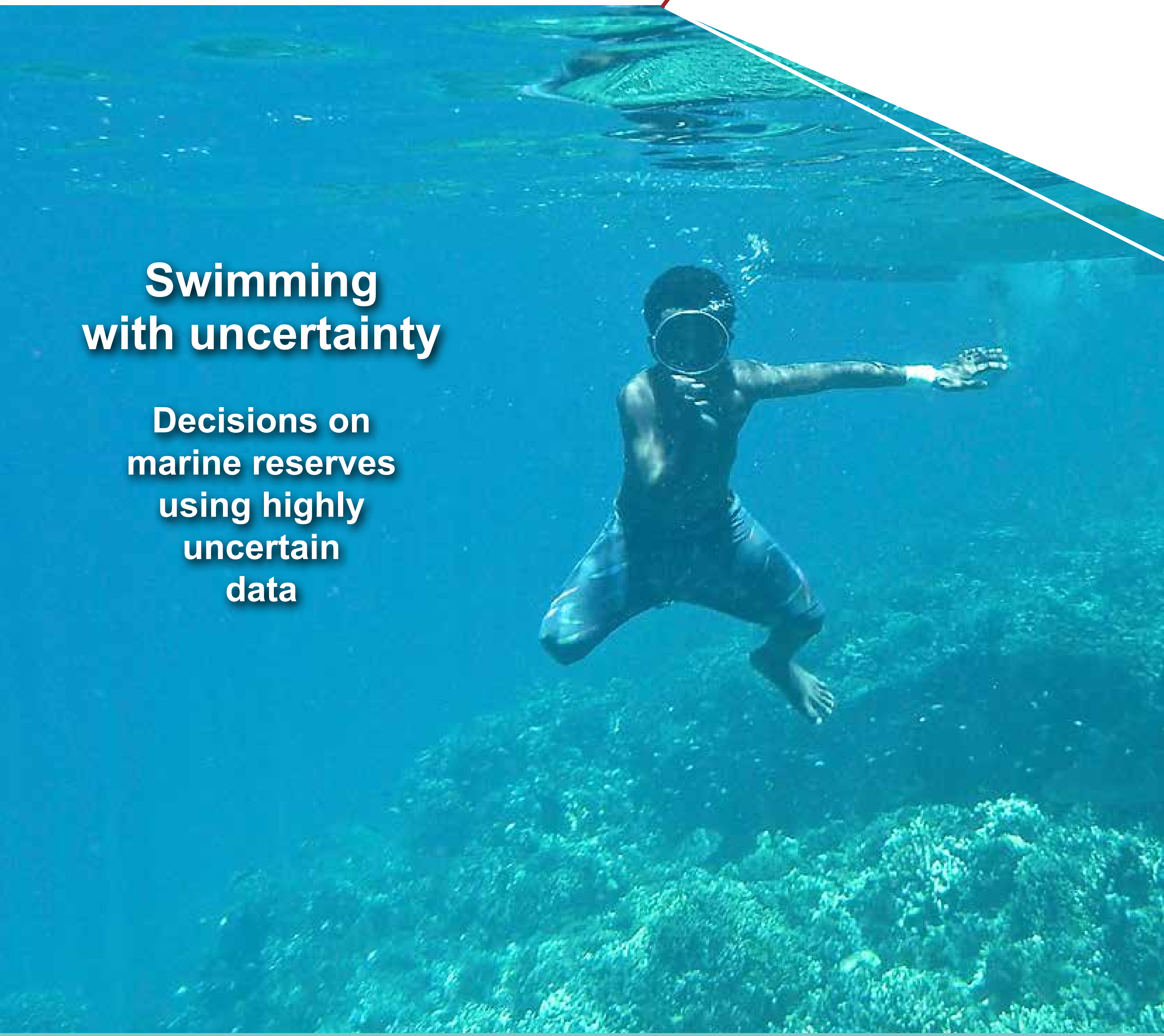
DECISION POINT

Connecting conservation policy makers, researchers and practitioners

Issue #100 / May 2017



In this issue

ARC ceed

Inside this issue

Decision Point **is the free 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
Website decision-point.com.au

Our cover Conservation planners often have to use habitat maps derived from remote sensing but these maps can be very inaccurate. See our story on MarProb on page 10 to find out how this uncertainty can be effectively dealt with.
(Photo by Viv Tulloch)

On the point

Happy 100th!

David Lindenmayer often talks about the challenge of running a Long-Term-Ecological-Research site over multiple decades when research money is only handed out in ad-hoc, short-term lumps. Indeed, the challenge of running a long-term project in an increasingly short-term world is enormous. Which is my way of saying happy hundredth issue of *Decision Point*!

Who'd have thought we'd be saying that back in 2008 when we launched our first issue? Not many I would suspect (and definitely not me).

What's the secret of our success? Well, it comes down to many things but let me suggest our longevity relates to good planning and good luck, mixed in with quality leadership, reader support and important science.

I'm not going to justify this list of ingredients here (I don't have the space and you don't have the time) except to say they all interact. The networks that *Decision Point* has served have been lucky in receiving continuous funding over a decade enabling relationships to grow and prosper; the leaders of this network have extended me trust and space in which to deliver a publication that has become symbolic with good environmental decision making, which in turn has lifted the profile of a community of interest in environmental decision science; our readers have given us encouragement and support which has deepened and widened the network; and our research has made a real difference in a time of biodiversity crisis, and *Decision Point* has helped sustain and grow an interest in that science.

And I'd like to thank you, our many readers (including our scientist contributors) for your feedback and support over the years. Without that feedback I am positive we would never have reached this milestone.

David Salt
Editor, David.Salt@anu.edu.au

Four of *Decision Point's* 'faces' over the years.

DECISION POINT #100
May 2017

On reflection

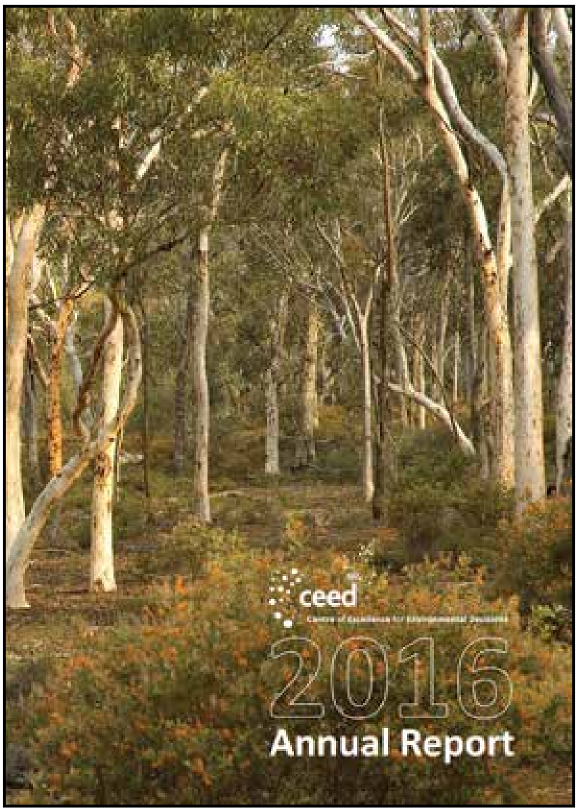
CEED really has made its mark

By Kerrie Wilson & Hugh Possingham (University of Queensland)

Environmental decision science is now a 'thing' and CEED and its related networks and partnerships can justifiably (and proudly) claim a lion share of the credit in raising the profile of this rapidly emerging field of conservation science.

Back in the 1990s, statistical ecology in Australia was strong, but there were few modellers and virtually no use of decision-science thinking in Australian conservation. Indeed, ecological meetings back in the early 90s were characterised by a mistrust of models and the notion that applied research was the work carried out by people not sufficiently talented to do 'pure' ecological research. How things have changed. CEED is both a product and a driver of that change.

If you want an example of that change, consider the number of topics covered in CEED's current annual report (as a representative example of what CEED does) that were not typically discussed two decades ago: restoration, monitoring and multi-disciplinarity. Restoration ecology in Australia, championed by our own Chief Investigator Richard Hobbs, for example has moved from strength to strength with many stories in *Decision Point* on landscape restoration planning integrated with the cost and feasibility of restoration.



How things have changed. CEED is both a product and a driver of that change.

Monitoring and data collection has always seemed like a slightly dull activity but CEED has added a new sparkle to these activities – how much information do we really need to make good environmental decisions and what else could we do with those resources? And we'd like to note the increasing prevalence of social science and economics thinking in the work that CEED does. This was always our aspiration and the stories and publications in *Decision Point* and CEED's just released annual report attest to that increasing emphasis.

As CEED matures, there are some obvious trends. First, both the quality and quantity of our research continue to grow, as can be seen from the number of publications and the quality of the journals in which they are published (numbers which far exceed our Key Performance Indicators). Second, our global impact continues to grow – CEED has become a Mecca for applied ecologists and we will capitalise on this with the new Environmental Decisions Alliance led by Eve McDonald-Madden.

But CEED's legacy is far more than our world class research. The impact of basic research on policy is often hard to track, especially since laws and policies implemented by government rarely cite the evidence or influences that underpin their development. As one example, CEED's work had a profound impact on the recent review of the NSW biodiversity legislation, a process that has taken well over a year (Hugh was a member of the expert review panel and can attest to the many and varied ways in which CEED research influenced that process). The NSW reforms include the fingerprints of CEED in at least three major ways: the prioritisation of species projects through the Save Our Species program, regional spatial planning as a preferred mechanism for delivering win-win conservation-development outcomes, and rigorous, transparent and quantitative biodiversity offsetting. All of these research endeavours have been discussed in *Decision Point*, some go back to the beginning of CEED (and its predecessor networks), and now they have significantly informed the policy of one of the most biodiverse regions in the world.

CEED's latest annual report is also filled with stories about another of CEED's legacies –the talented early-career researchers we have helped to nurture. Early-career researchers (ECRs) are the engine room of CEED's innovation. They are involved in the vast majority of our research, and as one can read in the report, they are already making their mark on the international scene. Further, while mentoring and facilitating the careers of CEED ECRs has been one of our core functions, sometimes we forget about our mid-career researchers. We have been impressed by the rapid progress of our mid-career researchers in achieving Future Fellowships, being promoted to full Professorships and having impact through workshop and conference invitations on the international stage.

We commend to you this year's annual report and congratulate Kathy Avent, CEED's new Chief Operating Officer, for her efforts in bringing it together. It's a worthy addition to CEED's range of communication products. Speaking of which, a central feature of our communication machinery has been *Decision Point*. In this 100th issue the diversity of CEED research, and it's researchers and our partners, are on display and will reach an audience much wider than that achieved by standard academic journals. Congratulations to you all, and to our editor David Salt on this milestone.

Note: This is an edited excerpt of the Director's statement in the 2016 CEED Annual Report (released in April 2017). To see the original statement or any of the other stories contained in last year's Annual Report please visit
http://www.ceed.edu.au/images/Annual_Reports/ARC-CEED-2016-Annual-report.pdf

(Above) Dogs and shorebirds don't mix and many species of shorebird are in dire trouble. How much effort do you spend patrolling a range of shorebird sites to ensure people are doing the right thing?
(Image by David Salt)

Using maths to decide when to put dogs on leashes

Reducing the threat to our endangered migratory shorebirds

By Kiran Dhanjal-Adams (University of Queensland)

Going for an evening stroll along the beach with the dogs is a great way to end a hot Australian summer's day. But, unbeknown to many, little migratory shorebirds are also often soaking up the late afternoon sunshine. These little creatures have made it all the way from their breeding grounds in eastern Russia and Alaska, to spend the Australian summer feeding on the abundant sea life found in the intertidal zone. Like Zen masters, they patiently wait until the tide has gone down to gorge on worms, shells and crabs, before retreating as the tide comes back in. They must then wait until the tide withdraws to feed again.

This feeding period, during low tide, is critical to these birds. Many will have flown non-stop all the way from Alaska to Australia, some 11,700 km in 6 days! That's like doing 293 marathons in one go. And like someone who has just run a marathon, migratory shorebirds are hungry. They will have lost between 50-80% of their body mass during this spectacular journey.

One dog can easily spook a flock of hundreds of birds. If this happens once, it is not so big a deal. But I have counted up to 1 dog per minute on some Australian beaches. That is 60 dogs in one hour and 120 in 2 hours – that's a lot of disturbance! Repeated disturbance can be highly detrimental for the birds as it forces them to leave a good feeding area for not-so-good feeding areas. And even if they move, dogs are likely to be wherever they move to.

Anything preventing birds from gaining enough weight can mean they are unable to migrate. It might even kill them.

This is a big problem. Many species of migratory shorebird are in rapid decline across Australia. Several species have been recently listed as threatened under the Environmental Protection and Biodiversity Conservation Act. In Moreton Bay, for example, some species have declined by 50-80% between 1995 and 2009.

While this is all quite depressing, there are several simple steps we can all take to minimise impacts on shorebirds. First up, restrain your dog. I have had 6 dogs in my life, and all of them have been fond of chasing birds – pigeons in particular. I am always careful to keep my dog on a leash near wildlife. I also walk around flocks of birds, not through them. It's easy, yet it makes a big difference.

Key messages:

We sought the most cost-effective allocation of patrol effort among sites with a limited budget to help manage disturbances to migratory shorebirds

We demonstrate a straightforward objective method for allocating enforcement effort while accounting for diminishing returns on investment over multiple visits to the same sites.

One dog's fun is another bird's terror. Repeated disturbance by dogs can stress and even kill shorebirds. (Photo by Kiran Dhanjal-Adams)

But not everyone is aware of the plight shorebirds or the need to give them peace, and local shorebird managers are encouraged to carry out information campaigns. And this is where a little decision science can help. Given they must also manage commercial and recreational fisheries and tourism on top of shorebirds, there is a need to optimise where and when they carry out information campaigns to avoid wasting precious time and funds, while delivering the best possible outcomes for the birds.

Consider this, if you have 10 sites that you could visit between 0 and 5 times, there would be a total of 60,466,176 possible combinations of site visits. How would you figure out which of these possible combinations delivers the best outcome?

A few other numbers and a bit of maths will help here. How many birds are at a site? How many disturbances? How much will it cost to manage that site? With this information it is possible to do a cost-benefit analysis to determine which combination of site visits delivers the best outcome within the specified budget.

However, the more you visit a site, the more you will start talking to the same people over and over again about shorebirds. There is, therefore, a trade-off between visiting a site too much and wasting your time talking to the same people, or visiting a site too little and not talking to enough people.

How do you explore this trade-off? We attempted it by expressing the trade-off as a mathematical formulation (Dhanjal-Adams et al, 2016). We found that if management was

Migratory shore-birds (ruddy turnstones) are foraging for food at low tide. (Photo by Kiran Dhanjal-Adams)

Moreton Bay near Brisbane is a popular place for shorebirds and people (and people's dogs). Between 1995 and 2009 some species have migratory shorebird have declined around Moreton Bay by 50-80%. (Photo by Kiran Dhanjal-Adams)

effective (ie, that almost everyone started putting their dog on a leash after talking to marine park officials), then it was best to manage a lot of sites a few times. However, if management was not very effective (ie, that only a handful of people started putting their dog on a leash after talking to marine park officials), then it was best to find sites with lots of birds being disturbed, and repeatedly visiting them. This ensures as many people as possible are persuaded to keep their dogs on a leash near shorebirds.

These methods apply to a range of management scenarios extending well beyond shorebirds. Say for instance you are deciding which sites to visit to ensure as many rhinos as possible are protected from poaching, or where to patrol to ensure fish stocks are not depleted. All that is needed is information on target species (average number of rhino or fish), infractions (numbers of caught poachers or illegal fishers) and the cost of patrolling (how much petrol do you need to get to those sites).

It's important to note that enforcement is not the only tool available in the manager's toolbox. For shorebirds, for example, better dog walking facilities (where dog owners can go and let their dogs run off-leash) would reduce the number of people walking their dogs on the beach, and would in turn reduce the need to carry out information campaigns.

The underlying message is that everything is a balancing act, and successful conservation requires a mix of community involvement, government engagement and implementable management plans. Engaging communities and governments is a long and complex process, but devising cost-effective management plans need not be so with the right tools.

More info: kiran.dhanjal.adams@googlemail.com

Reference

Dhanjal-Adams KL, K Mustin, HP Possingham & RA Fuller (2016). Optimizing disturbance management for wildlife protection: the enforcement allocation problem. *Journal of Applied Ecology* 53: 1215–1224.

Using fire to promote wildlife conservation

Understanding how pyrodiversity begets biodiversity

By Luke Kelly (University of Melbourne)

(Above) Planned burning is undertaken in Albacete, east-central Spain. There is a growing awareness about the importance of pyrodiversity to sustaining biodiversity.

All around the world fire is profoundly influencing people, climate and ecosystems. The impacts of this interaction are likely to increase with rising global temperatures, and there are growing calls to use our knowledge of the connection between fire and biodiversity more effectively.

Many plants and animals need fire for their survival, yet even in fire-prone areas, some species are sensitive to fire. How then, can a fire regime support the conservation of species with different requirements? Our new paper in the magazine *Science* shows how researchers and fire managers are confronting this challenge in a rapidly changing world (Kelly & Brotons 2017).

Large bushfires occur in the mallee shrublands and woodlands of Victoria, NSW and South Australia. Policymakers need to pay more attention to the connection between fire and biodiversity conservation. (Photo by Lauren Brown)

Variation in the time between fires, their severity, size and patchiness is called 'pyrodiversity'. Because plants and animals often depend on resources that vary as a result of fire, it is argued that pyrodiversity will produce a diversity of habitats that can support more species. It's an idea that has been discussed for some time but is only now being tested at large scales.

Morgan Tingley & colleagues (2016) recently tested this hypothesis in a study of how variation in fires shapes bird diversity in conifer forests in California. They collected more than 38,000 observations of birds from a total of 97 fires, and showed that different burn severities created unique habitats at local and regional scales, including areas with low and high cover of trees. Bird diversity was higher in places that had experienced fires with greater variation in burn severity; this effect increased in the decade after fire.

Key messages:

Pyrodiversity describes the variation in the time between fires, their severity, size and patchiness

New work is advancing our knowledge of the connection between pyrodiversity and biodiversity but there is a need to further develop approaches that are better tailored to local conditions

Studies on the endangered Carnaby's black-cockatoo (in Western Australia) have shown their continued presence in the landscape will require a good understanding of fire regime. Researchers have shown they need large areas of native woodland burned with less frequency. (Photo by Leonie Valentine; and see *Decision Point #84*)

The yellow-plumed honeyeater is one of many birds in mallee shrublands and woodlands in Victoria that prefer older vegetation with large trees, features not favoured in a regime of frequent burning. (Photo by Rohan Clarke; and see *Decision Point #88*)

In another recent study, Lauren Ponisio & colleagues (2016) collected more than 7000 pollinator specimens at sites that differed in past fire intervals and burn severities in conifer forests of Yosemite National Park, California. Diversity of both pollinators and plants was higher in areas with higher variation in fire interval and severity.

However, just because increasing variation in fire regimes can lead to higher biodiversity in some circumstance, it doesn't necessarily mean it always will. For example, work we have done with colleagues in Australia found that in semi-arid eucalypt woodlands the diversity of birds was not correlated with increasing spatial variation in pyrodiversity (Kelly et al, 2016). This was because long-unburnt vegetation provided disproportionately important habitat and critical food and shelter resources such as large trees.

Similarly, Laurence Berry & colleagues (2015) found that large patches of long-unburnt eucalypt woodland have particularly high levels of bird diversity. The authors suggested that bird diversity would benefit from preservation of large, continuous areas of habitat rather than the creation of small unburnt patches.

Taken together, these recent studies suggest that it is important to consider how fire influences both the diversity and area of suitable habitat across a suite of species. Through studies such as these, we can begin to define desirable ranges of variation for multiple characteristics of fires, tailored to support particular ecosystems and species.

But fire and biodiversity cannot be understood in isolation from other drivers of environmental change. Climate models forecast widespread increases in fire frequency and intensity because of rising global temperatures. Urbanization in southern Australia and western USA, regrowth of forests on abandoned land in Europe's northern Mediterranean, deforestation in tropical South America and Asia, and invasive plants in South Africa are all radically modifying fire regimes and biodiversity.

Developments in fire ecology provide new ways to link models of animal and plant responses to fire with landscape simulations and scenario analyses to predict biodiversity change in these complex landscapes. These tools and approaches are increasingly being put to work by land managers and policy-makers. For example, new approaches we have developed that link species distribution models, biodiversity indices and numerical optimisation are already being used across large parts of southern Australia, such as in Murray Sunset National Park, to ensure that fire regimes benefit biodiversity.

Another practical management challenge lies in uncertainty about biodiversity responses to fire. Progress in the development of models and decision tools is also helping to make better choices about when and where to conduct planned burning and fire suppression, while considering uncertainties such as the occurrence of wildfires and droughts. Fire management will be strengthened by adaptive approaches that are underpinned by experimental manipulation of alternative fire regimes and decision frameworks involving ongoing research, monitoring, and evaluation.

A surge of new work has advanced knowledge of how spatial and temporal variation of fire influences biodiversity but there is a need to further develop approaches that are better tailored to local conditions (while still being supported by ecological theory).

Now, more than ever, understanding of animal and plant responses to fire should be used to determine fire management objectives and actions.

More info: Luke Kelly ltkelly@unimelb.edu.au

References

Berry LE, DB Lindenmayer & DA Driscoll (2015). Large unburnt areas, not small unburnt patches, are needed to conserve avian diversity in fire-prone landscapes. *J. Appl. Ecol.* 52: 486-495.

Kelly LT, L Brotons & MA McCarthy (2016). Putting pyrodiversity to work for animal conservation. *Conservation Biology* Doi: 10.1111/cobi.12861
http://onlinelibrary.wiley.com/doi/10.1111/cobi.12861/full

Kelly LT & L Brotons (2017). Using fire to promote biodiversity. *Science* 355: 1264-1265.
http://science.sciencemag.org/content/355/6331/1264

Ponisio LC, K Wilkin, L M'Gonigle, K Kulhanek, L Cook, R Thorp, T Griswold & C Kremen (2016). Pyrodiversity begets plant-pollinator community biodiversity, *Global Change Biology* 22(5):1794–1808.

Tingley MW, V Ruiz-Gutiérrez, RL Wilkerson, CA Howell & RB Siegel (2016). Pyrodiversity promotes avian diversity over the decade following forest fire. *Proc. R. Soc. B.* 283
http://rspb.royalsocietypublishing.org/content/283/1840/20161703

A biodiversity offset accounting system

Improving the estimation of ecological equivalence within offset exchanges

By Fleur Maseyk (University of Queensland)

Biodiversity offsetting is a simple idea that brings with it a large and complex set of issues. The idea is that if a development causes biodiversity losses in one place, then an offset can generate equivalent gains elsewhere (Figure 1). The concept has both critics and supporters. Some say the process poses risks to biodiversity, while others believe it has potential to enhance biodiversity conservation. Making the concept operational has many challenges (and contentions) including ethical, social, technical and governance considerations (see *Decision Point #91*). However, despite the many unresolved issues and differences of opinion, the practice of biodiversity offsetting is becoming increasingly common in many countries around the world (see *Decision Point #85*). Therefore, it is critical that we develop tools and processes that resolve or reduce issues where we can (and are honest about the consequences where we cannot).

One of the technical issues associated with offsetting is the challenge in achieving ecological equivalence between biodiversity that is lost (due to the impact of development) and biodiversity which is gained (due to an offset action). Evaluating this exchange requires a 'currency' to describe the biodiversity of interest, and a model to balance the losses and gains.

Existing methods tend to use aggregated currencies which combine multiple measures of biodiversity into a single unit. But there is a risk in doing this. Bundling of biodiversity into a single unit can sometimes obscure (conceal) what is being traded in an offset exchange. Concealed trades can compromise biodiversity conservation because when specific elements of biodiversity are not explicitly accounted for, they are either offset implicitly (but we wouldn't know), or lost in the exchange contributing to continuing trajectories of biodiversity decline. To reduce these risks a team of researchers and practitioners from Australia and New Zealand developed an accounting model to transparently design and evaluate biodiversity offsets (Maseyk, 2016).

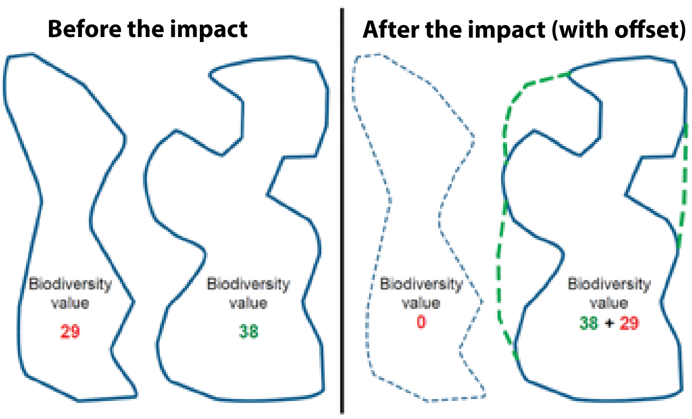


Figure 1: A highly simplified illustration of the goal of no net loss of biodiversity values. Values are lost due to the impact of the development and gained through management actions to improve the area and condition of the offset site. A major challenge is making sure that the values gained in the offset are equivalent to the values lost. The Disaggregated Model individually evaluates whether gains balance losses for all elements of biodiversity of interest and makes the trade-offs more transparent. (This diagram is in the report *Guidance on Good Practice Biodiversity Offsetting in New Zealand* available at *http://www.doc.govt.nz/documents/our-work/biodiversity-offsets/the-guidance.pdf*).

Key messages:

- Ecologically robust, user-friendly decision support tools improve the transparency of biodiversity offsetting and assist in the decision making process
- We developed a disaggregated accounting model to balance biodiversity trades within a 'no-net-loss' framework
- The model improves on other models that use aggregated metrics by describing and explicitly accounting for biodiversity elements of interest that are being exchanged

The structural foundation of the model we developed uses a hierarchical framework that categorises biodiversity elements into three levels: type; component; and attribute (Figure 2). These three levels collectively describe the biodiversity at both the impact and offset sites.

The model uses disaggregated area-by-condition currencies to calculate the 'net-present biodiversity value' (NPBV) for each biodiversity attribute. The NPBV is used to evaluate whether losses at the impact site and gains at the offset site balance accounting for time and uncertainty, and thus whether no net loss has been achieved.

The model's core outputs clearly identify 'winners and losers' within an exchange when no net loss is demonstrated for some biodiversity attributes but not for others. Our model also aggregates attributes to evaluate NPBV and demonstrate no net loss at the biodiversity component level.

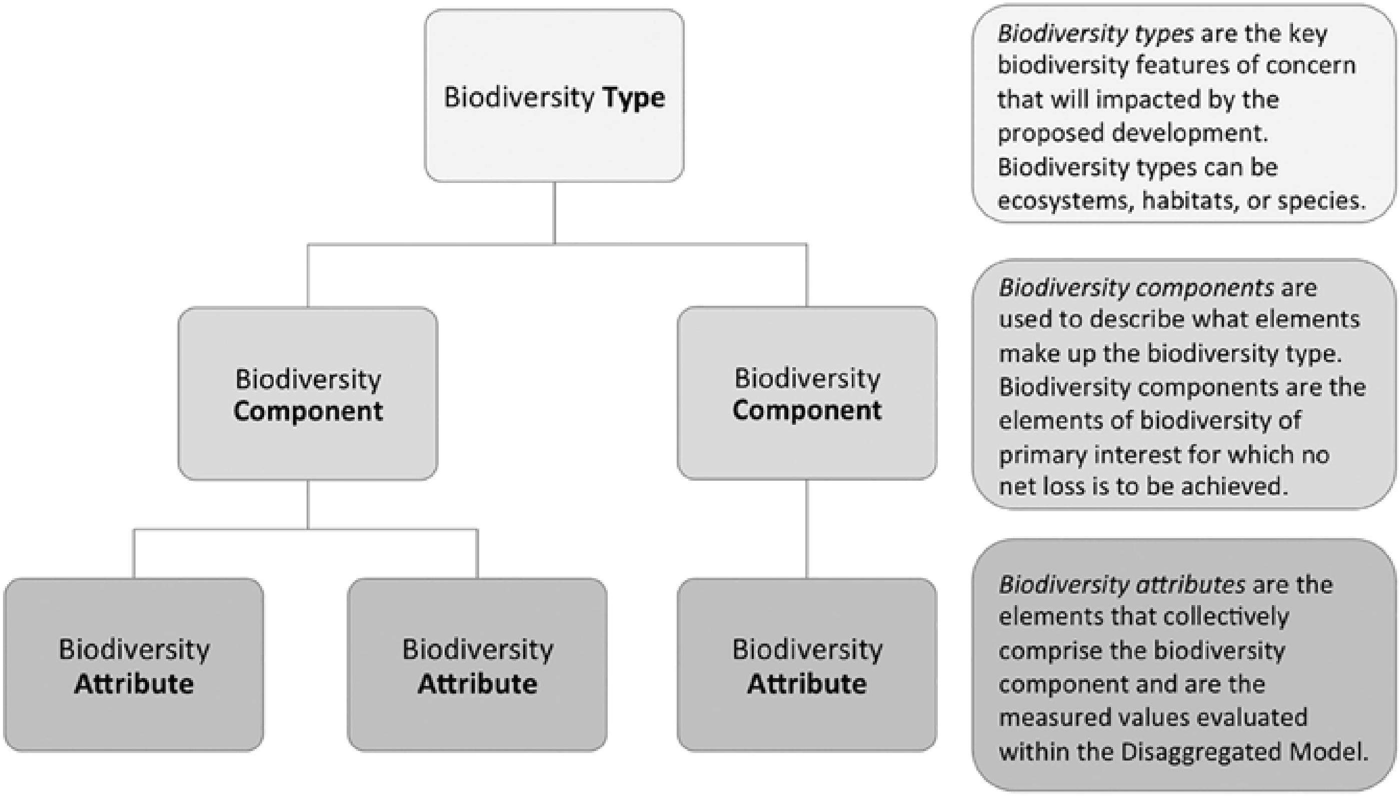
However, because outputs are produced for each attribute as well as each component, any tradeoffs between attributes (accepting loss in some in return for gains in another) required to achieve no net loss at the component level remains explicit. This improves transparency and assists decision making as to whether the tradeoffs, and thus the offset proposal, are ecologically and socially acceptable.

All currencies, will aggregate to some degree. What is critical is that the biodiversity elements of interest are individually described, measured, and evaluated. For example, if maintaining critical components of a forest habitat is the goal and canopy cover is one of those components, it may be acceptable to aggregate canopy cover of functionally similar

The Disaggregated Model

The Disaggregated Model discussed here was developed under contract with the New Zealand Department of Conservation (DOC), and the model template and accompanying User Manual can be freely accessed from: *http://www.doc.govt.nz/about-us/our-policies-and-plans/guidance-on-biodiversity-offsetting/biodiversity-offsets-accounting-system/*.

The Intellectual Property Rights of the Disaggregated Model and User Manual remain in the ownership of DOC.



Biodiversity Type	Biodiversity Component	Biodiversity Attribute
Podocarp/tawa forest	Emergent trees	Number of individuals
		Crown cover
	Canopy	Native cover
North Island kaka	Breeding population size	Number of breeding pairs

Figure 2: The hierarchical framework underpinning the structural foundation of the model (with an example of biodiversity type, component and attribute at the bottom). Collectively, the levels describe 'what we care about' in the context of a biodiversity offset proposal. Each biodiversity type impacted by a development is entered into a separate model template and as many components and attributes as required to describe the biodiversity type can be entered into the model.

species within a measure to represent canopy cover. However, this level of aggregation would not be appropriate if the target biota was individual tree species that contribute to canopy cover, or if a target species had a preference for a particular tree species.

The disaggregated structure of the model allows for the elements of biodiversity of primary interest to be individually described and measured. Further, while allowing for aggregation to occur across attributes within the same component, the model structure restricts aggregation across biodiversity components or biodiversity types preventing aggregation above the biodiversity of interest. This level of disaggregation is a key improvement on other offset accounting systems.

A further advantage of the model is that it is non-prescriptive and can be used to account for a variety of biodiversity types (ecosystems, habitats, or species), and for different scales and complexities of development and impacts within any planning framework.

As it is impossible to fully account for biodiversity loss across type, space, and time, biodiversity offsetting will remain an imperfect response to compensating for the impact of development. However, we can do things better, and improving support tools can reduce some of the technical limitations experienced in biodiversity offsetting. The principal advantage of our model is that it reduces concealed trades which in turn allows for more explicit estimation of whether no net loss goals can be achieved for biodiversity of interest. And that adds up to greater transparency in the decisions we make.

More info: Fleur Maseyk f.maseyk@uq.edu.au

References

Maseyk FJF, L Barea, RTT Stephens, HP Possingham, G Dutson & M Maron (2016). A disaggregated biodiversity offset accounting model to improve estimation of ecological equivalency and no net loss. *Biological Conservation* 204: 322–332. http://www.sciencedirect.com/science/article/pii/S0006320716305961

MarProb: conservation planning for the real (uncertain) world

Accounting for risk and dynamics in our spatial planning

By Viv Tulloch (University of Queensland)

Spatial conservation planning is all about using available information to weigh up options about which bits of the landscape (or seascape) will be put aside into conservation reserves – protected areas. But what if the information we are feeding into our planning processes contains errors or uncertainty (think remote-sensed reef data or population models) or there is a chance that threatening processes destroy habitats or ecosystems (think climate-change impacts into the future). What if we don't account for these uncertainties? Then our management decisions may be suboptimal or ineffective; which translates to the reserves we select being in the wrong place, or the wrong size.

Unfortunately, decision makers are often required to make planning decisions based on inadequate or uncertain knowledge. It's not a matter of simply collecting better information, this takes time and money that is usually not available. Given this reality, it's important to incorporate risk or uncertainty associated with the outcome of protected area decisions into the planning process itself and a recent version of the conservation-planning software Marxan does just that. It's called MarProb (or Marxan with Probability) and to demonstrate its utility (and the importance of taking uncertainty in planning into account) I'd like to share with you three recent research projects I've been involved with in which MarProb was applied.

The first describes a marine spatial planning framework which targets good condition coral reefs for protection, given the chance of oil-palm development and associated runoff degrading reefs (in Papua New Guinea). The second accounts for data uncertainty by evaluating trade-offs between accuracy and resolution of coral-reef habitat data derived from remote sensing (in Fiji). And the final example discusses how conservation planning in boreal forests can incorporate threats posed by future climate change (in Canada).

Three conservation challenges dealing with different forms of uncertainty in three very different parts of the world. What they demonstrate together is that by acknowledging and incorporating uncertainty up front it's possible to generate significantly improved conservation outcomes.

More info: Vivitskaia Tulloch v.tulloch@uq.edu.au

How MarProb works

The traditional version of Marxan aims to achieve biodiversity objectives for the lowest cost (see *Decision Point #62*). MarProb solves the same problem but is also able to maximise the probability of protecting every conservation feature given uncertainty in its distribution, or the chance that features in a site are lost or degraded due to threatening processes. It does this by applying a penalty to habitats or planning units that do not meet a certain level of confidence or certainty, and so is less likely to include them in the final solution as doing so will increase the objective function score.

Essentially, this makes Marprob risk averse – we either target sites where we are more certain that the species or habitat is there, or we target sites that have a lower risk of being destroyed by a threatening process (such as climate change). But if we need to target species or habitats associated with high risk (eg, coral reefs), Marxan chooses more. In this sense MarProb is hedging your bets – making sure you don't end up with nothing at the end of the day.

Key messages:

There is a need to better account for risk and dynamics in conservation spatial planning

MarProb is risk averse. It either targets sites where we are more certain that the species or habitat is (or will be) there, or it targets sites that have a lower risk of being destroyed by a threatening process

If uncertainty is not explicitly incorporated in all stages of the decision-making process, then the cost of not representing this uncertainty increases leading to failures in conservation planning

1. Oil palm and conservation planning

Mention oil-palm plantations and most people think of the impact to tropical rainforests that usually get cleared to make way for the plantations. What's often overlooked is that clearing forests for oil-palm plantations is also a major threat to tropical freshwater biodiversity, and can potentially affect downstream marine ecosystems such as coral reefs. Planners aiming to protect coastal coral reefs (and other marine ecosystems) should account for the impacts of current and possible future development on the land using 'ridge-to-reef' planning. The aim is to avoid placing marine reserves in areas that might be degraded from runoff (meaning the reserves would fail to protect the values they were set up for).

We also need to find ways to modify oil-palm development to reduce negative impacts on connected marine ecosystems. In many cases this requires knowledge on how coral reefs respond to runoff from oil palm, which we don't have because most oil-palm plantations are in remote tropical areas where data is scarce.

We developed a holistic ridge-to-reef approach for marine conservation that predicts the response of coral and seagrass ecosystems to changing land-based threats (current land-

The establishment of oil palm plantations in south east Asian countries often results in large changes to the quantity and quality of water running off a landscape into adjoining marine ecosystems. How to do you plan marine reserves in these situations when data is scarce. Ridge-to-reef planning using MarProb might offer a solution.

Protecting coral reefs requires careful consideration of what's happening on the adjacent land. Heavy degradation of freshwater and marine ecosystems can occur due to runoff and erosion from land-based activities. Planning marine reserves is pointless if development is likely to occur and ridge-to-reef processes are ignored. Pictured above is a satellite image of run-off from the PNG coastline. (Image CC, Eric Lawrey, NASA).

use, and three oil-palm development scenarios ranging from extreme to best practice).

We applied this in a data-limited region in Papua New Guinea (Tulloch et al, 2016). We then developed a network of marine reserves that avoid highly degraded reefs from possible oil palm expansion in the future. Marxan with Probability offers a new approach to considering threatening processes, allowing planners to incorporate information on the probability that the feature exists but is degraded from threatening processes and can not contribute towards conservation goals.

Almost 60% of coastal ecosystems were predicted to be substantially degraded in five years' time if all suitable land was converted to oil palm.

Strategic planning for palm oil can deliver substantial benefits to reefs in PNG – we should be placing new marine reserves in turbid areas containing coral reefs that are more tolerant to high levels of sediment in the water, as these areas are more likely to be in good condition even if oil palm expansion occurs in the future.

Importantly, we evaluated global sustainability guidelines for oil-palm development, and show that these guidelines cannot be truly ecologically sustainable unless they are modified to account for the impacts of oil palm on coastal marine ecosystems. Substantially reducing the impact of oil palm development on marine ecosystems requires limiting new plantings to hill slopes below 15°, a more stringent restriction than currently allowed for in the RSPO (Roundtable on Sustainable Oil Palm) guidelines.

The work is critically important as conservation organisations continue to work in regions where there are substantial trade-offs between economic development and conservation activities, but data are scarce to evaluate options for sustainability.

Reference

Tulloch VJD, CJ Brown, HP Possingham, SD Jupiter, JM Maina & C Klein (2016). Improving conservation outcomes for coral reefs affected by future oil palm development in Papua New Guinea. *Biological Conservation* 203: 43-54. http://www.sciencedirect.com/science/article/pii/S0006320716303160

2. Mapping uncertainty when planning MPAs in Fiji

One of the challenges faced by researchers and conservation practitioners in making decisions is reconciling the trade-offs associated with using biodiversity data of differing qualities, particularly when funds are limited.

Conservation planners often have to use habitat maps derived from remote sensing because there is limited information on the distribution of species, but these maps can be very inaccurate, and vary in their ability to represent other species distributions.

Coarse-scale habitat maps are commonly used as proxies to design marine reserve networks when detailed biodiversity data are incomplete or unavailable. Although finer-resolution habitat data provide more detail, they may have more errors due to misclassification, a common problem with remotely sensed data (see Decision Point #79). Despite this, planners usually don't think about habitat map quality or the effect of mapping errors in when planning reserves.

How much difference can this make? We attempted to find this out. We evaluated how habitat-mapping accuracy at different spatial scales affects reserve priorities and costs by comparing reserves designed using Marxan with Probability that used two different map classifications – one highly accurate simple map of nine coarse-scale seabed structures (slope, reef crest, etc), the other more complex habitat map describing 33 small-scale coral reef with high classification error (Tulloch et al, 2017).

By making this comparison we highlighted the trade-offs between the choice of habitat data, costs, and surrogacy value. These are all important variables when making decisions in conservation planning as they affect the location, size, and cost-effectiveness of the selected priority conservation areas.

Our analysis demonstrates that it is cheaper to use simple maps of reef structure to design reserves due to the high costs of

Satellite remote sensing provides a means for mapping remote coral reefs which are otherwise difficult to survey. But all maps have error. If we don't account for this error during the planning process, we could be under-protecting important pristine reef habitats such as the one pictured here, and over-protecting less valuable or degraded habitats. (Photo by Viv Tulloch) obtaining and verifying more detailed habitat data. Using these simpler maps, however, means the selected reserves might not contain the full diversity of coral reef habitats.

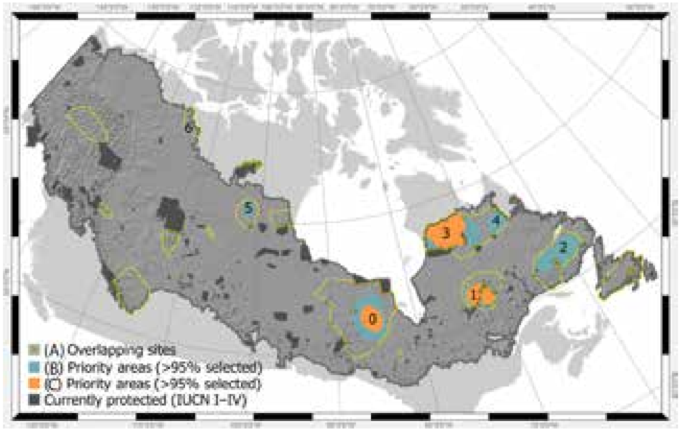
Using more detailed or complex habitat information ensures that we are targeting the full diversity of coral habitats, but these data are more expensive to obtain, leading to a more costly reserve design process.

Using more detailed or complex habitat information also results in larger reserves being selected. This is because these data have more misclassification errors so we need to protect more area to buffer our uncertainty in terms of what we are getting.

Our study highlights the need for error information to be provided with any habitat map, and this information needs to be included in the decision-making process. This is particularly the case when maps of high thematic complexity and error are used.

Reference

Tulloch VJ, CJ Klein, SD Jupiter, AIT Tulloch, C Roelfsema & HP Possingham (2017). Trade-offs between data resolution, accuracy, and cost when choosing information to plan reserves for coral reef ecosystems, *Journal of Environmental Management* 188: 108-119. http://dx.doi.org/10.1016/j.



Forest reserve sites commonly selected for different climate scenarios. (A) Overlapping best solutions for the 25% target. (B) Areas frequently selected (>95%) in the 200 MarProb runs for the 15% target in scenarios 2, 3 and 4. (C) Areas frequently selected (>95%) in the 200 MarProb runs for the 25% target in scenarios 2, 3 and 4. (From Powers et al, 2016)

3. Designing forest reserves for future climate

Canada's boreal forest is one of Earth's largest remaining wilderness areas but changing climate is expected to have large impacts on its function and structure due to altered temperature, rainfall and seasonality. When planning conservation reserves in such landscapes, how do we incorporate knowledge about such change when there is considerable uncertainty around future conditions?

Marxan with Probability offers new approaches to planning under climate change. It is especially useful for dealing with the uncertainty around the exact response of species and habitats to climate change, which may vary from place to place.

In this research we showed how ecologically based strategies for climate change adaptation could be integrated (Powers et al, 2016). We used predicted spatial distributions of biodiversity in Canada's boreal for the year 2080 based on vegetation productivity.

We targeted areas that minimise variability in projected vegetation productivity, as these may represent a less risky conservation investment by reducing the amount of anticipated environmental change.

We developed hypothetical protected area networks designed for future vegetation variability under a range of different IPCC climate scenarios (least change (B1), business as usual (A1B) and most extreme change (A2)).

Including future climate change impacts into national or boreal-wide conservation assessments increases the total area and cost of reserve networks. But failing to do so risks the conservation value of the network. Reserve networks designed for current or least change (B1) climate scenarios will likely not achieve conservation targets when faced with more severe conditions, and will require additional sites.

We can use assessments like these to provide recommendations for adaptive conservation for future climate change that support ongoing boreal conservation and land-use planning.

Reference

Powers RP, NC Coops, VJ Tulloch, SE Gergel, TA Nelson, & MA Wulder (2016). A conservation assessment of Canada's boreal forest incorporating alternate climate change scenarios. *Remote Sens Ecol Conserv*. doi:10.1002/rse2.34 http://onlinelibrary.wiley.com/doi/10.1002/rse2.34/abstract

Part of Canada's vast boreal forest. Predictions of future climate largely agree that this ecosystem will experience substantial warming, and face multiple direct and indirect effects, from more frequent large wildfires and extreme droughts. This could lead to potential shifts in ecosystem state. (Photo CC2.0 peupleloup)

Marxan plumbs new depths

Planning deep-sea protected areas around Brazilian oil fields

Since its inception, CEED has played a strong supporting role in developing, promoting and extending the impact of the Marxan, the world's most widely used conservation-planning software. In 2016, Marxan once again demonstrated its power and widespread utility by assisting in the design of a network of deep-sea marine reserves in the Campos Basin, an important area for oil fields off the Brazilian coastline.

Gustavo Almada from Brazil's Ministry of Environment worked with ProfessorAngelo Bernardino from the Federal University of Espírito Santo to design a possible network of deep-sea reserves. At the end of 2015 Almada participated in a Marxan training course at Brazil's Mato Grosso do Sul Federal University being conducted by CEED's Morena Mills & Jennifer McGowan.

"The Campos Basin lies offshore of south-eastern Brazil," explains Almada. "It contains many of the most productive oil and gas fields of Brazil, accounting for more the 60% of total annual production. Our aim was to propose a network of marine protected areas (MPAs) that would offer protection to areas of high natural value within current offshore fields, with minimal impact on existing production activities in order to provide a politically feasible outcome."

Over the last three decades, Brazil's main oil company, Petrobras, has been collecting a range of information about the Campos Basin comprising biological, geophysical, geochemical, hydrochemical, oceanographic and socioeconomic data. Using this extensive database, Almada and colleagues developed a map of benthic habitats and then used Marxan to provide options of networks of MPAs that protected at least 30% of the area of each habitat.

A deep sea fish in a spawning ground in the Campos Basin. The image was taken by a remotely controlled submarine operating in water over a kilometre deep. (Photo by Gustavo Almada)

"Our analysis provided options that we believe are politically feasible as they have little impact on the ongoing oil industry activity," says Almada. "But our results have wider potential because we believe our approach can be applied to other deep sea provinces along the Brazilian margin and serve as a model for other regions seeking to protect deep-sea biodiversity on and around deep-sea oil fields, mining prospects or fishing areas.

Students and teachers in the Marxan training course run at Brazil's Mato Grosso do Sul Federal University in 2015. Morena Mills, Jennifer McGowan and Gustavo Almada each have their intitials over their heads. Special mention also should be made of Prof Reinaldo Lourival (RL). He's an experienced Marxan user and helped realise the Marxan workshop.

"The Marxan workshop was critical to our research. It allowed me to use the Marxan software properly, to develop the input files with confidence, to completely understand the mechanics of Marxan's underlying algorithm (and its limitations and premises) and to appropriately interpret the software's outputs."

And the result is a conservation plan that all parties can work with.

More info: Gustavo Almada Gustavo.Almada@ibama.gov.br

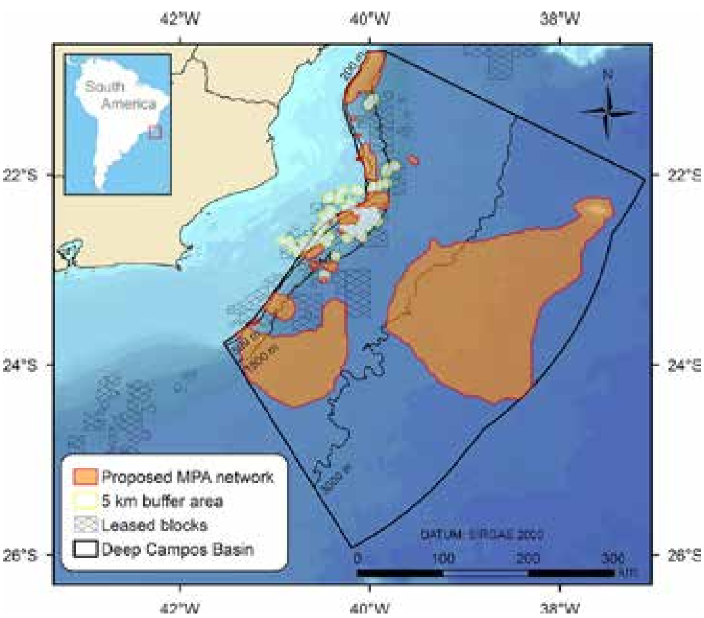
Reference

Almada G & AF Bernardino (2017). Conservation of deep-sea ecosystems within offshore oil fields on the Brazilian margin, SW Atlantic. *Biological Conservation* 206: 92-101. http://dx.doi.org/10.1016/j.biocon.2016.12.026

Key messages:

Marxan was used to explore options for deep-sea MPAs that are politically feasible and environmentally rigorous

The process developed has application for other regions seeking to protect deep-sea biodiversity on and around deep-sea oil fields, mining prospects or fishing areas



The Campos Basin off the Brazilian coastline showing the location of a proposed MPA network. The plan was generated using Marxan.

Building bridges to the island city-state

CEED and the National University of Singapore

Singapore is an important regional centre for biodiversity and conservation science. In recent years CEED has established many collaborations with researchers at the country's national university - the National University of Singapore (NUS). These growing links are proving mutually beneficial to both countries as well as advancing environmental decision science in several areas. Here are some examples.

Located one degree north of the Equator, Singapore (the world's only island city-state) seeks to become a 'City in a Garden'. More than 50 years of greening has given rise to a cityscape incorporating a network of nature reserves and nature parks nestled within a matrix of verdant streetscapes, urban parks and park connectors. The challenge of developing and sustaining such an ecosystem in a land-scarce city is enormous and requires scientific inputs from a wide range of disciplines. CEED is working with NUS on multiple projects relating to urban and park biodiversity.

Chong Kwek Yan has been visiting CEED's UQ node from October 2015 to 2017. He received the NUS Overseas Postdoctoral Fellowship, and is working on the optimal planning of urban greenspaces with CEED CIs Kerrie Wilson, Richard Fuller, Jonathan Rhodes and Hugh Possingham.

In May 2016, Roman Carrasco from NUS visited with his two graduate students, William Symes and Zhang Yuchen. Roman is collaborating on a new project with CEED on expanding conservation objectives to incorporate development objectives with James Watson, Oscar Venter and Hugh Possingham.

At Roman's invitation, Richard Fuller and his new graduate student, Micha Jackson, visited Singapore in August 2016 to give a talk at the NUS Department of Biological Sciences' Biology Colloquium on conservation issues surrounding migratory birds. Micha remained at NUS for several days afterwards and has ongoing plans to collaborate with Roman and his lab on aspects of her PhD research relating to coastal land-use change.

Kerrie Wilson was also invited to give talks on systematic conservation planning and structured decision-making at the NUS Biology Colloquium and at the Centre for Urban Greenery and Ecology's (CUGE) Professional Speakers Series in September 2016. CUGE is part of the National Parks Board, the agency that handles matters related to biodiversity and greenery in Singapore.

Bishan Park, a great example of innovative urban planning in Singapore. (Photo by National Parks Board, Singapore)

Nao Takashina also spent some time with Ryan Chisholm's lab in NUS from September to November last year. Nao is a Post-doctoral Fellow visiting CEED from the University of the Ryukyus (Japan).

Yong Ding Li, a PhD student with David Lindenmayer at CEED's ANU node, coordinated the Arctic Migratory Birds Initiative-East Asian-Australasian Flyway Workshop in Singapore in January 2017. The event was attended by a contingent of three graduate students from CEED: Stephanie Avery-Gomm, Eduardo Gallo-Cajiao and Micha Jackson. Ding Li is a NUS alumni, having completed his Honours under the supervision of the late Navjot Sodhi, a giant in Southeast-Asian conservation.

NUS is ranked consistently among the top universities in the world. Its interactions with CEED will help deepen its research capacity and impact, as well as develop enduring collaborations with Australia. It's a relationship benefitting both countries, and can only grow in the years ahead.

More info: Chong Kwek Yan kwek@nus.edu.sg

CEED Director Kerrie Wilson lectures on conservation decision-making in social-ecological systems at NUS' Biology Colloquium. (Photo by Chong Kwek Yan)

Reflecting on risk & uncertainty

2016 Theo Murphy High Flyer Think Tank

A critical aspect of environmental decision making involves dealing with risk and uncertainty, and much of CEED's research revolves around incorporating these elements into decision frameworks. Given this, it's not surprising that CEED researchers played a leading role in the 2016 Theo Murphy High Flyer Think Tank.

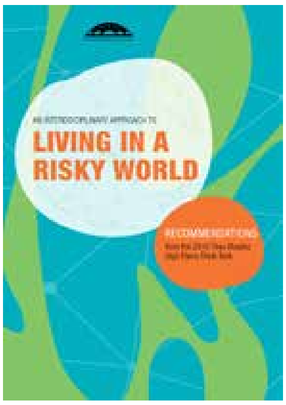
Each year the Australian Academy of Science hosts the Theo Murphy High Flyer Think Tank. It brings together a varied group of early- and mid-career researchers from a wide range of disciplines – rising high flyers in their respective disciplines – to focus on an emerging area of challenge and get them to solve a series of related problems. The 2016 event asked think tankers to formulate an interdisciplinary approach to 'living in a risky world'.

CEED's Director (at the time), Hugh Possingham, convened the event while CEED members Gwen Iacona, Alienor Chauvenet, Jonathan Rhodes and Lucie Bland took part as think tankers, joining around 60 other participants coming from a range of disciplines (from physicists to social science). The assembled thinkers were set four challenges to explore: (1) risk in international security, (2) risk and resource allocation for the environment, (3) antimicrobial resistance in a connected world, and (4) uncertainty, ignorance and partial knowledge.

Hugh Possingham holds up a finished report from the 2016 Theo Murphy High Flyer Think Tank on living in a risky world.

The CEED participants contributed primarily to the problem of risk and resource allocation for the environment. This group was composed of experts in environmental sciences, social sciences, economics, law, and history. Such a diversity of disciplines created a rich and challenging discussion. Invited experts and members of the Academy were also available for guidance and discussion (including CEED's Mark Burgman). Each group came up with 2-3 recommendations associated with their topic, focusing on what major risks and uncertainties we should be aware of, and what potential solutions might exist.

"The format challenged us to work as a group and to quickly and clearly identify (and articulate) the most important points for policy makers," says CEED's Gwen Iacona. "There was deep discussion, many interesting chats and a lot of hard work. However, by the end of the workshop I think it's fair to say we also had a lot of fun."



The findings of each group were released earlier this year and are now available to government, stakeholders and the public at https://www.science.org.au/files/userfiles/events/documents/think-tank-risk-recommendations.pdf

To Antarctica and back

Justine & Nancy are Homeward Bound

Two CEED scientists, Dr Justine Shaw and Dr Nancy Auerbach, recently took part in the inaugural program of Homeward Bound, a pioneering leadership, strategy and science initiative for women, set against the backdrop of Antarctica.

Homeward Bound acknowledges the effects that climate change and anthropogenic alterations are having on our planet. The initiative aims to heighten the influence and impact of women with a science background in directing policy and decision-making as it shapes our planet's future.

Launching in 2016, Homeward Bound gathered the first 76 of a targeted 1000 women from around the world, all with science backgrounds. The women undertook a year-long state-of-the-art program for developing leadership and strategic capabilities to enhance scientific expertise. The program culminated in the largest-ever female expedition to Antarctica in December 2016. The science program was led by Justine Shaw and Mary-Anne Lea from the Institute of Marine & Antarctic Studies, UTAS. Nancy Auerbach, was also on the expedition, selected from a field of over 270 applications to participate.

Justine Shaw: "This isn't simply a trip to Antarctica, it's about bringing women scientists together and exploring leadership and strategy and how we can make a change."

The Antarctic trip involved an intense schedule of leadership, strategy execution and global change science. The expeditioners presented their own research in a symposium while at sea in Antarctica. They were encouraged to explore opportunities for collaborations and to show how their work could have greater impact and reach.

"It's incredibly exciting when you look at the group of women (who went), the range of backgrounds and experiences, their scientific disciplines and career stages," says Shaw. "This isn't simply a trip to Antarctica, it's about bringing women scientists together and exploring leadership and strategy and how we can make a change. We can't wait to see what comes out of this voyage, the future collaborations and what it all means for science."

The women of Homeward Bound on route to Antarctica.

Achieving the targets of global conventions

A special issue of *Conservation Letters*

By Caitlin Kuempel, Moreno Di Marco, James Watson, Hugh Possingham (University of Queensland)

In December 2016, *Conservation Letters* released its first special issue with the theme of 'Achieving the targets of global biodiversity conventions'. The issue was spearheaded by members of CEED and the Centre for Biodiversity and Conservation Science (CBCS), specifically Moreno Di Marco, James Watson, Oscar Venter, and Hugh Possingham in collaboration with the journal's Editor-in-Chief, Eddie Game.

This unique issue includes 13 articles authored by a diverse group of conservation scientists from NGOs and universities, with input from representatives from the private and government sector. The unifying theme underpinning this issue focuses on the problems, progress and potential of national and international conservation targets at halting biodiversity loss on the land and in the sea. The release of the special issue is particularly timely given the approaching 2020 deadline to achieve the Aichi Targets (as set out in the Convention on Biological Diversity).

The entire special issue is open access meaning individual articles or the whole issue can be downloaded for free. Of the 13 contributed papers, 6 feature work by CEED and CBCS members, which we highlight below.

The issue opens by focusing on the essential role of conservation targets for coordinating global conservation efforts. Moreno Di Marco and colleagues (Di Marco et al, 2016) stress the need to determine what is 'sufficient' in conservation terms (ie, adequate levels of conservation inputs, outputs, and outcomes necessary for the protection of biodiversity), and how to be 'efficient' in achieving it (ie, how much, where, and when to best spend limited resources and how to monitor progress).

These sentiments are echoed by Stuart Butchart and colleagues (Butchart et al, 2016) who identified four key problems with the current Aichi Targets: ambiguity, unquantifiability, complexity and redundancy. They argue that these shortfalls make the targets difficult to operationalise, and provide guidelines on how more consistent and streamlined interpretation can be ensured in future targets.

An up-to-date assessment of trends in habitat protection versus habitat conversion is presented by James Watson and colleagues (Watson et al, 2016). It highlights the scale of the issue, with 447 ecoregions still exhibiting high conversion-to-protection ratios and 41 'crisis ecoregions' that require urgent action due to very low protected area coverage coupled with high recent habitat conversion rates. With decreasing habitat availability and increasing – but varying – rates of habitat loss, there is a clear need to reconcile trade-offs in conservation targets and actions.

An analysis of the potential trade-off between protected area expansion and the equality of habitat representation within protected areas (both key elements of Aichi Target 11) by Caitlin Kuempel and colleagues (Kuempel et al, 2016) found that, while the equality of protection has been generally increasing, these changes have likely been by chance rather than through the explicit consideration of representation targets in protected area expansion. The ambiguity and unquantifiability of 'representation' within Aichi Target 11 likely contributes to this implementation gap.

Tal Polak and colleagues (Polak et al, 2016) provide an approach that maximises representation of both ecosystems (Aichi Target 11) and threatened species (Aichi Target 12) to ensure each unique habitat type or species is included within Australia's protected area network under financial and geographical constraints. This approach could help countries more efficiently achieve multiple targets, particularly as new goals and information arise.

Finally, there is also a paper involving two of CEED's overseas researchers EJ Milner-Gulland and Andrew Knight on the status and trends in global ecosystem services and natural capital (Shepherd et al, 2016).

All papers in the special issue are policy oriented, focusing attention on what we can learn from previous efforts to meet global conservation targets. The hope is that this research will guide the development of a more integrated and better-informed set of global biodiversity targets in the future. These future targets are likely to play a fundamental role in supporting the UN's Agenda for Sustainable Development through which the world's governments have agreed to achieve ambitious social, economic, and environmental goals by 2030.

More info: Caitlin Kuempel c.kuempel@uq.edu.au

Reference

Special Issue: Achieving the targets of global biodiversity conventions (2016). *Conservation Letters* 9: 393-494.
Individual stories can be downloaded from:
http://onlinelibrary.wiley.com/doi/10.1111/conl.2016.9.issue-6/issuetoc
Or the whole issue:
http://media.wix.com/ugd/59af53_d67cebb45abc4a6d8ca095a1e276192d.pdf