

Supplementary Information for :

Poor air quality raises mortality in honey bees, a concern for all pollinators

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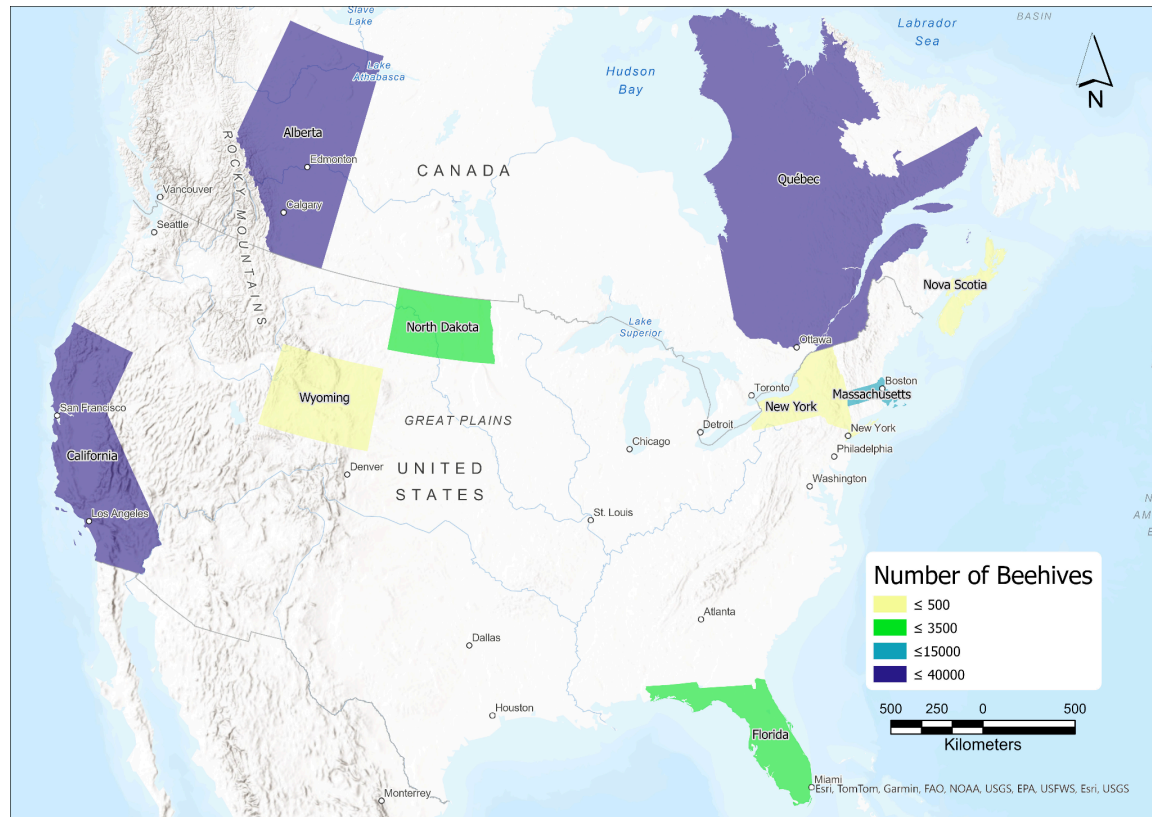
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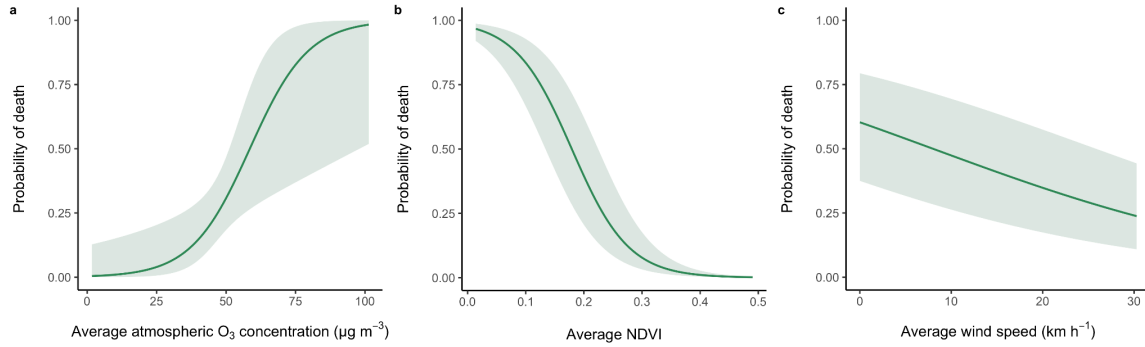
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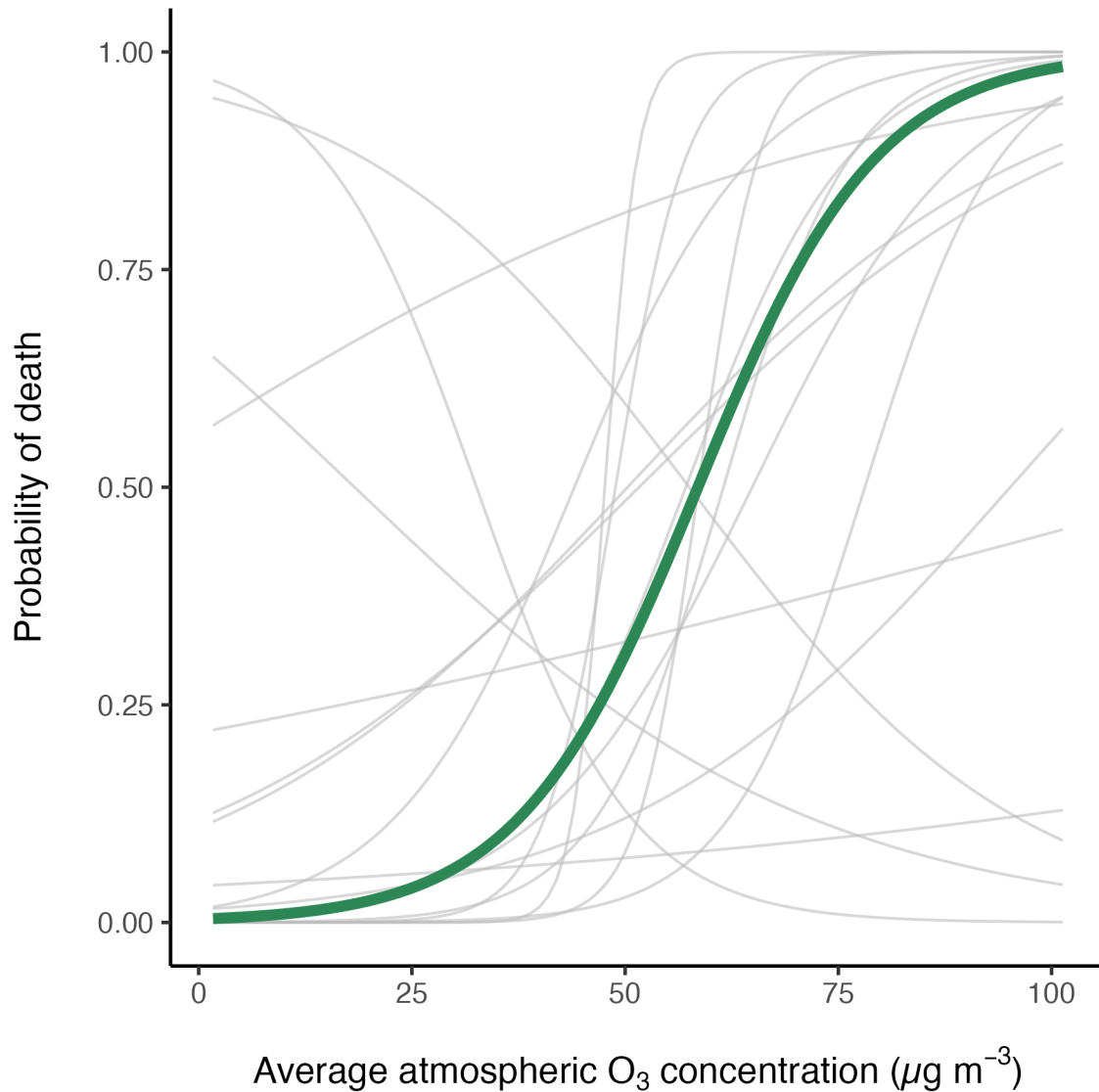
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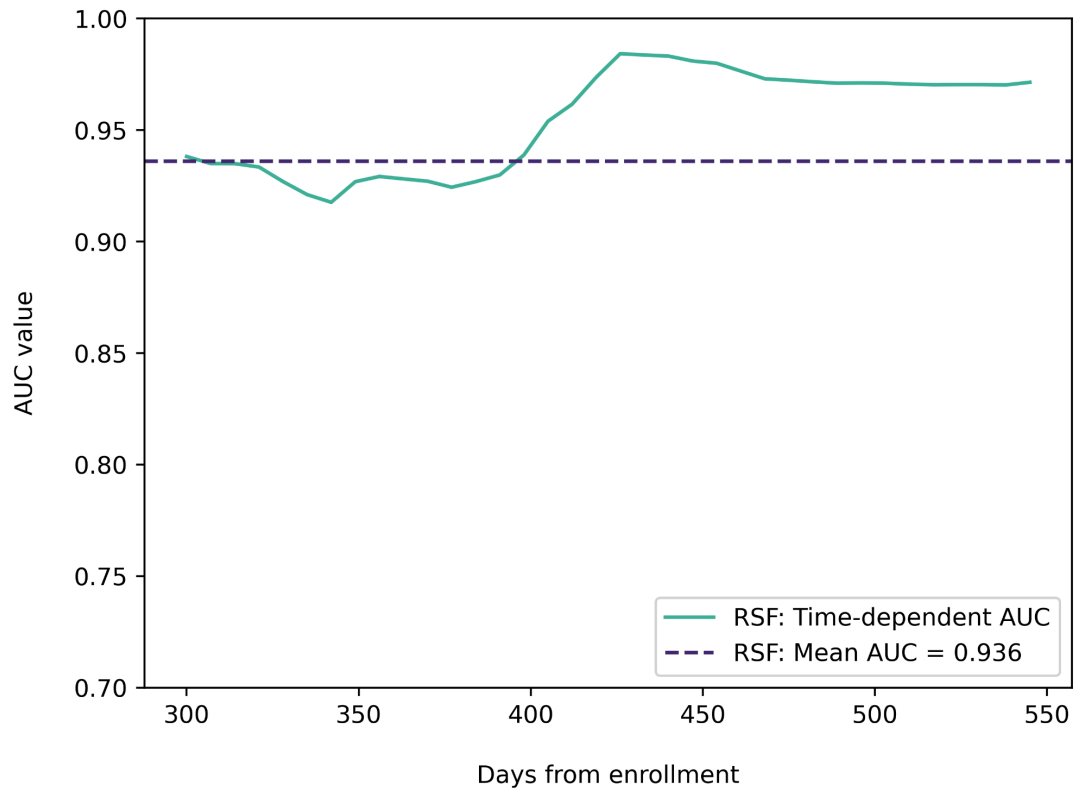
Supplementary Fig. 1 | Map of the bee colony dataset. The dataset of the beekeeping operations was retrieved from a subset of anonymised data of Nectar Technologies Inc. Each colored region represents a Canadian province or American state where beekeeping operations were found. The color gradient shows the number of hives reported for the region, with darker colors indicating a larger amount of hives. The map was generated using ArcGIS Pro version 3.4.



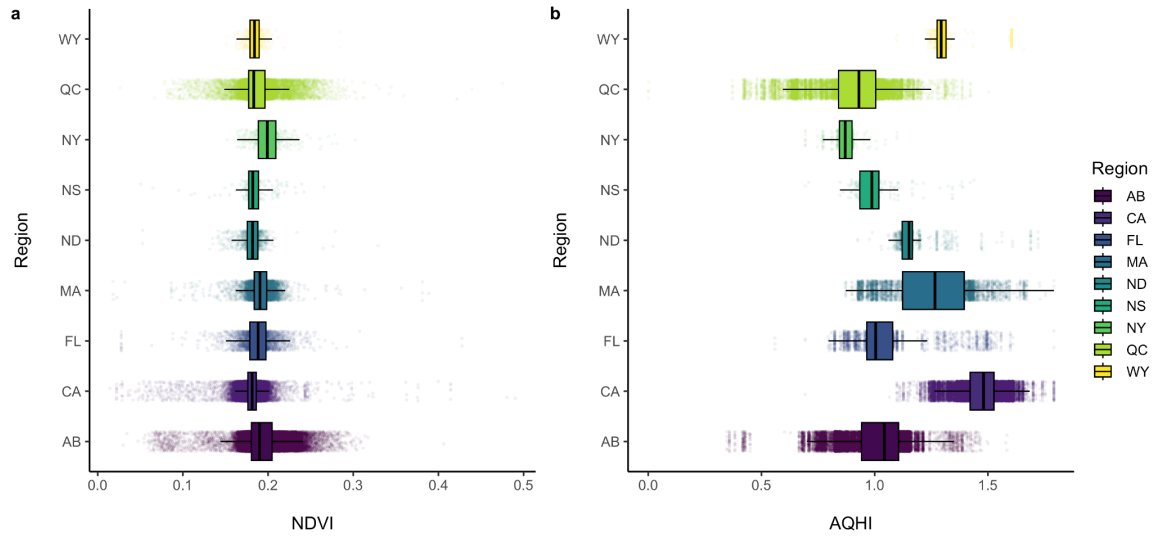
Supplementary Fig. 2 | Fixed effects of the GLMM predicting honey beehive mortality. The predictions were generated while holding other variables at their mean. On each panel, the solid darker (green) lines are the predictions, and the lighter (green) bands represent the 95% confidence intervals. Panel a shows the predictions for ozone concentration, panel b for the average NDVI, and panel c for average wind speed.



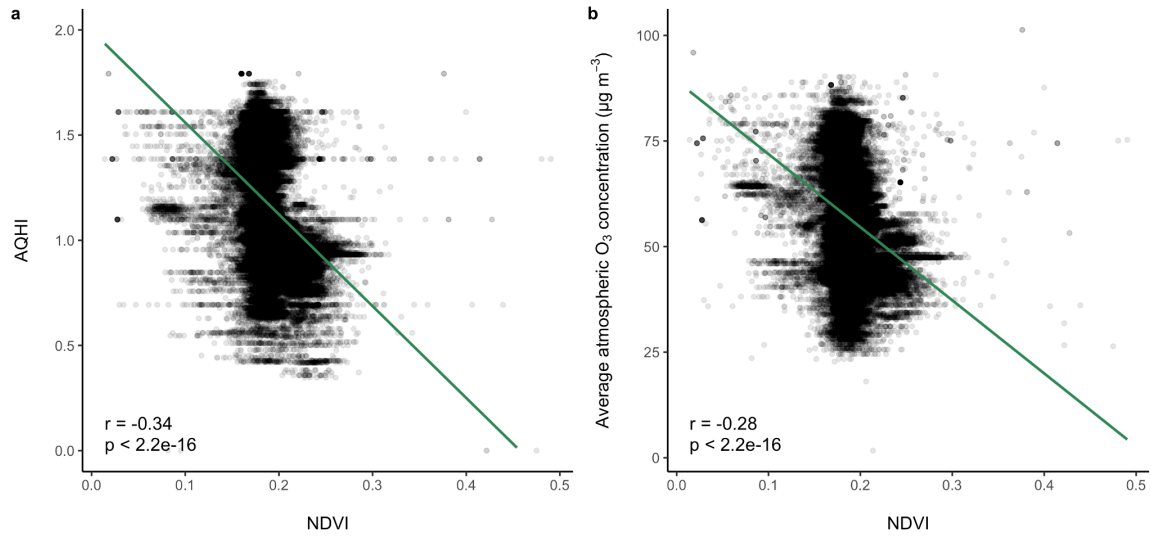
Supplementary Fig. 3 | Reaction norm of the relationship between beehive mortality and the average ozone concentration for each beekeeping operation estimated by the GLMM. The thinner (gray) lines are the reaction norms for each beekeeping operation (random effects), and the overlaid (green) thicker line is the mean trend estimated by the model (fixed effect). We can distinguish different patterns as we allow the intercepts and slopes to vary for each beekeeping operation.



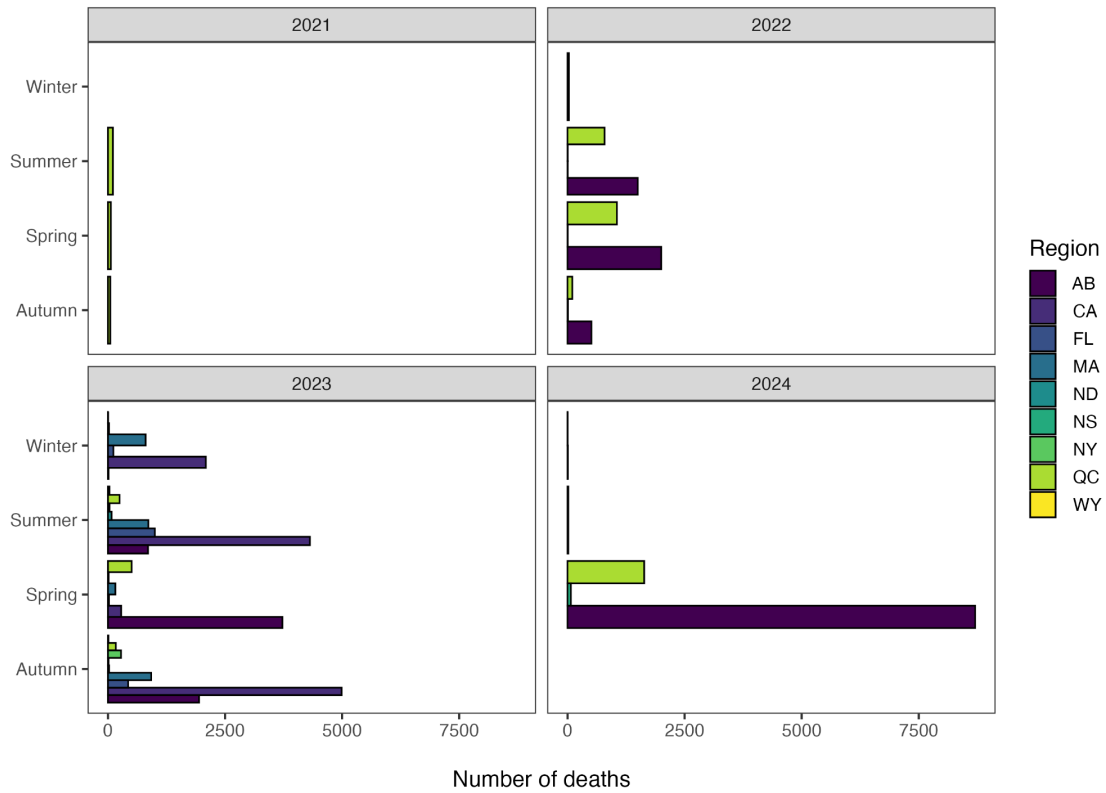
Supplementary Fig. 4 | Cumulative-dynamic area under the curve (AUC) assessing the discriminatory power of the Random Survival Forest on hold-out data. The solid line shows how AUC values change over time, indicating the model's ability to discriminate between bee colonies that will experience mortality or not at any given point in time.



Supplementary Fig. 5 | Regional variation in vegetation availability (NDVI) and air quality (AQHI). Regions displayed include Alberta, California, Florida, Maine, North Dakota, Nova Scotia, New-York, Québec, and Wyoming. For Canadian provinces, we see that mortality often occurs in spring after hive overwintering as beekeepers count deaths before starting a new season.



Supplementary Fig. 6 | Relationship between air quality variables and vegetation availability (NDVI). Panel a shows the relationship between the AQHI and the NDVI. Panel b shows the relationship between the average ozone concentration and the NDVI. The correlation coefficient is displayed on the lower left part of each plot alongside the p-value of a t test assessing the correlation's statistical significance.



Supplementary Fig. 7 | Raw counts of beehive mortality by season for each region. Regions displayed include Alberta, California, Florida, Maine, North Dakota, Nova Scotia, New-York, Québec, and Wyoming. For Canadian provinces, we see that mortality often occurs in spring after hive overwintering as beekeepers count deaths before starting a new season.

Supplementary Table 1 | AIC table comparing the predictive accuracy of the 33 generalized linear mixed models relating beehive mortality to environmental predictors. Number of observations: 112 616. We used model 33 (in bold) as it had the lowest AIC, and we were interested in assessing the effect of each environmental variable on the beehive mortality, including the random effects that the air quality can have over the different beehive locations.

Model	AIC	Convergence	Model	AIC	Convergence
1	142 319.24	Yes	18	129 511.73	Yes
2	138 946.96	Yes	19	139 831.76	Yes
3	138 683.27	Yes	20	139 113.90	Yes
4	136 834.70	Yes	21	138 032.51	Yes
5	136 833.73	Yes	22	137 998.78	Yes
6	139 108.91	Yes	23	139 958.98	Yes
7	136 885.23	Yes	24	139 864.78	Yes
8	139 088.12	Yes	25	130 636.42	Yes
9	132 924.32	Yes	26	130 534.66	Yes
10	131 344.03	Yes	27	139 396.11	Yes
11	132 965.33	Yes	28	139 323.59	Yes
12	131 367.32	Yes	29	132 148.43	Yes
13	131 364.94	Yes	30	129 405.30	Yes
14	132 775.43	Yes	31	129 319.58	Yes
15	132 762.65	Yes	32	129 195.62	Yes
16	131 268.60	Yes	33	129 054.58	Yes
17	129 516.06	Yes			