Population dynamics

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Increases or decreases in the size of populations over space and time are, arguably, the motivation for much of pure and applied ecological research. The fundamental model for the dynamics of any population is straightforward: the net change over time in the abundance of some population is the simple difference between the number of additions (individuals entering the population) minus the number of subtractions (individuals leaving the population). Of course, the precise nature of the pattern and process of these additions and subtractions is often complex, and population biology is often replete with fairly dense mathematical representations of both processes. While there is no doubt that analysis of such abstract descriptions of populations has been of considerable value in advancing our, there has often existed a palpable discomfort when the "beautiful math" is faced with the often "ugly realities" of empirical data. In some cases, this attempted merger is abandoned altogether, because of the paucity of "good empirical data" with which the theoretician can modify and evaluate more conceptually–based models.

In some cases, the lack of "data" is more accurately represented as a lack of robust estimates of one or more parameters. It is in this arena that methods developed to analyze multiple encounter data from individually marked organisms has seen perhaps the greatest advances. These methods have rapidly evolved to facilitate not only estimation of one or more vital rates, critical to population modeling and analysis, but also to allow for direct estimation of both the dynamics of populations (e.g., Pradel, 1996), and factors influencing those dynamics (e.g., Nichols et al., 2000). The interconnections between the various vital rates, their estimation, and incorporation into models, was the general subject of our plenary presentation by Hal Caswell (Caswell & Fujiwara, 2004). Caswell notes that although interest has traditionally focused on estimation of survival rate (arguably, use of data from marked individuals has been used for estimation of survival more than any other parameter, save perhaps abundance), it is only one of many transitions in the life cycle. Others discussed include transitions between age or size classes, breeding states, and physical locations. The demographic consequences of these transitions can be captured by matrix population models, and such models provide a natural link connecting multi–stage mark–recapture methods and population dynamics. The utility of the matrix approach for both prospective, and retrospective, analysis of variation in the dynamics of populations is well–known; such comparisons of results of prospective and retrospective analysis is fundamental to considerations of conservation management (*sensu* Caswell, 2000). What is intriguing is the degree to which these methods can be combined, or contrasted, with more direct estimation of one or more measures of the trajectory of a population (e.g., Sandercock & Beissinger, 2002).

The five additional papers presented in the population dynamics session clearly reflected these considerations. In particular, the three papers submitted for this volume indicate the various ways in which complex empirical data can be analyzed, and often combined with more classical modeling approaches, to provide more robust insights to the dynamics of the study population. The paper by Francis & Saurola

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(2004) is an example of rigorous analysis and modeling applied to a large, carefully collected dataset from a long–term study of the biology of the Tawny Owl. Using a combination of live encounters and dead recoveries, the authors were able to separate the relative contributions of various processes (emigration, mortality) on variation in survival rates. These analyses were combined with periodic matrix models to explore comparisons of direct estimation of changes in population size (based on both census and mark–recapture analysis) with model estimates.

The utility of combining sources of information into analysis of populations was the explicit subject of the other two papers. Gauthier & Lebreton (2004) draw on a long–term study of an Arctic–breeding Goose population, where both extensive mark–recapture, ring recovery, and census data are available. The primary goal is to use these various sources of information to to evaluate the effect of increased harvests on dynamics of the population. A number of methods are compared; most notably they describe an approach based on the Kalman filter which allows for different sources of information to be used in the same model, that is demographic data (i.e. transition matrix) and census data (i.e. annual survey). They note that one advantage of this approach is that it attempts to minimize both uncertainties associated with the survey and demographic parameters based on the variance of each estimate.

The final paper, by Brooks, King and Morgan (Brooks et al., 2004) extends the notion of the combining information in a common model further. They present a Bayesian analysis of joint ring–recovery and census data using a state–space model allowing for the fact that not all members of the population are directly observable. They then impose a Leslie–matrix–based model on the true population counts describing the natural birth–death and age transition processes. Using a Markov Chain Monte Carlo (MCMC) approach (which eliminates the need for some of the standard assumption often invoked in use of a Kalman filter), Brooks and colleagues describe methods to combine information, including potentially relevant covariates that might explain some of the variation, within a larger framework that allows for discrimination (selection) amongst alternative models.

We submit that all of the papers presented in this session indicate clearly significant interest in approaches for combining data and modeling approaches. The Bayesian framework appears a natural framework for this effort, since it is able to not only provide a rigorous way to evaluate and integrate multiple sources of information, but provides an explicit mechanism to accommodate various sources of uncertainty about the system. With the advent of numerical approaches to addressing some of the traditionally "tricky" parts of Bayesian inference (e.g., MCMC), and relatively user–friendly software, we suspect that there will be a marked increase in the application of Bayesian inference to the analysis of population dynamics. We believe that the papers presented in this, and other sessions, are harbingers of this trend.

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