Increasing the tractability of occupancy models

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Abstract

1. occupancy models are everywhere, but model fitting and assessment are extrememly computationally intensive
2. Using the NIMBLE package for R, we develop combined computational approaches to improve computational efficiency including user defined and automatic blocking of parameters for MCMC, filtering over latent states, and customized MCMC samplers for specific parameters. We test these approaches for three representative occupancy models of varying levels of complexity including a single species dynamic (i.e., multi-season) model with spatial auto correlation, and a mutli-species model. We also use calibrated posterior p-values to assess model fit.
3. These computation approaches lead to an improvement in MCMC sampling efficiency, particularly with the more complex, mutli-species model.
4. Ours results highlight the need for more customizable approaches to MCMC to fit and assess hierachical models in order to ensure occupancy models are accessible to practitioners. By implementing MCMC procedures and model assessment techniques open source software, we have made progress toward tis aim.
5. *Implications:*

NIMBLE, Markov chain Monte Carlo, latent states, block sampling, dynamic occupancy, mutli species occupancy, spatial occupancy, JAGS

Introduction

Estimating the proportion of sites occupied by a species is common challange for many subdisciplines ecology and evolution including metapopulation, engangered and invasion biology. Greater acceptance of the biases of imperfect detection has lead to the development and proliferation of occupancy models, which model the occurrence of a species at a site as a latent state layered underneath a detection process (e.g., MacKenzie *et al.*, 2006; Royle & Kéry, 2007). Now only a little over a decade after occupancy models were introduced to ecology, they are being used to model the occurence of everything from bees (M'Gonigle *et al.*, 2015) to tigers (**?**) in an endless variety of complexity.

Occupancy models are part of a larger class of models known as Hidden Markov Models. For discrete Hidden Markov Models like occupancy models where a species is either present or absent from a site, likelihood calculation involves summing over the distribution of latent states. Because estimating the effect of explanatory variables on site occupancy or shared variation of in occupancy across species is often of greatest interest to ecologsits (e.g., **?**), the Hidden Markov Models are embedded in a larger hierarchical model. In such cases, practitioners may rely on Markov chain Monte Carlo (MCMC) to perform a Bayesian analysis. Such models are computationally intensive, and large models requiring hundreds or thousands of dimensions which require MCMC can be computationally intensive. In addition, fitting these models is such a challenge that users often forgo adding any additional computation to asses model fit. To ensure occupancy models are accessible to practitioners, more efficient methods for fitting and assessing these models are necessary.

Materials & Methods

Results

Discussion

Acknowledgments

References

MacKenzie, D., Nichols, J., Royle, J., Pollock, K., Bailey, L. & Hines, J. (2006) *Occupancy estimation and modeling: inferring patterns and dynamics of species occurrence*. Elsevier, Burlington, Massachusetts, USA.

M'Gonigle, L., Ponisio, L., Cutler, K. & Kremen, C. (2015) Habitat restoration promotes pollinator persistence and colonization in intensively-managed agriculture. *Ecol Appl*, **25**, 1557–1565.

Royle, A. & Kéry, M. (2007) A bayesian state-space formulation of dynamic occupancy models. *Ecology*, **88**, 1813–1823.