Analysis of ecological time series using state-space models

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Prediction of population level responses to global change is the holy grail of population dynamics. Ecological time series provide incomplete snapshots of the state of a system and fitting dynamic models to such data necessitates the inclusion of stochastic elements to account for the influence of unmodeled processes. In ecology, state-space models (SSM) are used to couple stochastic dynamic models of populations (the "state-space") with models accounting for incomplete observation of underlying processes. Ecological SSMs are typically non-linear and non-Gaussian making conventional parameter estimation methods inapplicable. Markov chain Monte Carlo (MCMC) methods are widely used for parameter estimation of missing data problems, but it has not been obvious how to sample state-space trajectories and obtain efficient MCMC mixing for SSMs. Particle Markov chain Monte Carlo (PMCMC) algorithms were recently proposed as a solution to this problem (Andrieu, Doucet & Holstein *et al*. 2010). These algorithms utilise sequential Monte Carlo (a.k.a. particle filtering) to generate efficient proposal distributions that enable the sampling of state-space trajectories within standard MCMC routines - an advance that could potentially revolutionize ecological time series analysis. The French National *Culicoides* Surveillance Network has collected more than five million biting midges of 80 different species from 160 sites over 4 to 7 years. We explore the use of PMCMC to fit simple dynamic models to a relatively small subset of this data and attempt to assess the potential of upscaling to an analysis of the entire data set. We fit a number of different models with various levels of biological detail and seek a compromise between biological detail, computation time and predictive power. Implications of our results on ecological forecasting and the relative efficiency of PMCMC algorithms are discussed.

References

ANDRIEU, C., DOUCET, A. & HOLENSTEIN, R. 2010. Particle markov chain monte carlo methods. *Journal of the Royal Statistical Society: Series B (Statistical Methodology*) 72:269–342.