# Incorporating sampling error in the estimation of autoregressive coefficients of animal population dynamics using capture-recapture data

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## Abstract

Population dynamics models combine density-dependence and environmental effects. Ignoring sampling uncertainty might lead to biased estimation of the strength of density-dependence. This is typically addressed using state-space model approaches, which integrate sampling error and population process estimates. Such models seldom include an explicit link between the sampling procedures and the true abundance, which is common in capture-recapture settings. However, many of the models proposed to estimate abundance in the presence of heterogeneity lead to incomplete likelihood functions and cannot be straightforwardly included in state-space models. We assessed the importance of estimating sampling error explicitly by taking an intermediate approach between ignoring uncertainty in abundance estimates and fully specified state-space models for density-dependence estimation based on autoregressive processes. First, we estimated individual capture probabilities based on a heterogeneity model, using a conditional multinomial likelihood, followed by a Horvitz-Thompson estimate for abundance. Second, we estimated coefficients of autoregressive models for the log abundance. Inference was performed using the methodology of integrated nested Laplace approximation (INLA). We performed an extensive simulation study to compare our approach with estimates disregarding capture history information, and using R-package VGAM, for different parameter specifications. The methods were then applied to a real dataset of gray-sided voles *Myodes rufocanus* from Northern Norway. We found that density-dependence estimation was improved when explicitly modelling sampling error in scenarios with low innovation variances, in which differences in coverage reached up to 8% in estimating the coefficients of the autoregressive processes. In this case, the bias also increased assuming a Poisson distribution in the observational model. For high innovation variances, the differences between methods were small and it appeared less important to model heterogeneity.

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