DECISION POINT

Connecting conservation policy makers, researchers and practitioners

Issue #98 / November 2016

‘Planning’ for climate change

Conservation prioritisation in a changing world

Also in this issue

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Decision Point is the bimonthly magazine of the ARC Centre of Excellence for Environmental Decisions (CEED). CEED is a network of conservation researchers working on the science of effective decision making to better conserve biodiversity. Our members are largely based at the University of Queensland, the Australian National University, the University of Melbourne, the University of Western Australia and RMIT University.

Editor David Salt
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Our cover: Part of the impact of the 2016 bleaching event on the Great Barrier Reef. Unfortunately, most studies in spatial conservation planning don't incorporate climate change into their analysis. How is that possible? See our story on page 5. (Photo courtesy of Oregon State University, CC BY-SA 2.0)

On the point

What are we missing?

What's missing when it comes to securing the future of the planet's threatened species and ecosystems? In this issue of *Decision Point* we present a range of CEED-related stories that answers this very question.

Up front our new Director, Kerrie Wilson, paints us a rather confronting picture of where conservation scientists are focusing their effort and sadly it's not in the places facing the biggest biodiversity conservation problems (see page 2). Bit of a mismatch there.

Sam Banks and his colleagues from evolutionary biology make a case on page 8 that conservation policy could do with a little more input from evolutionary biologists – and provide several compelling examples of how it can help.

On page 10 Sayed Iftekhar does something similar with economics. He describes how economic principles and tools can enhance the success of a restoration project.

Kendall Jones reviewed the literature on conservation planning and was somewhat surprised to discover climate change is almost never factored in (page 14). Could that be true?!

And Kiran Dhanjal-Adams asks how much information do you need on migrating animals to better conserve their migratory networks (page 16)? It turns out you can get valuable information from as few as 3 tracked migrating individuals to help you plan your conservation priorities. Which is fortunate because it seems our migrating species are in the direst of straights when it comes to looming extinctions.

Of course, what's usually missing when it comes to biodiversity conservation is inadequate resources stemming from a lack of political will. At the end of the day, conservation doesn't seem as important as defence or health. And yet, as Danielle Shanahan describes on page 4, a dose of nature is exactly what we need to keep us healthy – and 30 minutes a week is all you need to get started. Maybe this is a message we all need to start sharing with our political leaders.

David Salt
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DECISION POINT #98
November 2016

Conservation research is not happening in the right places

A wake-up call to all conservation scientists

By Kerrie Wilson (Director, CEED)

Conservation research is not being done in the countries where it is most needed, and this will likely undermine efforts to preserve global biodiversity. If that sounds like a harsh judgement, consider the facts.

We analysed over 10,000 conservation science papers from over 1,000 journals published since 2014. We then compared the countries where these studies were done (and by whom) with where most of the world's biodiversity is found. What we found suggested a massive mismatch in terms of need and effort (Wilson et al, 2016; and see Figure 1).

If you dig a little deeper, it gets worse. The science conducted in the countries with the most biodiversity is often not led by researchers based in those countries. Scientists based in biodiversity-rich countries are also underrepresented in important international forums.

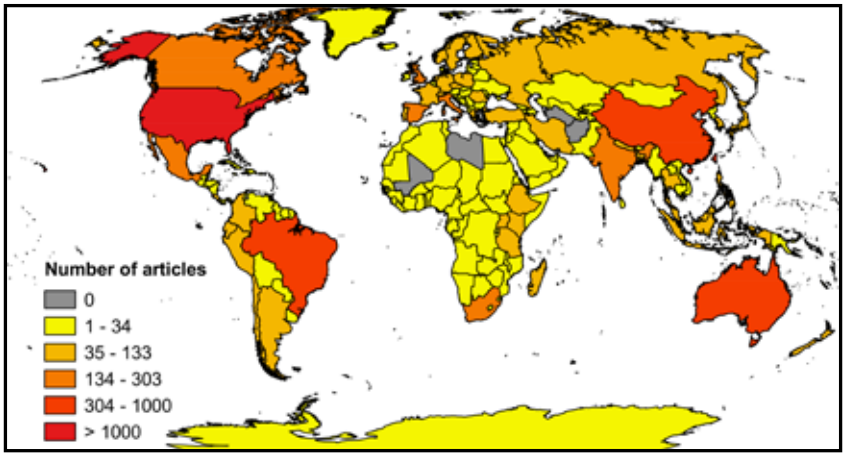

Figure 1: Global distribution of publications on biodiversity conservation. Yellow and grey countries, places containing important levels of biodiversity, are severely under studied. (From Wilson et al, 2016)

What this adds up to is a widespread bias in the field of conservation science. If research is biased away from the most biodiverse areas then this will accentuate the impacts of the global biodiversity crisis and reduce our capacity to protect and manage the natural ecosystems that underpin human well-being.

Biases in conservation science will also undermine our ability to meet Target 19 of the Convention on Biodiversity (CBD). Target 19 states that: "By 2020, knowledge, the science base and technologies relating to biodiversity, its values, functioning, status and trends, and the consequences of its loss, are improved, widely shared and transferred, and applied."

Our comprehensive analysis of publishing trends in conservation science literature suggest we won't meet this target if these biases aren't addressed.

Information sharing is also limited by the fact that most of the science being done in the countries with the greatest needs is not being published in open-access journals.

So, what should we do about it? A range of solutions is needed. These include reforming open access publishing policies, enhancing science-communication strategies, changing author-attribution practices, improving representation in international processes, and strengthening infrastructure and human capacity for research in countries where it is most needed.

Of course, there are massive challenges in attempting to initiate any of these solutions. However, an important starting point is for researchers to examine their own agendas and focus on areas with the greatest need.

One thing we can say for certain, we won't change the situation by simply ignoring it.

Reference

Wilson KA, NA Auerbach, K Sam, AG Magini, ASL Moss, SD Langhans, et al. (2016) Conservation Research Is Not Happening Where It Is Most Needed. *PLoS Biol* 14(3): e1002413. doi:10.1371/journal.pbio.100241 http://journals.plos.org/plosbiology/article?id=10.1371/journal.pbio.1002413

Changing of the guard

A big hello to all readers of *Decision Point*. As you might have gathered from the byline in this story, I'm CEED's new Director.

I'm hoping my name might be familiar to some of you as I've been involved with many CEED research projects over the years (and have authored several *Decision Point* stories in that time). One prominent (and ongoing) area of research involves landuse planning and conservation in Kalimantan in Indonesia (see *Decision Point #86*) in collaboration with our long-term collaborator Dr Erik Meijaard.

However, with Hugh Possingham's departure to The Nature Conservancy, Mick McCarthy and I have been given the honour of carrying on his fantastic work in steering the good ship CEED.

Hugh and I have been close collaborators for over 15 years, so I've seen first hand his tireless dedication to environmental decision science and to growing *Decision Point*. We are all proud of what he has achieved, and we hope as CEED's new leadership team that we can build on that legacy.

If you're a new friend to CEED or a long-time associate, I hope you'll continue to support us and our efforts to explore new ways of making better decisions for better enviornmental outcomes. Of course, the best way to keep in contact with our work is to open that link whenever you hear there's a new issue of *Decision Point* available.

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A dose of nature is just what the doctor ordered

But how big a dose makes a difference?

By Danielle Shanahan, Richard Fuller (University of Queensland) and Brenda Lin (CSIRO)

It's widely acknowledged that a 'dose of nature' is good for us but how much is enough to generate positive outcomes? We recently analysed people's health outcomes resulting from an exposure to green spaces and nature and found it didn't take much to create enduring benefits. We found that people who manage to get a 30 minute (or more) 'dose of nature' each week are less likely to have high blood pressure or depression (Shanahan et al, 2016). The public health and financial implications of this are immense. Depression alone costs Australia $12.6 billion per annum as well as being a huge impact on the quality of life, and around a third of Australian adults are affected by high blood pressure.

Our analysis shows that the prevalence of depression could be reduced by up to 7% and that of high blood pressure reduced by 9% if everyone met this 30-minute minimum-dose guideline. The potential savings to public health budgets associated with this simple behavior change are likely to be substantial.

Deconstructing exposure

Despite the fact that over 30 years of research has demonstrated an association between nature and health, experiences of nature continue to decline as our lives become increasingly urban. Indeed, more than 90% of Australians live in cities, often many kilometres from the nearest patch of bushland. Given this, it is now more important than ever to understand the consequences of this change, and how city-scapes need to modified to maintain the health and wellbeing of city residents. This was the key motivation behind our work, which ultimately aimed to explore what type, and what amount, of nature people require in order to receive the best health benefits.

Our study used the medical approach of dose–response modelling, where variation in a dose of nature is modeled against a health response. We deconstructed exposure to nature into three components:

- The 'intensity' of nature (that is, characteristics of nature itself—in this case this was vegetation complexity in a visited location),

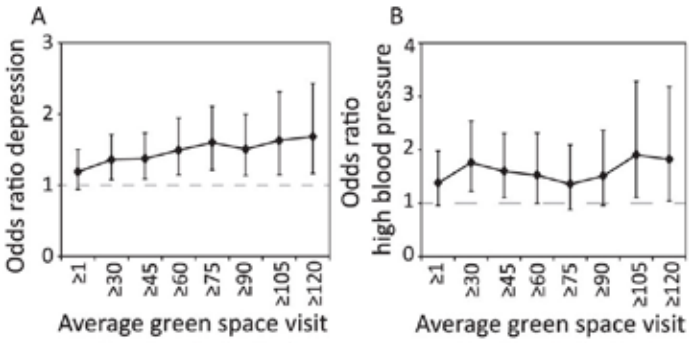

Figure 1: The dose-response graphs here show the likelihood (or 'odds ratio') an individual has A) depression, or B) high blood pressure given incrementally increasing the average duration of a vist to a green space (95% confidence intervals are shown). An odds ratio above one indicates an individual is more likely to have the illness where the threshold of green space visitation is not met.

Key messages:

A 30 minute exposure to nature per week improves health

The prevalence of depression could be reduced by up to 7% and that of high blood pressure reduced by 9% if everyone met this 30-minute minimum-dose guideline

Urban nature is a promising tool for enhancing the well-being of the world's growing urban population

Thirty minutes of exposure to nature every week helps reduce depression and blood pressure. How much to you get?

- The 'frequency' of nature experiences, and
- The average 'duration' of those experiences.

We modelled these relationships using survey data from over 1500 residents in Brisbane, Australia, taking into account all the other variables that influence a person's health and wellbeing, such as gender, age and income.

Green spaces as a health resource

Importantly our study first showed that nature delivered multiple health and wellbeing benefits across the population all at once, thus highlighting the uniqueness and importance of green spaces as a health resource.

Our research also showed how behavioural interventions might be altered to deliver health outcomes of particular interest to different communities. For example, we showed that people who made long visits to green spaces had lower rates of depression and high blood pressure, and those who visited more frequently had greater social cohesion (Figure 1).

Higher levels of physical activity were linked to both duration and frequency of green space visits. Social cohesion and physical activity themselves are itself important for public

Opportunity or orientation

A surprising number of Brisbane residents in our study failed to meet even the 30-minutes-a-week recommendation for nature exposure. In fact, around 40% of residents spent no time at all in green spaces during our survey week. In one of the studies in this project we explored whether it's the opportunity to experience green space (that is, its availability), or orientation towards nature (measured as nature relatedness) that is the more important predictor of actual use. We found that while availability was of course important, nature relatedness was a much more important predictor (Figure 2).

Reference

Lin BB, RA Fuller, R Bush, KJ Gaston & DF Shanahan (2014). Opportunity or Orientation? Who Uses Urban Parks and Why. *PLoS ONE* 9 http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0087422

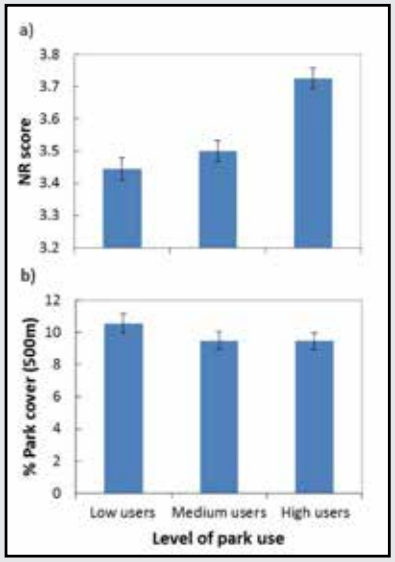

Figure 2: Comparisons of low, medium, and high park users (based on time spent in parks) according to a) participants' nature relatedness (NR) score, b) coverage by parks at a 250 m, 500 m, and 1 km radius around the home.

health, as they have positive associations with physical and mental wellbeing. These flow-on benefits are likely to add considerably to the economic and social value of urban green space.

There was no indication in our study that the complexity of vegetation had a significant effect on the health outcome measures in this study. This is despite the fact that previous research has shown that more biologically diverse areas can provide greater restoration benefits (Fuller et al, 2007), or that more densely vegetated landscapes are often less preferred.

However, we suspect our results point to the challenges in measuring the nature experienced by individuals at the population level, and suggest that further experimental work in this area is warranted.

Diverse benefits

The benefits we get from spending time in nature are spectacularly diverse. In our study alone we showed benefits for mental health (depression), physical health (high blood pressure), social health (social cohesion), and a positive health behavior (physical activity). Given this, the cumulative cost savings across all health outcomes could be immense if this behavioral change was targeted.

Together this work shows that urban nature is an incredibly promising tool for enhancing the physical, psychological, and social well-being of the world's growing urban population.

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Note: Danielle Shanahan undertook this investigation as a Research Fellow at the University of Queensland. She is now actively engaged in enhancing nature experiences for urban populations as the new Manager of Conservation, Research, Learning and Experience at the Zealandia wildlife sanctuary in Wellington.
See https://www.visitzealandia.com/

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Fuller RA, KN Irvine, P Devine-Wright, PH Warren & KJ Gaston (2007). Psychological benefits of greenspace increase with biodiversity. *Biology Letters* 3: 390-394. (And see *Decision Point #68*)

Shanahan DF, R Bush, KJ Gaston, BB Lin, J Dean, E Barber & RA Fuller (2016). Health benefits from nature experiences depend on

Does nature help us get active?

Brisbane residents who get plenty of physical exercise tend to visit green spaces more frequently and for a longer duration (Shanahan et al, 2016), yet it remains unclear whether having green spaces close by actually encourages people to exercise that otherwise would not. Intriguingly, it appears that the benefits of exercising in natural surroundings are greater than the same amount of exercise indoors a non-natural setting such as a gym, conferring a synergistic effect on health benefits.

There are several potential reasons for this – air quality is often better in natural areas, experiences of nature can reduce blood pressure or stress, and the psychological restorativeness of nature might in some way interact with exercise to produce a greater overall benefit than either in isolation. Thus, encouraging physical activity in natural, green spaces may be able to increase the health and wellbeing benefits more than what might be expected in current estimates.

Wherever we look, we seem to find benefits of experiencing nature!

Reference

Shanahan DF, L Franco, BB Lin, KJ Gaston & RA Fuller (2016). The benefits of natural environments for physical activity. *Sports Medicine* 46: 989-995.

What's the cost and feasibility of a cane-toad barrier?

Ground-truthing a model in outback WA

By Darren Southwell and Reid Tingley (University of Melbourne)

When building models of ecological systems, there are many reasons to engage with practitioners. For starters, practitioners often have a better understanding of the system being modelled and have access to the most relevant data. Such information can improve the realism and accuracy of model predictions. Practitioners can also benefit from engagement through an increased understanding and awareness of a model and its capabilities. This two-way dialogue can improve trust in a model and increase the chance it will be adopted to support decision-making.

Despite these advantages, engagement between modellers and practitioners is often limited. We recently attempted to bridge this gap between theory and practice for one of the worst invasive species in Australia: the cane toad. We updated an existing theoretical model predicting cane toad spread through arid regions of Australia with local knowledge of weather and land use, to find the most cost-effective location for a 'waterless barrier' to contain the spread of toads (Southwell et al, 2016).

A waterless barrier

The idea behind a 'waterless barrier' is that cane toads need access to water every 3-4 days. Because of their inability to retain water, the toads simply can't survive without it. So, in very dry regions, we may be able to halt their spread by excluding them from permanent water sources.

In arid areas of Australia, artificial water points, such as pastoral dams and tanks, are the only permanent water sources at which toads can rehydrate and breed. If we could prevent toads from accessing these water points, by replacing dams with leak-proof tanks, we could halt the invasion dead in its tracks.

A previous study (Tingley et al, 2013) suggested that a 'waterless barrier' composed of around 100 'managed' dams in a thin 'corridor' of pastoral land between Broome and Port Hedland, in Western Australia, would likely contain the spread of toads into the Pilbara.

The cane toad can't retain water. Consequently, it's remorseless spread might be stopped if we can build a waterless barrier. (Photo by Reid Tingley)

Key messages:

- There is much value in ecological modellers getting input from conservation practitioners
- We demonstrated this point by refining a model predicting the effectiveness of a waterless barrier to stop the cane toad invasion in Western Australia
- Our updated model has produced a feasible and cost-effective solution

This arid coastal strip is a gap where the Great Sandy Desert almost reaches the coast. The cane toads really have to squeeze through this narrow bottleneck to reach the Pilbara and then continue spreading through WA. This corridor is the perfect trap.

Locals and experts

While a number of NGOs and local management groups have expressed interest in the waterless barrier idea, some practitioners had reservations. Why the doubt? Were they concerned with the data and assumptions underpinning the model? Or did they just misunderstand its limitations and capabilities?

To find out, we decided to ask them. To do that, we ran a workshop in Broome with local practitioners and experts in cane toad biology. Attendees revealed that they were most concerned about the accuracy of input data going into the model, such as rainfall variability, the locations of dams, and other land uses in the corridor that might support toad populations.

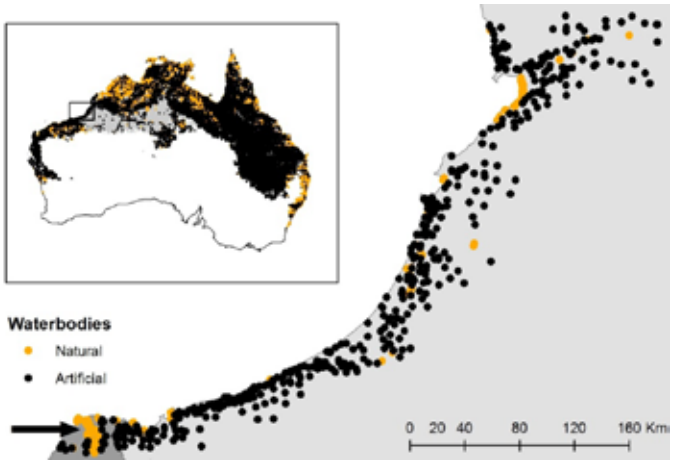
In response to these concerns, we updated the previous spread model to incorporate this information. We also drove the entire length of the corridor, verifying the locations of artificial and natural waterbodies on every property between Broome and Port Hedland.

In addition, we mapped a variety of other points that could potentially provide refuges for toads, such as dwellings, homesteads, roadhouses, as well as regions of irrigation and cropping.

Our fieldwork enabled us to produce the most up-to-date map of permanent water and land use on pastoral land between Broome and Port Hedland.

Waterless and cost-effective

With these updated maps, we then investigated the most-cost effective location for a 'waterless barrier' in the corridor. This involved simulating the spread of toads through the region in the absence of management, and then testing barriers placed at 17 potential locations. An economic model estimating the upfront installation and ongoing maintenance costs of a barrier was developed to



Natural and artificial water bodies in the study area. The black arrow in the lower left-hand corner of the main figure shows the location of the De Grey River.

find the most-cost effective barrier location. The updated model was run with and without local knowledge of the landscape, to determine if this information affected the best barrier location.

The results of the analysis suggest that the toad invasion front could be contained by excluding toads from fewer than 100 waterbodies, at a cost of approximately AUS$4.5 million over 50 years (that's less than $100,000 a year). This is considerably less than the amount spent on other invasive species management programs in Australia. For example, the Australian government recently spent $19 million on feral camels in central Australia over 4 years, and $35 million on the fox eradication program in Tasmania over 8 years.

Just as importantly in terms of the environmental decision science, our research demonstrates the importance of practitioner engagement during model development. Local knowledge overlooked in the original incarnation of the model – specifically knowledge about irrigation and dwellings – influenced the best place for a barrier.

Our new research suggests that the idea of a waterless barrier to halt the spread of cane toads is both feasible and cost-effective, and promises big conservation outcomes. This proposal is also a win–win situation for pastoralists and conservationists, because installing leak-proof tanks improves farm productivity, while simultaneously mitigating a key threatening process for biodiversity.

Structured decision making

While there are various ways to engage practitioners, to date, there is little understanding of which approaches achieve and maintain collaboration. For our waterless barrier workshop we adopted a structured decision-making approach, which is being increasingly advocated in the conservation literature for explicitly acknowledging uncertainty, facilitating relationship building and revealing hidden agendas (Addison et al, 2013). There is no doubt that in this case, the engagement process, facilitated by structured decision-making, helped all parties agree on the problem and objective, while improving practitioners' understanding of the model's capabilities and limitations, as well as modellers' understanding of the landscape.

Reference

Addison PFE, L Rumpff, SS Bau, JM Carey, YE Chee, FC Jarrad, MF McBride & MA Burgman (2013). Practical solutions for making models indispensable in conservation decision-making. *Diversity and Distributions* 19: 490–502. (see *Decision Point #74*)

More info: Darren Southwell darren.southwell@unimelb.edu.au

Note: The workshop in Broome was funded by the NERP Environmental Decisions Hub.

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Southwell D, R Tingley, M Bode, E Nicholson & BL Phillips (2016). Cost and feasibility of a barrier to halt the spread of invasive cane toads in arid Australia: incorporating expert knowledge into model-based decision-making. *Journal of Applied Ecology* http://onlinelibrary.wiley.com/doi/10.1111/1365-2664.12744/full

Tingley R, BL Phillips, M Letnic, GP Brown, R Shine & SJE Baird (2013). Identifying optimal barriers to halt the invasion of cane toads *Rhinella marina* in arid Australia. *Journal of Applied Ecology* 50: 129-137. (And see *Decision Point #82*)

An example of a leaky trough system on a property between Broome and Port Hedland. Developing a waterless barrier would involve replacing this water point with a leak-proof tank, so that toads cannot access the surface water in the dry season. (Photo by Darren Southwell)

An example of a 'leak-proof tank'. No water is available for toads to rehydrate. (Photo by Darren Southwell)

Evolutionary biology – what is it good for?

And can it guide conservation decisions?

*By Sam Banks (ANU) and colleagues**

Ongoing evolution will be critical for the persistence of biodiversity under global environmental change. That's a big idea but there is little disagreement about this principle among environmental researchers, policy makers and managers. How does this principle translate into practice? Unfortunately, the integration of evolutionary biology into environmental policy and management has proved challenging and often lags behind ecology.

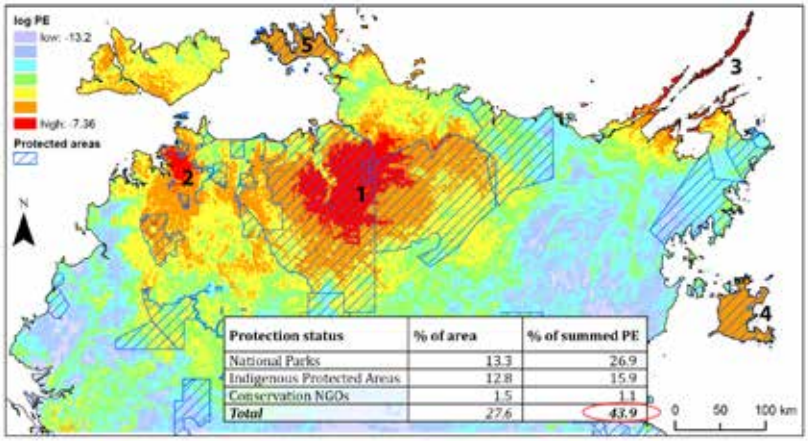
Part of the reason for this lag has been the inability of conservation policy, which traditionally has focussed on species, to engage with genetic variability, the well spring of evolutionary change. Part of it has had to do with the time and expense of monitoring and analysing genetic material.

However, in recent years there has been many technological and conceptual advances in evolutionary biology that are 'game changers'. In particular, the rapidly decreasing cost and time requirements for DNA sequencing mean that genetic data are increasingly accessible to inform environmental decisions and to evaluate the evolutionary consequences of their outcomes.

So, what's possible and why bother? Consider these recent investigations and their potential to inform policy and management. The first two case studies show how new methods for understanding evolutionary diversity can be used in conservation planning. The diversity and distribution of biodiversity is core information for the environmental management and decision-making process. The last two illustrate how a knowledge of genetic variation can directly feed into conservation management.

Genes in Top End lizards

ANU researchers have recently used genetic data to understand the evolutionary diversity of lizards across the monsoonal tropics of Australia. (Rosauer et al, 2016). Aside from discovering that northern Australia's biodiversity was much more complex than expected, they were able to identify geographic regions where reptiles are particularly distinctive in an evolutionary sense.



Protection status	% of area	% of summed PE
National Parks	13.3	26.9
Indigenous Protected Areas	12.8	15.9
Conservation NGOs	1.5	1.1
Total	*27.6*	*43.9*

Figure 1: A map of endemic diversity created from phylogenetic data to inform conservation planning for Top End lizards (PE: phylogenetic endemism)

Key messages:

- Evolutionary processes will be critical to biodiversity conservation in a time of global environmental change
- New advances in molecular biology make it faster and cheaper to do genetic analysis
- Environmental decison making needs to better integrate with evolutionary biology to create enduring solutions

Although conservation reserves in the Northern Territory's 'Top End' occupy 28% of land area, they protect 44% of these lizards' evolutionary diversity (see Figure 1). This information is currently being applied to conservation planning by the WA Department of Parks and Wildlife.

The approach applied here uses phylogenetic information in conservation planning. In doing so it sidesteps the arguments about where to draw the species boundaries in order to capture ancient as well as adaptive variation so important for conservation.

Microbes in the soil

In contrast to tropical lizards, the diversity of some ecological communities, such as soil microbiomes, has been largely invisible. But that's changing with the recent advent of new DNA-based approaches. Soil microbial communities are among the most diverse and important biological systems on earth. A gram of soil can contain one billion microbes and these tiny ecosystem engineers provide a raft of ecosystem services such as carbon sequestration, nutrient cycling, decomposition and water purification.

'Metagenomics' has recently allowed the measurement of both the evolutionary and functional diversity of these organisms across Australia as part of the Biomes of Australian Soil Environments initiative (Bissett et al, 2016; and see http://www.bioplatforms.com/soil-biodiversity/).

Soil microbes have not featured strongly in environmental policy and management until now, but the knowledge from this project is opening new opportunities to measure, monitor and manipulate soil microbes to achieve improved outcomes in conservation, ecological remediation, biosecurity, forensics, minerology and agriculture.

To mix or not to mix

An understanding of evolutionary processes can be incorporated directly into conservation policy and practice. For example, a hotly debated question in the management of small populations of threatened species has been whether to mix genetically divergent populations to maximise diversity and adaptive capacity. Some biologists believe there is a risk that doing so could render the population less suited to its local environment.

Sampling soils for metagenomic analysis of microbial diversity at a recently burnt site at Uluru. (Photo courtey of Andrew Bissett)

Scientists from the University of Melbourne and LaTrobe University translocated a handful of mountain pygmy possums from a large genetically diverse population at Mt Hotham in Victoria to small population at Mt Buller (Weeks et al, 2016). The Buller population had been declining as a result of inbreeding. Progeny from these males were larger, fitter and more genetically diverse which has resulted in the Mt Buller population growing by 50% each year since 2012. Today there are more mountain pygmy possums on Mt Buller than when they were first discovered in 1996.

This approach is now being incorporated into recovery efforts for several other threatened mammals where a lack of genetic diversity is likely to compromise recovery efforts.

Assisted migration

Innovative research collaborations on the genetics of eucalypt restoration have addressed the issue of 'assisted migration' to facilitate climate-change adaptation. Eucalypts are foundational species in many Australian landscapes, and restoration of eucalypt woodlands is a key conservation activity.

While the 'local-is-best' perspective has been pervasive in plant restoration, a new strategy aims to maximise adaptive capacity in restoration projects. This approach, called 'climate-adjusted provenancing' involves introducing seed from populations in the direction of climate change into restoration efforts, as these populations are likely to have seeds with adaptations to future climates (Prober et al, 2015).

Adaptation across climate gradients has been shown in red ironbark (*E. tricarpa*) (Steane et al, 2014) and is currently being investigated in other foundational tree species such as yellow box (*E. melliodora*), a key species in the critically endangered Box-Gum Grassy Woodlands, and jarrah (*E. marginata*), the main forest species of south-western Australia.

A critical role

These case studies highlight a critical role for evolutionary principles and insights in conservation decision making. Effective engagement of managers and scientists enables the integration of evolutionary biology into conservation management and policy thus maximising long term persistence of our iconic plants and animals.

Evidence-based policy that draws on fundamental principles in evolutionary biology will provide a foundation for cost-effective management of Australia's environment. So, there's no longer any excuse for not making better use of evolutionary biology when it comes to safe guarding our precious and unique natural heritage.

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**This editorial arose from the recent Annual Conference of the Centre for Biodiversity Analysis at the ANU, Canberra, in which a diverse group of researchers, conservation policy makers and practitioners discussed the interface of evolutionary biology and conservation policy and management. Discussions highlighted how recent breakthroughs in genetics have helped to overcome barriers to integrating evolutionary principles and insights into environmental policy and decision making. A number of pioneering collaborations were discussed that showcased how new thinking and techniques in evolutionary biology have generated important developments in conservation policy and improved management outcomes. Sam Banks (a CEED associate) led the creation of the editorial with assistance from Justin Borevitz, Linda Broadhurst, Margaret Byrne, Sue Fyfe, Tania Laity, Craig Moritz, Adrienne Nicotra, Dan Rosauer, Megan Supple, Andrew Weeks and Andrew Young.*

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Steane DA et al. (2014). Genome-wide scans detect adaptation to aridity in a widespread forest tree species. *Molecular Ecology* 23: 2500-2513

Weeks AR et al. (2016). Conservation of genetic uniqueness of populations may increase extinction likelihood of endangered species: the case of Aust mammals. *Frontier in Zoology* 13: 31.

Following the genetic rescue, Mt Buller mountain pygmy possums are now bigger, fitter and more genetically diverse than before the translocation of males from Mt Hotham. (Photo by Andrew Weeks)

I'm an economist – I'm here to help

How economics can enhance the success of ecological restoration

By Sayed Iftekhar (University of Western Australia)

What would an economist know about ecological restoration? Well, while he or she may not be up on the taxonomy or ecology of the plants and animals being targeted in a restoration effort, an economist brings considerable expertise when it comes to evaluating the costs of a project (expertise that historically has been lacking in some of the solutions proposed by conservation scientists). Accurately evaluating likely costs is an important dimension of effective ecological restoration, however, the discipline of economics has so much more to offer. Unfortunately, many restoration practitioners don't think beyond 'costs' when it comes to economics. Well, it's time they did because economics has a lot more to offer to enhance the likelihood of success of a restoration effort.

Up front it needs to be said that ecological restoration is a complex process with many ecological, technical, social, and economic challenges. Many of these can be addressed by applying sound economic principles and techniques. Here are four key aspects of restoration where economics can provide valuable assistance: estimation of restoration benefits; estimation of the costs of restoration; selection and prioritisation of projects, and securing long-term financial resources to support restoration.

Estimating restoration benefits

In many cases, practitioners fail to demonstrate the links between the ecological restoration and society. In so doing they undersell the social benefits of restoration. Consideration of the broader social and economic benefits of restoration may help practitioners tailor their programs to promote better engagement.

Key messages:

Economic principles, tools and instruments can be applied to a range of factors that affect the success of a restoration project

Addressing four key aspects of ecological restoration would enhance their success
(1) assessing social/economic benefits,
(2) estimating overall costs,
(3) effective prioritisation, and
(4) long-term financing

Several economic methods are available for benefit assessment. The method applied depends on the type of value likely to be produced by the project. Market-based methods are generally not applicable because most of the values generated through the restoration are not traded in formal markets (ie, they are non-market values). Non-market values have either a use value (eg, recreation) or a non-use value (eg, preserving a threatened species for future generations).

Revealed-preference approaches are applied to measure use values, and stated-preference approaches are applied to non-use values. Benefit-transfer method could be applied when it is too expensive to conduct primary studies.

Estimating costs of ecological restoration

Cost information is important for ecological restoration planning because it informs decisions on whether to conserve or to restore, which projects to pursue, and which methods to use. The four main costs involved are acquisition, establishment, maintenance and transaction. Acquisition costs are the costs of acquiring the property rights to the land to be restored. Establishment costs are upfront capital investments involved. Maintenance costs include ongoing management, administration, and monitoring. And transaction costs may include searching for suitable sites, organising programs, and negotiating and signing contracts.

Ecological restoration is complex and expensive. Economists can provide multiple insights on how to make it more effective. (Photo courtesy of Greening Australia)

Different economic tools are used to estimate different types of costs. Establishment and maintenance costs are often most easy to estimate because market prices are available for most items in these costs categories.

Acquisition costs and opportunity costs are estimated using capitalised gross revenue or gross margin of the productive use of land or using methods based on property or sales prices, such as hedonic pricing.

It's one thing to know the cost of a restoration activity (such as direct seed drilling as pictured here), but to ensure the best outcomes of ecological restoration it's critical to incorporate the full range of social, ecological and economic benefits into your planning.
(Photo courtesy of Greening Australia)

Transaction costs can be estimated by conducting surveys among the participating landholders or agencies and reviewing documents.

Prioritising restoration projects

Once the costs and benefits have been appropriately measured, the choice among projects requires an index or metric to help guide which projects are chosen (and which are not). A metric is a formula or a model that 'translates' the various parameters of a project (such as cost, effectiveness, and area) into a single score that can be compared to the score of other projects (see the box on strong and weak metrics).

The use of a rigorously designed metric is even more important when combining multiple benefits (which could be complex and conflicting).

Concessions may be required in the location, design, and complexity of restoration projects to achieve broader benefits. The acceptability of such a trade-off is likely to vary between restoration projects and depends on factors such as project outcomes specified by regulatory or funding bodies, threat status of the biodiversity asset, and value of the biodiversity asset to the community.

Long-term financing of restoration projects

Even when restoration benefits and costs have been correctly assessed and an appropriate prioritisation procedure has been employed, without adequate financial support failure is possible, particularly for long-term (decades) projects. While there are examples of long-running environmental programs (such as the Conservation Reserve Program in the United States which was established over 30 years ago), in most cases environmental programs have short funding time-frames. Given this, it might be useful for agencies to consider innovative solutions to securing long-term funding, an issue considered by some as one of the greatest hurdles to restoration.

Long-term funding could be implemented by working within existing funding arrangements; developing synergy among existing programs; financing through property taxes, developing public-private partnership and through volunteerism.

Strong and weak metrics

The metric used to compare restoration projects is critical to outcomes. Fiona Gibson and David Pannell analysed the impact of using strong versus weak metrics and found that poor metrics resulted in environmental losses of up to 80% – not much better than completely random uninformed project selection (Gibson and Pannell, 2016).

The most costly errors that contribute to a metric being 'weak' is omitted information about environmental values, project costs or the effectiveness of management actions. Using a weighted-additive decision metric for variables that should be multiplied is another costly error commonly made in real-world decision metrics.

They found that omitting information about project costs or the effectiveness of management actions, or using a weighted-additive decision metric (that should be multiplied) can reduce potential environmental benefits by 30 to 50 per cent.

Think about how hard it would be to double your budget (achieve a bigger slice of the funding pie); yet an equivalent environmental benefit could be achieved in effect in many cases by simply strengthening the decision metric being used.

Reference

Gibson F & D Pannell (2016). What a difference a metric makes: Strong (and weak) metrics for agri-environment schemes in Ansell D, F Gibson & D Salt (Eds) (2016). *Learning from agri-environment schemes in Australia: Investing in biodiversity and other ecosystem services on farms*. ANU Press, Canberra. http://press.anu.edu.au?p=346093
And see *Decision Point #82*

Bring an economist into your discussion

The science and practice of ecosystem restoration has for many years been based primarily on ecological considerations. Only recently have restoration scientists and practitioners begun to include economic aspects in the design of restoration projects.

Given the enormous challenge and cost of effective ecological restoration, we believe it's important that restoration practitioners increase their engagement with economists to better tap into the value that economics can provide. On the other side of the coin, we'd encourage economists to be more active in sharing the lessons of economics with practitioners working outside of the field of economics.

At the end of the day, if we fail to capture the full suite of benefits and costs involved in a restoration process, we risk undervaluing restoration and making poor investment decisions.

More info: Sayed Iftekhar mdsayed.iftekhar@uwa.edu.au

Reference

Md Sayed Iftekhar, Maksym Polyakov, Dean Ansell, Fiona Gibson & Geoffrey Kay (2016). How economics can further the success of ecological restoration. *Conservation Biology*. http://onlinelibrary.wiley.com/doi/10.1111/cobi.12778/abstract

Deriving survival estimates for microbats

From banding to Bayesian analysis

By Pia Lentini (University of Melbourne)

Microbats are fascinating creatures. They make up 17% of mammal species. They occur in a broad range of habitats, from deserts to rainforests to our cities, and are incredibly diverse in their ecology, feeding on everything from nectar to insects to fish and frogs. In doing so, microbats provide us with a range of vital services including pollination and pest control (see the box on 'bat service'.).

Despite their ubiquity, variety and value, microbats remain poorly understood. To most people they are invisible – tiny, nocturnal and with calls at frequencies that are mostly beyond human hearing. Maybe that's why so many species of microbats are currently threatened by a range of human impacts. These include the devastating impacts from the introduction of white-nose syndrome, wind-energy development, cave disturbances, sensory pollution, and loss of roosting and foraging habitat.

There is now a pressing need to understand how these threats are affecting the viability of bat populations. Population viability analyses (see *Decision Point #68*) can help us predict how bat populations might respond to management interventions, but their application is limited by high levels of uncertainty about vital rates, especially survival.

Banded bats

It has long been recognised that survival rates and associated longevity for many mammals follows rate of living theory: if you're a small mammal, you tend to live fast and die young. Our knowledge of this relationship can help us predict what the survival rate of a mammal species may be. Not so for bats, the oddballs of the placental mammal world, which live for decades despite their size. One particularly stoic species, Brandt's bat (*Myotis brandtii*), is known to live for over 40 years in the wild and only weighs around 6 grams.

Because mass alone was unlikely to be the primary driver of differences in survival rates, we set out to identify alternative traits which could be informative for bat population studies.

Bats have been banded since the 1910s, so there were a substantial number of mark-recapture studies for us to base our analyses on. We searched the literature for published annual survival estimates of wild bat populations, and extracted 193 survival estimates which covered 44 species and seven families (Lentini et al, 2015). For each of the 44 species, we used databases and reference literature to characterise the traits we suspected could be affecting longevity or survival. This included body mass, what they were feeding on and how, where they tended to roost, latitude, age at which females reach reproductive maturity, and the average number of young born per female each year (bats generally breed once a year).

The wing joints of a Gould's wattled bat (removed from a bat box during the monitoring program) are inspected for ossification. This allows researchers to determine the bat's age. (Image by Claire Keely)

Key messages:

- Microbats are important but poorly understood
- To improve management decisions for wildlife populations we need better estimates of survival rates
- We provided these estimates via a literature review of microbat banding studies, combined with monitoring data and Bayesian analysis

Modelled bats

So what did our resultant model tell us? Well, if you're a bat then it's not how big you are that matters when it comes to annual survival, but how many young you have per year. This is probably unsurprising for anyone that's ever seen a newborn bat – they are massive (relative to the size of the mother). For some species it's up to a third of the mother's mass after she has given birth. So, having two of these huge things at a time instead of one is likely to be associated with great physical stress and energetic expenditure.

What you're feeding on is also important – species that feed on fruits and nectar, that tend to occur in tropical regions, experience higher survival than species that hawk insects on the wing, possibly because they are less exposed to predators.

Finally, and unexpectedly given our note above about young and birth, males had lower survival rates than females. This could be explained by the fact that the majority of the species in our trait model were vespertilionids or 'evening bats', and for these species it tends to be the males that disperse from where they are born. During this time there is increased mortality as a result of predation, the energetic costs of movements, or lack of familiarity with habitats.

Armed with our model, we were now able to predict the survival rates of species for which we had no data, but their traits were known.

Boxed bats

There are many factors which may influence survival that will not be captured by trait models such as ours, so the existence of these models does not in any way diminish the need for good empirical data. Rather than blindly accept the model predictions, we demonstrated how to combine the ecological knowledge we gained from the trait model with real-world survey data, using an eight-year monitoring program conducted on two species which occupy bat boxes in

Melbourne's north: Gould's wattled bat (*Chalinolobus gouldii*) and the white-striped free-tailed bat (*Austronomus australis*).

Bat boxes can serve a number of important functions. The obvious one is to provide a roost for bats in areas which lack natural hollows due to the loss of large dead trees in the landscape. Within Melbourne however, monitoring programs are showing that the boxes are only being used by the most common species, so their role in conservation of threatened species is questionable.

However, boxes provide researchers with direct access to study populations, helping us gain insights into the ecology of some species which are difficult to capture. The boxes also allow for community education opportunities, where members of the public are able to see and hear about the bats, often for the first time. In the process, we are able to dispel some common myths and misunderstandings.

Bayesian bats

Our model predicted that survival of the white-stripe free-tailed bat (average range of 0.57-0.79) would be higher than Gould's wattled bat (average range of 0.44-0.69), because the latter bears twins. We used these ranges of values as prior information in a Bayesian analysis of survival for the bat box data, a powerful advantage of Bayesian approaches (see *Decision Point #58*). By constraining our analyses to a range of values (the prior distribution) which we know are reasonable based on our ecological knowledge (the trait model in this case) we can reduce the amount of survey data needed to reach a given level of precision in our final survival estimates.

In a time when resources for ecological research are limited and responses to threats must be rapid, it is surprising that we are not making better use of these types of approaches. Trait-based modelling provides insight into the processes driving communities and populations, and in using the learnings of past studies instead of starting from scratch we are able to better inform viability analysis and the range of management applications it serves.

Volunteers at the Organ Pipes National Park (just outside of Melbourne) help collect bats from bat boxes. The boxes, attached to the tree trunk, are around 6m off the ground. (Image by Claire Keely)

The white-striped freetail bat is one of the few microbats with echolocation calls that can be heard by humans. (Image by Stewart Macdonald)

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And for more info on Melbourne's Bat Box Monitoring Program see https://batboxes.wordpress.com/

Reference

Lentini PE, Bird T, Griffiths SR, Godinho LN & BA Wintle (2015). A global synthesis of survival estimates for microbats. *Biology Letters* DOI: 10.1098/rsbl.2015.0371 http://rsbl.royalsocietypublishing.org/content/11/8/20150371#sec-15

Bat service

Prior to working on bats around Melbourne I had the opportunity to carry out some research on bats in agricultural areas as part of my PhD (see Lentini et al, 2013, for what we discovered). Most people don't think of bats around farms but they provide a very valuable ecosystem service in terms of insect control. Bats are relatively hardy little creatures, and often make up a large proportion of the mammalian fauna in agricultural areas when other species have become locally extinct. As insectivores, they provide a vital ecosystem service to farms by controlling insect pests, and consume 40-100% of their body weight in a single night.

Reference

Lentini PE, P Gibbons, J Fischer, B Law, J Hanspach & TG Martin (2013). Bats in a farming landscape benefit from linear remnants and unimproved pastures. *PLOS One*. http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0048201

‘Planning’ for climate change

Incorporating climate change into spatial conservation prioritisation

By Kendall Jones (University of Queensland)

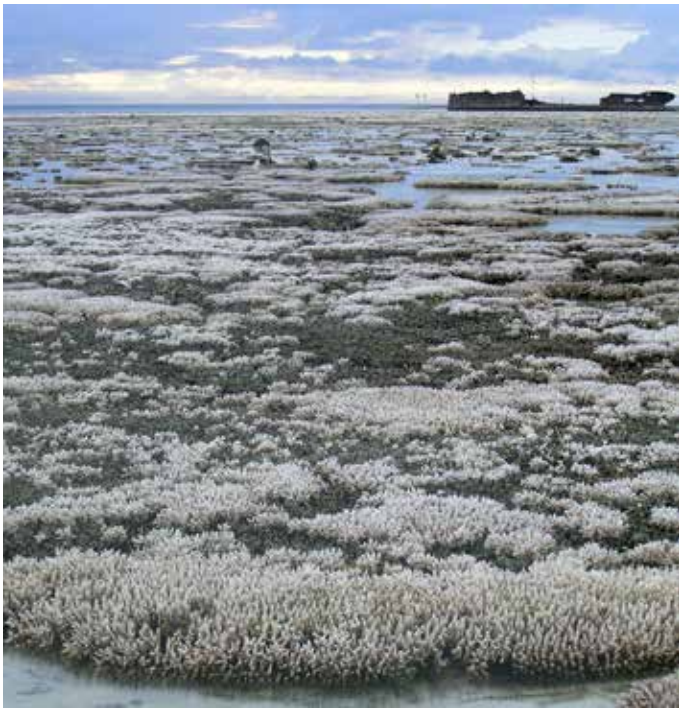
Human-forced climate change is affecting biodiversity in many ways, including changes in species ranges, mass coral bleaching events, and changes in the timing of biological events (eg, breeding or fruiting seasons, see *Decision Point #93*). On top of this, human responses to climate change are also threatening biodiversity, through agricultural expansion, construction of seawalls and changes in fishing areas (see *Decision Point #79*). And the impacts are likely to worsen, with climate change expected to become the main cause of species extinction over the coming century.

So, what can conservation planners do? We recently reviewed the literature on different approaches to spatial conservation prioritisation that incorporate climate change. We examined the impacts and timeframes being incorporated in the different methods.

The first thing to say is that the vast majority (96%) of articles on spatial prioritisation don’t incorporate any aspect of climate change. Of the papers which did incorporate climate change, most forecasted species distributions and aimed to either protect future species habitats or identify areas where climate change will have the least effect.

Forecasting species distributions is a useful strategy as it is applicable to a wide range of taxa, and can be targeted to single or multiple species. However, such forecasts are limited to well-known species, because climate data is not fine-scale enough to forecast distributions for rare species or those with small range sizes.

Identifying areas where climate change will have little effect is good for large-scale prioritisations, especially where predicting species distributions is limited by data availability, but it is difficult to target this strategy towards specific species.



Climate change presents a real and present danger to our natural ecosystems yet most studies on spatial conservation planning don’t even incorporate it in their analysis. Pictured here are the impacts of the 2016 bleaching event on the Great Barrier Reef.
(Photo courtesy of Oregon State University, CC BY-SA 2.0)

Key messages:

96% of studies on spatial prioritisation don’t incorporate any aspect of climate change

Those that do mainly forecast changing species distributions

There is a need to incorporate extreme events, and human responses to climate change into conservation planning

We also found that human responses to climate change, and extreme events such as droughts and coral bleaching, are almost totally ignored in the literature. This is alarming, as human responses to climate change are predicted to be as damaging if not worse for biodiversity, than the direct impacts of climate change.

On Pacific islands, for example, humans are being forced inland by rising sea levels. As humans move they clear forest for agriculture and housing, and the impacts of this activity are likely to be worse for biodiversity than the habitat lost directly from sea level rise.

Human responses to climate change can also impact existing protected areas, as changing crop suitability and increased food scarcity make people more likely to exploit protected areas for food and fuel.

Overall, despite numerous mandates and calls for climate change to be incorporated into conservation planning, the methods available for conservation planners remain few, and ignore some of the most harmful aspects of climate change. It is essential that future research develops planning approaches which both strengthen current conservation efforts, and also anticipate and respond to future conditions.

Most actions which strengthen current conservation efforts (eg, increasing the size and effectiveness of protected areas, reducing poaching pressure) will likely be good actions to take, even if climate change plays out differently than projected. These would constitute ‘no-regret’ responses.

Anticipating and responding to future conditions is hampered by uncertain climate predictions, but the impacts of climate change will be so great that there is no option but to accept this uncertainty and continue planning regardless. While identifying how species will respond to climate change is important, the crucial challenge is in developing planning methods that incorporate the full range of climate impacts. Only by doing so will we give biodiversity the best shot at surviving rapid climate change.

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Reference

Jones KR, JEM Watson, HP Possingham & CJ Klein (2016). Incorporating Climate Change into Spatial Conservation Prioritisation: A Review. *Biological Conservation* 194: 121-130. http://www.sciencedirect.com/science/article/pii/S0006320715301877

Restoring waterways cost-effectively

How and at what cost?

By Chrystal Mantyka-Pringle (University of Saskatchewan), Tara Martin (University of British Columbia) and Jonathan Rhodes (University of Queensland)

Southeast Queensland's waterways provide over $10 billion annually in economic benefits through drinking water supply, fishing, tourism, and recreation (see the *Healthy Waterways Report Card 2015*). But these goods and services are under threat from intensive agricultural, urban development and climate change. It is clear that restoration is essential to protect biodiversity and improve flood and climate protection, but what should we do under a growing population and at what cost to maintain the quality of benefits from our waterways?

Working with researchers from Griffith University, Healthy Waterways and the Queensland Government, we recently documented how to maximize the return on investment in freshwater conservation with limited financial resources under future climate and land-cover change scenarios (Mantyka-Pringle et al, 2016). The team focused on south-east Queensland as it is the fastest growing region in Australia and has less than 25% of its native vegetation remaining.

Restoration is key but costly

Stream and riparian restoration (fencing out livestock, bank stabilization, weed removal, replanting native vegetation, and expanding floodplain areas) provide the greatest protection to freshwater biodiversity in response to climate change and/or urban growth (see *Decision Point #78*). However, when one also considers the costs of management actions, farm and land management along with stream and riparian restoration are the most cost-effective strategies for freshwater biodiversity conservation. Farm and land-management include activities such as pasture rotation, erosion reduction through smart burning practices, and better management of pesticides and nutrients.

Managers identified that the cost of fencing for stream and riparian restoration can vary between AU$10,000-15,000 per kilometre. Revegetation can cost around AU$30,000-40,000 per hectare. Stabilization of banks and the construction of chutes/stepped weirs to transport runoff can also be very costly.

Riparian vegetation along Brisbane River. Queensland's waterways provide over $10 billion annually in economic benefits.

Key messages:

We document how to maximize the return on investment in freshwater conservation with limited financial resources under future climate and land-cover change scenarios.

Riparian restoration is the most effective adaptation strategy to climate change and urban development, but it is expensive

Farm and land management along with stream and riparian restoration are the most cost-effective strategies for freshwater biodiversity conservation

The cost of farm and land management on the other hand, is cheap by comparison. In many countries, government policy relies heavily on voluntary arrangements, education and information as the main policy instruments through which to persuade landholders and community groups to adopt better environmental management.

Better bang for your buck

So, changing farm and land-use practices in the broader catchment can improve water quality (eg, reduce nutrients, pesticides and sediments) 'cheaply', but overall these may only have a modest effect on biodiversity – especially if the riparian land is degraded. The Queensland Government has worked hard to improve the environmental condition of its waterways by managing pollutant loads through better urban and rural management and engaging with community members. As a result we have seen improvements in a few catchments, but a legacy of long-term riparian clearing in others continue to result in poor grading of water quality (see the *Healthy Waterways Report Card 2015*).

Yet, many lessons can be learnt from south-east Queensland for our neighbors and especially the sustained management of the World Heritage Listed Great Barrier Reef (GBR). For instance, in order to improve water quality reaching the GBR, we cannot just target best management practice programs for the sugar cane and grazing industries located in the upper catchments of North Queensland. Instead, to achieve the greatest bang for buck when it comes to waterway protection, conservation efforts need to first focus on protecting areas where the riparian cover is in relatively good condition and then on re-vegetating the stream network in partnership with best farm and land management practices.

Together, these actions will buffer pollutants from entering the freshwater and marine environments and provide better protection for biodiversity under climate change and urban development. Private landholders could also benefit financially as restoring riparian land could provide an alternative income through carbon farming.

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Reference

Mantyka-Pringle CS, TG Martin, DB Moffatt, J Udy, J Olley, N Saxton, F Sheldon, SE Bunn & JR Rhodes (2016). Prioritizing management actions for the conservation of freshwater biodiversity under changing climate and land-cover. *Biological Conservation* 197: 80-89. http://dx.doi.org/10.1016/j.biocon.2016.02.033

Priorities for migratory networks

Making good decisions with limited information

By Kiran Dhanjal-Adams (University of Queensland)

The movie *Jaws* turned great white sharks into world-famous human eaters. Less well-known about great whites is that they can undertake astounding migrations. In 2002, a shark tagged in South Africa was tracked all the way to Western Australia (see Figure 1). Though it lost its tag in Australia, it was re-sighted again in South Africa, proving the species capable of migrating some 20,000 kilometers.

Great whites are, however, far from being alone when it comes to astounding feats of migration. Dragonflies have been found to travel similar distances between India and Africa, stopping off in the Maldives on the way. The longest recorded migration of all is that of an Arctic tern, which flew 70,000 km over a year from one pole to the other and back, in search of an eternal summer.

A lifestyle on the move is not without risk. Migration is physically demanding, and migratory species are highly reliant on places to stop, rest and feed along the way. Unfortunately, human activities are making it riskier for animals to travel, while also reducing the number of places they can travel to. Fishing, culling, fence-building, deforestation, land-reclamation and plastic pollution are all making it increasingly difficult for many species to migrate. So much so, that migratory species populations are declining at much greater rates than non-migratory species.

This suggests that current conservation strategies are not working as well as we would like them to. We are still at the early stages of understanding migration, and data detailing where, when and how far many species migrate is still sparse. Though a few individuals of some species have been tracked, it remains unclear how these few tracked individuals reflect the migration patterns of an entire species.

What should we measure?

Because of this poor understanding of where animals migrate, conservation strategies are currently set using the data we have – animal counts. Indeed, it is not unreasonable to assume that sites with lots of migrants are probably more useful to the population than sites with fewer migrants.

However, research is increasingly showing that where these sites are relative to each other is equally important. This is because the distance between two sites is likely to impact the number of animals able to travel between the two. Connected sites are therefore more useful to the population than unconnected sites.

So, how do we marry abundance measures with connectivity measures to set conservation priorities for migratory species when so few animals have been tracked?

To help maximise the value of limited information, we have developed a methodology for using as few as three tracked individuals to calculate the probability of an animal travelling between any two places (Dhanjal-Adams et al, 2016). By augmenting these measures with count data, it is then easy to draw up the migratory network of a species.

What should we prioritise?

We did this for seven migratory shorebird species in the East Asian-Australasian Flyway. We found that conservation strategies that prioritise sites based

Key messages:

Migratory species are declining globally at greater rates than non-migratory species, and are in need of urgent and strategic conservation action

We show how small amounts of tracking data can be used to increase our understand of where migratory animals travel (which helps in setting conservation priorities)

Including connectivity information always improves conservation outcomes for migratory species

Catching and tagging birds is a large part of understanding where they migrate. However, if we tag a few birds in multiple locations, we can learn more about how the population behaves as a whole, than if we tag many birds in the same location. (Photo by Kiran Dhanjal-Adams)

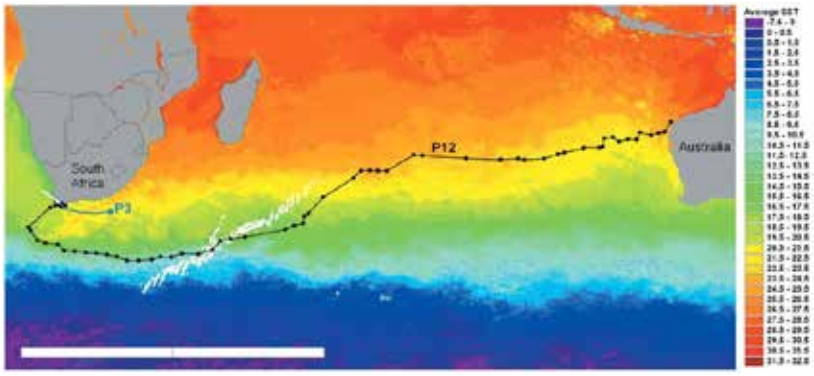

Figure1. Positions of (dots) and track followed by (black line) shark 'P12' during coastal and transoceanic movement. (Image from Bonfil et al, 2005)

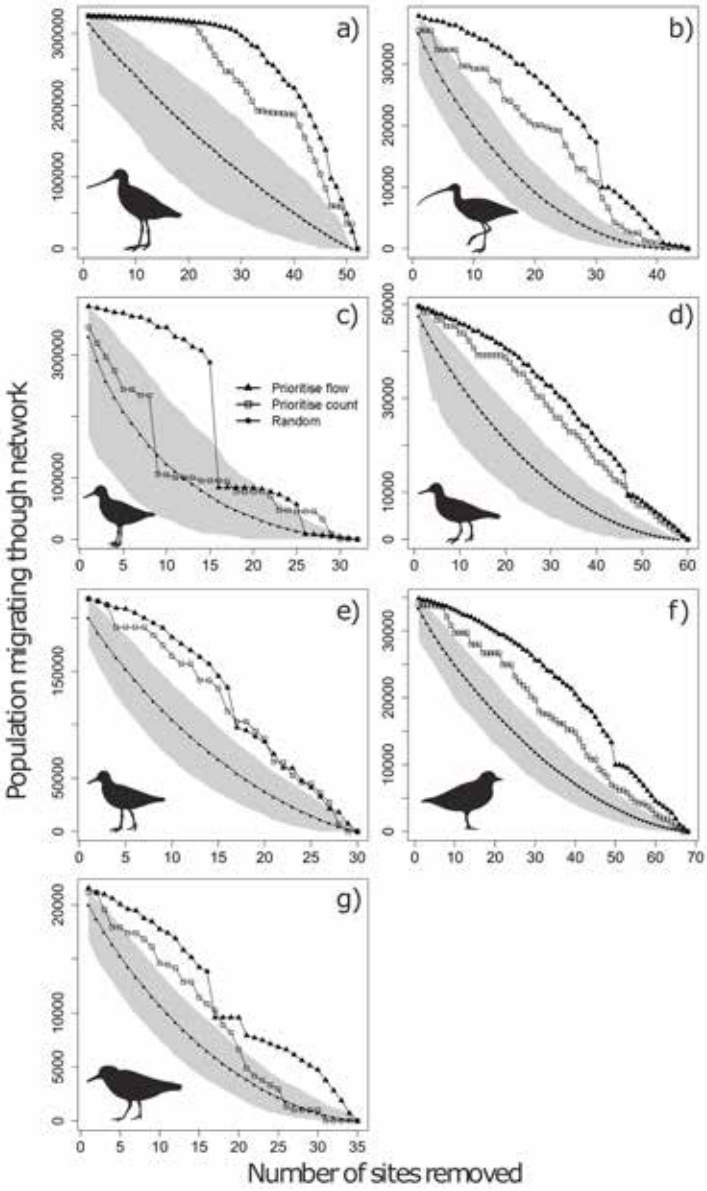

Figure 2: In our study, we drew up a migratory network and removed sites according to different prioritisation strategies to see how they influenced population declines. The flow prioritisation strategy (black triangles) includes connectivity data as well as abundance data. The maximum count prioritisation strategy only includes abundance data (squares). The random prioritisation strategy does not include any connectivity data or abundance data, but choses sites at random for conservation. We therefore perform the random prioritisation strategy 1000 times to have a representative spread of possible results (black circles; ±95% quantiles) We compared these three strategies for seven different migratory shorebird species: a) bar-tailed godwit, b) eastern curlew, c) great knot, d) grey-tailed tattler, e) red knot, f) ruddy turnstone and g) sanderling. As you can see, the flow prioritisation strategy always outperforms the count prioritisation strategy and random prioritisation strategy.

on connectivity and abundance together, always outperform strategies that only prioritise sites based on abundance (Fig 2).

Interestingly, sites with a smaller number of birds can be given a higher conservation priority than sites with lots of birds. This is because groupings of small sites can act as a unit, which together, support a higher proportion of the population than an isolated site with a higher bird count. These groupings of small sites are therefore prioritized over the site with slightly more birds. However, these tradeoffs are complex and difficult to predict, making it important to draw up a migratory network during the planning process.

By using very simple metrics, we show that it is possible, despite a lack of tracking data, to come up with estimates of where migratory species might travel, which in turn can be used to inform conservation planning.

Importantly, given migratory species are declining despite the current protection, methods like the one we have developed can be used to determine the value of adding additional habitat to the current network of protected areas.

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Reference

Dhanjal-Adams KL, M Klaassen, S Nicol, HP Possingham, I Chadès & RA Fuller (2016). Setting conservation priorities for migratory networks under uncertainty. *Conservation Biology*. http://onlinelibrary.wiley.com/doi/10.1111/cobi.12842/epdf

Tracking turtles

Another example of the importance of information for planning conservation management for migratory species comes from a recent CEED investigation on loggerhead sea turtles in the Mediterranean. Tessa Mazor and colleagues developed conservation plans for the loggerhead turtles using four approaches (Mazor et al, 2016). Each approach required increasing amounts of information (and therefore increasing cost). Their analysis revealed that spatial priorities for sea turtle conservation are very sensitive to the type of information being used. Setting conservation targets for migration tracks altered the location of conservation priorities. This indicates that conservation plans designed without such data would miss important sea turtle habitat.

Reference

Mazor T, M Beger, J McGowan, HP Possingham & S Kark (2016). The value of migration information for conservation prioritization of sea turtles in the Mediterranean. Global Ecology and Biogeography. 25: 540–552. doi: 10.1111/geb.12434
(And see *Decision Point #96*)

Developing conservation plans for a threatened migratory animal like the loggerhead sea turtle presents multiple challenges.
(Photo by Tessa Mazor)

Making 'good' decisions easier

Behavioural economics to improve environmental decision making

By Rachel Friedman, Angela Guerrero Gonzalez, Elizabeth Law & Kerrie Wilson (University of Queensland)

Behavioural economics melds ideas from psychology and economics to ask how our cognitive biases and limitations change our behaviour from that of so-called rational economic actors. It examines when and why *Homo sapiens* fail to match the expectations for those of *Homo economicus*, and helps explain why humans generally might not make the best decisions. For example, we often favour the present and discount the future; we have a greater aversion to loss than a desire to gain; framing and social norms influence what is perceived as good or right; and there are limits to our cognitive capacities.

As you can imagine, the field holds a lot of promise for environmental decision-making, which is why four CEED researchers (Rachel, Angela, Liz and Kerrie) recently attended a winter school in behavioural economics up in the beautiful setting of Queensland's Lamington National Park. We joined other academics and practitioners from a range of disciplines including economics, psychology, business, and education to better understand how behavioural economics can help us identify these biases and limitations that may impact our decision making.

One application of behavioural economics – the 'nudge' – incorporates the understanding of behavioural drivers into the design of procedures, options, physical environment, and information. Positive attitudes don't always translate into desirable behaviour, and some of the biases and limitations discussed earlier may cause this to occur (eg, see *Decision Point #93*). Behavioural economics is about identifying and dealing with these biases and nudging is about making good choices 'easier' for people.

The winter school also taught us the importance of evaluating interventions aimed at shifting behaviours. Michael Hiscox, head of the Australian Government's Behavioural Economics

Four CEEDites at a behavioural-economics winter school. Pictured (from the left) are Rachel Friedman, Liz Law, Kerrie Wilson and Angela Guerrero-Gonzalez.

Team (BETA), detailed the use of randomised control trials to assess what works. Unfortunately, conservation interventions (like designating a new protected area) often don't lend themselves easily to such controls. Usually, randomising 'treatment' is not possible – we can't protect an area based on the roll of a die, for example – and we often don't have good baseline data to compare the impacts with. Yet some activities could be designed from the outset in a way that better enables us to assess their efficacy. This is something conservation scientists should keep in mind when developing new studies.

All in all, it was a fabulous winter school. We were exposed to the potential of behavioural economics, made new connections across disciplinary divides, and sparked some fresh ideas for pushing our environmental decision science.

At the start of 2017, we'll be pursuing some of these ideas by hosting a week-long workshop to apply behavioural economics principles and methods to the challenge of reducing land clearing in Australia.

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Don't let 'climate' crush coral efforts

Following a recent international coral science conference, CEED researcher Jennifer McGowan led a short correspondence to *Nature* asking to researchers and managers not to lose sight of where they can make the most difference.

"The message of the correspondence aims to unite the coral reef science and management communities after the International Coral Reef Symposium held in Hawaii last June," explains McGowan. "The conference brought together over 2,500 of the most prolific and influential people working on coral reefs.

"With the juggernaut of climate change as the centerpiece, despondent group discussions and panels focused on the need for global-scale initiatives that will hold the worst carbon polluters more accountable, halt the human population growth rate, and reengineer a capitalist system that ignores the health and wellbeing of biodiversity.

"We argue that these conversations are unproductive for environmental managers and scientists on the ground. Few individuals have a platform to engage with global political leaders to drive the conservation agenda and influence policies that will affect climate trajectories.

"We suggest we missed an opportunity to unite our collective efforts behind cost-efficient actions that deliver measurable, 'uncertainty-proof', benefits at a local scale."

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

Reference

Jennifer McGowan J, HP Possingham & K Anthony (2016). Conservation: Don't let climate crush coral effort. *Nature* 536. http://www.nature.com/nature/journal/v536/n7617/full/536396a.html

Getting interdisciplinary at Oxford

ECRs attend the ICN workshop

By Nicki Shumway (University of Queensland)

In June I was very fortunate to be hosted by the Interdisciplinary Centre for Conservation Science (ICCS) at the University of Oxford (led by EJ Milner-Gulland, one of CEED's international PIs). While there I helped organise and participate in a workshop of the Interdisciplinary Conservation Network (ICN). The workshop gave early-career researchers, such as myself, the opportunity to interact with other conservation scientists and to learn key career skills.

Three research themes were run over the two day event: the application of predictive approaches to conservation; the integration of inter-disciplinary approaches to help manage 'wicked' conservation conflicts; and the future for no-net-loss of biodiversity in the marine environment.

It was this last theme that captured my attention. My PhD research focuses primarily on the improved implementation of no-net-loss (NNL) policies aimed at protecting marine biodiversity.

The NNL research theme was developed and organised by Will Arlidge (an Oxford PhD student), Prue Addison (an Oxford Post-doc) and myself. For the weeks leading up to the workshop we had many discussions about the increasing use of biodiversity offsetting and the need to refocus the conversation on the achievement of NNL by using the entire mitigation hierarchy rather than focusing primarily on offsetting.

Given the lack of data in the marine environment, avoidance will be a key component of successful NNL. The workshop brought together people from varied backgrounds to discuss the application of NNL in other industries and what factors could be hindering a broader application of the mitigation hierarchy.

The green fields of Oxford – workshoppers take a moment in the sun for the group pic.

(The mitigation hierarchy requires that all reasonable measures have been taken first to avoid and minimize the impact of a development project and then to restore biodiversity on-site before moving to 'offsets'.)

While only running for three days, the workshop was an amazing chance to get other perspectives on my PhD research, a wonderful opportunity to network with fellow students and researchers working in biodiversity conservation from a range of interdisciplinary fields.

More info: Nicki Shumway n.shumway@uq.edu.au
http://www.iccs.org.uk/interdisciplinary-conservation-network-workshop/

Note: CEED provided funding for Nicki and Angela Guerrero Gonzalez to attend the ICN Workshop.

Kerrie Wilson receives the Fenner Prize from PM

CEED's Associate Professor Kerrie Wilson has been awarded one of Australia's most prestigious science awards – the Fenner Prize for Life Scientist of the Year (as part of the this year's Prime Minister's Prizes for Science).

University of Queensland's Vice-Chancellor Professor Peter Høj said Dr Wilson's research built connections between ecosystems, governments and people.

"Kerrie is one of UQ's rising stars and her work epitomises our focus at UQ – to create change in the world," says Professor Høj.

Of course, CEED is just as proud of Kerrie and her accomplishments. Working with her colleagues at CEED she has been generated an important legacy for better environmental decision making. Kerrie and her team have generated an impressive series of more than 120 papers with about 7,000 citations. Just as importantly, her work with CEED is connecting global leaders in environmental decision science.

The award is open to all disciplines in the life sciences from biomedical research through to ecology. Dr Jane Elith took the gong in 2015 and Kerrie in 2016. Both have worked part-time for much of their careers revealing a greater acceptance of diversity in the sciences and of the multiple pathways that can lead to successful and fulfilling careers.

"The award not only recognises CEED's significant contribution to Australia's goals by demonstrating scientific excellence, but also to our contribution to delivering innovative solutions to addressing the loss of biodiversity" says Kerrie.

More info: http://www.scienceinpublic.com.au/prime-ministers-prize/2016life

Kerrie Wilson is the 2016 Fenner Prize for Life Scientist of the Year. (Image Science/WildBear)

Gums could be goners as climate changes

Australians could see suitable environments for the country's iconic eucalypt trees in decline within a generation, according to new international research involving a CEED Researcher Nathalie Butt. The findings, published in the journal *Nature Climate Change*, paint a stark picture with the habitat of more than 90% of eucalypt species set to decline, with 16 species forecast to lose their home environments entirely within 60 years, due to climate change.

"Changes are likely to be more drastic under severe climate change scenarios," says Nathalie Butt. "While some of the predicted effects could be reduced if we manage to significantly reduce greenhouse gas emissions".

Associate Professor Bernd Gruber of the University of Canberra's Institute for Applied Ecology, one of the co-authors of the report, said the study is the first to examine the impact of climate change on the distribution of a large group of closely related tree species on a continental scale.

"This study demonstrates the importance of not simply counting the number of species in biodiversity conservation, but also considering their evolutionary history, which determines how closely related species are to each other," says Bernd Gruber. "Using this approach we were able to identify hotspots that will contain high levels of eucalypt diversity under a changing climate, both in terms of the number of species and their reflection of the trees' evolutionary pathways. Protecting these hotspots will be important to ensure we retain biodiversity in the future.

"We predict that a three degree rise in temperature over the next 60 years would see a decline of suitable habitat for 91% of the 657 species of eucalypts we studied."

Reference

González-Orozco CE, LJ Pollock, AH Thornhill, BD Mishler, N Knerr, SW Laffan, JT Miller, DF Rosauer, DP Faith, DA Nipperess, H Kujala, S Linke, N Butt, C Külheim, MD Crisp & B Gruber (2016). *Nature Climate Change*. http://www.nature.com/nclimate/journal/vaop/ncurrent/full/nclimate3126.html#contrib-auth

Socio-economic conditions critical to PAs

An international study published in *Nature Communications* involving CEED researchers from the University of Queensland has found that protected areas (PAs) have been largely successful at safeguarding wildlife within their boundaries, particularly in wealthier, more developed countries.

Lead author Megan Barnes said the socio-economic conditions of the country in which a park was located was found to be a more important indicator of success than other factors such as the protected area size, design or type.

"National Parks are the cornerstone of most country's conservation plans, so it's essential they work as well as possible," says Megan Barnes. "It's important to tailor protected area management strategies to social and political conditions. Wildlife protection needs strong national governance to be successful."

Reference

Barnes MD, ID Craigie, LB Harrison, J Geldmann, B Collen, S Whitmee, A Balmford, ND Burgess, T Brooks, M Hockings & S Woodley (2016). Wildlife population trends in protected areas predicted by national socio-economic metrics and body size. *Nature Communications*. http://www.nature.com/articles/ncomms12747

Strategic framing for landholder engagement

A study of how private-land conservation organisations frame the benefits of participation has found a bias for emphasising the environmental benefits, while under-emphasising the benefits to landholders and the wider social benefits.

"The success of these conservation efforts is tied to the engagement of landholders, however only a small proportion of landholders participate in conservation" says RMIT's Alex Kusmanoff, the lead author on the study.

Alex's study analysed the websites of 20 most notable Australian private land conservation schemes and categorised how the benefits of participation were framed; whether framed as benefits to landholders, to society or to the environment.

"To be as relevant and engaging to as broad a range of landholders as possible, all three kinds of benefits should be well represented," says Kusmanoff. "Yet, we found a predominance of environmentally-framed benefits.

"The lack of emphasis on social benefits in particular is a missed opportunity to engage community-minded landholders who don't necessarily identify with the conservation movement. By appealing to those people who are already receptive to conservation messages, we are only ever going to recruit from the same potential pool of landholders. But we can increase that pool beyond the conservation-minded, by emphasising both the social and personal benefits of conservation.

"We must think strategically about who we are trying to reach, what motivates them, and how to frame our messages to better engage them."

Reference

Kusmanoff AM, MJ Hardy, F Fidler, G Maffey, C Raymond, MS Reed, JA Fitzsimons & SA Bekessy (2016). Framing the private land conservation conversation: Strategic framing of the benefits of conservation participation could increase landholder engagement. *Environmental Science & Policy* 61: 124-128. http://dx.doi.org/10.1016/j.envsci.2016.03.016