How to make biological conservation a success

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Summary

I discuss some of the research we have completed in our conservation science centres over the past 15 years and how it has delivered conservation outcomes in policy and on the ground, both nationally and globally.

First, I will illustrate our approach to prioritising actions and species triage. This cost-effectiveness approach has recently been adopted by two states – why isn't it more widely used? Second, we have developed a tool for building networks of marine and terrestrial reserves called Marxan (http://en.wikipedia.org/wiki/Marxan). I will explain how it was used to rezone the Great Barrier Reef at the beginning of this century, and some of the benefits and pitfalls of its application globally. Marxan is now used for spatial planning in over 140 countries. Finally I will explain some of our thinking about how and why to invest in monitoring for nature conservation. Why is a logical approach to monitoring so hard to pursue, or is it just a matter of time? I conclude that our approaches eventually deliver conservation outcomes and efficiencies; however the path to adoption is very slow.

There are two keys to our success in delivering conservation outcomes in the real world. First we work closely with government, not just in delivering research outcomes but also in formulating the problems we tackle through partnerships. Building this relationship consumes 20 % of my working life and requires respect and consideration – although it has frustrating moments. The reward of collaboration includes fifty million dollars of applied research income on top of protecting a large amount of biodiversity. Second, we couple the basic science with decision science tools. Without decision science thinking and proper problem formulation, our work would be divorced from real world social and economic constraints. The cost and feasibility of actions and policies must form a part of any translation of science into outcomes.

Zusammenfassung

Wie wird Naturschutz zum Erfolg?

In dem Beitrag werden einige der Forschungsarbeiten, die in den letzten 15 Jahren an unseren Naturschutzzentren durchgeführt worden sind, und die durch sie auf politischer Ebene und in der Praxis erzielten Ergebnisse vorgestellt, sowohl national als auch international.

(1) Um Schutzmaßnahmen zu priorisieren und Arten für den Schutz auszuwählen, haben wir einen Kosten-Effektivitäts-Ansatz entwickelt, der vor kurzem von zwei Ländern übernommen worden ist. Es stellt sich die Frage, warum dieser Ansatz weltweit nicht öfter genutzt wird. (2) Das Instrument Marxan wurde von uns entwickelt, um marine und terrestrische Schutzgebiete optimal zu vernetzen (http://en.wikipedia.org/wiki/Marxan). Neben der Neuzonierung des Great Barrier Reefs Anfang unseres Jahrhunderts werden anhand nationaler und globaler Projekte weitere Vorteile, aber auch mögliche Fallstricke bei der Anwendung von Marxan erläutert. Mittlerweile wird Marxan in über 140 Ländern zur Raumplanung verwendet. (3) Schließlich werde ich der Frage nachgehen, wie viel und warum wir im Naturschutz in Monitoringprogramme investieren sollten. Wieso ist es so schwierig, einen logischen, auf Mathematik basierten Ansatz für Monitoring durchzusetzen – oder ist dies schlicht eine Frage der Zeit? Letztlich dient unsere gesamte Arbeit einem erfolgreichen und effizienten Naturschutz; dennoch ist der Weg zu ihrer Akzeptanz mühsam und schleppend.

Zwei Schlüsselfaktoren bestimmen die erfolgreiche Umsetzung der von uns erzielten Ergebnisse in die

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Rundgespräche der Kommission für Ökologie, Bd. 44 »Wie viel Wissenschaft braucht der Naturschutz?«, S. 137–142.
 – ISSN 2366-2875 – ISBN 978-3-89937-200-7

Praxis. Zum einen arbeiten wie eng mit der Regierung zusammen, nicht nur bei der Vermittlung der Ergebnisse, sondern auch in Bezug auf die Identifizierung von Problemen im Naturschutz, die wir gemeinsam mit unseren Partnern vornehmen. Diese enge Zusammenarbeit aufzubauen kostet ein Fünftel meiner Arbeitszeit und bedarf des gegenseitigen Respekts und sorgfältiger Abwägungen – und kann frustrierend sein. Belohnt wird sie jedoch u. a. durch 50 Millionen Dollar für die angewandte Forschung und durch den erfolgreichen Schutz der Biodiversität. Zum anderen verbinden wir Grundlagenforschung mit Hilfsmitteln zur wissenschaftlichen Entscheidungsfindung (decision science tools). Ohne diese und ohne die richtige Formulierung der zu lösenden Probleme würde unsere Arbeit ihren Bezug zu den sozialen und wirtschaftlichen Zwängen verlieren: Kosten und Machbarkeit von Naturschutzmaßnahmen und Naturschutzpolitik sind ein unabdingbarer Bestandteil bei der Umsetzung wissenschaftlicher Ergebnisse in die Praxis.

Introduction

My talk is going to be very different from the other talks in this symposium. I'm not really going to talk much about science, but about decision making, and that is more mathematics and economics. That is what our research group, 80 Ph.D. students and 50 postdocs over 20 years, does and what I have been doing for 20 years. For 20 years we have been stealing ideas from engineers, economists and applied mathematicians and applying them to nature conservation. The key to this and the key to engagement is quite simple: turn up and engage. As you are all here today, you should know that. You have to turn up to everything you can, and with government you have to turn up often.

Decision-science thinking

Delivering environmental outcomes is all about making better decisions. People have talked about decisions today, and two things have been mentioned repeatedly: *objectives* – if you cannot state a clear objective, you are lost. You cannot proceed with using decision-science. Generally, in the conservation sector, the process of *prioritising actions* is poor and inefficient. The first mistake people make is not realising that you can only prioritise actions. The literature is full of people prioritising places and species. But you cannot do a place, you cannot do a species, you can only do an action. I repeat – you can only prioritise actions. The actions are for species, habitats and ecosystem services, and they deliver outcomes and occur in places. If you understand that single sentence – you can only prioritise actions, not species nor places – than you will realise that a great deal of conservation science is not very useful.

So, basically that is the take-home message:

- Our decision-science thinking has delivered a number of important on-ground conservation outcomes in Australia and globally, but progress is slow and erratic.
- Managers make decisions so they need the scientific knowledge integrated into decision-science tools, not just the science. They need to know about money, about people and about feasibility.
- Success requires persistence, simplicity and a champion in the management/policy agency, someone who gets what we are talking about and then drives the process ahead.

Using cost-effectiveness to choose conservation actions

Let me give you a very simple 'toy' conservation problem, not to trivialise the problem, but to illustrate the power of cost-effective thinking. Let's imagine, we have some species and we have a set of actions for every species (table 1). It's all about choosing actions, so we have got a recovery plan for each of the species. Most organizations spend their threatened species money on the species that are most likely to become extinct. So, in our example, that would be: save the tiger. That answer ignores the fact we haven't defined our problem. Let us assume that our aim is to spend our money on actions, given a fixed budget, so we maximise the expected number of species 'secured' over the next 50 years. Maybe we should recover the polar bear because it is relatively threatened and relatively cheap? Where should we spend our money first to get the greatest return on investment?

So, how do we rationally combine the factors in Table 1? Generally, what happens is that a lot of money goes to the tiger, some money goes to the polar bear and the orchid, but no money goes to koalas, because they are not threatened enough. But is that the right thing to do? What we often do is to turn these numbers into scores and add them up – and that is wrong as well. This problem is called the knapsack problem (Kellerer et al. 2004), and the simple idea of cost-effectiveness provides near-optimal and practical solutions.

There is only one logical way of combining those numbers: cost-effectiveness, that is: expected benefit divided by cost:

Probability of extinction × probability of success / cost to secure.

If you do this, you will spend your money on the orchid (table 1). That is the only rational way. If you spend your money in that way, you get the biggest number of species saved per million dollars: You have maximized an objective process. Of course you would do this with hundreds of species in a spreadsheet.

New Zealand case study

New Zealand came to us with this problem because they have limited funds and a lot of threatened species. In this case it is a 'champion', Richard Maloney, who worked with the government department that enabled the implementation of our work. They took two years and prioritised about 600 species. Table 2 shows calculations for two of the species. They added a rational wrinkle to the method and chose a weighting for each species based on its taxonomic distinctiveness (W in Table 2).

Using our method, New Zealand can conserve more than twice as many species than before and inform government how much they would need to spend to save all species. The mathematics proves that a triage approach, a word much disliked by some in the conservation movement, delivers a much better outcome for conservation (technically every choice is triage; Weitzman 1988, Bottrill et al. 2009).

There are lots of people who don't like this approach, but I don't know why. They say they are going to save everything so prioritisation is unnecessary – but are we saving everything? Based on the publications asserting an extinction rate 100–1000 times the background rate, I don't think we are saving everything.

Furthermore, the amazing thing is, that if you get the prioritisation process right, you can increase your budget. New South Wales is Australia's most populous state with many threatened species. They recently allocated an extra 100 million dollars to threatened species – because they used our rational formula and that compelled the government to act and invest more.

Table 1. Choosing actions for threatened species (four species as an example): combining probability of extinction (B; V: vulnerable, CE: critically endangered, NT: near threatened, E: endangered), costs to secure (C; M: million dollar), and probability of success (P) in the only logical way to maximise cost-effectiveness. The example uses imaginary data.

Species	Probability of extinction B	Cost to secure C	Probability of success P	Cost-effectiveness B × P / C
Polar bear	40 %, V	$ 5 M	30 %	0.024
Sumatran Tiger	90 %, CE	$ 20 M	50 %	0.025
Koala	10 %, NT	$ 5 M	100 %	0.020
Orchid	60 %, E	$ 10 M	50 %	**0.030**

Table 2. New Zealand case study: Project parameters (C: cost, B: benefit, S: probability of success) and species parameters (W: genetic taxonomic distinctiveness) which were used to calculate the weighted project efficiency (PE × 10^{12}). – Data from Joseph et al. (2009).

Rank	Project (species)	C	B	S	W	PE × 10^{12}
1	Wood rose (*Dactylanthus taylorii*)	$ 1 231 194	0.70	1.00	0.236	134 009
2	Maud Island frog (*Leiopelma pakeka*)	$ 2 076 132	0.70	1.00	0.087	29 346

The principle of representation in designing reserve systems and actions in general

The second example of decision-science thinking is more spatial. How can we get the principle of representation, that is, conserving a sample of every species and habitat, into on-ground actions? In this example we are talking about the action of taking sites in the sea or land and deciding what actions to take in those sites.

Less than 1 percent of the world's oceans are marine protected areas – there are take and non-take zones (marine reserves and marine protected areas) in that 1 percent. Until recently, most of the marine reserves were selected based on eclectic criteria – such as being close to a marine research station. Thus, the processes for choosing them have had little to do with ecology or decision science. What we really need are systems of protected areas – not just disconnected sites. Natura 2000 is the European version of this system.

The Marxan algorithm

Systematic spatial conservation planning is the process of selecting sites for conservation action that delivers conservation outcomes (such as reserving a sample of every species and habitat) in a well connected system for the minimum impact on other users of the land or sea. This boils down to minimising the cost of the research system, making the research system compact, and reaching all conservation targets (Possingham et al. 2000, Ball et al. 2009, http://www.uq.edu.au/marxan). In mathematics this is:

$$\text{minimize} \quad \sum_{i}^{N_S} x_i c_i + b \sum_{i}^{N_S}\sum_{h}^{N_S} x_i (1-x_h)\, cv_{ih}$$

subject to the constraint that all the representation targets are met (each species being represented at least once):

$$\sum_{i}^{N_f} x_i r_{ij} \geq T_j \; \forall \, Tj$$

and x_i, the control variables which tell you if a site is in or out, is either zero or 1:

$$x_i \in \{0,1\} \; \forall \, i$$

where N_s is the number of sites, c_i is the cost of a site, b reflects our interest in keeping the site selection compact and connected, cv_{ih} reflects the value of a connection between sites i and h, r_{ij} is the amount of feature j in site i, and T_j is how much we want to conserve of feature j. We used this decision support tool for rezoning the Great Barrier Reef with 17000 planning units and about 250 conservation features. We found good answers to the rezoning problem, we delivered them to the politicians, and the software and decision support tool contributed to the rezoning of the Great Barrier Reef on July 1st, 2004. It was the first large-scale systematically designed reserve system in the world, accommodating huge amounts of biological and economic data. At least 20 percent of every single habitat type was conserved as a no-take area.

Since then, 120 countries have used our Marxan software planning on the land or sea to inform conservation decisions. Why does it help? It is free, logical, flexible and repeatable. The program "Marxan with zones" could be used for zoning any conservation actions in Bavaria, such as the location of wind farms or timber harvesting (it is not just about reserve design).

When and why do we need monitoring?

Some people have asked us whether decision-science thinking can be applied to decisions about what and how to monitor ecological systems. Also, a few people ask how much money is it worth spending on collecting new data to achieve conservation outcomes. Why do we not just go and save the species – what is the value of information? Firstly, money you don't spend on monitoring could be spent on managing. The value of information (VoI) theory is a formal approach that gives the answer to the question of how much time and money you should spend gathering information to solve a problem. If we analyse problems like this we often find the best thing is to do no more monitoring or data collection (McDonald-Madden et al. 2010, Possingham et al. 2012, Grantham et al. 2009).

You have to be very clear on what the science is for. If you had the extra information, what decisions would you change? If you cannot answer that question, then you can't justify gathering new information from a purely utilitarian perspective – although you could from a pure science perspective.

Many people think monitoring in applied conservation is a statistical problem. But it is first and foremost an optimisation problem. Statistics is part of the mechanics but should not proceed without a problem definition that clearly states objectives and constraints. Some monitoring is very cheap, some involves the community, and some involves engagement – and that is wonderful. Some monitoring leads to serendipitous outcomes, as we have heard today. Often, however, it happens that monitoring is a political displacement activity intended to keep scientists busy. The politicians want some scientific employ. They try to get away with not making a decision and give the scientists a lot of money, and ten years later they do it again – to stop making a decision.

There are more of these questions like: What is the value of data relative to taking action? Do we have to know everything before we start? Some of our papers are about optimal monitoring and information gain: How long should I monitor a stock before fixing the reserve size (Gerber et al. 2005)? Should all conservation assets be monitored (Chades et al. 2008)? How much data do I need to start buying reserves (Grantham et al. 2009)? What about the VoI analysis (Maxwell et al. 2014)?

For me, an important question is: Why has our optimal monitoring work failed to have impact so far? Generally, the success of our previous decision-science work has taken 10–20 years to be implemented. Large scale policy reform input by science and economics takes a long time. I used to get frustrated by that, but now I realise that translation of science into action simply takes a long time.

These messages for a successful partnership between scientists and managers or policy-makers is:

1. Turn up.
2. If you don't put money in, nobody is engaged in the process.
3. What is interesting is not always important, what is important is not always interesting.
4. Applied discovery science is science that could change management decisions, but all science is not useful for decision-making.
5. You can only logically prioritise actions (not species or sites).
6. Coupling science to decision-science is the key to having impact – find economists and make them your friend.

Our centre spends about 15 percent of its budget on communication and engagement. If you want to learn more about it, you can subscribe to our magazine "Decision Point" (www.decision-point.com.au). It is free and online, and comes out every month. That is how we try to do what several people have mentioned today: How can we make the science freely available and turn it into something that anybody – a manager, a politician, another scientist – can read in one or two pages with pictures, diagrams and no mathematics? We have a brilliant person who is incredibly talented, David Salt, who turns up turgid papers into something people will read.

Acknowledgements

My research is done in huge collaborative groups and tens of people, if not hundreds, have contributed to the ideas in this paper. The Australian Research Council and the Federal Environment Department – amongst others, generously fund us.

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