Non-stationarity and local approaches to modelling the distributions of wildlife

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ABSTRACT

Despite a growing interest in species distribution modelling, relatively little attention has been paid to spatial autocorrelation and non-stationarity. Both spatial autocorrelation (the tendency for adjacent locations to be more similar than distant ones) and non-stationarity (the variation in modelled relationships over space) are likely to be common properties of ecological systems. This paper focuses on non-stationarity and uses two local techniques, geographically weighted regression (GWR) and varying coefficient modelling (VCM), to assess its impact on model predictions. We extend two published studies, one on the presence–absence of calandra larks in Spain and the other on bird species richness in Britain, to compare GWR and VCM with the more usual global generalized linear modelling (GLM) and generalized additive modelling (GAM). For the calandra lark data, GWR and VCM produced better-fitting models than GLM or GAM. VCM in particular gave significantly reduced spatial autocorrelation in the model residuals. GWR showed that individual predictors became stationary at different spatial scales, indicating that distributions are influenced by ecological processes operating over multiple scales. VCM was able to predict occurrence accurately on independent data from the same geographical area as the training data but not beyond, whereas the GAM produced good results on all areas. Individual predictions from the local methods often differed substantially from the global models. For the species richness data, VCM and GWR produced far better predictions than ordinary regression. Our analyses suggest that modellers interpolating data to produce maps for practical actions (e.g. conservation) should consider local methods, whereas they should not be used for extrapolation to new areas. We argue that local methods are complementary to global methods, revealing details of habitat associations and data properties which global methods average out and miss.

Keywords

GLM, GAM, geographically weighted regression, habitat selection, spatial autocorrelation, varying coefficient modelling.

INTRODUCTION

Interest in building models to predict the distributions of organisms is increasingly popular in applied ecology. General and specific reviews (e.g. Guisan & Zimmerman, 2000; Scott et al., 2002; Gottschalk et al., 2005; Pettorelli et al., 2005), special issues of journals (e.g. Ecological Modelling 2002; Biodiversity and Conservation 2002; Journal of Applied Ecology 2004, this issue of Diversity and Distributions), and international meetings (e.g. Riederalp, Switzerland 2001, 2004; Baeza, Spain, 2005) all attest to the activity of researchers in this field. Progress has been made in laying the ecological foundation for predictive distribution modelling (Austin, 2002) and models have been built to understand niche requirements, for nature conservation, to predict the impacts of land use or environmental change on a species, and to assess the risks of biological invasions. A wide range of techniques (Segurado & Araujo, 2004) has been applied to organisms such as invertebrates, fish, amphibians, lower and higher plants, birds, and mammals.

Application of new techniques and to new situations has outstripped attention to issues of data quality, spatial scale, and meeting the assumptions of the techniques applied. Two issues stand out, spatial autocorrelation and stationarity, both of which interact with spatial scale. Spatial autocorrelation is the tendency for objects that are close together to be more similar than those that are further apart and is a widespread and natural property of ecological systems (Legendre, 1993). Nonetheless, until recently (e.g. Segurado & Araujo, 2004; Luoto et al., 2005) most