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Modeling aerial dispersal of eastern spruce budworm moths during summer migration

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Abstract

Background/Question/Methods

Passive aerial transport depends only on wind speed and direction, but 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. We have used an individual-based model of dispersal behavior, combined with independent weather model outputs at high spatial and temporal resolution, to generate individual flight trajectories that, in large numbers, can then be compared with weather radar observations to validate and calibrate dispersal model parameters. This rule-based flight model was developed and refined from decades of empirical aerobiological research and is coupled with the BioSIM phenological model. We use high-resolution wind and temperature fields from the Weather Research and Forecasting (WRF v4) model to drive high-density agent-based simulations of nocturnal dispersal activity for the adult eastern spruce budworm (*Choristoneura fumiferana* [Clem.]; SBW) moth. We applied this approach to SBW migration events during the current outbreak period in Québec, specifically during an active three-week period in July 2013 along the lower St. Lawrence River with concurrent weather radar observations at Val d'Irène.

Results/Conclusions

Our model accurately represented flight/no-flight nights as indicated by radar observations in an area centered on the St. Lawrence River over the 2013 period of SBW migration activity, suggesting that our modeled triggers for moth lift-off (temperature range, minimum wind speed, etc.) are generally accurate. On individual nights, modeled SBW migratory flights closely follow development of a nocturnal boundary layer inversion, which can support long-range migration events along and across the St. Lawrence River. Our model trajectories aligned closely with radar observations of both moth concentration and flight direction and allowed us to reduce the uncertainty in several flight-oriented biophysical parameters in the model. Overall, our migratory flight modeling results are consistent with observed regional patterns of SBW dispersal from defoliated areas with known spring feeding activity, and significantly advance our understanding of the spatiotemporal variability and interannual dynamics of the current SBW outbreak in the eastern North American boreal forest. Our quantitative parameter-estimation methodology may have broader application to other species where weather radar observations of dispersal events are available. Applied to numerous individuals on a regional domain, the calibrated model can then express emergent results indicating collective aerial migration across a landscape.

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