credibility of the researchers based on their prior track record of carrying out quantitative analyses relating to population management.

C. effective engagement between policy and research to understand the requirements. This included the researchers being commissioned to develop the design for the surveys (which were undertaken by consultants).

D. a technical capacity to carry out a rigorous and robust assessment of the population provided an outcome that has contributed to clarity in implementing policy (e.g. a robust basis for setting quotas).

A1.3 Evaluating the benefits of a fishway at Dight's Falls, Yarra River

Interviewees: Frank Amtstaetter (Project Leader, ARI), Dan Borg (formerly Melbourne Water)

Context

Fishways are installed where there is a barrier (such as a weir) to fish movement that limits or prevents the free movement of individuals up or down a stream. Barriers are particularly important for species that migrate as part of their life-cycle, such as diadromous species that move between freshwater rivers and the ocean. If juvenile fish are not able to move upstream or can do so only intermittently (e.g. when a high river discharge floods the barrier), then the species may occur in low abundance in upstream habitats or be locally eliminated.

At Dight's Falls on the Yarra River, a low weir limits the capacity of several diadromous species, including Australian Grayling *Protroctes maraena* and Tupong *Pseudaphritis urvillii*, to recolonise upstream habitats. While historically present, they were no longer being detected upstream. The Common Galaxias *Galaxias maculatus*, a common species, was also reduced in abundance upstream, though able to pass the barrier at times of high discharge.

A rock ramp fishway was established at Dight's Falls in the 1990s, and later a vertical slot fishway was constructed in 2012, to assist migration of fish to upstream sections of the Yarra River. To be effective, a fishway must not only allow movement of individuals past the barrier, but the extent and timing of such movements must be sufficient to restore fish populations and communities.

Inter-related project components, funded by Melbourne Water, ran from 2011 to 2017. One component focussed on the function of the fishway, whether it would be effective in facilitating the passage of fish past the barrier. The second focussed on the broader population-level benefits to fish species of movement through the fishway. For the latter, there was one year of pre-treatment surveys prior to the installation of the vertical slot fishway in 2012, then 4 years of post-treatment surveys (with surveys in one year missing).

Aims

1. To examine the effectiveness of the new vertical slot fishway in facilitating passage of fish past the weir
2. To test whether increased passage of individual fish through the fishway would have a population-level benefit upstream
3. To determine whether the fishway would be effective in the re-establishment of rarer species that are no longer present upstream (e.g. Australian Grayling, Tupong).

Key results

- The new fishway was effective in facilitating the passage of fish upstream past the weir wall. However, with high flows when river discharge was above 800-1000 ML per day, passage decreased due to turbulence at the fishway entrance and the fish not being able to find the entrance. Further work will be undertaken on design.
- Abundance of the Common Galaxias increased upstream of the fishway, there was a higher proportion of juveniles, and greater range of size classes (i.e. effective passage). This effect of increased abundance extended many kms upstream (up to 90 kms), and also in tributaries of the Yarra River.
- Species richness of native fish was greater upstream after the fishway. Tupong were captured upstream and anecdotal evidence is of increased numbers (but sample sizes not sufficient for statistical analysis). Australian Grayling were also captured upstream, where they had not been recorded in many previous surveys.

Communication

There was regular contact throughout the project between researchers and Melbourne Water, particularly in development and design of project components (frequently meeting on-site). Melbourne Water had a need for an applied outcome, fit for purpose; and ARI researchers were willing to work to achieve that goal.

Annual client reports were provided, results were presented to Melbourne Water as part of regular seminars, and at a larger meeting to review ideas for modifying the fishway. A manuscript has been prepared for publication in an international journal, and the results presented at an international Fishways Conference in 2018.

Impact of the research

The research demonstrated the efficacy of the new fishway, that it allows passage of individuals, and which species can move through. It provides Melbourne Water with evidence of the outcomes of their substantial investment in waterway infrastructure and allows confidence in their management.

It has also highlighted issues, and gave insight into where further design and modification of the fishway is needed (e.g. during high discharge), to enhance its operational effectiveness.

It has demonstrated not only the passage of individual fish, but population-level benefits arising from the increased movements of fish. That is, the fishway has demonstrable benefits for the size and structure of the Common Galaxias population for many kms upstream. It apparently also allowed re-establishment of two rare species to their former distribution, although sampling intensity was not sufficient for statistical analysis. These are important scientific findings on the effectiveness of restoring aquatic connectivity.

Pathway to impact

Key aspects of the pathway to impact included:

A. a close relationship and engagement between researchers and Melbourne Water, working together from the start in planning and project design. The relationship and regular communication meant there was confidence on both sides in the research.

B. agreement on the objectives, particularly recognition by both parties that this project needed to focus on applied outcomes to improve fish passage. Melbourne Water appreciated the need to evaluate the population-level effects of the fishway as a measure of its effectiveness. This mutual agreement and understanding led to greater appreciation and recognition of the outcomes.

C. recognition by both parties of the value of a rigorously designed project, including researchers carrying out statistical power analysis to determine the level of sampling required to demonstrate effects.

D. A longer-term relationship between researchers and Melbourne Water staff, such that the history of working together had generated mutual respect. This has led to further project partnerships.

A1.4 Koala management: evaluating the translocation of Koalas from an overabundant population in the Otway Ranges

Interviews: Peter Menkhorst (Project Leader, ARI), Vural Yazgin (DELWP state-wide)

Context

Koala populations that occur at high density impose severe browsing pressure and can defoliate preferred browse trees. In extreme situations this can result in death of trees and starvation of Koalas. Cape Otway, south-western Victoria, is one such location where a high-density population of Koalas led to extensive defoliation of Manna Gum *Eucalyptus viminalis* and mass starvation of Koalas in 2013. In response to this Koala management problem and substantial community concern, a Cape Otway Expert Panel was established to provide advice and recommendations. One recommendation from the Panel was that an experimental translocation be carried out to monitor and evaluate the impact on translocated Koalas, as a basis for understanding the likely impacts of larger-scale translocation programs.

Translocation of Koalas has been undertaken as part of Koala management in Victoria for more than 90 years, and more than 40,000 Koalas have been translocated to over 250 sites. However, there has been limited scientific investigation of the fate of translocated individuals, and a lack of a rigorous method for selecting suitable release sites.

This project was initiated by the Barwon SW Region (DELWP), who initially sought advice from ARI on suitable locations to which Koalas could be translocated. Scientists at ARI had developed a Koala Habitat Index, a spatial model of suitable habitat based on species distribution models for the Koala and four *Eucalyptus* species preferred as forage (*E. viminalis*, *E. globulus*, *E. camaldulensis* and *E. ovata*). Koalas for experimental translocation (and as 'controls') were selected in Sept 2015 from those captured at Cape Otway as part of a larger management program.

Aims

1. to assess the short to medium-term survival, body condition and movement of Koalas translocated from an over-browsed habitat and released into unoccupied habitat, compared with that of Koalas that remained at the original location.
2. to use the Koala Habitat Index as a means of selecting a suitable translocation site.

Key results

- Sixty koalas were involved: 36 were translocated to a location in the Greater Otway National Park (selected on habitat suitability), and 24 were processed in the same way (health checks, radio collar fitted) and returned (as controls) to the Cape Otway site. Individuals (that could be located) were monitored between 26-41 days after translocation and again at 128-146 days.
- Survival rates over 9 months post-translocation were similar for translocated and control animals.
- Translocated koalas fared better than those left *in situ.* After 137 days, control animals had a lower scaled body mass; whereas translocated animals, after an initial reduction, had mostly regained or increased their scaled body mass.
- Translocated koalas moved farther from release than controls. For both groups, males had higher rates of movement than females, and translocated koalas had slightly higher rates than did controls.

- The koala-habitat index predicted suitable habitat, as evidenced by survival of translocated animals.

Communication

Communication occurred throughout the project between researchers and regional DELWP staff, also facilitated by a staff member committed to Koala management in the region.

Presentations have been made to Koala management forums involving DELWP and PV staff, including to the Expert Panel.

A scientific paper was published in *Wildlife Research* in 2019.

Research impact

The research outcomes have assisted Koala management by providing scientific evidence that translocation is not detrimental to the health and survival of Koalas. Indeed, translocated Koalas may be in better condition than if remaining in a high-density population.

The results give confidence to managers to consider translocations as a management response in other situations. Further translocations have occurred (e.g. French Island to Tallarook). Future use of translocations in Koala management will depend on factors such as the availability of suitable sites, in the context of a changing climate.

It has enhanced relationships between DELWP wildlife managers and the wider community and given credibility to the DELWP program (especially with increasing concern about animal welfare). Trust and positive relationships are an essential part of wildlife management.

The research findings will be relevant to Koala management in other states (NSW, Qld). Demonstrated outcomes will also help deflect criticism of aspects of Koala management in Victoria from interstate, where there are different views about management.

It has supported the value of the Koala Habitat Index as a tool for selecting suitable locations for future translocations. This also is essential for public perceptions of the overall management program.

Pathway to impact

Key aspects of the pathway to impact included:

A. Positive relationships between ARI and regional staff and goodwill to cooperate with the research project were a strength. ARI scientists were there, amongst the management activities, as animals were being collected, assessed by veterinarians and allocated to actions. Regional staff collaborated with scientific requirements for selecting animals for translocation or to be released at the site as controls. The research effectively piggybacked on the management program.

B. The high profile of the Koala and political and public interest meant there was an imperative to respond to the situation at Cape Otway. A scientific component to evaluate the outcome of the translocations was recognised as important.

C. Background knowledge and experience from prior work on Koalas in SW Victoria by ARI staff was available. Peter Menkhorst had prepared a history of Koala management in SW Victoria and identified research needs. This background helped inform the design of the management work.

D. Carrying out the research as a scientific trial enhanced the credibility of the research. Publication in a peer-reviewed journal (Wildlife Research) gives further credibility and authority to the work and its outcomes.

A1.5 Design of pre-harvest and landscape surveys for fauna in forests

Interviewees: Lindy Lumsden (Project Leader, ARI), Jamie Molloy (FFR, DELWP)

Context

Timber harvesting operations can detrimentally affect habitats of some forest-dependent species, including threatened species. The Code of Practice for Timber Production 2014 aims for sound environmental performance when conducting commercial timber harvesting operations. Under the Code, VicForests is required to undertake actions to protect species 'where evidence of a value is found in the field'. In March 2018, the Victorian government announced a new initiative, 'Delivering greater community value from our forests', which included an extensive program of pre-harvest and landscape scale surveys to detect forest-dependent species likely to be affected by timber harvesting, especially threatened species. Surveys are to be restricted to forests on public land, east of the Hume Highway, and will take place over a four-year period.

To carry out these surveys effectively and to ensure they deliver appropriate knowledge it was necessary to first develop a rigorous survey design and consider how the surveys would be implemented. This project was commissioned by Forests, Fire and Regions, DELWP, for this purpose. It was undertaken in 2018.

Aims

1. To develop a systematic basis for survey design that addresses *which* species to survey, *where* to survey (i.e. which coupes), *when* to survey (seasonal timing), *how* to survey species (methods), and how the *data* will be managed and used.
2. To document these recommendations in a form that will guide those making decisions about the implementation of the survey program.

Key results

The task of carrying out the proposed surveys is potentially huge, with dozens of species involved and hundreds of logging coupes. This project developed a risk-based framework (including flow charts) for implementing a survey program for threatened species and ecosystems most likely to be affected by timber harvesting. It set out a logical framework to guide decisions about which species require survey effort, on which coupes these surveys should be undertaken, the timing of surveys, the methods to be used, and how the data will be managed and used.

Specific guidance was provided for all relevant species in relation to the timing of surveys and survey methods to use.

Options were provided on how the survey work could be done with different levels of risk tolerance, and therefore survey effort.

Communication

A comprehensive client report (unpublished) was completed. This was complemented by regular interaction between ARI and FFR staff throughout the project, meetings, and discussions to test ideas and approaches. An Excel spreadsheet listing species, together with detail about their timber harvesting prescriptions and relevant information from the Code of Forest Practice was provided.

Impacts of research

The outputs from this project have underpinned the implementation of the forest survey program (commenced July 2018), a large multi-year program with $4 million expenditure per year. The approach and recommendations have been implemented largely as proposed.

Key users of the research output include:

- DELWP Forest, Fire and Regions - Monitoring Evaluation and Reporting Unit, responsible for implementing the survey program,
- DELWP Biodiversity Division, responsible for implementing Biodiversity 2037, which advocates a landscape-scale approach to managing threatened species,
- Technical specialists engaged to further develop program design (e.g. developing survey standards),
- Stakeholders who needed to be informed of the proposed survey program design.

Pathway to impact

Factors that have contributed to impact include:

A. Close liaison of ARI and FFR staff throughout the project, involving co-design of what was required for the surveys. This close working relationship meant the work was targeted to the user's needs, it was accepted, and when the survey program began the Program Leader was familiar with the recommendations.

B. A direct purpose for the work (the planned forest survey program) which meant that project outputs were used immediately (even before the report was completed!).

C. The rigour and scientific approach to the survey design gave credibility to the recommendations. The work also was reviewed externally by respected scientists.

A1.6 Restoration of structural habitat for fish in a lowland river

Interviewees: Jarod Lyon (ARI), Stuart Little (Native Fish Recovery Strategy, MDBA)

Context

Extensive de-snagging of rivers (removal of large woody debris) has occurred historically to improve passage for people along river systems. However, such woody debris provides important structural habitat for fish (e.g. refuge, shelter, breeding sites) and its loss is thought to affect the distribution and abundance of populations. Re-snagging, the deliberate addition of large woody debris in rivers, is being conducted as a restoration measure for fish populations in a variety of locations but its benefits are not clear. Does an increase in fish abundance after re-snagging represent a genuine increase in the population, or does it simply result from a re-distribution of fish to areas where snags are now present (i.e. a 'honeypot' effect).

This project was undertaken as a large-scale, long-term test of the benefits of re-snagging in a lowland river system, as part of the 'Living Murray' program (a partnership between the MDBA, Australian Government and Basin state governments, managed by MDBA). An 'intervention reach' in the Murray River, ~125 km from Lake Hume downstream to Lake Mulwala, had 4,450 large (mostly >1 tonne) pieces of woody debris restored within four 5000 m priority zones between 2007 and 2010. Monitoring of fish populations was undertaken from 2006 to 2013. Monitoring was also undertaken of three 'control' populations (no re-snagging) in two reaches further downstream in the Murray, and in the Ovens River. The focal species of fish were the Murray Cod *Maccullochella peeli* and Golden Perch *Macquaria ambigua*.

Aims

To test the hypothesis that restoring woody debris at a reach scale (>100 km) results in a net increase in population size for two target species of fish, rather than merely re-distributing fishes already present.

Key results

A Bayesian hierarchical model was used to estimate changes in population parameters, including immigration, emigration and mortality rates:

- For Murray Cod, there was a threefold increase in abundance of the population in the intervention reach, while populations declined or fluctuated in the control reaches.
- For Golden Perch, population densities increased twofold in the intervention reach, but also increased substantially in one of the control reaches.
- Restoring habitat heterogeneity by adding coarse woody debris can increase the abundance of fish at a population scale in a large lowland river.
- Successful restoration for target species relies on connectivity with high quality source habitats.

Communication

Communication and engagement occurred throughout the project, taking a number of forms. A Project Management Committee formed a liaison between scientists and the Murray Darling Basin Authority, with meetings and formal reporting each year, as well as informal communication between ARI scientists and MDBA managers. Communication occurred around study design, including an expert panel and several workshops. Annual progress reports to the MDBA facilitated internal communication on the benefits of the

project, and helped with ensuring ongoing funding support for this longer-term project. There also was close liaison by the project team with local agencies, including Catchment Management Authorities and NSW Fisheries, who became supporters of the project.

Researchers worked closely with anglers, including a program that involved anglers collecting fish otoliths (data used in predictive models), log-book data, fishing weekends, and collecting data on changes in catch per unit effort.

Other communication has included numerous presentations to groups, papers at scientific conferences, fact sheets, and a scientific publication (in *Ecological Applications*) on the overall project outcomes.

Impact of the research

The research provided empirical evidence that re-snagging as a restoration and management practice is valuable for fish species, given the availability of source populations. Importantly, the outcomes of this restoration practice were demonstrated at the population level. That is, the benefits of re-snagging go beyond that of individual fish using the snag habitat; rather, that re-snagging has benefits for the population as a whole. Assessment of outcomes at the population level also stimulates greater awareness by managers of directing management towards population-level processes, such as breeding, recruitment and survival.

Having scientific evidence that this restoration practice is effective gives credibility and confidence to management agencies to implement such management actions more widely. Demonstration of the effectiveness of restoration also assists managers personally, by giving confidence and capacity to do their job better.

Re-snagging is now being carried out more widely, with confidence, by CMAs, DELWP and local government. It contributes to targets for restoration in the Murray Darling Basin Plan. VicRoads, for example, has recently made an agreement to use trees felled on roadsides during roadworks as a source of woody debris to be placed in streams.

Other components of the research program also had benefits, including an improved understanding of electrofishing efficiency and the likely proportion of a local population actually sampled. Such knowledge has benefits for interpreting other MDBA projects and surveys. The project has also contributed to a long-term data set on fish populations in the Murray River, such long-term data sets being scarce, but critical for understanding the dynamics of fish populations.

Strong relationships and communication between researchers and the MDBA have had wider mutual benefits, and have facilitated development of new project opportunities and research directions of benefit to both parties and management of the Basin as a whole.

Pathway to impact

A. The issue was of direct relevance and importance to waterway managers and anglers. It related to a specific management intervention for which managers were seeking information and answers.
B. Careful project design and a research team with appropriate expertise meant that the quality of the data collection and analyses was high.
C. There was a strong, mutual relationship with managers (from several organisations), who were closely engaged with the project. They came into the field, helped collect data, and understood what the project was about. Consequently they were able to advocate for the project within the organisation, and adopt recommendations arising from research outputs. They were part of the answer.
D. The relevance of the knowledge generated by the project assists managers to carry out their role, and provides greater certainty to move forward.
E. There was strong community support (social acceptance) for the project, from anglers and those with a commitment to conservation of native fish. The aim of the project was of interest and relevant to their activities and concerns.

A1.7 Fire analysis module for ecological values (FAME)

Interviewees: Josephine MacHunter (Project Leader, ARI), Simon Watson (Forest Fire and Regions, DELWP)

Context

Victoria is one of the most fire-prone regions in the world, and in recent decades has experienced a number of major bushfires that have had catastrophic consequences for human life and property. Bushfires also have major implications for environmental values. Fire management is a challenging issue, requiring making decisions in relation to multiple, often-competing, values and objectives. The Code of Practice for Bushfire Management on Public Land 2012 and Victoria's Safer Together policy document set out the State's approach to managing bushfire risk. The primary objectives of bushfire management on public land in Victoria are: 1) to minimise risk to human life and property, and 2) to maintain or improve ecosystem resilience. The integration of science into bushfire management policy and decision making, and the adoption of a strategic, risk-based approach to planning are critical to achieving these objectives.

Victoria has made substantial progress in developing a risk-based process and tools for assessing the likely consequences of bushfire on human life and property; but a consistent and transparent approach to account for biodiversity values in fire management has been lacking. The purpose of this project was to develop a risk assessment tool that would integrate existing knowledge and ecological models of the fire responses of biota into a framework to assist in decision making for fire planning and management at a regional scale.

The project was undertaken from July 2017 to June 2019, funded by DELWP Forests, Fire and Regions through the CRC Bushfire and Natural Hazards.

Aims

1. To develop a decision framework that describes the development and application of ecological models (including ecosystem resilience and threatened species) to inform planning for strategic bushfire management.
2. To develop an ecological module that integrates existing ecological data and models into a single platform. This will enable a more user-friendly approach to undertaking ecological risk assessments to support decision-making.

Key results

The research team used a structured decision-making process and extensive consultation with stakeholders (policy leads, fire risk assessment teams, fire ecologists) as key elements in the project. Key results included:

- Developing a decision framework to support the integration of ecological values in fire management, including an agreed set of performance measures, but allowing flexibility between regions.
- Producing a decision-support tool that consolidates fire history, potential future fire patterns, biodiversity data and ecological responses to fire into single web-based user interface that undertakes complex analyses.
- Providing outputs that can be used to estimate the consequence of different fire management strategies on ecological values based on different performance measures (e.g. evaluate 'what if' scenarios). The tool was designed to be user friendly, to assist regional fire planners to undertake ecological risk assessments to support Strategic Bushfire Management Planning.

Communication

There was extensive communication throughout the project. In particular, there was a series of five workshops including DELWP policy and practitioners, Parks Victoria staff and regional risk and evaluation

teams as part of the structured decision-making process. This ensured a strong participatory process throughout. Meetings were also held with the DELWP policy lead and the Monitoring Evaluation and Reporting Unit in FFR.

Presentations were also made to the Hume Fire Ecology Forum, the Metro region Bushfire Strategy Advisory Group, and the Forest and Fire Risk Assessment Working Group. A training session with the FAME tool was held for end users. Several fact sheets were prepared and a final written report. Two conference posters were prepared.

Impact of the research

The project has assisted fire managers to carry out their work more effectively, and to be able to more clearly integrate ecological values into fire planning. It has provided a repeatable, transparent and defendable method for incorporating ecological values into decision making, while providing flexibility for different regional contexts and priorities.

The structured decision-making process and extensive consultation with end-users gave fire managers a voice in the development of the tool, and in doing so has enhanced their acceptance and uptake of the approach.

FAME has been widely adopted and implemented as a planning tool for strategic bushfire management planning (done every 2-5 years) in most regions in Victoria. The decision framework and choice of performance measures are being used in all regions.

Ecological values are now explicitly on the table in the planning phase and in making fire-management decisions, whereas previously they had a much lower (or no) profile.

FFR policy personnel noted that this is the most significant step forward for incorporating ecological values into fire management planning that has occurred in Victoria in the last 30 years. FAME was nominated for, and won, the Decision Analysis Practice Award – an international award – in the USA in 2019.

Pathway to impact

A. Extensive engagement with end users was a critical component in the success of the project. Structured decision making provided a means for engagement, it helped in identifying and understanding issues and problems from the end-users perspective, and in managing expectations.

B. The complementary skills and expertise in the project team (e.g. managing data sets, decision analysis, fire ecology, ecological modelling) ensured that there was strong capability to undertake the project to a high standard.

C. Long-standing research collaborations with other scientists meant it was possible to call on other expertise as needed. It also facilitated broader buy-in by researchers.

D. A strong relationship with the FFR policy lead (Simon Watson) was important. As a scientist, he could see the potential of the project, acted as a ‘champion’ within DELWP, and had the authority to advocate for the use of the approach.

E. Having a planning process (Strategic Bushfire Management Planning) in place was beneficial, where the outputs of the research (decision framework, performance measures, FAME tool) could be immediately applied.

Appendix 2. Interview questions for case studies

With the Project Leader from ARI

1. Project Title
2. Duration (which years)
3. Funding source (who commissioned the project)
4. Context — Background to the project, why was it commissioned, what was the underlying issue or purpose from a) the perspective of the commissioning agency; b) science perspective
5. Aims — What were the aims of the project
6. Key results — What were the main results (in a 'practical sense' and in 'new scientific knowledge')
7. How have the results/outputs been communicated (e.g. reports, fact sheets, talks, journal papers etc)
8. How has the research been used?

   Who has used the outputs?

   What has changed? (actions, policy, approaches, standards etc?)

   What were the most useful aspects (new knowledge/advice) arising from the project?

   Are there likely to be further impacts in the future from this work?
9. What contributed to (or limited) the use of this research by the stakeholders? What were the most important aspects of the 'pathway' to use and implementation?

With a stakeholder (who commissioned the project, or is an end-user)

(Questions provided to the interviewee beforehand)

Thanks for agreeing to an interview. The Arthur Rylah Institute is undertaking a review of its research, particularly relating to the impact of its research and engagement. As part of that review, a set of 8 case study projects have been selected as illustrative of the range of projects that ARI undertakes. We're keen to understand how the research undertaken in these projects has been used, the extent to which it may have contributed to change, and what factors might contribute (or limit) the uptake and application of the research.

1. From your perspective, what was the background to this project and the reason you wanted it to be done?
2. In what ways and at what stages were you involved in the life of this project?
3. What were the most important results from this project for your organisation?
4. How did you learn about these results and findings?
5. In what ways have the results been used by you or your agency?

   What has changed as a result of this work? Can you give examples?

   Is there likely to be further change, or other impacts in the future (e.g. 1-3 years, 3-10 years)?

   Are there other people or groups who have also used this research, or to whom it is relevant?
6. Can you identify what contributed most to this research being used by you and your organisation?
7. Do you have any recommendations for how a similar project in the future might have maximum benefits and impact?
8. Do you envisage any 'next steps' to build on from this project? Has it opened up new possibilities?

Thank you for your assistance.

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