

International Society for Bayesian Analysis, 9th World Meeting,
Hamilton Island, Australia, 2008.

HOW BAYES IS CHANGING ENVIRONMENTAL SCIENCE:
APPLICATION TO CLIMATE CHANGE AND THE BIODIVERSITY
PARADOX

Jim Clark^{1*}

¹ Duke University, Durham, USA

* jimclark@duke.edu

The combined advantages of graphical modeling and Bayesian inference are transforming environmental science. Ecological processes are highly scale- and setting-dependent and only indirectly related to observations. Ecological data are remarkably heterogeneous, ranging from photosynthetic rate measurements on leaves to remote sensing of landscapes. By modern standards, the problems are not overwhelmingly large they are frustratingly complex. I illustrate some of the potential to address complex relationships, together with new issues that emerge, when modern tools are applied to these dynamic, highly connected systems. The application concerns a long-standing effort to understand controls on forest diversity described a half century ago as a paradox in the context of contemporary rapid climate change. Theoretical models tell us that species must differ in specific ways in order to coexist as stable ecological communities. These differences must involve tradeoffs among species to insure that the best competitors do not drive all others to extinction. Yet many coexisting species do not appear to possess such differences. The lack of observable tradeoffs presents a paradox when taken in light of the fact that species do indeed coexist in nature. A key challenge involves identifying the important differences among species that allow each to persist in the face of competition from many others. In this talk I discuss why inconsistent assumptions of theoretical and statistical models lead to the paradox. I suggest that coexistence is best understood in terms of population heterogeneity, an old idea, but one that has not been properly interpreted from data or theory. First, species differences occur along many axes and are missed by traditional data modeling approaches. Second, theoretical (stochastic) models contain unrecognized species differences, which are simply hidden from view. I show how a proper treatment of heterogeneity resolves the paradox. Species differences responsible for coexistence are high-dimensional, and can be captured in data and in models by admitting an appropriate structure for unknowns. Much of the unexplained variation in data results from differences among individuals. It

occurs across a large number of axes, most of which will be hard to capture in simple experiments and observational data sets. By providing a consistent treatment of information from many scales and complex, interacting processes, modern Bayes allows a more integrated view. The example involves parameterization of the joint distribution of demographic rates (fecundity, dispersal, growth, mortality) for all of the trees in selected forests as coupled, non-linear state space models that accommodate the interactions among individuals and with their local environments. We are fitting the forest and the trees. Prediction of biodiversity response to climate change involves mixing over all sources of heterogeneity, allowing us to better anticipate vulnerabilities. Specific issues include ways to organize an analysis that can involve updating at several stages, how to weight information deriving from multiple data sources, and efficient computation when conditional relationships are complex and spatio-temporal.