# Corvid and mosquito pool surveillance data for the detection of West Nile virus in Ontario, 2002-2008:

## A comparison using survival analyses and spatial scan statistics.

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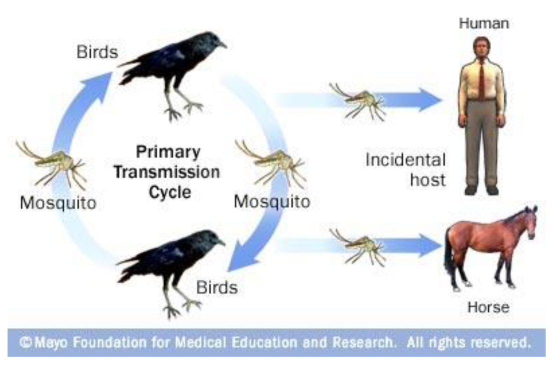
## Background




• West Nile virus (WNv) is an arbovirus that infects humans and horses through the bite of a mosquito.

• The virus is maintained in a transmission cycle between birds and mosquitoes.

➢ Detection of WNv in Ontario has involved enhanced passive surveillance of found dead wild corvids and active surveillance of suspected vector mosquito species since 2000[1].

➢ Each year, Ontario public health units (PHUs) stopped testing found dead birds once several tested positive for WNv.

➢ Thus, traditional risk-based measures are not appropriate for evaluating these data; we employed survival analyses using time-to-first positive tests within PHUs.

## Objectives

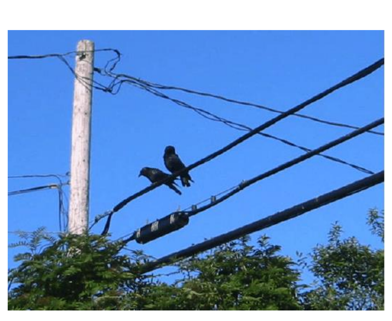
1) To compare timing and distribution of first WNv-positive test results based on bird and mosquito surveillance in Ontario.

2) To investigate yearly trends, socio-demographic and geographic patterns that may influence the performance of these surveillance modalities.

## Materials and methods

**Data sources:**

1) Dead wild bird, mosquito pool and human case surveillance data were obtained from the Canadian Wildlife Health Cooperative and Public Health Ontario.



CDC light trap for mosquito surveillance

image courtesy of Wikipedia commons

2) PHU geographic health regions were based on the Ontario Ministry of Health and Longterm Care (MoHLTC) designations:

**Central west**
**Northwest**
**Northeast**
**Eastern**
**Central east**
**Southwest**


3) PHU socio-demographic profiles were based on Statistics Canada and MoHLTC designations:

**Urban centre, urban/rural, sparsely populated urban/rural, rural, rural northern region.**

### Data analyses

**Survival models**

➢ Multilevel Cox proportional hazards models were constructed to investigated the yearly trends, socio-demographic and geographic associations with the first WNV-positive dead birds and mosquito pools detected within public health units (PHUs).

➢Exponential survival models were developed to study geographic and socio-demographic associations with time-to-first positive dead corvids, mosquito pools and human cases to use for spatial scan adjustments[2].

**Spatial scan statistics**

➢Survival times were adjusted based on exponential survival models to control for confounding by geographic and socio-demographic characteristics of PHUs.

➢A spatial scan statistic with exponential distribution statistic was employed to identify clusters of PHUs with faster than expected times-to-WNv detection using raw and model-adjusted dead corvid, mosquito pool and human surveillance data.

## Results

### Cox proportional hazards frailty model

➢ Significant (ρ <=0.05) explanatory variables in the multi-level Cox PH frailty model included:

| Main effects | Interactions |
|---|---|
| 1. Data source (dead corvids vs. mosquito pools)<br>2. Year of surveillance (2002 – 2008)<br>3. Geographic region<br>4. Socio-demographic profile | 1. Data source x year of surveillance<br>2. Data source x socio-demographic profile |

➢ There was a significant frailty for PHU-level variation.

➢ PHUs within urban centres and rural regions witnessed faster time-to-detect WNv using dead corvid data in comparison with mosquito pool data.

**Table 1. Predicted hazard ratios* for the interaction between data source and year of surveillance: corvid versus mosquito data.**

| Year | Hazard ratio | p-value | 95% confidence interval |
|---|---|---|---|
| **2002** | **2.66** | **0.004** | **1.36 – 5.21** |
| **2003** | **3.01** | **0.001** | **1.55 – 5.82** |
| **2004** | **5.29** | **<0.001** | **2.65 – 10.56** |
| 2005 | 1.76 | 0.59 | 0.92 – 3.39 |
| **2006** | **2.23** | **0.01** | **1.18 – 4.43** |
| **2007** | **0.49** | **0.04** | **0.25 – 0.96** |
| 2008 | 0.85 | 0.64 | 0.44 – 1.65 |

Hazard ratio = a ratio of two hazard functions: a higher hazard ratio reflects a shorter time-to-detect a first WNv-positive test.

### Spatial scan statistics

**Figure 1. Dead corvid clusters**

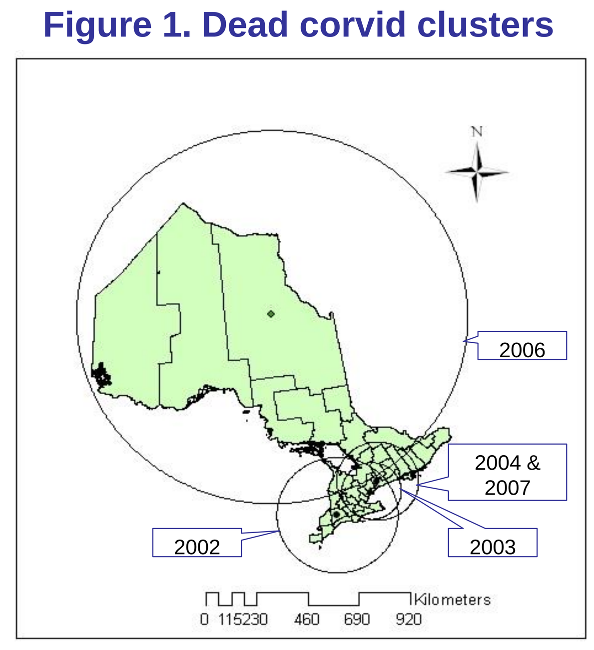



**Figure 2. Mosquito pool clusters**

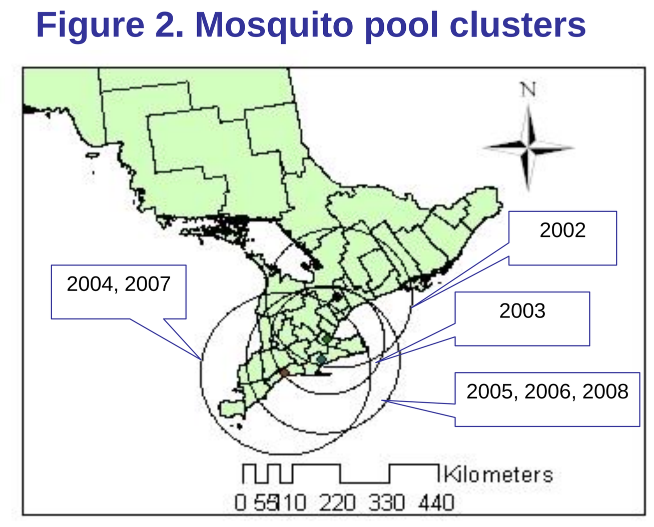



**Figure 3. Human case clusters**

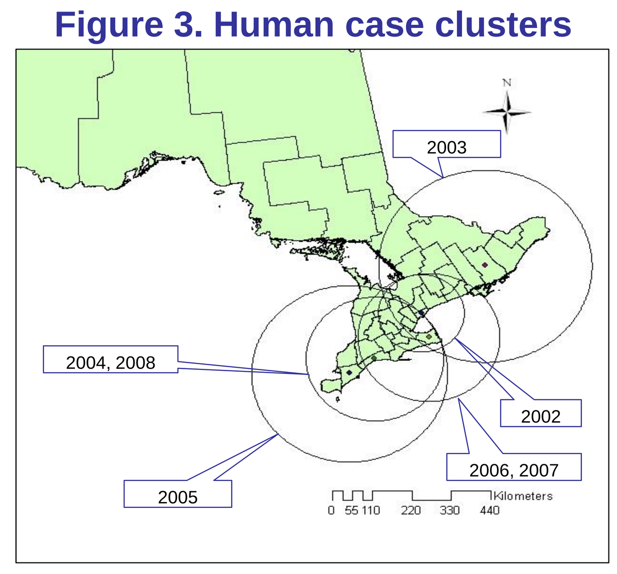



**Figure 4. Model-adjusted clusters: Birds and humans (2006)**

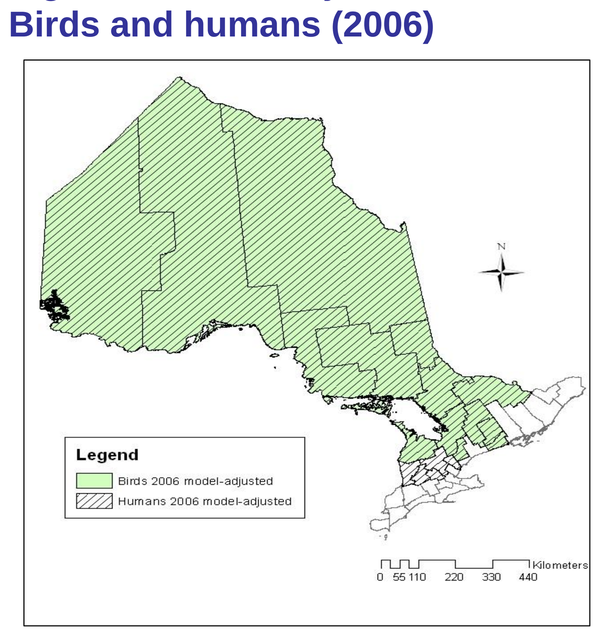



**Table 2. Timing of clusters of PHUs with early detection of WNv using unadjusted dead birds, mosquito pools and human cases.**

| Year | Birds | Mosquitoes | Humans |
|---|---|---|---|
| 2002 | May 23 – July 5 | June 16 – Aug 22 | July 18 – Sept 19 |
| 2003 | April 24 – June 26 | July 8 – Sept 3 | June 26 – Sept 4 |
| 2004 | May 21 – June 22 | July 15 – Sept 8 | July 28 – Sept 22 |
| 2005 | No significant clusters | July 7 – Aug 30 | July 6 – Sept 21 |
| 2006 | May 24 – July 6 | July 13 – Sept 6 | July 30 – Sept 6 Only 2/17 PHUs same as birds |
| 2007 | June 1 – Aug 31 | July 18 – Aug 28 | Aug 8 – Oct 10 |
| 2008 | No significant clusters | July 29 – Sept 10 Identical location to human case cluster | July 9 – Sept 10 |

➢ Mosquito, human and most bird clusters located in south and central Ontario; most populated regions.
➢ Bird clusters show northerly distribution in 2006.
➢ Model-adjusted human cluster in 2006 similar to bird cluster (adjusted and unadjusted).
➢ Dead bird clusters appear prior to human clusters during most years; mosquito clusters less timely.

## Discussion

### Cox proportional hazards frailty model

➢ During 2002, 2003, 2004 & 2006 PHUs detected WNv more quickly using the dead corvid data in comparison with the mosquito pool data.

➢ Later years showed a trend towards improved time-to-detect WNv using mosquito pool data, with a significantly faster detection during 2007 surveillance year (p<0.05).

➢ This may reflect changes in public reporting of dead birds, the impact of WNv on corvid population, changing immunity of corvids and improved detection of positive mosquito pools gained through strategic trap placement.

➢ Differences in time-to-detection of WNv by geographic region and socio-demographic profile may reflect differences in the likelihood of public detection and reporting of dead birds, differences in public perception of risk, as well as environmental features and micro-climatic factors that influence corvid and mosquito abundance.

### Spatial scan statistics

➢ Dead corvid clusters moved from south to north from early to later years, which may reflect changing bird immunity and population declines.

➢ Mosquito pool clusters generally located in most populated regions, where *Culex* mosquito species are more common.

➢ Early human case clusters were located in the most populated regions of the province, where transmission is also more likely to occur based on proximity to habitats, and likelihood of biting by bridge vector mosquito species.

➢ Model-adjusted clusters were similar for most years/surveillance streams, except 2006 in which a northerly cluster of early human cases overlapped in space with dead corvid cluster.

➢This highlights the importance of controlling for confounding factors to identify areas with unexpected differences in time-to-detection.

➢ Dead corvid clusters took place earlier than most human case clusters, while mosquito pool clusters began earlier in some years, but overlapped in time (i.e., were not predictive of early human case clusters).

## Conclusions

➢ Multi-level, multivariable survival analyses and spatial scan statistics based on the exponential model can be employed to explore time-to-event surveillance data.

➢In Ontario, PHUs detected WNv earlier at the start of the surveillance program using the dead corvid data, whereas the mosquito data demonstrated improved time-to-detection during later years.

➢Time-to-detect first WNv-positive dead birds compared to mosquito pools also varied by sociodemographic characteristics and geographic regions of the PHUs.

➢There was geographic overlap between clusters of positive dead birds, mosquito pools and human cases during all years in which significant clusters were found.

➢The dead bird dataset generally outperformed the mosquito pool dataset with respect to time of onset of clusters.

➢Using survival model-adjusted data, clusters of first-positive dead corvids predicted human case clusters during some years.

## Future directions

➢ Explore dead corvid sightings data for similarities and differences with corvid submissions/test results, and examine biases related to these data for detection of West Nile virus.

➢ Consider costs of the different surveillance programs.

## References

1. Drebot M.A. et al., 2003. Can. J. Infect. Dis. 14(2):105–114.
2. Huang L. et al., 2007. Biometrics. 63(1):109-118.

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