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Smart Decisions for the Environment

Abstract

People that are involved in managing natural environments face the challenge of achieving conservation goals with limited funds, and also of balancing needs for nature conservation with competing demands from society. This context has been a motivation for much of my research over the past 12 years, and I will share my career story with you as part of this paper. I will also describe progress we have made developing methods for prioritising where, when, and how to invest funds for protecting biodiversity. Progress in the field of ecosystem services, combined with progress in prioritisation has been a key driver of the shift in opinion that conservation investments should be influenced by biodiversity values alone. I will outline examples of the development and application of applied techniques to systematically evaluate the impact of environmental actions, a field that has lagged significantly. The overall impact of my body of research has been to reveal that through smarter investment, significant public and private funds could be saved and far greater benefits for biodiversity and society could be achieved. I finish with some insights into how we can improve the future for women in Science, Technology, Engineering and Mathematics (STEM).

A non-linear career in science

From about the age of 10 my mother used to accompany me to environmental activist meetings, including extensive tree hugging/sit in sessions on Fraser Island prior to its World Heritage Area listing. As a child I'd recycle my own paper, make my own skin care products, grow my own veggies, and spend school holidays wandering around the tropical forests and savannahs of North Queensland. I desperately wanted to be a national park ranger and my other career dream laid in naturopathy. Through negotiations with my school Guidance Officer, I ended up doing Environmental Science – a relatively new field at the time, and indeed the first year it was offered at The University of Queensland as a degree. I consistently worked two jobs during my undergraduate period - one in a record store and the second with one of several engineering and environmental consultancy firms in Queensland. I graduated with a job in a major engineering firm, and after 6 months was left twiddling my thumbs. At that point one of my honours supervisors mentioned doing a PhD and I got a scholarship at Melbourne University and couldn't get myself quicker out of the environmental consultancy world.

If the starting point of my career in science was unplanned, the future was to be non-linear. For example, I had a co-supervisor in the United Kingdom (Professor Adrian Newton) who at the time I started my PhD was based in Edinburg. I received a Commonwealth Scholarship to spend one year there, but as I was packing he informed me he was changing jobs to work for UNEP-WCMC and I should go to Cambridge instead. After 10 months my aversion to the English Winter took us to Chile. In true young person style, we walked around door knocking in the city of Valdivia until someone offered us a room to rent. I then set about understanding the deforestation patterns in Valdivian forests and wrote the 3rd and 4th chapters of my thesis – chapters 1 and 2 were to wait until the end of my PhD candidature.

When we returned to Australia we headed back to Brisbane. I wandered into my alma mater to see if I could find Professors David Doley, David Lamb and David Yates to no avail due to recent restructuring, but instead was directed to a "new guy" called Hugh Possingham. He gave me a desk to write up my thesis. My PhD was submitted after three years and required no corrections. I had travelled A LOT during my PhD – the UK, all through Europe, Africa, Asia, South America, and was exposed to a diversity of conservation challenges, social contexts and the creation of high level environmental policy.

After one year of completing my PhD I was terribly bored. I had lost contact with my environmental roots and started applying for jobs outside of academic circles. I accepted a job as Director of Conservation for The Nature Conservancy in Australia at this point. This role was nothing short of inspiring and it exposed me to my own country in detail. I had also turned 30, the fertility clock had started ticking, and it was clear that only a handful of weeks of maternity leave wasn't going to be sufficient. At that point I also found out that I was awarded an ARC fellowship, so we headed back to Brisbane.

The early days of setting up a lab at UQ was admittedly stressful. I had a lot of colleague-inspired anxiety associated with separating myself from my senior colleagues and establishing my own patch. We put in for a Centre of Excellence bid just before I went on maternity leave for the first time, I got tenure when I was 38 weeks pregnant and my feet were so swollen that I couldn't wear my shoes to the interview. I was awarded my second ARC fellowship while (literally) giving birth to my first child.

I've been supported by numerous colleagues including Cath Lovelock (who, after I gave a school seminar in my first year as a tenured academic, decided that I could make good use of some funding she had for collaborative research), Hugh Possingham (for numerous acts of generosity and support – too many to mention here), Erik Meijaard (who has been a supplier of endless inspiration), Niels Strange (my key collaborator at The University of Copenhagen and work-life balance mentor), Jonathan Rhodes (for his professional integrity and work ethic), Jenny Martin (who opened my eyes to the trials of female researchers) and Karen Hussey (for helping me to understand policy and politics). On reflection, there has been little structure to my career planning, but a consistent theme has been being surrounded by supportive colleagues.

On the science side, I'd proffer that my main contributions to conservation science have been in three complementary areas: conservation prioritisation (deploying economic principles to conservation practices to ensure efficient use of funds), ecosystem services (quantifying and mapping the benefits that nature provides humans), and conservation policy evaluation. I now give an overview of this work, and finish with some insights into how we can improve the future lot for women in STEM.

Prioritising what to do where and when

Smart decisions for the environment necessitates prioritisation. In order to prevent long-term loss and degradation of biodiversity the funds available for conservation need to be allocated both efficiently and effectively. While we can attempt to increase the resources available for conservation, at present funding is insufficient to achieve stated goals, and environmental concerns compete with other societal priorities, such as global food production, energy generation, and resource extraction. A generic framework for prioritising environmental interventions is based on the principles of classic decision theory. This framework encapsulates the key elements of any problem, including the objective function, knowledge of the system, control variables, and constraints (Wilson *et al.* 2007). In the next few paragraphs I will give 'decision theory 101' for conservation scientists, knowing that most undergraduate and Master's programs rarely offer such teachings, despite it being key for good environmental decision making.

In all problem formulations, the objective function reflects our goal and, importantly, also has an explicit measure of performance. Conservation goals might be related to species protection or to the prevention of species extinction. Often there is more than one objective, which means that trade-offs will likely be invoked and compromises must be made (Wilson *et al.* 2010). Making those trade-offs explicit is key, as choices then become transparent. What we are required to know about the system (the system knowledge) will depend on the particular problem at hand—in a conservation prioritization context we might want to know where the species of interest occur, or the distribution of ecosystem types and the environmental and anthropogenic factors that determine these distributions, or the patterns of water flows through a catchment. We may also want to know what the threats are to the species and ecosystems, what actions can be taken to abate these threats, and the cost of carrying out those actions, which may vary over the area of interest and through time.

The control variables reflect the options available to us. In the context of conservation prioritization we control how much money or resources we direct toward different conservation actions in any location and at a particular time (Wilson *et al*. 2006; 2007). The constraints limit the choice of control variables and may include a budget or how many parcels of land can be restored each year due to operational and seasonal limitations. The overall aim of a prioritisation analysis is to find the best solution through manipulation of the control variables that has the highest possible value of the objective function subject to our constraints. While optimal solutions might be desired, multiple near-optimal solutions are often sought for the sake of flexibility and the ease of calculation and communication. Now you know all the ingredients for solving a conservation problem, and many problems for that matter, inclusive of how to organise your weekly shopping through to planning your next holiday. Let's now think more deeply about the types of actions that we might undertake and when.

In contemporary Western Society, the creation of protected areas has traditionally been the primary action to achieve conservation goals. Natural resource managers routinely invest in a diverse array of activities such as fire management, invasive species control, and habitat restoration, either in protected areas, or on government or privately owned land (Box 1). In many places land acquisition just isn't feasible, and neither appropriate nor cost effective. More recent approaches to conservation prioritisation seek to prioritize between multiple actions (and locations) to achieve conservation objectives. Some approaches are also dynamic, capable of prioritizing actions temporally as well as spatially. In dynamic versions of the multiple-action prioritization problem our management decision is how much of our budget to allocate to each environmental action at each time step. For each action we need to know what it costs per unit area and the benefits that will be delivered. We can then generate dynamic investment schedules that reflect shifts in the allocation of funds as the return from investing in each conservation action diminishes and as uncertainty associated with the relative effectiveness of actions is reduced. A significant next frontier in conservation prioritisation is the inclusion of predictive models of human behaviour to better capture socio-ecological dynamics.

Box 1. Restoration prioritisation with City of Gold Coast

I have spent over a decade developing approaches to prioritise the investment of limited funds in biodiversity conservation. Prioritisation of spending in the context of restoration activities is a relatively new area of applied research. Restoration of habitat involves putting back the native vegetation that has been removed from a site with the plants and animals that were previously there. Our restoration prioritisation work has had important implications for on-ground practice: we have been able to identify the additional time and money required to restore sites and therefore grow the size of the funding pie for biodiversity conservation. We also identified sites that should be restored now to reduce the overall cost of restoration in the long term – i.e. to use the funds that we have more wisely. An important partner in our research has been the City of Gold Coast, one of the nation's fastest growing local government areas and an area of immense ecological and economic value. Our collaborative partnership is delivering transferable new approaches to define strategic restoration objectives (Guerrero *et al.* 2017), schedule investments, and reassess goals and priorities when objectives, budgets, and quality and cover of vegetation itself changes. As a result of this project we are now doing a better job of analysing the data we already have and also refocussing monitoring and reporting efforts. But what really sets this project apart has been the significant learning opportunity this partnership has created for all the team – be it the students and staff in universities or the on-ground restoration practitioners. This is a real partnership with regular exchange between all parties and a positive example of transdisciplinary research. From this project I have experienced that working with partners in the co-design of projects ensures that research is grounded in practitioner needs, exposes research staff and students to real world opportunities and constraints associated with environmental management, and ensures that research will translate to improvements in on-ground biodiversity outcomes. It is immensely satisfying as an academic researcher to be able to do innovative research, but innovative research with impact is the ultimate goal. This type of research makes me optimistic about the future of the environmental sciences.

Multiple benefits from environmental projects

Ecosystem services – the benefits people obtain from ecosystems – has stimulated diverse elicitation of why and how different people value nature. These benefits can include, among other things, the production of food and clean water, the regulation of floods, the provision of recreation and scenic beauty, a connection to place and inspiration. Ecosystem services can be used to understand what matters (beyond biodiversity), provide metrics for valuing decisions, deliver indicators for measuring trade-offs, and a communication and marketing tool. The ecosystem services framework has stimulated diverse deliberation on why and how we value nature, the consequences of alternative valuation perspectives and how such values might be best communicated (Schröter *et al*. 2014; Guerry *et al*. 2015).

It is my opinion that current application of an ecosystem service framework has not reached its full potential, due to an undue focus on mapping and markets. Researchers and practitioners have been distracted by analysing the spatial congruence between measures of the importance of areas for biodiversity conservation and the provision of ecosystem services, with the aim to identifying potential locations for 'win-win' outcomes. My early work also focussed on such analyses, which unsurprisingly indicated that there will be trade-offs.

While ecosystem services becoming an increasingly popular and utilised framework, the biodiversity conservation community needs to strategically engage in the identification, implementation, governance and evaluation of projects aimed to sustain ecosystem services (Wilson and Law 2016). The following are suggestions that one of my first to graduate PhD students, Dr Elizabeth Law and I generated to enhance conservation outcomes from ecosystem services protection:

1. Have a clearly identified objective, as opposed to seeking to only map values.
2. Target geographic locations for project engagement in the context of a broader conservation plan for the region, as opposed to focussing only on single sites.
3. Seek leverage opportunities, by supporting the implementation of actions to mitigate threats to the ongoing provision of ecosystem services and also to the persistence of biodiversity.
4. Ensure biodiversity conservation outcomes are additional benefits and go beyond the business-as-usual or the standard duty of environmental care.
5. Document and learn by compiling lessons from projects that have delivered conservation outcomes (or failed to deliver) and the underlying reasons – what was the context and the drivers of success (or failure) so that similar opportunities in the future can be identified (or avoided).

Evaluating environmental interventions

Natural resource management stakeholders are varied. They include governments, development-orientated sectors, local communities, and conservation groups. Each stakeholder would ideally be provided with rigorous, evidence-based evaluations to ensure that environmental interventions are effective, and that management is being efficiently delivered (Joppa and Pfaff 2011; Leverington *et al*. 2010). Methods required to evaluate the performance of environmental actions require a comprehensive analytical design and thorough treatment of the underlying mechanisms that determine effectiveness (Hett *et al*. 2012; Dewi *et al.* 2013). Such analyses are seldom executed as the required baseline data are often scarce and there are many complex determinants of the effectiveness of environmental actions that are difficult to disentangle and control for (Cook *et al.* 2009; Margoulis *et al.* 2009; Ferraro and Hanauer 2014).

Our projects on community forestry management in Indonesian Borneo (Box 2) are underpinned by complex theories of change, which is rare in the environmental sciences (Ferraro and Pattanayak 2006; Miteva *et al.* 2012). Conservation evaluation often leans on pseudo experimental design and sub-optimal data. The results of our body of evaluation research has elucidated current barriers to performance of conservation actions and tangible opportunities to enhance their performance in the future. I'm also incredibly fond of this work because it has been driven by one of the cleverest and dedicated conservation scientists

I have had the privilege of working with, Dr Truly Santika and my long term partner in conservation research, Professor Erik Meijaard.

Box 2. Case study on evaluating land use policy in Indonesia

Our work in Indonesian Borneo has demonstrated the utility of causal inference methods to evaluate the role of alternative land uses in protecting tropical forest. We investigated four single land uses (protected areas, natural forest logging concessions, and timber and oil palm plantation concessions) and two mixed land uses (mixed forest concessions and where protected areas and logging and/or plantation concessions overlap) were assessed (Santika *et al.* 2015). The rate of deforestation was found to be lowest for protected areas, followed by natural forest logging concessions. However, inside protected areas where logging and/or plantation concessions have been assigned, the deforestation rate was considerably higher revealing the need to explicitly account for overlapping land uses when assessing the effectiveness of protected areas. Importantly, our research design revealed that the deforestation rate inside all land uses tended to be higher for locations sharing similar characteristics to where plantation concessions have been assigned elsewhere, suggesting that these areas are inherently more susceptible to deforestation due to the economic competitiveness of agricultural or plantation opportunities. We have also assessed the extent to which deforestation has been avoided as a result of the Indonesian government's community forestry scheme, Hutan Desa (Village Forest). We used recent annual data on deforestation rates from two rapidly developing islands of Borneo: Sumatra and Kalimantan (Santika *et al*. 2017). The total area of Hutan Desa increased from 750 km^2 in 2012 to 2,500 km^2 in 2016. Performance at avoiding deforestation was assessed relative to a counterfactual likelihood of deforestation in the absence of Hutan Desa tenure, whilst controlling for potentially confounding biophysical variables and the original selection criteria for this type of land use. We found that Hutan Desa management has successfully achieved avoided deforestation overall, but performance has been variable through time. Hutan Desa performance was influenced by anthropogenic and climatic factors, and importantly, also land use history. Hutan Desa allocated on watershed protection forest or limited production forest typically led to less avoided deforestation regardless of location. Conversely, Hutan Desa granted on permanent or convertible production forest had variable performance across different years and locations. Extremely dry conditions during drought years pose additional challenges to Hutan Desa management, particularly on peatland, due to increased vulnerability to fire outbreaks. This insight has further fuelled my engagement in peatland restoration initiatives in Indonesia over recent years. Overall, this type of research improves understanding on where and when environmental policy is most effective with respect to deforestation, and helps identify opportunities to improve policy implementation to enhance the achievement of both social and environmental goals into the future. We are now in the process of undertaking such studies in respect to vegetation management policy in Queensland.

Success as a female in STEM – more than just luck?

Until recently when people ask me about my career, I would tell them that I have been **lucky.** And recently I have started to ask myself why I do that, and whether that is an appropriate or accurate response. I got high grades during school and university, was awarded a university medal, and have been awarded two consecutive highly competitive ARC Fellowships and secured a fully tenured position and full professorship in my 30s. There was quite a lot hard work and sacrifices in achieving those things, but not a lot of luck *per se*. I've also chosen to meet my career goals whilst working in industry at points. Being outside the academic circle expanded my world view, and gave new appreciation for on-ground challenges in conservation and of the freedom of thinking afforded in academia. After returning to academia I took two full years maternity leave and worked part-time for five years to see both of children into school. My partner and I have perfected the art of juggling, but the work-life balance has been good and I have achieved both personal as well as academic goals in my life to date. None of these decisions slowed down my career, and it has probably enhanced the personal satisfaction that I obtain from my work and the quality and efficiency of my professional contributions. None of these decisions were due to luck though.

So perhaps I consider myself lucky because I have a passion for the Biological Sciences which is a field of science that has the most women participating at higher levels, or my university employer has (at least in recent years) been very proactive in supporting female academics, or because the colleagues that I value the most don't discriminate based on sex, or perhaps more importantly I was born into a family where nobody ever suggested that I couldn’t do something because of my gender. Reflecting on these things I know that it is not only inaccurate to say that I have been lucky, but also highly inappropriate - none of the above contextual factors should boil down to luck…all people regardless of gender, race or religion should be able to achieve what they are capable of achieving. Gender equity and equality is a key piece of that puzzle.

Here are my five suggestions for everyone in STEM trying to navigate the puzzle themselves, based on my own experiences and observations:

1. **Be yourself and follow your values** (but first, find out what your own values are).
2. **Recognise your biases** and do something about them.
3. **Speak up** – call out discriminative behaviour and policies.
4. **Challenge the status quo and ask why?** For example, when you don’t feel genders are being equitably represented (e.g. at a conference, in a panel, in tutorials, on staff).
5. **Become informed** about women’s issues, gender equality and what governments, universities and businesses could do to achieve cultural change. Write letters. Encourage choice. Encourage flexibility.

Conclusions

Just like smart environmental decision-making, smart career planning requires: (1) Prioritisation (what to do where and when); (2) Evaluation of trade-offs and considering multiple benefits given longer-term objectives (e.g. life-work balance, family time), and (3) using evaluation and feedback to adaptively manage a career (what works and what doesn’t, and therefore what needs to change). Lucky are those people that can recognise an opportunity and dare to take it, or similarly recognise mistakes and correct them. Importantly, a fulfilled career requires thinking and working in a way that reflects more broadly the way you live, your principles and ideals, and recognising the role we all have to play in making work places and opportunities more accessible for everyone.

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