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# A comparison of West Nile virus surveillance using survival analyses of dead corvid and mosquito pool data in Ontario, 2002–2008

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ABSTRACT

The aim of this study was to improve understanding of the relative performance of the use of dead wild corvids and mosquito pools infected with West Nile virus (WNv) in surveillance for WNv activity in the environment. To this end, all records on dead corvid submissions and mosquito pools tested in Public Health Units (PHUs) in Ontario, from 2002 to 2008, were explored. Survival analyses were employed using the first-WNv-positive cases detected each year for each PHU, and censored observations for PHUs which did not detect WNv during a given year using each data source (504 observations). Survival analyses were employed to compare the number of surveillance weeks before WNv was detected by either data source, and the influence of temporal, geographic and sociodemographic factors on these data. The outcome measurement for the final accelerated failure time (AFT) model with log-logistic distribution was a time ratio, which represents the ratio of the survival time of one group relative to another. Dead corvid surveillance was faster at detecting WNv than testing mosquito pools during the early years of WNv incursion into Ontario, while mosquito testing found WNv more quickly later in the study period. There was also regional variation in time-to-detection of WNv, by modality, as well as for various types of urban/rural settings. In comparison to mosquito surveillance, West Nile virus was detected more quickly using dead corvid surveillance in sparsely populated regions. These areas may benefit from collection of dead corvids to optimize detection and direct early surveillance efforts. When we compared the time-to-detection of WNv using dead corvids and the onset of human cases in PHUs, we found that dead corvid surveillance was predictive of West Nile activity in health units that reported human cases during the first 3 years of the incursion into Ontario.



## 1. Introduction

West Nile virus (WNv) is a mosquito-borne arbovirus in the Flavivirus genus, which is maintained and amplified in a complex cycle between birds and bird-feeding mosquitoes (Ciota and Kramer, 2013). Under favorable environmental conditions, particularly during late summer and autumn in the northern hemisphere, the virus sufficiently amplifies within the local bird and mosquito populations (Gray and Webb, 2014). Human infections are the result of spill-over from this enzootic cycle. One study found evidence of a shift in the feeding-behaviour of carrier mosquitoes from birds to humans late in the summer, when migratory birds are not readily available for feeding (Kilpatrick et al., 2010). Most human WNv infections are subclinical and go undetected. However, approximately 20% of infections result in febrile illness, while fewer than 1% of those infected may develop severe neurological symptoms that can be fatal (Petersen and Marfin 2002).

The first human cases of WNv in North America were detected in New York State in 1999 (Nash et al., 2001). Surveillance for the disease began in Ontario in 2000, including enhanced passive surveillance of dead birds submitted by the public, with very limited active surveillance of suspected vector mosquito species through trapping and WNv-testing (Drebot et al., 2003). In 2001, wild bird surveillance was restricted to the Corvidae (blue jays, crows, magpies and ravens) due to their high susceptibility to WNv and near 100% case fatality rate (Hochachka et al., 2004). More widespread active surveillance using mosquito pools was intro-

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**Table 1**
Descriptive statistics pertaining to West Nile virus surveillance programs for dead birds and mosquito pools in Ontario public health units (2002–2008), and timeliness of tests.

| Year | Percentage of WNV-positive birds (WNV-positive/tested[a]) | Percentage of WNV-positive mosquito pools (WNV-positive/tested) | Number of mosquito trap sites tested in Ontario | Median number [range] of mosquito trap sites per PHU (interquartile range) | Median number of mosquito pools tested per PHU (interquartile range) [range] | Median number of days between dead bird sighting and test results reported to public health unit or recorded (interquartile range) [range] | Median number of days between mosquito collection and mosquito pools test results recorded (interquartile range) [range] |
|---|---|---|---|---|---|---|---|
| 2002 | 17.35 (289/1666) | 4.81 (580/12052) | 405 | 10.5 (5.5–19.5) [4–58] | 352 (127–640.5) [12–1435] | 14 (11–18) [3–83] | 82 (27–130) [3–256] |
| 2003 | 14.07 (242/1720) | 0.70 (122/17452) | 766 | 12 (7–29.5) [5–157] | 314 (196.5–473.5) [45–2219] | 5 (3–8) [1–198] | No results available |
| 2004 | 17.36 (250/1440) | 0.27 (72/26915) | 1079 | 24 (13.5–37.5) [5–191] | 578 (341–866) [143–3714] | 5 (2–7) [1–98] | 3 (2–5) [1–9] |
| 2005 | 23.26 (300/1289) | 1.44 (289/20064) | 984 | 21 (16.5–36) [5–121] | 398.5 (281–624) [92–2289] | 4 (2–7) [1–60] | 3 (2–4) [1–25] |
| 2006 | 26.34 (256/972) | 0.95 (182/19216) | 939 | 21 (14–35) [2–54] | 399 (249–681) [36–1862] | 4 (2–7) [1–38] | 3 (2–4) [1–16] |
| 2007 | 10.49 (79/753) | 0.26 (51/19585) | 823 | 20 (13–32) [1–49] | 398 (274–829.5) [20–1392] | 4 (2–7) [1–47] | 2 (1–3) [1–3] |
| 2008 | 18.90 (150/794) | 0.21 (41/19124) | 846 | 21 (14–32) [1–50] | 354 (227–814.5) [1–1719] | 4 (2–6) [1–141] | 2 (1–3) [1–6] |

[a] Ontario health units discontinued testing after approximately 4 birds tested positive for WNv.

duced in 2002, and extended to the entire province in 2003. The first WNv-positive mosquitoes and dead corvids were detected in Ontario in 2001, and the first human case was reported in 2002 (Drebot et al., 2003). To conserve resources, individual public health units (PHUs) discontinued dead corvid testing after 4–7 birds tested positive for WNv each year. Because the dead birds were only tested by each PHU until the end of season or until a maximum of approximately 4 positive tests (whichever occurred first), it is not appropriate to use prevalence or incidence rate measures to compare the dead corvid and mosquito surveillance programs. The mosquito pool and dead corvid surveillance data collected during the first eight years of the Ontario experience with WNv have not been compared for their relative time-to-detection and ability to detect WNv within PHU areas. By employing survival analyses to explore the time-to-first positive test within a PHU, the dead bird and mosquito pool data could be compared.

West Nile virus is now considered endemic throughout Ontario. However, against the background of endemicity, local outbreaks are likely to occur, depending on a complex interaction of environmental conditions driving mosquito abundance, WNv amplification (Zheng et al., 2014), bird and mosquito distribution and mosquito feeding behavior (Kilpatrick et al., 2006), as well as evolving viral genetics and changing immunity amongst mosquito, avian and human populations (Ciota and Kramer 2013).

Due to the complexities involved in WNv distribution and transmission, predicting areas of higher risk on a fine-scale has remained an elusive goal (Zheng et al., 2014). Until predictive models improve, timely and accurate regional WNv detection can be used to inform local public health strategies, particularly public awareness campaigns to promote personal protection, which currently is the first line of defense for reducing human risk (Gray and Webb, 2014). Given limited resources for vector-borne disease surveillance, it is important to evaluate surveillance program activities (dead bird and mosquito pool testing), in terms of their ability to detect WNv, timeliness-to-detection, and potential biases.

This study investigated the time-to-detection of WNv in Ontario at the PHU level over the period 2002–2008. The 36 PHUs (http://www.alphaweb.org/?page=PHU) are regions designated to plan and provide public health services in the province of Ontario (Ministry of Health and Longterm Care, Health Analytics Branch, 2012). Specific project objectives were (i) to compare mosquito pool to dead corvid surveillance for their ability and timeliness of WNv detection within PHUs, and (ii) to examine the influence of socio-demographic, temporal and geographic patterns on the speed of WNv detection using dead corvid and mosquito surveillance.

## 2. Materials and methods

### 2.1. Data sources

From 2001–2008, over each WNv season (generally mid-May to late October), dead birds found by the public were collected by each local public health unit (PHU) with support from the Ontario Ministry of Health and Longterm Care (MOHLTC), and recorded and sampled by the Ontario Region of the Canadian Wildlife Health Cooperative (CWHC). Samples were subsequently tested for WNv by real-time reverse transcriptase polymerase chain reaction (rRT-PCR) at the National Microbiology Laboratory, Public Health Agency of Canada in Winnipeg MB (2001, 2002). From 2003–2008, testing was done by CWHC on oral swabs, using a wicking antigen capture ELISA test (VecTest®). Samples producing an inconclusive VecTest® result were re-tested using rRT-PCR, and VecTest® results representing the first case of WNv detected in a PHU were confirmed using rRT-PCR, by the Animal Health Laboratory, University of Guelph (Lanciotti et al., 2000; Beroll et al., 2007).