Michael J. Conroy and James T. Peterson

# Decision Making in Natural Resource Management

## A Structured, Adaptive Approach

free companion website

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# Decision making in natural resource management: a structured, adaptive approach

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# Preface

This book is intended for use by natural resources managers and scientists, and students in the fields of natural resource management, ecology, and conservation biology, who are or will be confronted with complex and difficult decision-making problems. This audience will find that you will be called upon to assist with solving problems because you have a technical expertise in a certain area. Perhaps you are a specialist in fish nutrition and physiology, or statistical modeling, or in spatial analysis; or, you may specialize in the human-dimensions side of the equation, dealing with people's attitudes, values, and behavior. Often you will be asked to provide input on just one narrow aspect of a problem, and you might assume that your client (e.g., the natural resources agency that pays your contract) knows how to take your information, apply it in the context of solving a bigger problem, and that all will be well. You would often be mistaken.

In our experience, agencies, NGOs, and other organizations dealing with conservation problems often seek technical solutions to problem solving, when in fact their difficulties lie at a deeper level. What these organizations typically lack is an understanding of how the components of their decision-making problem relate to one another, and to the overarching goals and mission of the organization. That is, typically their approach to decision making lacks *structure*. Besides being an inefficient use of resources (something we have little to spare in these days of economic belt tightening), this sort of ad hoc approach to decision making can play into the criticism emanating from some camps that conservation and natural resource management are not based on rigorous, repeatable methods and thus, need not be taken as seriously as “real” sciences. In fact, natural resource management draws from numerous scientific fields (ecology, biology, physics, and geography to name a few), as well as the quantitative (statistics, mathematics, computer sciences) and social sciences (economics, policy, human dimensions). However, when we see actual decision-making processes in action, they can appear fragmented and poorly focused, often using the (sometimes copious) information that is available from the sciences in an informal way. Our hope is that the methods describe in this book will help biologists and managers better focus the rich sources of knowledge we have from these fields to solving pressing conservation problems.

# Acknowledgements

Many people have helped make this book possible, and we thank them. The authors thank their spouses, Liz and Rebecca, for putting up with us during this project. We thank our graduate students and colleagues at Georgia and Oregon State for their feedback and insights that help make this a better book. Between the two of us we have (either jointly or independently) now conducted over twenty workshops applying principles of Structured Decision Making to solving a wide range of natural resource problems. Each workshop has increased our understanding of how SDM works, and given us insights into why it occasionally does not work; this book is in large part the product of that experience.

We are especially grateful to the following colleagues who volunteered their time to provide us detailed reviews of each of the chapters: Paige Barlow, John Carroll, Sarah Converse, Jason Dunham, Andrea Goijman, Tom Kwak, Clint Moore, Rebecca Moore, Krishna Pacifici, Colin Shea, and Seth Wenger. Their comments were extremely helpful to us, both in catching errors as well as for insights on how to deliver our message with greater accuracy and clarity. Any remaining errors, which we hope are few and unimportant, belong to the authors. The use of trade, product, industry, or firm names or products is for informative purposes only and does not constitute an endorsement by the US Government or the US Geological Survey. The Oregon Cooperative Fish and Wildlife Research Unit is jointly sponsored by the US Geological Survey, the US Fish and Wildlife Service, the Oregon Department of Fish and Wildlife, the Oregon State University, and the Wildlife Management Institute.

# Guide to Using this Book

This book is divided into three major parts: Introduction, Tools, and Applications, and we recommend some depth of reading for all users of all three parts. For Part I – Introduction, we recommend that all readers examine Chapters 1 and 2; however, those already familiar with the basics of SDM might quickly skim these sections, since presumably the major concepts will be familiar. We highly recommend that all readers who seek to actually develop decision models carefully read Chapter 3 on developing objectives, and those who plan to work with stakeholder groups should definitely read Chapter 4. We also recommend that administrators and policy makers read these sections, if for no other reason than to become familiar with the terminology of SDM, as well as to have a more realistic expectation of what can, and cannot be achieved.

Part II of the book gets into the nuts and bolts of how to assemble decision models and to use information from field studies and monitoring to inform decision making. These chapters should be read in depth and we recommend that everyone read the introductory sections of both chapters, scan the topic sentences for the remainders, and refer back in detail to specific sections as needed. For example, one not need have a detailed knowledge of linear modeling, to appreciate the fact that linear models can both capture essential hypothetical relationships as well as form testable predictions that can be used in decision making. Likewise, one need not know the details of dynamic programming to understand the basic principles of optimization, and appreciating that casting decisions in a dynamic framework greatly complicates this process. On the other hand, if one is actually constructing and applying linear models, or using dynamic decision models, a deeper understanding and a more comprehensive reading is essential.

Part III covers applications of these approaches, and should be read by all. In particular, our coverage of case studies that “worked” (Chapter 9) and those that were less than fully successful (Chapter 10) should provide important insights to those seeking to apply these methods.

We also have provided a glossary, several technical appendices, and an Electronic Companion, and we encourage readers to use all three of these resources. The glossary provides a comprehensive list of terms we have used, together with brief definitions for each; we think readers will find this a useful guide to navigating a sometimes confusing terrain. The appendices provide a level of technical detail that is important to have available, but was inappropriate to include in the body of the book, and should be referred to for elaboration on these topics. Finally, the Electronic Companion provides worked examples with computer code for all of the Box examples, except those with trivial solutions, some additional useful code and explanation, as well as links to other resources available on the Internet including example exercises (problems) for coursework.

# Companion Website

As noted above, we have provided a companion website for the book, which can be accessed via www.wiley.com/go/conroy/naturalresourcemanagement. Additional resources on the companion provide details for the Box examples, including data input and program output. In most cases (except commonly available commercial software like Microsoft Excel ®), the programs are freely available via the Internet. We have provided additional modeling software and examples that, while not directly referenced in the book, may be useful to readers. We also have provided links to both freely available as well as commercial software; readers should always obtain the most current versions of these applications. Finally, we have provided links to several workshops and courses we have conducted in this area, which should be of interest, especially to advanced undergraduates and graduate students seeking to use these approaches in their research.

# PART I. INTRODUCTION TO DECISION MAKING

# 1

# Introduction: Why a Structured Approach in Natural Resources?

In this chapter, we provide a general motivation for a structured approach to decision making in natural resource management. We discuss the role of decision making in natural resource management, common problems made when framing natural resource decisions, and the advantages and limitations of a structured approach to decision making. We will also define terms such as **objective, management**, **decision**, **model**, and **adaptive management**, each of which will be a key element in the development of a structured decision approach.

The first and obvious question is: why do we need a structured approach to decision making in natural resource management? We have thought a lot about this question, and realize that while the answer may not be obvious, it really comes down to some basic premises. For us, natural resource management is a developing field, and many aspects of it are not "mature." In many respects we think that conservation and natural resource management suffer from the perception that many have that it is an ad hoc and not particularly scientific field. In our view, we have a choice: we can either use ad hoc and arguably non-scientific means to arrive at decisions; or we can use methods that are more formal and repeatable. In our view, the latter will better serve the field in the long run.

We also want to emphasize that when we refer to "management" we are speaking very broadly. That is, “management” includes virtually every type of decision we could make about a natural resource system, which would include traditional game management tools (e.g., harvest and habitat management), but also reserve design, legal protection and enforcement, translocation, captive propagation, and any other action intended to effect a conservation objective. This means that we consider conservation and management as one and the same and believe that artificial distinctions only serve to confuse students and practitioners.

# The Role of Decision Making in Natural Resource Management

Virtually all problems in natural resource management involve decisions: choices that must be made among alternative actions to achieve an objective. We will define “decisions” and “objectives” more formally in the coming chapters, but can illustrate each with some simple examples. Examples of decisions include:

- Location on the landscape for a new biological reserve.
- Allowable season lengths and bag limits for a harvested population.
- Whether to capture a remnant population in danger of extinction and conduct captive breeding.
- Whether to use lethal control for an exotic invasive limiting an endemic population, and if so, which type of control.
- Whether and how to mitigate the impact of wind turbines on bird mortality.

Note that in each case, there is a choice of an action, and that some choices preclude others. So for example, if we choose location *A* for our reserve, given finite resources and other limitations, we have likely precluded locations *B*–*D*. Similarly, if we close the hunting season we cannot at the same time allow liberal bag limits. If we capture the remnant population we have (at least immediately) foregone natural reproduction, and so on.

Also, each of the above decisions is presumably connected to one or more objectives. We will develop objectives more fully in Chapter 3, but broadly stated, the objectives associated with the above decisions might be, respectively:

- Provide the greatest biodiversity benefit for the available funds and personnel.
- Provide maximum sustainable harvest opportunity.
- Avoid species extinction and foster species recovery.
- Restore an endemic population.
- Minimize bird mortality while fostering "green" energy.

So, at a very basic level, decision making is about connecting decisions to objectives, and **structured decision making** (**SDM**; Hammond et al. 1999, Clemen and Reilly 2001) is just a formalized way of accomplishing that connection. For some of us this connection (and way of thinking) is so obvious that it hardly needs stating, and certainly doesn't require a book-length coverage. However, we have in our careers in academia and government, and working with natural resource management agencies, NGOs, and business, encountered numerous examples in which we believed that problems in the management of resources were exacerbated, and in some cases directly caused, by poor framing of the decision problem.

We also want to emphasize the important role of science in decision making. Science should inform decision making, but we must always recognize that science is a process and not an end. Thus, we can use science to inform decision making, but we must always be seeking to improve our scientific understanding as we make decisions. We sometimes use the analogy of a 3-legged stool of management, research, and monitoring to make this point (Conroy and Peterson 2009).

# Common Mistakes in Framing Decisions

## Poorly Stated Objectives

It is apparent to us that, in many cases, the objectives of management are poorly stated, if they are stated at all. This can lead to decisions that lead nowhere – that is, they are not connected to any apparent objectives. This in turn means that the decisions do not address the management problem, waste resources, and potentially create unnecessary conflict among the stakeholders. The reverse also can occur when objectives are stated, but management decisions are apparently arrived at by an independent process. As a result, the objectives cannot be achieved because they are not connected to management actions. Again, the management problem is not addressed, resources are wasted, and unnecessary conflict created; additionally, **stakeholders** (parties who have an interest in the outcome of decision making, and who may or may not be **decision makers**) may feel disenfranchised, since apparently their input in forming objectives has been ignored.

## Prescriptive Decisions

A related situation arises in cases where “decisions” are formulated in a rule-based, prescriptive manner that presumes that certain sets of conditions (perhaps attributes measured via monitoring) necessarily trigger particular actions. Such formulaic approaches (common in many species recovery plans) may be useful tools in a decision-making process, but do not constitute decision making (except in the trivial sense of having decided to follow the formula).

# Confusion of Values and Science

When attempts are made to define objectives, a very common problem that we see is the *confusion of values* (or objectives) with *science* (or data/ information). That is, conflating what we know (or think we know) about a problem, with what we are trying to achieve. Most natural resource professionals come from a background in the biological or earth sciences, and are more comfortable discussing “facts” and data than they are discussing values. As we will see, “facts” come into play when we try to connect candidate decisions to the objectives we are trying to achieve. Objectives, on the other hand, reflect our values (or the values of those with a stake in the decision whose proxies we hold). If we do not get the values (objectives) right, the “facts” will be useless for arriving at a decision. More insidiously, disagreements about “facts” or “science” are frequently a smokescreen or proxy for disagreement about values. One needs to look no further than the cases of the Northern Spotted Owl (*Strix occidentalis caurina*) or anthropogenic climate change. In each case, scientific belief (and supporting “facts”) coincides remarkably with the values of the respective stakeholder communities, with for example timber industry advocates tending to be skeptical of the obligate nature of ancient forests for owls, and many political or social conservatives questioning the science of climate change (Lange 1993, McCright and Dunlap 2011, Martin et al. 2011, Russill 2011).

# Poor Use of Information

Another very common disconnect we see is the *poor use of information from monitoring programs*. While some general-purpose monitoring can perhaps be justified (e.g., the Long Term Ecological Research Network [LTER; http://www.lternet.edu/] programs that provide baseline monitoring in relatively undisturbed areas), omnibus monitoring programs that are not connected to and do not support decision making are often unproductive (see also Nichols and Williams 2006). Rather, we agree with Nichols and Williams (2006) that changing the focus and design of monitoring programs as part of an overarching program of conservation-oriented science or management.

This is not to say that monitoring (of any kind) is an absolute requirement of decision making. In some cases, there are few data to support quantitative statements about a decision's impact, and little prospect that sufficient data will be acquired in the near term to allow unequivocal statements about management; many problems involving imperiled species and their habitats fall into this category. Nonetheless, it is incumbent on managers to make decisions given whatever data or other knowledge is available. Putting off a decision until more information is available is, of course, itself a decision, with potentially disastrous consequences ("paralysis by analysis" is another variant). The reality is that we can always learn more about a system; the trick is to use what we know *now* to make a good decision, while always striving to do better with future decisions.

# What Is Structured Decision Making (SDM)?

SDM consists of three basic components. The first is explicit, quantifiable objectives, such as maximizing bear population size or minimizing human–bear conflicts. The second is explicit management alternatives (actions) (e.g., harvest regulations or habitat management) that can be taken to meet the objectives. The third component is models that are used to predict the effect of management actions on resource objectives (e.g., models predicting population size after various harvest regulations). Because knowledge about large-scale ecological processes and responses of resources to management are always imperfect, **uncertainty** is incorporated in SDM through alternative models representing hypotheses of ecological dynamics and statistical distributions representing error in model parameters and environmental variability.

# Why Should We Use a Structured Approach to Decision Making?

Some decision problems have an obvious solution and need no further analysis. In such cases, two or more decision makers with the same objective would probably arrive at the same decision, perhaps without even consciously making a choice. Such decision problems probably do not require a structured approach.

However, we suggest that these types of problems are not typical of natural resource management. In our experience, natural resource decision problems are typically complex,