Ministry of Health and Long-Term Care

West Nile Virus Preparedness and Prevention Plan

Population and Public Health Division,
Ministry of Health and Long-Term Care

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Acknowledgements

This 2018 update to the West Nile Virus Preparedness and Prevention Plan is a collaborative effort between the Population and Public Health Division of the Ministry of Health and Long-Term Care and Public Health Ontario, with valuable input from the public health units and other contributors including the Ministry of the Environment and Climate Change.

Due to the extent of the revisions made between the 2010 and 2018 versions of the plan, individual changes will not be highlighted within the text.

1 Introduction

The first formal *West Nile Virus Preparedness and Prevention Plan* was issued by the Ministry of Health and Long-Term Care (ministry) in 2003. Since then, Ontario has made great strides in providing further protection to the public from West Nile virus (WNV) and continues to build on its reputation as a leader in mosquito surveillance and management in Canada.

This document incorporates the cumulative experience of North America's public health community with mosquito-borne diseases and their prevention and control. Specifically, the collective experience is adapted and applied to Ontario and its unique topography, climate, and vector species. The updating of this document emphasizes the ministry's commitment to the public health units (PHUs) to provide leadership and expertise in the science of mosquito-borne diseases with the continual goal of reducing the risk of WNV using integrated methods that take into account both efficacy and the environment. There are several approaches to integrated prevention and control of arthropods (e.g., Integrated Pest Management for agricultural pests); Ontario's approach focuses on Best Management Practices (BMPs) within an Integrated Vector Management (IVM) program.

Any program targeting the control of mosquitoes and prevention of mosquito-borne diseases must continually be evaluated and improvements made. PHUs and stakeholders provide input to Ontario's program and their contributions are considered when revising this document. Recommendations are subject to change based on the best available science and practices and will continue to change in order to reflect the challenges facing Ontario in combating WNV.

2 Purpose

The *West Nile Virus Preparedness and Prevention Plan* is a technical reference document to assist Ontario's public health units (PHUs) with the implementation of the *Control of West Nile Virus Regulation 199/03* (*O.Reg. 199/03*) under the *Health Protection and Promotion Act*.[1,2] For this document, PHU will refer to the organization including the medical officer of health (MOH) and staff.

Information is provided for BMPs used within the framework of IVM to ensure consistency in programs. IVM is an inclusive mosquito control strategy that employs all available mosquito control methods individually or in combination to exploit the vulnerabilities of mosquitoes in order to reduce their numbers, while minimizing the impact to the environment. The focus of Ontario's IVM is control programs that are based on surveillance results and further strengthened by public education and outreach to health care providers.

The implementation of the recommendations in this document is based on PHUs undertaking risk assessments within their jurisdictions. When taking appropriate actions against mosquitoes, PHUs must consider all relevant factors as required by *O. Reg. 199/03.* To ensure that mosquito management is performed in the most effective manner possible, this 2018 document continues to provide information to support the development and implementation of BMPs, based on IVM.

Although eastern equine encephalitis virus (EEEV) is not referenced in *O. Reg*. *199/03,* it is discussed in this document because of its similarity to the ecology of WNV, surveillance techniques, and viral testing procedures. PHUs should consider the application of EEEV measures (with any necessary modification) as it relates to WNV below.

3 Public Health Partners: Roles, Responsibilities and Reporting Requirements

3.1 Public Health Units

PHU responsibilities with regard to infectious diseases are discussed in the *Health Protection and Promotion Act* (HPPA) and its Regulations, the *Ontario Public Health Standards: Requirements for Programs, Services, and Accountability* and in the *Infectious Diseases Protocol, 2018* (or as current).[2,3,4] For WNV control, PHUs are required to carry out appropriate surveillance activities to permit WNV risk assessments to be performed within their respective jurisdictions. Under *O. Reg. 199/03*, PHUs (specifically, medical officers of health (MOHs)) are required to make a determination of whether action is required by a municipality to decrease the risk of WNV to persons either inside or outside the geographical boundaries of the area served by the MOH, based on a local risk assessment. The PHU should take measures deemed necessary to prepare for and prevent, if possible, WNV illness within their regions. Each PHU is required to maintain a regular communication link with their communities to ensure that current information on WNV within the region is widely available.

As part of its surveillance work, PHUs are responsible for the collection and submission of mosquitoes to their mosquito-testing service provider for laboratory analysis. The PHUs are required to establish and maintain mosquito sample collection and human disease investigation records. All WNV results are reported to PHO to permit recording of the disease incidence in Ontario into various surveillance reports and maps for public health response coordination.

Program evaluation is an important component of effective public health practice and should be conducted by each PHU based on their respective WNV programs. An outline of some example measures that may be considered by a PHU undertaking local level program evaluation is provided in Appendix I. Applicable measures to include will vary for each PHU.

WNV illness is a Disease of Public Health Significance under the *Health Protection and Promotion Act.*[2] PHU personnel are asked to remind health care providers in their jurisdictions of their duty to report individuals who have or may have WNV to the MOH.

As part of disease surveillance, PHUs investigate reported WNV-positive human cases and communicate relevant organ-donor information to the Trillium Gift of Life Network. PHUs should enter the results of their investigations of WNV cases into the integrated Public Health Information System (iPHIS), or any other method specified by the ministry within one (1) business day of receipt of initial notification (see the *Infectious Diseases Protocol, 2018* (or as current) appendices available at http://www.health.gov.on.ca/en/pro/programs/publichealth/oph_standards/infdispro.aspx).[4]

WNV illness cases which may be travel-related require PHUs to coordinate and exchange information with jurisdictions in which their patient may have traveled as part of the investigation, concentrating on patient's most likely location of WNV exposure.

3.1.1 Public Health Units and Risk Assessments

Under *O. Reg 199/03*, the MOH is required to conduct a risk assessment of potential indicators of WNV in the region and make a determination of whether action is required by a municipality to decrease the risk of WNV in persons either inside or outside the region. This risk assessment should identify the relative risk of human infection from WNV using mosquito surveillance data, equine infections, human cases, and other relevant information available to the PHU (e.g., accumulated degree-day models and maps).

Completion of the risk assessment in accordance with *O. Reg. 199/03* will offer guidance to the appropriate WNV preparedness and prevention activities for the MOH, and if needed, provides a review of appropriate mosquito control activities (i.e., larval and adult) and their effective application. *O. Reg 199/03* requires the local municipality, if given notice by the MOH, to undertake those measures in the notice necessary for mosquito control and disease prevention.

In addition, the MOH is also required to record, investigate, and report any confirmed or probable adverse or unintended human health effects attributed to mosquito control activities, and to report any non-human environmental adverse effects that he/she knows about to the Ministry of the Environment and Climate Change (MOECC) and/or other relevant local or provincial authorities.

3.2 Ministry of Health and Long-Term Care

The ministry provides support to PHUs for WNV preparedness, prevention, and control. A WNV webpage is maintained by the ministry that provides general information on WNV, along with important resource links.

Three times per season (typically April, June, and October) the ministry will host a Vector-Borne Disease teleconference with PHUs and partners. These meetings provide an opportunity to share updates and discuss current issues throughout the mosquito season.

The ministry also works collaboratively with the Public Health Agency of Canada (PHAC) and other stakeholders on WNV prevention and control, as well as enhanced surveillance initiatives for other mosquito-related issues as needed. The ministry, along with PHO, will provide coordination of risk assessment and response to emerging multijurisdictional issues in the province when necessary.

3.3 Public Health Ontario

PHO provides provincial data analysis based on information provided by PHUs following their investigation of WNV human case reports, together with the results of Ontario's mosquito surveillance program.

PHO provides entomological expertise and is available directly to PHUs as requested to provide field consultation and training to review local mosquito surveillance programs. PHO provides up-to-date information based on the best available science and practices.

PHO maintains a provincial vector surveillance database which contains mosquito surveillance data. This data is uploaded on a weekly basis from mosquito-testing service providers. The data includes trap locations, mosquito species abundance and distribution, as well as WNV-positive mosquito pools. The data is analyzed, during the WNV season, to produce weekly updates of maps, figures, and tables posted on PHO's WNV surveillance webpage. These data provide a comprehensive provincial picture of the WNV vectors and assist in assessing the human risk of WNV in Ontario.

4 West Nile Virus Overview

The public health threat posed by WNV remains, as the arbovirus is endemic to the province. Ontario must maintain the capacity to monitor and manage vector populations. Continuous refinement of this document allows for a dynamic WNV program that will continue to grow and adapt to changing WNV ecology.

For further government documents on WNV, please visit:

- *Ontario Public Health Standards: Requirements for Programs, Services, and Accountability (Standards)* available from: http://www.health.gov.on.ca/english/providers/program/pubhealth/oph_standards/ophs/index.html[3]
- *Health Protection and Promotion Act* available from: https://www.ontario.ca/laws/statute/90h07[2]
- *Control of West Nile Virus Regulation, O.R. 199/03* available from: https://www.ontario.ca/laws/regulation/030199[1]
- *Designation of Diseases Regulation*, *O.R. 135/18* available from: https://www.ontario.ca/laws/regulation/R181355[5]
- Ontario government West Nile virus general information page available from: https://www.ontario.ca/page/west-nile-virus
- Permit application guide for municipalities and health units available from: https://www.ontario.ca/page/permit-applicant-guide-municipalities-and-health-units
- Application of Malathion by Ultra Low Volume Equipment for Control of Adult Mosquitoes in West Nile Virus Control Programs available from: https://www.ontario.ca/page/application-malathion-ultra-low-volume-equipment-control-adult-mosquitoes-west-nile-virus-control

For further information on WNV from PHO, please visit:

- West Nile virus general information landing page available from: https://www.publichealthontario.ca/en/BrowseByTopic/InfectiousDiseases/Pages/IDLandingPages/West-Nile-Virus.aspx
- West Nile virus surveillance information available from: http://www.publichealthontario.ca/en/DataAndAnalytics/Pages/WNV.aspx

Additional internet resources:

- Public Health Agency of Canada available from: https://www.canada.ca/en/public-health/services/diseases/west-nile-virus.html
- CDC West Nile virus available from: https://www.cdc.gov/westnile/index.html

4.1 History

WNV is a mosquito-borne arbovirus in the *Flavivirus* genus (Flaviviridae) and is related to St. Louis encephalitis virus, yellow fever virus, Japanese encephalitis virus, and Zika virus. Since its introduction into New York City in 1999, WNV activity has been found in Canada, the USA, Mexico, the Caribbean, and South America. Canada's first record of WNV occurred when Ontario birds tested positive for the virus in 2001; a year later, Ontario recorded its first human cases.

4.2 Vector-Virus Ecology

WNV is similar to several arboviruses in that it is maintained within an avian-mosquito, enzootic cycle. The urban cycle of WNV requires mosquito species that feed on birds and people. These are known as bridge vectors and the primary vector species in Ontario are *Culex pipiens* and *Culex restuans*. A mosquito species can be termed an enzootic vector and a bridge vector at the same time. Enzootic vectors primarily feed on birds and maintain the zoonotic cycle of viral transmission. Bridge vectors consist of mosquito species that feed on birds and mammals, and can transfer the virus to the human population. While birds comprise the primary reservoir hosts for the virus, mammals (including humans) function as dead-end hosts.

Risk factors for human infection include a suite of climatological and ecological factors, which are regionally or locally specific. Vertebrate-host and vector surveillance remain effective as indicators of local WNV activity. While corvid mortality was initially a useful risk-assessment tool, immunologically-naïve populations have decreased; therefore, avian surveillance has decreased in its utility as a predictor of WNV risk and was discontinued in 2009.

Higher risks of infection are usually located in urban-suburban areas or locations with large, infective mosquito populations of the primary enzootic and bridge vectors; vector surveillance remains the most useful tool for determining risk in these areas. Information on assessing transmission risk is discussed in the **Vector Surveillance Programs** section.

4.3 Alternate Modes of Transmission

The mode of transmission that accounts for the majority of human infections is through the bite of an infected mosquito. Alternate modes include human blood-borne transmission, organ transplant, vertical transmission via mother's milk, intrauterine transmission, and transmission via occupational hazards in the case of laboratory employees.

5 Surveillance Indicators of WNV

5.1 Equine Surveillance

The purpose of equine surveillance is to monitor WNV in horses in Ontario and to identify the geographic presence of WNV. Ontario equine WNV cases were first recorded in 2002. Since 2002, equine cases have occurred sporadically and in low numbers. With the introduction of an equine WNV vaccine, the utility of equine surveillance has been significantly reduced.

Equine practitioners can send serum or tissue samples to the Animal Health Laboratory in Guelph, or to other private veterinary diagnostic laboratories, for analysis.

Equine WNV cases will be reported to the ministry, and PHO, by the Ontario Ministry of Agriculture, Food and Rural Affairs (OMAFRA). The Canadian Food Inspection Agency has made WNV in horses an immediately notifiable disease under its legislation, which requires animal diagnostic laboratories to report WNV-positive test results. OMAFRA places case data on the OMAFRA website for public reference and notifies PHUs of positive cases in their respective jurisdictions.

5.2 Human Surveillance

The purpose of performing human surveillance for WNV illness is to help identify areas of risk and to assist PHUs in the preparation of risk assessments. Human surveillance activities and programs are implemented throughout the health care system and involve hospitals, physicians, public health laboratories, local MOHs/PHUs, the ministry, and PHO. In addition, surveillance information is shared with the Trillium Gift of Life Network to ensure the safety of Canada's blood supply and organ donations.

Human surveillance is activated when the PHO Laboratory reports a positive WNV-test result (human serology) to the respective physician; the physician then reports it to the local MOH. The laboratory also reports positive WNV results to the local MOH under the reporting requirement in section 29(1) of the HPPA.[2] PHU staff then interview the WNV-positive individual and/or the individual's physician. The PHUs enter the results of their WNV investigations into iPHIS, or any other method specified by the ministry within one (1) business day of receipt of initial notification (see the *Infectious Diseases Protocol, 2018* (or as current) appendices available at http://www.health.gov.on.ca/en/pro/programs/publichealth/oph_standards/infdispro.aspx).[4]

6 Vector Surveillance Programs

The WNV vector surveillance program includes both mosquito population monitoring coupled with arbovirus assays from vector species. The WNV program focuses on *Culex pipiens*/*restuans* surveillance. The objective of WNV vector surveillance is to identify local areas where the presence of the arbovirus poses the most direct threat to humans through data analyses and risk assessment. This section also includes the secondary surveillance program for EEEV and its vectors. Appendix II outlines the mosquitoes to be identified and reported during surveillance operations.

Within Ontario, the majority of WNV-positive pools, and the target of surveillance, has been *Culex pipiens* and *Culex restuans* (*Culex pipiens*/*restuans*). These vector species are the targets of WNV programs throughout much of southern Canada and the northeastern United States. When determining which mosquito species to assay for WNV or EEEV, and the order of testing preference, Ontario produces guidelines that are based upon historical surveillance data and the most-up-to-date science on the species' biology (Appendix II and III).

As it would be too difficult, and time-consuming, to test each individual mosquito for WNV, the mosquito species are pooled into a sample of a maximum of 50 mosquitoes. This allows for timely testing. As each pool can have a different number of mosquitoes in the test, and it is unknown how many are positive for WNV, there are calculations that can be done to standardize the testing and compare the positive values between locations. One of these calculations is the minimum infection rate (MIR), which is used to estimate the minimum number of WNV positive mosquitoes in the environment. Stated as the number of positive mosquitoes per 1000 mosquitoes tested, it is a population-adjusted rate used for comparison and analysis and is calculated by the formula (# WNV-positive pools/total # mosquitoes tested)/ 1000). While MIR can be used to indicate the level of positive mosquitoes in the environment, it can be somewhat misleading in areas with lower numbers of mosquito traps. In those areas, one positive mosquito pool can make the MIR seem quite large, when compared to the level of WNV activity.

6.1 WNV Vector Surveillance Program

Ontario's WNV mosquito vector surveillance program remains the mainstay for the prevention and control of WNV. The purpose of vector surveillance is to help determine the immediate risk of contracting WNV in the respective PHU region. This data is used by the MOH for risk assessments in the prevention and control of WNV illness.

The WNV vector surveillance program consists of adult mosquito trapping from spring through fall to:

- identify trapped mosquitoes to the species level, in reference to the list of known WNV vectors (Appendix II),

- establish population numbers of mosquitoes by species, as listed in Appendix II, and
- perform Real Time Reverse Transcriptase Polymerase Chain Reaction (RT-PCR) testing to determine the WNV status of three of the mosquito pools per trap (Appendix III); and determine vector index (as described in PHO's Guide for the Public Health Units: Considerations for Adult Mosquito Control).[6]

Surveillance data indicates that *Culex pipiens*/*restuans* are the main vectors of concern in Ontario. Carbon-dioxide-baited CDC light (ultraviolet light, UV) traps are used for *Culex* spp. surveillance.

There are two important aspects to consider when developing trapping protocols:

- The mosquito traps utilized in Ontario are mainly CDC light traps, which use both CO_2 and UV light to attract host-seeking mosquitoes.
- Permanent trap locations are set in the same community location year after year. Flexible trap locations may be added to determine the mosquito species and possible presence of WNV in new locations of interest. The number and location of traps is based on a local risk assessment. Having both fixed and flexible trap locations gives the most useful representative coverage of the jurisdiction in most cases in Ontario. It also permits a response to local concerns.

6.2 EEEV Vector Surveillance Program

Ontario initiated a vector surveillance program targeting *Culiseta melanura*, the primary enzootic vector of EEEV. Surveillance for this vector was incorporated into the WNV surveillance programming across Ontario in 2004. The primary objective for performing EEEV surveillance is to determine the risk of EEEV infection to the Ontario public. For more information on EEEV in Ontario, please refer to PHO's Eastern Equine Encephalitis: History and Enhanced Surveillance in Ontario.[7]

Through activities conducted by PHO, the ministry will continue to monitor for the presence of EEEV in the primary vectors when determining risk of human infection in Ontario. The EEEV program component will help the MOH in decision-making processes, as well as building a historical entomological database around EEEV.

PHUs may ask their mosquito-testing service provider to test all *Culiseta melanura* for EEEV. ***Note:*** Testing *Culiseta melanura* for EEEV will count as one of the three mosquito pools tested. Testing EEEV enzootic and bridge vectors should be at the discretion of the PHU and based on available resources, presence of infected avian or equine hosts, presence of appropriate conditions for transmission to humans, and/or the presence of appropriate enzootic and bridge vectors.

If a PHU identifies EEEV-positive animals, it may want to conduct temporary mosquito surveillance around the area where the positive animals were found. PHUs can have their service provider conduct EEEV testing on possible bridge vectors: *Aedes vexans*, *Coquillettidia perturbans*, *Culex salinarius*, *Ochlerotatus canadensis,* and *Ochlerotatus sollicitans*. While all of these bridge vectors may be submitted for EEEV testing, *Aedes vexans* and *Coquillettidia perturbans* are two of the most abundant mosquito species found in Ontario, and a PHU may choose to focus on submitting these species for EEEV testing. Surveillance around local cases may only have to take place for a couple of weeks after detection of an infected human or animal; surveillance should be initiated and continued based on the best scientific data available while carefully weighing the risk for human disease in the surrounding area.

6.3 Service Providers for Mosquito Identification and WNV/EEEV Testing

WNV mosquito species identification, enumeration, and viral testing, is provided by qualified mosquito-testing service providers, selected individually, and contracted by PHUs. The ministry requires each mosquito-testing service provider to undergo and pass a 'proficiency panel' verification test each year provided by the National Microbiology Laboratory (Winnipeg, MB) and coordinated by PHO. Simultaneously, service providers are required to report the mosquito surveillance data to the PHU and PHO. Results of the proficiency panel are reported to the PHUs by PHO prior to the start of vector surveillance season.

The mosquito-testing service providers are required to use the established WNV vector templates created by PHO. The mosquito-testing service providers are requested to provide PHO with weekly data during the WNV season for the specific mosquito species reported (Appendix II). PHUs are requested to have their mosquito-testing service provider share the mosquito surveillance data concurrently with PHO for monitoring and for posting on the PHO website.

6.4 Vector Surveillance Data

Vector surveillance includes mosquito enumeration, identification, and viral testing, which is combined with human and equine surveillance indicators to assess and manage the risk of vector-borne diseases in Ontario.

Vector surveillance data is used for the following functions: assisting PHUs in preparation of WNV risk assessments, initiation of mosquito control and public notifications, and other steps within the decision-making processes of the respective PHU; providing information and direction to PHUs and the public with respect to WNV-disease risk based on current surveillance data; assisting PHUs in evaluating their WNV control operations; and aiding in the calculation of MIRs and vector indexes of vector population.

7 Integrated Vector Management and Best Management Practices

Integrated Pest Management (IPM) is a term used to describe the application of a suite of methodologies that was initially developed for sustained and effective control of agricultural pests. IPM has been applied to other areas of insect management, including vectors (IVM) and mosquitoes [Integrated Mosquito Management (IMM)]. In the case of Ontario's programs, the focus is on the vector mosquitoes and does not specifically address nuisance or pest mosquitoes, as is the case for IMM; therefore, the WNV program is developed around an IVM philosophy. The overarching goal of Ontario's management program is to mitigate the threat of mosquito-borne disease to humans through implementation of IVM principles.

Ontario's IVM program is a comprehensive strategy utilizing all available techniques for the management of vector mosquitoes, thus reducing the threat of mosquito-borne disease in Ontarians, while minimizing the impact on the environment. While comprehensive in philosophy, the following IVM components or BMPs can be used singly or in combination depending on the needs of a particular PHU: surveillance, risk assessments (decision-making), physical and/or source reduction, chemical control, monitoring efficacy/resistance, public education/outreach, program evaluation, record-keeping, and mapping.

It is recommended that PHUs adopt the IVM program and develop their own use of BMPs according to their needs. The resources of a particular PHU and the relative risk of human disease will dictate the maximum extent to which any one BMP can be implemented. Developing a WNV-vector control program involves considerable resources; however, preventative programs are much less expensive than implementing emergency programs if an outbreak occurs. Careful planning is therefore needed when developing PHU programs, targeting the risks of particular areas.

While not described in full in this document, record keeping and mapping (surveillance, control, and complaints) are two other important aspects of the IVM. Surveillance is the cornerstone of IVM and is described in the **Surveillance Indicators for WNV** and **Vector Surveillance Programs** sections.

7.1 Action Thresholds, Risk Assessments, and Decision-Making

Action thresholds are parameters set in place before the mosquito season begins (set by the individual health unit) and are used to determine when and where management strategies need to be implemented, especially when applying larvicides or adulticides. For additional information on adulticiding, see PHO's Guide for the Public Health Units: Considerations for Adult Mosquito Control.[6]

Application of WNV control measures, particularly larvicides or an adulticide requires a local risk assessment. The risk assessment should weigh the level of WNV risk to public health based on the most current evidence of local WNV activity in the human population and in non-human species (WNV-positive mosquito pools, mosquito infection rates, and reported equine infections). These factors, as well as other control measures available (e.g., source reduction), should be considered in weighing the expected benefits and risks of pesticide use.

The MOH is the appropriate official to make decisions regarding larviciding or adulticiding for WNV after receiving the aforementioned information from PHU staff and/or other municipal or regional agencies. If necessary, consultation can occur with provincial, federal, or private sector experts. The ministry and PHO will provide consultation to the PHUs and assist regarding any of these decisions.

A local risk assessment is the most critical step to decision-making regarding where and when to commence vector control. The risk assessment must be based on the most current and accurate surveillance data available.

Components that should be considered in a WNV risk assessment are outlined, but not limited to, those listed in Box 1. These components may be used in developing risk categories for a particular PHU and can help in identifying appropriate responses.

BOX 1: Components of a WNV Risk Assessment

- Local mosquito and arbovirus surveillance findings
- Local vector species, distribution, density, and MIRs
- Evidence of WNV illness in the health unit region and consideration of activity in adjacent health units
- Trends in local human morbidity and mortality that indicate the relative urgency of the risk to human health
- Demographic and geographic distribution of the human population at risk
- Nature and location of the larval development site(s) to be treated, including the habitat type, its proximity to at risk human populations, and logistics of larvicide application
- Season and local weather conditions
- Current and historical vector data from the health unit and surrounding health units

7.2 Physical and/or Source Reduction

Targeting the elimination of larval development sites is referred to as source reduction and is a relatively simple and effective means of managing immature mosquitoes. Through education, the public can make significant impacts in reducing the number of human-made immature mosquito habitats. Source reduction is economically effective in the long-term and reduces the need to use larvicides for management. PHUs should emphasize elimination of larval development sites within their local communities at a resident level, including commercial sites, which are often significant sources of potential larval development. In addition, PHUs should inform local municipalities as to appropriate larval control measures in municipally-controlled bodies of water such as catch basins, ponds, sewage treatment plants, drainage systems, and storm water management ponds.

7.2.1 Physical Exclusion

An often overlooked adult mosquito control measure is simply providing a barrier between humans and host-seeking mosquitoes. PHUs should provide public education around physical exclusion methods. The main type of exclusion is the use of metal or cloth meshing to control mosquito access through doors, windows and over beds. Physical barriers should be inspected regularly to ensure there are no holes or gaps that mosquitoes could get through.

Covering up when going outside between the hours of dusk and dawn (when most mosquitoes feed) can also provide a physical barrier to mosquito bites. Wearing a light-coloured, long-sleeved shirt or jacket and long pants (tucked into your socks for extra protection), or special clothing designed to protect from bites (e.g. bug jackets), is another example of a physical barrier to being bitten by mosquitoes.

7.2.2 Source Reduction

Municipal, local, or regional authorities can engage in the following examples of source reduction strategies:

- Consider enacting by-laws to require site elimination or reduction, particularly in urban areas.
- Conduct mapping of known or possible vector habitats. In addition to existing paper maps, mapping tools such as a geographic information system (GIS) with global positioning system (GPS) units is helpful.
- Monitoring mosquito larval populations (larval dipping) in bodies of stagnant water or in ditches/depressions 24 to 36 hours after major rainfalls. Storm water management ponds located in urban settings must be maintained with grass cut low on the edges of ponds. Urban drainage ditches and ground depressions may be drained, filled in, or re-graded in order to prevent the accumulation of long-standing stagnant water or periodic rain pools.

- Wetlands must not be drained or altered in any way, unless there is an exceptional circumstance of significant human health risk from vector mosquitoes. Consultation with, and permission from, the Ministry of Natural Resources and Forestry and the appropriate conservation authority will be required.
- Store tires inside a garage or shed or other water-protected situation. Discarded tires left outside collect water after each rainfall and create perfect aquatic sites for female mosquitoes to lay their eggs. Tires that have a field function, such as being anchors for tarpaulins, should have several holes drilled in them to allow drainage.
- Tire Drives can be sponsored at the local level (i.e., encourage citizens to bring in discarded tires for recycling).
- Flush or vacuum storm drains and catch basins frequently and ensure that ditches drain properly to remove stagnant water. This should be coordinated with larval control programs to ensure that catch basins are not cleaned after the application of a product.
- Monitor sewage treatment plants, sewage lagoons, and retention ponds to ensure they are not developing vectors. Cut grass and remove vegetation around the banks of sewage lagoons. When building new facilities design ways to limit mosquito habitat.
- Every effort and initiative must be considered to eliminate vector development sites on public and private property. Source reduction promotion and initiatives should be developed using the most effective means for the PHU region (e.g. social media, presentations, displays at various locations, fact sheets, newspaper ads etc.)
- Adopt municipal lead-by-example activities to encourage source reduction and promote these activities as applicable.
- Consider offering presentations or displays at retail garden outlets, seniors' centers, and gardening clubs in order to increase awareness among persons more susceptible to WNV illness (e.g., older adults).

7.3 Chemical Control

7.3.1 Larvicides

Vector control to manage larval populations for WNV or other vector-borne diseases normally requires larviciding, involving the use of MOECC-approved pesticides. Initiation and discontinuation of larviciding is determined at the local level (varies amongst PHUs) and may include the use of larval surveillance data if available.

Larvicides are usually dispensed in the form of pellets, granules, or briquettes (ingots) that are dropped into pools or containers of stagnant water where vectors are developing. Larvicides can be biological or chemical products.

The MOECC has classified three pesticides to be used for the control of mosquito larvae, with the use of *Bacillus sphaericus* (*B. sphaericus*) and *Bacillus thuringiensis israelensis* (*Bti*) approved for use in surface waters of irrigation ditches, flood ditches, flood pastures, marshes, woodland pools, standing ponds, or storm water retention and detention ponds. (S)-methoprene and *B. sphaericus* are approved for use in catch basins and sewage/sludge lagoons for larval mosquito control. In Ontario, there are many classified products available for use containing these three pesticides.

PHUs should consult with their service providers on which products to use, formulations available and for options on the mode of larviciding. All products must be applied by a licensed exterminator and a permit must be obtained from the MOECC authorizing the application of the larvicide to a water body. All pesticides must be used in accordance with the *Pesticides Act* and *O. Reg. 63/09*.[8,9] The permit application guide for municipalities and health units is available from https://www.ontario.ca/page/permit-applicant-guide-municipalities-and-health-units.

7.3.1.1 Bacillus thuringiensis israelensis and Bacillus sphaericus

Bacillus sphaericus and *Bti* are bacterial spores that are ingested by mosquito larva. Inside the mosquito's gut, the spores release a crystallized toxin that causes damage to the gut resulting in an inability to feed and subsequent death. Safety evaluations of *Bti* and *B. sphaericus* application for larval control have shown little or no risk to wildlife, non-target aquatic organisms, or human health.

Bti and *B. sphaericus* must be applied when mosquito larvae are present in various mosquito larval development sites as indicated on the product labels, and are most effective when applied to early- to mid- developmental stages of larvae (1st, 2nd, and 3rd instars). *B. sphaericus* is normally effective for longer periods (up to 6 weeks) compared to *Bti* (residual decreases after 48 hours). *B. sphaericus* is not effective against *Anopheles* spp.

7.3.1.2 (S)-methoprene

Insect growth regulators (IGR), such as (S)-methoprene, have been used to combat immature mosquitoes since the mid-1970s. (S)-methoprene is a mimic of juvenile hormone III (naturally found in mosquitoes) and targets 4th instars by interfering with cell division and cell death processes, creating midguts in pupae that are similar to larval midguts and preventing normal development. (S)-methoprene does not kill mosquitoes directly; it prevents the development of larvae and pupae into adult mosquitoes which can potentially transmit WNV and other vector-borne diseases.

(S)-methoprene is applied to catch basins and sewage lagoons and must be applied before larvae pupate. Efficacy of (S)-methoprene is dependent upon several factors, including the target mosquito species, precipitation, water temperature, catch-basin flushing, and levels of organics in water. Combined, these factors, with the formulation used, will determine the duration of residual activity.

When used in the approved manner, (S)-methoprene is not expected to pose unreasonable risks to wildlife, people, or the environment.

7.3.2 Adulticides

Vector control to manage adult mosquito populations for WNV requires the use of an approved adulticide. Adulticides control the adult stage of mosquitoes, and usually are dispensed in the form of a liquid suspension in air using special equipment called ultra-low volume (ULV) application units. These units create a mist containing very small droplets of pesticide that are airborne for up to 30 minutes depending on weather conditions, killing any mosquitoes that are exposed to the droplets. Adulticides may be delivered by backpack sprayers, truck-mounted ULV equipment, or by aircraft.

There are two pesticides currently classified in Ontario for use in adult mosquito control: malathion and deltamethrin. Several classified adulticide products containing these two pesticides are available for use.

All products must be applied by a licensed exterminator and a permit must be obtained from the MOECC authorizing the application of the adulticide, if required. All pesticides must be used in accordance with the *Pesticides Act* and *O. Reg. 63/09*. For further guidance on the use of malathion, please see the Application of Malathion by Ultra Low Volume Equipment for Control of Adult Mosquitoes in West Nile Virus Control Programs available at https://www.ontario.ca/page/application-malathion-ultra-low-volume-equipment-control-adult-mosquitoes-west-nile-virus-control.

7.3.2.1 Adulticiding or Mosquito Fogging

A local risk assessment is an essential step in decision-making regarding the need to adulticide and where or when to start an adulticiding program, after consultation with the ministry and PHO. The MOECC may also be consulted as needed if the use of an adulticide is being considered. While larval control programs, including larviciding, are an important means of proactive prevention, adulticiding is an additional option in the control of WNV. As of the date of this publication, adulticiding has never been used in Ontario for the control of WNV.

For additional information on adulticiding, see PHO's Guide for Public Health Units: Considerations for Adult Mosquito Control.

7.3.2.2 Contingency Adulticiding

For over 14 years, the ministry maintained a contingency program, including ultra-low volume sprayers and a store of malathion, for the adulticiding of mosquitoes should it have been requested by a MOH from a PHU for the control of mosquito-borne disease such as WNV. During the time period it was available, this contingency program was never requested or used by any PHU in the province.

Upon the expiration of the malathion stores, a review of the necessity of maintaining this program was conducted. The discontinuation in 2017 of the mosquito adulticiding contingency program aligned with current scientific recommendations regarding the need for this program for WNV in Ontario.

In the rare and exceptional circumstance that mosquito adulticiding should be required in the province, service providers already involved in mosquito surveillance and larviciding work in the province could be sourced at the time to provide this service.

7.3.3 Monitoring Efficacy and Resistance

A specific and immediate field evaluation of effectiveness for larviciding consists of continued sampling of larvae before and after treatment. To determine the efficacy of *Bti* or *B. sphaericus* in preventing 4th instar larvae and pupae development, the relative number of larvae collected before and after larviciding can be compared. The general aim of larviciding with *Bti* is to obtain 95% control within 24 to 48 hours of application after all label directions have been followed and after 48 hours of larviciding with *B. sphaericus*. To determine the efficacy of (S)-methoprene in preventing the emergence of adult mosquitoes, collection, and rearing of live pupae to determine emergence inhibition rates is required. The level of efficacy monitoring is determined by each individual PHU.

Following adulticiding, the relative numbers of adult mosquitoes collected in light traps should be compared to the numbers collected immediately prior to the insecticide application and/or numbers collected in adjacent “untreated” areas.

Possible reasons for these control measures to fail are varied. The impacts of larviciding or adulticiding may be extremely dependent on many variables affecting local conditions (i.e., weather conditions, mosquito counts, or proximity to residential areas). Weather conditions, for example, influence mosquito populations – their distribution (e.g., strong winds may blow mosquitoes in from outside the “control zone”) and the extent and rate of their development (e.g., high temperatures or humidity) and may affect adulticiding efforts to control adult mosquitoes over large urban areas.

Vector management programs vary between jurisdictions and differ over time; therefore, it is difficult to make a generalization about the expected effectiveness of larviciding or adulticiding in preventing mosquito-borne virus transmission to humans. The insecticide products, however, have been evaluated and approved for their general effectiveness in reducing mosquito populations when used according to the label.

7.4 Public Education and Outreach

Education is a key component in an IVM program, whereby the public and health care providers are educated on the biology of mosquitoes and how to take personal precautions and how to prevent the establishment of mosquitoes on their private property and throughout the community.

7.4.1 Education of Health Care Providers

Health care providers, especially those in acute care hospitals, should be informed about the human case definition for WNV illness, which is a disease of public health significance in Ontario. The ministry and PHO websites provide physicians, other health care workers, and the public access to the latest information on WNV surveillance, clinical information, and diagnostic testing.

Many PHUs maintain a very close association with local hospitals as a routine component of their community disease surveillance.

7.4.2 Public Education Activities in Public Health Units

The public and other local community stakeholders will require information and updates about the surveillance activities and the risk assessment outcomes determined by the MOH regarding vector control activities.

In terms of prevention measures, the general public education campaign message must be re-emphasized around personal protection against mosquito bites, including the application of an approved insect repellent. Outdoor recreational, tourism groups, and senior citizens' residences may be targeted for presentations and advice on personal protective measures. Parents, schools, and child care settings need information on the use of domestic mosquito control products such as DEET or icaridin-containing repellents on children (available from https://www.canada.ca/en/health-canada/services/about-pesticides/insect-repellents.html).

Public and stakeholder education is also needed at the local level to encourage source reduction activities such as eliminating sites of standing water on private properties (residential or commercial) and on public properties (e.g., ditches, ponds, reservoirs, street catch basins, sewage treatment facilities). The importance of source reduction increases when vector larval development sites have been identified close to residential areas. Source reduction at the local and regional level may involve the municipal departments of Public Works or Parks and Recreation, as well as local conservation authorities, and private property owners.

Furthering the public education message can also be accomplished with schoolchildren (both elementary level and high schools), adolescents and senior citizens' groups, as well as other community-based organizations. All of these groups are beneficial

resources that should be encouraged to undertake standing water surveillance/source reduction in local neighborhoods. Increased awareness among the members of these groups will result in enhanced personal awareness. This may also result in local media coverage of activities that will further support WNV public educational or promotional activities. PHUs are encouraged to continue their active community development role through such WNV education work.

7.4.2.1 Planned Messaging

- General public education messages should reinforce protective clothing: wear shoes, socks, long pants, and a long-sleeved shirt when outdoors for long periods, or when mosquitoes are most active. Clothing should be light-colored and made of tightly woven materials that keep mosquitoes away from the skin. The use of mesh "bug jackets" or "bug hats" is recommended.
- If WNV is found in a community, advisories (type determined by the PHU) should be issued to remind residents to:
    - Minimize unprotected time spent outdoors at all times, particularly between dusk and dawn when mosquitoes are most active.
    - Use mosquito netting when sleeping outdoors or in an unscreened structure and to protect small babies when outdoors.
    - Consider the use of mosquito repellents and use according to directions when it is necessary to be outdoors.
- With respect to personal property, general public education messaging should be reinforced to encourage the public to remove any type of standing or stagnant water. Emphasis will be to:
    - Clean up and empty containers of stagnant water such as old tires, flower pots, wheelbarrows, barrels or tin cans that are outdoors
    - Change water in bird baths at least once per week
    - Check swimming pools - remove water that collects on pool covers. Make sure the pool's pump is circulating
    - Turn over wading pools when not in use
    - Check and clear eaves troughs and drains - clear obstructions from eaves troughs and roof gutters throughout the summer
    - Make sure drainage ditches are not clogged
    - Check flat roofs frequently for standing water
    - Carry out regular yard and lawn maintenance: lawn cuttings, raked leaves or other decaying debris (such as apples or berries that fall from trees) should be collected and recycled or mulched so that organic matter does not end up in storm sewers as a food source for mosquito larvae
    - Turn over compost frequently
    - Fill in low depression areas in lawns
    - Trim dense shrubbery where mosquitoes like to rest.

Glossary

Arbovirus. Viruses maintained in nature through biological transmission between susceptible vertebrate hosts by blood-feeding arthropods (mosquitoes, sand flies, ceratopogonids "no-see-ums", and ticks).

Biological Control. The use of parasites, predators, and pathogens for the regulation of unwanted animal or plant populations. Also called biocontrol.

Bridge Vector. A pathogen-carrying mosquito that will feed on birds and mammals and transmit the pathogen.

Case Definition. A set of standard criteria for deciding whether a person has a particular disease or health-related problem. Criteria can be clinical, laboratory or epidemiologic.

Dead-end Hosts. An intermediate host (e.g., humans and horses) that does not allow virus transmission to the definite host (birds), thereby, preventing the virus from completing its development. These hosts have low levels of virus in circulating blood.

DEET. N,N-Diethyl-meta-toluamide (DEET). An active ingredient in common insect repellents.

Encephalitis. Inflammation of the brain usually caused by a virus; symptoms include headache and neck pain, drowsiness, and nausea and fever.

Endemic. A disease naturally present in certain human and animal populations.

Enzootic. A disease that is constantly present in the animal community and a particular area.

Enzootic Vector. Mosquitoes that maintain infection in the animal population.

Epidemic. The rapid spread of a disease that affects a large number of humans at the same time in a particular area.

Epizootic. The rapid spread of a disease that affects a large number of animals at the same time in a particular area.

Gravid. Female mosquito ready to lay eggs; “pregnant” mosquito.

Icaridin. 2-(2-hydroxyethyl)-1-piperidinecarboxylic acid 1-methylpropyl ester. An active ingredient in common insect repellents.

Immunologically Naïve. An animal that has not been previously exposed to a pathogen and does not have antibodies against the pathogen.

Intrauterine. Refers to an event within the uterus or womb.

Pool. The assignment of a mixed collection of adult mosquitoes to specific groups (e.g., site location, species, and physiology) for the purposes reducing the amount of viral testing needed while still giving an estimate of viral activity in a given area.

Reservoir. An animal population that normally harbors a disease-causing organism capable of being transmitted to human or other animal populations.

Residual Activity. The length of time that a chemical control product remains active in managing mosquitoes.

Vector. An arthropod carrier of a disease-causing organism.

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Appendix I: Program Measurements at the PHU Level

Measuring the local effectiveness of a PHU's program is difficult because vector-borne disease control programs often contain measures that are hard to quantify. The measures that are most useful in evaluating the effect of a program include the inputs and outputs.

To better plan and develop a surveillance and control program, measures of what was put into the program are essential. Program inputs must also be measured for reasons for financial accountability and budgetary control.

A program's input measures can include, but not be limited to, the total:

- money spent on surveillance and control
- number of people required to maintain the program
- number of public presentations and/or information requests
- amount of each type of chemical used
- mosquitoes collected
- trap numbers for each trap type
- mileage for surveillance and control efforts
- number of public complaints

With many vector-borne disease control programs, public and partner agencies will request some measure of output or outcomes. Specifically, they will want to know if the program decreased the risk of infection or if the program is using its resources in the best manner possible. These outcomes need to be quantified and supported by measurable results based on scientific data collection (e.g., surveillance data or efficacy trials).

A program's outcome measures can include, but not be limited to, the percentage reduction in:

- vector mosquito larvae and/or pupae
- host-seeking female mosquitoes
- human incidence of disease

Appendix II: Mosquito Species and Species Groups to be Reported

Mosquito Species for Identification (Revised February 15, 2018):

- *Aedes albopictus* (WNV) (EEEV)
- *Aedes cinereus* (EEEV)
- *Aedes vexans* (WNV) (EEEV)
- *Aedes*/*Ochlerotatus s*pecies
- *Anopheles punctipennis* (WNV)
- *Anopheles quadrimaculatus* (WNV) (EEEV)
- *Anopheles quadrimaculatus*/*walkeri*
- *Anopheles walkeri* (WNV)
- *Anopheles* species
- *Coquillettidia perturbans* (WNV) (EEEV)
- *Culiseta melanura* (EEEV)
- *Culiseta morsitans* (EEEV)
- *Culex pipiens*/*restuans* (WNV)
- *Culex salinarius* (WNV) (EEEV)
- *Culex tarsalis* (WNV)
- *Culex* species
- *Ochlerotatus black-legged*
- *Ochlerotatus broad-banded* (WNV)
- *Ochlerotatus canadensis* (EEEV)
- *Ochlerotatus cantator* (WNV)
- *Ochlerotatus excrucians*
- *Ochlerotatus hendersoni* (WNV)
- *Ochlerotatus japonicus* (WNV)
- *Ochlerotatus provocans*
- *Ochlerotatus sollicitans* (WNV) (EEEV)
- *Ochlerotatus stimulans* (WNV)
- *Ochlerotatus triseriatus* (WNV)
- *Ochlerotatus triseriatus*/*hendersoni*
- *Ochlerotatus trivittatus* (WNV)

This list is prepared based on analysis of entomological data of Ontario and other variables. Changes to this list will be made as required, based on new information and analysis of entomological data.

Appendix III: Mosquito Species: WNV Testing Order of Preference

The following is a list of WNV vector species of concern in Ontario. These species are listed in order of preference when considering what species to test in the event that a trap contains more than three different vectors. Note that *Culex pipiens* and *Culex restuans* should be grouped into *Culex pipiens*/*restuans*.

Mosquito Species for Viral Testing (Revised February 15, 2018):

1. *Culex pipiens*/*restuans*
2. *Culex salinarius*
3. *Ochlerotatus japonicas*
4. *Culex tarsalis*
5. *Aedes vexans*
6. *Ochlerotatus triseriatus*
7. *Anopheles punctipennis*
8. *Ochlerotatus trivittatus*
9. *Anopheles walker*
10. *Ochlerotatus stimulans*
11. *Anopheles quadrimaculatus*
12. *Ochlerotatus Canadensis*
* *Aedes albopictus*
* *Aedes aegypti*

* Since this species may sporadically occur in very low numbers and is a highly competent vector, it is suggested that it be tested for WNV as part of the three-pool limit.

This list is prepared based on analysis of entomological data of Ontario and other variables. Changes to this list will be made as required, based on new information and analysis of entomological data.

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