The role of science in saving species

David Gibbons

Summary

I argue that it is the job of conservation practitioners to solve conservation problems, while it is the job of conservation scientists to help practitioners by identifying, prioritising, diagnosing and finding solutions to those problems. Without the scientist, the practitioner would have to guess the solution; sometimes this might work, often it won't.

In this presentation, I will give examples of how scientists identify current conservation problems and predict future ones, and how they then prioritise the most important of those problems to ensure limited conservation resources are not wasted. I will also discuss the methods that scientists use to diagnose the causes of those problems, often a necessary step before they can then find a solution to them. Once they have found a solution, scientists need to communicate it effectively to practitioners who endeavour to implement it to solve the problem. Inevitably, in the real world, solutions need continual refining. Because scientific research is not cheap, and not always quick, practitioners are sometimes tempted to short-cut this process, for example by cutting the diagnostic stage. I will provide examples that bring to life the role of science in conservation, focusing especially on how it has helped to save species.

Zusammenfassung

Zur Rolle der Wissenschaft im Artenschutz

Während es die Aufgabe des angewandten Naturschutzes ist, Probleme im Arten- und Naturschutz erfolgreich zu lösen, besteht die Aufgabe der Wissenschaft darin, die Probleme a) zu identifizieren, b) Prioritäten zu setzen, c) ihre Ursachen zu erforschen und d) Lösungsmöglichkeiten zu finden. In dem Beitrag werden diese vier Schritte anhand von Beispielen erläutert. Ohne die Beteiligung der Wissenschaft fehlen der Praxis die Entscheidungsgrundlagen, was in der Regel zu falschen Entscheidungen führt.

Am Beispiel des Kuckucks, einem Langstreckenzieher, wird gezeigt, wie Wissenschaftler aktuelle Probleme im Naturschutz identifizieren und künftige, die sich z.B. im Zuge einer Klimaerwärmung voraussichtlich ergeben werden, vorhersagen. Um begrenzte Ressourcen (vor allem Geldmittel) zu sparen, müssen dabei vorrangige Schutzziele definiert werden. Zur anschließenden Ursachenforschung – meist die Voraussetzung für die Erarbeitung von Lösungsvorschlägen – stehen verschiedene wissenschaftliche Methoden zur Verfügung, z.B. der Vergleich von Zeitreihen oder von Habitaten unter Verwendung vorhandener Monitoringdatensätze. Ist eine mögliche Lösung gefunden, müssen Wissenschaftler diese an die Politik und die (Naturschutz-) Verwaltung herantragen, damit sie in der Praxis umgesetzt werden kann. Für diesen Schritt sind effektive Kommunikationsstrukturen unerlässlich. Die Erfahrungen in der Praxis wiederum fließen idealerweise in die Wissenschaft zurück und führen so zu einer steten Optimierung des eingeschlagenen Lösungsweges. Da Forschung teuer und zeitaufwändig ist, besteht die Gefahr, dass in der Praxis einer oder mehrere dieser Schritte umgangen werden. Welche Auswirkungen mangelnde Ursachenforschung haben kann, wird am Beispiel des Quendel-Ameisenbläulings gezeigt, einer Schmetterlingsart, die eng mit einer bestimmten Ameisenart vergesellschaftet ist.

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Introduction

My talk today is about the role of science in conservation, particularly the role of science in saving species. I believe it is the job of the conservation *practitioner* to solve conservation problems. There are many such problems. For example: the conflict between large carnivores and livestock; the replacement of tropical rainforest by oil palm; the loss of common species across Europe; the impact of accidental bycatch – such as albatrosses caught on long-lining hooks; the problems caused by introduced, non-native species, and the decline of our pollinators. All of these are conservation problems, and it is the job of the practitioner to solve them. By contrast, I believe that it is the job of the conservation *scientist* to help conservation practitioners by: identifying the problems, prioritising them, diagnosing their causes, finding solutions to them, communicating these to practitioners, and ensuring they work when implemented. Figure 1 shows a simple flow chart of the whole process.

Identifying conservation problems

The first stage for the conservation scientist is to identify the conservation problems. The usual way to identify current problems is through survey and monitoring, for example to determine the status of a species. However, science can do more than that, as it can also predict future problems, such as future changes to species or ecosystems. Common approaches include predictive modelling, population viability analysis, horizon scanning and expert best guesses.

An example of a current conservation problem is the decline of the cuckoo (*Cuculus canorus*; fig. 2) in the United Kingdom. The map (fig. 3; BTO 2015) is taken from the Breeding Bird Survey in the UK, and shows where the cuckoo's population is in decline (the red dots) and where it is increasing (blue dots). As you can see, the cuckoo is declining across most of Britain, particularly in the south, though with some increases in the north. This example shows how good monitoring information can help to identify a conservation problem, but it is also beginning to tell us about a wider issue. The cuckoo is a long-distance migrant that winters south of the Sahara. We have looked at whether this trend for cuckoos is true for all of our long-distance migrant birds by using the Birds in Europe database (Tucker & Heath 1994, BirdLife International 2004). This analysis shows that long-distance Afro-Palearctic migrants are particularly threatened (Sanderson et al. 2006). Figure 4 shows the changing status of birds that are resident in Europe, partial migrants, migrants within Europe, short-distance migrants, and long-distance migrants that winter in sub-Saharan

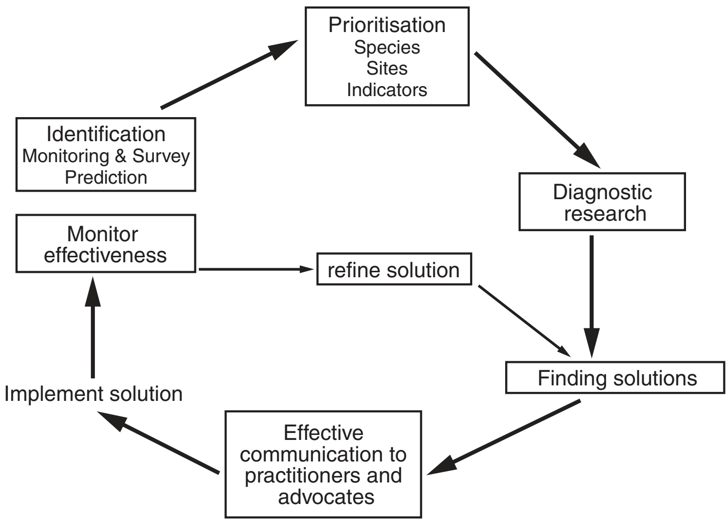

Fig. 1. Schematic of the role of science in solving conservation problems; science plays a role in all those aspects in black boxes. – Adapted from Gibbons et al. (2011).

Fig. 2. Cuckoo (*Cuculus canorus*). – Photo: Tim Peukert, www.foto-peukert.de.

Africa. As can be seen, it is the long-distance migrants that are most in decline. Thus, this monitoring information has helped to identify a problem we did not previously know about, of which the cuckoo is a part.

Monitoring and survey information can also help to make projections into the future. For example, The National Audubon Society has projected the future distributions of many North American birds under a changing climate, by combining information on their existing distribution with climate data. This has allowed them to project the likely 2020, 2050 and 2080 distributions of many species, such as the common loon (*Gavia immer*) (Audubon 2015). According to their analysis, the summer breeding range of this species is set to contract northwards as the climate warms. Similar analyses have been undertaken in Europe.

Prioritising conservation problems

Once we have identified the problems, we need to prioritise them to make sure we focus our conservation action and resources on the most threatened species, the most important sites and networks, and the most important issues. The gold standard for deciding the most threatened species is the IUCN red list (fig. 5, IUCN 2012). Whether or not a species belongs to the most threatened categories is dependent on the population size, the extent to which the population is declining, and the area it occupies on the planet. This approach works well on a global scale, but it does introduce some problems when adopted at a local scale. Nevertheless, the IUCN approach has provided us with a very robust way of prioritising species.

Diagnosing conservation problems

Once the most important problems have been prioritised, it is usually helpful to know what the cause of the problem is in order to think up remedial solutions. In some cases, the reason may be quite obvious; for example, if a species is declining, it may be because it is a specialist of a particular habitat type that has been destroyed. Invariably, however, the reason is not clear, or at least not clear enough to give pointers to potential solutions. Discovering the causes of population decline is the 'diagnostic' phase of species conservation (fig. 1). An approach typically used at this stage is the 'comparative approach', where populations of a species are compared across sites, or across years, and

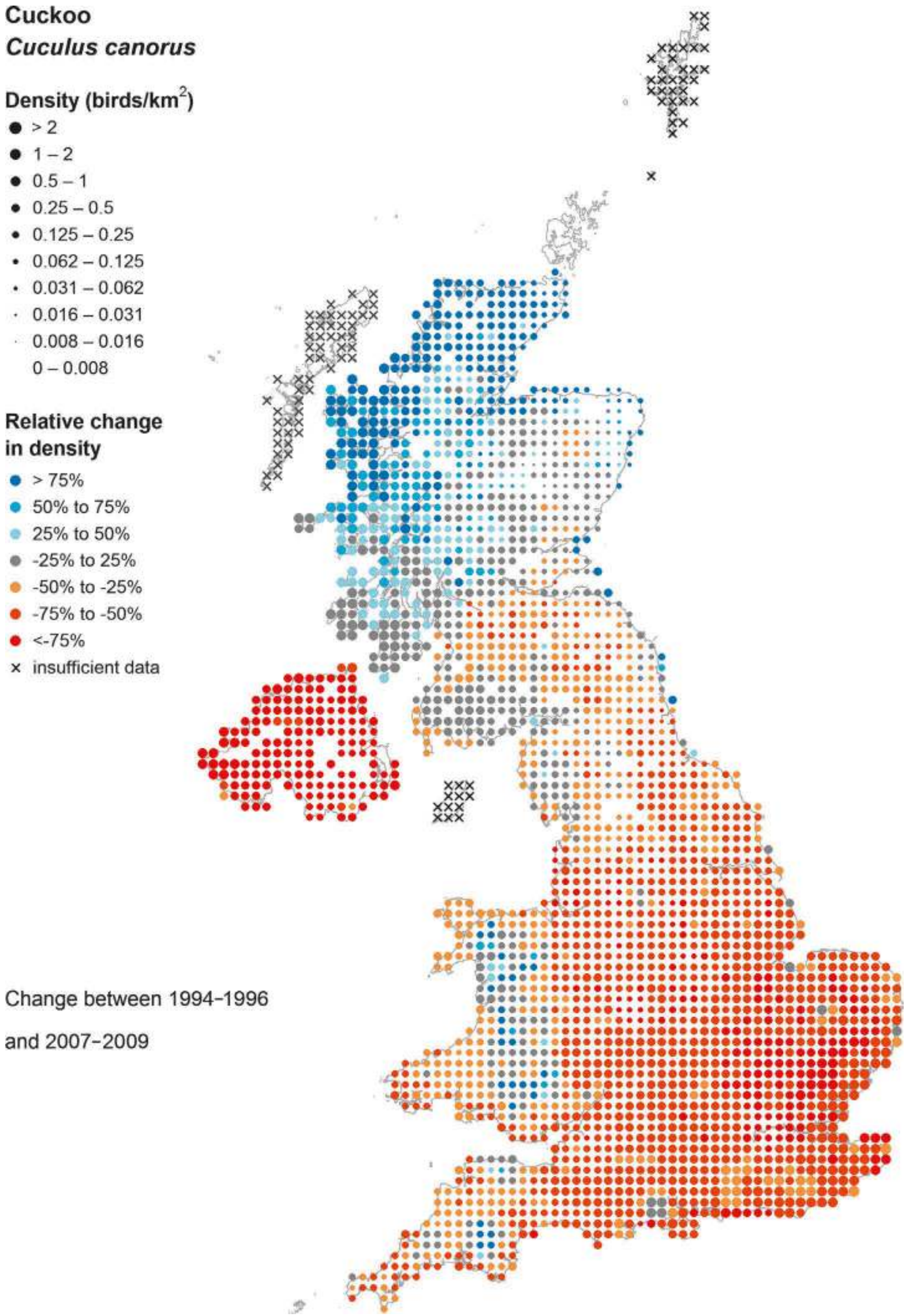

Fig. 3. Density (birds/km^2) and relative change in density between 1994–1996 and 2007–2009 of the Cuckoo (*Cuculus canorus*) in the UK. – Map derived from the BTO/RSPB/JNCC Breeding Bird Survey and reproduced from http://www.bto.org/volunteer-surveys/bbs/latest-results/maps-population-density-and-trends [28.08.2015] with permission from the British Trust for Ornithology.

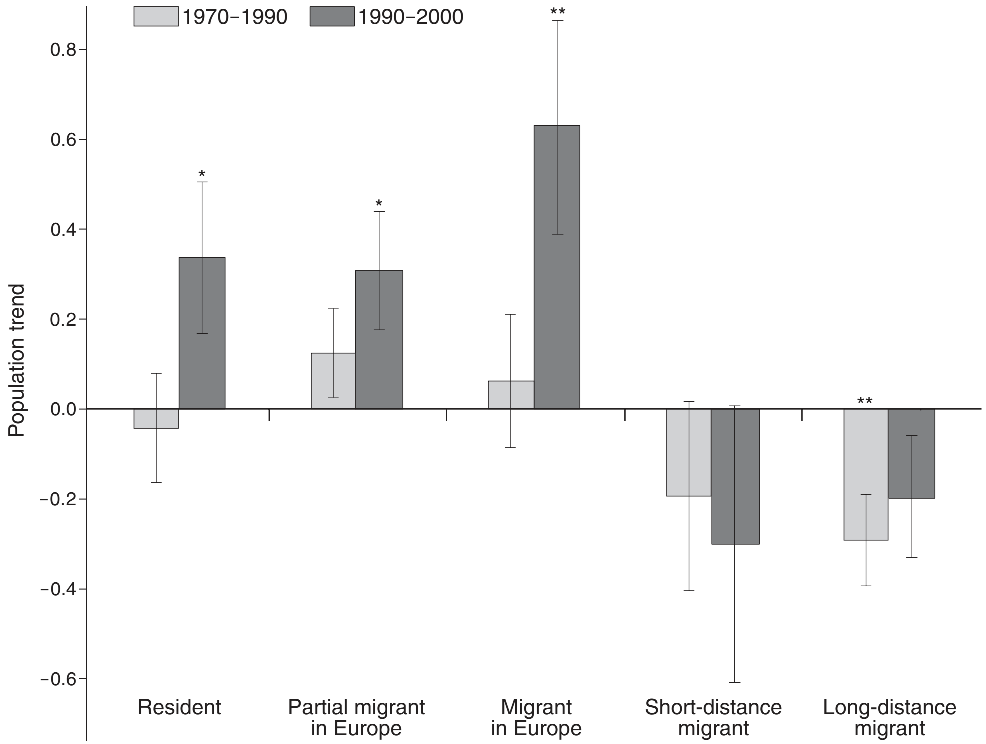

Fig. 4. Mean population trends 1970–1990 and 1990–2000 (± 1 SE) of all European bird species by migratory status. Trends significantly different from 0: *$p < 0.05$, **$p < 0.01$. – Data according to Sanderson et al. (2006).

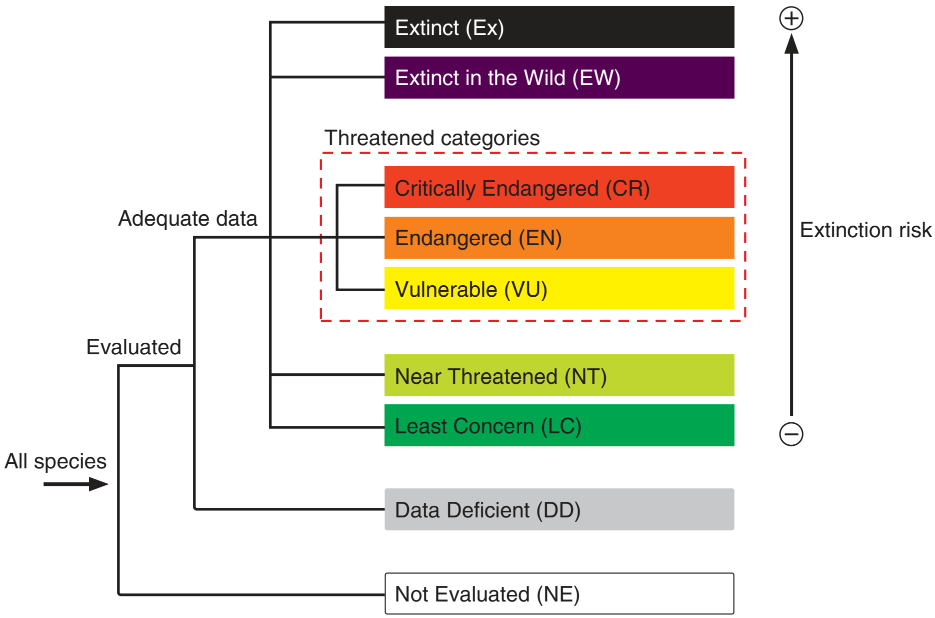

Fig. 5. Categories according to the IUCN red list of threatened species. – IUCN (2012).

Fig. 6. Black-legged kittiwake (*Rissa tridactyla*). – Photo: Andreas Trepte, www.photo-natur.de.

differences between sites or years compared to potential environmental drivers.

The black-legged kittiwake (*Rissa tridactyla*, fig. 6) is a common seabird species which is in decline in the UK. A long-term study on the Isle of May, in Scotland, measured year-on-year variation in kittiwake breeding success from 1986 to 2002 (Frederiksen et al. 2004). The authors showed that the breeding success of kittiwakes declined as the local sea surface temperature rose – which is projected to happen increasingly under climate change. However, there is something else as well. Lesser sandeels (*Ammodytes marinus*) are the favourite prey of kittiwakes. In years when the sandeel fishery was closed, and thus humans were not competing with kittiwakes for sandeels, kittiwake breeding success was higher for any given sea surface temperature than it was in years when the sandeel fishery was open. It is quite likely that the sea surface temperature is actually working through the kittiwakes prey: as the sea warms, sandeels – which are cold-water species – move away, and consequently the kittiwake breeding success fails. But in principle, you could mitigate the impacts of climate change by closing the sandeel fishery.

The second example is an across-sites comparison for the Eurasian curlew (*Numenius arquata*, fig. 7), a ground-nesting wading bird. The UK has an unusually important responsibility for the curlew, as it holds a high proportion of this globally near-threatened species (Douglas et al. 2014). Each of the dots in figure 8 represents a site in N England or S Scotland on which breeding curlew occurred. At each of these sites, surveys were undertaken recently and a decade earlier, allowing the change in curlew population to be determined. Two things are clear from this graph. Firstly, the curlew is still in decline, as the population trend on most sites (on the vertical axis) is less than zero. Secondly, the best predictor of change in curlew population size at a site was the extent of woodland around it; populations have declined more where woodland is more extensive. This gives a very clear pointer to the potential cause of the curlew's decline. We are not certain, but it may be that woodland acts as a refuge for predators, such as foxes or crows, which take curlew eggs and chicks.

Both of these examples, whether across years or sites, have yielded valuable clues to the potential drivers of species declines.

Fig. 7. Eurasian curlew (*Numenius arquata*). – Photo: Andreas Trepte, www.photo-natur.de.

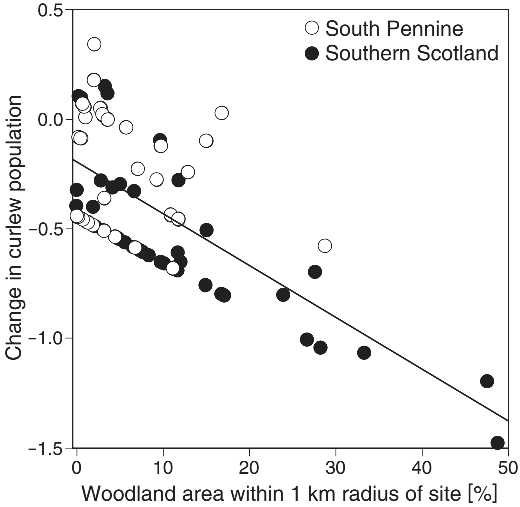

Fig. 8. An across-sites comparison: log ratio of curlew (*Numenius arquata*) population change at different sites within 10 years (zero: no population change between the surveys) and percentage of woodland area within 1 km radius of the sites. – RSPB, David Douglas; Douglas et al. (2014).

Finding solutions to conservation problems

Once we understand the cause(s) of a species decline from the diagnostic research, we are in a better position to be able to propose some potential solutions to recover its population. A common approach at this stage is to test such solutions with small-scale experiments.

The corn bunting (*Emberiza calandra*, fig. 9), a small brown bird, frequently nests in the north of its British range in fields cut for grass silage. During several years of diagnostic research, we showed quite clearly that the reason why this bird was struggling was that its nests were destroyed during harvesting operations. These observations suggested some potential solutions; either to delay harvesting or to leave the

Fig. 9. Corn bunting (*Emberiza calandra*). – Photo: Tim Peukert, www.foto-peukert.de.

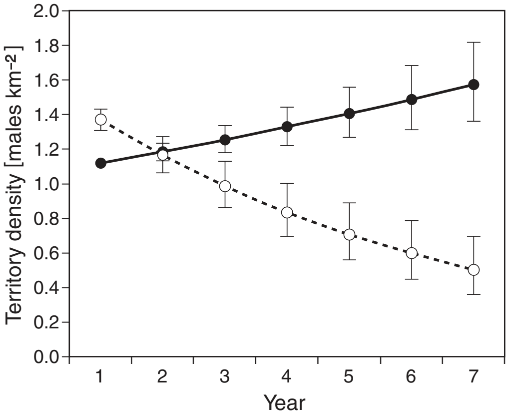

Fig. 10. Population trends (territory density, males/km[2]) of corn bunting (*Emberiza calandra*) on control farms (-○-) and on farms with targeted agri-environment schemes (-●-). – RSPB, Allan J. Perkins; Perkins et al. (2011).

crop un-harvested, to allow corn buntings to fledge their chicks. Subsequently, we initiated an experiment to test these potential solutions (Perkins et al. 2011). On a number of farms, we did not intervene; on these sites, the population continued to decline at about 14 % per year (fig. 10, control farms). On other farms, farmers were paid via agri-environment schemes to delay harvesting or sacrifice their crop entirely, and on these farms the corn bunting's population rose about 6 % per year (fig. 10). Such experimental testing provided an example of a workable solution which, when implemented across a species range, could recover its population over a much larger geographical (e.g. national) scale.

Effective communication to practitioners and advocates

The next step, once you have discovered a solution, is to communicate it to practitioners. I am going to use a rugby game as an analogy. Let us imagine one player, the scrum-half, is about to throw the ball to another, the fly-half. The scrum-half is a scientist, the fly-half is the practitioner, and the ball is the solution. Hopefully, these two players talk to another a lot, such that when the scrum-half throws the ball, the practitioner is expecting it, and so catches it and runs to score a successful try, i.e. uses the solution to recover the species.

Too often, though, the ball is thrown in the air, and the practitioner does not catch it or, if (s)he does, it has no impact. This could be for various reasons. For example, the scientist may not have seen the need for a practitioner in the first place, and simply hoped that someone might catch the solution when thrown; the practitioner may not have been made aware that a solution had been discovered, nor that it was about to be thrown; alternatively, the practitioner may have no interest in the ball, or no resource to implement the solution. In my opinion, it is very important for the practitioner and the scientist to talk together from the very beginning of a project, instead of talking only at the end of the process. In the current language of the science-policy interface, for successful conservation science, the scientist needs to know and work with their 'end-user' or 'customer'. And the 'end-user' has to need the solution.

Solving conservation problems

Once a practitioner is provided with a solution, hopefully they will have been thinking of a mechanism to implement it. For example, this could be lobbying governments to bring about policy or regulatory change, managing land, persuading other people how to manage their land or change their behaviours, or intervening directly in other ways – there are a range of mechanisms available to solve conservation problems. If you look at figure 1, you might think that conservation science is almost all of conservation. In reality, implementing the solution is probably about 90 percent of conservation, and science makes up the rest.

Sometimes, even when we have tested the solution on a small scale in an experiment, we find when we introduce it on a large scale it does not work as well as we expected. Therefore, we have to refine the solution, a process known as adaptive management.

The temptation to short-cut

Among conservation practitioners, there is a huge temptation to short-cut, particularly to skip the 'diagnostic' stage. The reason for this is two-fold; it is expensive and it is time-consuming. Countless times conservation practitioners have said to me that a problem is too urgent to wait for the science. So, after prioritising a problem they skip the diagnostic research and go straight to trying to find a solution. In addition, sometimes practitioners jump directly from the prioritisation to implementing a solution and cut out all the science in-between (fig. 1). This short-cutting may sometimes be justifiable when there is already sufficient general background knowledge available, for example on a species' ecology, but it can come at the risk of picking an unworkable solution. If short-cuts are undertaken, for urgency or financial reasons, then I strongly recommend that at least the effectiveness of any intervention made is monitored – so often, even this does not happen.

I am going to tell a small cautionary tale about short-cutting the diagnostic research stage. The large blue (*Maculinea arion*, fig. 11) is a butterfly which declined rapidly in the UK during the first half of the 20th century, becoming extinct at the end of the 1970s. During this period of decline, the perceived wisdom was that one of the main causes of decline was that their eggs were being collected from the wild. Therefore, during this period fences were erected around all the remaining UK colonies to deter egg collectors. In the 1970s, the scientist Jeremy Thomas started to work on the large blue, and unravelled the remarkable life cycle of this species (Thomas et al. 2009). Adults lay their eggs on the host plant, thyme, on which their larvae grow and from which they move into the nests of a particular species of ant, *Myrmica sabuleti*, parasitising the ant and eating its brood. *M. sabuleti* is a species with a very narrow temperature tolerance, and if the sward above the ant colony grows too long, the temperature of the soil becomes too low for *M. sabuleti* to thrive. Thomas et al. (2009) showed clearly that the probability of *M. sabuleti* occurring in thyme grasslands was highest when the sward was only one or two centimetres high. Consequently, thyme grassland sites are now grazed by livestock, to ensure the sward remains at the optimum height for the ants, and large blues are once again flourishing on these sites. Now cast your mind back to the interventions that were made during the period of decline. Sites with large blues were fenced in an attempt to stop egg collecting. In practice, all this did was to stop grazing animals from gaining access, so the grass grew and the ants and large blues consequently disappeared. So, in this case an intervention that was not supported by any science (fencing) actually helped to drive a

Fig. 11. The large blue (*Maculinea arion*). – Photo: PJC&Co, wikipedia, CC BY-SA 3.0.

species to extinction in the UK, and it was only following creative diagnostic research and solution testing that the species has successfully recovered.

Solving conservation problems successfully: vultures in India

One of the best examples of science driven conservation recovery is of the Oriental white-backed vulture (*Gyps bengalensis*, fig. 12) in India.

Fig. 12. Oriental white-backed vulture (*Gyps bengalensis*). – Photo: Goran Ekstrom, in Gross (2006).

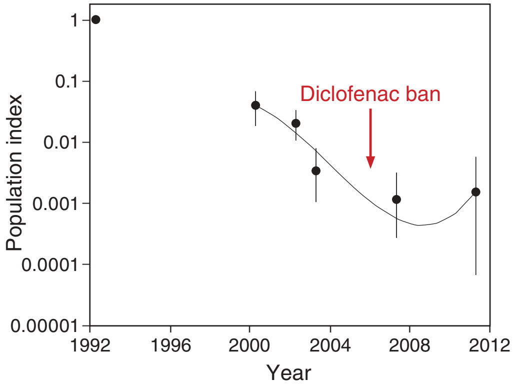

Fig. 13. Population indices (relative to that in 1992) and trend (log-linear Poisson regression) of *Gyps bengalensis* according to surveys in India from 1992 to 2012. – Prakash et al. (2012).

Identifying the problem: The Oriental white-backed vulture was formerly one of the most widespread raptors in the world. By 2007, however, the population in the whole of India had declined to 1/1000th of its numbers in the early 1990s – an enormous decline (fig. 13, Prakash et al. 2012).

Prioritising the problem: Because of this dramatic decline, the Oriental white-backed vulture and two co-generic species, the long-billed vulture (*Gyps indicus*) and the slender-billed vulture (*Gyps tenuirostris*), became listed by IUCN as critically endangered. Consequently, conservation resources were made available to determine the cause of the decline.

Diagnosing the problem took several years. We spent some time investigating blind alleys, in particular thinking that the cause might be an infectious disease. Eventually, it was a vet working for the Peregrine Fund who diagnosed the problem (Oaks et al. 2004). Oaks went to Pakistan and asked livestock owners whether they had changed any of their practices since the early 1990s. They informed him that they were now using a non-steroidal anti-inflammatory drug, diclofenac, which had recently come off patent, to treat their cattle with joint problems. Oaks subsequently collected vulture carcasses to determine the causes of death. He noticed that in many cases this was due to visceral gout, a build-up of uric acid crystals in the kidney, and discovered that in every case where visceral gout was present, diclofenac was also found in the bird's tissues. Over the next few years, further research showed clearly that the dramatic decline of vultures was entirely due to them being killed by feeding on the carcasses of livestock that had been treated with diclofenac.

Finding the solution: To find a solution, we became a drug-testing company, eventually finding an alternative drug, meloxicam, which was as effective as diclofenac for cattle, but was entirely safe to vultures (Swan et al. 2006).

Effective communication to practitioners and advocates: Subsequent to the discovery of meloxicam as a suitable alternative, scientists and conservation advocates met with Indian government officials to draw up an action plan for the recovery of vultures. One of the key recommendations of the plan was the banning of veterinary diclofenac, and its replacement with meloxicam. The strength of the science and the simplicity of the solution helped convince officials that this was an appropriate action.

Implementation of the solution: In 2006, the Indian government, followed by those of Pakistan and Nepal, eventually banned the veterinary use of diclofenac, recommending meloxicam as a suitable alternative. This was a major achievement; getting previously approved drugs banned is very challenging.

Refine solutions – adaptive management: sometimes what works in the lab, might need refining in the field. While meloxicam was a great solution to the vulture crisis, there were some problems with this drug, too. Some livestock owners would not use it, because whenever they injected their cattle with it, the cattle reacted badly. Meloxicam does not dissolve easily, and some companies overcome this by dissolving the drug in a caustic solution that causes the pain reaction in cattle. Therefore, we refined our drug testing and investigated the pain reactions of goats when being injected with different formulations of meloxicam (Cuthbert et al. 2014). We found one, Metacam®, that caused the least pain, and are now promoting this particular variant of meloxicam as an alternative to diclofenac.

Monitor effectiveness of intervention: The population of Oriental white-backed vulture (*Gyps bengalensis*) declined to its lowest level in 2007 with only 0.1 % of the numbers of 1992. However, more recent surveys indicate that the decline began to slow a year or two after the banning of diclofenac, and since then vulture populations have shown the first signs of a recovery (fig. 13, Prakash et al. 2012), although there is still a long way to go.

Conclusions

I hope that what you have taken from this talk is that science has a very important role to play in nature conservation. It ensures that conservation resources are focussed on the most important problems, and that conservation interventions are more likely to be successful. Science also brings credibility when advocating a view to decision makers, making them more likely to act in favour of nature conservation.

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Discussion

A. Bresinsky: The large blue (*Maculinea arion*) has been discussed in the context of protective measures by using the ant species *Myrmica sabuleti* as a form of biological control. By favouring one species against the other one in the ecosystem, one has to consider unexpected negative results. In general, promotion of only one species may influence other species and thus may result in new problems.

D. Gibbons: It is very clear that if you work to conserve one species, you may have effects on other species, which may be positive or negative. In fact, in that particular example, boosting populations of the ant also helped populations of the butterfly. Therefore, they weren't in conflict. However, there could be examples where these things are in conflict. People often say, "Isn't working on a single species a waste of resources? Shouldn't we be working on habitats or ecosystems to influence more than one species?" I think I do agree with that, but so much can be learned from single-species studies that tell you about wider conservation problems. The vulture example I told you about was focused on one species, the Oriental white-backed vulture (*Gyps bengalensis*) in India. But actually it is becoming increasingly apparent that diclofenac may be affecting a whole range of species including not only other vultures, but also some other scavengers. So working on that one species has told us about a much broader environmental issue. In the UK, there are certainly cases in which one threatened species poses a threat to another threatened species. For example, in the forests of North Scotland we have a large grouse species, the capercaillie (*Tetrao urogallus*), Europe's biggest grouse, but we also have a growing population of pine marten (*Martes martes*), a small mustelid that eats grouse eggs and chicks. Both are species of conservation concern, and we are trying to think of ways of reducing the impact of pine martens on capercaillie, but without harming the population of pine martens.

J. Kollmann: You have shown convincingly how the ball could be moved from the scientist to the practitioner – but I would also like to see the ball coming back from the practitioner to the scientist.

D. Gibbons: My perception about this is that science will be translated best into policy and practice, if it is devised by the practitioner and scientist together. In fact, the ideas for some of the best applied science come from practitioners, not scientists. I wouldn't like to give the impression that practitioners are simply waiting for the ball to be thrown. The practitioner and the scientist should talk early in any project about what they can do to make sure that the ball is thrown at the right time and in the right way. So it is very much a two way thing. It is not simply the practitioner receiving the ball.

N. Schäffer: You did show the need for research very well and I witnessed this in Great Britain over many years. Can you imagine situations, where you as a scientist would say "Hold on, we do not need any more research. We know the answer to this particular problem, so let us get on with it"? Is there a risk that research will delay conservation actions? Where very expensive conservation actions are concerned, lack of knowledge may sometimes give an excuse to people who do not want to fund these conservation actions.

D. Gibbons: Do we go slightly over the top? Do we actually need as much science as we undertake? To be honest, the perception about this varies depending on whether you are a scientist or a practitioner. To my mind, we need to do just enough science to ensure we can solve the problem. We could do a lot more clever science with the data we collect, but tend not to do this, as its influence on conservation may be limited. Some people talk about the Goldilocks hypothesis. This is based on a fairy tale, in which Goldilocks was faced with three bowls of porridge; one was too hot, another was too cold, and the third was about right. What we want to do for science investment is to get it 'about right'. Your and my view of 'about right' may differ a little, but perhaps not as much as you might think. Certainly, we only need enough science to give the correct answer to a particular problem.

W. Weisser: The scheme you showed about solving conservation problems looks very nice. I guess at the RSPB you are in a privileged position, because the conservation scientist just has to go next door to meet the practitioner. In Germany, they sit in different buildings and often they even belong to different institutions, with often little communication. What would be your advice to bring scientists and practitioners together?

D. Gibbons: You said we (RSPB) are lucky, that we have scientists and practitioners in the same building. That isn't luck and that didn't come about purely by chance. That came about intentionally. We wanted to ensure that we were a conservation organisation that did the science at one end, feeding up to the conservation practitioner at the other, and that the links in the chain between scientists and conservation practitioners were as short as possible.

How can you really change things in Germany? I think it is good to improve communication and a meeting like today is a step in the right direction. Another approach is to co-locate scientists and practitioners. This is exactly what we are doing in the UK as part of the Cambridge Conservation Initiative. We are building a new conservation campus, which opens in late 2015, and into which will move more than 100 scientists from the University of Cambridge, and nearly 400 practitioners from nine different conservation organisations. While there will be no governmental staff in the campus, there will nevertheless be a much greater degree of collaboration between scientists and conservation practitioners. Maybe that would be a solution for you also.

T. Gschlößl: Many populations all over the world are declining because of climate change, but not all of them. Do you have any idea how to judge whether a decline happens because of climate change or because of other influences like nitrogen or something else? Is long-term monitoring the only solution to solve this problem?

D. Gibbons: Long-term-monitoring certainly helps, as I showed in the example of the kittiwake (*Rissa tridactyla*), where a long-term monitoring study showed quite clearly the influence of climate change as well as the influence of local fishery. Otherwise you are quite right; climate change is affecting many species. I showed an example from the National Audubon Society, which predicts the future changes in geographical ranges of several bird species in North America. We have done a very similar thing in Europe.[1] We produced an atlas of maps showing where the geographical distributions of all of Europe's bird species will be by the end of the century. So we can see which species we project will likely change most and which will likely change least. What we have done subsequently is to compare these projections with the changes in population size that have actually occurred over the last 30 or so years, and a lot of the projections are coming true. So some of the species which we think will increase have done so, similarly some of those that we have projected will decline have done so, but not all have followed their projections. So we can begin to get a feeling for which species are probably being affected by climate change and which are not. A number of research groups are now undertaking species climate change risk assessments. Using information on, for example species traits and ecological knowledge, they try to predict those species that are most likely to be affected by climate change. Investigating some of these assessments would be a good place to start to allow you to judge which species are most likely influenced by climate change.

Another way we have done this (and are doing so at the moment) for a wide range of taxonomic groups in the UK is by using expert opinion. What is intriguing here is that climate change can be a positive driver for many invertebrate species in the UK. Actually, quite a number of invertebrates are moving into the UK and others are expanding their distribution northwards in the UK. So, climate change is not always a negative driver.

Thus, the combination of predictive models, species risk assessments and expert opinion can tell us a lot about the species most likely to be affected by climate change.

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1 Huntley, B., R. E. Green, Y. C. Collingham & S. G. Willis. 2007. A climatic Atlas of European Breeding Birds. – Durham University, The RSPB and Lynx Editions, Barcelona, 521 pp.