Modeling assumptions of repeated-visit, single-visit, and integrated occupancy models

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Supporting information of the article *Using single visits into integrated occupancy models to make the most of existing monitoring programs,* in *Ecology.*

Modeling assumptions

In this section we aimed to list the modeling assumptions of the Repeated-Visit (RV), Single-Visit (SV), and Integrated occupancy models that we used.

Repeated-visits occupancy models

There are several critical assumptions for the standard occupancy model, i.e. RV occupancy (MacKenzie 2006).

1. Occupancy status at each site does not change over the survey season; that is, sites are "closed" to changes in occupancy.
2. The probability of occupancy is constant across sites, or differences in occupancy probability are modeled using covariates.
3. The probability of detection is constant across all sites and surveys or is a function of site-survey covariates.
4. There is no unmodeled heterogeneity in detection probabilities.
5. Detection of species and detection histories at each location are independent.

Single-visit occupancy

(Lele, Moreno, and Bayne 2012) underlined that SV occupancy models relax the closure assumption of sampled sites between visits. Besides, the literature about SV provide some requirements and guidance to a valid application of SV occupancy models. We listed the elements below:

1. Occupancy probability and detection probability depend on covariates

2. At least two independent continuous covariates are used to estimate occupancy probability and detection probability. Shared covariates can result in biased estimates for regression coefficients.
3. There should be an adequate numbers of occurrence. (Peach, Cohen, and Frair 2017), suggested that "estimates of occupancy probability remained unbiased across our scenarios, whereas colonization and extinction estimates became biased as occupancy probability approached extremes (i.e. 0.1 or 0.9)."
4. Nonlinear detection model should be preferred to provide accurate parameter estimates and to assume a more realistic relationship between detection and effort (Knape and Korner-Nievergelt 2015).

Integrated occupancy models

Combining multiple datasets into occupancy models have been developed previously by (Nichols et al. 2008) in details for estimating occupancy at two the spatial scales. In our approach, we extended the parametrization of a standard occupancy model detection process to include two different datasets with different detection probabilities. Doing it, our model relies on the following assumption:

- The two monitoring programs are independent, i.e. detection by program 1 does not affect detection probability of program 2, and vice-versa.

Subsequently, integrated repeated-visis occupancy models have the same modeling assumption of both RV occupancy and of integrated occupancy. Similarly, using integrated single-visit occupancy models combine the assumptions of SV occupancy and integrated occupancy.

Table summarizing assumptions for all models

Modeling assumptions	RV occupancy	SV occupancy
Closure assumption, i.e. site does not change over the survey season	Yes	No
Latent occupancy process	Occupancy prob. constant across sites, or modeled with covariates	Continuous covariate needed, **independent from the covariate used for the detection prob.**
Detection process	Detection prob. constant across sites, or modeled with covariates	Continuous covariate needed, **independent from the covariate used for the occupancy prob.**
No unmodeled heterogeneity in detection prob.	Yes	Yes
Detection of species and detection histories at each site are independent	Yes	Yes
Proportion of occurence over the total number of sites is > 10%	No	Yes
Data integration Detection process	**Integrated RV occupancy** Monitoring programs must be independent, or dependency must be accounted for.	**Integrated SV occupancy** Monitoring programs must be independent, or dependency must be accounted for.

Literature cited

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