

"Mixed" occupancy designs: when do single visits add information to multi-visit data?

Occupancy models (OMs) have become popular for assessing species distributions while accounting for detection errors. Most OM applications conduct repeated visits to each site, but numerous surveys and biodiversity monitoring programs choose a more economic, mixed sampling design, where only a subset of sites is visited repeatedly, while the remainder are visited only once. It is not clear, however, whether these single-visit (SV) sites contribute information to occupancy, detection, both or none. To gauge the degree to which such additional data are useful to estimation, we conducted two simulation studies. In both simulation studies, we generated detection/non-detection data from M repeated-visit sites with $J \geq 2$ visits and data from between 0 and 5000 additional SV sites, and varied occupancy (Ψ) and detection (p) probabilities to emulate a wide range of biological and sampling conditions. The amount of information contributed by SV sites was inferred from a change in the precision of the estimates Ψ and \hat{p} as the number of SV sites was increased. In Simulation 1, we fitted intercept-only OMs to three schemes of repeated sampling: 2 visits to 150 sites, 2 visits to 300 sites, and 4 visits to 150 repeated-visit sites. In Simulation 2, we compared the intercept-only model to three models which had one continuous covariate in either occupancy or in detection, or in both, to investigate whether the presence of informative covariates could increase the information content of SV sites in estimation of an occupancy model. Our results indicate that SV sites do, under all conditions tested here, contribute information to the estimation of both Ψ and \hat{p} under a mixed design. Their relative contribution varies depending on the structure of the repeated-visit data and on occupancy and detection probabilities. More information still is provided by inclusion of suitable continuous covariates for occupancy and detection. Our results suggest that greater precision in parameter estimation can be gained by utilizing any available SV data in mixed-design occupancy models to make the best possible assessment of occupancy while correcting for imperfect detection.