

Part I

MANAGING A POLITICAL-ECOLOGICAL SYSTEM

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Introduction

1.1 The problem to be addressed

In this book, biodiversity is considered a nonrenewable natural resource (USAID 2005, p. 6, USGS 1997, Wikipedia 2010, UFZ 2008). Many species are headed for extinction in habitats that straddle two or more developing countries. With our current understanding of biological processes (circa 2010), the loss of a species is irreversible. Because of this irreversibility, it can be argued that this problem should be of high priority to all countries. This book gives one way to address this problem.

Two characteristics of this problem make solutions difficult to find. First, within developed countries, constituencies prefer their policy makers to spend most of their conservation budget on internal conservation programs. Because of this internal focus, developing countries, with inadequate budgets for conservation programs, can expect to receive (currently) only modest supplemental conservation resources from developed countries. Second, because the habitat of many at-risk species straddles the political boundaries of several developing countries, conventional wildlife conservation strategies (such as government-run command and control programs) may not be implemented with sufficient completeness to achieve a species' long-term survival.

These considerations have motivated the development here of an approach to ecosystem management that does not assume central control but instead, after building scientific models of both the political processes at work in the habitat-hosting countries and the dynamics of the ecosystem in which the managed species is a participant, searches for politically feasible management plans. In other words, this book proposes a two-step procedure: first understand how the political–ecological system works at a mechanistic level and only then begin a search for management

plans that require the least change in human belief systems in order to effect behavioral changes that result in a sequence of actions that leads to the survival of the species being managed. The term *political–ecological system* is used rather than *socio-ecological system* to emphasize the active, institution- and ecosystem-changing tendencies of human groups across an ecosystem.

Such an approach to ecosystem management is different from so-called ‘adaptive management’ because it emphasizes a positivist and reductionist understanding of the entire political–ecological system before attempts are made to manipulate it. Adaptive management, on the other hand, can be viewed as a sequence of ecosystem management experiments that are conducted with the hope that a successful strategy will be found before the managed species becomes globally extinct. For example, Moir and Block (2001) argue that adaptive management’s eight-step cycle of Propose Actions, Form Hypotheses, Determine Data Needs, Design Monitoring Program, Install Monitoring Program, Monitor, Analyze Collected Data, Implement a Management Action results in a monitoring protocol over a time scale that is not derived from an understanding of the ecosystem’s dynamics but, rather, is short in duration so that feedback (adaptation) can be used to possibly adjust the management plan. These authors argue that this forced short time interval in the feedback loop invites ‘False Effects’ to drive management action revisions. Further, many applications of adaptive management depend on statistical hypothesis testing which, in turn, usually relies on linear statistical models of ecosystem processes rather than mechanistic, (possibly) nonlinear models of ecosystem dynamics that may be dominated by cycles with long periods (Moir and Block 2001).

But in this author’s view, wildlife management is in a state of crisis. Environmental degradation and loss of biodiversity are occurring at unprecedented rates while efforts to stem this often-irreversible damage are on the whole inadequate. Funding for these problems, however, is low relative to other fields such as defense or human health. In developing countries, where most species reside, such funding is glaringly inadequate. The ecosystem management problem on the other hand is complex in that effective management strategies need to take into account how political realities impede or promote the implementation of options that could protect an ecosystem. If a freely available system, based on the best available science, existed and was capable of finding politically feasible but effective (this book’s definition of ‘practical’) ecosystem management plans, managers and observers of at-risk ecosystems could use this tool to develop specific, defensible proposals for stemming this destruction. Because of their practicality, these proposals would have the best chance of actually being implemented.

There is a dearth of books that combine the social sciences and conservation and few individuals have training in both areas. The need to integrate the social sciences and conservation disciplines, however, has been recognized by the conservation community, see Fox *et al.* (2006) and Liu *et al.* (2007) for extended discussions of this deficiency.

Decisions to actually implement an ecosystem management policy typically have a political component. The majority of current ecosystem management research, however, is concerned with ecological and/or physical processes.

Management plans that are suggested by examining the output of these models and/or data analyses may not be supported by the affected human population unless the option addresses the goals of each involved social group (hereafter, *group*).

As a step towards meeting this need, this book describes an Ecosystem Management Tool (EMT) that links political processes and political goals to ecosystem processes and ecosystem health goals. Because of this effort to incorporate the effects of politics on ecosystem management decision making, the EMT described in this book is referred to as a *politically realistic EMT* – or simply the *EMT*. This tool can help managers identify ecosystem management plans that have a realistic chance of being accepted by all involved groups and that are the most beneficial to the ecosystem. Haas (2001) gives one way of defining the main components, workings, and delivery of an EMT (referred to there as an Ecosystem Management System). The central component of this EMT is a quantitative, stochastic and causal model of the ecosystem being managed and the social groups involved with this management. This model is called the *political–ecological system simulator* (hereafter, *simulator*). In this simulator, group decision-making models and the ecosystem model are developed in a probabilistic form known as an *influence diagram* (ID) (see Pearl 1988, p. 125). The other components of the EMT are links to data streams, freely available software for performing all ecosystem management computations and displays, and, lastly, a web-based archive and delivery system for the first three of these components.

The two main uses of the EMT are first to find practical ecosystem management plans, and second to allow any literate person with access to the Web the ability to assess for themselves the status of a species being managed with the EMT. This second use is intended to make more accessible to developed countries the status and challenges of managing critical ecosystems in distant, developing countries.

A core message of this book is that ecosystem analyses and optimal management plan studies cannot be one-off and performed at only one time point. Rather, such applied ecosystem research needs to be on going and constantly updated. Present journal publishing practices encourage one-off studies but ecosystems are on going and dynamic. The tools contained in this book's EMT are in part meant to make such on going analysis easier to perform repeatedly and more cost effective in both hardware and labor.

1.2 The book's running example: East African cheetah

To fix ideas and to show feasibility, a politically realistic EMT for the management of the cheetah (*Acinonyx jubatus*) in a portion of East Africa is developed and applied as a running example throughout the book. The cheetah is listed as *vulnerable* in the Red List of Threatened Species maintained by the International Union for Conservation of Nature (IUCN) (Cat Specialist Group 2007). The portion of East Africa studied in this example is the land enclosed by the political boundaries

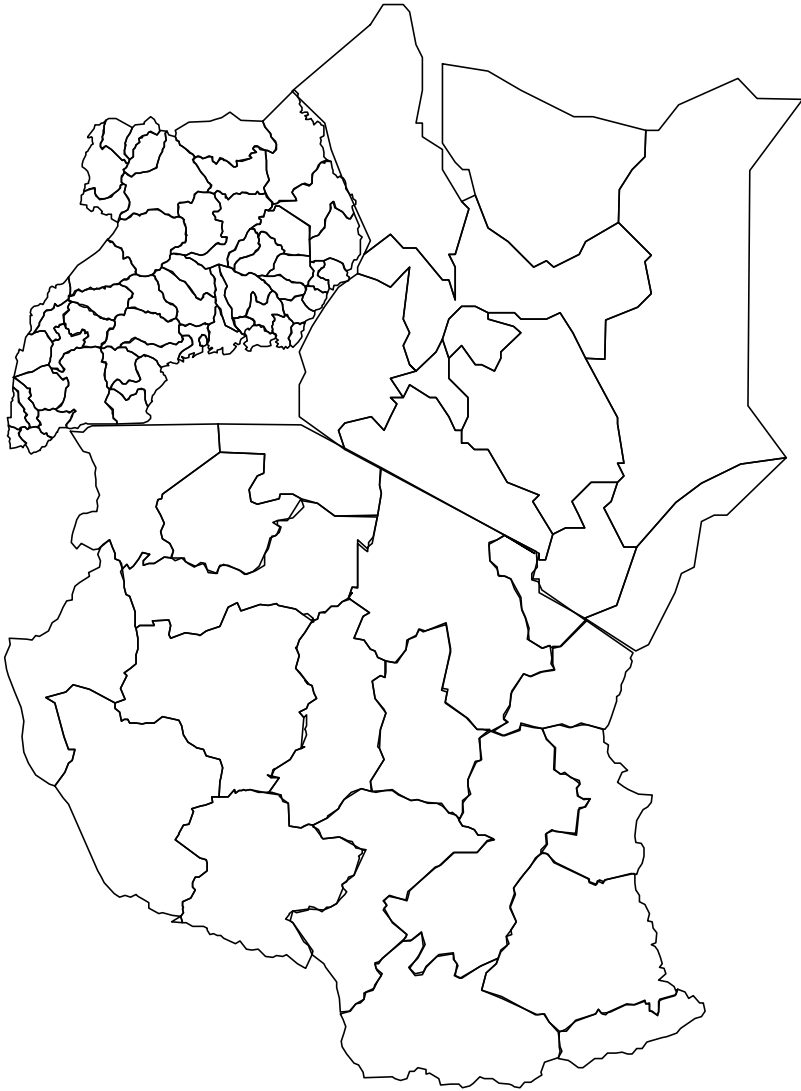


Figure 1.1 Area of East Africa that is the subject of the politically realistic East African cheetah EMT.

of Kenya, Tanzania, and Uganda (Figure 1.1). This ecosystem involves at least the cheetahs themselves, their prey, and the habitat in which these animals live. Humans are also a part of this ecosystem but here are modeled separately from the nonhuman aspects of the ecosystem. Specifically, along with an ID of the ecosystem, this EMT's simulator represents the following groups: (a) within each of the countries

of Kenya, Tanzania, and Uganda, the president's office, the agency charged with executing wildlife and/or habitat protection actions (referred to herein as the *environmental protection agency* (EPA)), nonpastoralist rural residents (hereafter, *rural residents*), and pastoralists; and (b) a group of nongovernmental organizations (NGOs) that seeks to protect biodiversity within these countries (hereafter, *conservation NGOs*). This example was chosen in part to demonstrate the feasibility of applying the EMT to an at-risk species whose habitat ranges across several developing countries.

1.2.1 Background

Cheetah preservation is a prominent example of the difficulties surrounding the preservation of a large land mammal whose range extends over several countries. The main threats to cheetah preservation are loss of habitat, cub predation by other carnivores, and being shot to control predation on livestock (Gros 1998, Kelly and Durant 2000).

Kelly and Durant (2000) note that juvenile survival is reduced by lion predation inside wildlife reserves because these reserves are not big enough for cheetahs to find areas uninhabited by lions. Over crowding of reserves in Africa is widespread (see O'Connell-Rodwell *et al.* 2000) and cheetahs do not compete well for space with other carnivores (Kelly and Durant 2000). Although many cheetahs are currently existing on commercial land, this coexistence with human economic activities may not be a secure long-term solution for the cheetah. Bashir *et al.* (2004) also note that cheetahs do not compete well with lions and hyenas in protected areas (reserves or national parks) – and hence their survival in open areas and farmlands is crucial to their overall survival. These authors note, however, that cheetahs outside protected areas run the risk of being shot or poisoned by (a) trophy hunters for their skins or (b) farmers and pastoralists because they occasionally prey on their goats and calves.

One albeit expensive solution would be larger reserves that are free of poachers – possibly enclosed by an electrified fence. Such a solution was found to be the most viable for keeping elephants from destroying crops in Namibia (see O'Connell-Rodwell *et al.* 2000). Pelkey *et al.* (2000) also conclude that reserves with regular anti-poaching and anti-logging patrols are the most effective strategy for African wildlife and forest conservation.

A large portion of cheetah range is controlled by Kenya, Tanzania, and Uganda (see Kingdon 1977). In this range, cheetahs prey mostly on herbivores. Kingdon notes that because cheetahs take their prey via a strangulation bite attack, they have little success with prey that weigh more than about 60 kg. For this reason, cheetahs typically prey on the impala *Aepyceros melampus* (40 kg), Thomson's gazelle *Eudorcas thomsonii* (15 kg), Grant's gazelle *Nanger granti* (40 kg), lesser kudu *Tragelaphus imberbis* (40 kg), and gerenuk *Litocranius walleri* (25 kg) (Kingdon 1977). The average mass of these cheetah-prey herbivores is 32 kg. Hereafter, herbivores that weigh less than 60 kg will be referred to as *prey*.

Currently, the poverty rates in Kenya, Tanzania, and Uganda are 52%, 35.7%, and 44%, respectively. The adult literacy rates are 90%/79% (males/females) for Kenya, 85%/69% for Tanzania, and 79%/59% for Uganda (World Resources Institute 2005). With close to half of the population living in poverty, many rural Africans in these countries feel that conservation programs put wildlife ahead of their welfare and that large mammals are a threat to their small irrigated patches of ground and their livestock (Gibson 1999, p. 123). For these reasons, many such individuals are not interested in biodiversity or wildlife conservation.

Gibson (1999, p. 122) finds that the three reasons for poaching are the need for meat, the need for cash from selling animal ‘trophies,’ and the protection of livestock. Gibson’s analysis suggests that to reduce poaching, policy packages need to be instituted that (a) deliver meat to specific families, not just to the tribal chief, (b) increase the enforcement of laws against the taking of trophies, and (c) improve livestock protection.

1.3 The EMT simulator

The simulator functions by having each group implement an action chosen from a predetermined repertoire that maximizes a multiple-goal utility function (specifically, the weighted sum of goal utility functions in which weights reflect relative goal importance). A temporal sequence of actions taken by those groups that affect the ecosystem (the result of playing this sequential game) is called an *ecosystem management plan*. Such an *actions history* may or may not be the result of a formal, articulated policy for managing the ecosystem.

1.3.1 Characteristics of an ideal simulator

To be convincing to all stakeholders, the EMT simulator needs to have the following two characteristics:

1. *Usability*: because of its predictive and construct validity, the simulator contributes to the ecosystem management debate by delivering insight into how groups reach ecosystem management decisions, what strategies are effective in influencing these decisions, how ecosystems respond to management actions, and which management actions contribute to ecosystem health. In other words, by running different management scenarios through the model, stakeholders both within and outside the ecosystem-enclosing countries are able to learn how political beliefs and actions need to change to improve measures of ecosystem health such as achieving the preservation of a threatened species.
2. *Clarity*: the simulator’s construction and operation can be understood by individuals having a wide range of educational backgrounds.

These two simulator characteristics are seen as the most important for the development of a useful ecosystem management decision support system and are in agreement with recommendations given in Miles (2000).

For descriptions of predictive and construct validity see Feinsten and Cannon (2001), Babbie (1992), or Carmines and Zeller (1979). A model that possesses predictive validity displays prediction error rates that are lower than that of blind guessing. Here, predictive validity will be assessed with the simulator's one-step-ahead prediction error rate wherein, at every step, the simulator is refitted with all available data up to but not including that time step.

A model that possesses construct validity uses relationships, functions, and mechanisms that operationalize the current state of understanding of how groups reach decisions and how ecosystems unfold through time (ecosystem dynamics). Here, construct validity will be assessed by the degree to which the simulator's internal structure (variables and inter variable relationships) agrees with current theories of group decision making and mathematical models of wildlife population dynamics.

There is a tension between predictive and construct validity in that the development of a model sufficiently rich in structure to represent current theories of group decision making and ecosystem dynamics can easily become overparameterized, which, in turn, may reduce its predictive performance. The approach taken here is to develop a simple model that is faithful to theories of how groups reach decisions and to theories of ecosystem dynamics – followed by a fit of this model to data to help maximize its predictive performance.

At present, theories of group decision making and ecosystem dynamics are evolving. Models, then, will need to be modified and re-evaluated from time to time to incorporate advances in our understanding of how these processes work. A method is needed for determining whether a proposed model modification that improves the model's construct validity is also consistent with observations. For this purpose, a Monte Carlo (MC) hypothesis-testing procedure has been built into this book's EMT that allows an analyst to use statistical hypothesis testing to assess such modifications.

1.4 How to use the EMT to manage an ecosystem

The procedure for developing and using the EMT to manage an ecosystem is as follows:

1. Construct a stochastic model of each group's decision-making activity.
2. Construct a stochastic model of those elements of the ecosystem that are to be managed.
3. Collect data on group actions and on the output nodes of the ecosystem model.

4. Use this data to estimate the values of all parameters in these models.
5. Decide on ecosystem state goals.
6. Compute the *Most Practical Ecosystem Management Plan* (MPEMP) for these goals.
7. Enact the command elements of the MPEMP and execute activities that are intended to cause belief structure change towards the needed parameter values given in the MPEMP.
8. Continue to collect data and recompute the MPEMP as new data is acquired.

1.4.1 Ecosystem state goals

Step 5 involves the specification of desired ecosystem states in the future. The ecosystem state studied in the running example is the long-term survival of a species. Such a goal needs to be expressed stochastically since the simulator's ecosystem model is stochastic. Therefore, this goal is expressed herein as 'A species has a low risk of extinction in the future.' The definition of *low extinction risk* is given below.

1.4.1.1 One definition of *low extinction risk*

Although genetic variation concerns are important, for example Frankham *et al.* (2002), for purposes of easy interpretation, the phrase *low extinction risk* will mean herein that the probability of a species population falling below 10 animals 50 animal generations into the future is less than .01. Use of a number-of-generations definition of time accommodates differences of species lifespan in the assessment of extinction risk (Armbruster *et al.* 1999). The average lifespan of a cheetah in the wild is about 6.9 years (Honolulu Zoo 2008). Hence, cheetah abundance predictions with attendant measures of uncertainty would need to be computed about 350 years into the future.

1.4.2 No valuation of ecosystem services

No attempt will be made in this book to assign a value to natural resources such as biodiversity. Ecosystem state goals are identified exogenously to the proposed EMT. Of course, having the goal of preserving a species implies a value judgment. But the proposed EMT does not need estimates of the value of a species before it can be used to find the MPEMP. Rather, it only needs to be given desired ecosystem endpoints.

There is a large body of knowledge on how to assign value to natural resources, for example, The Economics of Ecosystems and Biodiversity (TEEB) project (TEEB 2010). Apart from brief discussions of these ideas in Chapter 4, the present work will avoid such efforts. The reason for this downplaying of ecosystem

valuation is that, as the cheetah example will illustrate, different groups place different values on the same natural resource. Pastoralists in East Africa see live cheetahs as a liability to their livestock (negative value). Poachers in East Africa see value in a harvested cheetah and, by their actions, no value in future generations of cheetahs. Tourists and those who pay to watch wildlife television programs see value in a live cheetah. Whose valuation should be used? What markets exist along with legally enforced rights of ownership to make such valuations real in terms of hard currency? This author will make no attempt to answer these questions.

1.5 Chapter topics and order

Chapter 2 contains a sociological argument for the use of an interacting-groups-and-ecosystem approach to the simulator's construction. Then, computational details are given of how group IDs interact with each other and with the ecosystem ID over time. The book's running example of cheetah management in Kenya, Tanzania, and Uganda, referred to as the *East African cheetah EMT*, is introduced in this chapter.

Chapter 3 contains a short, self-contained example of an EMT for managing the global population of blue whales (*Baleanoptera musculus*). The intent of this chapter is to give the reader an overview of how an EMT is constructed from the identification of the at-risk species, development of models of involved groups, the ecosystem model, and data sources for group actions and ecosystem outputs.

A method for finding the MPEMP with a simulator that has been fitted to data is given in Chapter 4 along with an application of the method to the management of the East African cheetah. The MPEMP was first described in Haas (2008a). Although this method relies on first statistically fitting the simulator to data, it is presented before the statistical fitting chapter so that the primary use of a politically realistic EMT can be shown to the reader as early in the book as possible.

Chapter 5 contains a description of the book's web-based EMT and how it would be used to manage an ecosystem.

A review is given in Chapter 6 of some current theories of political decision making. Then, aspects of these theories are used to construct a general model of group decision making that is realized as an ID. Chapter 7 contains an application of the model developed in Chapter 6 to the presidential office, EPA, rural residents, and pastoralists within each of the countries of Kenya, Tanzania, and Uganda – and to a group of conservation NGOs operating in these countries.

A review is given in Chapter 8 of current differential equation models of wildlife population dynamics. Then, one of these models is used to construct an ecosystem ID that represents cheetah and prey population dynamics within the cheetah habitat that is continuously enclosed by the political boundaries of Kenya, Tanzania, and Uganda.

The book's section on the statistical fitting of the simulator and its reliability assessment begins with Chapter 9. In this chapter, the protocol used to gather

political data is given. The sources of ecosystem data used in the East African cheetah EMT appear in Chapter 10. This data consists of cheetah and prey abundance observations, vegetation type, and landuse – all by administrative district. The EMT’s geographic information system (GIS) capabilities are used to display this data set. In Chapter 11, the model is statistically fitted to observations on group actions and wildlife abundance using an estimation method, called *consistency analysis*, that accounts for subject matter theory within the frequentist statistical estimation paradigm.

The simulator’s parameter sensitivity is assessed and prediction error rates are computed in Chapter 12. This chapter also gives an MC hypothesis-testing procedure that can be used to improve the simulator’s construct validity. Hypothesis testing can lead to erroneous conclusions when the data comes from an *observational study* (see Rosenbaum 2002) rather than a designed experiment. The size of this hazard can be ascertained by conducting a *sensitivity to hidden bias* analysis (also see Rosenbaum 2002) on the model and data set if a hypothesis test is computed to be significant. Chapter 12, therefore, also contains a review of this issue and one way to conduct a sensitivity to hidden bias analysis.

Current capabilities and limitations of the EMT are discussed in Chapter 13. This chapter also contains a plan for raising the training level of ecosystem managers. Managing natural resources is a complicated political–ecological problem and current graduate programs need to cover a wider range of material and at a higher level.

Exercises are included at the end of Chapters 2–4, 6–8, and 10–12 so that the book may be used in a lecture course on ecosystem management. Reading only Chapters 1 through 5 avoids most of the statistical material but should give the reader an outline of how the EMT is used to manage an ecosystem. Indeed, the intent of this organization is for the first five chapters to contain a concise overview of an EMT that is reinforced with examples – followed by a detailed user’s manual for how to build an EMT, collect the needed data, and justify the political and ecological models that will form the EMT simulator.

1.6 The book’s accompanying web resources

An extensive and free website supports the book’s description of a web-based EMT. The site, www4.uwm.edu/people/haas/cheetah_empt, contains:

- All software described in the book (namely the **id** software package) in the form of Java source (.java) and Windows class (.class) files.
- A user’s manual for **id**.
- The political actions data set for the East African cheetah EMT along with the data collection protocol and a suite of web-based data acquisition aids.

- The ecosystem data set for the East African cheetah EMT.
- Output files from (a) the East African cheetah EMT's ecosystem management plan search, (b) statistical estimation of the EMT simulator, and (c) the simulator's sensitivity analysis.
- A web-based tutorial that covers the basics of probability, statistics, and influence diagrams.
- Answers to all of the book's exercises.

