313

Know what you don't know: Embracing uncertainty in hidden Markov models

Ecological hidden Markov models, like capture-recapture and dynamic occupancy models, are widely used to describe ecological state processes that are partially or completely unobserved. Multistate models are often of particular interest when researchers are interested in describing the features of different subcomponents of populations or species. Examples in disease ecology include capture-recapture models that describe survival of infected and uninfected individuals. Traditional multistate models assume that states are correctly assigned upon capture, and multievent models were developed to introduce uncertainty about the observed states. However, state assignment errors can occur at more than one level of detection: in a disease context, errors can arise in the sampling process but also in the diagnostic process that these samples are subjected to. Critically, both false-negative and false-positive errors can occur at both levels of detection. In addition, the true pathogen detection rate is likely to be dependent on pathogen load, which induces heterogeneity which can be modeled. We developed an extended multievent capture-recapture model that accounts for errors at two levels of pathogen detection. We illustrate our model with a capture-recapture dataset of an endangered Australian rainforest frog to investigate its susceptibility of the amphibian chytrid fungus. We show that pathogen detection is highly load-dependent resulting in an average of 63% probability of detecting the fungus on a swab, with a false-positive rate of 5%. Failing to account for these sources of error introduces considerable bias in the parameter estimation, including an underestimation of infection prevalence and overestimation of the frequency of infection state transitions. Our model is readily applied to other hidden Markov models, and we recommend accounting for state assignment errors more generally in multistate models.