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contents

Students are great. If they were not, this special issue would not exist. The idea was born after the Network Analysis workshop at the 3rd Student Conference on Conservation Science in Bangalore, 2012. It was clear that while both students and silverback scientists like network analysis and its applications, more needed to be done to familiarise decision-makers and stakeholders with the network perspective and what it offers. Networks are an entertaining way to model life, both nature and society: quantitative enough for the mathematical-minded, complex enough for the physical-minded, realistic enough for the biological-minded, visual enough for the artistic-minded and simple enough for the non-necessarily-scientist-minded (i.e. for ordinary people). Networks help to link various kinds of data and connect different disciplines. The dream is that networks will help also to link scientists to society. This special issue of Current Conservation can help.

If many kinds of people read it, we will be satisfied that we achieved what we set out to do. Enjoy the contribution of some great experts in the field and do not forget the art in the background.

Forest mafia

Dicrurus paradiseus, Madhya Pradesh

Ramki Sreenivasan

A pair of greater racket-tailed drongos in Kanha National Park, Central India. Racket-tailed drongos are known to run a "protection racket" in mixed-species bird flocks in tropical forests; warning other species of predators while extracting a fee in terms of insect prey in return. Read more about the role of drongos in flocks in Sridhar's article (p 12).

Social networks help explain the spread of diseases

Sub-grouping in large social groups reduces the spread of infection

Social species such as primates and dolphins are known to engage in activities like grooming and playing, which help maintain bonds between individuals in a group. These otherwise casual behaviours, in fact, play very important roles in getting rid of parasites. One monkey pulls out a tick or a louse from another monkey in one of his routine inspections and prevents possible parasitic infection.

However, the risk of disease spread is also high in these species because individuals are constantly interacting with each other. Ecological theory suggests that disease transmission rates will be higher in larger groups because there is more potential for interaction. However studies examining the link between disease and group size have come up with mixed results—some find disease transmission increases with group size while others find the opposite pattern. In a recent study, Randi Griffin and Charles Nunn try and explain this incongruence using a network approach.

Griffin and Nunn first simulated the spread of a pathogen in artificially built social networks and found that spread is lower in networks that are more "modular", i.e. consisting of more subgroups. This could be because pathogens quickly spread within modules but also die out before being able to spread to other modules. Then, using data from 19 species of primates from around the world, they examined the relationships between parasite richness and primate social structure. First, they found that primates that lived in larger social groups tended to have more modular social organisation. Also, those primate species which tended to have more modular social organisation had lower richness of socially-transmitted parasites. In other words, parasite richness tended to be lower in primates with larger group size because large groups tended to be more modular. These findings, taken together, provide some resolution to the inconsistency in findings with regard to the relationships between group size and disease risk. An interesting analogy to consider in humans? Having a close inner circle of friends might help prevent the spreading of your secrets all across your Facebook network!


Kalyan Varma

Griffin R & C Nunn. 2012. Community structure and the spread of infectious disease in primate social networks. *Evolutionary Ecology*, 26:779–800. doi:10.1007/s10682-011-9526-2

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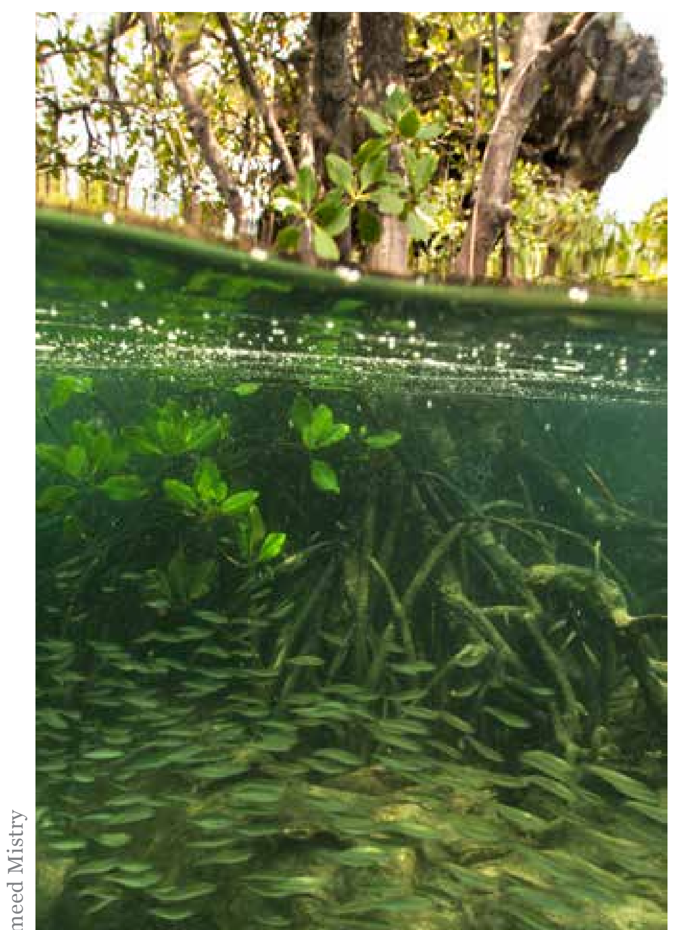
Identifying key players in ecological networks

Bacteria and dead material among crucial components of ecological systems

A primary goal of understanding complex systems is to identify components critical for their functioning. In conservation science, this includes identifying species that are vital to ecosystem processes and important patches in fragmented habitats. A network approach enables us to identify such critical components. A network is a visual representation of the system, where each component (species/habitat) is portrayed as a node connected to other nodes via edges that represent interaction.

Measures of centrality allow us to identify important nodes within networks. The concept of network centrality was introduced in the social sciences in order to identify important members within human communities. Many centrality indices are available that can be applied to different systems based on need. The simplest measure (degree centrality) weighs each node based on the number of nodes it is connected to. Other more complex indices (e.g. eigenvector centrality) take into account centrality of surrounding nodes as well in their calculations.


Umeed Mistry

In this paper, Borrett shows how "throughflow" can be used as a measure of centrality in ecological systems. This measure weighs each node based on the amount of biomass/energy flowing through it. This index captures the impact of a given node across the entire system and not just its immediate locality.

Borrett then applies his new measure on 45 trophic datasets to identify dominant species/groups. In most of the networks, four or fewer nodes were found to be responsible for about 50% of the flow. These "important" nodes generally corresponded to primary producers, dead organic material or bacteria. This corroborates previously established hypotheses in ecology which state that most communities contained only a few dominant species which tend to be primary producers or decomposers. The use of "throughflow" and other centrality concepts will aid in the understanding and management of complex ecosystems in the future.

Borrett SR. 2013. Throughflow centrality is a global indicator of the functional importance of species in ecosystems. *Ecological Indicators* 32:182-196

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Understanding a "network of networks"

Understanding interactions between ecological networks is key to understanding how ecosystems respond to change

Any given ecosystem includes many different kinds of ecological networks such as food webs, plant-pollinator, plant-disperser and host-parasite networks. While recent research has detailed the workings of each of these networks individually, the interactions among these networks is much less known. In a first-of-its-kind study, Pocock and co-authors examined a "network of networks" in a 125 ha farm in the United Kingdom, which has been maintained organically and has been the focus of agri-environment management.

Over a period of 2 years, Pocock and colleagues recorded 1,501 interactions among 560 species of plants and animals on the farm. The animals recorded included pollinators and dispersers such as birds and butterflies (bio-indicators), a variety of parasitoid insects and predators such as spiders and beetles. Therefore, the interactions included were part of linked trophic, mutualistic and parasitic networks linked in a diverse agri-ecosystem.

In order to understand the resilience of the ecosystem to change, Pocock and colleagues used computer simulations to examine the removal of plant taxa and its consequences on different animal groups. They found certain groups such as pollinators were particularly susceptible to plant removal, while others such as parasitoids were more resilient to simulated plant extinctions. In general, an important finding to emerge from this study is that the responses of different functional groups of animals were not congruent, i.e. different animal groups showed varied responses to the same simulated change. This finding has important implications for restoration measures because the same measure might benefit one kind of species but might harm another. The study also identifies 27 "keystone" plant species whose removal is likely to have the largest impacts on the study system.

Pocock MOJ, DM Evans & Jane Memmott. 2012. The robustness and restoration of a network of ecological networks. *Science* 335:973-977. doi: 10.1126/science.1214915.

Erica Marshall of muddyboots.org

Saving the future

Protected area networks help buffer the effects of climate change on species and communities

Global climate change is a key issue in ongoing conservation efforts worldwide, especially for protected areas. How will our networks of protected areas fare in the future? Do these networks contain suitable climate space to accommodate species range shifts resulting from climate change? In a recent study, Hole and colleagues answered this question for avifauna in a network of Important Bird Areas (IBAs) in sub-Saharan Africa. The authors focussed on the 803 mainly-terrestrial IBAs (as opposed to marine) in this region and modelled shifts in distribution of 1608 bird species within them, in response to anticipated climate change. Shifts in distribution were examined over three time periods, from now till: (1) 2025; (2) 2055; (3) 2085. The projections of future climate change for these exercises were obtained using three different global climatic models, i.e. three different scenarios of how climate will change in the future. The study presents some good and bad news. The bad news is that there will be substantial species turnover (replacement of one species by another) at the level of individual IBAs. Median turnover across all species is expected to be 10-13% by 2025 and 20-26% by 2085; numbers for "priority" species, i.e. species of particular conservation concern, are 20-26% and 35-45% respectively. The good news is that, at the whole sub-Saharan IBA network level, persistence of avian species is remarkably high. A majority (74-80 % for all species and 55-68 % for priority species) of the ensembles of species currently present in individual IBAs will continue to persist in the IBA network in 2085. For individual species, the conditions become less suitable for some while more suitable for colonization in the case of others. Overall persistence among 815 priority species remains remarkably high at 88-92 % and only 7-8 species completely lose suitable space within the networks by 2085. In conclusion, this study shows that though future climate change is likely to cause substantial disruption at the level of individual protected areas, networks of protected areas can play key roles in buffering these impacts for species and communities.

Neil Palmer/CIAT

Hole DG, SG Willis, DJ Pain, LD Fishpool, SHM Butchart, YC Collingham, C Rahbek & B Huntley. 2009. Projected impacts of climate change on a continent-wide protected area network. *Ecology Letters*, 12:420–431. doi: 10.1111/j.1461-0248.2009.01297.x

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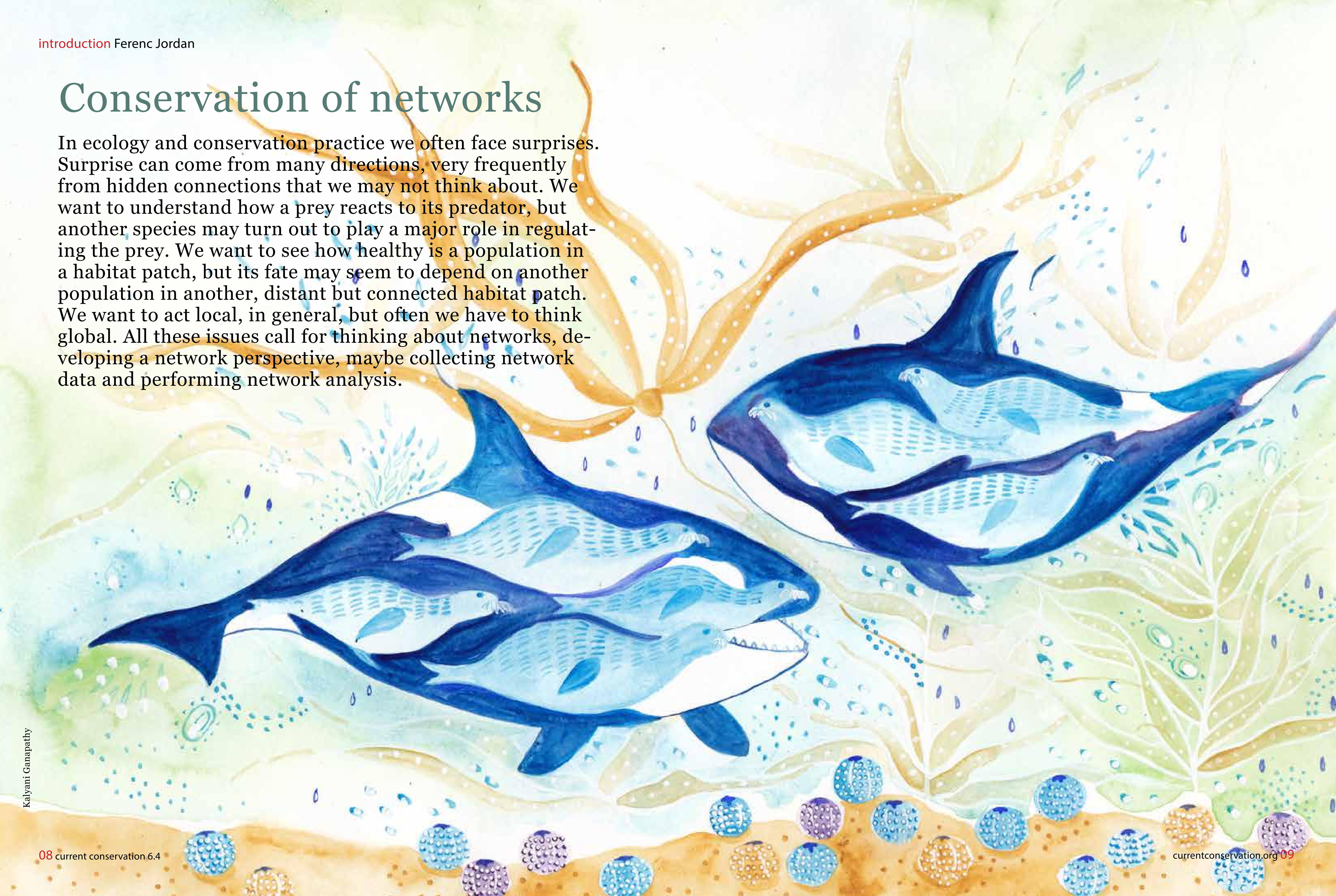
Conservation of networks

In ecology and conservation practice we often face surprises. Surprise can come from many directions, very frequently from hidden connections that we may not think about. We want to understand how a prey reacts to its predator, but another species may turn out to play a major role in regulating the prey. We want to see how healthy is a population in a habitat patch, but its fate may seem to depend on another population in another, distant but connected habitat patch. We want to act local, in general, but often we have to think global. All these issues call for thinking about networks, developing a network perspective, maybe collecting network data and performing network analysis.



Kalyani Ganapathy

Network analysis, supported by its rich mathematical background, offers more and more solutions for thinking different about a bunch of conservation issues. If one is not sure about the potential inter-relationships among several elements of the ecosystem (species, habitats, individuals, populations etc), a network perspective may help at least to sketch and overview the potential sources of surprise. Indirect effects can be mapped and even their strength can be quantified, which is surely a way to better explain surprising findings. I do not mean that network analysis always provides exact predictions, but it may help to integrate information, design new experiments and increase efficiency of efforts. In brief, it helps to get closer to a more informed, more intelligent and more efficient conservation practice. All this is more abstract (this sounds bad) but also more holistic (this sounds good) than traditional efforts.

The earliest interest in ecological networks was probably raised by marine ecologists. The "no fish is an island" paradigm is becoming stronger and more supported as various network analytical software appear. Multispecies models were developed and experimental studies were done as a response to recognising the importance of indirect effects like trophic cascades. A trophic cascade means that a consumer indirectly helps the prey of its prey (by eating what eats it). The most famous example is the chain of interactions (and the resulting indirect chain effect) from intensified fisheries in Alaska to the emergence of urchin deserts in California. Fisheries reduced fish stocks causing seals to move south from Alaska. The seals were followed by killer whales, which also fed on sea otters. The reduced sea otter population meant that sea urchins, their preferred prey, benefited. Urchins expanded and massively consumed kelp forests causing the disappearance of not only small fish hiding in the kelp forest , but also the kelp forest itself. Eventually, without food, the urchins also died leaving a desert of dead urchins rolling on the pure sandy bottom. All in all, a well-documented chain of interactions happened, ranging over a wide geographical area. Without a large-scale network thinking, connecting overfishing in Alaska to disappearing kelp forests in California would not have been possible.

Two other major conservation (but also economical) issues in marine systems are harmful algal blooms and overfishing predatory fish stocks. We tend to think that the two may be interrelated: overfishing can reduce the strength of important trophic cascade mechanisms and finally lead to the bloom of algae under weaker control. Networks help to understand, quantify, and hopefully in time also predict blooms.

A good example of how to use network thinking to convince stakeholders, is the case of seal cull in South Africa. Seals consumed roughly as much commercially important fish as caught by fisheries. The issue emerged whether a massive cull of seals could improve the performance of fisheries. Following a long political discussion, with important inputs from ecologists, the plan was eventually rejected. Network analysis by the ecologists showed that even if there is a clearly competitive situation between seals and fisherman, longer indirect pathways in the same food web may actually cause contrasting effects. If some of these long indirect effects are stronger than the shorter ones (which is quite possible), seal cull may be even worse for fishermen. Let alone moral and ethical issues, this is a sound scientific argument, supported by numbers.

Sustainability is a major interest in fisheries (just like in agricultural management). There is an emerging interest in shifting focus from single-species evaluation of the maximum sustainable yield (MSY) towards a multispecies assessment. Though MSY sounds like a measure calculated for a particular species, it could be better computed only if the stocks of several other species are much better known. If we recall the "no fish is an island" paradigm, we can be sure that the maximal sustainable yield is a function of the whole community and for each species it should be evaluated and quantified in the context of the whole ecosystem. Fishing on several species in parallel causes multiple changes in the system and the combined effects will be faced by the community.

Community effects and landscape effects are often combined, and this raises a "network of networks" issue. Here, network analysis is not only a modeling tool, but also a conceptually important help.

A famous example is the one of the extinctions in the avifauna following habitat fragmentation in California. It was not clear why certain birds were so sensitive to habitat fragmentation, especially since they were not found to be restricted only to large habitat fragments. The solution was found by the "network of networks" thinking. Habitat fragmentation and the loss of connectivity between patches led to the disappearance of coyotes, the top predator in this ecosystem, from the smaller fragments. Consequently, in these small fragments, smaller predators, having escaped top-down control earlier exerted by the coyote (mesopredator release) started to benefit. These small predators increased in population size and consumed some bird species to local extinction in the small fragments. The change in the landscape network (connectivity of patches) generated changes in the community network (the food web) within the small fragments.

Now the question emerges how to protect networks, of any of the kinds presented above. How do we focus conservation efforts on networks? Network theory says that network conservation is not the conservation of all elements of the network. Instead, network analysis may help to identify key network elements (key species and key interactions in food webs, key habitat patches and key corridors in landscape networks) and focusing on these elements seems to be an optimal way to try to efficiently protect also the rest of the network. If the same amount of resources are needed for a keystone species or for a "redundant" species, it is more efficient and economical to focus conservation efforts on the former instead of the latter. The same is also true for prioritising patches in a habitat network for conservation, because otherwise identical landscape elements may differ in conservation value due to their relative network position.

In this special issue, we feature three examples of the applications of network analysis in conservation. These range from multispecies bird groups to food webs of large marine ecosystems and to forest landscapes.

In the first paper, Hari Sridhar presents how network thinking helps identify important bird species in a tropical bird community. Here, the network is composed of bird species, and their connections are based on who groups with whom in mixed-species bird flocks. The conservation of the key players in this network, the species that are sought out for grouping by other species, can efficiently and automatically help the other species in the community too. Instead, protecting the not-so-popular species in the network can only provide a species-specific solution and transitory success.

In the second paper, Andrés Felipe Navia, Enric Cortés and Víctor Hugo Cruz-Escalona show the power of network analysis in assessing the vulnerability and sustainability of marine ecosystems. Network tools help to identify keystone species, key interactions and characterise the general "architecture" of whole ecosystems.

In the third paper, Santiago Saura and Begoña de la Fuente use network analysis for landscape ecology. The extinction probability of many species depends on their spatial movements. In fragmented natural habitats, survival in disconnected patches is hard for several reasons, including genetics, demography and chance. For many species, it is thus essential to evaluate the possibilities of how to migrate, move and disperse among habitat patches. Network analysis helps to identify the patches and ecological corridors that are in key positions to maintain the connectivity of the habitat network.

After reading these papers, our hope is the reader will agree with us that there is much to do in systems-based conservation (focusing on several ecosystem components in parallel), and the integrative and holistic perspective of network ecology is a vital alternative to the traditional efforts. Alternative does not mean a competing view. Rather, the winning strategy is some mix of the more precise but limited analyses of local effects and the more integrative but less accurate approach focusing on the entire ecosystem.

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Insect-eating birds need friends in the forest

If you were given a pot of conservation money to spend on species of your choosing, who would you choose? Hari Sridhar would pick six common, unremarkable birds of the forests of Anshi in the Western Ghats. In this article he tells you why.

I am happy now. In fact, I am in one of those rare moments when I would not rather be somewhere else, or doing something else. I am sitting in the dining area of the forest department-run tourist camp in Anshi National park. After two plates of poha and three cups of tea, I am ready and looking forward to the fieldwork that lies ahead of me. It is a bright day and the birds are talking; a definite relief from yesterday's gloomy silence. The sounds I hear hold the promise of drama and excitement. This is more than abstract anticipation, for, from where I sit, I can hear the very birds that I will see shortly, on the trail that runs behind our camp. First a fulvetta calls, then fulvetta and drongo, then a monarch joins in... a flock is forming. Nagesh and I set off immediately.

Five minutes later, we are at the point on the trail nearest to the flock. I hear the birds clearly from here - fulvetta, drongo, monarch, as well as warbler and minivet - to the right of the trail, across the stream, about 100 metres away. I step off the trail and start making my way through the forest – dense and wet forest, what you might call 'jungle', but not difficult to walk through. Nagesh stays behind, as he usually does. Not for him this mindless bird-chasing. He settles down, on a concrete-made-to-look-like-wood park bench, and pulls his phone out of his shirt pocket. I reach the stream and pause, deciding how to cross. The water is only ankle-deep but I do not want to get my shoes wet. I try jumping from rock to rock but, as always, I miss a step and my left shoe is filled with water. As I climb out of the stream and up the other bank, I hear the birds just ahead of me. Fulvetta, drongo, monarch, warbler, minivet, nuthatch. I am at the edge of the flock, peering in. Binoculars uncapped, dictaphone switched on, I am ready to report on the action, like a commentator at the start of a cricket match. At first I see nothing. Then slowly, bit-by-bit, the flock reveals itself.

A drongo—the one with long tail streamers—sitting still, on a branch at eye level, and looking upwards. At the end of the drongo's gaze, on the same tree, is a flameback woodpecker. Clinging precariously to the trunk, he scans his surroundings with a slow sweep of his head. I know he is a 'he' because of his red crown. Now, he flies to another tree, and a second later, the drongo follows him. Higher up, on the same tree, a nuthatch zigzags all over the trunk—up and down, left and right, front and back—probing the bark for tiny in-

sects. I do not know why, but from where I stand, the scurrying nuthatch looks more beetle than bird. My thoughts are distracted by a small green bird flying across my field of vision, from left to right, between me and the nuthatch. Through my binoculars, I recognise it as a warbler. As I lower the binoculars from my eyes, I notice many more flying in and settling on the trees around... ten... fifteen... at least fifteen warblers. As soon as they land they get busy, checking every leaf, above and below, for insects. Among the pale green warblers, is a bright blue bird—a monarch—watching the warblers with keen interest, following their every move, occasionally flying out to snap up an insect, in mid-air. It seems like the frenetic activity of the warbler army, is, somehow, making flying insects available to the monarch. A pair of bulbuls flies into the flock, from across the stream. They sit, on a low-hanging liana, shoulders touching, and clean themselves. They are wet, and in their wetness they look more green than yellow. One of them calls intermittently, a loud and harsh call, with no discernible rhythm, a bunch of notes randomly thrown together. In comparison, the calls of the minivets that I hear from the upper reaches, sound pleasant and happy, like the laughter of children on a playground. I see the minivets now, orange males and yellow females, flying between trees, like confetti in the sky. A sharp monosyllabic "kraak" pulls my gaze down. The maker of the sound, the drongo, is now clinging to a tree trunk, and watching the woodpecker, a few centimetres below, extricate a grub from under the bark. When the woodpecker finally pulls the grub out, the drongo tries to snatch it, but is unsuccessful. Just then, a flash of white draws my attention. A paradise flycatcher has joined the flock. Like the monarch, he too is hanging around the warblers and chasing insects in the air. His handsomeness when perched is only matched by the clumsiness of his flight. A description that applies equally to another bird I just notice: a trogon. He is sitting motionless on a branch about four metres high. The calls of the minivets make me look up again. A different drongo - the slender one with a deeply forked tail - is flying behind the minivets, doing to the minivets what the other drongo was doing to the woodpecker.

Rangu Narayan

I have been watching this flock for ten minutes now. But there is still one bird, which I know is in the flock, but that I have not seen yet. I know this because I have been hearing it all along. The fulvettas' loud, rhythmic calls have been a constant presence, like a background score to the flock's visual theatre. But, try as I may, I am unable to spot the fulvettas. Even now, I can hear their sounds, one directly above me, one to my left, one roughly 30 metres ahead. In fact, it seems like the whole flock is contained and moving within imaginary lines that connect the calling fulvettas. I wonder if the fulvettas' calls serve as the flock's rallying point. Are the fulvettas inadvertent pied pipers, leading all the other birds?

I will have my answer soon. The flock is at the edge of the stream, about to cross. I stand in the middle of the stream and wait, no longer caring about my shoes becoming wet. My hunch seems right. The first to cross are three fulvettas. Then the drongo with the long streamers, then two more fulvettas, four warblers, monarch, seven more warblers, bulbuls, trogon, more warblers, paradise flycatcher, minivets, the other drongo, nuthatch, and finally the woodpecker. Eleven species, more than 30 individuals. The flock makes its way into the forest on the other side of the stream, moving too fast for me to follow. Binoculars capped, dictaphone switched off, I too head to the other side, to find Nagesh and continue along the trail.

A mixed-species flock is extraordinary in two different ways. The first is aesthetic. My attempt at description does little justice to the visual and acoustic spectacle that a flock provides. Watching a flock is like watching a movie trailer: snatches of action coming at you at a pace too quick to process. Visuals, sounds and movement flooding your senses, demanding your attention all at once. And just when you are getting used to the sensory overload, the trailer ends; the flock has passed. It is as if all the drama of the forest is encapsulated in a brief moment of time.

A flock is also remarkable in an ecological sense. We, ecologists, tend to view interactions in the animal kingdom through a lens of nastiness. We expect animals of different kinds - of different species—to chase, to fight, to kill or to eat each other; at best, to ignore each other. Niceties have no place in our construct of the animal world. A mixed-species flock flies in the face of this conventional view because friendship and cooperation lie at the flock's heart, of a kind that we only expect among kith and kin. Do not get me wrong. I am not talking about sacrifice—about one species losing out for the benefit of another. A flock is a win-win situation, one in which all parties involved stand to gain. In the flock I saw that morning on the trail behind the camp, it was clear that some birds were getting food from the other birds—drongos stealing from the woodpecker and the minivets; monarch and paradise flycatcher snapping up flying insects that the warblers made available. But what about the other birds—nuthatch, fulvetta, warbler, bulbul, minivet, trogon, woodpecker—what were they gaining? The answer is not clear but it probably has to do with safety and protection. In the flock, in the company of other species, these birds are safer than if they were on their own—maybe because there are more eyes to spot an approaching danger; maybe because they are each less likely to be singled out by a predator; maybe they can all gang up and chase the predator away. It is also known—and I have seen it myself - that birds like the fulvetta and drongos are especially quick to spot approaching danger and cry out warnings. That is probably why the other birds followed the fulvetta; probably why the woodpecker and the minivet tolerated the sustained harassment by the drongos—a small payment for the safety they get in return.

So far, I have focused on a single example. One flock, one moment in time, one point in space. A collection of 30-odd individuals of 11 species whose fates were closely intertwined. But even as I was watching that one flock that day, if, somehow, I had been able to zoom out, and see the entire forest like a soaring raptor would, I would have seen and heard hundreds of flocks all over Anshi. Flocks that differed in composition—different sizes, different individuals, different species—yet, identical in purpose—a way to food and safety for the actors involved. In fact, if I had looked really carefully from my vantage point high above, I would have noticed that almost every insect-eating bird of the forest was in one flock or the other.

Rangu Narayan

If you are wondering where I am going with this, or what this has to do with conservation, here is my answer. To protect a species, any species, to ensure that it stays with us in the future, there are a few steps that we must take. We must ensure that the place it lives in is safe, that this place has enough food, that its enemies—both those that might eat it and those that might fight it—are not too many. There are other steps too, but these are the important ones. But, if the species that we want to protect is an insect-eating bird, there is an additional precaution required: we must protect its friends too. From what I just described, it is clear that insect-eating birds are not islands in the forest. They are dependent on each other for food and safety, linked to each other through invisible bonds of cooperation. These bonds form the building blocks of a network—a friendship network—that connect all the insect-eating bird species in the forest. But not all bonds in the network are equal. Just like us humans, each insect-eating bird too, picks and chooses its friends carefully, driven by more than one consideration: is the potential friend's behaviour compatible with mine? What kind of help will the friend provide? Will the friend be available and willing to flock with me when I need to? To protect an insect-eating bird species therefore, we need to identify and protect its chosen friends.

We can look at this issue in a different way. Instead of asking who a particular species' chosen friends are, we can ask how often a particular species is the chosen friend of others. Think of it like a popularity chart. We can rank each species according to its popularity in the friendship network, according to how often and how many other species want to flock with it. How does this help? If ever we have the unfortunate situation where we had to prioritise species to protect, then we could work our way down from the most popular to the least popular in our list. Because, by protecting the popular ones, 'keystones' in ecological parlance, we also help the many others that depend upon them for food or protection.

That day, after the flock crossed the stream, Nagesh and I continued along the trail behind the camp and encountered two more flocks. The first one, on a hilltop, had only two species—a lone white-bellied blue flycatcher and 5 dark-fronted babblers—all keeping close to the ground, flycatcher following the babblers. In contrast, the next flock was the biggest I had ever seen, including as many as 55 individuals of 23 species. Over the next four months, I walked all over the forests of Anshi, trying to observe as many flocks as possible, to observe from the ground what I might have seen that day if I had been able to soar like a raptor. During this time, I encountered 250 flocks and recorded all that each of them contained. Back in Bangalore, we used this information to construct the network of "friendships" among the insect-eating birds of Anshi. I will not go into the details of how we did this. If you would like to know more, you can find it in the paper mentioned under 'Further reading'. What I want to tell you is who the popular ones, the superstars of the network, were.

The answer could not be clearer. If you arrange the 36 species in the Anshi friendship network from most popular to least popular—and indicate each species' level of popularity by the height of a vertical bar, you will see six tall skyscrapers followed by 30 little stumps that hardly get off the ground. In other words, six species were much much more popular than all the others. Who are these superstars? In no particular order, since they were all equally popular, the six species were: *brown-cheeked fulvetta, scarlet minivet, yellow-browed bulbul, black-naped monarch, western crowned warbler* and *greater racket-tailed drongo*. To confirm our findings, we went back to Anshi the next year and repeated the entire exercise. Walked all the trails again, recorded all the flocks, built the network, and found out who the popular ones were. The answer was identical. Therefore, there is no doubt about who the key players are—the go-to birds for food and safety in the Anshi friendship network. That part was easy. What is puzzling is why these six species, and not any others? The puzzle deepens when you consider these six are an odd assortment with little in common. Is it because their behaviours are compatible with those of many other birds? Is it because they are particularly good at helping and at providing benefits to other birds? Or is it because they are easily available and willing to flock? We do not know, and as with most such questions with multiple possibilities, the answer is probably a little of everything. What we do know is that that these six species are important and play crucial roles in determining the fates of numerous other species.

The good news is that all six species are doing well. They are abundant in the forest and show no signs of imminent decline. There is little risk of any of them going extinct in the near future. The bad news is, also, that all six species are doing well, because it means that they will attract no conservation attention. The enterprise of conservation is interested in the rare and the threatened, not in the safe and the common. While this might be a good strategy generally, it requires a rethink in this case, because the fates of many an uncommon species rests on the future of these common birds. Therefore, if I was given a pot of money to spend on the species of my choosing, I would choose these six birds. I would use the money to find out what makes these birds tick. And once I found that out, I would also make sure that what keeps them going, keeps going too. Because, if these six species, which hold the reins of the friendship network in Anshi, go down, they will take everyone else down with them. A loss, both ecological and aesthetic.

Further reading:

Sridhar H, F Jordán & K Shanker. 2013. Species importance in a heterospecific foraging association network. *Oikos* 122:1325-1334

Acknowledgements

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Andrés Felipe Navia, Enric Cortés and Víctor H Cruz-Escalona

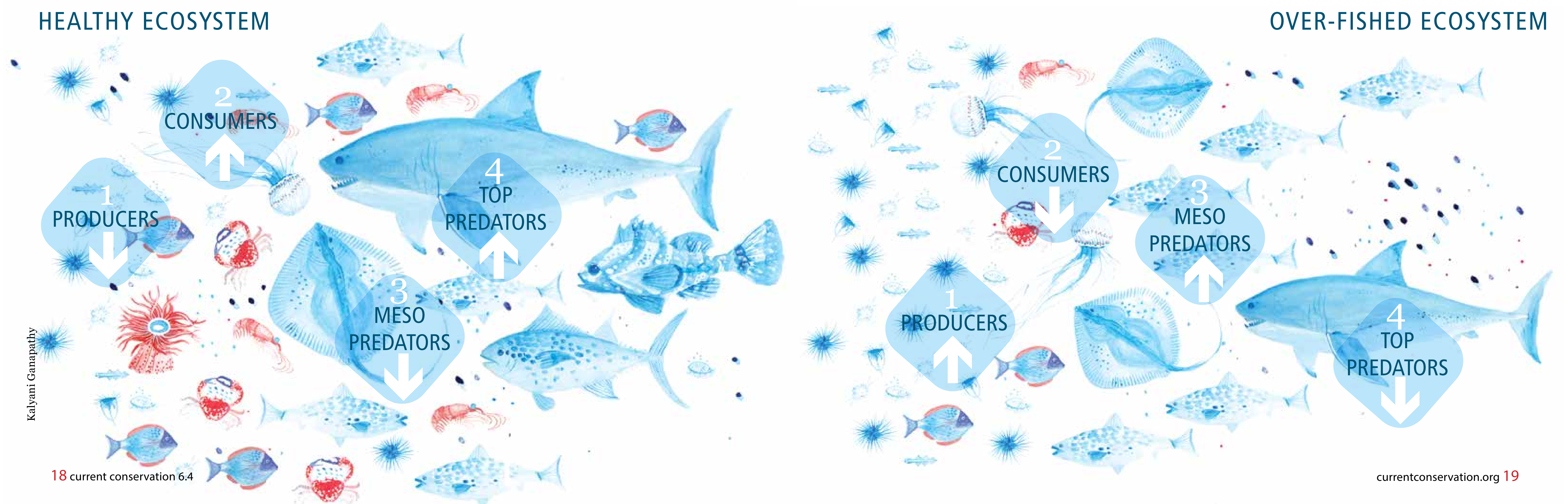
Use of network analysis in food web conservation

Human pressure on marine and terrestrial ecosystems has increased in the past few decades leading to significant, often irreversible, changes. Some of the strongest sources of pressure include habitat destruction or degradation, contamination, fishing and hunting, all of which have caused changes in the abundance and distribution of species, the productivity of ecosystems, and even in the organisation required for the adequate functioning of these ecosystems. Although the organisation of ecosystems is resilient to natural stressors over long time scales, human action has induced strong pressures over time periods too short for these ecosystems to adapt.

This state of affairs has given rise to multiple approaches to try to understand how human activities have modified, and continue to modify, different ecosystems. On the way to gaining this understanding, numerous differences and controversies have emerged among researchers, not so much as to whether humans cause deleterious effects, but rather about the magnitude and extent of such effects. One of the most common approaches is the study of food webs and the effects of human activity on them. For example, some studies suggest that intense fishing pressure in the past 50 years has drastically modified the composition of marine food webs. In contrast, other researchers propose that the changes observed in the composition of marine food webs reflect effects on the species targeted by fisheries rather than network degradation. Some studies further suggest that human activity has substantially altered existing feeding relationships among species within the networks, leading to network reorganisation only a few years after being impacted by humans.

The study of food webs has generated a lot of interest in the past few decades, especially recently, when the focus on ecosystems has become a central theme in fisheries management and conservation of ecosystem services around the world. A number of theoretical approaches have been developed to study food webs and associated tools to build, analyse, and interpret the network of interactions in food webs. Studies on the structure and function of these networks have generated the most attention. Research on network structure focuses on describing and interpreting the species composition of the food web and identifying guilds or functional groups of species that play similar roles in the web. By contrast, studies on network function attempt to quantify energy flow among network components and the strength of interactions among species.

The tools we described above allow us to model how food webs will respond to different kinds of management interventions, such as reducing fishing pressure, setting fish catch quotas, or selectively removing particular species from the web. These tools also help anticipate the consequences, on food webs, of natural changes such as decreases in abundance of top predators, structural simplifi-



Kalyani Ganapathy

cation of food webs, and decreases in productivity. Using these approaches, studies have indicated that many ecosystems are transitioning to new organisational states that are more sensitive to natural changes. These tools have also been used to compare highly impacted ecosystems to others that were relatively unchanged, showing that the latter are more stable and thus less susceptible to environmental modifications (this is called "resilience"). It is important to note that, for those interested in using this approach, the models we describe are highly dependent on information available, how the model itself is specified, and previous knowledge of the system modeled. Thus these models must be developed and applied with extreme caution and all assumptions and implications carefully examined.

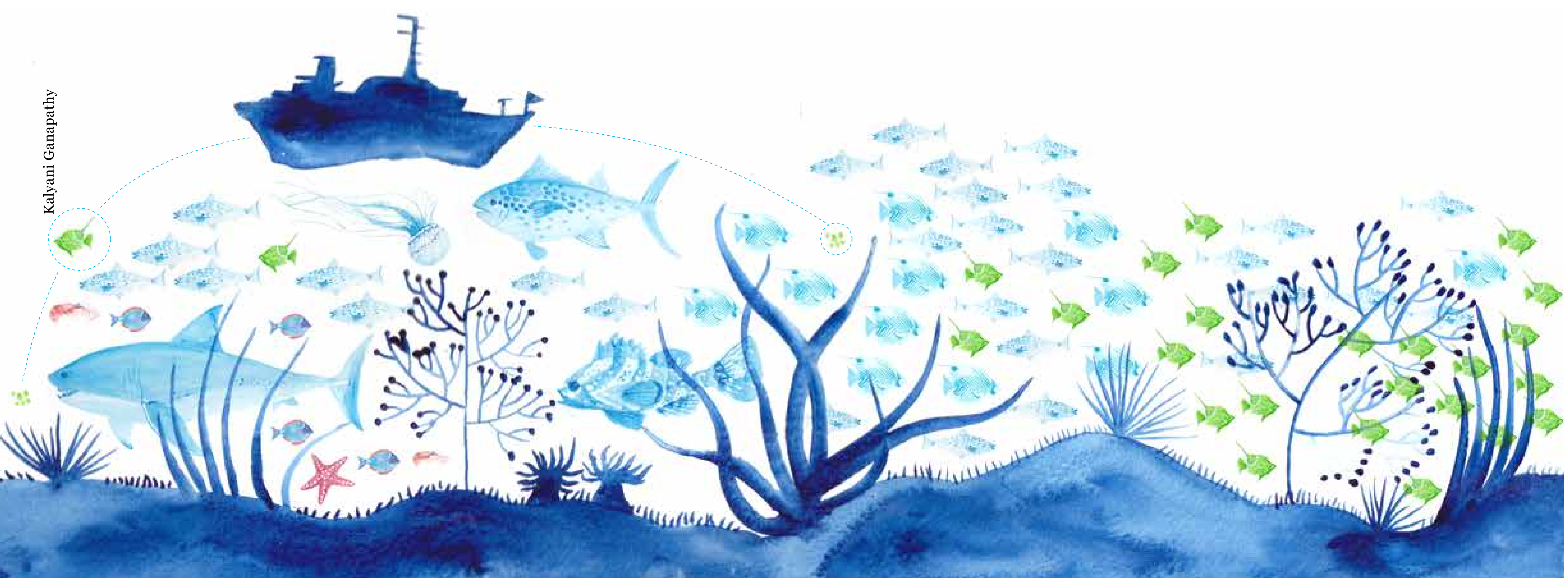
The structural analysis of trophic networks is a more recent approach that has borrowed very useful tools for ecology from the social sciences. Based on information on the presence of interactions among predators and prey in food webs, structural analysis allows us to explore different properties of food webs such as which species have the highest connectivity, those that are the most central and important for maintaining network organisation, as well as the key species in terms of interactions or network cohesion. Recent findings suggest that not only species of high commercial value are the most important for organising or protecting ecosystems, but that, to the contrary, even species or groups of species without any apparent value may be those that contribute the most to maintaining the organisation of a trophic network, which means that management measures aimed at those species are needed to conserve the food web and its functions. This approach allows studying direct and indirect trophic relationships between predators and their prey, considered important forces in network organisation, by analysing real or modeled scenarios of removing, or adding, species from the network under study.

Regardless of the approach used, a good food web study hinges on the availability of basic information that allows one to build solid models from the outset. Knowledge of the diet and feeding ecology of species to the finest level of detail is desirable, since it enables nuanced modeling of important ecological effects such as temporal, spatial, and sex-specific diet shifts. Depending on the approach used, it is also necessary to have population-level information on the species included in the model, such as production (i.e. biomass), productivity (i.e. mortality rates), and data on catches and discards among others.

Tools for network analysis are particularly useful in large, difficult-to-delineate ecosystems, such as the oceans, or when populations under study cannot be manipulated, such as large cats in the African savannah, where experiments aimed at studying relationships between the loss of species and community stability cannot be conducted. It is in these situations that having a toolbox to partially reproduce the complexity of the ecosystem under study and conduct "experiments by computer" is especially useful: it allows researchers and decision-makers to have access to information that would otherwise be very difficult to obtain (such as the effects on predatory function, predator-prey relationships, and trophic interactions among species). All in all, it is very important to consider the context of the assumptions and limitations of each mathematical model to avoid indiscriminate errors of extrapolation or overreaching conclusions.

Although the different pressures on food web networks may at first appear to be disconnected from each other, in reality they are all interrelated and may even become magnified as pressures increase. For example, a "simple" imbalance in the proportion between predator and prey could spread a new indirect effect, which in turn could enhance a previously non-significant interaction in the web. If the species involved are not adapted to adjust to this new dynamic, it may lead to reductions in abundance of some of them, which in turn could spread another sequence of indirect effects that could even modify some ecosystem functions. Thus, considering the complexity of food webs, tools such as those we described are needed because they allow researchers to gain an understanding of networks, their properties, complexity, and possible responses to human-induced effects.

Up to now, different approaches to studying networks have typically been applied independently of one another, with few attempts at comparing and contrasting results. In the future, it is important that the best features of each of these tools are integrated with the aim of optimising results and increasing the efficiency of network studies. This will, in turn, give us a higher degree of confidence in the models we develop to plan the conservation and management of food webs in the future.



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Suggested reading:

Christensen V & C Walters. 2004. Ecopath with Ecosim: methods, capabilities and limitations. *Ecological Modelling* 172:109-139.

Dunne JA. 2006. The Network Structure of Food Webs. pp 27.86. In *Ecological Networks: Linking Structure to Dynamics in Food Webs.* (Eds M Pascual and JA Dunne). Oxford University Press, USA.

Gaichas SK & RC Francis. 2008. Network models for ecosystem-based fishery analysis: a review of concepts and application to the Gulf of Alaska marine food web. *Canadian Journal of Fisheries and Aquatic Sciences* 65(9): 1965-1982.

Navia AF, E Cortés, F Jordán, VH Cruz-Escalona & PA Mejía-Falla. 2012. Changes to marine trophic networks caused by fishing. pp 417-452, In: *Diversity of Ecosystems* (Ed A Mahamane). Intech, Croatia.

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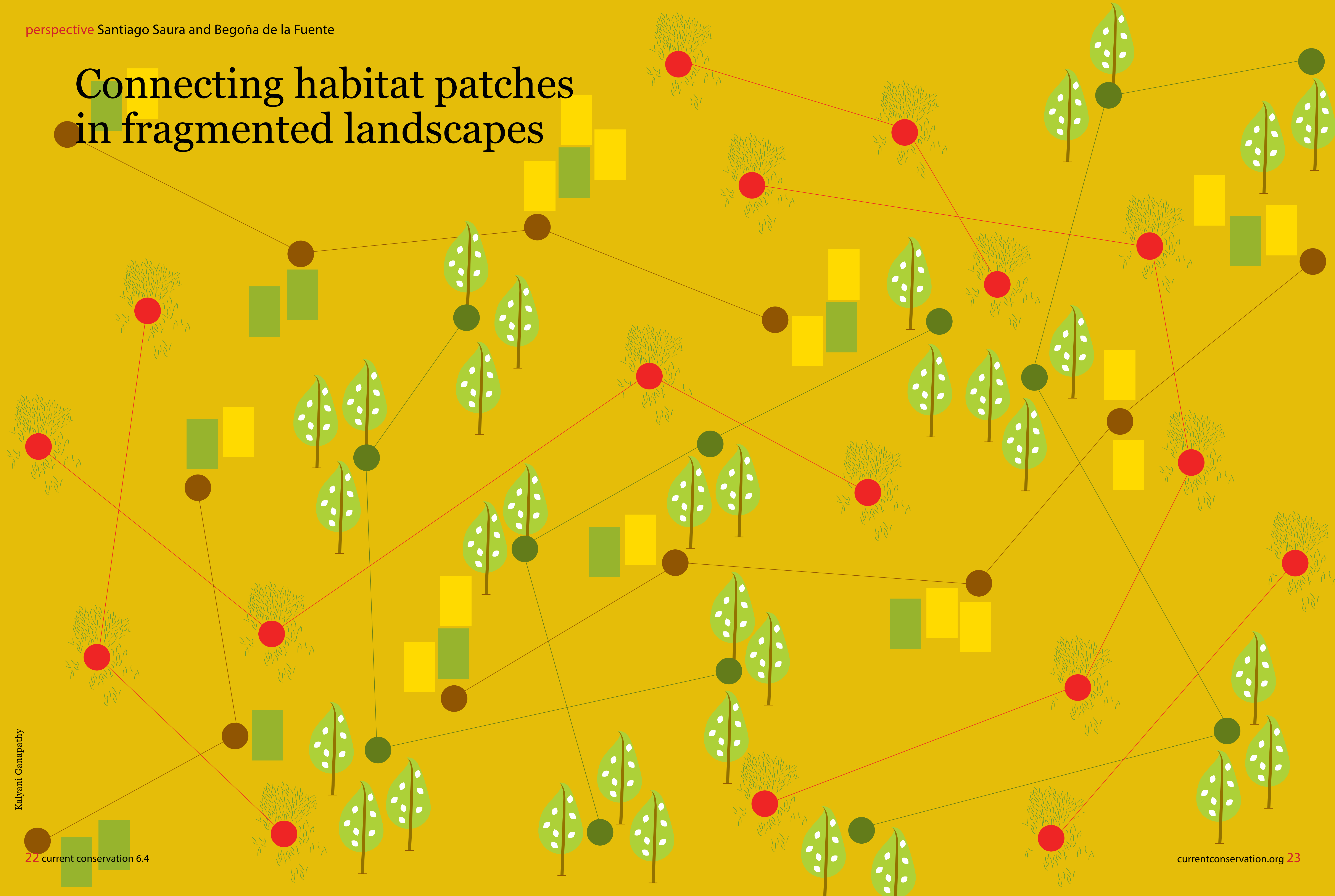
Santiago Saura and Begoña de la Fuente

Connecting habitat patches in fragmented landscapes



Kalyani Ganapathy

CONSERVATION, LANDSCAPE CONNECTIVITY AND THE NEED FOR HABITAT NETWORKS

Many natural habitats that once occupied large and continuous areas on the planet are now restricted to small patches scattered throughout human-dominated landscapes. For many species, each of these patches, alone, may be too small to harbor stable and resilient populations. Therefore, species' long-term persistence depends on connectivity among spatially separated habitat patches in the landscape. The intervening landscape matrix that separates habitat patches is, in many parts of the world, increasingly hostile and less permeable for species' movement due to global change processes such as deforestation, agricultural intensification or urban sprawl. Additionally, climate change will inevitably make currently suitable areas inhospitable for many species while new habitats matching species' environmental requirements may become available at higher latitudes or altitudes. The survival of many species therefore depends upon their capacity to respond to these changes by moving large distances across human-modified landscapes. In all these cases, a top concern in conservation is to maintain or improve the connections among habitat patches or protected areas. That is, to conserve or create habitat networks that connect different parts of land and allow for the long-term persistence of native biota.

HOW TO REPRESENT THE HABITAT AS A NETWORK

In a network perspective, the habitat existing in a landscape is represented as a set of nodes that are connected by links. Nodes are habitat patches separated by unsuitable areas and links represent ecological corridors. Whether two patches can be considered as linked or not is dependent on the dispersal distances and movement behaviour of a given species. For species with large movement abilities, most nodes in a habitat network will be linked, while for species with poor dispersal, only very few patches will be connected to each other. In cases where the area between habitat patches is uniform, we can define links just based on geographical distance between patches. But in other cases, where the matrix around patches is heterogeneous and this makes a difference for species movement, links need to be based on effective distances that consider the accumulated cost of moving between patches (with higher costs when traversing inhospitable areas and lower costs for more hospitable ones). Using network analytical tools, we can compare the numerous possible paths, both direct and indirect, connecting nodes in a habitat network and determine the most important patches and connections to conserve. Other options for defining links based directly on empirical information exist, ranging from radio-tracking data and mark-recapture procedures to genetic information of individuals sampled in different parts of the landscape to infer the levels of gene flow (and hence of connectivity between them). Some of these latter options however, may be affordable only within research projects and not within the typical resources for data gathering available in a given conservation plan.

MO Anand

ADVANTAGES OF NETWORKS FOR INFORMING CONSERVATION PRACTICE

The large variety of options, information types and spatial and ecological details that can be used to define and model habitat networks makes this approach very useful to inform many different conservation problems. The approach is flexible enough to accommodate data of different types and quality. If the only information available consists of a map depicting the distribution of a given habitat type (e.g. forest) in a region, a network can be built using habitat patches and their areas for the nodes and defining links based on geographical distances. If, in another study, or later on in the same conservation problem, more detailed information is available (e.g. species population size in the different patches or radio-tracking of many individuals), such information can be incorporated without completely changing the analytical approach, i.e. by using much the same network model but now improved by being enriched with more biological detail. This flexibility is important in conservation practice because the information available that is relevant to conservation decision making can be highly varied in quality and type. Networks are not data-hungry (even though they can accommodate complex information if it is available), and they work even with modest data as is usually the case in many conservation problems covering large spatial scales. This has led many scientists and conservationists to conclude that network-based approaches may possess the greatest benefit-to-effort ratio for conservation problems that require characterisation of connectivity at relatively large scales.

Probably one of the most important and appreciated advantages of network analysis is that it provides spatially explicit guidelines by assessing the individual contribution of each habitat patch and corridor to maintain landscape connectivity. Networks not only provide a simply descriptive analysis in which the degree of connectivity is summarised at the level of the entire landscape, but also allow us to identify areas that are critical for conserving (or eventually upholding) current connectivity levels.

Finally, a network approach is intuitive and powerful. It is intuitive because, even for practitioners with little analytical or mathematical background, it is natural to think of a landscape as a network of habitat patches connected by links. It is powerful because, even though network analysis is a recent entrant in spatial ecology and conservation, it has been intensively developed for decades in other disciplines (transportation, computers, chemistry, social sciences, etc.), which offers a wealth of algorithms and analytical techniques that, with the necessary modifications, can be adapted and applied for conservation purposes.

It is true that some algorithmic and mathematical aspects of network analysis may be difficult for practitioners who are not specifically trained in this field. However, even on that front, there is recent good news. Several solid quantitative tools are now available in the form of free and user-driven software packages based on different variants of network analysis. These tools are being widely and increasingly used worldwide to carry out habitat connectivity analysis and related decision making in conservation. Some examples of such software include Conefor (http://www.conefor.org/), Circuitscape (http://www.circuitscape.org/), Corridor Designer (http://corridordesign.org/), Unicor (http://cel.dbs.umt.edu/cms/index.php/software/unicor), Linkage Mapper (http://code.google.com/p/linkage-mapper/) or Guidos (http://forest.jrc.ec.europa.eu/download/software/guidos/).

APPLIED GUIDELINES THAT NETWORK ANALYSIS CAN OFFER TO CONSERVATIONISTS

Network analysis can help conservation decisions by providing answers to a variety of questions, such as the following:

Which habitat patches and links should be prioritised for conservation?

One of the decision-support guidelines that is often required by conservation practitioners consists of a ranking of individual habitat patches in a region by their importance to sustain habitat connectivity. Since not all the habitat patches can be protected due to limited conservation resources, which patches should be prioritised for conservation? Network analysis is particularly efficient to deliver quantitative estimates of the contribution of each individual patch, as well as each individual link (e.g. corridor), to the functioning of the entire system, considering the dependences and interactions between all the landscape elements. Network analysis has shown that the importance of some network elements can be disproportionally higher than others. Usually only a few patches and links function as irreplaceable connectivity providers. By conserving a relatively small (but carefully selected) portion of the total habitat much of the connectivity in the landscape might be maintained. The conservation of these priority patches and links can even have a spillover effect, i.e. it can help the conservation of many other habitat patches by extending and expanding their beneficial influence throughout the landscape network.

Which habitat patches or linkage areas are of little importance and can be converted to other land uses?

The ability of network analysis to rank habitat patches and links by their contribution to connectivity means that we can also identify patches and links of low importance that can be exploited or converted to other land uses while minimising the negative ecological consequences, i.e. having the smallest possible negative impact on connectivity.

Where can the spread of invasive species, diseases, pests or forest fires be halted more efficiently?

In the same way in which network analysis can identify critical areas for the dispersal of endangered species, it can also pinpoint those places where to target to control the spread of exotic species or pathogens across the landscape. Depending on the particular species or ecological process of concern and on the conservation goals, practitioners may want to maintain, enhance or decrease connectivity, but in all these cases a network perspective is particularly efficient in identifying the critical areas in which to intervene.

Which areas of the landscape are well connected?

When locations for species reintroductions are sought, not just the habitat quality at that location but also the degree of connectivity to other populations or habitat areas is crucial to ensure long term species persistence. When a reserve needs to be established, current local species richness might not be sufficient as a criterion for where to locate the reserve. This is because most of the present diversity may be lost with time if there are no connections to sources of colonisers that can repopulate that reserve after local extinctions occurring as a result of demographic stochasticity or changing environmental conditions. In both these cases, network analysis can tell us how connected a particular reserve is, i.e. how much direct and indirect fluxes of genes and individuals it will receive, which will be crucial to sustain biodiversity over the long-term.

In how many ways do particular habitat patches contribute to connectivity?

Habitat patches can have different roles as connectivity providers, and network analysis is able to quantify each role separately and provide a more detailed assessment of connectivity. A habitat patch provides some amount of connected habitat resources within itself and, in addition, it can be well connected through strong links to other habitat patches. Moreover, it can either act as a source or a sink, and, eventually, it can be important as a stepping stone upholding dispersal among other habitat patches that would otherwise be more weakly connected or completely isolated. Network analysis can provide an integrated analytical framework for the different ways in which habitat patches can increase the amount of habitat resources that are available to species in the landscape. Through this, we avoid subjective decisions in conservation by providing a quantitative basis to determine the relative weight that different conservation strategies should have, such as focusing on the spatial configuration of habitats compared to investing just in the amount or quality of habitat irrespectively of its spatial arrangement.

Vijay Kumar

For which type of species is connectivity a conservation concern?

In a large landscape or region there might be many species of conservation importance, and in general it is not feasible to develop a connectivity conservation plan for each of them. Network analysis can help simplify this problem by identifying those (potentially few) species that are really dependent on connectivity levels and their potential changes in a given region. Usually, the species with short to intermediate dispersal abilities are those that can benefit more from the maintenance or improvement of landscape connectivity, and those for which connectivity investments (such as maintaining or creating corridors, stepping stone patches or permeable matrices) translate into a more clear and positive response in terms of species abundance, genetic diversity and persistence. Species that traverse large distances across the landscape depend little on network topology and habitat spatial configuration, since they can almost directly move to any habitat area without limitations, while for other species dispersing very short distances, or lacking the ability to move through the matrix, conservation of current connectivity levels may be clearly insufficient to provide any significant contribution to their abundance or survival.

What are the temporal trends in connectivity and how does habitat loss translate into connectivity loss?

Landscape networks change through time, as a result of habitat loss and changes in the matrix in between habitat patches. Network analysis can quantify the degree to which these changes are deleterious for the ability of species to traverse fragmented landscapes and reach habitat resources further apart. It can also indicate if the amount of habitat loss has translated into a comparatively large or small decrease in habitat connectivity, depending on whether key connecting, irreplaceable elements or peripheral, potentially redundant patches have been lost from the landscape.

CONCLUSIONS

Determining the actual role of habitat connectivity for species movement is of paramount importance for developing effective conservation strategies that help to mitigate the impacts of global change on biodiversity. Achieving this objective requires methods that are able to assess the connectivity between habitat patches and to quantify the impacts of landscape change and fragmentation on the capacity of species to disperse among suitable habitat patches. Network analysis is already playing a big role towards this end, both in the scientific community and among conservation practitioners. Network analysis is a flexible, appealing and powerful tool that provides a spatial representation of the landscape that can be examined in relation to land use activities and conservation measures. Networks offer a well-developed mathematical framework that has the virtue of revealing key aspects of the functioning of landscapes and provides an operational way of quantifying the impacts of management decisions on landscape connectivity. Many of the natural and human-modified systems that we need to manage and conserve can indeed benefit from the insights that a network perspective is able to provide. This perspective means that local conservation actions should be framed in a broader context of landscape networks, in which the individual habitat patches depend on each other in such a way that their interactions can determine the success (or failure) of the objectives of a given conservation plan.

Suggested reading:

Calabrese JM & WF Fagan. 2004. A comparison-shopper's guide to connectivity metrics. *Frontiers in Ecology and the Environment* 2: 529-536.

Galpern P, M Manseau & A Fall. 2011. Patch-based graphs of landscape connectivity: a guide to construction, analysis, and application for conservation. *Biological Conservation* 144: 44-55.

Urban DL, ES Minor, EA Treml & RS Schick. 2009. Graph models of habitat mosaics. *Ecology Letters* 12:260-273.

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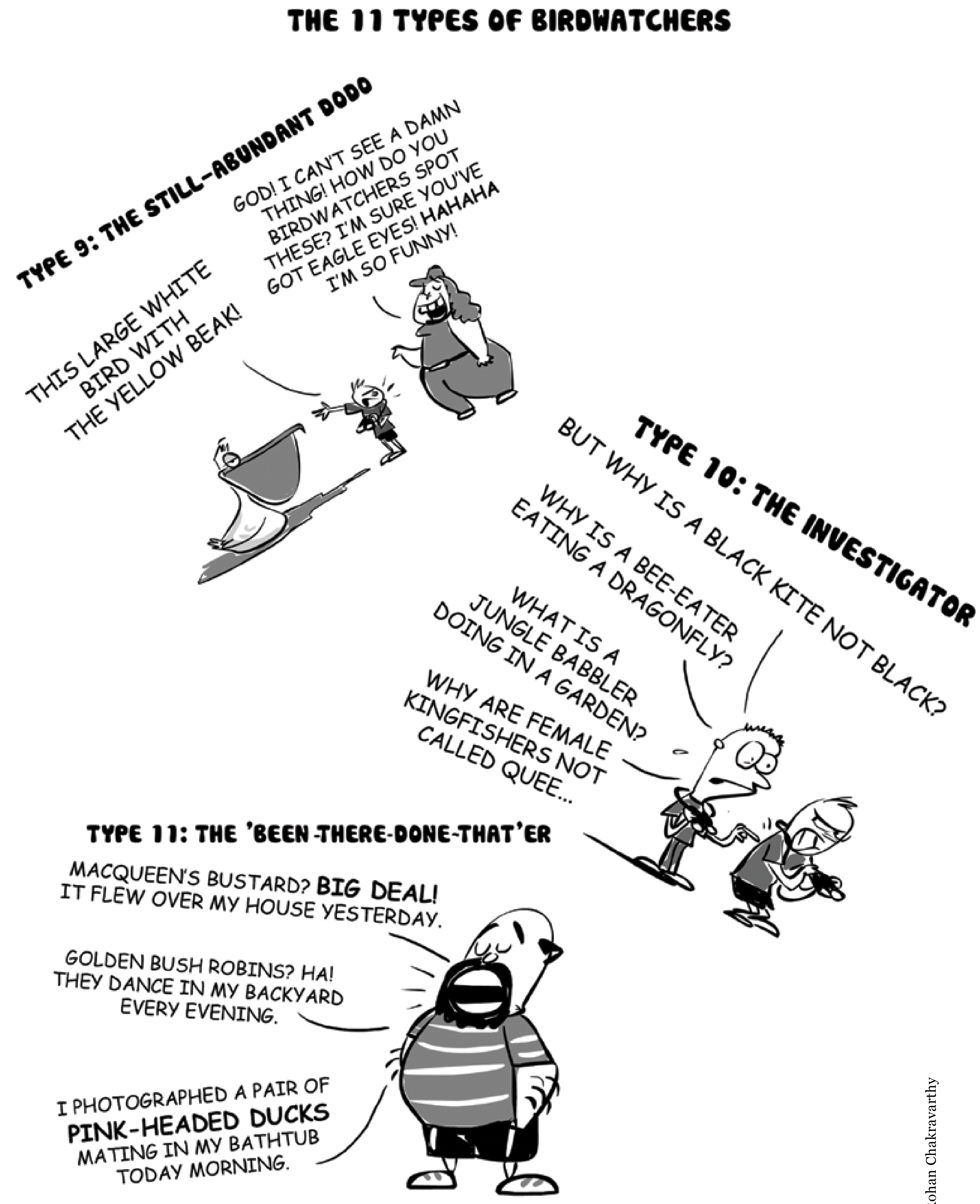
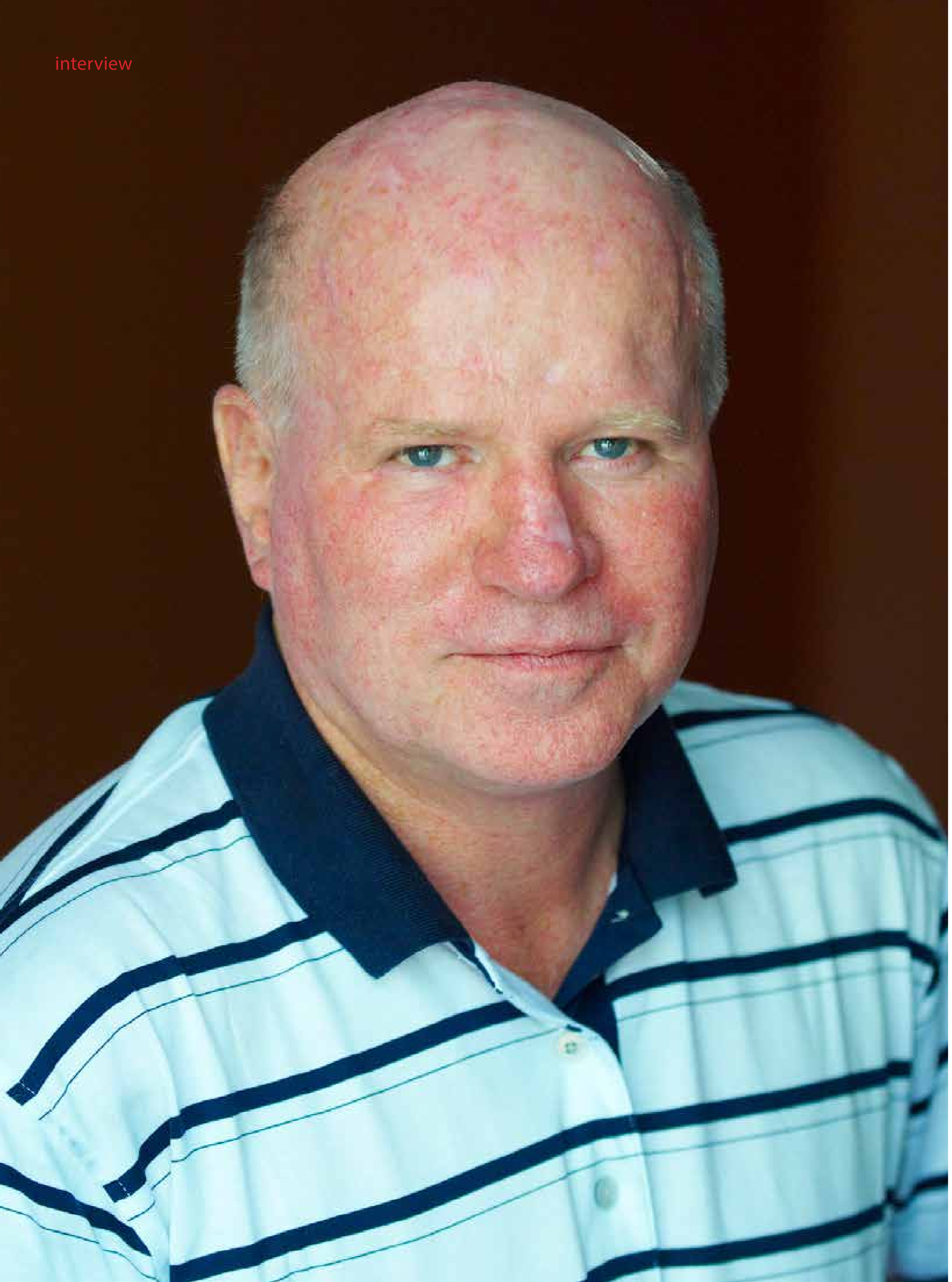


Rohan Chakravarthy

In previous issues, we brought you 8 of the 11 types of birdwatchers. Here are the remaining three.



Robert ‘Bob’ Pressey

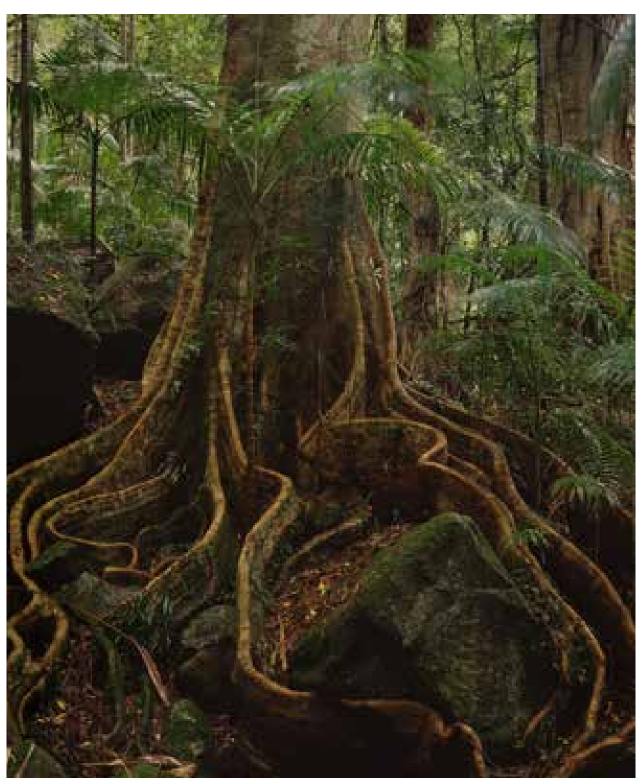
Robert ‘Bob’ Pressey is Professor at James Cook University, Townsville, Australia. He is one of the world’s leading conservation planners, and was one of the pioneers of the method of systematic conservation planning. He has extensive experience in marine, terrestrial and freshwater environments in many parts of the world and is one of the few researchers in conservation science with a strong history of connection to managers and policy makers. He now leads a large research group in planning and management for coral reef conservation, with study areas in the Coral Triangle, western Pacific and further afield. He has published 132 peer-reviewed journal papers and 25 book chapters, with over 8000 citations of his papers. His numerous national and international awards include election to the Australian Academy of Science in 2010.

DD: How did the idea of systematic conservation planning come about?

BP: The first person to conceptualise systematic conservation planning in its rudimentary form was Jamie Kirkpatrick, in Tasmania. He did the work in about 1980 or so, but he didn’t publish until 1983. So I’d date systematic conservation planning to be 30 years old this year. Jamie was the first but, interestingly, others had the same sort of idea at about the same time. In the years that followed, CSIRO [Australia], the Natural History Museum [UK] and Tony Rebelo in South Africa independently built these ideas. The basic idea was to break away from the ‘scoring approach’ as it was being used at the time. The scoring approach is quite explicit, which was one of its appeals, but it had limitations that were understood only later. With the scoring approach, people ask what makes a place valuable: richness, rarity, biodiversity, or other criteria? They rate each place—which could be a forest fragment, or a beach, or a farm—according to one or more criteria. They work out some way of defining each criterion and then combining it with the others, adding or multiplying, and then they end up with an overall assessment of conservation value. This was done a lot and published quite widely, especially in the1970s. The problem with the scoring approach is getting areas that are really rich, say in species, sitting on the top of the list, but all the ones that are highly ranked tending to have the same things in them. You’d just get those things again and again, but not the things that are at the bottom of the list, which could be species needing conservation action. Some things that matter for conservation are only going to turn up in places that don’t have much richness—that’s just the way things are.

What Jamie and others did, independently, was to come up with a better idea. They later found out about each other’s work, and at least 3 groups started working together. I’ve written a paper about that, because it is a nice piece of history in conservation planning, and because I like Jamie and admire his work.

So, Jamie was dealing with rare plants in one square kilometre grid cells in eastern Tasmania. He first tried the scoring approach and realised that, to get every species he cared for protected, he would have to go so far down the list that the required area would be unacceptable to the people whose land would be required for reservation. So he came up with what he called the 'iterative method'. He identified the grid cell that had the greatest richness of species that was not adequately protected, and that became a notional reserve. That way he took out the species that were being adequately protected in existing reserves. Once the notional reserve was demarcated, he took the species that were being protected there out of the list and recalculated richness. He then took the next richest place, called that reserved, took the species out and recalculated. He did this with pencil and paper—this was before personal computers—and ended up with seven or eight areas that protected all of his species. He then adjusted the boundaries to enhance manageability, and they've all become reserves, largely through his persistence.



Steve Hall

The reason Jamie's method was systematic rests on two characteristics. First, he had quite specific and quantitative objectives that clearly defined what he meant by adequate protection. Second, he introduced the idea of 'complementarity', although that term was coined later. By going through the iterative method you end up with areas that are complementary in terms of the things they contain.

So with that background, my own start in systematic conservation planning was fortuitous. I had been applying scoring approaches to the evaluation of coastal wetlands, and I got a job with the National Park and Wildlife Service as a research scientist in 1986. I got a bit of funding to look at conservation planning in western New South Wales. I discovered this very early work on systematic methods that was just brewing, and I teamed up with CSIRO and we did some analyses using iterative methods. That led to one of our early collaborative papers demonstrating the advantages of systematic over scoring evaluation.

DD: If you had to use a case study to illustrate the concept of systematic conservation planning as it is today, which would it be?

BP: I can give you two that are from Australia, one of which I was directly involved in. The first one was called the Regional Forest Agreement Process in New South Wales. We had been brewing some new ideas, and by then I was completely committed to conservation planning. And by about 1995, we came up with some new ideas for mapping the irreplaceability of areas, or the options for achieving conservation objectives. We knew this was potentially the basis of an interactive, participatory kind of negotiation. So the next step was to build some kind of software system that would allow people to explore options, and debate and negotiate, and put areas into conservation, pull them out, see what happens, and reconfigure. I guess the planets aligned. We had a new State Government that was committed to expanding the forest reserves system. Our director knew about our work, managed to convince people in high places that it was worth funding, and we got a lot of money to take it forward. We built a software system called C-Plan that ended up being used in this negotiation process. It was used over several rounds of negotiations over about 4 years, the first time in 1996. That was the first time anyone had set up an interactive decision-support tool for conservation planning. We had players around the table who didn't necessarily like everybody else around the table, but the negotiations were designed so that everyone had to play by the rules. And they knew it was for real in the sense that there were going to be new reserves, it was just a matter of where and how extensive. That was bit of a breakthrough for us in lots of ways. It finally got the doubters off our backs—there had been several calls within the agency to shut down this research, but it was defended by some key people with vision. So finally, these methods were proven to be important and useful, and all the research we'd been doing was seen as worthwhile.

Rebecca Weeks

The other one that I'll mention more briefly is the re-zoning of the Great Barrier Reef Marine Park in 2004. That used a systematic approach, with a different software system called Marxan, but was essentially the same: complementarity, clear objectives, and the like. And that was, demonstrably, quite successful.

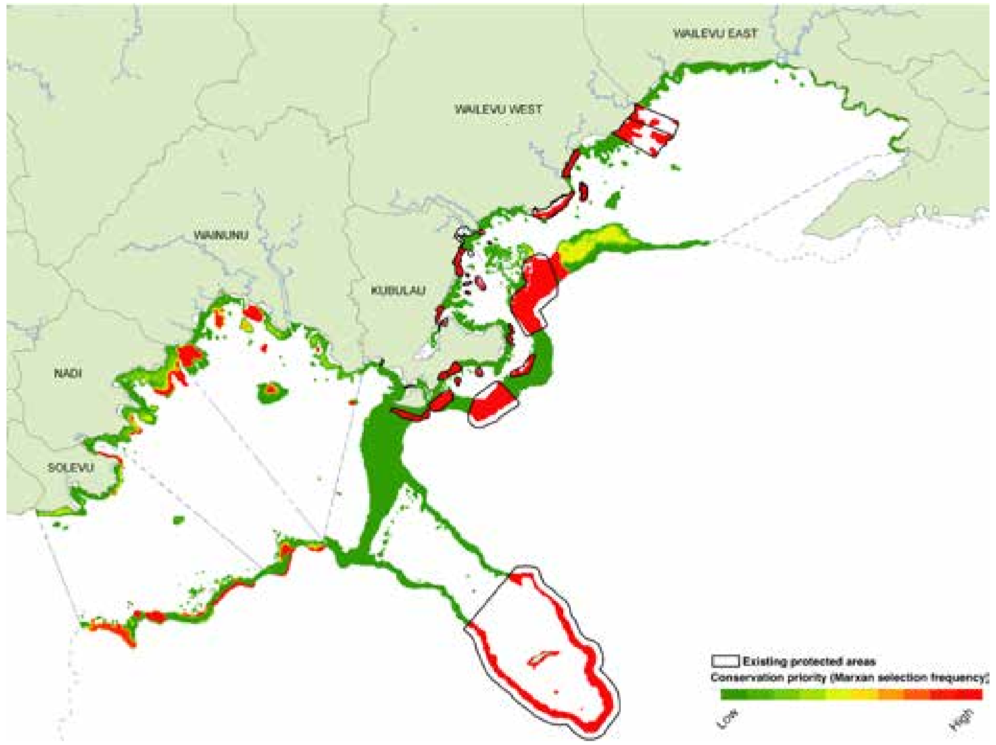
What I have come to realise, however, just recently, is that the success stories seem quite idiosyncratic in the global context. The original Forest Agreement Process focused only on public forests. The politicians didn't want to go anywhere near private land because it was too contentious. And politicians are pragmatists, they wanted a success story, so this was the way to go. The Great Barrier Reef, not to take away from the hard work that went into it, was also in a very simple governance system. There is one marine park, one manager really, the Marine Park Authority. I'm just thinking about the wider replicability of these case studies. One could not do this in the Coral Triangle, for example. There is very complex governance, with finely textured management and ownership, much more resource dependence, and much less occupational mobility. This very common marine situation is analogous to private land. Anything you do for conservation must be slow and accumulate from many small pieces.

That is not to say that good things have not happened in more complex governance situations, but they are not as spectacular. They tend to be small and tend to grow more slowly because when we are dealing with complex governance we've got a lot of private landholders or a lot of communities to deal with. It's necessarily slow, and it's also necessarily expensive. We've got a big challenge for us as conservation planners to deal with those widespread complex situations. And we should be careful because we can't just say "look at these two case studies from Australia, now we can go out and do this everywhere", because we can't. The idea is good, the idea is translatable... but with considerable adaptation.

DD: So, C-Plan, the software you developed, how does it work?

BP: Well, we developed C-Plan in 1995-96. We'd been working with an idea called 'irreplaceability', which is a twist on the analytical methods that were being developed earlier. The basic ingredients are still the same. We have a table of areas and features showing the species and vegetation types that each area contains, with areas or abundances when we know them. We have objectives for each of the features. But instead of finding a set of areas that achieves all our objectives, we put a value on every place that is the likelihood of it being needed.

Running an analysis to get a predetermined set of areas gives somewhat artificial answers. It might



WCS Fiji/ Rebecca Weeks

A Marxan selection frequency output map from a planning process undertaken across five districts in Vanua Levu, Fiji. Coral reefs in red are prioritised for inclusion in a marine protected area network designed to build upon, and be complementary to, existing protected areas in Kubulau and Wailevu districts (indicated on the map, and "locked in" to the planning scenarios)

say these are 42 areas needed to achieve our objectives, perhaps accounting for existing reserves. But are those 42 areas the most important in that region or are they the ones that emerge from the computer analysis, because of the rules you taught it to use? Really, it's the second. There might be a thousand ways of putting together a set of 42 areas, all slightly different. Some of those first 42 sites chosen by a single analysis will be unique, so you will have to have them. Some of them could be pulled out and replaced with 20 or 50 others. So you've got room to manoeuvre. What you can't see when a computer programme selects a single set of areas is your room to manoeuvre.

Irreplaceability puts these areas in a scale between 1 and zero. 1 means that if that area is not protected, you will fail to achieve one or more of your objectives. In other words it is fully irreplaceable. At the bottom end of the scale, you have areas with lots of spatial options. It was obvious to us from the start that irreplaceability wasn't static because once you started making decisions using your irreplaceability map, the pattern would change. Imagine for example that a portion of your landscape was identified as not available for conservation, being politically committed to logging or farming. Immediately after that, other places that are available would become more irreplaceable, because they become more important to achieve your objectives. You've then got fewer options spatially. On the other hand, if you are going to choose 12 areas and commit them to conservation, this will achieve quite a few objectives making some of your other areas less irreplaceable. So we knew from the outset that a map of irreplaceability would be dynamic as we made decisions. And C-Plan was a dynamic system that allowed us to work like that. We had bit of a dream when we were making it, in that we visualised people sitting around and negotiating. We built it with the stakeholders over a period of months. We showed them a prototype and they gave us feedback. We thought there was no point in showing just how the options change unless you can tell how much closer you are to your objectives after several rounds of decisions. So we brought up tables, built a lot of interactivity, some requested and some initiated by us. If you take an individual area and ask what is making it irreplaceable, you're also going to find that out. So there was a lot of graphical support. And a year and a half of hard work later, it was actually happening. We were in the negotiation room making decisions, and had a really useful software system that was then applied to many different regions around the world.

DD: Systematic conservation planning seems to be a very data-intensive procedure requiring extensive field work, etc. which may take a lot of time and may not always be viable. How would you make systematic conservation planning attractive to policy-makers, or people who want quick solutions to conservation problems?

BP: The image of systematic conservation planning being data-hungry and therefore intractable in most places is artificial. There are lots of places even in Australia where there are not enough data to plan properly with species. Instead we have to work with what we have: a map of vegetation types, or an environmental classification. So we're assuming for the purpose of this planning exercise that representing a sample of each of those environmental units or vegetation types is doing pretty well for biodiversity at large, even though we don't know a lot about the species. And that is a very common approach around the world. One has to decide the minimum required to do systematic conservation planning. It could be some kind of uniform subdivision of the landscape into units like vegetation types or environments that we hope reflects the distribution of biodiversity composition, or differences in biodiversity. And this is used commonly. Another thing that would be useful to know is transformation, or conversion of native vegetation to crops or towns. We all have freely downloadable satellite imagery that could be used for that. So there are a lot of data out there right now that could be pulled together in a relatively short time to do an exercise in systematic conservation planning. Obviously you always want more data, but even in really well known areas you have to make pragmatic decisions or judgements about how much data you have and how much of them you can use. And there are lots of situations where we don't have the time or the money to go and get more data.

DD: And to work with C-plan, how much data would I need to feed?

BP: Generally speaking, the more data the better. But you can drive C-Plan with a vegetation map or

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Community members from Wainunu district using these maps in discussions about which sites they wish to protect.


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map of physical environments and nothing else if you have to.

DD: So it has built-in systems that will extrapolate from that given data...

BP: Not really. The thing about conservation planning software is that the system will help you identify priority areas, but there is nothing absolute about priorities. Priorities are a function of the data you put in and the objectives you set. You change your dataset, the priorities will change. Change your objectives and hold the data the same, and your priorities will change. So you can absolutely use C-Plan with nothing more than a vegetation map, but you'd get a different answer than if you had a vegetation map plus data on species. And that's just the way conservation planning is. But what we hope is that, if all we have is a vegetation map, then we will come up with a more intelligent set of conservation areas than if we had just placed them at random or in a totally ad-hoc way.

DD: So you are saying that systematic conservation planning can be used even in data-scarce situations? Because that would be a pertinent question in the Indian context...

BP: Yes that is right. But remember that there are plenty of data-scarce situations in Australia too. I'm sure that systematic conservation planning can be used extensively in India, and it has already been applied in the Western Ghats. Here's an example of data scarcity in Australia. Across the islands in the Great Barrier Reef, we have a project on prioritising management actions. We're working with the managers; they are very keen on this and want to be part of the process. You'd think that with all the studies from all the universities over the years that the islands would be very well known. We were looking at data and found huge holes in knowledge, of species in particular, and even the vegetation mapping is quite patchy. So now we have to decide what our minimum dataset is going to be. What is acceptable as a basis for prioritisation? We will go to the managers, show them aerial photos of where vegetation mapping has not been done, and ask them what vegetation types they think are there. That is how we are going to fill the gaps in our data table. Species data across the islands are a complete mess—very patchy both spatially and taxonomically. Someone has worked extensively on lizards on three islands and that is it. So there is a big data table with islands as rows and species as columns, with a huge number of false negatives. We cannot use most of those species in this planning exercise because we cannot fill the gaps. So we will focus on a few key things like nesting turtles, nesting seabirds and federally or state listed threatened species, and a few plants and vegetation types. We'll try to be explicit about the uncertainties involved. That is a very small of snapshot of biodiversity, but that's what we have to use.

DD: So coming back to systematic conservation planning generally, what have been the major challenges since it started, and how have they been managed?

BP: Well, I'm going to talk about one. In 30 years, the conservation planning community has done a lot of clever work, had policy uptake and legislative uptake in some areas. But I think it's fair to say there's been a lot less implementation than planning. We have done a lot of plans with the best of intentions, and a lot of them have just not led to anything. So there is a big gap between designing conservation areas and actually making them happen. The solution to overcoming that barrier is multipronged, and we've yet to work out how many prongs. There is not any one factor that one can identify and say if we can nail that, we've solved the problem. There's going to be twenty or more of those factors. A lot of it revolves around governance and understanding people's needs. Taking the time to actually work with people is very important, which is what we're seeing here [at Dakshin] through the work on marine governance.

And one of the sources of that barrier I suppose is that a lot of scientists stop at the planning phase, write a paper and move on. Not many follow through. And that is why organisations like The Nature Conservancy (TNC) are really doing some very important work, because they are there to follow through. They too have done a lot of plans that have stayed on the shelves as well, but their 'business' is trying to make a difference in ways that are consistent with all the planning that they are doing. I think that, among all the big NGOs, TNC is doing very well in bridging the gap between planning and application, although TNC is facing some difficulties too. That is something that interests me a lot, because like a lot of people in the science of conservation planning, I would be very disappointed if I finish my career and just had a long CV and nothing to show for it in terms of outcomes on the ground. So that's the biggest challenge for us.

DD: So that would be the way forward?

BP: Yes. There are a lot of people working on that and making some progress. And my main reason for visiting India is to learn more about how to combine Australian technical expertise in planning (which can be adopted readily with the skill base here in India) with the advances made here in "conservation with a human face". I like working in places where nature conservation is faced with challenges. Indian scientists are showing us that there are ways to overcome those challenges.

DD: Finally, before we wrap this up, is there something you would like to add.

BP: Well, probably that this is my first time in India, and it's been a fantastic trip. I've met some great people and I'm learning a lot. This trip was about starting collaborations and working with people here, and it looks very promising. I find that prospect very exciting. I look forward to coming back.

DD: We look forward to seeing you here again! Thank you so much for your time.

BP: Thank you!

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Animal social networks: Unraveling (biological) relations

Exploring animal social networks
Darren P Croft, Richard James & Jens Krause

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SOCIAL NETWORK ANALYSIS WEIGHED AGAINST THE TRADITIONAL ANALYTICAL METHODS IN BEHAVIOURAL SCIENCES

Some time ago, my supervisor posed a question that many people who study behaviour have wondered about: what are the new insights that social network analysis (SNA) can provide that are not possible with traditional analytical means in behavioural sciences? If you have also wondered the same and want to know how SNA can contribute to studying behaviour, ecology and evolution, *Exploring Animal Social Networks*, by Darren Croft, Richard James and Jens Krause, provides a lucid account. The book describes why SNA is a powerful tool in describing social structures across different levels of organisation, from the individual to the population.

Academia, like governmental intelligence agencies, has, in the last decade, paid great attention to the growing networks of people connected through microblogging and social networking sites, with a focus on understanding who is connected to whom and the nature of these connections in the network. Network analysis has provided an analytical framework for studying such a complex and large body of interactions. Historically, SNA has been widely used in the social sciences to understand complex human interactions with statistical physicists contributing a great deal in developing the methods of SNA. Croft et al give a brief account of these historical developments in the opening chapter of the book. Assuming no prior knowledge on the part of the reader, the authors anticipate the questions that a reader is most likely to have—What is a network? Why use network analysis? How is SNA different from other statistical methods? While providing answers to these questions, the authors keep the readers interested with numerous examples from research that cut across taxa, from primates to social insects—à la the hugely popular textbook "An Introduction to Behavioural Ecology" by John Krebs and Nicholas Davies.

How does one collect data for SNA? How can one extract information on interactions from existing datasets using network analysis? The authors devote a chapter (Chapter 2) on data collection, which deals with a wide range of questions from arranging data to representing relational data to designing sampling protocols for collecting data. This chapter engages in the fundamental questions of defining associations, either based on proximity or space use, or based on interactions.

How do we visualise interactions or customise networks based on our biological questions? In chapters 3-6, the authors carry out a thorough quantitative exploration of different properties and types of social networks (but with numerous real and made-up examples, it is never boring or scary!). These chapters are very useful for researchers and students who want to learn the nitty-gritty of network analysis. For example, chapter 4 explains different components and parameters in a network (like centrality measures) that are important for understanding biological interactions. Based on the network and their parameters, there are statistical tests (Chapter 5), like randomisation, which help in comparing the observed network with a randomised network that provides a null hypothesis. Further to this, the authors also explain how to filter out the not-so-significant interactions in a network and focus on the core interactions.

In the animal world, heterogeneity is ubiquitous, with individuals in groups often differing from each other in their phenotypes (morphology or behaviour). In chapter 6, the authors discuss how this heterogeneity can be understood using SNA, looking at the finer substructures of the network. This is particularly relevant for those who want to study the role of individuals, thereby formulating testable hypotheses. Furthermore, long-term studies commonly deal with data on individuals over time and under different ecological conditions. The chapter on comparing networks (Chapter 7) deals at length with both the methods and biological relevance of comparing networks separated in time. This contributes to understanding not only the role of ecological or individual variations in animal societies, but also provides insights into evolution of social organisations in animals.

Throughout the book, authors briefly discuss software like SOCPROG and UCINET useful for network analyses, along with the visualisation package NETDRAW. Though these are either freeware or shareware, these require platforms like Windows or MATLAB, which are proprietary themselves. However, this shortcoming of dependency in software running on proprietary platforms can be discounted for two reasons—first, this book is not meant to be a software guide to SNA and predominantly deals with the concepts and questions to understand interactions in animal world using SNA; second, many of the packages, especially those in R-statistical package (like tnet, sna or igraph) widely used now, have been developed after the publication of the book (2008).

Network analysis is, today, an important tool for researchers from a wide spectrum of fields in biology which includes conservation biologists, community ecologists, epidemiologists and behavioural ecologists. Across this spectrum, the greatest interest in SNA has been in its ability to link individual behaviour and population-level phenomena. This book is clearly the first such effort in the context of animal societies.

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