

Dear Drs. Nathan and Giuggioli,

My colleagues and I are excited to submit this manuscript, “Enhancing hidden Markov models using additional data streams can better track a migratory bird with incomplete or missing GPS data” for consideration at Movement Ecology. Our study focuses on extending hidden Markov models (HMMs) to species which are too small to collect frequent tracking data, which can often cause issues with HMM model fit. Our study species, American Woodcock (*Scolopax minor*) can carry a maximum satellite GPS transmitter size of 4–6 g, providing enough data to characterize migratory movements but impeding our ability to fit those movements using an HMM. We found that, by incorporating additional data streams representing spatial and temporal variables into the HMM (e.g., latitude, ordinal day), we were able to substantially improve classification accuracy, and better characterize woodcock migratory distance, duration, phenology, and the presence of long-distance movements outside of fall and spring migration.

We believe that this HMM-based approach is a widely applicable solution to a common issue in avian studies: classifying tracking data into migratory movements. Prior techniques for doing so have been unable to compensate for overlap between breeding, migratory, and wintering ranges (spatial threshold method) or have been unable to classify a terminal migratory state should the bird stop transmitting before the end of the season (absolute displacement method). In contrast, our method allows classification of migratory movements for species with overlapping seasonal ranges, incomplete or irregular data, and prolonged stopover activity.

Our manuscript also joins a growing number of studies demonstrating how external data streams can be used to supplement sparse tracking data and allow for insights into movement behaviors for small-bodied bird species which are not capable of recording frequent locations. We hope that these insights will help to expand the application of common movement models so that they can be used for a wider range of avifauna.

We believe that this manuscript’s focus on delineating avian migratory movements would be well suited to the audience of Movement Ecology. If there are any questions regarding the submission, please contact me at (703) 888-8284 or at liamaberigan@gmail.com. Thank you for your consideration, and we look forward to hearing from you.

Sincerely,

Liam A. Berigan

Dr. Liam Berigan