Eva Grigorovsky , Jem Barrett, Jessica Underwood, Santhija Jegatheeswaran
EEB313 - Group G

# Exploring the Dynamics of Emerald Ash Borer Presence in Ontario

**Abstract:**

The Emerald Ash Borer (EAB) is an invasive insect species that decimates North American ash species. Research into how environmental factors such as time, ecosystem, and temperature promote their spread is limited. This study will examine trends in EAB detection over time, community type, and temperature using a dataset that combines EAB surveillance data from 2002 to 2020, Stats Canada census data, and historical weather data. By fitting the data to several generalized linear models, we concluded that EAB detection was higher in rural communities compared to urban and that EAB presence was more likely in communities with higher average annual temperatures. Understanding these factors is key in developing targeted strategies for EAB management while highlighting the influence of climate change and human-mediated spread.

## Introduction:

Invasive species are defined by their ability to negatively impact invaded environments in addition to their high fecundity (Koh et al., 2013; Rogers, 2018).The emerald ash borer (EAB, *Agrilus planipennis,* Buprestidae family) is a highly fecund invasive wood boring beetle species from northeast Asia that was accidentally introduced into North America in 2002 (Cappaert et al., 2005). Since detection in Windsor Ontario, EAB has spread to five Canadian provinces with the potential to spread nationwide (Butler et al., 2022). Buprestidae typically attack stressed trees, though EAB have been recorded colonizing healthy ash trees (*Fraxinus spp.*) (Muilenburg & Herms, 2012). This is concerning as *Fraxinus spp.* is a widely distributed species that is popular in urban environments and all species are susceptible to EAB invasion (Herms & McCullough, 2014). Larval EABs tunnel within host trees and feed on the phloem, with 2-3 years of repeated attacks leading to tree mortality (Cappaert et al., 2005). Adult EAB emergence leaves distinctive D-shaped exit holes (Herms & McCullough, 2014). To date, EAB damage has devastated millions of ash trees in Ontario, and resulted in 1.4 billions of dollars in loss (Herms & McCullough, 2014; Hope et al., 2020). Despite numerous studies on the EAB, there remains a gap in Canadian EAB detection studies. Due to the pressing ecological and economic consequences, this study aims to better understand patterns of EAB detection, such as time, locality, and temperature in Ontario. To do so, this study utilizes Canadian EAB surveillance data in addition to census information and historical weather data.

Specifically, we test three hypotheses for EAB detection in Ontario communities; 1) time, in years, impacts the detection of EAB, 2) differences in urban and rural populations impact the detection of EAB, 3) differences in temperature impact the detection of EAB. Since EAB is a highly fecund species (Rutledge & Keena, 2012), we'd expect to see more detections as time progresses due to the increased adult population. Additionally, due to the prolific distribution of *Fraxinus spp.* in rural areas compared to urban, we'd expect to see more detection in rural communities (Herms & McCullough, 2014). Lastly, since higher temperatures can accelerate life history traits, we would expect more EAB detections in communities with warmer average temperatures (Butler et al., 2022).

## Methods:

### *Data Description*

This study uses a dataset composed of EAB surveillance data across Canada from the years 2002 to 2020 (obtained from (Government of Canada, 2017), Table 1). Two additional columns were manually added; community type and average temperature. The first denotes a community as urban or rural based on 2021 census information (Statistics Canada, 2022a) in combination with Statistics Canada's definition of population centres (Statistics Canada, 2022b). The second contains historical annual average temperatures in degrees celsius for each community in the first year it appears in the EAB survey (obtained from ClimateData.ca, 2023). We then subsetted this dataset to include only Ontario communities with more than 10 observations from 2002-2020, after which 92 communities remained.

*Data Analysis*

Since the results are binary, the data was fitted to various generalized linear models using a binomial distribution. Separate models were created for regression of result on year, year and community, longitude, latitude, community type, average annual temperature, as well as the interactions between some of these variables (Table 2). We ran ANOVAs on some GLMs to check they were representative of the data (Table 3). For more details on statistical analysis, see supplemental RScript in the Appendix.

**Results**

*EAB Detection Over Time*

Fitting a logistic regression of result on year revealed that the odds of EAB detection increased by 7% every year ($P < 0.001$). Upon graphing our observations, it became evident that there was sampling bias both for year (Fig. 1a) and community (Fig. 1b).

*EAB Detection By Community Type*

After we confirmed visible trends between the geographical coordinates of the observations and EAB detection (Fig. 2a), community type (Fig. 2b), and average annual temperature (Fig. 2c), we fitted a logistic regression of the result on community type. It revealed that the odds of EAB detection in urban communities decreased by 81% compared to rural communities ($P < 0.001$). However, we found that despite rural communities having more observations, both community types had a similar number of EAB detections (Fig. 3a). The data showed little significant trends when plotted (Fig. 3b, 3c).

*Temperature Impact on EAB Detection*

Fitting a logistic regression of result on average annual temperature showed that the odds of EAB detection decreased by 22% with each degree Celsius increase in temperature ($P < 0.001$). On the other hand, we observed that EAB detections were more common in communities with higher average annual temperatures (Fig. 4a).

**Conclusion/Implications:**

In conclusion, our study emphasizes the observer bias in sampling and the need for investment in standardized surveillance methods. As time progressed, observations declined, and the focus shifted to specific communities. As a consequence, rural communities are at higher risk of EAB outbreaks due to limited funding and government priority (Rangi, 2018). It is necessary to highlight this bias to ensure the preservation of ash trees in all regions.

The results of the study highlight the implications for assessing the effectiveness of our current EAB management strategies involving firewood production and quarantine of infected sites, understanding the impact of climate change on EAB populations, evaluating human-mediated EAB spread, and recognizing the public health and environmental consequences of EAB infestations, including rises rates of respiratory illness and air pollution (Donovan et al., 2013). Improvements in targeted interventions, regulations, and policy decisions to help control the spread of EAB and preserve ash tree species and public health in Ontario communities are needed (Johny et al., 2012; Butler et al., 2022).

**References (APA):**


Butler, S., Dedes, J., Jones, G., Hughes, C., Ladd, T., Martel, V., Ryall, K., Sweeney, J., & MacQuarrie, C. J. K. (2022). Introduction and establishment of biological control agents for control of Emerald Ash Borer (agrilus planipennis) in Canada. *The Canadian Entomologist*, 154(1). https://doi.org/10.4039/tce.2022.32

Cappaert, D., McCullough, D. G., Poland, T. M., & Siegert, N. W. (2005). Emerald ash borer in North America: A research and regulatory challenge. *American Entomologist. 51(3), 152-165.*, *51*. https://www.fs.usda.gov/research/treesearch/13648

Donovan, G. H., Butry, D. T., Michael, Y. L., Prestemon, J. P., Liebhold, A. M., Gatziolis, D., & Mao, M. Y. (2013). The relationship between trees and human health. *American Journal of Preventive Medicine*, 44(2), 139–145. https://doi.org/10.1016/j.amepre.2012.09.066

Government of Canada. (2017). CFIA Observations of EAB: Government of Canada, Emerald Ash Borer Surveillance Data 2002-2020, Canadian Food Inspection Agency. [online] https://open.canada.ca/ data/en/dataset/69f4ecd8-9761-4d40-b0f9-e186f2fcce5b.

Herms, D. A., & McCullough, D. G. (2014). Emerald Ash Borer Invasion of North America: History, Biology, Ecology, Impacts, and Management. *Annual Review of Entomology*, *59*(1), 13–30. https://doi.org/10.1146/annurev-ento-011613-162051

Hope, E., Sun, L., McKenney, D., Bogdanski, B., Pedlar, J., MacDonald, H., & Lawrence, K. (n.d.). *Emerald Ash Borer, Agrilus planipennis: An Economic Analysis of Regulations in Canada*.

Johny, S., Kyei-Poku, G., Gauthier, D., Frankenhuyzen, K. V., & Krell, P. J. (2012). Characterization and virulence of Beauveria spp. recovered from emerald ash borer in southwestern Ontario, Canada. *Journal of Invertebrate Pathology*, 111(1), 41–49. https://doi.org/10.1016/j.jip.2012.05.008

Koh, L. P., Kettle, C. J., Sheil, D., Lee, T. M., Giam, X., Gibson, L., & Clements, G. R. (2013). Biodiversity State and Trends in Southeast Asia. In *Encyclopedia of Biodiversity.* 509–527. Elsevier. https://doi.org/10.1016/B978-0-12-384719-5.00357-9

Muilenburg, V. L., & Herms, D. A. (2012). A review of bronze birch borer (Agrilus anxius, Coleoptera: Buprestidae) life history, ecology, and management. *Environ. Entomol.* 41, 1372–85.

Rangi, D. (2018, September). *Invasive species: The hidden threat to sustainable development. CABI.org*. https://www.cabi.org/cabi-publications/invasive-species-the-hidden-threat-to-sustainable-development/

Rogers, W. E. (2018). Invasive Species. In D. A. Dellasala & M. I. Goldstein (Eds.), *Encyclopedia of the Anthropocene.* 273–280. Elsevier. https://doi.org/10.1016/B978-0-12-809665-9.10295-2

Rutledge, C. E., & Keena, M. A. (2012). Mating frequency and fecundity in the emerald ash borer Agrilus planipennis (Coleoptera: Buprestidae). *Annals of the Entomological Society of America. 105(1): 66-72.*, *105*, 66–72.

Statistics Canada. (2022a). Illustrated Glossary: Population centre (POPCTR). *https://www150.statcan.gc.ca/n1/pub/92-195-x/2021001/geo/pop/pop-eng.htm*

Statistics Canada. (2022b). Population and dwelling counts: Canada and population centres.. *https://www150.statcan.gc.ca/t1/tbl1/en/tv.action?pid=9810001101*

# EEB313 Project Figures and Tables

Group G (Eva Grigorovsky, Jem Barrett, Jessica Underwood, Santhija Jegatheeswaran)

## Table 1: Description of EAB Data Variables

| Variable_Name | Variable_Description | Units | Type |
|---|---|---|---|
| Latitude | Latitudinal position of observational site | degrees (°) | Numeric |
| Longitude | Latitudinal position of observational site | degrees (°) | Numeric |
| Year | Year of sampling | N/A | Numeric |
| Community | Communities of Ontario that were surveilled for EAB presence (n=92) | N/A | Categorical |
| Community Type | Characterized each Ontario community as either rural or urban | N/A | Categorical |
| Avg Temp | Average annual temperature for each Ontario community | degree Celsius (°C) | Numeric |
| Result | EAB presence denoted in the dataset as detected or not detected | N/A | Categorical |

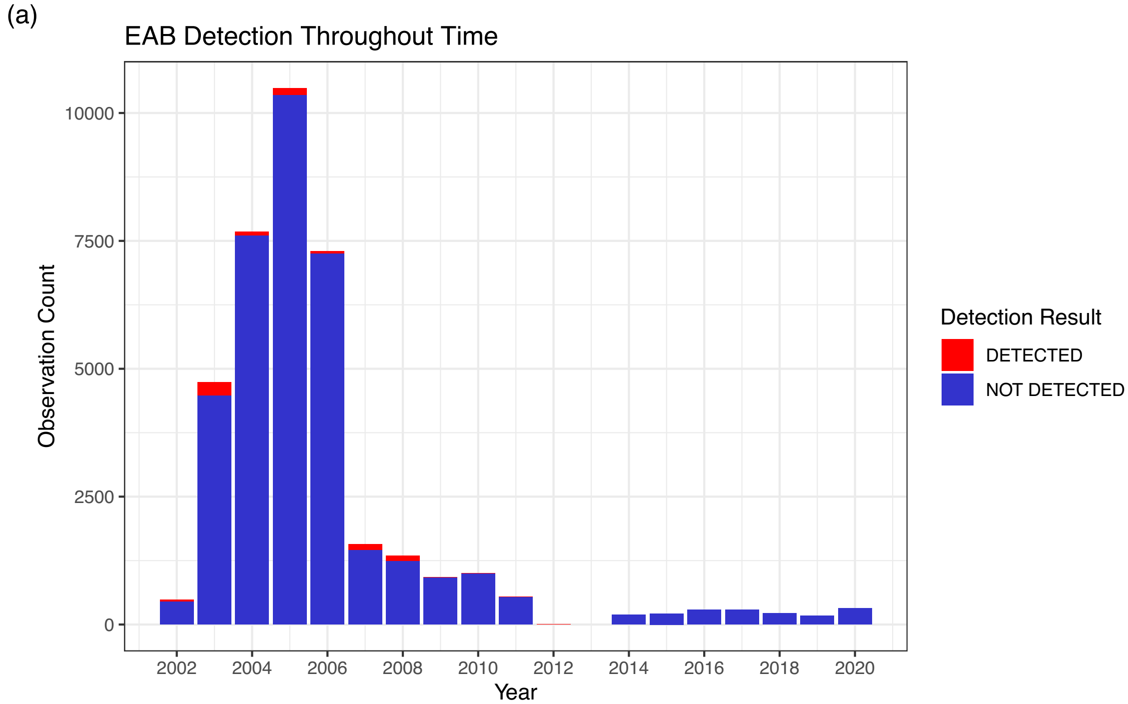
**Table 2. Results from the summaries of the GLM models constructed.**

| Model_Description | GLM | Statistical_Significance | P_Value | Model_AIC |
|---|---|---|---|---|
| 1: The effect of time on EAB detection. | glm(as.factor(result)~ year, family = binomial, data = ont_eab_data) | Yes | 0.8*10−7 | 8152.5 |
| 2: The effect of time, community, and their interaction on EAB detection. | glm(as.factor(result)~ year*community, family = binomial, data = ont_eab_data) | No | 0.997−1.00 | 6391 |
| 3: The effect of community type on EAB detection. | glm(as.factor(result)~ community_type, family = binomial, data = ont_eab_data) | Yes | <2*10−16 | 7656.8 |
| 4: The effect of temperature on EAB detection. | glm(as.factor(result)~ avg_temp, family = binomial, data = ont_eab_data) | Yes | <2*10−16 | 8048.4 |
| 5: The effect of temperature and community on EAB detection. | glm(as.factor(result)~ avg_temp + community, family = binomial, data = ont_eab_data) | 2 out of 92 communities were statistically significant. Average temperature was not. | <2*10−16 | 6806.3 |
| 6: The effect of temperature, community type and their interaction on EAB detection. | glm(as.factor(result)~ avg_temp * community_type, family = binomial, data = ont_eab_data) | Community type was statistically significant. The interaction between temperature and community type was statistically significant. Temperature alone was not. | 0.000183 (community type) 7.74*10−16 (interaction) 0.171271 (temperature) | 7343.5 |

**Table 3. Results from post hoc ANOVAs (test = "Chi") on GLM models that included individual communities.**

| Model_Description | Variables_Assessed | Associated_P_Values |
|---|---|---|
| 2: The effect of time, community, and their interaction on EAB detection. | Time<br>Community<br>Interaction | 8.3*10−8<br><2*10−16<br><2*10−16 |
| 5: The effect of temperature and community on EAB detection. | Average temperature<br>Community | <2.2*10−16<br><2.2*10−16 |

# Figure 1: EAB Data Visualizations



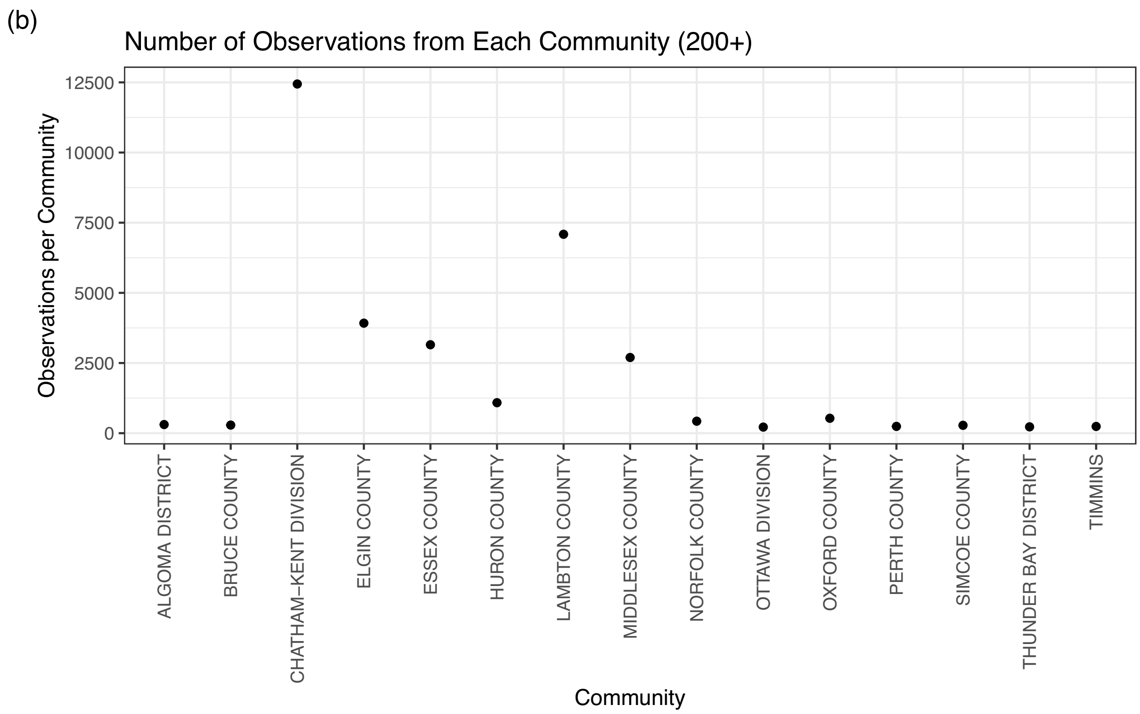
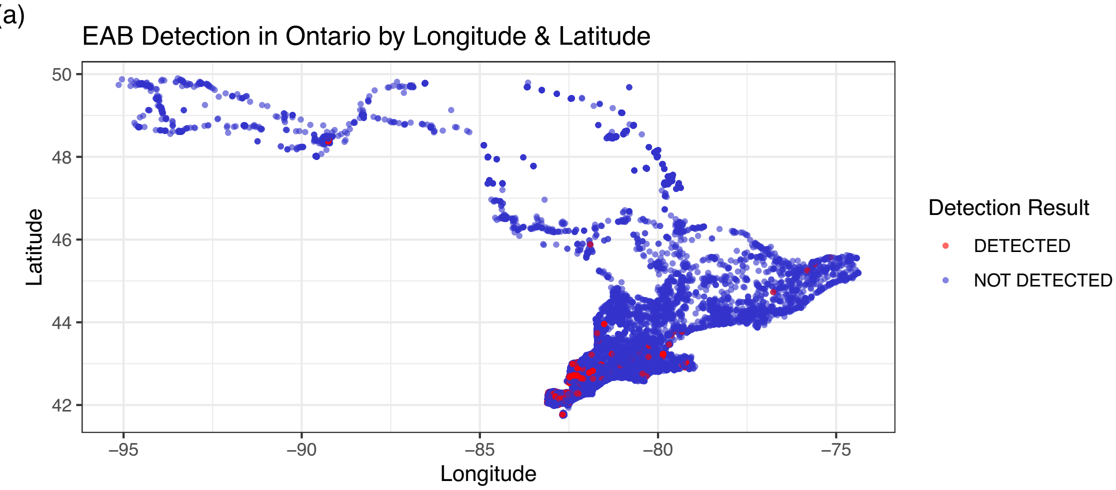



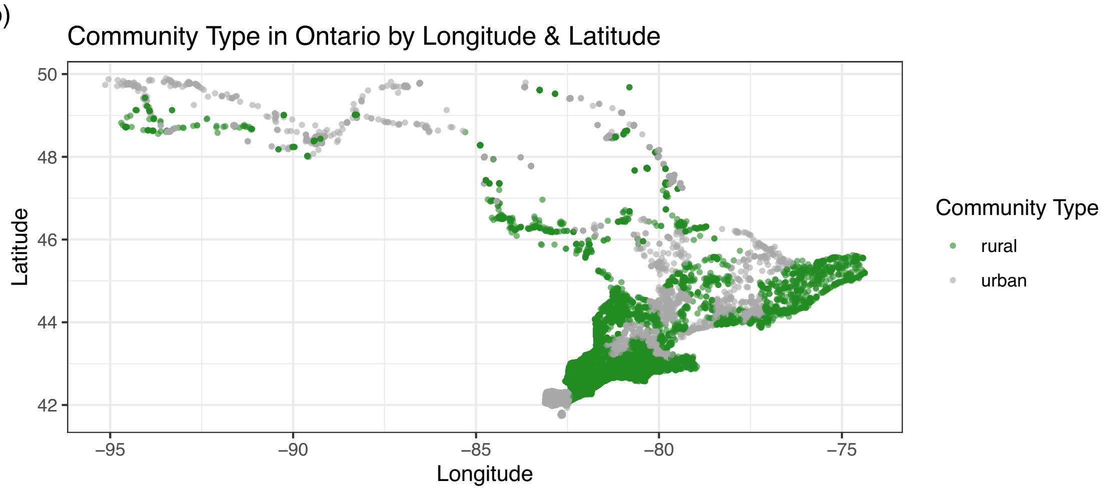

Fig. 1. Visualizing the EAB Data (a) Graph of EAB detection over the years, colour−coded by whether EAB were detected or not for each observation. Note how the number of total observations decreases sharply after 2006 and the number of EAB detections are barely visible given the high number of undetected observations, and (b) Number of observations plotted for communities with 200 or more observations to observe which communities carry the data. Note Chatham−Kent Division has more observations then the rest of the communities, with approximately 12,500 observations out of the total 37,801 observations in our data.

# Figure 2: Longitude and Latitude

(a)




(b)




(c)

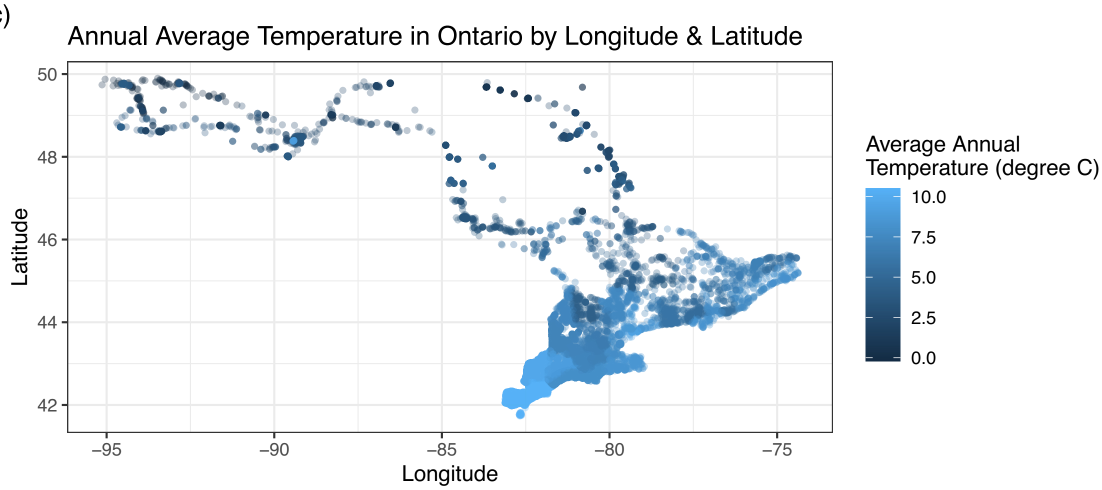


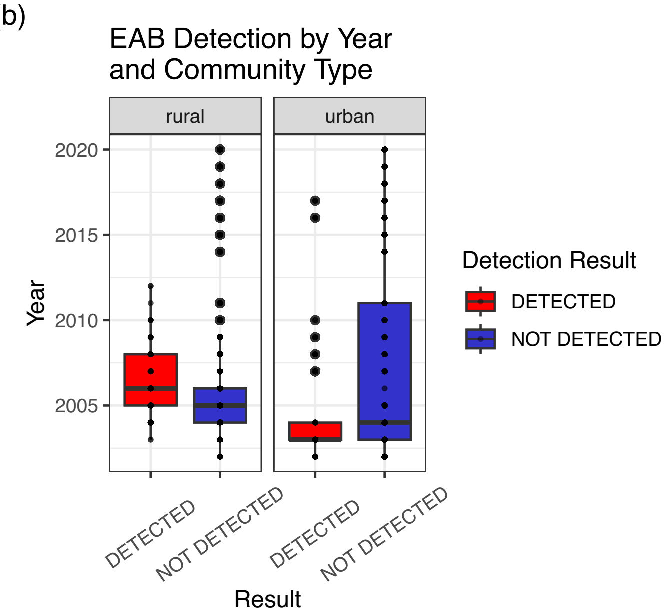

Fig. 2. Visualizing influence of geographical coordinates of observations on (a) EAB detection, (b) community type, and (c) average annual temperature. The longitude and latitude of EAB detections were found to be statistically significant to community type (GLM $P < 0.001$) and average annual temperature (GLM $P < 0.001$) of the communities. Note how EAB detections are clustered in southern Ontario, where we can observe more rural communities and higher average annual temperatures.

## Figure 3: Community Type and EAB Detections

(a)

| | DETECTED | NOT DETECTED |
|---|---|---|
| *rural* | 430 | 31175 |
| *urban* | 426 | 5770 |

(b)




(c)

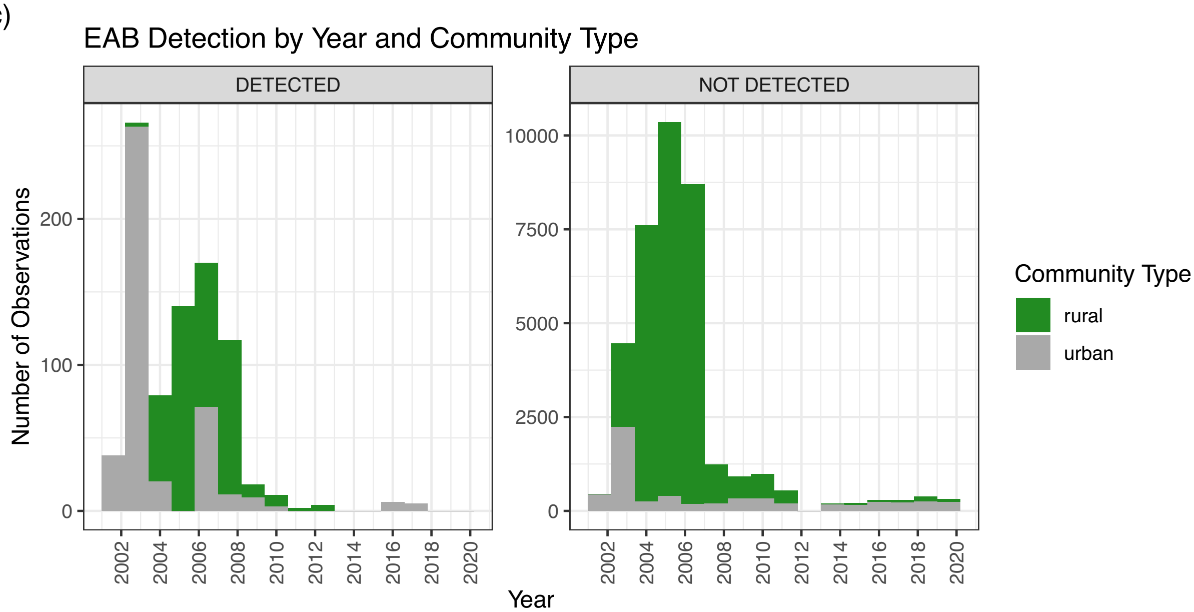



Fig. 3. (a) Number of EAB detected vs not detected for urban and rural community types, (b) boxplot showing EAB detection over the years for each community type, and (c) histogram of observations over the years sorted by community type and whether EAB were detected or not. Note how in the boxplot, the number of EAB detections in rural communities lasts for several years whereas EAB detections in urban communities last a shorter time.

## Figure 4: Temperature and EAB Detections

(a)

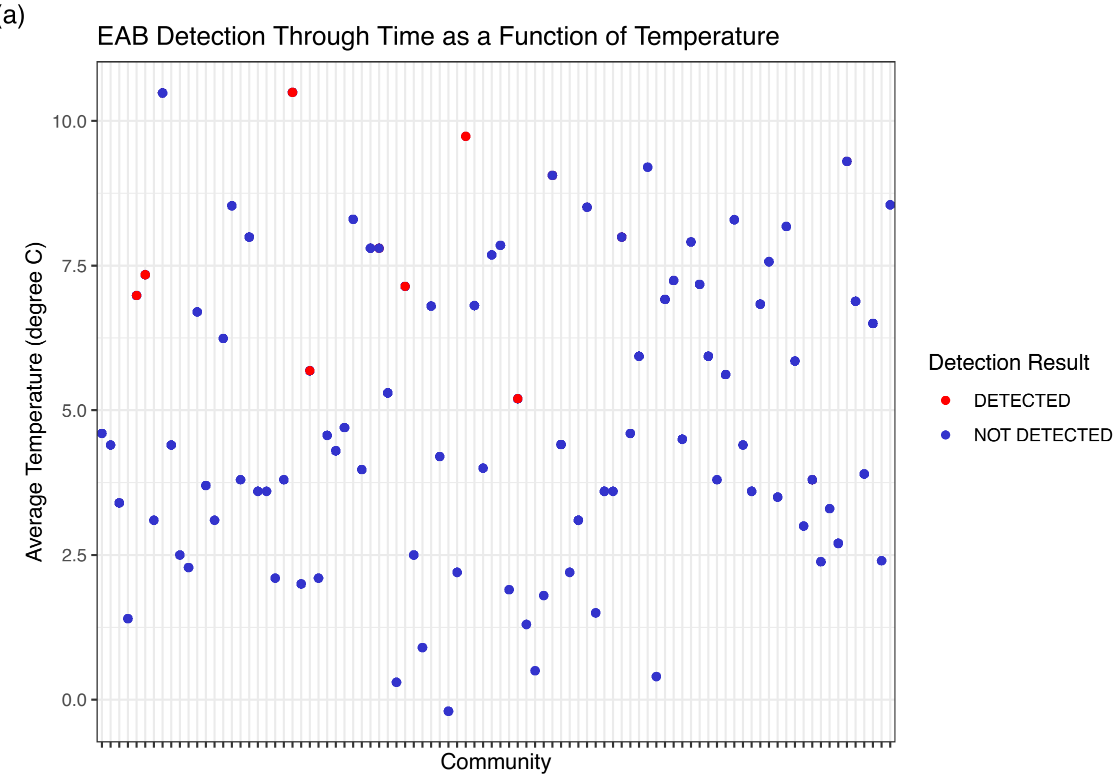



Fig. 4. (a) Comparison of average annual temperatures for the Ontario communities with EAB detections coloured in red. Communities with higher average annual temperatures were more likely to have EAB detections, and as the average temperature decreases, EAB detections become sparser.