Abstract:

Ecologists are increasingly challenged to anticipate variability in the flows of ecosystem goods and services and to assess emerging vulnerabilities. Despite a long research tradition on population dynamics, species interactions, and ecosystem processes, ecologists frequently have little to offer when confronted with questions of pending climate-forced range shifts, fragmentation, design of reserves, and where and when biodiversity loss is likely to have feedback effects on ecosystem services. There is growing awareness of how difficult it can be to connect confidence and predictive intervals from models back to the data that went into their construction.

Advances in computation and statistics have produced new tools for inference and prediction in complex settings. Whereas modeling constraints have long caused most of the stochasticity that impacts data (and, thus, prediction) to be ignored, new hierarchical Bayes (HB) structures bring flexibility. Sampling based approaches, such as Markov chain Monte Carlo (MCMC), allow for analysis of high-dimensional problems. They can admit heterogeneous information that derives from a range of spatial scales. They can provide for inference and prediction in the common situation where more may be unknown than known.

I summarize the framework for hierarchical Bayes and demonstrate how it applies to high-dimensional systems in the environmental sciences, and I carry that dimensionality forward to the problem of prediction. Using examples from forest dynamics I show how HB admits disparate sources of information for modeling complex systems within a consistent framework. I follow with illustration of recent algorithms for simulating high-dimensional systems (the so-called N-body problem), which allows for known approximation errors in large problems. I argue that new simulation methods that provide approximate answers (with known error) are especially promising in the context of HB estimation, which puts simulation error in the context of stochasticity associated with process, sampling, and context (e.g., aggregation associated with spatial scales).