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Modelling the spatial spread of invasive aliens: process-based models and Bayesian inference

Discrete state-space Markov processes provide a remarkably flexible framework both to describe and infer the behaviour of a broad range of systems in epidemiology and beyond. For many models of interest reversible jump Markov chain Monte Carlo methods are a practical approach to implementing statistically sound parameter estimation for such models when, as is typically the case, only partial observations are available. We consider the application of such inference approaches, applied with spatial epidemic models, to describe the spread of invasive species at large spatial scales. In such applications local environmental characteristics determine susceptibility (suitability for the invasive species) which emphasises the role of landscape heterogeneity.

In particular we present a generic Bayesian approach to parameter inference in a grid-based stochastic, spatio-temporal model of dispersal and establishment describing the invasion of a region by an alien plant species. The method requires species distribution data from multiple time points, and accounts for temporal uncertainty in colonisation times inherent in such data. The impact on colonisation suitability of covariates, which capture landscape heterogeneities, is also inferred. The model and inference algorithm are applied to British floristic atlas data for Heracleum mantegazzianum (giant hogweed), an invasive alien plant that has rapidly increased its range since 1970. Using systematic surveys of species distribution across a 10km grid covering the British Isles, we infer key characteristics of this species, predict its future spread, and use the resulting fitted model to inform a simulation-based assessment of the methodology.