Assessment of Engagement and Impact for the ARC Centre of Excellence for Environmental Decisions

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2018

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Editor: Casey Fung, University of Queensland

Publisher

ARC Centre of Excellence for Environmental Decisions

University of Queensland, Saint Lucia 4067 Queensland, Australia

www.ceed.edu.au

An appropriate citation for this document is:

Thamo, T., Harold, T., Polyakov, M. and Pannell D.J. (2018) Assessment of Engagement and Impact for the ARC Centre of Excellence for Environmental Decisions. ARC Centre of Excellence for Environmental Decisions, Brisbane, Australia.

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Executive summary

The ARC Centre of Excellence for Environmental Decisions was established to provide international leadership in tackling complex problems of environmental management and monitoring in an uncertain world: Its mission was to be a world-leading research organisation and influence environmental policy and management to deliver greater environmental outcomes through decision science.

This report provides the results of an assessment of the engagement and impacts of CEED. The assessment includes impacts on policy, management and the community, as well as measures of academic performance, including publications, citations and collaborations. Data were collected in several ways: a survey of all project leaders for the Centre's 87 projects, the preparation of detailed case studies for selected projects, and collection of statistics on publications, citations and collaborations.

Engagement with end users and stakeholders was strong in Australia and around the world. Researchers reported many examples of engagement with research users involved in policy and management. Results were highly heterogeneous and somewhat skewed, with the majority of observed impact occurring in a minority of the projects. For almost half of the projects, the potential future increase in impact was assessed as being moderate or high. To some extent, this reflects the time lags involved in research attempting to influence policy and management, but the information has also been used to identify projects for which additional engagement effort could be beneficial. The correlation between impact and academic performance was positive but low.

To obtain richer detail about impacts, detailed case studies were prepared for nine research projects. The projects were selected to be diverse, rather than representative. These case studies highlight the unique circumstances faced by each project in endeavouring to have an impact. Each project must be framed within a strong understanding its domain and be deeply engaged with research users if impact is to occur. Substantial benefits for policy or management are apparent in a number of the case studies.

A contributing factor to the impact of CEED is the research communication magazine *Decision Point*. This publication is widely accepted as a valued communication resource for academic findings in the field of environmental decision sciences, and is

rated by people in government and academic institutions as relevant and informative.

Some valuable lessons and implications of the impact analysis are identified in this report. Research impact does not depend only on good relationships, engagement and communication, but also importantly on what research is done. Therefore, embedding a research culture that values impact and considers how it may be achieved before the selection of research projects is potentially important. The role of the Centre leadership team in this is critical. Embedding impact into the culture of a centre likely occurs more effectively if expertise in evaluation is available internally, either through training or appointments.

A challenge in conducting this analysis was obtaining information related to engagement and impact. We recommend there may be merit in institutionalising the collection of impact-related data from early in the life of a new research centre.

In this analysis, there was little relationship between impact from translation and engagement and measures of academic merit. It should not be presumed that the most impactful projects will be those of greatest academic performance.

At the time of this assessment, CEED had generated 848 publications which had been cited 14,996 times according to the Web of Science. CEED publications are disproportionately among the most cited papers in their disciplines. More than a quarter of CEED publications are in the top 10% of the literature, based on their citations. For 39 CEED publications (one in 22), their citations place them in the top 1% of their academic fields in the past 10 years.

There are often long lags between the start of research and delivering the impact — decades in many cases. Therefore, there is a need to allow the longest possible time lag when assessing impact. On shorter timescales, it may be possible to detect engagement, but not the full impact that will eventually result.

Introduction

> *"CEED's legacy is far more than our world-class research. The impact of basic research on policy is often hard to track, especially since laws and policies implemented by government rarely cite the evidence or influences that underpin their development." Hugh Possingham, former director of CEED*

Environmental research may generate benefits in a variety of ways including by providing: information or technology that allows improved management of an environmental issue; information that fosters improved decision-making about priorities for environmental management or policy; or information about an environmental issue that is of intrinsic interest to the community. The benefits generate an increasing acknowledgement of the need to measure the impacts of research (Pannell et al. 2018). The reasons include making a case for the funding of environmental research, informing decisions about research priorities and helping researchers make decisions about their research that increase its ultimate benefits.

While there have been studies considering the relationship between research and policy (Pannell & Roberts 2009), quantitative analyses of the impact of research on environmental management, environmental policy and environmental outcomes are relatively rare (Boaz et al. 2009).

CEED background and aims

The Centre of Excellence for Environmental Decisions (CEED) started in 2011 with funding from the Australian Research Council (ARC). CEED is a partnership of five Collaborating Organisations (University of Queensland, University of Melbourne, Australian National University, RMIT University and University of Western Australia) and five Partner Organisations (CSIRO, Trinity College Dublin, Imperial College London, Hebrew University of Jerusalem Israel and the United States Geological Survey). The CEED headquarters is based at and administered by the University of Queensland and is led by director Professor Kerrie Wilson. It was previously led by Professor Hugh Possingham, until 2016, with deputy director Professor Michael McCarthy based at the University of Melbourne. CEED is a highly collaborative and interdisciplinary team of more than 100 researchers made up of chief investigators,

partner investigators, postdoctoral fellows, senior researchers, professional support staff and postgraduate research students.

CEED was funded to the value of $11,900,000 over a seven-year period from 2011 to 2017, with the aims of pushing the frontiers of environmental decision science and solving environmental management problems for the benefit of environmental policy, management and science across Australia and around the world. Research in the Centre was broken into the following themed areas: Environmental Policy & Management Evaluation; Optimal Monitoring; Socio/Ecological Analysis and Modelling; Ecological Theory and Processes; and Quantitative Tools and Approaches.

Aims and scope of this assessment

The aims of the assessment were to: capture the impacts of CEED research and related activities on environmental policy and management; quantify measures of academic performance and networks from the research; and identify lessons for research agencies and future centres.

The scope included all research and related activities conducted by CEED chief investigators, partner investigators, postdoctoral fellows, senior researchers, professional support staff and postgraduate research students from 2011 to 2017. The wide scope and large volume of CEED research make evaluating its impacts a considerable task.

The approaches taken in this analysis were guided by a workshop involving chief investigators, the Centre Advisory Board, an independent expert with extensive relevant experience and the team conducting the analysis. At this workshop, preliminary findings were presented and discussed, and the ideas on further areas that could be included in the analysis were put forward. The independent expert was able to provide objective feedback on the methodology and integrity of the data.

Structure of the report

The following section discusses challenges in measuring the benefits of environmental research and outlines a conceptual framework for doing so. After that, we outline the methods used to collect and assess the data used in this analysis.

Then we present results of the analysis, in four sections. First, we present information about the impacts of 87 projects conducted within CEED. Second, we present more detailed information about nine case studies selected from the larger set of 87 projects. The nine case studies vary widely in the types of environmental issues addressed, the type of research and the scale of impact. Evidence presented includes statements by end users of the research. Third, we present an assessment of publications, citations and collaborations within the Centre. Fourth, we discuss the role played by *Decision Point* (the Centre's main outreach publication) in building a culture of engagement by environmental researchers, and a culture of using evidence and analysis among environmental managers and policymakers. Finally, we discuss the lessons and implications arising from the analysis.

Measuring the benefits of environmental research

Pannell et al. (2018) describe the economic theory for conceptualising the benefits from environmental research, particularly focusing on environmental research that is intended to benefit society through informing policy decisions. They identify several challenges that exist in quantifying these benefits.

A key challenge is the "attribution" problem: the difficulty of determining the contribution of particular research investments to an environmental outcome. Part of the difficulty arises because we have to estimate benefits from research as the difference between two scenarios: outcomes that occur with the research vs outcomes without the research (the "counterfactual" — Ferraro 2009; McConnachie et al. 2016). Even if the research has already been undertaken and the results are known and in use, the counterfactual is not observable. We have to estimate what would have been different if the research had not been undertaken. The challenge includes predicting what the research will yield, regarding knowledge about the world, as well as how that new knowledge might be used in management or policy and what the consequences of that use might be, allowing for the behavioural responses of diverse individuals.

Defining these scenarios (with research and without research) is made more difficult because research time lags are long and uncertain and many changes occur in tandem. Typically, applied research takes years, perhaps decades, before it yields useful results that can be adopted. The adoption process itself then takes time as managers learn about

the innovation and how to make it work best in their specific contexts. The effects of that adoption may persist for many years. For example, Alston et al. (2010) found that aggregate US public agricultural research and extension had little effect on farm productivity within the first 10 years and reached its maximum impact with a lag of 24 years, with residual impacts detectable beyond 40 years. Notably, these long time lags are predominantly for research that generates private benefits for the adopters. For environmental research, the lags may be even longer because the intended research users may lack the incentive to adopt or face political barriers to adoption.

To rigorously quantify the net benefits of environmental research, it is necessary to make estimates of various parameters (see Alston et al. 1995): the costs attributable to the particular research investment (and to the associated adoption process if additional resources are required for that); the time path and extent of adoption and use of the research results; the magnitudes of the impacts on outcomes of interest (e.g. environmental conditions, costs) with adoption of the research results compared with a well-defined counterfactual without-research scenario; the values associated with the changed environmental conditions attributable to the research and the benefits or costs of any side effects of the changes resulting from the research investment. Realistic assessments of research benefits need to weigh up all of these factors, rather than focusing on one or a few factors. A research project focusing on an area of policy that is judged negatively on one factor (e.g. political feasibility) might still be judged to be a priority if the other factors are sufficiently positive.

In the case of policy-oriented environmental research, these challenges are exacerbated for at least two reasons. First, the benefits typically cannot be observed in market transactions. Second, the "adopter" of the research results is a policymaker or policy administrator rather than a commercial firm, so we usually cannot observe "adoption" as such. We may observe a policy change, but we typically do not know whether we can ascribe it to a particular cause. In short, in addition to the general challenges in research evaluation, evaluating policy-oriented environmental research is especially problematic because of the difficulties in ascribing a particular policy change to a particular research investment, estimating the consequential changes in environmental outcomes and assigning a monetary value to them.

The chain from research to environmental changes

Another challenge in quantifying the benefits of environmental research is that the links between environmental research and environmental outcomes can be complex, especially in cases where the benefit is generated via policy changes. There are around four stages in the process that may be thought of as forming a chain: research, policy or management decision, behaviour and environmental conditions (Figure 1). The influence of research needs to be traced through each link in the chain. The existence of multiple stages (and potential feedbacks between them) means that benefits are not just difficult to estimate but can be difficult to achieve. The process can fail at any of the stages, which means the research fails to deliver benefits. Here we discuss each of the stages. For simplicity, Figure 1 portrays outcomes at each stage as binary; in reality, each is a continuum.

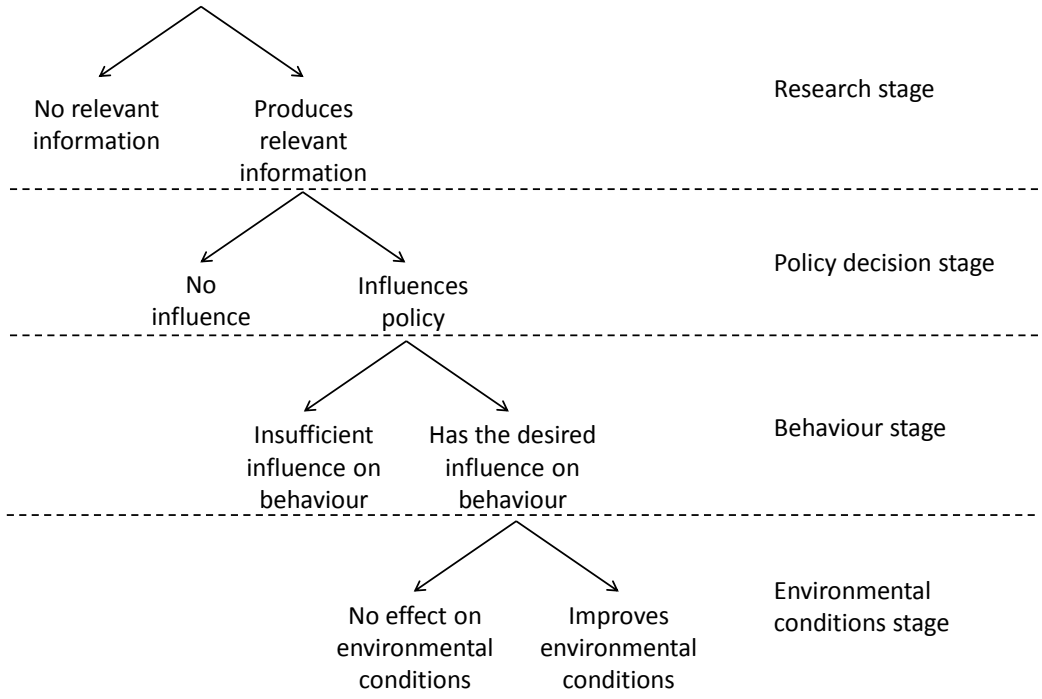

Figure 1. The chain from research to environmental changes.

Research stage. Two key elements should be considered when predicting or estimating the production of relevant information from the research. The first is, what policy-

relevant information has arisen or is likely to arise from the research. We also need to estimate the time lag until the delivery of useful information. Shorter time lags in both the research and adoption phases are potentially beneficial for three reasons: further environmental degradation is prevented; benefits are generated over a longer period; and benefits are generated sooner (Pannell & Schilizzi, 2006).

Decision stage. The next step is to identify or predict the extent and timing of the change in management or policy. The time lag between the completion of the research and the occurrence of the change in management or policy affects benefits in the same ways as described earlier for the research lag. In some cases, this second lag is brief. For example, research contributed substantially to the design of a system of no-take areas in the Great Barrier Reef Marine Park, with the new system being implemented within a few years (Fernandes et al. 2005). In contrast, the first study on the causes of salinisation of non-irrigated land in Western Australia was published in 1924 (Wood 1924), but it was not until 1996 that government established and resourced a cohesive policy (Beresford et al. 2001). The duration of the policy change prompted by the research will also affect the benefits of the research. For example, the introduction of Australia's carbon tax in 2012 was attributable to the global research effort on climate change (IPCC 2014), but it lasted only two years before being repealed following a change of government. Information is needed about the extent to which an observed or predicted policy change can be attributed to particular research. It can be difficult to determine this when other research results vie for attention, or when policy decisions are influenced by factors other than research-based information. Policy is also often influenced by lobbyists and interest groups, who may dispute scientific findings that imply policy decisions that conflict with their interests (Jasanoff 1987). Where an environmental issue is politically contested, the contest may include conflicting scientific arguments and evidence being put forward by different groups of scientists (championed by competing interest groups). This reduces the probability of any particular set of research results having a decisive influence on policy.

Behaviour stage. In many cases, the benefits of environmental research will depend on the behaviour of the people involved in managing the relevant environmental assets or managing other resources that have impacts on the environmental assets. These people may or may not respond to the policy or management program in the intended ways. A great deal of research has investigated the determinants of behaviour change, especially

by landholders (e.g. Feder & Umali 1993; Pannell et al. 2006; Knowler & Bradshaw 2007). This research highlights the complex nature of behaviour change, with numerous variables coming into play in different cases. The attribution problem recurs here in a different form: observed changes in behaviour may or may not be attributable to a policy or management program. Behaviours change regularly in response to many factors, so it can, therefore, be difficult to discern the effects of a particular factor from the mix of influences.

A time lag is likely between the implementation of a policy or management program and behaviour change. Evidence about the lengths of time lags in the adoption of new practices in agriculture shows considerable variation. Practices that are simple to adopt and highly profitable are often adopted rapidly — in some cases most growers will adopt within a few years, while other practices that are more complex or less profitable or have other disadvantages (e.g. requiring local adaptation) may take much longer, potentially several decades (Alston et al. 1995, 2010).

Environmental-conditions stage. The changes in behaviour induced by the policy or program are intended to result in improvements in the condition or security of the relevant environmental assets. Even if the changes in behaviour were known with certainty, determining the nature and extent of physical changes in the environment can be challenging. Cases with such strong evidence are relatively rare, particularly for issues relating to biodiversity, threatened species and vegetation. Often, little or no research results are available on the relationship between management and environmental outcomes, so the best available information is that derived from expert judgements (Yamada et al. 2003; Czembor & Vesk 2009). In such cases, uncertainty about the relationships is unavoidably great.

It may be necessary to estimate a time lag between action and consequence. For example, the mechanism by which environmental benefits are generated may be the planting of trees to contribute to the restoration of habitat. The full environmental benefits from this strategy will not be realised until after the trees have matured, which, depending on the environment and the tree species, may take from decades to centuries (Vesk et al. 2008).

Methods for this assessment

Given the variety of outputs, activities and impacts that we wished to measure, we used a range of different methods.

Survey of research projects

In late 2016, all CEED researchers were asked to fill in a survey questionnaire for each distinct area of research undertaken in CEED. (Hereafter, each distinct research activity is referred to as a ‘‘project’’.) The questionnaire consisted of 16 questions, covering the following issues:

- project details—title, duration, researchers involved and collaboration
- overview—summary, aims, key results
- outputs—publications, conferences, tools, media, policy briefings
- academic metrics
- impacts on policy and management—types and most significant impacts, evidence for impacts, factors contributing to impacts, trajectory, stakeholder/end user engagement.

From the survey, 87 distinct research projects were identified. Many projects involved researchers from multiple CEED nodes. A list of all projects is provided in Appendix 4.

Case studies

From the 87 research projects identified above, nine projects were selected for more detailed analysis. The selected case studies were not intended to provide a representative sample but instead to illustrate a range of project types and outcomes. For each case study, interviews were conducted with CEED researchers, collaborators and research users. Information from the survey, the interviews and academic metrics are synthesised into an outline of the case study.

Analysis of publications, citations and collaborations

Collaborations, citations and collaborations were analysed based on “authors-institution-weighted papers”. With author-institution weighting, a proportional share of

the paper is assigned to each author's listed affiliations based on the number of authors and the number of institutional affiliations for each of the authors. Affiliations to the same institutions from different authors are then added together. There is no perfect way to attribute or share out the authorship of a publication, particularly for papers with many authors. However, this method of author-institution weighting has been used by others (e.g. Shane 1997; Markin et al. 2017).

The analysis was based on 848 CEED papers that were indexed in the Web of Science. For both the 848 CEED publications and the 10,460 publications citing those CEED publications, institution affiliations were assigned to each publication on an "author-institution weighted papers" basis, such that the sum of the "author-institution weighted" institution affiliations on CEED publications = 848, and the sum of the "author-institution weighted" institution affiliations on publications citing CEED publications = 10,460. Note that when assigning author-institution weightings to CEED publications and citers of CEED publications, affiliations were based on "parent" institutions (e.g. universities) rather than addresses (departments and centres). So an author listed on a publication with an affiliation to a centre and a department at the same university was treated as having only one affiliation (to that university).

The timing of the assessment

CEED began in 2011 with funding to May 2018. This evaluation of the impact of CEED's research was conducted from late 2016 through 2017. Timing can have important implications for research impact. As noted earlier, the time lags between research and impact are typically long, often decades (Alston et al. 2010). Although less protracted, academic writing and publication can also be slow, taking one to five years in most cases. Once published, citations of the publication take years to accumulate (Wang et al. 2013). As a result of these time lags, the observed impacts of CEED's research, as reported here, are likely to be substantially less than the eventual impacts.

Impacts on policy, management and the community

Engagement with end users and stakeholders

Engagement with end users and stakeholders was reported in the survey to have occurred in 68% of projects. Much of the engagement has been with government, either at the policy/decision-maker level (parliament, minister, local government, departmental leader) or the management/implementation level. Often, it also included non-government organisations (NGOs), land care/natural resource management groups and specific/local environmental asset managers. In total, engagement has occurred with 110 different end users and stakeholders, 79 from within Australia and 31 international.

In some projects, an organisation or institution was reported as being both a partner/collaborator and an end user or stakeholder. In our analysis, research-provider organisations (e.g. universities, CSIRO) were counted as partners/collaborators.

We found that 27 end users had been engaged in multiple CEED research projects. For example, the Australian Antarctic Division, Department of Parks and Wildlife (WA), Department of Environment, Land, Water and Planning (Vic), International Union for Conservation of Nature (IUCN), North Central Catchment Management Authority (Vic) and The Nature Conservancy (TNC) Australia were all engaged over at least four research projects. All Australian and international end users and stakeholders reported as being engaged are listed in Appendix 3. It is highly likely that there are additional research users who sought out CEED research findings in their own right (e.g. through publications) and used them without the knowledge of CEED.

The results of 17% of projects were reported as having been used in at least one policy briefing or submission to inquiries or reviews. The findings of one project have been used in 19 different briefings or submissions. However, this understates the contribution of CEED to the policy process, as there were also many contributions not confined to individual projects. For instance, in 2015 alone, CEED researchers made 45 submissions to government on policy-related issues and conducted 181 briefings with government, industry and business (source: CEED 2015 annual report). Much of this engagement was based on insights CEED researchers had gained across multiple projects and the knowledge they had acquired more generally. The engagement reflects

CEED's ethos regarding the use of credible evidence to improve environmental decision-making and was generally made in response to proposals or policies under consideration

Rating the impacts of CEED research projects

To explore the distribution of impacts for the body of CEED research, all projects reported in the survey were rated for three different factors:

- impact on policy, management and the community (thus far)
- the potential for an increase in impact on policy, management and the community
- academic performance.

Criteria used when rating these aspects were as follows:

Impact on policy, management and the community (thus far)

The impact of each project at the time of the survey was classified as either "low", "moderate" or "high" as follows.

Low. Little or no contribution to policy or management, at least at this stage.

Moderate. Results presented to decision-makers, policymakers, etc. or received significant coverage in the media. Probably has influenced people's thinking or knowledge, but there is no evidence of resulting large changes in policy or management. May have been used to justify an existing decision or policy. There may have been a transfer of knowledge outside academia, though the extent of the utilisation and application of the knowledge is uncertain.

High. Precipitated or contributed to identifiable, substantive changes in policy or management.

Ratings were assigned to projects by two of the authors of this report (Thamo and Harold). In rating the project impacts, we noted that there was an important distinction between the *size of an impact* (e.g. did it cause a large or small change in policy and/or management?) and the *scale over which the impact applied* (e.g. was the change in local

management or national policy?) In reality, a small change in a national policy may have a larger environmental impact than a substantial change applied at a small scale, such as a local catchment. Consideration has been given to this trade-off when assigning ratings.

As noted earlier, after the implementation of a change in management or policy, there is likely to be a time lag before the resultant beneficial change in environmental outcomes occurs, or occurs to its full extent. When classifying impacts of the 87 different projects, some were effectively being considered more or less from an *ex-post* perspective and others from a more *ex-ante* perspective, depending on when the research had been conducted and the timeframes required for any environmental impacts to be realised. To allow for this and to compare different projects on a more consistent basis, when rating the impact of a project it was assumed that the prospective impacts had been fully achieved immediately following adoption of a change in management or policy. If undertaking an economic analysis of the benefits, we would have needed to account for the time lags when using discounting to compare benefits.

We note that knowledge generation and academic outputs can have broader and more tangible impacts (e.g. education is Australia's third largest export earner). However, such impacts were not included in this analysis.

The potential for an increase in impact on policy, management and the community

Many projects were still on-going at the time of the survey, so there is a likelihood of increased impact in future. This remains true, even for completed projects. Accordingly, we asked project leaders to consider and report on the future potential for greater impacts. Classification of the potential for increased impact required consideration of both the *probability/likelihood of increased impact* and what *the magnitude of that impact* might be. Depending on the combination of these two factors, a classification of "low", "moderate" or "high" was made, as follows:

		Probability/likelihood of increased impact in future		
		Low	**Moderate**	**Strong**
How big that impact could be	**Small**	Low	Low	Moderate
	Moderate	Low	Moderate	High
	Big	Moderate	High	High

This rating relates to the potential for new and increased adoption or uptake of the research findings. It is not about increased future impact as a result of the adoption of the research that has *already* occurred: these benefits were already accounted for in the rating of impact.

Using the above criteria, the 87 CEED projects were rated on these three aspects of their impact by two of the authors of this report. Ratings were completed independently and then crosschecked, with any differences resolved by discussion. To enhance the consistency of ratings based on qualitative criteria, the leaders of each of the five CEED nodes were also asked to rate the projects that were led by researchers from their nodes. These ratings were also used to crosscheck the rating assigned by the report's authors. Some node leaders were more conservative than others in their ratings, but the relative differences between projects from the same node were still useful.

Academic performance

Academic metrics are assessed in detail in a later section. Here we pre-empt the results related to academic performance to allow us to present graphs that combine academic and non-academic performance. First, projects were rated based on the number of journal publications (including those in press and under review) using the following scale:

- **Low.** Up to two articles published over the life of the project
- **Moderate.** Three to five articles
- **High.** Six to 10 articles

- **Very high.** More than 10 articles.

Secondly, the ratings were adjusted taking into account the following factors:

- other academic outputs, including books, book chapters and conference papers
- the number of citations to the project's publications
- quality/prestige of the journal(s) in which the publications appeared
- number of collaborating co-authors (publications with more co-authors, especially co-authors with international affiliations, were considered more likely to have greater academic performance — Polyakov et al. 2017)
- whether or not the research appeared to have achieved a significant breakthrough.

It is acknowledged that these criteria are biased toward larger projects because they tend to have more publications. Ideally, the relative impact of publications (e.g. average citations per dollar invested in research) would be considered. However, because in many cases publications were only recently published or in press, this was not feasible.

Rating of projects: results

Figure 2 and Table 1 show the results of the rating process. As would be expected, there is a skewed distribution of impact levels, with 71 of the 87 projects (82%) rated moderate or low for impact (meaning management, policy and community impact) and 16 of the projects (18%) rated as high.

Of the 43 projects with low impact so far, only one was assessed as having the potential for a large increase in impact in future. On the other hand, five of the 28 projects assessed as having moderate impact so far, and three of 16 high-impact projects were seen as having the potential for a large increase in impact in future. Over a third of the projects across all current categories were seen as having the potential for a moderate increase in impact in the future. These findings provide the impetus for CEED to support renewed efforts to connect these moderate- and high-potential projects to prospective research users.

About 66% of the projects were rated below high for both impact and academic performance, and more than half of these were assessed by the researchers as having no realistic potential for much-increased impact. It may be that it was difficult for researchers to identify projects that would score highly on one or both of the axes. On the other hand, it may be that there is more scope for researchers to explicitly consider the impact and academic merit at the point at which they select and design specific research projects.

The graph suggests that there might be a slight positive correlation between impact and academic performance across this sample of projects. Low-impact projects are more likely to have low-moderate academic performance, and high-impact projects are less likely to have low academic performance. However, there are examples of projects for all possible combinations of scores.

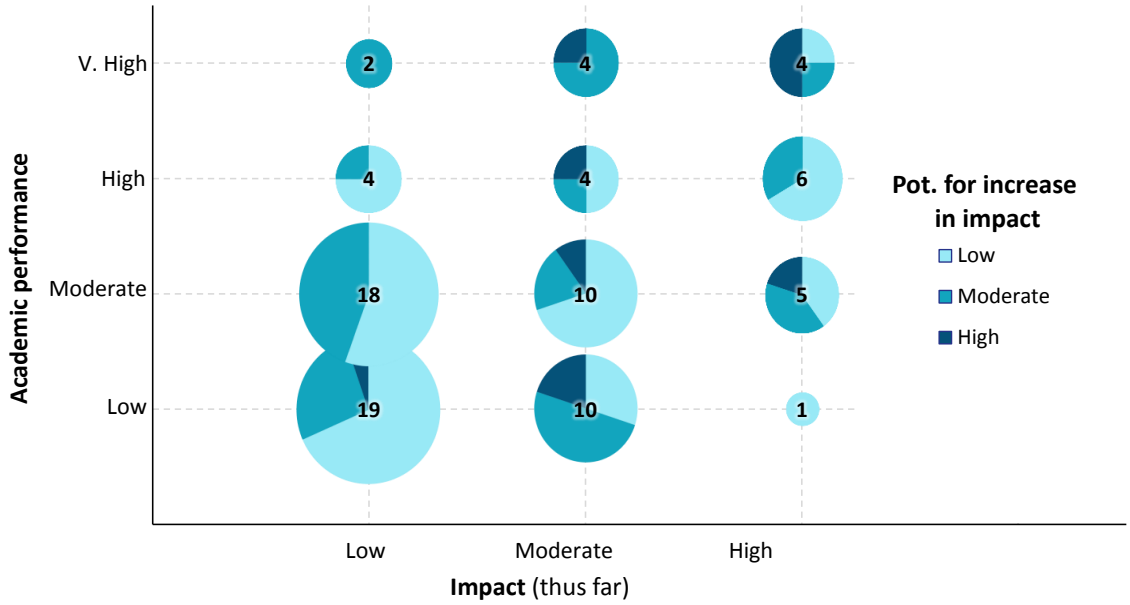

Figure 2. Results of the rating process. The number of projects in each category is reflected in the size of the pie and the numerical label.

Table 1. Results of the rating process

Impact (thus far)	**Potential for increase in impact**	Academic performance				
		Low	Mod.	High	V. High	**Total**
Low	Low	13	10	3	0	**26**
Low	Moderate	5	8	1	2	**16**
Low	High	1	0	0	0	**1**
Moderate	Low	3	7	2	0	**12**
Moderate	Moderate	5	2	1	3	**11**
Moderate	High	2	1	1	1	**5**
High	Low	1	2	4	1	**8**
High	Moderate	0	2	2	1	5
High	High	0	1	0	2	3
Total		**30**	**33**	**14**	**10**	**87**

Evidence of the time lag in achieving impact (remembering that the projects were surveyed at the end of 2016) can be seen in Figure 3. There is a strong tendency for impact to be higher for those projects started earlier. Notably, 47 of the 87 projects reported that they were still on-going at the time of the survey. These two observations suggest that an evaluation of CEED's impact conducted at a later time would likely report a much-higher level of impact.

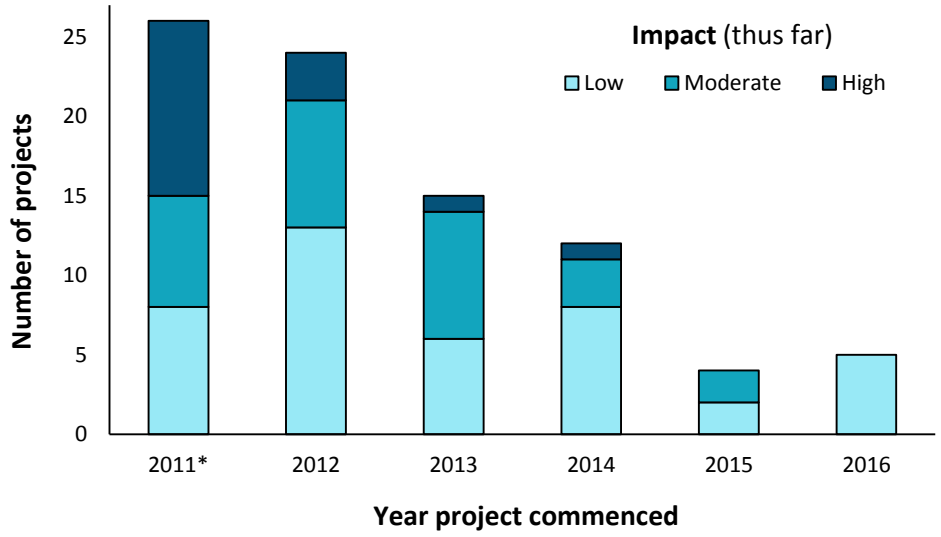

Figure 3. Impact levels for projects by year of project commencement.

*Includes nine projects that started before 2011 under other funding sources

Case studies

Nine case studies were selected for deeper investigation. Case studies have been used in other research evaluation exercises including the Research Excellence Framework in the United Kingdom and the Engagement and Impact Assessment in Australia. While case studies help to capture nuance and complexity, it is difficult to draw general conclusions from them (Bell et al. 2011). The chosen projects vary in impact (moderate or high), potential future increase in impact (low to high) and academic performance (low to very high). The selected case studies were not intended to provide a representative sample but instead to illustrate a range of project types and outcomes. Descriptions of each case study are provided below.

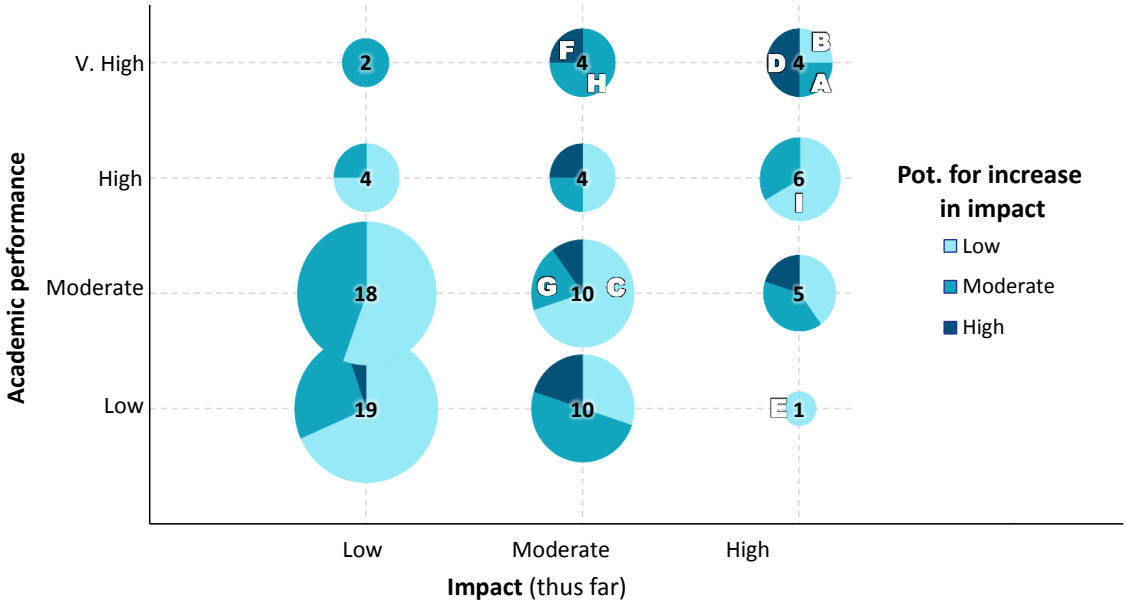

Figure 4. Mapping of the nine case studies onto the project ratings. Project titles: A = Borneo Futures; B = Managing diffuse-source water pollution; C = Development impacts on the Great Western Woodlands; D = Koala conservation; E = Valuing access to national parks; F = Making the most of biodiversity offsetting; G = Extending Marxan's reach: Building capacity and outreach; H = Playing with fire: managing fire and weeds for biodiversity conservation; I = Metapopulation models to manage threatened frogs.

Case study A: Borneo Futures

CEED has played a major role in an international network called the Borneo Futures Research Initiative. The network seeks to develop the knowledge, tools and skills to enable the restoration and maintenance of Borneo's rainforest ecosystems. Work to date has contributed to the establishment of new protected areas and the conservation up-listing of the orangutan from Endangered to Critically Endangered.

CEED researchers: Kerrie Wilson (CI), Professor Hugh Possingham, Truly Santika, Elizabeth Law, Madeleine Stigner, Courtney Morgans, Rachel Friedman, Jessie Wells, Sugeng Budiharta, Rebecca Runting (all based at The University of Queensland). Further researchers have been involved in short-term capacities.

Principal collaborators: Erik Meijaard (Borneo Future Research Initiative director and Adjunct Professor at University of Queensland).

The challenge

Borneo was once an island of dense rainforest and high biodiversity. In the past 30 years, significant areas of high-value rainforest have been destroyed resulting in loss of habitat and many species becoming endangered. Implementing sustainable land management has been difficult, in part because three countries control different parts of Borneo: Indonesia, Malaysia and Brunei.

Borneo is one of the most understudied regions in the world. The Borneo Futures Research Initiative (commonly referred to as Borneo Futures) seeks to address this lack of knowledge with help from a large international network. It was established in October 2010. It aims to develop innovative, applied research to ensure that the knowledge, tools and skills exist to enable the restoration and maintenance of the biodiversity and ecosystem services that tropical nations rely on for livelihoods, economic development and human health.

CEED is an important player in Borneo Futures, undertaking much of its land-use and land-planning research. CEED has helped demonstrate how socio-ecological research can be used to address the complex problems of natural resource management in developing countries.

Impacts

The research has been able to identify the most important environmental problems in Borneo and translate these scientific findings into socially relevant natural-resource policy and planning advice that has led to more effective conservation actions and resource management policies and practices. For example, a team of Borneo Futures scientists, including CEED researchers, compiled the only comprehensive spatial dataset for Borneo showing the true cost of tropical deforestation and the benefits of sustainable forest management. This research informed the Strategic Plan of Action for Sabah – Heart of Borneo Initiative, which then contributed to Malaysia's Sabah government establishing new protected areas that are home to many threatened species including 4000 orangutans (Figure 5), clouded leopards, sun bears and elephants.

CEED researchers also developed new modelling techniques for threatened species. These models revealed how Borneo had lost 29,000 orangutans in the past decade due to hunting and land mismanagement. This evidence was instrumental to the International Union for the Conservation of Nature up-listing the status of the Bornean orangutan from endangered to critically endangered. The results contributed to Malaysia's Sarawak government pledging to protect additional habitat and end illegal poaching and logging. There have also been discussions involving Borneo Futures on the development of Indonesia's new National Plan for Orangutan Conservation 2017-2027. It should be noted that progress in developing this plan has recently been stalled due the Indonesian Government seizing on unreliable data from another source suggesting orangutan numbers are quite healthy; an example of how politics and vested interests can sometimes stall reform.

According to Dr Alue Dohong, the deputy for construction, operations and maintenance at Indonesia's Peatland Restoration Agency, Borneo Futures research provided the technical training needed to "support us in scientific ways of doing things". Dr Dohong said the research had benefited the government in Indonesia and "played a critical role in showing the social and economic value of timber" and contributed to the development of Regulation #57 (2016).

Academic outputs and impacts

Some noteworthy research outputs involving CEED researchers have been the collection of large datasets (e.g. interviews with 6983 individuals in 700 villages across Borneo), quantifying and mapping the value of ecosystem services and perceptions of rural people, identifying degraded forests suitable for restoration (and actions that should be implemented to restore it), and quantifying the economic and social impacts of flooding.

CEED researchers, who together comprise Borneo Futures' most productive academic partner, produced more than 50 research publications related to the project. These CEED papers have attracted nearly 500 citations. Collectively, the publications have co-authors from 53 institutions and more than 90% of the publications involved international collaboration. A recent evaluation of Borneo Futures by Wildlife Impact stated that: "The indicator data we evaluated shows Borneo Futures addressed numerous important information needs through well-regarded publications with high public attention measures (averaging in the 86th percentile of all science publications). We rate Borneo Futures' progress in this area as excellent."

Awards

In recognition of the contribution to advancing natural resource management knowledge in the tropics, CEED researchers were awarded Malaysia's 2016 Mahathir Science Award, which is the Malaysian Academy of Science's most prestigious award for tropical sciences. A CEED PhD student was awarded best paper at the 2016 Society for Conservation Biology Oceania conference, which was published in *Nature Communications* in 2015.

Collaboration

The collaboration with stakeholders across the three countries in Borneo, and the partnerships forged between academic institutions, global organisations (e.g. United Nations Environment Programme, International Union for the Conservation of Nature and the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services), government agencies, non-governmental organisations, industry, and local

conservation groups have been among the most important outcomes. This research network of 250 collaborating world-leading scientific experts has given Borneo Futures a voice representing a large group of influential people including experienced on-the-ground practitioners. This has facilitated top-to-bottom and bottom-to-top flows of information, ideas and shared datasets.

Communication and engagement

In Malaysia, research findings are directly discussed with key government people. In Indonesia, it is more effective to influence thinking by communicating through the media. The media coverage of this research has been extensive and has greatly contributed to the impact of this project.

"Borneo Futures has had the most tangible influence through our media work rather than through our research," said Erik Meijaard, director of Borneo Futures (and a CEED adjunct). "Through our extensive scientific work on Borneo, we have built up significant scientific credibility, which means that if we do say something in newspapers, policymakers are likely to pay attention."

As an example of this, when more than 500,000 people read an article by Borneo Futures in the *Jakarta Globe* on Indonesia's 2015 peat fire crisis being the biggest environmental crime of the century, the Indonesian Government rapidly reformed its policy on using fires as part of land management and followed up by investigating and prosecuting offenders.

Borneo Futures research and recommendations on the protection of Borneo's species and ecosystems have been widely published by local, national and international media. With more than 100 media stories, the message of Borneo Futures has also permeated social media platforms. The social media response on 22 popular stories accumulated to 1.4 million engagements, 815,000 shares and 600,000 petition signatures.

Prospects for future impacts

As a result of all this work, researchers from the Borneo Futures have been commissioned by the Sabah State Committee to spearhead the development of a conservation and sustainable development program (the Strategic Plan of Action for

Sabah) aimed at conserving and managing the contiguous tropical forest on the island of Borneo. With these types of research engagements, combined with a new cohort of researchers in training and the existing research partnerships, there is reason to hope that CEED and Borneo Futures have made a real difference to the people and environment of Borneo.

More information: Kerrie Wilson k.wilson2@uq.edu.au

Academic performance: Very High
Impact: High
Potential for Increase: Moderate

Figure 5. This research played an instrumental role in the International Union for the Conservation of Nature's up-listing of the status of the Bornean Orangutan to Critically Endangered.

Case study B: Managing diffuse-source water pollution

The management of diffuse-source water pollution has been an enduring challenge for governments worldwide. Research on policy design to tackle this problem by CEED researchers has helped to underpin the most-significant water-policy initiative developed in New Zealand's history.

CEED researchers: Graeme Doole and David Pannell (University of Western Australia).

Principal collaborators: Anna Roberts and Geoff Park (Natural Decisions Pty Ltd), Alvaro Romera (DairyNZ), Eloise Seymour and Alan Curtis (Charles Sturt University), Dan Marsh (University of Waikato), Thiagarajah Ramilan (University of Melbourne).

The challenge

The past 50 years have seen substantial progress in reducing pollution flows from point sources, where there is an obvious origin of the discharge (e.g. an industrial plant). In contrast, diffuse-source water pollution involves the contamination of a water catchment by many different sources, typically via run-off from rural and urban land. Because there can be numerous pollution sources, each of which is difficult to identify and monitor individually, management of diffuse-source water pollution is often challenging.

This research focused on the design of policy for the management of diffuse-source pollution, principally nitrogen but also phosphorus, sediments and faecal microbes. A change in the behaviour of both communities and businesses is required to reduce these inputs to waterways. Achieving such behaviour change can be greatly assisted by a sound understanding of the relative cost-effectiveness, complexity and feasibility of different pollution-abatement actions. Research was conducted for Victoria, for the Great Barrier Reef watershed and, particularly, for New Zealand where concern about agricultural intensification through growth in the dairy industry has made water quality the most-prominent environmental policy issue.

Overall, this research shows voluntary adoption of pollution-reducing practices is often too limited to meet community aspirations for water-quality. Indeed, the cost of achieving societal goals for improved water quality is usually so high the policy targets

are unachievable with the available program resources.

The research has helped agencies to identify more realistic targets, leading to actions that are more likely to be effective. The limitations of market-based instruments for dealing with diffuse-source pollution were also highlighted. These findings emphasised the importance of new theory and tools for environmental decision-making developed as part of CEED's greater research portfolio.

Relevance and impacts

Extensive publication about water quality management throughout Australasia and on-going research conducted with the assistance of CEED funding earnt the researchers (and in particular Dr Graeme Doole) respect and credibility, with Dr Doole becoming increasingly sought out for the expertise he has built up in this area.

In 2013, this culminated in his research evaluating the cost and distributional impact of various policies for water quality improvement in New Zealand being presented by Graeme to four senior ministers from the New Zealand Government, including the Deputy Prime Minister. He was later appointed as an economic adviser to the New Zealand Ministry for the Environment, with the Government providing 40% of the funding for Dr Doole's university position. This role included providing advice and economic analysis of water quality issues of both regional and national priority.

Much of his government work in this new role was confidential and so remains unpublished. However, CEED research provided the academic basis for this body of work. The work included modelling used to establish the economic case for the New Zealand National Policy Statement for Freshwater Management 2014.

Dr Vera Power, manager of Evidence and Policy Support in the New Zealand Ministry for the Environment, described this body of work as "not only the biggest environmental but perhaps also the biggest economic analysis ever conducted in New Zealand".

The resultant policy represents the most-significant water initiative developed in the country's history and is a landmark step towards communities working together to achieve water quality aspirations.

Dr Doole's research was also used to estimate the economic and environmental implications of water quality policy changes for New Zealand's largest river catchment, the Waikato River system (Figure 6). This is the largest and most-expensive regional water quality policy process ever undertaken in New Zealand, with around $NZ15 million spent on policy formulation alone.

Dr Doole also initiated a training program for policy analysts from the New Zealand Ministry for the Environment (and later extended to regional governments) on how to better incorporate environmental considerations into an evidence-based economic decision framework, helping to instil an approach to decision-making and a skillset that can be applied to other issues.

High-quality CEED-funded research provided the foundation for much of this policy work. However, it is difficult to ascribe exactly how much CEED-funded research impacted these policies. Policy development is often a complex, unstructured journey that is impacted by multiple stakeholders, media, political considerations and emergent factors. This makes it difficult to discern with rigour the value that research has contributed to the policy process. However, Dr Power describes the contribution of Dr Doole and his research to water policy in New Zealand as "critical".

In many ways, Dr Doole's career has followed the trajectory of this research. He held a postdoctoral position with CEED until 2016, when, at the conclusion of this project, he was appointed a full Professor at the University of Waikato.

Within Australia, the influence of the research has been less direct but nevertheless tangible. The analysis of pollution in the Gippsland Lakes established a modelling framework that has subsequently been applied in some Australian contexts to support the development of management plans. Notably, consulting firm Natural Decisions Pty Ltd has used the framework extensively to underpin the development of Water Quality Improvement Plans for three catchments fronting the Great Barrier Reef Lagoon. These plans have been formally adopted by regional natural resource management bodies, and they are being implemented over time.

Academic outputs and impacts

Research from this project has been published in 24 peer-reviewed journal articles.

Collaboration and Engagement

This project has seen extensive engagement (and often collaboration) with state and regional bodies in Australia and New Zealand and the national government in New Zealand. Industry representatives and conservation groups have also been engaged and have collaborated with the project on many occasions. The research itself has been extremely interdisciplinary, involving economists and modellers collaborating with experts in many different fields such as ecologists, microbiologists, hydrologists, agronomists and animal scientists. At times, Dr Doole has operated as a lead modeller coordinating the development and application of models involving teams of more than 30 researchers.

Prospects for future impacts

Although the research has influenced policy, most of the environmental impacts that will result from this are yet to be realised. This will occur over the next two decades and beyond, as the policy is implemented and its impacts are felt.

The research is likely to continue to be influential within Australia. It will likely underpin New Zealand policy for the foreseeable future. Although the evidence and data may change, the approach to environmental decision-making developed through this research (i.e. how to use the evidence) has now been well established and accepted by environmental decision-makers.

More information: Graeme Doole graeme.doole@waikato.ac.nz

Academic performance: Very High
Impact: High
Potential for Increase: Low (i.e. the work has had most of the influence on policy that it will have, especially in New Zealand. The actual environmental benefits will unfold over the next two decades.)

Figure 6. The Waikato River.

Case study C: Development impacts on the Great Western Woodlands

This research investigated the ‘‘under-the-radar’’ impacts of mining on the world’s largest remaining temperate woodlands. It has led to greater awareness of the environmental damage associated with ‘‘enigmatic’’ impacts.

CEED researchers: Keren Raiter, Richard Hobbs, Leonie Valentine (University of Western Australia); Hugh Possingham (University of Queensland).

Principal Collaborators: Suzanne Prober (CSIRO).

The challenge

Between Australia’s Nullarbor Plain and the cleared agricultural land in South-Western Australia lies the “Great Western Woodlands” (Figure 7). These are the world’s largest remaining temperate woodlands, home to almost a quarter of Australia's eucalypt species and 3000 species of flowering plants (representing around 20% of all known Australian flora). However, they also contain considerable mineral resources, and the Woodlands have been subject to a multitude of mineral exploration and extraction activities.

CEED PhD student Keren Raiter investigated the “enigmatic” impacts of these mining activities on the Great Western Woodlands. Enigmatic impacts are so named because they are often overlooked in environmental impact assessments conducted during the approval process for mining developments. They include impacts that: can be small but act cumulatively; occur outside the area considered in impact assessments; are hard to detect; and/or are facilitated, but not directly caused, by development.

In particular, this project focused on quantifying the cumulative impact of linear infrastructure such as roads, tracks and railways (Figure 8).

Using remote-sensing techniques, this research revealed there were 150,000 km of linear infrastructure constructed in the Great Western Woodlands (four times the circumference of the Earth). The majority of this linear infrastructure consists of access tracks that were unmapped and, as such, “fly under the radar”. Nonetheless, linear

infrastructure was found to have directly disturbed twice as much area as the infrastructure that is more commonly associated with environmental impacts: the mine pits, waste rock dumps and other "hub" infrastructure connected with resource extraction.

Field work was then conducted to quantify some of the impacts of linear infrastructure. It revealed that predator (foxes, cats and dingoes) activity was heightened around infrastructure routes, with the effects on predator activity extending into the woodland as far as 2.5 km away from roadways. A strong link between linear infrastructure and altered hydrology was also observed with nearly all stream crossings analysed showing evidence of flow impedance, concentration or diversion and/or channel initiation to varying extents.

Relevance and impacts

Findings from this research have been used to support submissions to Western Australia (WA)'s Environmental Protection Authority regarding specific mining proposals in the Great Western Woodlands. Presentations about the importance of giving due consideration to enigmatic impacts when assessing the impact of development proposals more generally have also been made to WA's Environmental Protection Authority, Department of Biodiversity, Conservation and Attractions, and the Department of Water and Environmental Regulation. The WA Department of Mines, Industry Regulation and Safety have also expressed an interest in utilising the findings of this research.

The Ngadju, holders of native title over a significant part of the Great Western Woodlands, have also incorporated findings from this research into a Conservation Action Plan they are developing for the Woodlands.

Academic outputs and impacts

This research has directly led to three journal articles, with another in preparation. The terminology used in these publications to describe "enigmatic impacts" have since been adopted by others in the literature. Findings were also presented at the International Conference for Conservation Biology in France.

Collaboration and engagement

This research involved collaboration between the University of Western Australia, CSIRO and University of Queensland. The Wilderness Society and Gondwana Link provided funding as well as extensive in-kind support, and the Wheatbelt Natural Resource Management group and mining company Cliffs Natural Resources supported field work. Local farmers and groups of volunteers also gave assistance.

In addition to the aforementioned presentations to government departments, findings were also presented to The Wilderness Society, Gondwana Link, the Kwongan Foundation, Birdlife Australia, the Ecological Society of Australia, local governments whose jurisdictions cover parts of the Woodlands and mining companies.

Prospects for future impacts

This research has contributed to a growing body of literature about "enigmatic" environmental impacts, which in turn is slowly leading to a greater understanding of their importance by environmental regulators and mining companies. Since completing her PhD Dr Raiter has been employed by the Department of Biodiversity, Conservation and Attractions providing advice on environmental impact assessment, utilising the knowledge gained from this project. She hopes to build upon this research when she begins a postdoctoral fellowship in strategic conservation planning at the Hebrew University of Jerusalem in 2018. Presentations about this research have also helped foster growing community interest in conserving the Great Western Woodlands.

More information: Keren Raiter keren.raiter@research.uwa.edu.au

Academic performance: Moderate
Impact: Moderate
Potential for Increase: Low

Figure 7. Map of the Great Western Woodlands.

Figure 8. Most of the linear infrastructure associated with this mine in the Great Western Woodlands was unmapped. Image: Keren Raiter

Case study D: Koala conservation

CEED researchers have been involved in a multi-pronged long-term research program aimed at arresting the decline in koala numbers in Queensland and New South Wales. The program has achieved a high level of academic rigor, as well as directly informing decision-makers and precipitated policy change.

CEED researchers: Jonathan Rhodes, Hawthorne Beyer, Truly Santika (University of Queensland).

The challenge

Although governments have supported major conservation programs to protect the koala, koala populations are in decline in Queensland and New South Wales. The decline is due to habitat loss, disease, car strikes and dog attacks but also indicates that the existing conservation activities are insufficient or misdirected.

The aim of this research work has been to understand the impact of climate and landscape change on koala populations and the policy and planning implications for koala conservation. This research included several state government-funded and ARC-funded projects, including CEED. It was led by CEED chief investigator Jonathan Rhodes.

Impacts

This project has been ongoing since 2001, with the first seven years mainly focusing on knowledge creation. In subsequent years, with assistance from CEED, the focus shifted to knowledge transfer and application, including policy change, prioritisation of investments, influencing strategic thinking and engagement at all levels of government. The research findings have been communicated in numerous policy briefings and presented to inquiries or reviews, with the most significant being a 2011 Senate Inquiry on koalas. Following this, the koala was listed as vulnerable on Australia's list of Threatened Species, which will ensure funding for a national recovery plan in the near future.

CEED support has enabled the research to continue and build on earlier success. For

example, in 2016 CEED chief investigator Jonathan Rhodes led a UniQuest study funded by the Department of Environment and Heritage Protection (Queensland Government) that directly drove a policy change in koala conservation in Queensland. The change included the announcement that the government would commit $12 million to boost koala conservation measures and improve population surveys over the next four years. This same UniQuest report has been pivotal in preparing a response strategy that encompasses other departments in the Queensland Government covering everything from the way habitats are mapped, to the way survey activities are conducted and including policy approaches such as a planning framework. The manager of Conservation and Biodiversity Policy in the Department of Environment and Heritage Protection confirms the study produced a report that, "gave the impetus for policy changes … ae have been using the outcomes of the UniQuest report for two years … we use it for general responses to the public, and we also use it for justifications for policy change." More generally, this body of ongoing research "informs policy but it also informs management approaches and modelling work".

Queensland's Redland City Council uses the outputs from this research program by incorporating the quantitative measures and modelling techniques in their work. They have partnered with CEED researchers on some conservation projects. Most notable was the introduction to and use of CircuitScape, a GIS-based add-on modelling tool that directly informed the drafting of the council's Wildlife Connections Plan 2017 (awaiting formal council consideration).

In recognition of Jonathan Rhodes' expertise and high level of engagement, the Queensland Environment Minister, Dr Steven Miles, appointed him chair of the Koala Expert Panel in 2016. The panel provided recommendations and advice on the best way forward to conserve the koala in Queensland.

Academic outputs and impacts

The academic outputs have been extensive, with around 20 publications and a very high-impact report. The research program has attracted many PhD students and been awarded grants to undertake research projects that have added to the depth of this program. The outputs have provided better quantitative information on population declines particularly due to landscape and climate change, a prioritisation framework

and recommendations for koala recovery. Based on analysis of data and the credentials of this research program, the Queensland Government and local councils refer to these papers in literature reviews and frequently seek their advice and recommendations on conservation policy.

Communication and engagement

This research program has collaborated with universities and local government through sharing datasets and working together to improve mapping and monitoring techniques to facilitate better planning and management decisions. Collaborative relationships have been formed with Logan City Council, Moreton Bay Regional Council, City of Gold Coast and Redland City Council. For example, a manager within the planning and policy arm of the Redland City Council commented "CEED provides a great system and service. Jonathan is my 'go-to' person for feedback and research advice that both directly and indirectly informs our work."

Due to the nature of these collaborative relationships, CEED researchers have been able to partner with councils for grant applications and, in some cases, have arranged for PhD candidates to undertake industry placements to work with councils on projects that extend their research training skills.

The CEED researchers on this project have developed multiple relationships with stakeholders at state and local government levels including decision-makers such as the Queensland Minister for the Environment. Some important stakeholders engaged during the project include the Queensland Museum; Department of Environment and Heritage Protection, New South Wales; Office of Environment and Heritage, Queensland; and the Office of the Chief Scientist, South East Queensland. The researchers keep the stakeholders informed through regular briefings, reports, workshops and journal articles.

There has been a range of media coverage relating to this research including radio, television, The Conversation and *Decision Point*. Government media releases and reports have referred to the outputs produced by this research.

Prospects for future impacts

This research has provided the evidence that koala populations are declining and solutions for how this can be resolved. Future research in this area will depend on the funding sources available. However, it is clear that there is an interest by government in this research program and that building on existing research is highly valuable. The ongoing support of this research program will allow for comparable studies over several decades to establish if population densities have improved or otherwise, thereby informing policy evaluation for decades to come.

More information: Jonathan Rhodes j.rhodes@uq.edu.au

Academic performance: Very High

Impact: High

Potential for Increase: High

Case study E: Valuing access to national parks

CEED-supported research on what visitors are willing to pay for entry into Nepal's national parks empowered the Nepalese Government to increase park entry fees, something it had previously been unwilling to do. The impact has been immediate with increased resources leading to a range of positive conservation outcomes.

CEED researchers: Ram Prandit and Maksym Polyakov (both University of Western Australia).

Principal collaborators: Maheswor Dhakal (Department of National Park & Wildlife Conservation, Nepal).

The challenge

Nepal is a mountainous and forested country spread over various altitudes with significant biodiversity. It boasts a considerable network of protected areas, including 10 national parks and many reserves and conservation areas. The oldest of these—Chitwan National Park—was established in 1973 to protect against deforestation and poaching, particularly of the one-horned rhinoceros. Chitwan was declared a UNESCO World Heritage Site in 1984 and has become one of Nepal's most popular tourism destinations, attracting thousands of local and international visitors each year.

Entry fees paid by visitors to protected areas are the primary source of revenue for Nepal's national parks. To encourage local support, many national parks also direct a portion of their entry fees to surrounding communities to use for development and natural resource management (including conservation) purposes (Figure 9).

Nepalese authorities suspected that existing entry fees for Chitwan National Park were too low, but the appropriate level of fee increase was uncertain.

Led by Dr Ram Pandit, this project investigated the "willingness-to-pay" for entry to Chitwan by domestic and international visitors. It also explored the factors affecting this willingness and the trade-offs between entry fees charged, visitation demand and park revenue. Results revealed that visitors' average willingness-to-pay was more than 2.5 times the existing entry fee.

Relevance and impacts

Using evidence from this research, the Department of National Parks and Wildlife Conservation successfully petitioned the Nepalese Ministry of Finance to revise the entry fee policy for protected areas throughout Nepal.

Tourism entrepreneurs had opposed previous attempts by the Nepalese Government to raise the entry fees, fearing a decline in visitor numbers. According to the Deputy Director General of the Department of National Parks and Wildlife Conservation, "the research findings provided the scientific basis to convince the politicians as well as [the] local people". Without this evidence "the process [for reviewing] the revenue rate would have been further delayed".

In the case of Chitwan, the immediate impact of fee revision was to nearly double park revenue (Figure 10). Local development has ensued and new conservation activities have been funded. For example, the extra revenue has helped finance the reintroduction of locally extinct species and funded successful anti-poaching programs that recently saw over 1000 days with no rhinoceros poaching (Figure 11).

Academic outputs and impacts

This project was highly weighted towards evidence-based policy rather than the creation of knowledge. An article about this research published in the journal *Tourism Management* has been cited three times in Web of Science since 2015. The work has also been presented at two conferences.

Collaboration and engagement

CEED-funded staff assisted in the analysis of the data and also in a mentoring capacity to integrate environmental decision science into the research outputs, extending the impact of these results. The research was conducted in close collaboration with staff from the Nepalese Department of National Parks and Wildlife Conservation who, with the assistance of some local hotels and tourist operators, did the on-ground data collection. Findings were communicated to stakeholders through briefings, workshops, presentations and networking opportunities.

Prospects for future impacts

Perhaps the most significant impact of this research has been the response from inside the Nepalese Department of National Parks and Wildlife Conservation. Chitwan National Park's chief park warden testified that the research had given the Department "an opportunity to enhance academic and managerial capability on science-based management". This has helped foster a new mind-set on the use of research to underpin policy development and decision-making processes, which is being transferred to other areas of their work.

Dr Pandit is looking at new research topics to strengthen links with the Department over the coming years.

More information: Ram Pandit ram.pandit@uwa.edu.au

Academic performance: Low
Impact: High
Potential for Increase: Low

Figure 9. Locals from the buffer zones surrounding Chitwan National Park being trained in improved agriculture and animal husbandry, using funds from park entry fees. (Photo: Ram Pandit).

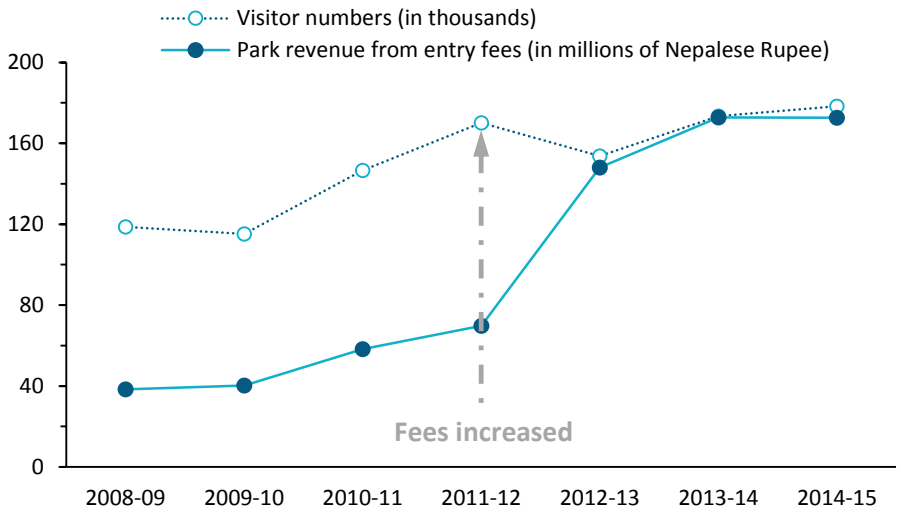

Figure 10. Chitwan National Park's revenue greatly increased when entry fees were revised based on this research (unpublished data from Ram Pandit).

Figure 11. A Minister in the Nepalese Government unveils a sign celebrating 1000 days with zero rhinoceros poaching. (Photo: Ram Pandit)

Case study F: Making the most of biodiversity offsetting

Biodiversity offsetting seeks to counterbalance impacts caused by development and it has become an important and widely-used policy tool both in Australia and internationally. However, its merit as a policy approach is strongly contested. CEED's multidisciplinary research on biodiversity offsetting has investigated the fundamental issues underpinning the approach. It has raised Australia's general understanding of the concept in both government, academia and with the general public, and it has improved assessment methods and strategic decision-making for biodiversity conservation.

CEED researchers: Ascelin Gordon, Sarah Bekessy (RMIT), Hugh Possingham, Megan Evans (University of Queensland), Brendan Wintle, Pia Lentini, (University of Melbourne), Richard Hobbs, David Pannell, Ram Pandit, Abbie Rogers (University of Western Australia). Further researchers were involved in this project at different points in the program.

Principal collaborators: Joseph Bull (University of Kent), E-J Milner-Gulland (Oxford), Martine Maron (University of Queensland), Phil Gibbons (Australian National University).

The challenge

Biodiversity is in decline worldwide. Developments such as roads, dams and buildings are a major contributor to this decline because they cause the loss or degradation of habitat. ''Biodiversity offsetting'' has been proposed as one way to deal with this impact by compensating for the environmental impacts caused by development.

Biodiversity offsetting works by counterbalancing losses of biodiversity in one place by generating equivalent biodiversity benefits elsewhere. The aim is to achieve "no net loss" of biodiversity. An effective biodiversity offset requires a developer to create, restore or protect habitats equal to or greater than the habitat being destroyed by a development. However, concerns have been raised regarding the process, with some studies showing that biodiversity is likely to be lost because the schemes are ineffectual, are inappropriately calculated or because sites do not have long-term protection (Figure 12).

This CEED project started in January 2012 with several aims: to understand how offset policies operate; to develop a range of new techniques, approaches and methods to structure biodiversity offset policies in the presence of real-world complexity; to understand unintended consequences that could result from offset policies; and, to explore perceptions of various stakeholders on biodiversity offsetting including policy and practice. It is a project that sought to incorporate multidisciplinary perspectives in tackling these knowledge gaps.

Relevance and impacts

Although the idea of offsetting seems straightforward, practical implementation faces some challenges. Research conducted in CEED has shown that use of the approach can have serious risks for biodiversity if it is not implemented in a theoretically sound way.

More than 15 reports and submissions to Australia's federal and state governments have been delivered under this project. One notable contribution was made in 2014 by Dr Ascelin Gordon and Dr Martine Maron, who were invited to review the New South Wales Government's draft framework for biodiversity assessment for assessing and offsetting state-significant development and state-significant infrastructure. This involved critically assessing several policy documents, meetings with government officials and the delivering of a report containing a set of recommendations. A team leader in the NSW Government's Office of Environment and Heritage spoke highly of this review, stating the recommendations "fed into the plan" by broadening the understanding of "the other factors that should be considered, such as social and economic factors" and "provided supplementary measures that could be used in conjunction with existing measures". Overall, they described CEED's research on biodiversity offsetting as well thought out, practical and applicable to assessment methods, such as evolving the variation rules and the strategic location of offsetting sites.

In another example, Dr Pia Lentini was an expert witness for a Planning Panels Victoria hearing, providing assessments as to whether the proposed offsets for the large development planned for Maldon, Victoria would lead to a net loss.

Anecdotally, this research has also informed legal cases and guided the development of

some offset projects. One of CEED's key collaborators, United Kingdom-based Joseph Bull, who is a co-author on many CEED-led papers, has referred to this body of research when developing "no net loss" or "net gain" strategies in Canada and Kazakhstan subject to the IMF's Performance Standard 6. Additionally, he was invited to join a panel with ministers from the United Kingdom to discuss the biodiversity offsetting. His messages have since been referred to and used by United Kingdom and European Union policymakers as part of their evidence base for policy decisions on biodiversity offsets.

Academic outputs and impacts

This project has benefited from collaboration with researchers from across the CEED nodes and partner organisations as well as other researchers in the CEED network. There has been a series of papers publishing the results, with CEED researchers leading 10 journal articles that have produced 258 citations collectively (as recorded on Google Scholar in March, 2017). Several of these papers have been identified as a best-practice resource for implementing offset projects and policies and are included in the international database Business and Biodiversity Offsets Programme (BBOP) library.

Collaboration and engagement

The research has been undertaken in a highly collaborative environment, drawing on expertise in all the CEED nodes (involving five chief investigators), CEED partners and the CEED network. Through a variety of engagement activities including scoping phases, working relationships were developed in Australia with offset providers/managers/regulators at both the federal and state level, as well as environmental consultants. For example, one study involved a collaboration with the Commonwealth Department of Environment and Western Australia's Department of Parks and Wildlife to better understand the perception of stakeholders on the practice of biodiversity offsetting. The results described commonalities and differences in perceptions among key stakeholders, which helps to bridge the gaps and generate better outcomes from biodiversity offsetting.

This research has been communicated through numerous briefings, conferences and workshops. For instance, a "Biodiversity offsetting: Policy and practice" workshop was

held in Perth during 2015 with academics, policymakers, state offset regulators and professionals exchanging ideas to improve biodiversity offsetting policy and practice in Australia.

A symposium was held as part of the 27th International Congress for Conservation Biology in Montpellier, France, August 2015. It included 11 speakers presenting various aspects of research around biodiversity offsetting including CEED researchers such as Dr Ascelin Gordon who presented "The use of model-based approaches for evaluating the effectiveness of no net loss policies".

Biodiversity offsetting is a highly topical issue and has received considerable media attention. Outputs from this research project, such as a comment piece in *Nature* (Vol 523, Issue 7561, pp. 401–403), have featured in media coverage around the world. There have been many articles published in Australia, specifically *Decision Point* (including a special feature on offsetting in August 2015), The Conversation, ABC Science Online, *Brisbane Times*, SBS News Australia and other editorials available to a general audience.

A 2015 publication titled "Perverse incentives risk undermining biodiversity offset policies", which was published in the European Commission's Science for Environment Policy newsletter, was sent to over 18,000 policymakers, academics and business people to assist in the development of effective, evidence-based policies.

Prospects for future impacts

This research project has played a significant role in developing some of the fundamental theory underpinning biodiversity offsetting including its ecological basis, as well as economic and social factors. As such, it lays the groundwork for continued research. As biodiversity offsetting is a relatively new concept, there will be many opportunities for future research that builds upon this work and advances strategic thinking in offsetting methodologies, implementation, assessments, policy and legislation. The research team is in a good position to collaborate with governments and continue to influence the research agenda.

More information: Ascelin Gordon ascelin.gordon@rmit.edu.au

Academic performance: Very High

Impact: Moderate

Potential for Increase: High

Figure 12. How many native trees do you need to plant to offset the loss of one old habitat tree that took 200 years to develop? This type of issue needs to be dealt with when calculating an appropriate biodiversity offset. Photo: David Salt

Case study G: Extending Marxan's reach: Building capacity and outreach

This project supports and extends the impact that the Marxan software is having in conservation planning by governments. It provides training, capacity building and collaboration to an ever-increasing international user base.

CEED researchers: Hugh Possingham, Jennifer McGowan (University of Queensland). Other Researchers and postgraduate research students have been involved in this project for short periods.

The challenge

Marxan is a suite of software tools that delivers decision support for conservation planning in marine and terrestrial environments. It informs the selection of new conservation areas that meet specified targets at least cost and it facilitates discussions around trade-offs between conservation and socio-economic goals. Marxan can also be used to evaluate the adequacy of existing reserves and highlight those areas, which if reserved, would improve the representativeness and comprehensiveness of a reserve network.

The original Marxan program was developed in the 1990s by a PhD candidate Ian Ball and his supervisor Professor Hugh Possingham, at The University of Adelaide, to assist with the Australian Government's Regional Forest Agreements process. Since then it has undergone a series of modifications and updates and been used in some applications, such as the rezoning of the Great Barrier Reef Marine Park in Australia.

Its flexibility and ease of use (and the fact that it is free) have made Marxan the world's most-used software for supporting the design of marine and terrestrial reserves and allocating scarce conservation resources. The challenge with Marxan is in continuing to grow its community of users and ensuring that it continues to evolve to meet an ever-growing range of conservation planning needs.

Marxan's development has been financed by a combination of government funds, grants and research contracts including, in more recent times, CEED. CEED support has been pivotal in increasing the global impact of Marxan by facilitating outreach, helping

disseminate expert advice and training (Figure 13 and Figure 14) and providing a capacity for collaboration with end users.

Relevance and impacts

When CEED first became associated with Marxan, there were approximately 2600 users of Marxan. There are now more than 7000 users in 180 countries. As much as 5% of the surface area of the world has been influenced by the implementation of Marxan plans. There are countless examples of Marxan being used around the world, many of them by users who received training and advice from CEED researchers under this project.

It is difficult to measure the impact of this outreach. One end user of Marxan and the outreach project is Dr Elena Gissi from the Department of Design and Planning in Complex Environment, University Iuav of Venice. She said: "In my case, I considered the training indispensable to try to apply Marxan in real decision-making processes that I am involved with. I am not sure I will succeed in applying what I have learned, but this is because of internal and external limitations of the real decision-making processes." She acknowledges that "Marxan: outreach and capacity building project is doing a great good job in bridging this gap". Considering this, it is highly possible that the tool would have less uptake without the existence of this project.

Another attendee of a Marxan training course was Gustavo Almada, from Brazil's Ministry of Environment. He used software to design a possible network of deep-sea reserves off the Brazilian coastline in a manner complementary to Brazil's off-shore oil fields. At the end of 2015, he participated in a Marxan training course led by Jennifer McGowan and believes it was essential for his conservation planning efforts. "The Marxan workshop was critical to our research," he said. "It allowed me to use the Marxan software properly, to develop the input files with confidence, to completely understand the mechanics of Marxan's underlying algorithm (and its limitations and premises) and to appropriately interpret the software's outputs."

Academic outputs and impacts

A book chapter on Marxan from 2009 (before the start of CEED) has been cited 634 times in Google Scholar. However, while funded under CEED, the focus has been on capacity building and outreach to extend the impact of Marxan rather than producing

academic outputs.

There is continuing strong demand for Marxan and the training associated with it delivered by CEED members. The demand for PhD placements far outweighs the intake and prospective users frequently visit CEED for training in Marxan. CEED postgraduate researchers have been given the opportunity to be actively involved in the running of Marxan workshops as part of their research training program. In 2016, CEED researcher Dr McGowan trained almost 250 professionals from 10 countries, which included people from at least 30 nationalities.

Collaboration and engagement

Marxan's user group includes members from over 220 universities, the UN, the IUCN, major conservation NGOs and over 50 government agencies. In addition to responding to requests for training and advice on the application of Marxan, several opportunities to collaborate with CEED researchers who assist in the design and implementation of conservation projects have been realised. For example, after Dr Gissi attended the Marxan training in Venice in 2016, she developed a research proposal with support from CEED researcher Dr McGowan that included a visit to the CEED Node (University of Queensland). The proposal has been put forward to the SUPREME project (Supporting Maritime Spatial Planning in the Eastern Mediterranean) and will involve working with the responsible authorities from European Union Countries. This type of collaboration keeps CEED researchers informed on how Marxan could be further developed and upgraded when funding becomes available.

Prospects for future impacts

The Marxan software is still cutting edge, and there continues to be a high demand for collaboration, training and support in its use. However, to maintain its relevancy and usability, on-going upgrades to the software as well as updates to material for training and workshops are required. With a continued and appropriate level of funding, it is possible Marxan could have an even greater impact around the world.

More information: Jennifer McGowan j.mcgowan@uq.edu.au

Academic performance: Moderate (in relation to CEED publications)

Impact: Moderate (in relation to CEED's contribution, which has primarily been training and support)

Potential for Increase: Moderate

Figure 13. Hugh Possingham launches another Introduction to Marxan course at the University of Queensland. Photo: David Salt

Figure 14. Matt Watt goes over a training exercise with Azusa Makino during the train-the-trainer day. Photo: David Salt

Case study H: Playing with fire: managing fire and weeds for biodiversity conservation

CEED research involving long-term ecological data is generating valuable insights into how governments can better manage fire to conserve biodiversity and control invasive weeds. The investigations are highly relevant to fire management guidelines in New South Wales.

CEED researchers: David Lindenmayer, Claire Foster, Jane Catford and Phil Barton (all from The Australian National University).

Principal collaborators: Chris MacGregor, Jeff Wood and Natasha Robinson (all from The Australian National University).

The challenge

Fire is a major force in shaping Australia's ecosystems and plays an important role in both weed management and biodiversity conservation. Starting in mid-2014, this on-going project involves the use of long-term data to test the impact of fire-management and weed-management strategies in New South Wales on plant and animal biodiversity. The research is being conducted in the 6400 ha Booderee National Park near Jervis Bay (NSW South Coast).

Specific questions under investigation include the following: Does the fire regime that best promotes diversity differ across vegetation types/environmental gradients within landscapes? Should fire management be adjusted after large unplanned fire events to preserve important habitat features? For bitou bush (*Chrysanthemoides monilifera* subsp. *rotundata*) (Figure 15), a nationally-significant invasive weed typically controlled with fire and herbicide application, what exactly are the most economically-effective and ecologically-effective control strategies?

The results are providing significant new insights into the inter-relationships between fire and the spatial and temporal responses of species and ecosystems. The work also has shown that the spray-then-burn-then-spray approach currently used widely for controlling bitou bush is the most cost-effective. The approach was found to stimulate the recovery of native plant species and colonisation by endangered animal species

(whereas other control strategies were less effective and sometimes even exacerbated the impact of invasive plants).

Relevance and impacts

Findings from this research have been incorporated into the weed control strategies and fire management plans (particularly around prescribed burning) for the Booderee National Park and also the adjacent Beecroft Weapons Range. While the impact of this study has been at the local level, the example of how scientific research can inform land management has been held up as an example of best practice management.

Academic outputs and impacts

This research has been published in seven journal articles with more in preparation/under review. Two CEED postgraduate students have obtained their doctorate qualifications as part of this research.

Collaboration and engagement

There has been extensive engagement with the managers of Booderee National Park and the Beecroft Weapons Range military estate. Researchers from CEED's Australian National University have a particularly strong relationship with the park's managers, regularly collaborating in the field, conducting joint workshops and sharing findings.

Prospects for future impacts

Findings are potentially applicable to other conservation areas with similar vegetation types (there has also been interest in the results of this research from other agencies responsible for park and natural resource management in New South Wales), and so there is potential that they will be utilised more broadly.

More information: David Lindenmayer david.lindenmayer@anu.edu.au

Academic performance: High

Impact: Moderate

Potential for Increase: Low

Figure 15. Nick Dexter (foreground), project officer Booderee National Park, discusses the control of Bitou bush at a workshop with managers and researchers in the park.

Case study I. Metapopulation models to manage threatened frogs

What conservation actions in which locations will maximise the likelihood of the survival of the threatened growling grass frog (Figure 16) in urban growth areas around Melbourne? Coming up with viable solutions amid high uncertainty is a major challenge, but CEED researchers at the University of Melbourne have worked with the Victorian Department of Environment, Land, Water and Planning to develop metapopulation models that have generated key insights that are guiding managers. The model that has been developed is now being used to guide one of the largest-ever investments in threatened species conservation in Victoria.

CEED researchers: Geoff Heard and Mick McCarthy (both University of Melbourne).

Principal collaborators: Michael Scroggie (Department of Environment, Land, Water and Planning, Victoria) and Kirsten Parris (University of Melbourne).

The challenge

Metapopulations often occur when a species has a naturally and/or artificially fragmented habitat. Each sub-population is (spatially) separated from the others, but there is movement or interaction between them. Such is the case with the endangered growling grass frog (*Litoria raniformis*). It was once very common in Victoria but has been heavily affected by disease and urban development. Protecting the species requires an understanding of how its metapopulations function.

This project sought to build models of the growling grass frog's extinction and colonisation dynamics among wetlands in the urbanising landscapes of Melbourne. The model takes into account wetland attributes, such as size, hydroperiod and vegetation, as well as spatial connectivity. This model was then integrated within a decision framework that encompassed all possible wetland creation, protection and enhancement options, the cost of each option and uncertainty about its effectiveness.

The result of this process was a prioritisation tool that can be used to identify which actions in which locations will maximise the likelihood of growling grass frog persistence within development zones. These management actions are robust to uncertainty yet achievable, given typical conservation budgets.

Relevance and impacts

The prioritisation tool developed during this project is now being used to guide one of the largest-ever investments in threatened species conservation in Victoria: an anticipated $60 million for wetland protection and construction across Melbourne's urban growth areas over the next 30 years (helping the Government meet a major objective of the Melbourne Strategic Assessment under the Environment Protection and Biodiversity Conservation Act). This investment is funded by fees paid by developers to offset the impact of their developments. This investment was not a result of the research, but it is being guided by the research.

As an example of the potential impact of this research, a case-study conducted as part of this research project revealed that in an urbanising region north of Melbourne, some conservation actions were likely to be 10-12 times more cost-effective (better value for money) than others. Of all the actions that could be taken to preserve the growling grass frog, only a limited subset of them offered near-zero probability extinction from the study area. This highlights the importance of undertaking the right actions in the right locations. Without the prioritisation tool, the expenditure of the funds for growling grass frog conservation would likely have been guided by some broad principles and guidelines developed from expert opinions. With the tool, more specific and objective guidance can be provided and confidence in the results can be higher.

According to Kathy Preece, from the Biodiversity Division of the Victorian Department of Environment, Land, Water and Planning, there have "been offsets for large developments projects in the past and in almost every case the offset wetlands have failed. We needed to account better for the requirements of the frogs and adopt a much more rigorous approach to offset design. So this research has been extremely useful."

This research has also been utilised by consultants working on the conservation of growling grass frog more generally, and some of the principles that have come out of this research have been adopted more broadly by the Victorian Government in their guidelines for wetland habitat creation and management. The models and tools developed in this research have also been adapted for a vulnerable amphibian in NSW, the green and golden bell frog.

Academic outputs and impacts

This research has been published in some of the leading ecology and conservation journals. Seven peer-reviewed journal articles have been produced with another forthcoming.

Collaboration and engagement

This research has involved numerous collaborations within the University of Melbourne and with government agencies including the Victorian Department of Environment, Land, Water and Planning (and its precursors), Melbourne Water and Parks Victoria. The government agencies have also been engaged as end users of the research.

According to Geoff Heard, the principal researcher on this project, "Financially, compared to other funders, the contribution of CEED to this research was relatively minor [CEED funded several PhDs and postdoctoral fellows involved with this research plus at various times more senior researchers]. However, what CEED did is create an environment and a capacity to do it [the research]. On numerous occasions, I approached colleagues from CEED to canvass their opinion or sought the technical assistance of CEED members with specific problems such as coding or elements of spatial analysis."

Prospects for future impacts

Now that it has been developed, the prioritisation tool can continue to be used to guide investment in urban wetland conservation for the foreseeable future with minimal updating. As it is potentially applicable for prioritising investment in the conservation of amphibian species with similar population characteristics, the model code has been downloaded by overseas researchers.

More information: Geoff Heard gheard@csu.edu.au

Academic performance: High

Impact: High

Potential for Increase: Low

Figure 16. Geoff Heard with a threatened growling grass frog.

The *Decision Point* magazine

The *Decision Point* magazine, edited by David Salt, was established as a way of engaging policymakers, resource managers and the wider public with the research being undertaken by CEED (and related research networks). It showcases CEED's research in brief, engaging and understandable articles. It is available online and in hard copy.

A key aim of CEED in producing *Decision Point* has been to contribute to a cultural shift in environmental policy and management in Australian governments at all levels. The intended shift is away from ad hoc, opaque decision-making towards more transparent, accountable, systematic and adaptive decision-making. Another aim is to produce a community of interest in environmental decision science. Over the course of *Decision Point*'s 10-year life, the field of environmental decision science has grown from a little-utilised academic pursuit to become a cornerstone of environmental policy and management. There is strong anecdotal evidence to suggest that, over its 100+ issues, *Decision Point* has played a role in this transformation in Australia.

Over its life-time, CEED has been the major funder of *Decision Point*. It was established in 2008 by the Applied Environmental Decision Analysis Hub, the precursor network to CEED. The magazine was also partly funded by the National Environmental Research Program Environmental Decisions Hub

Decision Point goes beyond the usual communication strategies of research centres (information sheets, press releases, briefings, seminars and so forth). It gives a "voice" to the network of environmental decision scientists in CEED that it serves. It carries editorials from Australia's leading decision scientists and conservation actors commenting on all aspects of environmental decision-making. It also presents stories and science from other networks and organisations (such as CSIRO and the Department of Environment and Energy).

The audience of subscribers consists of researchers, policymakers, resources managers and members of the general community. The approximate breakdown is 25% Australian state governments, 20% Australian researchers, 17% international researchers, 10% Australian Commonwealth Government, 25% public and corporate (Figure 17). Initially, *Decision Point* was circulated to several hundred people, but it has now grown to around 6500 subscribers.

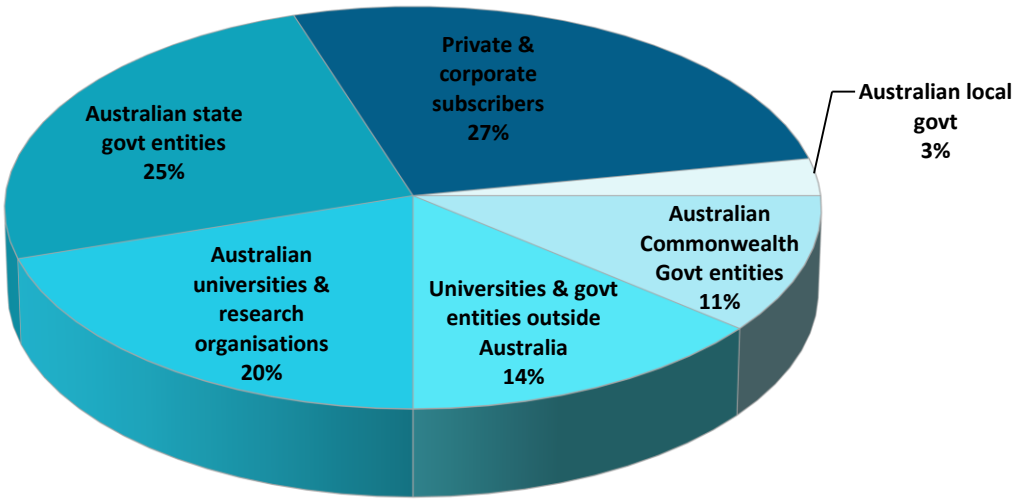

Figure 17. Breakdown of the readership of *Decision Point*.

Here are some examples of feedback from readers:

"*Decision Point* would have to be the most relevant and insightful publication I receive. The coverage of issues is excellent, the content innovative and the research findings are incredibly useful in my everyday work. Thanks to the team for a great resource and keep it up." Kirsti Sampson, Southern Rivers Catchment Management Authority, NSW

"I want to pass on how much I and the team enjoy reading *Decision Point*. We find it not only useful to apply information to get on-ground outcomes (environmental rehabilitation and restoration projects) but also feel inspired by the dedicated research occurring that keeps knowledge up to date." Mia Dalby-Ball, Environmental Consultant

"I really enjoy reading *Decision Point*; good information, relevant pitch, stimulating debate and provocative essays (should be more of it)." Peter Copley, Senior Ecologist, Threatened Species & Ecological Communities Unit, Department of Environment and Heritage, South Australia

"Would like to do something similar to *Decision Point* for ecosystems and biodiversity in South Africa - this is a lovely example - well done." Wiida Basson, Senior Communicator, Council for Scientific and Industrial Research, South Africa

"I just read your article in *Decision Point* and will forward it to our fire management staff in western NSW. Thank you for such a well-written article that provides some sensible management options." Belinda Kenny, Fire Science Interpretation Officer, NSW National Parks & Wildlife Service

"I love this magazine by the way. I have been sending it to colleagues of mine who are of the same opinion." Les Purves, Karara Mining Ltd, Perth

"Thanks for consistently filling your publication with interesting, frank and creative discussions. The reading material is appreciated." Jenni Timbs, Biodiversity Assessment and Management Pty Ltd, Queensland

"A lot of research centres have on-line newsletters and feeds that synthesise and break-down their research into useable and digestible chunks—an absolutely essential function given how time poor us readers and end users are. That said, *Decision Point* does this in a captivating and enticing format and manner that is head and shoulders above the rest. Frankly, *Decision Point* is one of the only newsletters I receive that I prioritise reading, and I do this because the content is captivating and the format makes it easy to understand and digest the huge amount of information. Cross-referencing to past issues, and the thematic focus of each issue is very reader-friendly. You and your team are to be congratulated on what is truly an exceptional product." Andrew Chin, Climate Change and Science Coordination, Environment and Sustainability Branch, Great Barrier Reef Marine Park Authority

Policy impact

Policymakers form a significant part of the readership of *Decision Point* (see the box on who reads *Decision Point*). And we know from direct feedback that *Decision Point* is influencing policy and management. For example, here are some examples of comments

made by senior policy officers on *Decision Point*'s influence.

"*Decision Point* was one of the best things to come out of the NERP Program*. Among other things, it provides a direct and timely link from the work of researchers to policy advisers and policymakers. One of the keys to its success is striking the right balance between providing engaging material and policy-relevant insights."" Paul Grimes, Secretary, Australian Government Department of Sustainability, Environment, Water, Population and Communities. (*The National Environmental Research Program, NERP, contributed to the funding of *Decision Point* 2011-2015)

"Just wanted to commend you guys on an excellent mag—we use it to inform a lot of our thinking." Todd Maher, Natural Resource Analyst, Natural Resources Commission, NSW Government

"It's of great benefit being able to tap into the current best practice approaches and ideas emerging from academia." Julian Seddon, Department of Environment and Sustainable Development, ACT Government

Assessment of publications, citations and collaborations

Background

In this analysis of CEED publications, the only types of publications considered were those in peer-reviewed periodicals. Publications were regarded as "CEED publications" and analysed in this section if they had an author affiliation in the byline and/or funding attribution to CEED. Some publications (<15%) did not meet either of these criteria but were approved for inclusion by CEED's director.

In all, 887 journal publications are included in the analysis. They span publications from the commencement of CEED up to, and including, those reported in the 2016 Annual Report (some were included in the 2016 Annual Report because they were available online in 2016, although they have an official publication year of 2017). It, therefore, does not include all the publications that will be produced by CEED over its life.

Unless otherwise stated, data on publications and citations were sourced from ISI Web of Science (WoS) as of 24 December 2017. While its coverage is wide, WoS does not index every publication. CEED publications in journals that WoS does not cover are therefore not part of the following analysis and results. Similarly, citations of CEED publications in journals not covered by WoS are also not captured. WoS was used as the data source for reasons of technical convenience. The coverage of alternative sources of data on publications and citations (Scopus and Google Scholar) is slightly different and would return different results (Google Scholar would tend to capture more non-journal citations of CEED publications, such as those in reports or books). Of the 887 CEED publications identified, 848 were indexed in WoS and are analysed below.

Journals

Due to the time needed to complete research and time lags in the publication process, the number of publications in the early years of CEED was initially lower (Figure 18). These time lags also mean that CEED research will continue to be published after the expiry of CEED and beyond the timeframes of this analysis.

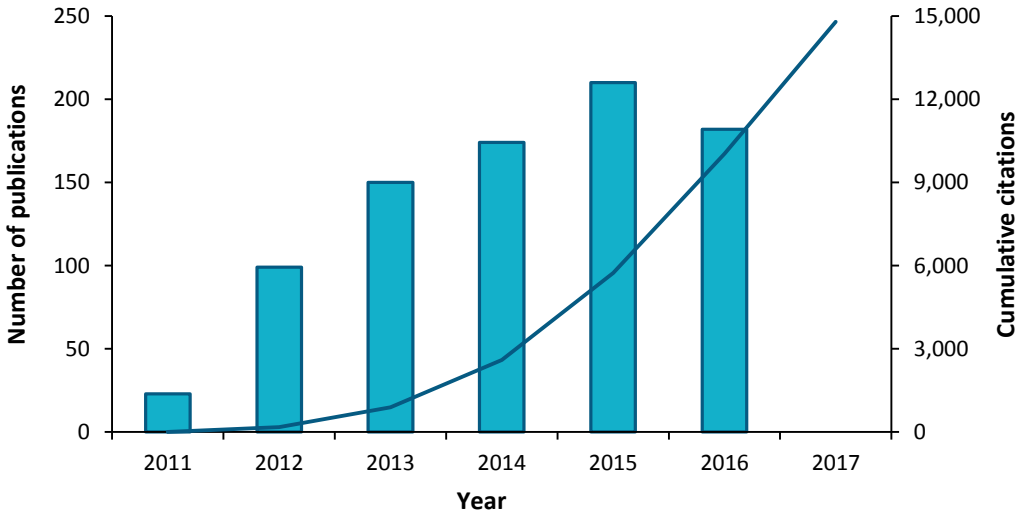

Figure 18. CEED publications (up to and including those reported in 2016) and cumulative citations of CEED publications (up until 2017).

CEED publications have appeared in 164 journals, most frequently in *Biological Conservation* (62 publications), *Conservation Biology* (60) and *PLOS ONE* (56)

(Table 2). All of these journals are strong in terms of Impact Factor. Of the 19 journals with 10 or more CEED publications, 17 are in the top quartile of their fields. Weighted by the number of publications in each journal, the average journal impact factor (based on 2016 impact factors) across all CEED publications is 5.4. There have been 58 publications in journals with an Impact Factors greater than 10, including nine papers in *Nature* and 14 in *Science* (Table 3).

Table 2. The journals within which CEED articles have been published most frequently

Journal	No. of publications	Journal Impact Factor (2016)
Biological Conservation	62	4.0
Conservation Biology	60	4.3
PLOS ONE	56	3.1
Diversity and Distributions	39	4.6
Journal of Applied Ecology	33	5.2
Conservation Letters	33	7.1
Ecological Applications	31	4.3
Global Change Biology	19	8.4

Table 3. CEED published 58 papers in journals with Impact Factors greater than 10 between 2011-2016

Journal	No. of publications	Journal Impact Factor (2016)
Nature	9	38.1
Science	14	34.7
Nature Climate Change	10	17.2
Trends in Ecology & Evolution	10	16.7
Nature Communications	7	11.3
Ecology Letters	6	10.8
Biological Reviews	2	10.7

Collaboration and co-authorship

The analysed CEED publications have involved co-authors from 74 countries. 82% of the publications have involved cross-institutional collaboration. 60% of the publications have involved international collaboration. The levels of cross-intuitional and international collaboration between 2011 and 2016 are shown in Figure 19. Tested with regression analysis, the proportion of CEED publications with international co-authors has significantly increased with over this period ($P<0.02$), while the proportion of

publications with cross-institutional collaboration has not significantly changed.

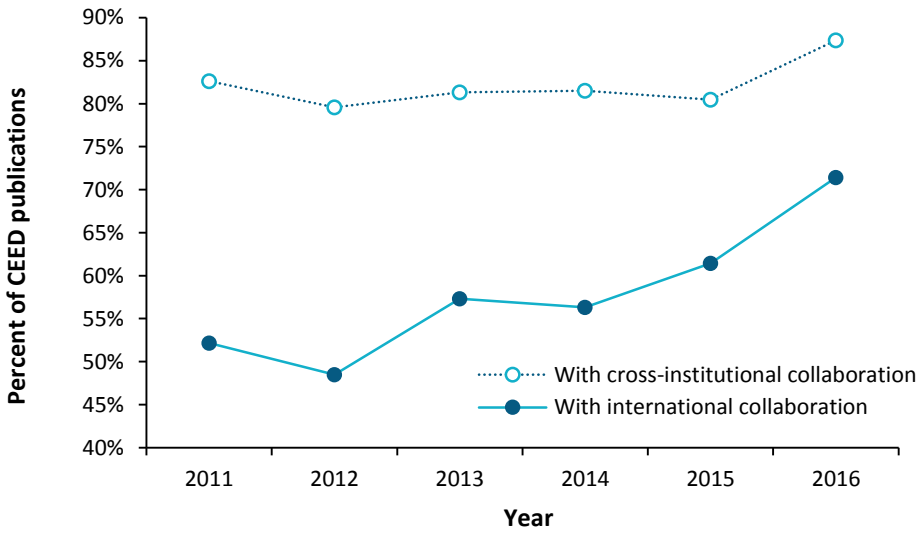

Figure 19. During CEED's lifetime, the proportion of publications involving international collaboration has increased.

Citations

The 848 publications have been cited 14,996 times by 10,460 different articles in WoS (meaning that, on average, each CEED publication has been cited 18 times). If self-citations are excluded (that is, not including any citations by any of the other 847 CEED publications), the 848 publications have been cited 13,482 times by 9,949 different articles in WoS (an average of 15.9 citations per publication). Overall, the CEED publications covered in WoS have an H-index of 53 (meaning that of 848 publications since 2011, 53 of them have cited at least 53 times in WoS)

CEED publications are disproportionately among the most cited papers in their disciplines. More than a quarter of CEED publications are in the top 10% of the literature, based on their citations. Based on data from Essential Science Indicators, 39 CEED publications (one in every 22 of the CEED publications covered in WoS) are "Highly Cited", which is defined as having received enough citations to place them in the top 1% of their academic fields in the past 10 years, taking into account the characteristics of the fields and publication date. Papers generally have to be published

for a year before they can be recognised as Highly Cited, so CEED is likely to have more Highly Cited papers over time.

Areas of research

Table 4 shows the distribution of CEED publications according to research areas, based on the categories used by Web of Science. By a considerable margin, the three most-covered research areas are Ecology, Biodiversity Conservation and Environmental Science. Nevertheless, the table illustrates the wide range of additional topics covered by CEED research, including pure biology, physical geography, meteorology and economics. For all but two of the research areas, well over 10% of publications are in the top 10% of journals.

Table 4. Performance of CEED publications broken down by the most covered areas of research (based on Web of Science categories)

Research Area[1]	Number of pubs	Highly Cited pubs[2]	Average citations per publication: (unadjusted)	Average citations per publication: (adjusted[3])	% pubs in top 10%[4] (adjusted[3])
Ecology	588	30	13	2.0	23%
Biodiversity Conservation	300	9	13	1.9	29%
Environmental Sciences	277	13	14	1.8	23%
Environmental Studies	55	5	14	2.7	36%
Evolutionary Biology	39	3	15	1.4	18%
Geography, Physical	36	4	12	2.3	25%
Biology	28	2	25	2.4	25%
Zoology	27	1	6	2.0	19%
Plant sciences	22	3	5	2.5	23%
Forestry	20	0	6	1.4	10%
Meteorology & Atmospherics	19	2	21	2.7	37%
Economics	17	0	7	2.4	41%
Geosciences, Multidisciplinary	17	0	8	1.1	6%

[1]A publication can belong to more than one research area

[2]Based on citations they are in the top 1% of their respective academic fields over the past 10 years, taking into account the characteristics of that field and publication date

[3]Adjusted for research area and year of publication

[4]Top 10% of that field based on average number of citations per paper

Altmetrics

The Altmetric Score for a research output provides an indicator of the level of online attention that it has received. This is based on data from a range of sources, including:

- science-specific media (e.g. New Scientist)
- mainstream media (more than 2000 news outlets, both English and non-English)
- social media (Facebook, Twitter, Pinterest, Google+, blogs, etc.).

Citations in academic publications are not included in an article's Altmetric Score, but citations in other ''grey'' literature like public policy documents can be. Altmetric data was sourced from Altmetric.com and was correct as of 16 June, 2017. There were 739 of the 887 CEED publications listed on altmetric.com

The data show that CEED performs strongly in gaining media and social media attention. When compared with publications of the same age, 324 (44%) of the 739 CEED publication have an Altmetric score above the 90th percentile and 671 CEED publications (91%) exceed the 50th percentile when compared with publications of the same age. The 739 CEED publications tracked by altmetric.com have been mentioned in a combined total of 15,600 tweets.

Altmetrics.com includes a measure of the number of times that a paper has been cited in policy documents. However, the measure is known to be biased towards North America and Europe (Bornmann et al. 2016), and we noted that many Australian policy citations of CEED research were not captured by Altmetrics. Despite this, CEED research performed strongly at the international level relative to other research. Of the several million publications covered in both altmetric.com and Web of Science, only 0.32% of them had been cited in at least one policy document and, when broken down by 228 Web of Science subject categories, there was no category in which more than 3% of publications were mentioned in policy documents (Haunschild and Bornmann 2017). Against this background, the performance of CEED in having 7.2% of its publications cited in policy documents (according to Altmetrics) is strong and, as noted above, the reality is even stronger.

IMPACT BRIEF: Outstanding Altmetrics performance

According to altmetrics.com, this CEED publication:

Watson, J., Shanahan, D., Di Marco, M., Allan, J., Laurance, W., Sanderson, E., Mackey, B. and Venter, O. (2016). Catastrophic declines in wilderness areas undermine global environment targets. *Current Biology*, 26(21), 2929-2934;

was the 59th most discussed out of all articles published in any discipline during 2016, and had the seventh highest Altmetric Score out of all publications with at least one Australian-affiliated author. It was also the fifth most discussed article globally in Earth and Environmental Sciences in 2016. Out of the nearly nine million publications altmetric.com has ever tracked in its entire database, it was ranked 334th highest, as of 22 August 2017.

Early career researchers

CEED invested strongly in training, mentoring and support for Early Career Researchers (ECR), and this investment is reflected in the academic metrics for CEED publications (Table 5). Out of the 848 CEED publications analysed, 36% had a CEED ECR as first author and 60% had at least one CEED ECR author. Regarding average citations per paper, the proportion of Highly Cited papers, and papers with very high Altmetric scores, papers with ECR lead authors or co-authors performed just as strongly as papers without ECRs (Table 5).

The criteria for being an ECR was postgraduate students and postdoctoral fellows within 5 years of the conferral of their PhD. Hence in some cases, a given researcher's publications were eligible as early career publications earlier in CEED's lifetime, but not later on.

Table 5. Breakdown of the involvement of CEED Early Career Researchers (ECRs) in the 848 CEED publications covered in Web of Science

	All CEED publications	Pubs with CEED ECR 1st author	Pubs with at least one CEED ECR author
% of CEED publications	100%	36%	60%
Total citations	14,996	4,699	8,202
Average citations per publication	17.7	15.4	16.0
No. of ''Highly Cited''	39	12	23
No. of pubs with score on altmetric.com ≥ 90th percentile[2]	324	126	213

[1]Based on citations that are in the top 1% of their respective academic fields over the past 10 years, taking into account the characteristics of that field and publication date.

[2]When compared with publications of the same age. Note: Altmetric data is correct as of 16 June, 2017.

Co-author collaboration on CEED publications

Figure 20 shows the geospatial extent of co-author collaboration on the 848 CEED publications, weighted by author-institution. Collaboration on CEED publications has mainly occurred between authors in Australia, Europe, the United States and South Africa.

Map (a) in Figure 20 shows collaboration on all CEED publications between all co-authors. The colour and weight of the lines linking institutions in different locations reflect the level of author-institutional weighted collaboration.

Map (b) shows collaboration between CEED researchers. For the purpose of this set of results a "CEED researcher" is defined as anyone who has ever been affiliated with CEED, either as a chief investigator, partner investigator, senior researcher, postdoctoral fellow, postgraduate or honours student, and/or research staff. On an author-institutional weighted basis, 23% of collaboration on CEED publications has been between CEED co-authors. In addition to strong links to within Australia, links between Europe (particularly the United Kingdom) and the eastern United States are pronounced.

Map (c) shows collaboration between CEED co-authors and non-CEED co-authors. On an author-institutional weighted basis, approximately 45% of the co-author collaboration on CEED publications has been of this sort.

Collaboration between non-CEED co-authors represents the remaining 32% of the author-institution weighted collaboration on CEED publications. Collaboration of this type is not shown in isolation on a dedicated map, although it is shown as part of all collaboration in map (a).

Citations of CEED publications

Figure 21 shows the location and extent of author-institution-weighted citations of CEED publications. The larger the dot, the more citations of CEED publications there has been by authors affiliated with institutions from that location. Citations are dominated by institutions from Australia and New Zealand, Europe and North America, with smaller contributions from China, South Africa and South America.

As mentioned above, CEED publications have been cited in Web of Science 14,996 times or 13,482 not including self-citations by other CEED publications. Perhaps unsurprisingly, in Figure 21 the only locations noticeably affected by the removal "self-citation" are the CEED nodes, as indicated by the dots for these institutions showing a lighter-shaded outer portion.

CEED publications: Collaboration vs citation

Figure 22 shows collaboration on CEED publications vs citations of CEED publications. The dark dots show collaboration on CEED publications and the light dots citations of CEED publications affiliated with institutions at each location. The two dots are not subsets of one another and are independent. Hence, in Figure 22 a much-larger light dot appears relative to the dark dot for institutions (as tends to be the case in the United States and China) indicating institutions that tend to be more consumers of (citers), rather than collaborators (co-authors) on CEED publications. Only in Australia and London are collaborations relatively large in relation to citations.

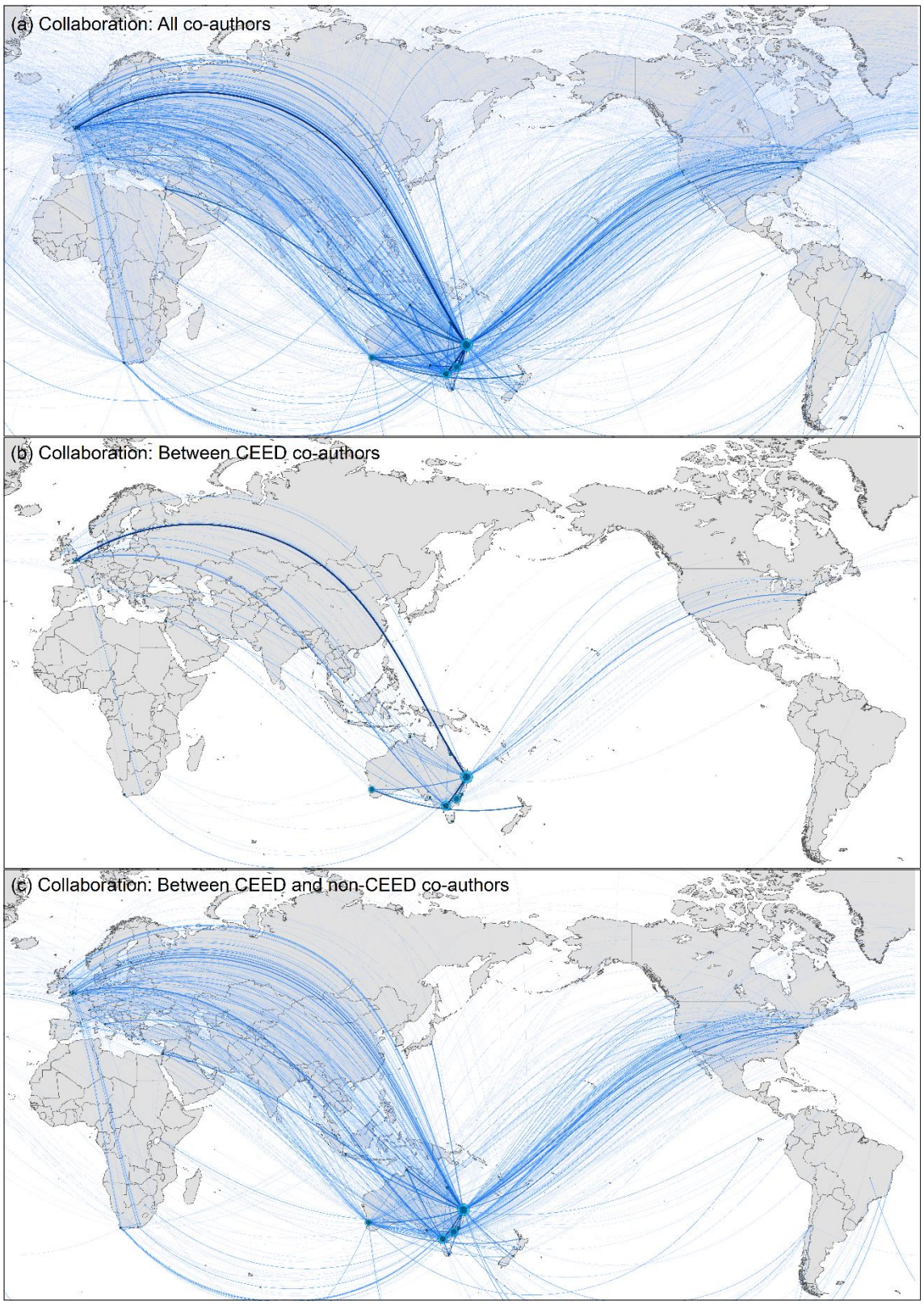

Figure 20. Collaboration on CEED publications. Between (a) all co-authors; (b) co-authors who have at some stage held a CEED affiliation; (c) co-authors who have at some stage held a CEED affiliation and those that have never been CEED affiliated. Width and colour of lines reflect the strength of collaboration—on an author-institution weighted papers basis—between

institutions at each location. Dot size is proportional to the number of author-institution weighted CEED publications for that institution: the light portion of the dots represents the contribution of co-authors who have at some stage held a CEED affiliation; the dark portion represents those who have never been CEED affiliated.

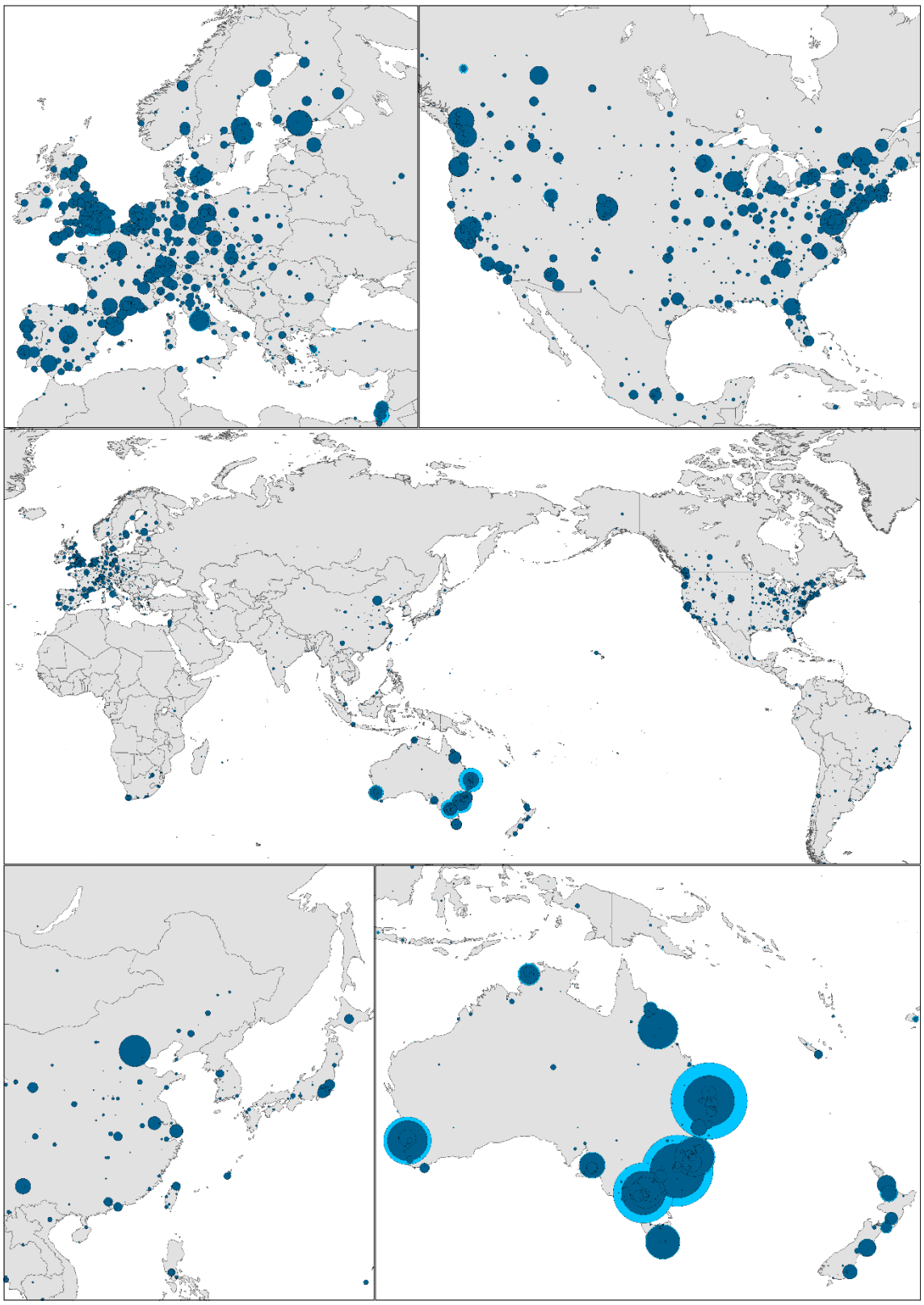

Figure 21. Citations of CEED publications. Dot size is proportionate to the number of author-institution-weighted citations of CEED publications by publications with co-authors with affiliations to institutions at that location. The lighter-shaded portion of the dots represents all

citations, the darker-shaded portion represents the subset of citations remaining after the removal of self-citations by any of the other 847 CEED publications.

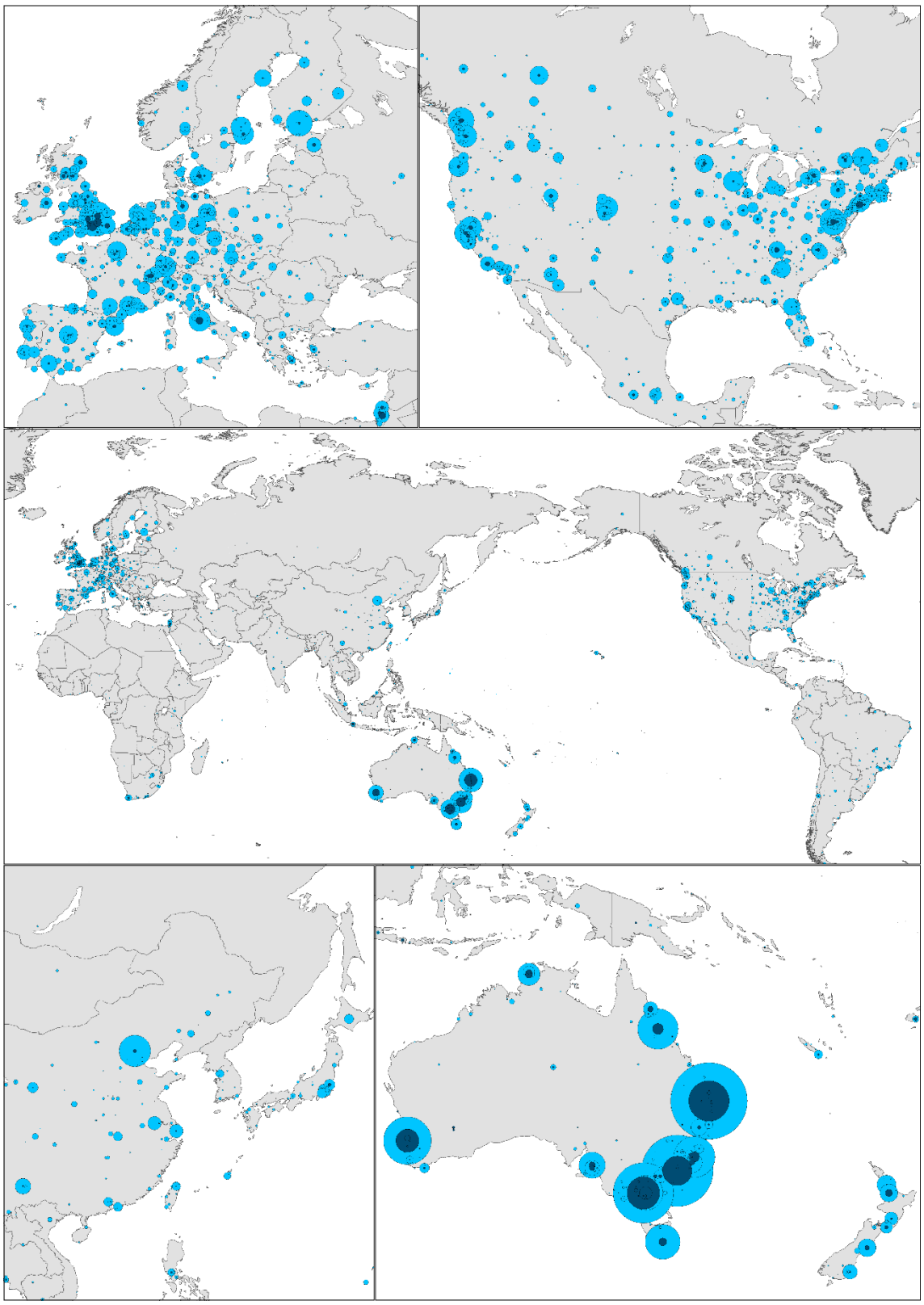

Figure 22. Collaborations on, and citations of, CEED publications. Dark dots show collaboration on CEED publications, light dots citations of CEED publications. Results are calculated on an author-institution weighted basis. Note: self-citation and self-collaboration have not been removed from these results.

A country-by-country breakdown of the proportional share of author-institution-weighted collaboration on CEED publications vs citations of CEED publications is shown in Figure 23. Collaboration on CEED publications relative to citations of CEED publications is high for Australia. It is also strong for the United Kingdom, South Africa, New Zealand and Israel, reflecting strong collaborative links that CEED researchers have established in these countries. Researchers from Canada, Brazil, some European countries and, in particular, China, contribute a much-greater proportional share of the citations of CEED publications than they collaborate on CEED publications (i.e. they are strongly net consumers of CEED research). Researchers from the United States are also strongly net consumers of CEED research (as a proportional share, citations from the United States are nearly three times more than the co-author collaboration). However, despite this, the United States is the largest source of co-author collaboration on CEED publications after Australia.

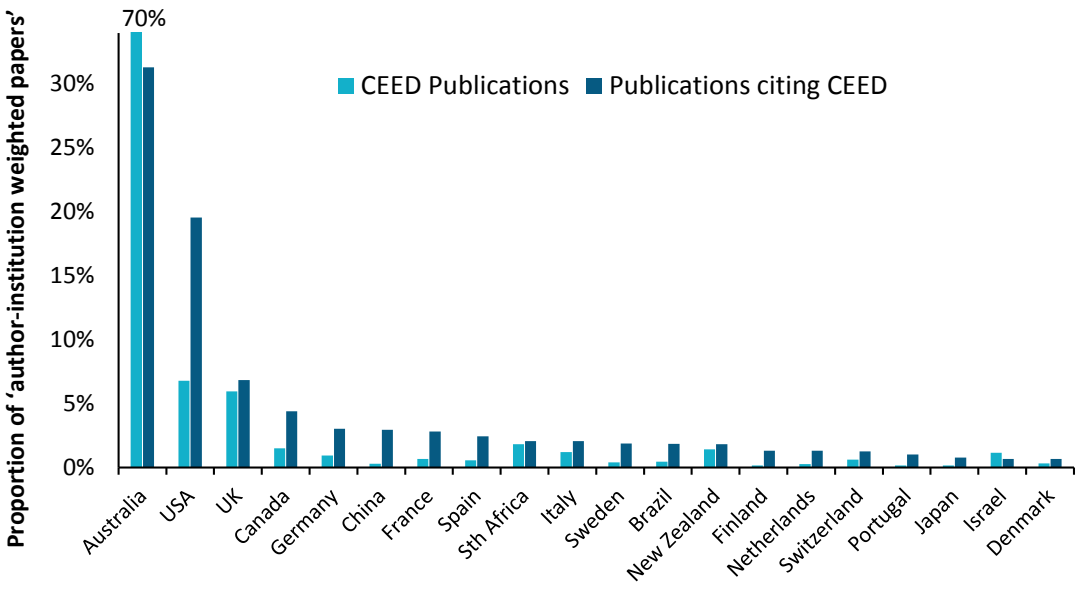

Figure 23. Breakdown of the amount of author-institution-weighted CEED publications vs publications citing CEED publications (as a proportion of the totals of each respectively) for 20 countries with the most CEED citations. Note: y-axis is truncated at 35%, although 70% of CEED publications (on an author-institution-weighted basis) are affiliated with Australia.

Table 6 shows which institutions around the world have been prominent collaborators with CEED and those which have been regular citers of CEED research (on an author-institution weighted basis).

As indicated in the last row of Table 6, it captures only approximately 40% and 72% of author-institution weighted citations and authorship of CEED publications respectively. A more extensive list of citers and collaborators is provided in Appendix 1.

The five CEED node universities are prominent citers of CEED publications, even if citations in other CEED publications are excluded from consideration. In other words, CEED co-authors cite CEED papers in their non-CEED papers. Other major citers of CEED publications include Australian government department and organisations, the CSIRO, James Cook University, University of California, University of Tasmania, the Chinese Academy of Sciences, the United States Geological Survey and the Swedish University of Agricultural Sciences.

Together the five CEED universities account for just over half of the author-institution-weighted authorship of CEED publications (Table 6). Other Australian institutions provide another 20% of the authorship. Hence, Australia accounts for 70% of the authorship on CEED publications (Figure 23).

International institutions that have collaborated the most on CEED publications include Imperial College London, University of California, Hebrew University Jerusalem, Wildlife Conservation Society (United States) and the University of Roma La Sapienza (Italy) (Table 6 and Appendix 1).

In addition to evidence about collaborations gathered from publications, we also obtained lists of collaborators for each of the 87 CEED projects by surveying CEED researchers. The list of collaborating organisations reported is presented in Appendix 2.

Across all 87 research projects, partnerships and collaboration were reported with 224 different organisations and institutions (74 Australian and 150 international). We note that the number of co-authoring organisations (over 900) is much greater than the 224 organisations that researchers reported they had collaborated with in their survey responses.

Many organisations collaborated on more than one CEED research project. Australian

organisations reported to have collaborated or partnered with at least three different research projects include CSIRO, Charles Darwin University, Deakin University, Australian Commonwealth Department of Environment, Department of Parks and Wildlife (DPaW, WA), Department of Primary Industries (DPI, Vic.), James Cook University, Natural Decisions Pty Ltd, North Central Catchment Management Authority (Vic.), The Nature Conservancy Australia and the University of New South Wales. International institutions that have collaborated on at least three different research projects include Imperial College London, International Union for Conservation of Nature (IUCN), Stanford University, University of British Colombia, University of California, University of Copenhagen, University of Kent, University of Kiel, University of Oxford and the Wildlife Conservation Society.

Table 6. Citers of, and collaborators on, CEED publications, listed in order of institutions with the most citations

Institution	% share (on an author-institution weighted basis) of: All citations of CEED	Citations excluding self-citations[1]	Authorship of CEED publications	Authorship (only CEED authors[2])
Univ Queensland, Australia	5.00%	2.13%	19.65%	31.87%
Australian Natl Univ, Australia	4.73%	2.86%	11.01%	17.34%
Univ Melbourne, Australia	3.05%	1.77%	11.80%	20.18%
State & Fed Gov Dept/Orgs, Australia*	2.67%	2.58%	4.01%	0.89%
CSIRO, Australia	1.98%	1.74%	3.38%	2.88%
James Cook Univ, Australia	1.79%	1.91%	1.74%	0.46%
Univ Calif, US	1.65%	1.80%	0.79%	0.02%
Univ West Australia, Australia	1.64%	1.21%	5.71%	8.68%
Univ Tasmania, Australia	0.96%	1.02%	0.57%	0.01%
Chinese Acad Sci, China	0.95%	1.08%	0.19%	0.00%
US Geol Survey, US	0.88%	0.99%	0.14%	0.19%
Swedish Univ Agr Sci, Sweden	0.81%	0.93%	0.21%	0.00%
Deakin Univ, Australia	0.72%	0.70%	0.89%	0.40%
Griffith Univ, Australia	0.68%	0.69%	0.61%	0.41%
Univ Helsinki, Finland	0.65%	0.74%	0.08%	0.00%
US Forest Serv, US	0.63%	0.73%	0.02%	0.00%
Imperial Coll London, UK	0.59%	0.42%	1.63%	2.87%
Univ British Columbia, Canada	0.58%	0.64%	0.31%	0.37%
Monash Univ, Australia	0.57%	0.64%	0.32%	0.07%
Charles Darwin Univ, Australia	0.51%	0.47%	0.88%	0.35%
Nat Res Council (CSIC), Spain	0.51%	0.57%	0.13%	0.00%
Univ Wisconsin, US	0.50%	0.55%	0.07%	0.00%
Univ Sydney, Australia	0.48%	0.50%	0.39%	0.09%
Univ Stellenbosch, South Africa	0.47%	0.48%	0.59%	0.21%
Wageningen Univ, Netherlands	0.46%	0.53%	0.08%	0.00%
Univ New S Wales, Australia	0.46%	0.50%	0.32%	0.07%
Univ Wollongong, Australia	0.45%	0.47%	0.42%	0.17%
Murdoch Univ, Australia	0.40%	0.36%	1.09%	0.77%
Univ Adelaide, Australia	0.40%	0.43%	0.20%	0.02%
Univ Cambridge, UK	0.39%	0.43%	0.13%	0.00%
Stockholm Univ, Sweden	0.39%	0.41%	0.10%	0.00%
Univ Washington, US	0.39%	0.44%	0.10%	0.00%
Univ Minnesota, US	0.38%	0.40%	0.19%	0.10%
RMIT Univ, Australia	0.37%	0.15%	2.11%	3.75%
Macquarie Univ, Australia	0.37%	0.39%	0.21%	0.11%
Univ Exeter, UK	0.37%	0.42%	0.12%	0.00%
Univ Copenhagen, Denmark	0.35%	0.36%	0.23%	0.09%
Oregon State Univ, US	0.34%	0.38%	0.14%	0.00%
Natl Inst Agr Res (INRA), France	0.34%	0.38%	0.07%	0.09%
Colorado State Univ, US	0.34%	0.38%	0.04%	0.01%
Zool Soc London, UK	0.33%	0.31%	0.46%	0.12%
Univ Oxford, UK	0.33%	0.35%	0.37%	0.11%
Sum of the percentages listed in column	**39.86%**	**34.24%**	**71.50%**	**92.70%**

[1]Defined as CEED publications citing other CEED publications

[2]Including only authors that have had a CEED affiliation at some stage

[*]Affiliations to government organisations from Australia were spread across myriad institutions, in part due to the frequent restructuring, merging and renaming of government departments. Therefore, to indicate the scope of their interaction with CEED all affiliations to Australian state and federal government institutions (except CSIRO) were merged under this one label.

Lessons and conclusions

Impacts on policy, management and the community

Results showed a wide range of impact levels for different projects, from low to high. For some projects that currently have low impact, it seems likely that a concerted investment in engagement and communications could increase impact. For other projects, this is not the case because the project is not providing information that is valuable to policymakers or managers.

This raises the question of whether it is possible to anticipate the potential impact of a research project at the time of its planning. It is no doubt true that some research has generated benefits that were not anticipated. On the other hand, it does not follow that there is no value in anticipating potential benefits and prioritising or adapting research accordingly. The feasibility of research delivering the benefits varies between projects and can be anticipated to some degree. Of course, these are difficult judgements and may be wrong for individual projects in retrospect, but across a portfolio of projects, making these judgements can contribute to improving aggregate impact. Engaging with potential end users at early stages in the research process is recognised as a strategy for increasing impact, on average.

One of the challenges encountered in this analysis was that of obtaining reliable and consistent data. The information requirements for a comprehensive assessment (e.g. in the form of a Benefit: Cost Analysis) are extensive and include the scale of environmental change, the intensity or quality of environmental change, the duration of environmental change, the importance or social value of that change, and the extent to which the observed change can be attributed to the research in question.

In this analysis, some of the information we attempted to collect from researchers was somewhat old and had never been documented. In the absence of an established culture

of monitoring impact, researchers often do not collect or record the information needed to demonstrate impact.

The process of environmental research influencing policy or management and translating to impact is complex and filled with uncertainty. As a result, there can be a serious challenge attributing observed changes in policy or management to any particular research. There are many factors that influence the decisions of environmental policymakers and managers; research is a source of information but not necessarily the most influential source.

Publications, citations and collaborations

As with the analysis of impact, academic performance varied widely between projects. Among the 87 projects analysed, there appeared to be a slight positive correlation between impact and academic performance, but every possible combination of impact and academic performance was observed. Thus, some projects with low academic performance have moderate or high impact.

Extremely high levels of collaboration were observed in CEED, both within Australia and internationally. This is probably a benefit of being established and funded as a major centre, with funds available to support travel, meetings, workshops, communications and so on.

The data for assessing academic performance were relatively feasible to obtain and analyse. We used a diversity of approaches and measures and found that this added richness to the story of our academic performance.

Institutional strategies

Many researchers tend to think about impact as resulting from good relationships, engagement and communication, but at least as important is what research is actually done. Many research topics could never have impact, no matter how well they were communicated. Therefore, researchers can probably increase their ultimate impacts on policy, management and the community by weighing up the likely impacts at the point where decisions are made about the priorities for research projects and the design of particular projects.

One of the factors contributing to high impact from CEED research appears to be a result of the culture of the Centre, which recognises the importance of delivering impact from research. Most CEED researchers have also been investigators in highly applied research centres or projects, such as the National Environmental Research Program. The broader lesson is that research impact can probably be improved if expectations about impact are communicated to centre members (e.g. chief investigators, postdoctoral fellows, research students). This could be done as part of an induction process, discussed at centre events (e.g. meetings, workshops, conferences) and conveyed through the centre newsletter. The centre director has a key role in conveying these expectations through the language used and the levels of support or reward offered for impactful projects. The rest of the centre's leadership team (advisory board, chief operating officer, etc.) also have important roles to play in fostering the culture and facilitating the required processes.

Some existing projects that were assessed as having low-impact currently were seen to have potential for moderate or large increases in impact in future. A process to identify such projects and support their efforts to increase impact could be another way to increase the overall impact of a research centre.

If the expectation in a centre is that evaluation of research impact will be done at some stage, our experience suggests that there would be benefits in recognising data needs and institutionalising data collection early in the life of a centre. This would not solve all difficulties (particularly the difficulties of attribution), but it would likely result in the use of more accurate and richer data on engagement and usage of research results.

Another requirement for research centres to conduct high-quality assessments of research impact is having expertise in impact evaluation. Commissioning external experts to contribute on a consulting basis is one obvious approach, although embedding impact into the culture of a centre probably happens more effectively if the expertise is internal, either through training or appointments.

We note the need to be aware of striking a reasonable balance when establishing processes around impact. Overly onerous or demanding processes may cost more than they are worth and may demotivate researchers.

Implications for the ARC

In this analysis, there was little relationship between the impact of translation and engagement and measures of academic merit. It should not be presumed that the most impactful projects will be those of greatest academic performance. One of CEED's most successful projects from an impact perspective was very small, quick and inexpensive – valuing access to national parks in Nepal. This lends support to the ARC's approach of running separate processes for assessing academic excellence, and engagement and impact.

It is important to have realistic expectations about the time lags required to have impact from research. In United States agriculture, where the impacts of research have been studied intensively, the peak impact of research occurs 24 years after investment and impact is detectable out beyond 40 years (Alston et al. 2010). One implication of this is the need to allow the longest possible time lag when assessing impact. Another is that it may not be possible to detect any impact from recently conducted research, even if that research would eventually result in major impacts. This lends support to the ARC's approach of assessing engagement as well as impact. On shorter timescales, engagement may be all that is detectable. And, given the risks of research (i.e. the limited ability to predict future impacts), acknowledging and recognising engagement is a sensible way to foster impacts in the long-term.

Research funders should have realistic expectations about impacts from individual projects. Even highly relevant research may have little impact for reasons outside the control of researchers. Therefore, any attempt to assess whether investments in research constitute good value for money should be made at an aggregate level, rather than for individual projects.

The case study approach to identifying and reporting impacts has merits but also limitations. Because of the great diversity of topics and contexts, case studies are needed to reveal the details, complexities and specific stories of particular projects. They highlight that impact is highly context-specific and dependent on the relevance of research to particular organisations, potentially with idiosyncratic needs or constraints. However, it is difficult to assess the overall impact of a centre or program based on a discrete number of case studies. Unless the number of case studies is large, and they are

selected to be representative, they provide examples but not a complete picture.

We had intended to undertake a Benefit: Cost Analysis (BCA) of some projects including expression of intangible benefits in monetary-equivalent terms, but we found that it was not feasible given the time frame and the resources we had. We continue to think that BCAs would be valuable supplements to the evaluations we have done, but they probably need to be done as a project in their own right. The biggest challenge in doing a BCA was judging what level of the observed benefits was attributable to the research project(s) in question. There can be many non-research factors that influence what happens in an environmental project or policy, and there can be multiple research inputs, so attributing the benefits to particular research is extremely difficult. Judgements about what would have happened in the absence of a particular research project are necessarily rather speculative.

Appendix 1: Citers and collaborators: author-institution-weighted basis

Table A1. Citers of, and collaborators on, CEED publications, listed in order of highest citing institutions

Institution	% share (on an author-institution weighted basis) of: All citations of CEED	Citations excluding self-citations[1]	Authorship of CEED publications	Authorship (only CEED authors[2])
Univ Queensland, Australia	5.00%	2.13%	19.65%	31.87%
Australian Natl Univ, Australia	4.73%	2.86%	11.01%	17.34%
Univ Melbourne, Australia	3.05%	1.77%	11.80%	20.18%
State & Fed Gov Dept/Orgs, Australia*	2.67%	2.58%	4.01%	0.89%
CSIRO, Australia	1.98%	1.74%	3.38%	2.88%
James Cook Univ, Australia	1.79%	1.91%	1.74%	0.46%
Univ Calif, US	1.65%	1.80%	0.79%	0.02%
Univ West Australia, Australia	1.64%	1.21%	5.71%	8.68%
Univ Tasmania, Australia	0.96%	1.02%	0.57%	0.01%
Chinese Acad Sci, China	0.95%	1.08%	0.19%	0.00%
US Geol Survey, US	0.88%	0.99%	0.14%	0.19%
Swedish Univ Agr Sci, Sweden	0.81%	0.93%	0.21%	0.00%
Deakin Univ, Australia	0.72%	0.70%	0.89%	0.40%
Griffith Univ, Australia	0.68%	0.69%	0.61%	0.41%
Univ Helsinki, Finland	0.65%	0.74%	0.08%	0.00%
US Forest Serv, US	0.63%	0.73%	0.02%	0.00%
Imperial Coll London, UK	0.59%	0.42%	1.63%	2.87%
Univ British Columbia, Canada	0.58%	0.64%	0.31%	0.37%
Monash Univ, Australia	0.57%	0.64%	0.32%	0.07%
Charles Darwin Univ, Australia	0.51%	0.47%	0.88%	0.35%
Nat Res Council (CSIC), Spain	0.51%	0.57%	0.13%	0.00%
Univ Wisconsin, US	0.50%	0.55%	0.07%	0.00%
Univ Sydney, Australia	0.48%	0.50%	0.39%	0.09%
Univ Stellenbosch, South Africa	0.47%	0.48%	0.59%	0.21%
Wageningen Univ, Netherlands	0.46%	0.53%	0.08%	0.00%
Univ New S Wales, Australia	0.46%	0.50%	0.32%	0.07%
Univ Wollongong, Australia	0.45%	0.47%	0.42%	0.17%
Murdoch Univ, Australia	0.40%	0.36%	1.09%	0.77%
Univ Adelaide, Australia	0.40%	0.43%	0.20%	0.02%
Univ Cambridge, UK	0.39%	0.43%	0.13%	0.00%
Stockholm Univ, Sweden	0.39%	0.41%	0.10%	0.00%
Univ Washington, US	0.39%	0.44%	0.10%	0.00%
Univ Minnesota, US	0.38%	0.40%	0.19%	0.10%
RMIT Univ, Australia	0.37%	0.15%	2.11%	3.75%
Macquarie Univ, Australia	0.37%	0.39%	0.21%	0.11%
Univ Exeter, UK	0.37%	0.42%	0.12%	0.00%
Univ Copenhagen, Denmark	0.35%	0.36%	0.23%	0.09%
Oregon State Univ, US	0.34%	0.38%	0.14%	0.00%

Institution	% share (on an author-institution weighted basis) of: All citations of CEED	Citations excluding self-citations[1]	Authorship of CEED publications	Authorship (only CEED authors[2])
Natl Inst Agr Res (INRA), France	0.34%	0.38%	0.07%	0.09%
Colorado State Univ, US	0.34%	0.38%	0.04%	0.01%
Zool Soc London, UK	0.33%	0.31%	0.46%	0.12%
Univ Oxford, UK	0.33%	0.35%	0.37%	0.11%
Nature Conservancy, US	0.33%	0.36%	0.17%	0.00%
Univ Alberta, Canada	0.32%	0.37%	0.07%	0.00%
Univ Cape Town, South Africa	0.32%	0.31%	0.24%	0.00%
Univ Kent, UK	0.32%	0.32%	0.43%	0.09%
Mcgill Univ, Canada	0.32%	0.36%	0.05%	0.00%
La Trobe Univ, Australia	0.32%	0.27%	0.75%	0.01%
Univ Porto, Portugal	0.31%	0.36%	0.09%	0.00%
Univ Tennessee, US	0.31%	0.31%	0.34%	0.18%
Univ Sao Paulo, Brazil	0.31%	0.34%	0.04%	0.00%
NOAA, US	0.30%	0.35%	0.06%	0.00%
Nat Environ Res Council, UK	0.30%	0.35%	0.04%	0.00%
Nat Ctr For Sci Res (CNRS), France	0.30%	0.34%	0.04%	0.01%
Wildlife Conservat Soc, US	0.29%	0.21%	0.70%	0.69%
Univ Roma La Sapienza, Italy	0.29%	0.23%	0.64%	0.27%
Univ New England, Australia	0.28%	0.33%	0.17%	0.00%
Univ Florida, US	0.28%	0.32%	0.03%	0.00%
Univ Gottingen, Germany	0.28%	0.32%	0.05%	0.00%
Leibniz Assoc, Germany	0.27%	0.29%	0.13%	0.00%
Helmholtz Ctr For Env Res, Germany	0.27%	0.30%	0.12%	0.00%
Univ Sunshine Coast, Australia	0.26%	0.27%	0.19%	0.03%
Stanford Univ, US	0.25%	0.26%	0.22%	0.18%
Arizona State Univ, US	0.25%	0.28%	0.04%	0.00%
Univ Auckland, New Zealand	0.25%	0.28%	0.01%	0.00%
State Univ of New York, US	0.24%	0.27%	0.07%	0.00%
Univ Quebec, Canada	0.24%	0.28%	0.02%	0.00%
Cornell Univ, US	0.24%	0.26%	0.20%	0.11%
Landcare Res Ltd, New Zealand	0.24%	0.27%	0.09%	0.00%
Univ Leeds, UK	0.24%	0.27%	0.10%	0.00%
Utah State Univ, US	0.23%	0.22%	0.20%	0.04%
US Dept Ag, US	0.23%	0.27%	0.02%	0.00%
Univ Nacl Autonoma Mexico, Mexico	0.23%	0.24%	0.11%	0.00%
Univ Canberra, Australia	0.23%	0.23%	0.28%	0.13%
Univ Lausanne, Switzerland	0.22%	0.24%	0.25%	0.04%
Uni Coll London, Univ London, UK	0.22%	0.18%	0.42%	0.00%
Univ Maine, US	0.21%	0.22%	0.11%	0.11%
Univ Ghent, Belgium	0.21%	0.21%	0.17%	0.00%
Hebrew Univ Jerusalem, Israel	0.21%	0.08%	0.72%	0.22%
Univ Waikato, New Zealand	0.21%	0.19%	0.44%	0.90%
Massey Univ, New Zealand	0.21%	0.22%	0.06%	0.00%
Duke Univ, US	0.20%	0.22%	0.11%	0.00%
Univ Tartu, Estonia	0.20%	0.23%	0.17%	0.03%
Univ Sheffield, UK	0.20%	0.22%	0.05%	0.04%
Michigan State Univ, US	0.20%	0.23%	0.01%	0.00%
Univ Colorado, US	0.20%	0.22%	0.12%	0.00%

Institution	% share (on an author-institution weighted basis) of: All citations of CEED	Citations excluding self-citations[1]	Authorship of CEED publications	Authorship (only CEED authors[2])
Tech Univ Munich, Germany	0.20%	0.23%	0.04%	0.00%
Univ Lisbon, Portugal	0.19%	0.22%	0.01%	0.00%
North Carolina State Univ, US	0.19%	0.22%	0.00%	0.00%
Univ Pretoria, South Africa	0.19%	0.21%	0.18%	0.00%
Univ Toronto, Canada	0.19%	0.21%	0.22%	0.07%
Univ Georgia, US	0.19%	0.22%	0.01%	0.00%
Simon Fraser Univ, Canada	0.19%	0.22%	0.02%	0.00%
Texas A&M Univ, US	0.19%	0.22%	0.04%	0.00%
Univ Illinois, US	0.19%	0.21%	0.09%	0.00%
Univ Otago, New Zealand	0.19%	0.22%	0.04%	0.00%
Smithsonian Inst, US	0.18%	0.20%	0.14%	0.00%
Univ Guelph, Canada	0.18%	0.19%	0.08%	0.00%
Aarhus Univ, Denmark	0.18%	0.19%	0.03%	0.00%
Univ Waterloo, Canada	0.17%	0.20%	0.01%	0.00%
Univ Maryland, US	0.17%	0.20%	0.06%	0.00%
Flinders Univ S Australia, Australia	0.17%	0.13%	0.43%	0.07%
Vrije Univ Amsterdam, Netherlands	0.17%	0.20%	0.01%	0.00%
Southern Cross Univ, Australia	0.17%	0.18%	0.11%	0.00%
Univ Montana, US	0.16%	0.18%	0.01%	0.00%
Univ Kwazulu, South Africa	0.16%	0.18%	0.01%	0.00%
Charles Sturt Univ, Australia	0.16%	0.17%	0.18%	0.05%
Univ Missouri, US	0.16%	0.18%	0.04%	0.00%
Edith Cowan Univ, Australia	0.16%	0.17%	0.06%	0.01%
Trinity Coll Dublin, Ireland	0.15%	0.12%	0.24%	0.48%
Carleton Univ, Canada	0.15%	0.16%	0.11%	0.12%
Beijing Normal Univ, China	0.15%	0.17%	0.00%	0.00%
Univ Eastern Finland, Finland	0.14%	0.17%	0.02%	0.00%
Ctr Int Forestry Res, Indonesia	0.14%	0.12%	0.32%	0.00%
Univ York, UK	0.14%	0.15%	0.10%	0.02%
Beijing Forestry Univ, China	0.14%	0.16%	0.00%	0.00%
Univ Montpellier, France	0.14%	0.15%	0.02%	0.00%
EU Commiss Joint Res Ctr, Italy	0.14%	0.13%	0.10%	0.00%
Nelson Mandela Metro Univ, Sth Africa	0.14%	0.14%	0.37%	0.50%
US Fish & Wildlife Serv, US	0.14%	0.15%	0.03%	0.00%
Univ Arizona, US	0.14%	0.16%	0.02%	0.00%
Peking Univ, China	0.13%	0.16%	0.00%	0.00%
Univ South Australia, Australia	0.13%	0.12%	0.07%	0.00%
Univ Aberdeen, UK	0.13%	0.15%	0.17%	0.08%
Univ Evora, Portugal	0.13%	0.15%	0.00%	0.00%
Queensland Univ Technol, Australia	0.13%	0.11%	0.22%	0.00%
Tel Aviv Univ, Israel	0.13%	0.13%	0.16%	0.07%
Czech Univ Life Sci, Czech Republic	0.13%	0.15%	0.00%	0.00%
Yale Univ, US	0.13%	0.15%	0.01%	0.00%
Lund Univ, Sweden	0.13%	0.15%	0.02%	0.00%
Univ Stirling, UK	0.13%	0.11%	0.12%	0.00%
Univ Massachusetts, US	0.13%	0.15%	0.00%	0.00%
Curtin Univ, Australia	0.13%	0.14%	0.09%	0.00%
Purdue Univ, US	0.13%	0.15%	0.01%	0.00%

Institution	% share (on an author-institution weighted basis) of: All citations of CEED	Citations excluding self-citations[1]	Authorship of CEED publications	Authorship (only CEED authors[2])
Univ Freiburg, Germany	0.12%	0.14%	0.02%	0.00%
Univ Vermont, US	0.12%	0.14%	0.00%	0.00%
Univ Wyoming, US	0.12%	0.14%	0.01%	0.00%
Res Inst for Development (IRD), France	0.12%	0.14%	0.06%	0.00%
Bournemouth Univ, UK	0.12%	0.14%	0.00%	0.00%
Natl Univ Singapore, Singapore	0.12%	0.12%	0.07%	0.00%
Sum of the percentages listed in column	**59.91%**	**55.66%**	**84.19%**	**97.27%**

[1]Defined as CEED publications citing other CEED publications

[2]Including only authors that have had a CEED affiliation at some stage

* Affiliations to government organisations from Australia were spread across myriad institutions, in part due to the frequent restructuring, merging and renaming of government departments in recent times. Therefore, to indicate the scope of their interaction with CEED, all affiliations to Australian state and federal government institutions (except CSIRO) were merged under this one label.

Appendix 2: Collaborating organisations reported in a survey of CEED researchers

Australian collaborators. Organisations/institutions that been partners or collaborators on CEED projects, as reported in the survey of CEED research projects. Note: Where there has been collaboration across multiple projects, the number of projects is shown in parenthesis.

CSIRO (21)
The Nature Conservancy (TNC) Australia (6)
Dept of Parks and Wildlife (DPaW, WA) (5)
James Cook University (4)
Nth Central Catchment Mgnt Authority (Vic.) (4)
Charles Darwin University (3)
Australian Institute of Marine Science (2)
Bush Heritage Australia (2)
Charles Sturt University (2)
Dept of Agriculture & Food WA (DAFWA) (2)
Griffith University (2)
Macquarie University (2)
Nat. Env. Res. Prog. Marine Biodiv Hub (2)
University of the Sunshine Coast (2)
Australian Animal Tracking Network
BirdLife Australia
CERF Environmental Economics Research Hub
Christmas Island National Park
Dept of Business Innovation & State Dev (Vic.)
Dept of Env, Land, Water & Plan (DELWP, Vic.)
Dept of Sust, Env, Water, Pop & Commun (Comm.)
eBird Australia
Enviroconnect Pty Ltd
Greenfleet
Healthy Waterways (Qld)
Logan City Council (Qld)
Moreton Bay Regional Council (Qld)
National Parks & Wildlife Service (NSW)
Nature Foundation SA
Parks Australia
Queensland Fire & Emergency Services
Queensland Trust for Nature
Royal Botanic Gardens Sydney
Swan River Trust (WA)
The Myer Foundation
University of Canberra
University of Tasmania
Deakin University (10)
Dept of Environment (Comm) (5)
Dept of Primary Industries (DPI, Vic.) (4)
Natural Decisions Pty Ltd (4)
University of New South Wales (4)
Australian Antarctic Division (2)
Birdlife International (2)
Central Queensland University (2)
City of Gold Coast (Qld) (2)
Dept of Primary Industries (DPI, NSW) (2)
La Trobe University (2)
Monash University (2)
Queensland University of Technology (2)
ACT Environment and Planning Directorate
Australian Wetlands and Rivers Centre
Brisbane City Council (Qld)
Cesar consulting
City of Joondalup (WA)
Dept of Environment & Natural Resources (SA)
Dept of Sci, Information Tech & Innovation (Qld)
Dept of Water (WA)
Ecology Australia
Flinders University
Greening Australia
Integrated Marine Observing System (IMOS)
Merri Creek Management Committee (Vic.)
Murdoch University
Nature Conservation Trust of NSW
Office of Environment and Heritage (OEH, NSW)
Phillip Island Nature Park (Vic.)
Queensland Museum
Redland City Council (Qld)
Southwest Australia Ecoregion Initiative
Tasmanian Land Conservancy
Trust for Nature (Vic.)
University of Sydney
WWF Australia

*Comm= Commonwealth Department of the Australian Federal Government, Vic.= Victoria, SA= South Australia, WA= Western Australia, NSW= New South Wales, Qld= Queensland.

International collaborators. Organisations/institutions that have been partners or collaborators on CEED projects, as reported in the survey of CEED research projects. Note: Where there has been collaboration across multiple projects, the number of projects is shown in parenthesis.

University of Oxford (6)
University of Kent (5)
Imperial College London (3)
University of British Colombia (3)
University of Copenhagen (3)
Centre for Int. Forestry Research (CIFOR) (2)
HUTAN (2)
National Autonomous University of Mexico (2)
Stockholm Resilience Centre (2)
University College London (2)
University of Alberta (2)
University of Salento (2)
World Cons Monitoring Ctr, UN Env Program (2)
University of Cambridge (2)
World Wide Fund for Nature (WWF) (2)
AgResearch, New Zealand
City University of New York
Coral Triangle Int on Coral Reefs, Fish & Food Sec
DairyNZ, New Zealand
Dept of Conservation, New Zealand
Digital Observatory for Protected Areas, Italy
Dundee University
East-Asian Australian Flyway
Ecopath International Initiative Research Assoc
Environment Agency Austria (EAA)
Federal Ministry of Environment, Austria
Florida State University
French Nat Institute for Agricultural Res (INRA)
Ghent University
Global Finprint
Hellenic Centre for Marine Research, Greece
Humboldt University, Germany
Indonesian Institute of Sciences (LIPI)
Institute for Tourism, Zagreb, Croatia
International Institute for Sustainability
Israel Oceanographic & Limnological Res Institute
Italian Institute for Marine Science
KNZ Wildlife (Sth African provincial gov org)
Landcare Res, Crown Res Institute, New Zealand
Louisiana State University
Misgurnus Association, Romania
National Marine Park of Zakyntho, Greece
Natural England, UK Gov
Nelson Mandela Metropolitan University
Oceana Brasil
Pontifícia Universidade Católica do Rio de Janeiro
Proteus Wildlife Res Consultants, New Zealand
Wildlife Conservation Society (WCS) (6)
Int Union for Conservation of Nature (IUCN) (3)
Stanford University (3)
University of California (3)
University of Kiel, Germany (3)
Blue World Inst of Marine Res & Cons, Croatia (2)
Hebrew University of Jerusalem (2)
Liverpool John Moores University (2)
Smithsonian Institute, US (2)
Pontifical Catholic University of Chile (2)
Trinity College, Dublin (2)
University of Aberdeen (2)
University of Amsterdam (2)
University of Tennessee (2)
Aarhus University
Archipelago Consulting, US
Aston University
Bangor University
Basque Centre for Climate Change, Spain
Colombia University
Cornell University
Dalhousie University
Dept of Nat Parks & Wildlife Conservation, Nepal
Duke University
Durham Univeristy
EcoHealth Alliance, New York
Embrapa-Cerrados (Brazilian Ag Res Corp)
Estacion Biologica de Doñana, Spain
Finnish Environment Institute
Forest Sciences Centre of Catalonia, Spain
German Federal Agency for Nature Conservation
Global Canopy Program
Group on Earth Observ Biodiv Observ Network
Heriot-Watt University, UK
IDH-The Sustain Trade Initiative, The Netherlands
Institut de Ciencies del Mar (CSIC), Spain
International Institute for Environ & Development
Israel Institute of Technology, Haifa
Israel Society of Ecology and Environ Sciences
Kinneret Limnological Laboratory, Israel
Lancaster University
Living Landscape Alliance, UK
Maritime Institute in Gdansk, Poland
National Institute of Oceanography, Israel
National University of Singapore
NatureServe, Arlington, Virginia
Newcastle University, UK

Pyrenean Institute of Ecology, Spain
Sabah Wildlife Department, Malaysia
Scotland's Rural College
Society for Conservation Biology
Swedish University of Agricultural Sciences
Taranaki Regional Council, New Zealand
The Biodiversity Consultancy, UK
The Rothschild Foundation
United Nations Environment Programme
Universidade Federal de Mato Grosso do Sul
Universidade Federal do Espírito Santo
University of Basel
University of Cape Town
University of Florida
University of Haifa, Israel
University of Helsinki
University of Istanbul
University of La Serena
University of Maryland
University of Northern British Columbia
University of Oregon
University of Rome
University of Stirling
University of the West Indies
University of Vienna
University of Washington
Utah State University
University of York
Pacific Marine Analysis and Research Association
Princeton University
Provita, Venezuela
Royal Botanic Gardens, Kew, England
San Diego State University
Scottish Marine Institute,
South African National Biodiversity Institute
Swiss Ornithological Institute
Temple University, Philadelphia
The Nature Conservancy
Tour du Valat Research Centre, France
Universidade de Aveiro
Universidade Federal do Amapá
University of Algarve
University of Exeter
University of Georgia
University of Hawaii
University of Idaho
University of Jerusalem
University of Liverpool
University of Minnesota
University of Nottingham
University of Reading
University of Southampton
University of the Aegean
University of Toronto
University of Waikato
Venezuelan Institute for Scientific Research (IVIC)

Appendix 3: Stakeholders and end users: research projects survey

Australian stakeholders and end users. Organisations engaging with CEED, as reported in the survey of CEED research projects. Note: Where there has been engagement across multiple projects, the number of projects is shown in parenthesis.

Dept of Parks & Wildlife (DPaW, WA) (10)
Australian Antarctic Division (4)
The Nature Conservancy (TNC) Australia (4)
Dept of Sustainability & Environ (DSE, Vic.) (3)
Federal Parliament of Australia (3)
BirdLife Australia (2)
Burnett-Mary Regional NRM Group (Qld) (2)
City of Port Phillip & Westernport CMA (Vic.) (2)
Dept of Environ & Natural Resources (SA) (2)
Environ Protection Authority (EPA, WA) (2)
Rangelands NRM regional body (WA) (2)
ACT Environment and Planning Directorate
Australian Animal Tracking Network
Australian Wildlife Conservancy
Booderee National Park (NSW)
City of Joondalup (WA)
Climate Council, Australia
Dept of Business Innovation & State Dev (Vic.)
Dept of Food & Fisheries (Qld)
eBird Australia
Dept of Premier & Cabinet (WA)
eButterfly Australia
Environs Kimberley
Gondwana Link (WA)
Integrated Marine Observing System (IMOS)
Kimberley to Cape Initiative
Knox Environment Society (Vic.)
Main Roads (WA)
Merri Creek Management Committee (Vic.)
Moreton Bay Seafood Industry Assoc (Qld)
Nature Foundation SA
Nyamba Buru Yawuru (Native title holders, WA)
Parks Australia
Phillip Island Nature Parks (Vic.)
Queensland Trust for Nature
Rio Tinto
SolarGreen Landscaping
Stop the Toad Foundation
Tasmanian Land Conservancy
The Wilderness Society (WA)
Dept of Env, Land, Water & Plan (Vic.) (6)
Nth Central Catchment Mgnt Authority (Vic.) (4)
Dept of Environment & Energy (Comm) (3)
Dept of the Environment (Comm) (3)
Office of Environ & Heritage (OEH, NSW) (3)
Brisbane City Council (2)
City of Gold Coast (Qld) (2)
Dept of Environment & Heritage Protect (Qld) (2)
Dept of Primary Industries (DPI Vic.) (2)
Natural Decisions Private Ltd (2)
Trust for Nature (Vic.) (2)
Atlas of Living Australia
Australian Citizen Science Association
Birding NSW
Christmas Island National Park
Clean Energy Regulator (Comm)
Department of Lands (WA)
Dept of Fire & Emergency Services (WA)
Dept of Industry, Innovation & Science (Comm)
Dept of Sust, Env, Water, Pop & Commun (Comm)
Dept of State Devel, Infrastruct & Planning (Qld)
Environment Centre NT
GEOBON Working Group
Greenfleet
Kimberley Land Council (WA)
Knox City Council (Vic.)
Logan City Council (Qld)
Melbourne Water
Moreton Bay Regional Council (Qld)
Nature Conservation Trust of NSW
Ngadju (Native title holders, WA)
Office of the Chief Scientist (NSW)
Parks Victoria
Queensland Parks and Wildlife Service
Redland City Council (Qld)
Society for Conservation Biology Brisbane
State Emergency Mgnt Committee (SEMC, WA)
Swan River Trust (WA)
Terrain (Wet Tropics regional NRM body, Qld)
WA Museum

*Comm= Commonwealth Department of the Australian Federal Government, Vic.= Victoria, SA= South Australia, WA= Western Australia, NSW= New South Wales, Qld= Queensland.

International stakeholders and end users. Organisations engaging with CEED, as reported in the survey of CEED research projects. Note: Where there has been engagement across multiple projects, the number of projects is shown in parenthesis.

Int Union for Conservation of Nature (IUCN) (6)
World Cons Monitoring Ctr, UN Env Program (2)
Birdlife International
Business & Biodiversity Offsets Program (BBOP)
DairyNZ
Dept for Int Development, UK (UK AID)
East Asian-Australasian Flyway Partnership
Guyana Forestry Commission
International Institute for Sustainability
Ministry for the Environment, New Zealand
Open Space Institute (North America)
The Nature Conservancy Tennessee
United Nations Development Programme
Waikato Regional Council, New Zealand
World Wide Fund for Nature (WWF)
Wildlife Conservation Society (WCS) (2)
Alberta government and catchment staff (Canada)
Brazilian Government
Committ for Env Protect, Antarctic Treaty System
Coral Triangle Int on Coral Reefs, Fish & Food Sec
Dept of Nat Parks & Wildlife Conserve, Nepal
eButterfly
Intergov Sci-Pol Platform on Biodiv & Ecosys Ser
Manitoba government & catchment staff (Canada)
OECD Environment Directorate
Society for Ecological Restoration Australasia
UK Parliament
US Agency for International Dev (USAID)
Waikato River Authority, New Zealand

Appendix 4: CEED research projects

The 87 projects reported in the survey of CEED researchers:

A revolution in conservation funding: Exploring the use of revolving funds to protect nature on private land

Agri-environmental policy

Behavioural biases in natural resource management

Biodiversity and carbon investment decisions

Biodiversity and ecosystem services on Indigenous land

Biodiversity and mining

Biodiversity offsetting (I)

Biodiversity offsetting (II)

Biodiversity sensitive urban design

Borneo Futures Research Initiative

Bridging the science-economics divide when modelling integrated agri-environmental systems

Citizen science and conservation

Climate change and soil carbon

Climate change impacts on eucalypts

Coextinction and its management

Conservation decision making in Antarctica

Conservation of mobile species

Conservation planning for wildlife on farms

Conserving migratory birds

Cost-efficient biodiversity monitoring using environmental DNA

Dealing with time lags in the management of offsets

Developing trait-based models of population dynamics

Developing, testing, applying and disseminating modern statistical methods for understanding where species are.

Economics of ecological restoration

Ecosystem Services Research Initiative

Ecosystem-wide management of invasive species in the face of severe uncertainty

Eliciting and integrating expert knowledge to assess the viability of the critically endangered golden sun-moth *Synemon plana*

Enigmatic ecological impacts of mining and linear infrastructure development in Australia's Great Western Woodlands

Environmental prioritisation

Equity-Efficiency trade-offs in conservation planning and management

Estimating locally relevant biodiversity benchmarks in dynamic environments

Evaluation of environmental research

Feral (invasive) species control

Finding optimal surrogates from networks of co-existing species

Fire and weed management for animal and plant conservation

Fire management and conservation

Fire planning for biodiversity

Forest phenology and climate extremes

Halting the spread of invasive cane toads in Western Australia.

Impact of social networks on conservation auction performance

Indigenous people in Guyana – Project Fauna.

Integrated land-sea conservation planning

Integrating regional spatial conservation goals with national priorities for coral reef conservation in the Coral Triangle: management and ecology of coral reefs along gradients

International biodiversity targets/Achieving the targets of global biodiversity conventions

IUCN Red List of Ecosystems

Koala conservation

Land sharing and land sparing – discussion and methods for evaluating multiple objectives across heterogeneous landscapes

Linking threat mapping with decisions

Managing diffuse-source water pollution

Marine connectivity: social and ecological dimensions

Marxan: outreach and capacity Building

Measuring habitat representation in protected area networks

Message framing for conservation

Metapopulation models for optimal management of threatened amphibians

Navigating conservation's illegal wildlife trade crisis

New approaches for prioritising multiple conservation actions

Optimal monitoring and indicators

Optimal time-dependent surveillance of invasive species

Performance of conservation auctions under uncertainty

Predator ecology in the arid rangelands of Western Australia

Prioritising management actions that abate threats to species

Publishing trends in Australian environmental economics

Quantifying and reporting the costs of conservation interventions

Quantifying community preferences for the environment

Quantifying the global extent of terrestrial threats to biodiversity

Restoration planning and biodiversity conservation in Brazil

Restoration prioritisation

Role of fauna in restoration ecology

Social networks in conservation

Soil conservation

Species vulnerability to climate change

Strategic behaviour of multiple conservation organizations

Temperate broadleaf forest systems: growth and climate dynamics

The economic costs and benefits of marine management

The role of collaboration and conflict in conservation and the Mediterranean case study

Trade-offs and synergies between carbon and biodiversity co-benefits of carbon farming

Trade-offs in water allocation between environment and industry

Turtle vulnerability to climate change

Uncertainty and conservation planning

Uniting predictive models for ecological and epidemiological mapping

Urban wildlife gardening

Use of non-market valuation in systematic conservation planning

Use of non-market values and decision tools in environmental policy

Using food web theory to conserve ecosystems

Valuing access to protected areas

Valuing environmental assets using the hedonic pricing method

When to declare successful eradication of an invasive predator? Foxes on Phillip Island, Victoria

Appendix 5: CEED alumni profiles

One of CEED's greatest legacies will be its people. CEED commenced in 2011 and has now generated a well-connected alumni network that spans the globe. These incredibly capable researchers are receiving national and international recognition for their achievements. They are securing coveted positions in the academy, and also taking up leadership roles in in governmental and non-governmental organisations.

CEED's alumni comprises of over 103 post-docs, 169 PhDs and 64 Masters and Honours students. Our alumni has cemented a solid and successful career path and collaborations have led to global employment and funding opportunities. Of the PhD and Masters students funded by CEED, 89 went on to further study, 11 went into industry, 21 to government in the 12 months following their time with CEED.

We profiled a selection of this community in *Decision Point* (issues #104-#106, see http://decision-point.com.au/). Here are some of their stories:

Maria Beger

Being a part of CEED benefited me in every aspect of academic life. The most valuable aspect was probably the academic independence I had. I don't think I particularly noticed a change in my operational procedures in going from a research fellowship at CEED to running my own lab.

Another aspect I valued was the lack of traditional hierarchy often apparent in many universities. Instead, at CEED everyone mingles and exchanges ideas. This was very special, and really enhanced the quality of everyone's science.

During my time at CEED I derived a lot of inspiration about how to deal with students, run lab groups, and develop activities to support students and postdocs; all aspects of what it is to be part of a research centre. This has helped me to engage with the UK-based research centre where I am currently located. I'm now a management committee member of the Priestley International Centre for Climate at the University of Leeds.

I had so many good experiences while at CEED, it's hard to pin down a best memory. I have very fond memories of the fact that CEED people often meet and talk about science in social settings, such as a bird walk or at St Lucy's. However, easily the best

memory is the buzz associated with the Centre itself, a place where everyone is driven by wanting to conserve biodiversity to some degree.

I am now an Academic Fellow at Leeds. It's kind of a cross between a Research Fellow and a Senior Lecturer. I still work on the same things that I also pursued at CEED (that is, incorporating ecological processes in spatial conservation decisions). However, lately, I have also focussed more on climate change related issues.

Maria's research: Conserving subtropical reefs

In a time of climate change, subtropical and temperate reefs are currently undergoing 'tropicalisation'. Going from tropical to temperate reefs, species richness in corals and fishes declines, but that of algae, echinoderms and other invertebrates can increase. We should aim to conserve sites that consistently remain important for conservation through time.

Reference

Beger M, B Sommer, PL Harrison, SDA Smith, & JM Pandolfi (2014). Conserving potential coral reef refugia at high latitudes. Diversity and Distributions 20: 245-257. And you can read about this study in Decision Point #96

Joe Bull

To this day, I still collaborate and publish with CEED, so I am not sure I truly ever left! However, since finishing my PhD, and official association with CEED, I have gone on to pursue a career in applied biodiversity conservation research through postdocs and other institutional positions. This has included winning funding for projects, including a 'no-net-loss' project in Uganda and a 'business and biodiversity' project with the University of Oxford. I have also set up a biodiversity consultancy called Wild Business that puts our research into practice. We have worked on numerous conservation projects throughout the world, from Canada to Kazakhstan.

I first became part of CEED in 2011 as an associate while undertaking a PhD at Imperial College London. In my first year I organised a biodiversity offsetting workshop with Sarah Bekessy's group at RMIT which kicked off a number of collaborations that have proven incredibly productive (both during my studies and

beyond). Through exposure to leading thinkers in decisions science and working with sch applied conservationists, I greatly benefited from my time with CEED. In fact, my best publications have all involved CEED collaborators.

CEED also strongly influenced the way I approach science, encouraging me to think more creatively and practically about my research and its outcomes. Without this influence, I might have gone back to industry instead of continuing along this path. It's fair to say, CEED has also been a key motivator in deciding to remain primarily in academia.

Joe's research: Comparing biodiversity offset methodologies

In 2015 Joe analysed how different offset schemes worked around the world. In Decision Point #85 he told us that: "Since the basic goal of all of these methodologies is the same – that is, no net loss – one might hope that they would give similar answers if they were applied to a common case study. Well, we tested this approach and it turns out they don't. This analysis highlights how different the philosophy behind biodiversity offsetting in different countries can be."

Carly Cook

CEED allowed me to meet and collaborate with world-leaders in decision science.

I joined CEED in 2011 after completing my PhD at Queensland Uni. CEED provided an outstanding intellectual environment for me to develop as an independent researcher. Richard Fuller and Hugh Possingham were fantastic mentors for me, contributing to the science I was conducting and in providing invaluable advice about how to develop my career in conservation science.

One of the many ways in which CEED benefited me, was through an early-career-researcher travel grant. The award allowed me to travel to the UK to meet with leaders in the field of evidence-based conservation: Bill Sutherland from Cambridge Uni and Andrew Pullin at Bangor Uni. This experience had a lasting impact on my career. It enabled me to form collaborations with both research groups, and encouraged me to become one of the founding members of the Australian arm of the Collaboration for Environmental Evidence: the Centre for Evidence-Informed Policy and Practice.

I am now a lecturer at Monash Uni where I have also started my own research group. Our focus is on integrating evidence into conservation decisions and developing decision support tools.

Carly's research: Strategies to bridge the divide

Back in 2013, Carly wrote about mechanisms that help scientists and decision makers work together. In Decision Point #73 she wrote: "We perceive at least three key challenges for those hoping to achieve boundary-spanning conservation science. First, scientific and management audiences can have contrasting perceptions about the salience of research. Second, the pursuit of scientific credibility can come at the cost of salience and the legitimacy of science in the eyes of decision makers, and third, different actors can have conflicting views about what constitutes legitimate information. The key to overcoming all three challenges is through meaningful collaboration between scientists and decision makers." And she then outlines four strategies as a good place to start."

Sylvaine Giakoumi

I joined CEED in 2012, just after also beginning postdoctoral fellowship funded by the European Union and the Greek Government. Thanks to financial support from CEED I was able organise international workshops, which also gave me the opportunity to meet and collaborate with leading scientists in my field of marine conservation. I was also able to participate in training sessions run by CEED which broadened my skills and capabilities. However, most importantly, being part of CEED gave me the opportunity to collaborate and share experiences on a daily basis with an amazing group of people.

I think my best memory is a workshop organised by Professor Salit Kark on Stradbroke Island. Not only did we do some great work, we got to watch dolphins and whales breaching just off shore.

While I am still an adjunct fellow at CEED, since physically leaving Australia in 2015 I have been a postdoc at the University of Nice Sophia Antipolis, France, where I led a collaborative project with the Interdisciplinary Studies of Coastal Oceans (PISCO). Currently, I am a principal investigator on a three-year project assessing the relationships between marine protected areas and invasive species, funded by the French

National Research Agency. I am also a group leader on a four-year European Union COST project, investigating integrated conservation planning.

Sylvaine's research: Prioritising actions to protect seagrass meadows

In Decision Point #96, Sylvaine discussed a study she led on what's the most cost effective approach to saving seagrass habitat.

Their analysis selected the most cost-effective actions to abate stoppable threats (trawling and anchoring), while avoiding areas affected by threats that are more difficult to manage, such as coastal development (Giakoumi et al, 2015). The relative improvement in cost achieved by using the proposed approach was examined by comparing with other common prioritisation criteria that do not consider cost, including choosing sites based on threat level or habitat cover alone.

The establishment of anti-trawling reefs (in the study region in the Mediterranean) was found to be the most cost-effective action to achieve the European Union conservation target for the protection of seagrass (Posidonia oceanica) meadows.

Reference

Giakoumi S, CJ Brown, S Katsanevakis, MI Saunders & Possingham HP (2015). Using threat maps for cost-effective prioritization of actions to conserve coastal habitats. Marine Policy 61: 95-102.

Ed Hammill

When I joined CEED in 2013 I had no formal experience in spatial analysis but I did have a strong desire to work in decision science for conservation. While with CEED, I learned how to implement the spatial planning software Marxan, and developed a new method to analyse the consequences of not accounting for risk in landscape decisions. I've continued to use both these techniques in the majority of the projects I have taken on (which have expanded to include rivers and streams).

My experiences at CEED provided me with the skills to produce high-impact publications, including one in Nature Communications (which then became the subject of a TED talk). And due to the highly collaborative nature of CEED, my time there also

allowed me to substantially expand my research network. The CEED conferences were not only useful to meet researchers from other universities, but provided a great sense of being part of a large group focused on the same mission.

Following my time at CEED, I have taken up a faculty position at Utah State Uni, where I lead the Spatial Community Ecology lab. The techniques I learned during my time at CEED were crucial in obtaining this position and my subsequent success. Recently, I began working with state agencies and The Nature Conservancy to address how the threat of climate change should be incorporated into management activities in the western US. This year, I will start working with the Department of Defence to investigate how best to conserve endangered aquatic species on military lands in California.

I will also be continuing the work I began during my time at CEED, investigating how the risk of armed conflict should be incorporated into conservation decisions. None of these projects would have been possible without the collaborations and skills I developed while working at CEED.

Chrystal Mantyka-Pringle

I'll always remember the infectious enthusiasm and common passion for conservation at CEED.

What I value most from that time was the continuous exposure to such a diversity of researchers, cultures and projects that all had a common passion for conservation and environmental decision-making. One day I would be learning about the benefits of a possible ivory trade in South Africa, whereas the next day I would be hearing about landscape restoration activities for big cat conservation in the Amazon, or zoning approaches for protecting biodiversity on the Great Barrier Reef. Researchers and staff were all excited to be a part of CEED and the enthusiasm was infectious!

I joined CEED when I started my PhD with Jonathan Rhodes and Tara Martin. During my four years there, the Centre provided training and professional skills that I still use today – media training, R workshops, Marxan training, networking, writing retreats, and conference participation.

In 2012, I was awarded a Visiting Fellowship Grant scheme from CEED, which I used

to visit the University of Saskatchewan to collaborate on an external project. This led to a new overseas network for me, and eventually led to a postdoc offer a few years later.

On graduating from my PhD, I worked for CSIRO on a short contract developing a quantitative Bayesian Belief Network model for minimizing the risk of invasive species colonisation in Australia. I them moved to Canada to accept a postdoctoral research fellowship with the School of Environment and Sustainability at the University of Saskatchewan. My research at Saskatchewan focused on collaborating with three First Nations and three Métis Nations from the Northwest Territories to develop a socio-ecological system model using both traditional indigenous knowledge and scientific knowledge for understanding the cumulative environmental impacts of multiple stressors on Canadian River Deltas, including both social and ecological consequences.

I was then awarded a Mitacs Elevate Research Fellowship from the Canadian Government, in partnership with Ducks Unlimited and Environment and Climate Change Canada to initiate a research program modelling interactions between climate change, wetland drainage and habitat loss on prairie wetland chemistry and ecological biodiversity.

I am also currently developing a decision-support framework for land-use management efforts designed to provide optimal solutions to practitioners for maximizing wetland functioning while minimizing or mitigating costs to crop production. This work involves collaboration with hydrologists, aquatic biogeochemists, ecologists, climatologists, economists, social scientists, wetland managers, policymakers and farmers. Amongst other things, I teach a graduate course on sustainable water resources at the University of Saskatchewan, but my greatest achievement since CEED is that I became a mum to two spirited little girls, Aurora and River, who inspire me daily for a better world.

Chrystal's research: Climate change AND land-cover change

In December 2015, Chrystal wrote in Decision Point about the impact of climate change when combined with the impact of land cover change.

Climate change can interact with land-cover change by exacerbating the impact of habitat loss and fragmentation on biodiversity. It does this by increasing the

susceptibility of fragmented biological populations to extinction risks connected with random events (like fires or disease outbreaks). Climate change can also hinder the ability of species to cope with modified land-cover. If climate change depresses population sizes or causes increased variability in population dynamics, for example as a consequence of increased incidents of extreme events, then habitat networks may require larger patches and improved connectivity to maintain populations. Loss and fragmentation of habitat may also hinder the movement of species and their ability to cope with climate change through tracking of suitable climatic conditions.

Their analysis found that climate change will exacerbate the risk of mammal and bird declines due to future land-cover change by up to 24% for mammals and 43% for birds (Mantyka-Pringle et al, 2015).

Reference

Mantyka-Pringle CS, P Visconti, M Di Marco, TG Martin, C Rondinini & JR Rhodes (2015). Climate change modifies risk of global biodiversity loss due to land-cover change. Biological Conservation 187: 103- 111.
See the story in Decision Point #93

Melinda Moir

CEED not only opened doors to people who I thought were out of reach (or I was not even aware of) but it also generated a supportive atmosphere. The support that I received was substantial and came in many forms: moral, financial and professional (including mentorship and meeting world-renowned scientists). I have attempted to replicate this environment of support for the people who work for me at the WA Department of Primary Industries and Resource Development, which I joined in 2015 after finishing at CEED's UWA Node. I lead a team working on the biosecurity of Barrow Island, an A-class Nature Reserve off Western Australia's north-west coast (associated with Chevron-related mining activities on the island).

My CEED journey began in 2010 at the Melbourne Uni node, with Peter Vesk and Mick McCarthy. I have many fond memories, but one of the best was attending the ESA conference in Canberra in 2010. Not only was it an opportunity to meet all the great people associated with CEED, but it gave me the feeling that I was a part of something

that was really going to make a difference to the conservation of Australia's biota in the long-term.

Melinda's research: Threatened plants and their dependent insects

Back in Decision Point #53, pages 6-7 Melinda wrote about co-extinction and how to stop it. As she explained: "When we move a threatened plant species to a new site to improve its chances of survival, should we be putting in a similar effort into moving the insects that live on that plant? If those insects only live on the threatened plant species then clearly we should. Unfortunately, not much work has been done on this aspect of translocation."

Roberto Salguero-Gómez

At CEED I was a DECRA fellow in a group of 65 postdocs and 93 PhD students. I had never worked with such a large group before, but the interactions and way we carried out collaborative projects forever changed the way I think about global ecological impacts and how I network with colleagues around the world.

CEED provided me with unique opportunities to interact with world-leaders in conservation, science, and ecology both in Australia and abroad. One of the highlights of my work at CEED was working with my colleagues to organise a workshop on the application of big data in decisions science. Other valued achievements from my time with CEED include becoming an honorary fellow at UQ, and becoming involved in the CEED mentoring program, where I was lucky to work with the very talented PhD candidate Stephanie Avery-Gomm.

Because of CEED's many nodes and connections, I was also able to collaborate with researchers from Melbourne and QAECO to obtain an ARC grant to evaluate the usefulness of various species distribution models and the interplay between these tools and population's models. Working with CEED scientists has truly shaped the way in which I work and think (not to mention it is where I met my wife!).

More recently, I have worked in the UK funded by a NERC independent research fellowship, at the University of Oxford's Department of Zoology. In late 2017, I was offered an Associate Professorship in ecology and tutorial fellowship with Pembroke College, Oxford.

Roberto's research: Two global demographic databases

COMADRE and COMPADRE are two demographic databases that I have been developing in collaboration with an international team (a project catalysed by the Max Planck Society and the ARC). COMPADRE is a Plant Matrix Database (the name comes from the letters in 'Comparative Plant Matrix Database'), while COMADRE is an Animal Matrix Database (from 'Comparative Animal Matrix Database'). Each database is unprecedented in terms of data quality, taxonomic richness and global coverage.

Reference

Salguero-Gómez et al. (2015) The COMPADRE Plant Matrix Database: an online repository for plant population dynamics. Journal of Ecology 103, 202-218.
See the story in Decision Point #94

Danielle Shanahan

I'm the Manager of Conservation & Research at Zealandia, a 225 ha wildlife sanctuary that lies in the centre of New Zealand's capital city of Wellington. It's a world-first experiment on how to combine effective restoration and threatened species management in the shadow of a major city.

Zealandia is an 'island sanctuary in a city'. Established around 20 years ago, it lies behind a predator-proof fence, over 8 kilometres long, that keeps out rats, cats, stoats, possums and hedgehogs; all introduced mammals that have decimated New Zealand's native fauna. New Zealand's rich native bird life, having evolved in isolation from mammals, has proved particularly vulnerable to these predators.

Our close proximity to people throws up heaps of challenges and opportunities. For example, how do we balance our restoration goals against the need to let visitors interact with the sanctuary? What is the best, most cost effective and efficient way to monitor for incursions of mammal predators? How do we ensure that birds flowing out of the sanctuary are safe and can continue to disperse across the landscape?

These questions are grist to the mill for an environmental decision scientist, and they are central to the decisions I have to make as Manager of Conservation & Research. So, this

is for real. Out in the real world decision making can be messy, noisy and often confusing. Sometimes it's obvious what the appropriate course of action is and your decision making can be transparent, accountable, efficient and adaptive. Often it's not.

Decision making in the real world often doesn't look like decision making described in academic journals. But that's OK—I have found that the science combined with my experience at CEED has provided me with the skills I need to approach each challenge in a considered and logical manner. Always in the background of what I do are questions about what is it I am trying to achieve, what are the available options, and what are the trade-offs between these options? There are no perfect solutions, but there are options that are fit-for-purpose, cost-effective with results that enable us to learn more about the systems we are managing.

CEED was instrumental in teaching me this. But it is also an important network of expertise that I continue to interact with and draw on. CEED also taught me the importance of the many values that feed into effective conservation. It's not just growing the numbers of a particular threatened species (important though that is). It's also how people regard and care for that species or ecosystem.

Rachel Standish

CEED gave me the opportunity to work with people outside my discipline. Since my research sits at the nexus between ecological theory and practice, I was excited to join CEED in 2012. Being part of the centre gave me the opportunity to work collaboratively with other motivated researchers in a wide variety of disciplines outside my own. Through CEED, I developed new, productive and fulfilling collaborations and gained valuable mentoring experience through the CEED ECR mentoring program. Lastly, and perhaps what was most beneficial, CEED reporting improved my ability to communicate the impact and benefit of my research beyond academia.

I appreciated CEED initiatives to bring ecologists together. In December 2013, Jane Catford and I hosted a CEED/NERP workshop at Rottnest Island (a 20 minutes ferry ride from Fremantle, Western Australia). It was my first experience hosting a workshop and a great opportunity to collaborate with Jane and other internationally renowned ecologists. I have fond memories of the workshop—serious intellectual pursuit mixed with leisurely cycle-rides to the pub and beach—and it was productive too! We

published a meta-analysis on the response of ecosystems to disturbance using datasets attendees brought to the workshop.

I am now a senior lecturer in ecology at Murdoch University, Perth.

Annabel Smith

CEED was also a great place to collaborate and form relationships with other researchers at different career stages. During a conference I co-led, I met Professor Yvonne Buckley, who I didn't know at the time, and would later become my employer at Trinity College Dublin and one of the most influential mentors in my career to date.

During my time at CEED I was selected as a representative for the Australian Research Council's mid-term review, where I provided feedback to the ARC on the impact the Centre has made to the scientific community, environmental policy makers and the general public at an international level.

Since finishing my appointment at CEED, I have worked as a freelance researcher, and in May 2016 I moved to Ireland to take up a position at Trinity College, where I led the landscape genomics component of the international research network PLANTPOPNET. The network uses Plantago lanceolata as a model species to analyse variation in plant population performance across global environmental gradients. During this time, I also won a Marie Skłodowska-Curie Research Fellowship. I am also the Meetings Officer for the Irish Ecological Association and am on the Organising Committee for the second IEA conference to take place in Galway, December 2018 and Associate Editor of the Journal of Applied Ecology.

Being part of CEED benefited me in three big ways: It increased the impact my research had in policy and environmental management; it vastly increased my research network; and it provided future employment and funding opportunities in the global research community.

Annabel's research: Fire in the mallee

Annabel published several stories in Decision Point on fire and biodiversity. In Decision Point #72 she reported on results of her doctoral research on reptiles and fire. She conducted a study in the mallee vegetation of South Australia to determine how reptiles

respond to fire in their habitat. The field effort involved in this study was enormous. Her results suggest that management that is likely to be of greatest benefit to reptiles in mallee ecosystems would aim to protect long-unburnt habitat (eg, 40–50 years old, and potentially older) from fire because these post-fire habitat stages are uncommon.

Reference

Smith AL, Bull CM, Driscoll DA (2013) Successional specialization in a reptile community cautions against widespread planned burning and complete fire suppression. Journal of Applied Ecology DOI: 10.1111/1365-2664.12119.
See the story in Decision Point #72

Gary Tabor

I came to CEED as a Professional Fulbright Scholar in Climate Change and Clean Energy in 2013-2014. I chose CEED because of its pool of talented scholars who were making advances in decision support science using a range of qualitative and quantitative approaches. Being exposed to this cohort of innovators and their work proved to be a great inspiration for my own work in helping policymakers and conservation practitioners make better decisions using the best available science. I still stay in touch with my colleagues and collaborators at CEED, who continue to help me and inspire me.

After CEED, I returned to the United States where I was appointed to serve on two US Department of Interior advisory councils during the last years of the Obama Administration. The first was the International Landscape Conservation Cooperative Council of the US Fish and Wildlife Service. It oversees 22 large-scale federal conservation collaborative operations from the Pacific Islands to the Caribbean Sea, from the Arctic realms to the tropical forests of Puerto Rico.

The second was the National Invasive Species Council that advises the Secretary of Interior on the latest threats and potential solutions to address the nation’s invasive species problems.

In 2016, I was asked by the IUCN World Commission on Protected Areas to chair a new technical group to advance ecological connectivity conservation – the Connectivity Conservation Specialist Group (CCSG). We are developing a new conservation

designation to conserve a critical ecological process – connectivity - through Areas of Connectivity Conservation. We hope that as the world develops more ambitious targets for conservation, connectivity will figure more prominently in these goals.

The CEED morning tea gatherings, where I was based at the UQ node, helped to foster a true collaborative community. In general, we don't have these social breaks in the US and I miss them now that I have returned home. I think tea is a small thing, but it truly helps cement teams.

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