Population dynamics and monitoring applied to decision–making

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Research in wildlife conservation and management often affects decisions made by managers. Improving understanding through applied research is key to advancing the ability to manage birds and other organisms efficiently. Indeed, many papers from EURING 2003 and previous EURING meetings describe research on problems of pressing management concern. In this session, we focus on a subset of studies in which modeling and statistical estimation is explicitly connected to management decision-making. In these decision–centric studies, data are gathered and models are constructed with the explicit intention of using the resulting information to inform decisions about conservation. Whereas ecological models often produce information of value to decision makers, decision models explicitly include two additional features. First, management options are modeled via *decision variables* that link to system attributes that are directly responsive to management actions, such as harvest and habitat management. Second, certain outcomes are assigned value, via an *objective* or *utility function*. Both of these features involve factors beyond the usual consideration of ecological modeling; the first implies the presence of one or more "decision makers", and the second characterizes the societal preferences of each possible outcome resulting from a prospective decision.

Our plenary paper, by Tim Haas (Haas, 2004), ventures the furthest into the realm of human behavior and societal processes by modeling the political context for conservation of the endangered cheetah (*Acinonyx jubatus*) in Africa. Haas shows that scientific information (e.g., population monitoring and population viability analyses) reaches decision makers through multiple pathways, each of which can modify or reinterpret the information signal. A predictive understanding of the country's political as well as ecological processes is essential. Hass uses a system of interacting ecological and political influence diagrams to capture the stochastic, temporal processes of managing cheetah population in Kenya. The model predicts likely management decisions made by various actors within these countries, (e.g., the President, the Environmental Protection Agency, and rural residents) and the resulting probability of cheetah extinction following these decisions. By approaching the problem in both its political and ecological contexts one avoids consideration of decisions that, while beneficial from a purely conservation point of view, are unlikely to be implemented because of conflicting political objectives. Haas's analysis demonstrates both the promise and challenges of this type of modeling, and he offers suggestions for overcoming inherent technical difficulties such as model calibration.

The second paper, by Simon Hoyle and Mark Maunder (Hoyle & Maunder, 2004), uses a Bayesian approach to model population dynamics and the effects of commercial fishing bycatch for the eastern Pacific Ocean spotted dolphin (*Stenella attenuata*). Their paper provides a good example of why Bayesian analysis is particularly suited to many management problems. Namely, because it allows the integration of disparate pieces of monitoring data in the simultaneous estimation of population parameters; allows for

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incorporation of expert judgment and data from other systems and species; and provides for explicit consideration of uncertainty in decision–making. Alternative management scenarios can then be explored via forward simulations.

In the third paper, Chris Fonnesbeck and Mike Conroy (Fonnesbeck & Conroy, 2004) present an integrated approach for estimating parameters and predicting abundance of American black duck (*Anas rubripes*) populations. They also employ a Bayesian approach and overcome some of the computational challenges by using Markov chain–Monte Carlo methods. Ring–recovery and harvest data are used to estimate fall age ratios under alternative reproductive models. These in turn are used to predict abundance of black ducks in each of 3 breeding areas. Finally, calibration of model parameters is obtained by comparing predicted with observed abundance. Although not currently implemented, the authors discuss how a Bayesian approach can be integrated into decision–making procedures using conditional modeling and application of reinforcement or machine learning.

The next paper, by Martin Drechler and Franz Wätzold (Drechler & Wätzold, 2004), considers the problem of optimally allocating a conservation budget over time to maximize the survival probability of an endangered species. This must be done in the presence of uncertainty both about the biological system (e.g., probability of extinction under alternative plans), as well as about the availability of future funding. On the one hand, it would be undesirable to imprudently spend money now that might be needed for future conservation effort, when funds may be limited. On the other hand, failure to take action (and thus spend funds) sooner might lead to a higher probability of extinction. Provided estimates of uncertainty in funding, a model for trend in funding, and a model relating funding levels to viability, stochastic dynamic programming can be used to solve for an optimal amount of expenditure during any budget period.

The final paper, by Clint Moore and Bill Kendall (Moore & Kendall, 2004), examines the costs incurred when uncalibrated indices to abundance are used in lieu of unbiased abundance estimates to make management decisions. Indices are often used instead of abundance estimates in the belief that the latter are too difficult and expensive. Moore and Kendall analyzed the impacts of using indices when making silvicultural decisions for the joint benefit of two bird populations, an endangered woodpecker and a shrub–nesting neotropical migrant. They computed the expected cost of uncertainty in the relationship between the monitoring index and population size, in currency units of the composite objective for both species. The authors found that substantial degradation of decision value can occur, depending on how uncertain the relationship between the index and true abundance. The results have important implications for managers, who may endeavor to cut costs by using index–based methods, while in the process incur these hidden costs of loss of decision utility.

The five papers summarized above provide a good sampling of applications and methodological approaches, but are not a comprehensive coverage of the topic. For useful introductions to decision theory and methods, we suggest that readers consult Lindley (1985) or Clemen & Reilly (2001). A more detailed coverage of optimal decision–making, decision–making under uncertainty, and adaptive resource management is provided in Williams et al. (2002: chapters 21–25).

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