Appendix C: Model sensitivity on data availability.

The complete fitting data set used for the data-rich experiments (see simulated experiments I & II in main text) comprised 20 environmental scenarios in each of which a population was initiated and allowed to grow for 30 simulation years. The distribution of the population in the 2500-cell landscape was recorded each year. To examine the sensitivity of the model's performance on these three types of information (scenarios, years, cells), data impoverishment was performed on each of them separately (i.e. this investigation was univariate, rather than factorial). We repeated the model fitting procedure, each time incrementally reducing the fitting data, such that the new sample size v was a decreasing proportion of the initial sample size V (i.e. $v = V, \frac{V}{2}, \frac{V}{3}, \ldots, \frac{V}{10}$). For example, halving the sample size could be achieved in one of three ways: by keeping 10 out of 20 environmental scenarios, selecting every second year in each population's time series (resulting in 15 years per scenario) or selecting every other cell in the spatial grid data (giving 1250 spatial data per year). From each data-impoverished model fit, we generated predictions of growth rate and carrying capacity for each year of the 100 validation scenarios. Each such annual prediction yielded a residual from the known, true value represented by the validation data. We used these residuals as well as the AIC of each model to compare the performance of the spatial model with that of the mean-field model. We present the results of these manipulations here in three types of figures.

First, to compare the ability of the spatial model to fit the data with the corresponding performance of the mean field model, we plotted the difference of the AIC of the spatial model subtracted from the AIC of the mean-field model (Fig. C1). These differences were consistently positive, indicating that the spatial model achieved a superior quality of fit. The goodness-of-fit of the two models was similar when the number of years available for each scenario was less than 5 (Fig. C1b) and the spatial model failed to converge when there were less than 4 environmental scenarios (Fig. C1c). This was mainly because of the use of Generalised Functional Responses for the calculation of the species distribution model. GFRs require statistical summaries (here, just the means) of the environmental covariates for each environmental scenario. The values of these summaries from each scenario are used as factor levels in the HSF model. If the data contain too few factor levels, some of the interaction coefficients needed by the GFR cannot be estimated.

Second, to compare the ability of the two models to predict the population's growth rate we fitted the models to the impoverished data sets and then generated predictions for the validation data set (comprising 100 new scenarios). We plotted the 95-percentiles from the distribution of residuals, of the models' predictions from the true values in the validation data set (Fig. C2). These plots allow us to inspect both the precision and accuracy of the models' predictions. We found that the spatial model was consistently more precise under impoverishment of spatial cells and years (Figs C2a & C2b). The spatial model was also better for data sets with as low as 10 environmental scenarios (Fig. C2c). Reducing the environmental scenarios further caused the precision of the spatial model to deteriorate rapidly.

Third, to compare the ability of the two models to predict carrying capacities we plotted the 95-percentiles from each model's distribution of residuals (Fig. C3). The results here echoed the pattern displayed by the predictions of growth rate.

We therefore conclude that our method's performance relies most crucially on having sufficient environmental diversity in the data. Lack of environmental diversity implies that the method will not perform well if the species is observed in few distinct environmental scenarios, compared to the number of environmental covariates being considered. The model also displayed some sensitivity on sufficient population data requiring observations at saturated and pre-saturated densities (i.e. replication once at carrying capacity was less informative). Sensitivity on the amount of spatial data was the lowest, as long as there was enough spatial data for an HSF to detect the spatial variations in distribution. Having explored sensitivity in this fashion we specified one depauperate data set that lacked both population and spatial information. In particular, we only used three (first, middle, last) out of the maximum of 30 years from each of 20 fitting scenarios and we kept information on only 125 spatial cells out of a maximum of 2500. This corresponds to a removal of approx. 99.5% of the less crucial information in the data. Although visibly impaired, the spatial model's ability to predict population growth remained higher than the mean-field model's (Fig. 5 in main text, plates e,f). The spatial model's ability to predict carrying capacity remained relatively unaffected by the information loss (Fig. 6 in main text, plates e,f).

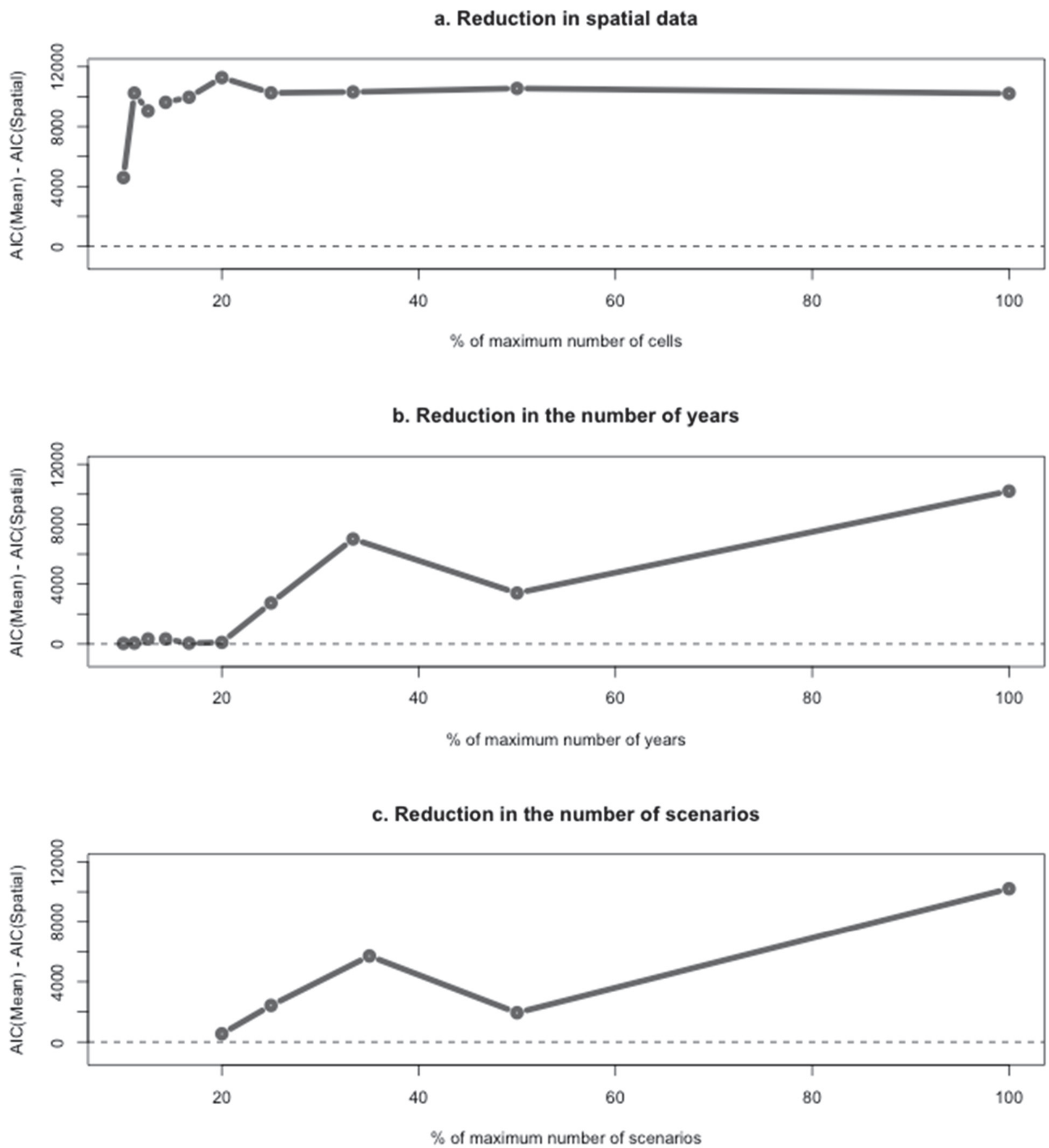

FIG. C1. Difference of the AIC of the spatial model from the AIC of the mean-field model for different manipulations of sample size. The manipulations reduced (a) the number of landscape cells used to estimate the habitat selection functions, (b) the number of years that were sampled from each population and (c) the number of populations (environmental scenarios) examined.

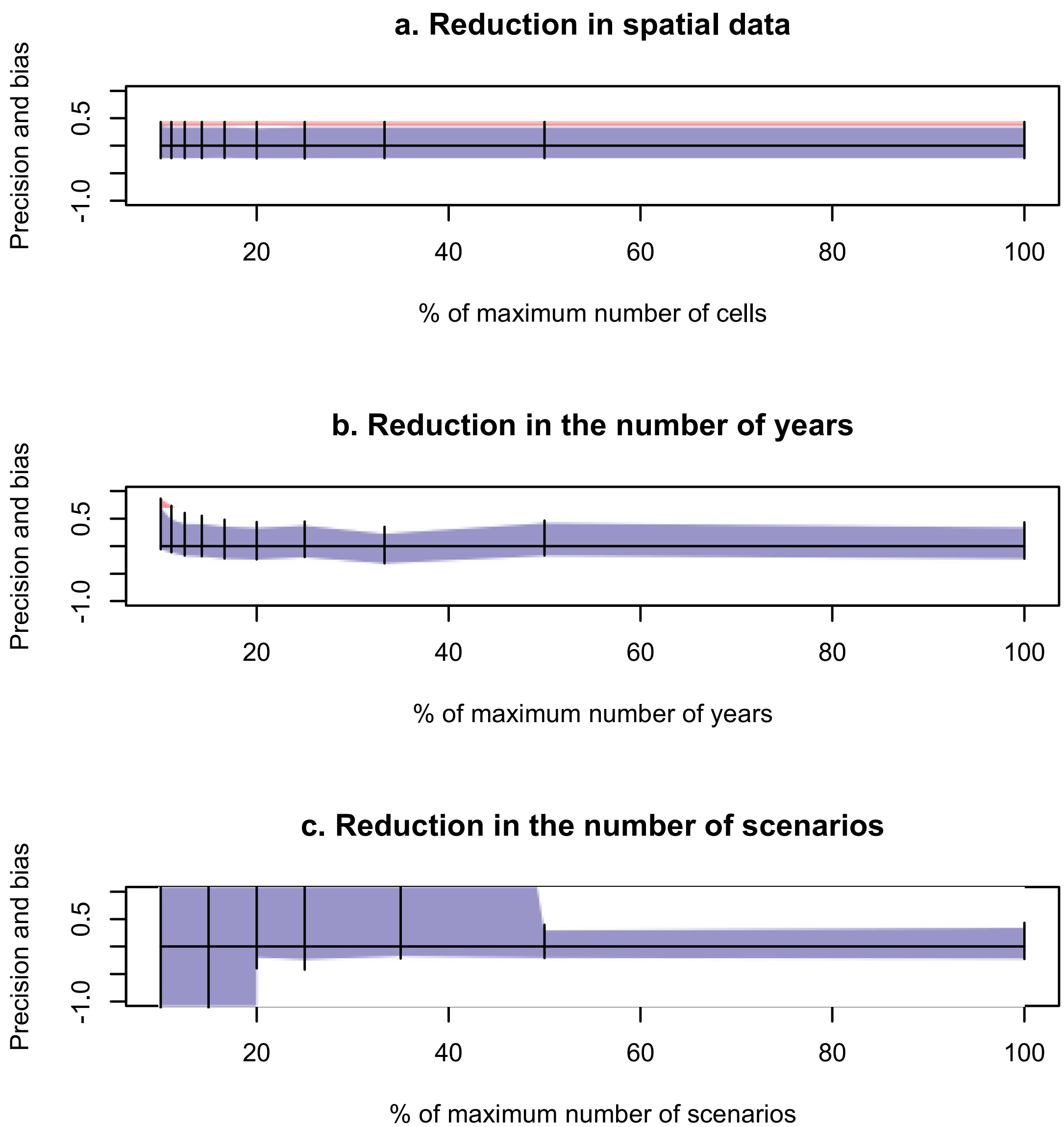

FIG. C2. Comparison of the predictions on population growth rates between the spatial (blue) and mean-field (salmon) models. The 95-percentile zones were derived from the distribution of residuals between the validation data set and the predictions of the two models, under different data-impoverishment manipulations. The manipulations reduced (a) the number of landscape cells used to estimate the habitat selection functions, (b) the number of years that were sampled from each population and (c) the number of populations (environmental scenarios) examined.

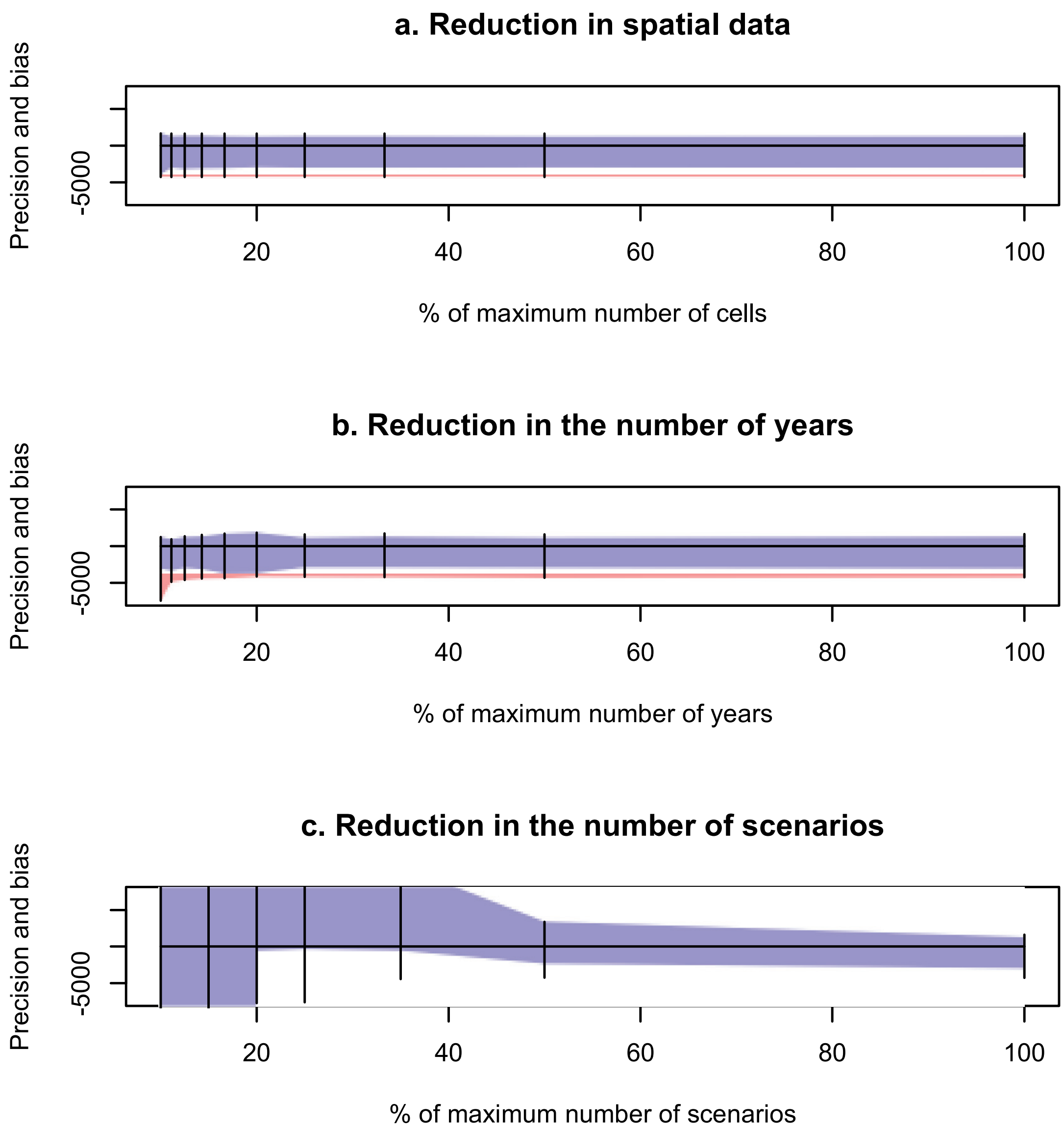

FIG. C3. Comparison of the predictions on population carrying capacities between the spatial (blue) and mean-field (salmon) models. The 95-percentile zones were derived from the distribution of residuals between the validation data set and the predictions of the two models, under different data-impoverishment manipulations. The manipulations reduced (a) the number of landscape cells used to estimate the habitat selection functions, (b) the number of years that were sampled from each population and (c) the number of populations (environmental scenarios) examined.