Dynamical modeling of mosquito population in Peel Region with weather conditions

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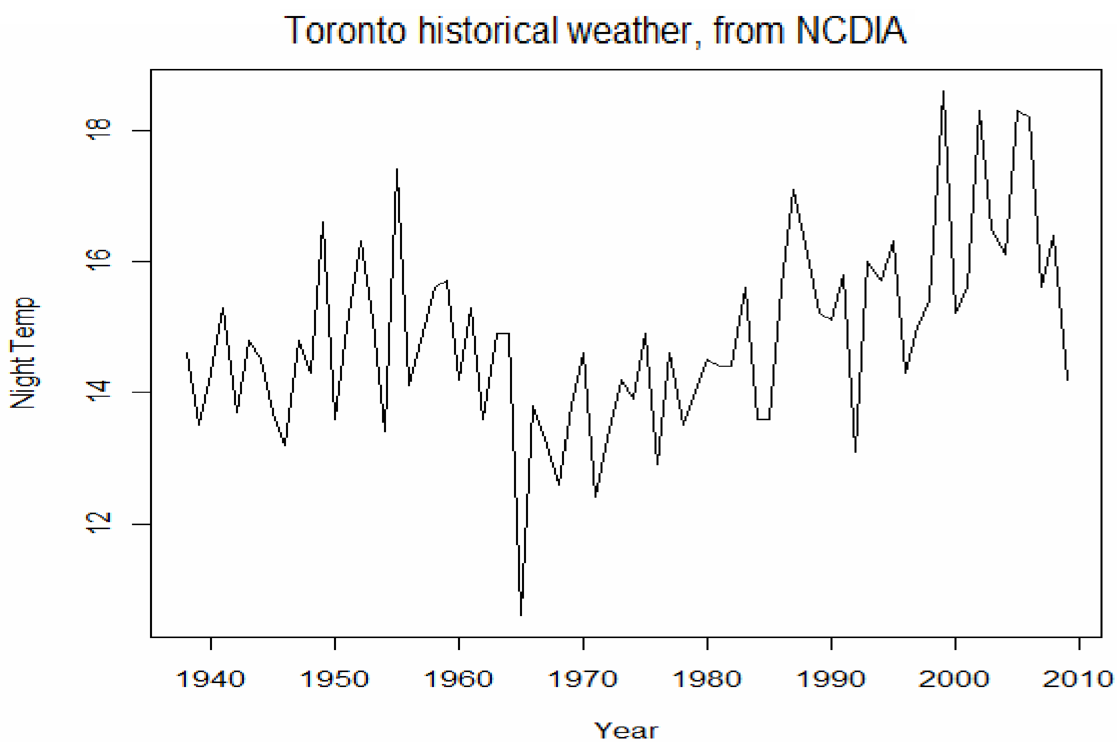
Outline

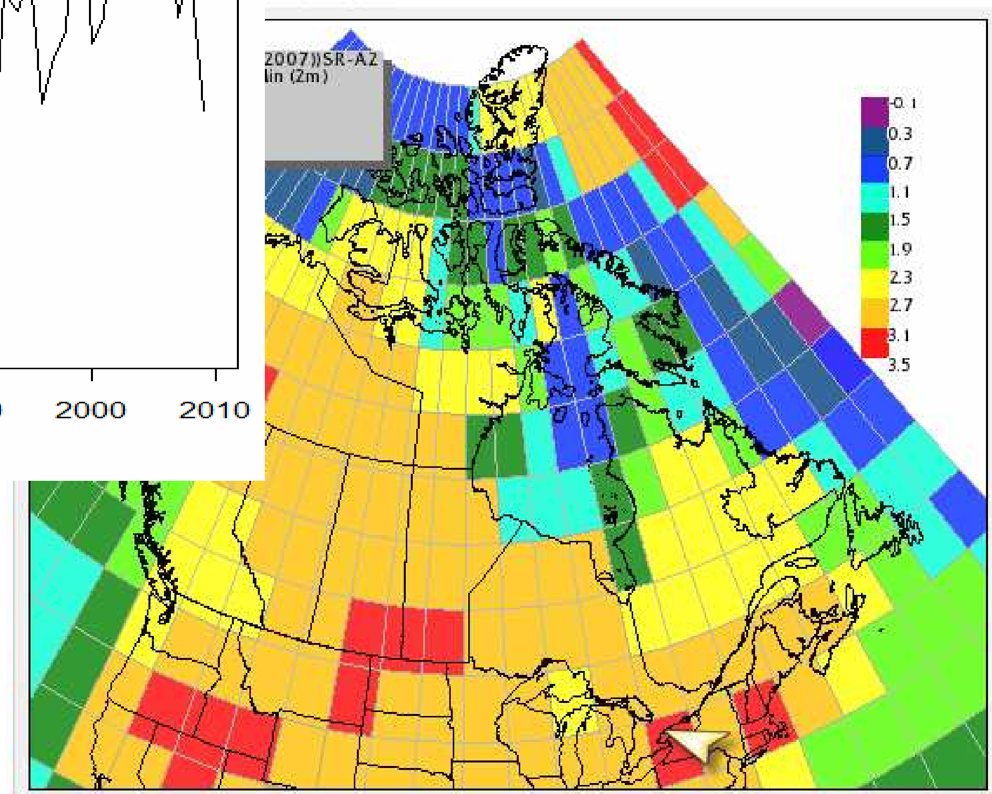
1. Background
2. Surveillance data
3. Statistical modeling
4. Dynamical modeling

1. Background

— Climate change issues



Projected temperature change from cccsn



The temperature change in 2050s from the baseline 1960-90 (Canadian Climate Model, IPCC SRES A2)

1. Background
— Climate change impact on infectious disease

- *Climate constrains the range of infectious disease, while weather affects the timing and intensity of outbreaks* — Epstein 2001

Climate change will impact infectious diseases worldwide, but questions remain as to how

By Katherine Harmon

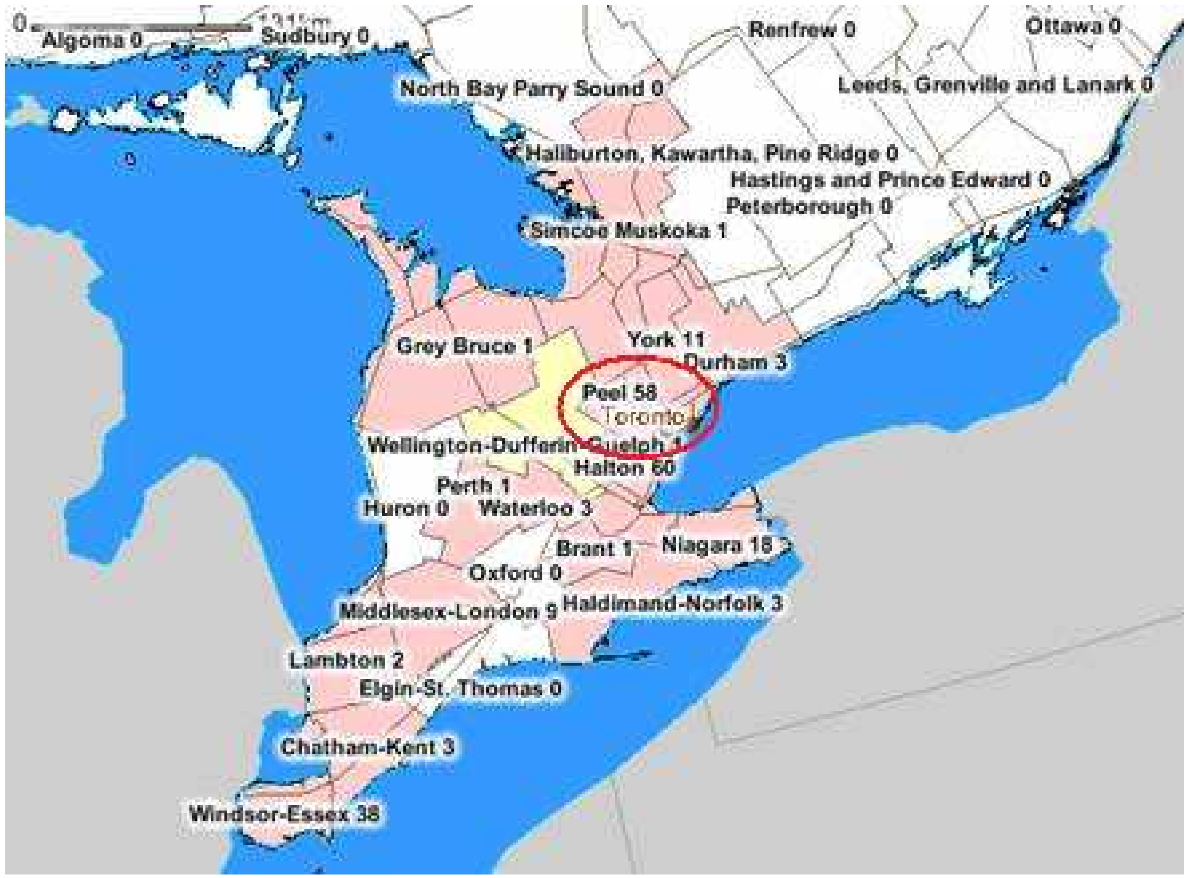
NEW YORK—As climatologists weather the IPCC controversy, another storm is brewing, and this one is filled with not with bloggers but with beasts, bugs and bacteria. It is the potential plague of infectious diseases—threatened to be made worse, many scientists propose, by projected changes in the Earth's climate.

Influence disease transmission can be exceedingly hard to track, climate is one thing you can actually measure.

— Thompson 2010

2. WNv Surveillance program in southern Ontario

Human infection WNv cases in southern Ontario
(2002 case, from PHAC)



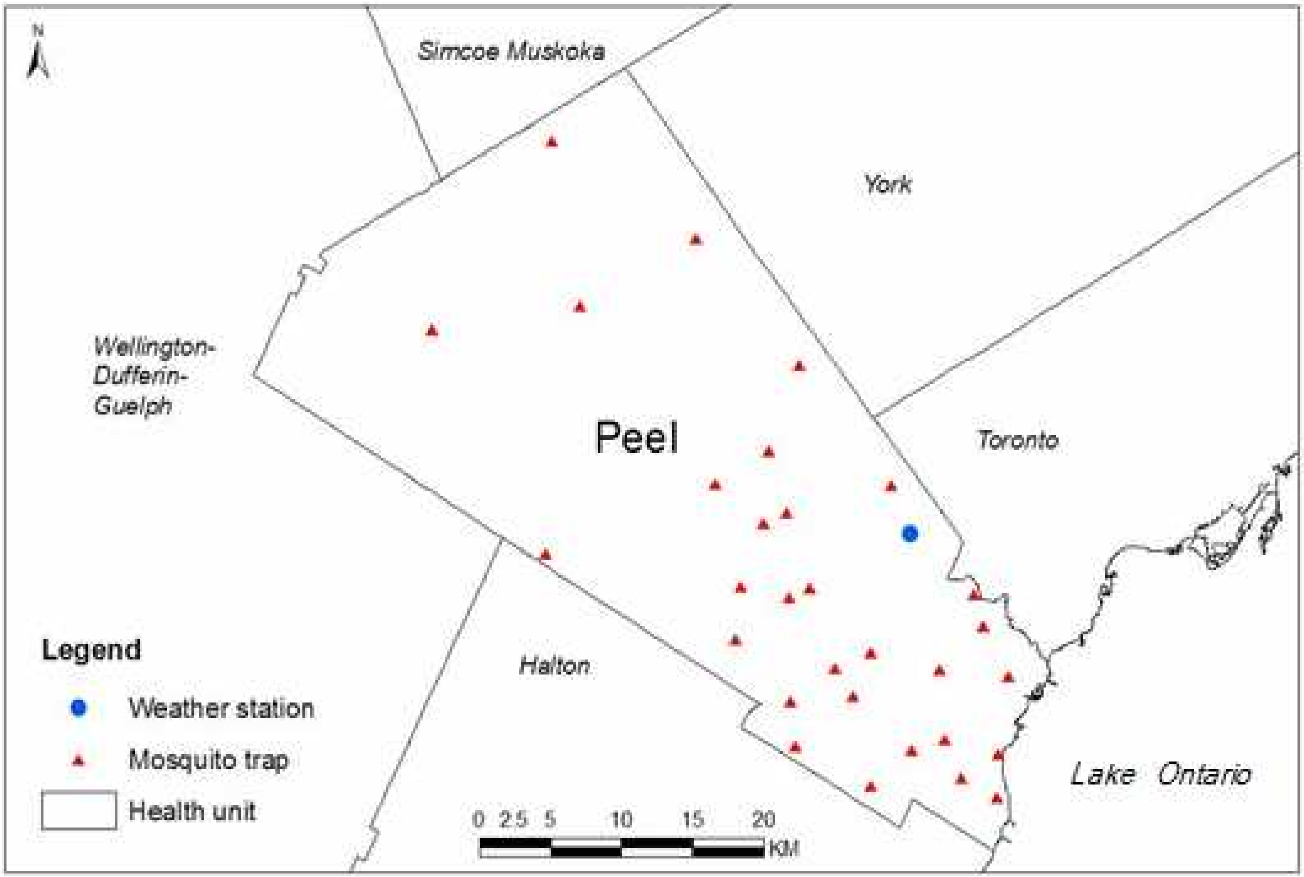
2. WNv Surveillance and weather data

- **Mosquito** Surveillance : Captured by CDC light trap, identified and WNv tested by microbiology Lab
- **Dead Bird** Surveillance : Telephone calls reporting dead bird, WNv tested by Canadian Cooperative Wildlife Health Centre (CCWHC) located in Guelph, Ontario
- **Human Case** Surveillance : All probable or confirmed cases identified by hospitals and physicians are reported to the Public Health department, WNv tested by MOH Central Public Health Laboratory in Toronto

- **Weather data** : Daily mean temperature and precipitation recorded at weather station

2. WNv Surveillance and data

Mosquito traps and weather station in Peel Region



3. Statistical Modeling
— Gamma-GLM for regional mosquito count

$$\rho \sim Gamma(\alpha, \beta), \quad \log(E(\rho)) = \log(\mu) = g(ddm, ppm),$$

$$g(ddm, ppm) = a_T ddm^2 + b_T ddm + a_p ppm^2 + b_p ppm + c,$$

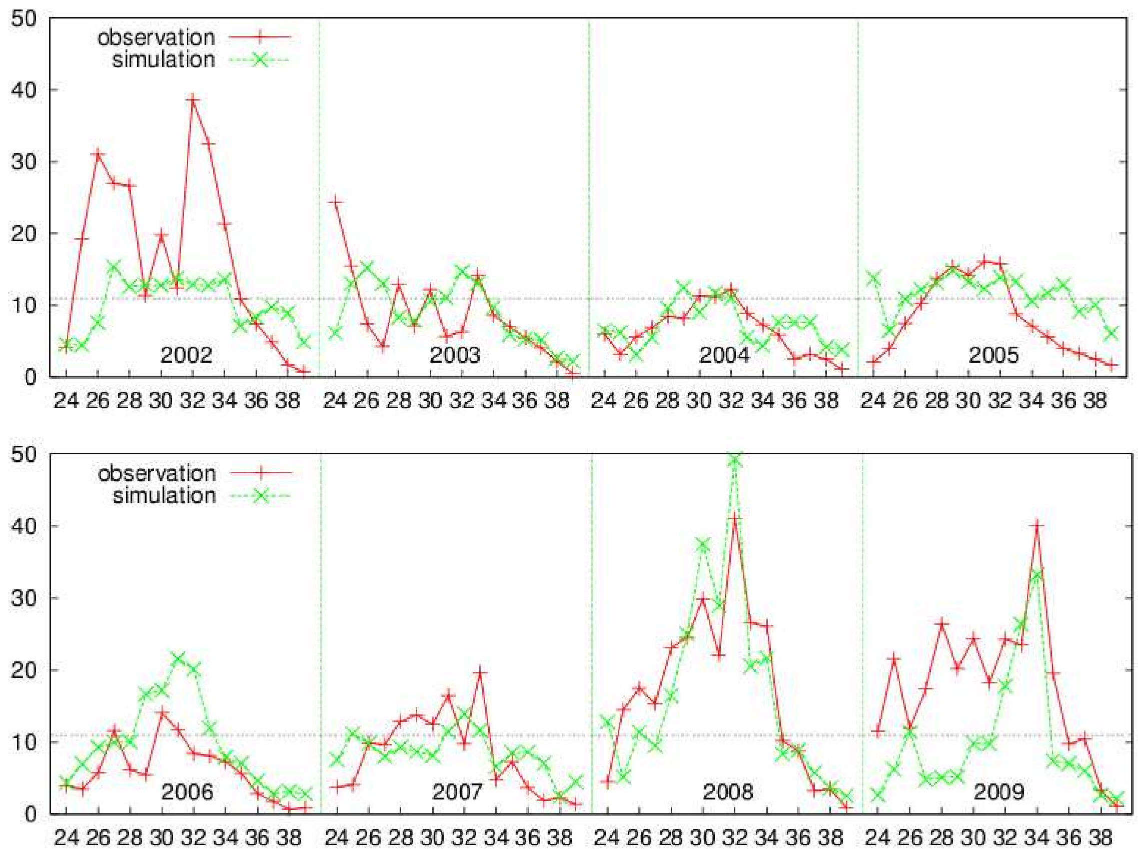
ρ is mosquito count,

α, β are distribution parameters for gamma distribution,

ddm, ppm are temperature and precipitation indices as covariates to mosquito count.

Wang, J., N.H. Ogden, and H. Zhu, The Impact of Weather Conditions on *Culex Pipiens* and *Culex Restuans* Mosquito Abundance — A Case Study in Peel Region. Submitted to *Journal of Medical Entomology,* 2010.

3. Statistical Modeling
— Result



The mosquito population time series is good for dynamical modeling

4. Dynamical Modeling
— Delayed mosquito population model

$$\frac{dM(t)}{dt} = b(\overline{T}, \overline{P})M(t-\tau)\left(1 - \frac{\overline{M}}{K}\right) - d(T(t))M(t),$$

where

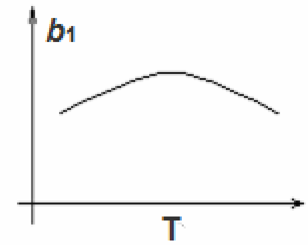
- $M(t)$, adult mosquito population at time t,
- τ, developing time from egg to adult mosquito,
- $\overline{T}$ and $\overline{P}$, the averaged temperature and precipitation condition from $t-\tau$ to t,
- $\overline{M}$, the average mosquito population from $t-\tau$ to t,
- $T(t)$ and $P(t)$ are the weather conditions at time t.
- $d(T(t))$, natural death rate of adult mosquito
- K, carrying capacity, the feature of the mosquito habitat

4. Dynamical Modeling
— Definition of parameters

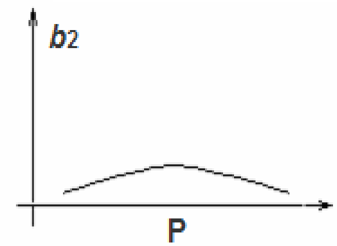
1) The development rate $b = b_0 \times b_1 \times b_2$:

- b_0: number of eggs laid per mosquito per day
- b_1: overall development rate of eggs

$$b_1(\overline{T}) = \alpha_1(\overline{T} - T_b)^2 + \alpha_0,$$

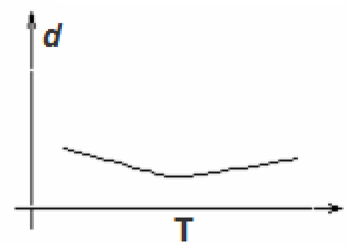


  - α_1: strength of response to T
  - T_b is the optimal temperature
  - α_0 max development rate



- b_2: survival rate for the immature mosquitos

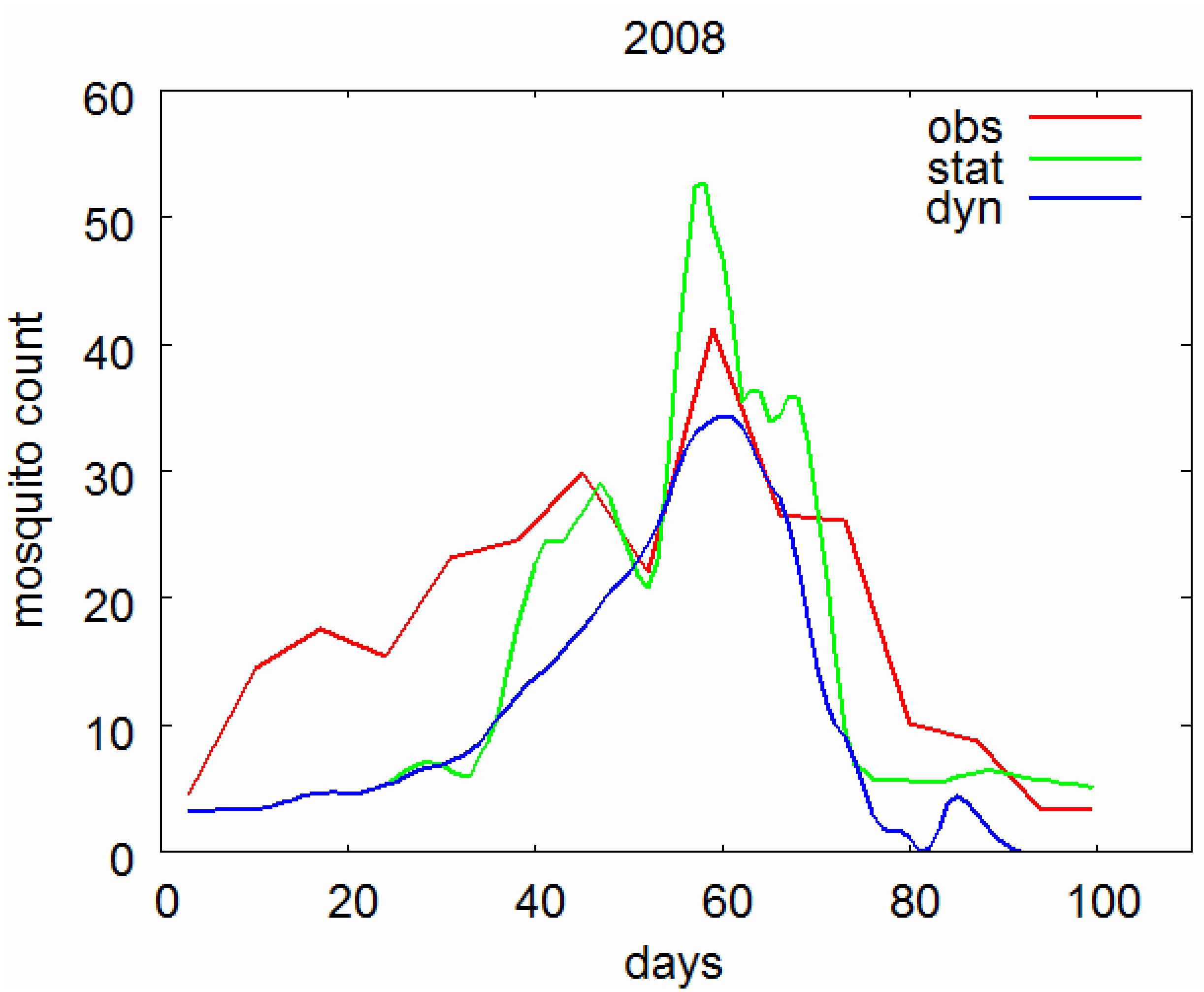
$$b_2(\overline{P}) = \beta_1(\overline{P} - P_b)^2 + \beta_0.$$



2) The natural death rate $d(T) = 0.05(1+\gamma_1(T - T_d)^2)$

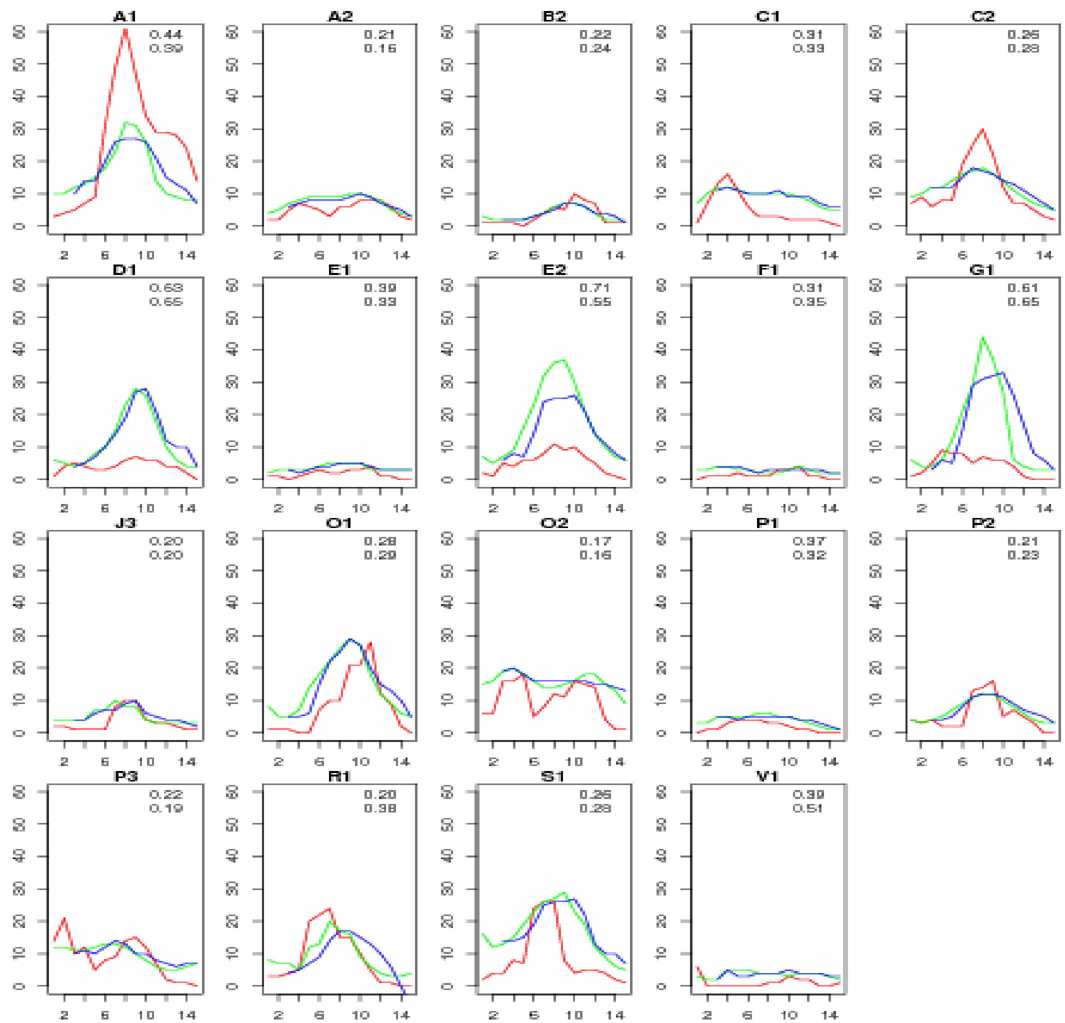
4. Dynamical Modeling

— Dynamical and statistical model simulation



4. Dynamical Modeling

— simulation for mosquito population at individual trap



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- Vector-Borne Disease Team of Peel Region

More information http://www.lamps.yorku.ca/

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