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Modeling Aerial Dispersal of Eastern Spruce Budworm Moths During Summer Migration

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Abstract: Unlike passive aerial transport that depends only on wind speed and direction, the aerial dispersal of insects and animals is an interactive process in which the individual expresses agency, both acting on and driven by its environment. Dispersal of birds, bats, and insects may frequently occur in numbers and at scales that are observed with weather radar. Using an individual-based model of dispersal behavior, combined with independent weather model outputs at high spatial and temporal resolution, we developed a methodology by which the resulting flight trajectories are then compared with weather radar observations to calibrate dispersal model parameters. Applied to numerous individuals on a regional domain, the calibrated model can then express emergent results indicating collective aerial migration across a landscape. We applied this approach to model eastern spruce budworm (*Choristoneura fumiferana* [Clem.]) migration events during the current outbreak period in Québec. Our rule-based flight model was developed from decades of empirical aerobiological research and is coupled with an established phenological model, BioSIM. We used the Weather Research and Forecasting (WRF) model to drive high-density agent-based simulations of spruce budworm moth nocturnal dispersal activity over a three-week period in July 2013. Flight model results were calibrated and validated using available weather radar observations in an area centered on the St. Lawrence River. Overall results are consistent with observed regional patterns of spruce budworm dispersal from defoliated areas with known spring feeding activity, and significantly advance our understanding of the spatiotemporal variability and interannual dynamics of the current spruce budworm outbreak in the eastern North American boreal forest. Our quantitative parameter-estimation methodology reduced uncertainty in several flight-oriented biophysical parameters and may have broader application to other species where weather radar observations of dispersal events are available.

Keywords: dispersal, individual-based modeling, eastern spruce budworm, insects, migration