6

Why We *Really* Don't Care about the Evidence in Evidence-Based Decision Making in Conservation (and How to Change This)

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IF WE VALUE NATURE, we should value scientific evidence to help manage and preserve it. These days, evidence-based decision making is touted as the way to improve everything from health care (Cochrane 1972), to environmental education (Keene and Blumstein 2010; Saylan and Blumstein 2011), to international developmental aid (Duflo and Kremer 2005), as well as an important way to improve conservation outcomes (Pullin and Knight 2001, 2009; Schreiber et al. 2004). In the field of conservation biology, managers talk about adaptive management, a process that ultimately uses evidence to improve management outcomes. Yet when one digs down beneath the surface, properly designed experiments that are explicitly part of adaptive management are rare, managers are reluctant to embrace the method, and many people hold that good decisions emerge from a process that has little to do with evidence. In this chapter I will explore the question of whether and when scientific evidence is important, and, when it may not be, how we can generate better conservation and management outcomes.

Why Scientific Evidence Should Be Valued

Many pundits now declare the end of science. For instance, in a *Wall Street Journal* Op-Ed, Daniel Henninger (2009) concluded that science had become postmodernist and therefore creates biased and relativistic results that should not have any special standing. From my perspective, nothing could be further from the truth.

The essence of the scientific method is to pose a testable hypothesis, collect data, and evaluate the results. Often these hypotheses are phrased in terms of a formal null hypothesis. For instance, does drug *x* have no influence on blood pressure. If we find that patients taking drug *x* have a 50 percent reduction in their blood pressure compared to those taking controls who had no change in blood pressure, we would infer that drug x reduces blood pressure. If we don't find an effect of drug *x* on blood pressure we are in a bit of a quandary: the drug could work but must be given at a different dosage, it may not work, or something else might be responsible for the lack of change. We learn more by refuting our null hypotheses than we learn by not refuting them.

By asking a series of questions using this "hypothetico-deductive method" (e.g., Popper 1958) we can quickly discover what drugs may reduce blood pressure and which don't. We can discover drugs to treat cancer. We can develop stem cell therapeutic technology. If we're so inclined, we can design better weapons and renewable sources of energy. We can learn about factors that may generate or maintain biodiversity in the oceans, in the forests, and in hospital operating rooms.

Posed this way, the scientific method is a brilliant way to efficiently generate knowledge and evaluate hypotheses. Science is a way of knowing (Moore 1999). Science does not tell us what questions should be asked (Should we develop weapons? Should we develop wave generated power?), but once asked, science is a process to separate the valid from the invalid. Part of the process that allows us to trust the outcome is that scientific findings are published in peer-reviewed journals.

Peer review is a process by which results are subjected to (usually) anonymous review by skeptical experts. Many scientists are brutally competitive and will look for the slightest reason to find fault with a submitted manuscript they are reviewing. Why? Ideally because they feel that only the best results deserve publication. And when peer review works, the reviewers take their own (almost always unpaid) time and make constructive comments that serve to improve the resulting paper. Sometimes scientists unethically reject competitors' papers for no other reason than that they are competitors, but these all-too-human outbreaks are rare in a process that generally works remarkably well.

Once published, a paper is a target and its findings are subjected to continued scrutiny by scientists who seek to refute it on empirical or theoretical grounds. Why? Ideally, and frequently, because scientists seek to better explain the world around us. However, scientists are people and careers are made not only on building new ideas but also by refuting high profile ideas. Imagine how famous an evolutionary biologist would be who suddenly discovered a major fault with evolutionary theory. However, to do so, experts must evaluate the challenger's hypothesis and findings. If the peers' evaluation is positive, we've made substantial scientific progress. The fact that evolutionary theory has withstood the test of time and been constructively modified over time is a testament to its validity.

Peers are those who have sufficient background knowledge in a field to properly evaluate a paper. Peers are those who have published and developed their reputation in that field by their work and their results. Just because someone may not "believe" in evolution (not that anyone should believe in evolution because it should be a testable hypothesis), doesn't mean that they are not a valid peer. Just because someone has a PhD doesn't mean they are necessarily able to evaluate a particular finding if it's outside their field. Of course, we must rigorously guard against "group-think" and processes that completely shut out alternative opinions, but experts in a field really are those who are best qualified to evaluate a new finding before publication.

For these reasons, I believe that scientific evidence should hold a special place in conservation and management. How then is scientific evidence used to make decisions?

Adaptive Management and Decision Making

Adaptive management is a very important process by which scientific evidence is used to enhance conservation outcomes (Walters and Holling 1990). Adaptive management uses controlled experiments or uncontrolled comparisons to quantify the effects of management interventions on management outcomes (Salafsky and Margoluis 2003).

In active adaptive management, managers design formal experiments that employ a BACI—before-after, control-impact—design (Walters and Holling 1990; Underwood 1992). In a BACI design, the difference before and after a treatment is compared across a control and some impact or management intervention. Formally, this design allows managers to isolate the effect of a particular impact or management intervention because there is a control. Controls are situations in which nothing is done and thus a control makes it possible to account for annual or other factors that might simultaneously be influencing an outcome.

An example will help illustrate active adaptive management. Assume you're trying to increase the success of a captive-rearing and reintroduction program. You have identified a problem—animals are killed by predators soon after release. You hypothesize that by training them to be more aware of predators before release they will survive better upon release. You divide up your animals to be released into two groups; one group gets trained, the other gets the added handling experience without formal training. You have data from the year before where there was 0 percent survival of introduced animals. You then release these animals and compare the survival of the trained versus untrained animals. Because you had 0 survival the year before, the analysis is simply whether the trained animals survived more than the untrained ones. If so, you can conclude that training was effective. However, what if the survival of both groups increased? In this case you might conclude that there are annual effects (maybe there was no predator around that year), or that the increased handling you did for your control group enhanced survival. If the training does not specifically enhance survival, you may decide it's too costly to do. This scenario illustrates how and why it is important to have a control group; it allows managers to isolate the effect of a management intervention and see if it specifically is responsible for enhanced survival.

Selecting controls in adaptive management scenarios is essential but creates some novel issues. What, for example, is one to do if by having a control, one knows that a population may lose a substantial number of individuals from an endangered species? Indeed, many managers find using controls in these situations ethically challenging and contrary to the goals of management, which may be desperately trying to increase the abundance of a threatened or endangered species (Johnson 1999). In the above example, having a control group in which you didn't train animals might be sentencing them to death—because all prior experience pointed to 0 percent survival for untrained animals. In such circumstances managers often find it ethically and indeed practically difficult to justify having a control.

In passive adaptive management, managers compare the outcomes of uncontrolled experiments to either previous outcomes or they may employ "natural controls." Because controls are not formally designed into the comparisons, it's not possible to isolate the effect of the treatment on the outcome. Thus without a control one wouldn't know whether it was the training, or annual variation, or simply the handling that enhanced survival. Nevertheless, and in spite of these shortcomings, it is perhaps better to be making these sorts of comparisons than not making comparisons and relying simply on intuition to make management decisions. Can we do better?

Darwinian Decision Making

In some cases it is ethically or politically difficult to run proper controls. For instance, if managers know that current captive breeding practices result in 50 percent mortality, and that 50 percent mortality is unsustainable, then it is essential to increase survival. Rather than having a control (which one knows will continue to have 50 percent mortality), perhaps it is better to directly compare two (or more) alternative treatments. In the medical literature this is known as comparative effectiveness evaluation.

The shortcoming of this is that without a proper control, there may be a nagging uncertainty about whether something else changed during the experiment. However, a comparative effectiveness approach may be defensible if there are welfare costs to a business as usual control that one already knows doesn't work. In other words, if one knows a lot of animals are going to suffer or die, it may be preferable to compare two different possible solutions rather than having a control.

A comparative effectiveness study is best conducted as a BACI design, except here we are comparing the after minus before to the two alternative treatments. I have previously suggested that to come up with the best alternative treatments, experts should be consulted (Blumstein 2007). This will to some extent mimic a Darwinian process whereby a variety of alternative treatments are generated, and the best will be rapidly identified. By this means, Darwinian decision making can be an important tool in adaptive management.

Does the Best Evidence Lead to the Best Management Outcomes?

Conservation and management are political. To be convinced, simply ask why the Yellowstone wolves were considered fully recovered and thus de-listed from the Endangered Species Act when by hunting and killing wolves straying from the safety of protected areas the population would immediately decline to levels that might not be considered sustainable (Bergstrom et al. 2009). Or ask why some species are listed while others are not (Harllee et al. 2009).

Decisions made in the political sphere are not necessarily based on the best available scientific evidence. Should they be? In a compelling book, *The Paradox of Scientific Authority: The Role of Scientific Advice in Democracies*, Bijker, Bal, and Hendriks (2009) argue that scientific evidence is best evaluated by a committee, working out of the spotlight, and charged with providing the best interpretation of the scientific results as possible to political decision makers. Such high-level committees are exemplified by the US National Academy of Sciences, which creates committees tasked with providing information to Congress. Bijker, Bal, and Hendriks focused on the Health Council of the Netherlands, a committee tasked with providing the best possible scientific evaluation for politicians with respect to health and medical issues. By working out of the spotlight and behind closed doors, these committees are free to evaluate evidence with little oversight. If the committee is well chosen and diverse, then the recommendations to the policy makers should be well thought out and useful. Employing such "expert" decision makers to evaluate evidence and develop reports that enable decision makers, however, is not the normal way that decisions are made.

Often, scientific evidence is mixed with politics without going through a committee's "filter." Or the results from the scientific experts are discounted. This is because good political outcomes are often viewed as those that go through a process that involves stakeholders (Burgman 2005). Stakeholders are those that self-identify with an issue. In a representative democracy, we want to involve people who care about issues and we want their views to be understood, and, if popular, represented. Thus many management decisions involve getting stakeholders involved in a process that generates a consensus. From a managers' view, this may be the sort of outcome that is most desirable.

Deciding whether to list or de-list a species is a political decision. Deciding to kill "problem" animals is a political decision (animals aren't problems—we perceive them as problems!—Goodall and Bekoff 2002). Deciding how to allocate funds among competing conservation needs is a political decision (funds going to wolf conservation are not going to sage grouse conservation). So what then is the role of scientific evidence in decision making?

How Should Evidence Be Used in Decision Making?

I suggest that there are many management decisions that require evidence to enhance effective conservation. The Centre for Evidence-Based Conservation (http://www.cebc.bangor.ac.uk/index) was founded in 2003 and is dedicated to using systematic reviews to enhance conservation efficacy. The Centre has sponsored a variety of reviews that include a variety of topics (all reviews are posted at http://www.environmentalevidence.org/Reviews.htm): Are mammal and bird populations declining in the proximity of roads and other infrastructure? Does MHC diversity decrease viability of vertebrate populations? What are the impacts of human recreational activity on the distribution, nest occupancy, and reproductive success of breeding raptors? Are marine protected areas effective tools for sustainable fisheries management? These topics are varied and provide managers with the best-available evidence to enable thoughtful decisions, even if decisions are made in the political sphere.

While I believe that evidence should be an important part of decision making, sustainable decisions *must* involve stakeholders (Schreiber et al. 2004). That said, stakeholders *must* be charged with using the available evidence to make the best decisions. In other words, creating decision-making processes that explicitly respect the process of using data, value experimental data more than correlative data, and seek to build in data collection as part of ongoing adaptive management. Evidence, viewed this way, is an essential part of the process of making a decision. Evaluation, viewed this way, is built into both ongoing monitoring and the decision-making process.

How Should Lack of Evidence Be Handled?

In many cases lack of sufficient evidence is often used as an excuse for inaction. If the consequences of inaction are small, there may be sufficient time to collect more data. However, if the consequences of inaction are great, it is probably best to adopt the "precautionary principal" that essentially states it's better to be safe than sorry and the onus is on those who want action to demonstrate that action will not be harmful (http://www.sehn.org/wing.html). It is important to realize that many opponents to action will harp on the uncertainties involved in the decision-making process and argue about the costs of action. For instance, opponents to limiting fossil fuel use or to developing "clean" energy often point to the costs associated with changing our fuel consumption habits. In cases like this, it is only sensible to articulate the costs of inaction. If the costs of inaction are greater than the costs of action, a rational decision is to proceed cautiously. For instance, I would suggest that the ecological and environmental consequences of melting the polar ice caps and releasing methane—a potent greenhouse gas—from the thawed permafrost are extreme and probably exceed the costs to increasing conservation and developing alternative fuel sources. Regardless, data should continue to be collected and analyzed and decisions modified based on current data.

Island Fox Conservation: Two Examples of Wise Management

The island fox (*Urocyon littoralis*) is a diminutive North American canid and is endemic to Southern California's Channel Islands. Island species are especially vulnerable to stochastic events, and different islands, each with its endemic subspecies, were threatened by some different problems. Two successful, scientifically based recovery programs illustrate features that should be (and often are) modeled in other recoveries. Coonan, Schwemm, and Garcelon (2010) describe much of this.

Santa Catalina Island, the largest of the southern Channel Islands, had a bout of canine distemper that caused a dramatic decline in population size (at one point there were fewer than one hundred foxes). Scientific management that included vaccination of surviving foxes, considerable work led by stakeholders (especially the Santa Catalina Island Company), as well as captive breeding followed with reintroduction to recover the population, ultimately led to the successful recovery of this island's population. This was facilitated by having relatively few stakeholders involved (most of the island is owned and managed by the Santa Catalina Island Company), a small population of residents, the ability to control visitor behavior, and a the presence of a strong "scientific culture" for management.

Meanwhile, the Northern Channel Island populations declined precipitously because golden eagles (*Aquila chrysaetos*) self-introduced themselves to the islands. Fortuitously, the foxes on some of the islands were being studied by graduate students and monitored by government researchers, and this decline was tracked with precision.

The best available evidence suggested that an ecological phenomenon called "hyperpredation" was responsible for their decline. Bald eagles were naturally on the islands but high levels of PCBs in the fish they ate took a toll on reproduction; it was hypothesized that the vacancy left by bald eagles permitted golden eagles to self-introduce themselves. Golden eagles were primarily supported by a large feral pig population on the islands, and foxes were inadvertent victims of a growing eagle population. Foxes were brought into captivity both for their safety and to begin a captive breeding program. Managers had been working for years to remove the pigs from the islands and stepped up their efforts on this. Many eagles were live-trapped and relocated to north-central California. A captive breeding program for bald eagles (*Haliaeetus leucocephalus*) was expanded with the ultimate goal being to replace the golden eagles with bald eagles.

Eventually, in 2004, the US Fish and Wildlife Service formally listed the foxes on the Northern Channel Islands as critically endangered. This brought the US Fish and Wildlife Service into the mix of stakeholders. From a low high of several thousand easy-to-see foxes active on the islands, to a low of about seventy animals scattered across all the Northern Channel Islands, the mix of management was successful and the population grew with the removal of pigs and golden eagles. By mid-2010, there were more than 1,700 foxes populating the northern islands and the species was headed for de-listing.

Throughout, various stakeholders that included the National Park Service, the Nature Conservancy, the US military, University of California researchers and land managers, as well as zoos, and public interest groups, were actively involved in discussing and debating management options. Scientific consultants were brought in, and while the process led to no formal active adaptive management projects, scientific evidence was highly valued by all stakeholders and used throughout the process.

Other Examples of Wise and Potentially Wise Management

Nichols and Williams (2006) review the case of adaptive harvest management of mallard ducks (*Anas platyrhynchos*) in North America. Scientific-based management of duck hunting involves stakeholders, and active monitoring is an explicit part of the process. Based on annual population estimates and population trajectory, along with a survey of juvenile survival, various population models are parameterized annually and recommendations are made for harvest size. The population remains stable despite extensive hunting.

Innovative adaptive management programs abound in New Zealand. One (Armstrong, Castro, and Griffiths 2007) has focused on the hihi (*Notiomystis cincta*), a critically endangered bird that was barely surviving on a single island. Managers wanted to expand the range and incorporated a series of population models and experimental reintroductions. Regular monitoring identified factors that could be used to increase survival (experimental provision of sugar water and experimental removal of mites) and those that influenced survival but could not be controlled (the presence of a fungal spore). Ultimately, animals were successfully introduced to several islands and removed from an island with high fungal spore levels.

Management of captive giant pandas (*Ailuropoda melanoleuca*) has always involved active participation of major stakeholders and experiments conducted in captivity (e.g., Swaisgood et al. 2001), yet field research lagged behind in scientific management. Future studies are being planned in an adaptive context that involves the Chinese government working with local communities in a way to employ manipulative experiments to inform the management of wild populations (Swaisgood et al. 2011). Time will reveal the degree and role of experimental active management in the field and whether it helps inform management and results in success.

Conclusions and Recommendations

Systematic reviews, whether conducted by an individual, a research group, or a private committee, are an excellent way to provide evidence to decision makers. Decision makers must include stakeholders who have a vested interest in the outcome; sustainable solutions involve stakeholder support. Stakeholders must be charged with using evidence to make decisions. The onus is on those who oppose the evidence to build compelling arguments about why the evidence should be ignored. It should be unacceptable to not act because of insufficient evidence if the consequence of inaction is potentially great. Because evidence is often lacking in many conservation problems, it is essential to build into the decision-making process the ability to collect new data and to reevaluate decisions based on these new data. Controlled experiments should be done unless there are good reasons not to. Viewed this way, adaptive management is a process that should be embraced because it provides ongoing evaluation of conservation outcomes and is designed to improve management outcomes.

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