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.
- 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.

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

Survival models
- Multilevel Cox proportional hazards models were constructed to investigate 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.

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 (p < 0.05) explanatory variables in the multi-level Cox PH frailty model included:
    - Data source (dead corvids vs. mosquito pools)
    - Geographic region
    - 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.

<table>
<thead>
<tr>
<th>Year</th>
<th>Hazard ratio</th>
<th>p-value</th>
<th>95% confidence interval</th>
</tr>
</thead>
<tbody>
<tr>
<td>2002</td>
<td>2.65</td>
<td>0.004</td>
<td>1.35 - 5.21</td>
</tr>
<tr>
<td>2003</td>
<td>3.01</td>
<td>0.001</td>
<td>1.55 - 8.82</td>
</tr>
<tr>
<td>2004</td>
<td>5.29</td>
<td>&lt;0.001</td>
<td>2.65 - 10.56</td>
</tr>
<tr>
<td>2005</td>
<td>1.76</td>
<td>0.59</td>
<td>0.92 - 3.39</td>
</tr>
<tr>
<td>2006</td>
<td>2.23</td>
<td>0.01</td>
<td>1.18 - 4.43</td>
</tr>
<tr>
<td>2007</td>
<td>0.49</td>
<td>0.04</td>
<td>0.25 - 0.96</td>
</tr>
<tr>
<td>2008</td>
<td>0.85</td>
<td>0.06</td>
<td>0.44 - 1.65</td>
</tr>
</tbody>
</table>

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.
- 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.
- Differences in time to-detect 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.

Discussion

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.
- Differences in time to-detect 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.
- 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).

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

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