Using ecological principles to develop statistical models for the prediction of species' distribution and abundance

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Abstract: The development of statistical models to predict species distribution and abundance continues to play an important role in ecology. The notion that the model should closely reflect underlying scientific understanding has encouraged ecologists to investigate complex statistical methods as they arise. In this study, we used ecological principles to guide the development of a Bayesian hierarchical model that relates multi-scaled environmental variables to the distribution and abundance of a single fish species. The model simultaneously quantified the hierarchy of environmental determinants of species' spatial distribution and spatiotemporal variation in abundance. We illustrate the model with a small-bodied, mobile species, the empire gudgeon (*Hypseleotris galii*), and a larger-bodied, sedentary species, the eel-tailed catfish (*Tandanus tandanus*) in the Mary and Albert Rivers, Queensland, Australia. Sampling occurred at 28 relatively undisturbed locations with local-scale habitat and large-scale environmental variables collected along with fish abundances. The model accounted for greater than 50% of the variation in the distribution and abundance of each species. Empire gudgeon had a distinct spatial distribution within each catchment with a higher probability of presence in mid-elevation reaches than lowland or headwater streams. However, there was considerable temporal variation in its distribution and abundance that could be explained by local-scale environmental variation. In contrast, eel-tailed catfish was present across the entire range of sampling and its abundance tended to co-vary with local-scale variables only. For both species, the extent of spatial autocorrelation was relatively low compared to the distances among sampling reaches. Our findings illustrate how Bayesian statistical modelling can provide a robust framework for statistical modelling that reflects our ecological understanding. This allows ecologists to address a range of ecological questions with a single unified probability model rather than a series of disconnected analyses.