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Back-trajectory analysis to understand black cutworm migration in Canada

Biovigilance research is critical to understand and anticipate pest movements, adapt agricultural practices, and improve crop health. Cutworms are part of a pest complex causing damage to a wide range of crops, including migratory species such as *Agrotis ipsilon*, the black cutworm (BCW). Upon arrival, these nocturnal moths oviposit in fields containing weeds or crop residues on the soil surface. Approximately one month later, larvae (**Figure 1**) cause damage to crops.

Supported by numerous studies demonstrating its usefulness in the United States, the Canadian Prairies, and Northern Europe, trajectory modelling of migratory pests such as BCW improves our capacity to estimate their arrival[1, 2]. However, this approach has never been used to predict cutworm infestations in Eastern Canada. In North America, previous studies have shown that BCW migration primarily occurs within the Great Plains low-level nocturnal jet[3] originating from the U.S. Great Plains[4].

The objective of this project was to study BCW migration in Eastern Canada. Winds derived from climate models and moth captures from provincial trapping networks were analyzed to identify wind trajectories and meteorological conditions favorable to moth migration into Canada. This study is part of a broader project aimed at modelling cutworm infestation risk in Canada under climate change scenarios and optimizing control methods.

Methodological and Statistical Approach

Black cutworm migration events in southern Québec and Ontario were investigated using historical meteorological data describing wind back-trajectories, associated climatic conditions, and moth catches from provincial trapping networks over the period 2010–2024. Wind trajectories were generated using the HYSPLIT model and meteorological data from the NOAA Air Resources Laboratory (www.ready.noaa.gov/HYSPLIT.php).

Photo: Laboratoire d'expertise et de diagnostic en phytoprotection – MAPAQ

Figure 1: Black cutworm (BCW) larvae.

More specifically, moth captures (1–7 days trapping periods) were obtained from the Great Lakes and Maritimes Pest Monitoring Network (GLMPMN) since 2019, as well as from the Québec Plant Protection Warning Network (Réseau d'avertissements phytosanitaires – Grandes cultures) since 2010. These data encompass 61 sites over a 15-year period (**Figure 2**). Moths were captured using pheromone-baited Unitrap traps installed near pasture and corn fields.

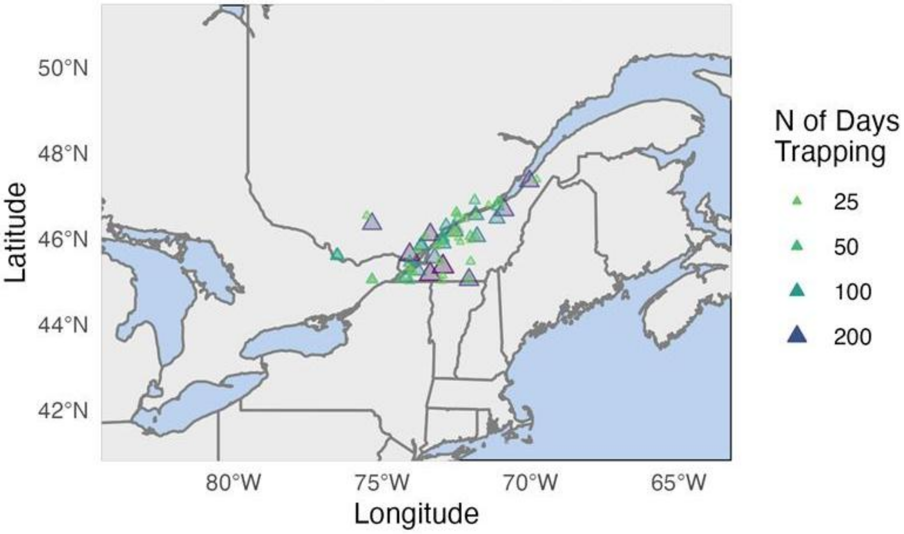

Figure 2: Trapping sites of BCW and total trapping days.

For each site and year, wind back-trajectories were modelled using HYSPLIT over the entire trapping period (i.e., from late April to mid-June). This modelling incorporated constraints related to moth behaviour, including nocturnal flight periods (8:00 PM to 5:00 AM), and limited exposure to precipitation and temperature[5], using two precipitation thresholds (< 0.1 mm/h or 0.5 mm/h) and two temperature thresholds (> 1°C or 5°C)[6, 7], as well as the inability of moths to land over water bodies. For each trapping day at each site, back-trajectories corresponding to three consecutive nights of flight were calculated at arrival altitudes of 200, 300, 400, 500, 600, and 700 m. These altitudes were selected to reflect the probable range of moth flight altitudes within the low-level jet stream[8, 9]. Subsequently, the study area was divided into a grid (60 km² resolution), and trajectories were converted into wind passage frequencies per grid cell, retaining associated capture rates, dates, and meteorological conditions.

A generalized additive mixed model (GAMM) was used to model capture rates associated with winds from different geographic regions and according to the day of the year. This model allows smoothing in three dimensions (x and y coordinates, and day of the year). Smoothing bases approximating a Gaussian process were used to account for spatio-temporal correlation inherent to the trajectories. Interannual variation was included as a random effect. As count data, captures were modelled using a negative binomial (log link) distribution weighted by trapping duration.

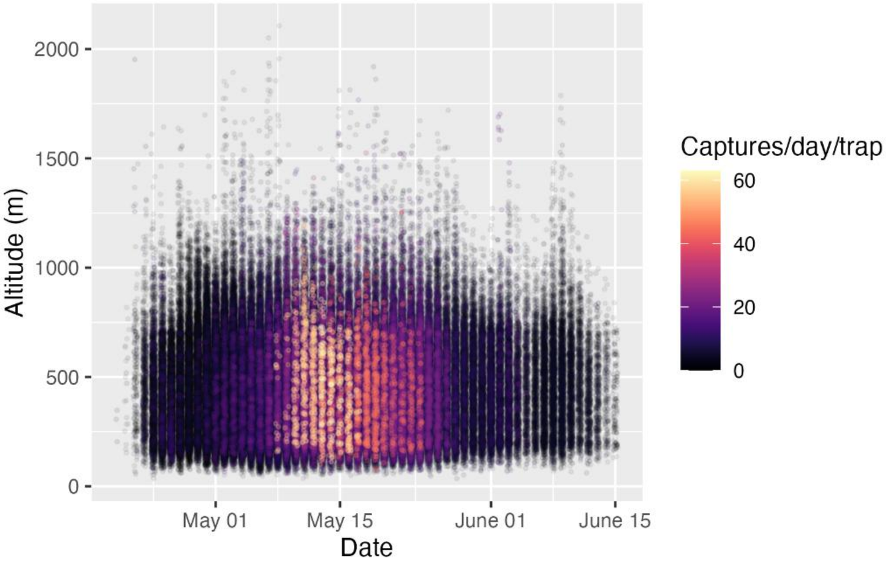

Figure 3: Historical trapping records of BCW (2010 to 2024) by date and backward-trajectory altitude.

Results

Figure 3 illustrates BCW capture rates throughout the season related to back-trajectory altitude. The highest capture values were primarily observed during the second and third weeks of May. Back-trajectory altitudes were mostly below 1000 m, regardless of associated capture rates. This variability is partly explained by the use of six different arrival altitudes in HYSPLIT simulations. It is important to note that these altitudes correspond only to the altitude of air masses at 5:00 AM, rather than their altitude throughout the trajectory.

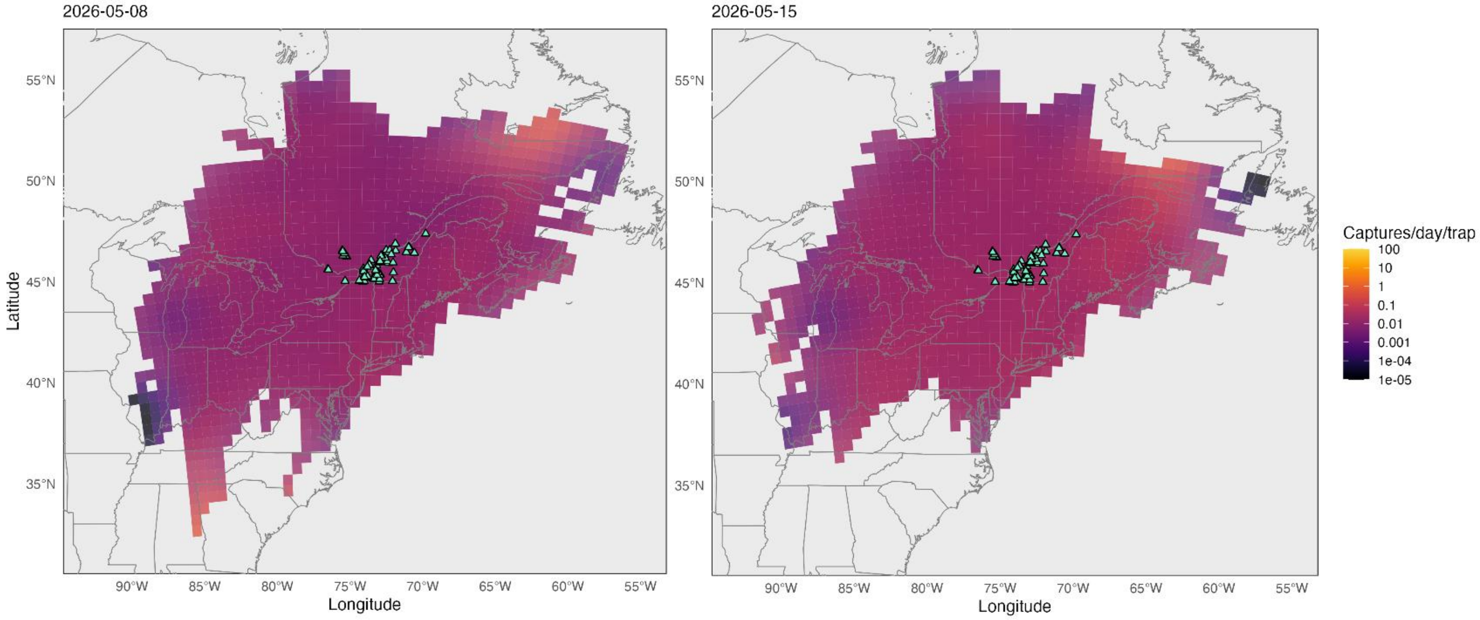

Figure 4: Geographical distribution of back trajectories generated from trapping sites and visualization of daily BCW capture rates per trap. High capture rates in early May are associated with winds originating from the southern United States and the North Shore/Newfoundland and Labrador region (left). In mid-May, slightly elevated capture rates are associated with winds originating from northeastern Québec (right).

The results presented are based on HYSPLIT simulations using thresholds of 0.5 mm/h precipitation and 1°C temperature. When more restrictive thresholds (0.1 mm/h precipitation and 5°C temperature) are applied, the spatial extent of trajectories is slightly reduced, although similar patterns are observed.

The model explained approximately 35% of the deviance, including 16% attributable to interannual variation and 19% to the spatio-temporal component. Deviance is a measure of model fit and would reach 100% for a model perfectly predicting captures. Therefore, for a new year, more than 80% of the deviance remains unexplained. Accurately predicting captures from a single wind event is not feasible using this approach. A large proportion of variation in moth captures remained unexplained in a similar previous study[10].

Nevertheless, our results identified two regions associated with high capture events (**Figure 4**): the southeastern United States and the North Shore/Newfoundland and Labrador region. Winds originating from the south were substantially warmer (21°C; range: 19.5- 24.2°C, min-max) than those from the northeast (2.0°C; -1.5- 4.8°C, min-max). On average, these air masses passed through these regions approximately three days prior to BCW captures, at mean altitudes of 599 m (398- 913 m, min-max) for southern U.S. origins and 497 m (245- 730 m, min-max) for northeastern origins.

The regions identified in our analysis reflect conditions favourable to insect migration toward southern Québec, notably the southeastern United States[8], as well as northerly winds that may indicate atmospheric convergence zones and thus favorable landing conditions[11]. Migratory insects frequently concentrate in regions of airflow convergence (i.e. areas where air masses meet, such as near cold or warm fronts) resulting in localized accumulations of insects[12]. In our case, a meteorological front moving from the North Shore toward southern Québec may indicate such a phenomenon. These winds are typically associated with synoptic configurations involving either a high-pressure system over Labrador or a low-pressure system south of Québec, creating a pressure gradient favorable to southward airflow[13].

Conclusion

Despite the limitations of our model in accurately predicting capture events, our approach identified key wind source regions that contribute to our understanding of BCW migration dynamics. It therefore provides a solid foundation for future research in this field. However, trajectory modelling did not adequately integrated processes associated with the atmospheric boundary layer, particularly those related to the low-level jet originating from the United States, which likely limited model accuracy.

A next step in studying BCW migration would be to integrate synoptic-scale conditions across North America to improve our ability to anticipate meteorological situations conducive to migratory events in agricultural fields. Furthermore, the use of automated traps and daily capture data would represent a significant advancement by reducing uncertainty associated with weekly observations. Integrating such high-resolution data, combined with key meteorological variables and wind forecasts, would enhance our capacity to predict BCW migration events.

Acknowledgements

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Photo credit: Laboratoire d'expertise et de diagnostic en phytoprotection – MAPAQ

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