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An integrated occupancy - abundance model for estimating species interactions

Species occurrence is driven by complex networks of interspecific interactions (e.g. predation, competition, disease) and environmental conditions. Current approaches for examining interspecific interactions through multispecies occupancy modelling are limited by an approach that is focused on co-occurrence. A focus on patterns of co-occurrence restricts inferences on the role of interspecific interactions in driving species occurrence to exceedingly strong interspecific actions resulting in exclusion of one species, which are very rare. A more common scenario exists, where species have strong interactions, however, these are countered by mechanisms for co-existence e.g. fine-scale spatial / temporal avoidance. Thus, we propose an integrated occupancy-abundance model that models the occurrence of one species in response to the abundance of another. We adapt the single-species occupancy model to include one or more nested n-mixture models for interacting species. We propose that a nested design that allows for updating of the n-mixture model with every iteration of the occupancy model greatly improves robustness comparative to applying single values from a separate model as is becoming common practice. As an example, we model a well-studied top-down interaction between an expanding dominant mesopredator; the coyote (Canis latrans) and two smaller native carnivores; the red fox (Vulpes vulpes) and the grey fox (Urocyon cineroargenteus) from a landscape scale camera trap survey conducted between 2013 – 2021 in New York. USA. We compare the outputs of an existing multi-species co-occurrence model with our integrated occupancy-abundance model. We show that whilst a co-occurrence approach reports positive co-occurrence between the coyote and the subordinate species, the integrated occupancy-abundance model demonstrates that high abundance of coyotes lowers the occurrence of the red fox, but not the grey fox, with differences likely due to higher availability of refuges to the arboreal grey fox lowering population-level impacts. Our model has wide applications for investigating the role of interspecific interactions in structuring ecological communities and thereby informing evidence-based management of animal populations where contemporary methods cannot. This approach represents a key improvement in our ability to make community level inferences on the occurrence of species that are subject to imperfect detection.