TORONTO STAFF REPORT

January 20, 2003

To: Board of Health

From: Dr. Sheela Basrur, Medical Officer of Health

Subject: Protocol for the Control of Mosquito Larvae to Prevent and Control West Nile Virus (WNV)

Purpose:

To recommend a protocol for the control of mosquito larvae to prevent and control the spread of West Nile Virus (WNV).

Financial Implications and Impact Statement:

Financial impacts from the adoption of this report were outlined in the November 13, 2002 report which was adopted by the Board of Health, the budget for which was referred to Budget Advisory Committee for consideration during the 2003 Operating Budget process.

Recommendations:

It is recommended that:

(1) the Board of Health endorse the Integrated Pest Management (IPM) protocol for the control of West Nile Virus (WNV) as outlined in this report;

(2) the Board of Health forward a copy of this report to City Council and to the Works Committee for their information;

(3) the Board of Health forward copies of this report to the Ontario Public Health Association, the Association of Local Public Health Agencies, the Ontario Ministry of Environment and the Ontario Ministry of Health and Long Term Care for their information; and

(4) the appropriate City Officials be authorized and directed to take the necessary action to give effect thereto.

Background:

At its meeting of November 18, 2002, the Board of Health requested that the Medical Officer of Health (MOH) report back no later than April 2003 on a protocol for pesticide applications for mosquito control to prevent the spread of West Nile Virus. This protocol would be based on an assessment of health risks and benefits and would pertain to pesticide applications to both natural bodies of water (e.g. wetlands) and human-made water containers (e.g. storm water catch basins). The protocol would address the use of pesticides to control mosquitoes during their larval stage (larvicides) and as adults (adulticides).

An integrated pest management (IPM) program uses a number of different approaches to control target pests in order to minimize the use of pesticides. Preference is given to non-chemical and biological control with chemical pesticides only used as a last resort. Controlling mosquitoes in their larval stage is preferable to using pesticides once they have become adults since less toxic pesticides are available for this purpose and the products can be released in a more controlled fashion. Experience elsewhere also shows that an IPM program for mosquito control can reduce the overall use of pesticides by using a mix of methods and by controlling mosquitoes when they are still in their larval stage.

This report provides a brief analysis of the feasibility of using alternative control measures, including biological control (e.g. dragonflies), for mosquito abatement. This report only addresses the use of larvicides. No decisions on the control of adult mosquitoes will be made without ongoing consultation with Medical Officers of Health of other health units facing similar WNV-related risks, the Chief Medical Officer of Health for Ontario, and the appropriate provincial ministries. Toronto Public Health (TPH) will be preparing a second report in Spring 2003 that will address those aspects of the protocol that pertain to the control of adult mosquitoes.

This report was prepared in consultation with Works and Emergency Services (WES).

Comments:

This report outlines a generic protocol to be used by TPH in making decisions regarding the control of mosquitoes in the City, with the goal of reducing the risk of human illness due to WNV while minimizing the use of pesticides. The protocol gives guidance for the application of pesticides and is based on an integrated pest management (IPM) approach that incorporates a range of measures in order to minimize impacts on human health and the environment. This protocol will guide decisions on the use of pesticides to control mosquitoes in the City of Toronto. Appendix A outlines the various steps in the protocol.

The protocol has been developed in consultation with Health Canada, the Ontario Ministry of the Environment (MOE) and the Ontario Ministry of Health and Long Term Care (MOHLTC). Since pesticides applied in catch basins may also reach natural bodies of water, the Ontario Ministry of Natural Resources (MNR) will also be consulted as needed. TPH is part of the Central East WNV Task Group, comprised of representatives of health units in and around the

Central East region of Ontario. This group has been meeting regularly to develop and evaluate a co-ordinated local public health response to WNV.

In developing this protocol, TPH has sought advice from key informants with expertise in entomology, ecology and pest control applications. Toronto Public Health has also adhered to the Health Canada National WNV Guidelines, which provide a framework for the development of local responses that:

(a) Minimize human disease
(b) Provide a graded response based on an assessment of the specific risks within each jurisdiction; and
(c) Minimize environmental impacts.

Toronto Public Health used these guidelines to develop and implement the WNV program in 2002. Given that there were no human cases in Ontario and that the impact of WNV in 2001 was relatively low, the City's 2002 WNV program focused on surveillance, public education and enhanced communication with health professionals. The elements of the TPH plan in 2002 were virtually identical to plans in neighbouring health units. Despite these efforts, Toronto (and Southern Ontario) saw its first and many human cases of WNV-related disease in 2002.

Given that WNV has resulted in considerable human illness and deaths in Toronto in 2002, additional measures are necessary in 2003 to reduce the risk of human transmission. In 2003, TPH will continue to raise public awareness of the need for personal protective measures and removal of standing water on private property, in order to reduce the need for pesticide-based mosquito control. Therefore TPH is recommending greater emphasis on mosquito control measures. However, non-chemical measures alone may not be sufficient to manage the risk of human WNV infection in Toronto in 2003.

Research data and information from other jurisdictions across North America show that storm water catch basins are important breeding grounds for mosquitoes in urban areas, in particular for Culex pipiens, the main mosquito involved in the transmission cycle for WNV. Sampling done in 2002 confirmed that catch basins in Toronto are breeding areas for mosquitoes, therefore measures to reduce mosquito breeding in these structures will need to be part of the strategy to control the spread of WNV. Toronto Public Health therefore is investigating ways to control mosquitoes, including the possible use of larvicides in catch basins across the City to help reduce the numbers of mosquitoes, and thus the risk of transmission of WNV in 2003.

There remain many unanswered questions that make it difficult to predict the future prevalence of WNV-related disease in humans. New data on WNV regarding its rate of spread, modes of transmission, and the effectiveness of control measures emerges regularly. The proposed WNV program for 2003 is based on the most recent information available to Toronto Public Health. Supplementing educational and source reduction measures with the selective use of larvicides balances the risks of human illness from WNV with environmental and health concerns from the use of pesticides. Whether additional control measures are needed to reduce the human health risk cannot be predicted at this time.

Burden of Illness from WNV:

As of January 13, 2003, there were 56 confirmed, 84 probable and 152 suspect cases for a total of 292 WNV infections reported to Toronto Public Health, including 10 deaths.

Contrary to initial expectations, serious WNV disease in Toronto was not confined solely to elderly people with pre-existing medical conditions. Significant morbidity occurred among previously healthy young individuals, 46 (15%) of whom were less than 35 years of age. Even among cases that have not yet been confirmed, illness frequently required hospitalization and caused prolonged fatigue, muscle weakness, disability and substantial recuperation time. Recently reported figures suggest that on the whole, one in every 150 WNV infections can result in severe neurologic illness.

It is difficult to predict what human impact WNV will have in 2003. However, unless greater efforts are made to prevent and control the transmission of WNV, it can be anticipated that the number of human cases will be similar to or greater than those for 2002. Efforts to reduce these risks must take place before the peak incidence of WNV disease in late summer and early fall, when it is too late to make an effective impact on the transmission of WNV by mosquitoes. Hence, although there is uncertainty, a decision on which control measures to use in 2003 must be made now.

While the overall population risk of serious illness remains low, TPH must prepare for the possibility of substantial human illness in 2003 and beyond. Because certain species of mosquitoes are the key transmitters of WNV to humans, efforts to control viral transmission are best aimed at these mosquitoes. TPH deems it prudent therefore, and in keeping with the experience and response of other jurisdictions, to take steps to enhance its mosquito control activities to reduce human exposure to WNV in Toronto for the 2003 season. This is based on mosquito and bird surveillance data from the 2002 season, ie. the presence of positive mosquito pools, positive birds and mosquito larvae in stormwater catch basins and data on human illness.

Protocol for the Control of Mosquitoes to Prevent and Control WNV:

Toronto Public Health is proposing the adoption of IPM principles in its WNV program, using a tiered approach to mosquito control. This places first emphasis on preventative approaches that have the least negative impact on human health and the environment, followed by additional methods that are applied only if the initial efforts do not sufficiently reduce mosquito populations. TPH has developed a 3-tier framework to guide decision-making on mosquito control for WNV risk management. Table 1 summarizes the major elements of the framework. More details are provided in Appendix B.

Table 1 - Toronto Public Health’s Integrated Pest Management (IPM) Framework for WNV

Priority	IPM Component	Examples
Tier 1	Environmental Management & Public Education	Source reduction by environmental modifications Surveillance and monitoring of WNV activity Personal precautions, mosquito avoidance
Tier 2	Larval Mosquito Control	a) Non-chemical methods Introduction of natural enemies (e.g. dragonflies) Cleaning of catch basins
		b) Lowest Impact Larvicides Bacterial agents (e.g. Bti) Hormonal agents (e.g. Methoprene)
		c) Other Larvicides e.g. Fenthion, Chlorpyrifos
Tier 3	Adult Mosquito Control	Adulticides e.g. Malathion

Selection of the Appropriate Control Strategies:

Tier 1 strategies are the first line of defence and are used if there is the potential for WNV to be transmitted to humans. It is implemented when WNV has been detected in sentinel species such as crows and/or detected in neighbouring jurisdictions. Tier 1 strategies were used in 2002 and will continue to be used throughout the 2003 WNV season.

Tier 2 strategies are considered when the risk of WNV related disease in humans is known to occur. Given that there were many human cases of WNV in Toronto in 2002, the risk of human disease from WNV in 2003 is considered significant. Toronto Public Health is therefore recommending that Tier 2 strategies be considered to control mosquitoes during the 2003 WNV season if enhanced efforts of Tier 1 strategies are not sufficient to control mosquito populations. Within Tier 2, three options for intervention have been identified. TPH will give preference to the option that is most effective and is of lowest risk to human health and the environment.

Tier 3 control measures are the least desirable because of the potential of adverse effects to health and the environment. Thus, they will only be considered when Tier 1 and Tier 2 efforts have not been successful in reducing the risk to human health from WNV. Specific details are still under discussion and will be reported to the Board of Health in Spring 2003.

Specific Considerations for Mosquito Control Measures:

(a) Nature of the Mosquito Habitat to be Targeted (Step 6, Appendix B)

There are many types of areas where mosquitoes breed. In Toronto, mosquito-breeding areas exist in natural bodies of water and artificial or human-made collections of standing water. Natural bodies include lakes, ponds, swamps and wetlands. Artificial collections of standing water where stagnant water may collect in Toronto include containers (e.g. buckets, rain barrels, boxes), coverings (e.g. tarps, pool covers, awnings), and water management systems (e.g.

retention ponds, storm water catch basins). A primary strategy to reduce the risk of WNV is to encourage residents and businesses in Toronto to prevent mosquitoes breeding on their properties.

Natural areas require special consideration from the standpoint of preserving ecosystems. Culex pipiens, the mosquito that is the main vector of WNV, prefers to live in small containers and areas such as stormwater catch basins. The application of pesticide products directly to natural water bodies and wetlands is not planned for 2003 because the associated extensive preparatory work has yet to be undertaken. Based on review of surveillance data in 2003, TPH will consider whether or not the City's mosquito control efforts will need to be expanded to natural areas in 2004. Should TPH consider this necessary, City staff will consider IPM strategies when treating natural bodies of water and wetlands in the City, including the use of natural predators such as dragonflies. However, no chemical mosquito control interventions will be undertaken in these areas without an impact assessment and consultation with the Board of Health, other city departments, the appropriate provincial ministries, and other stakeholders. More information on the use of natural predators is found in Appendix C.

Stormwater catch basins are designed with a well below the surface opening. This well collects sediments and other debris and helps smooth the flow of water during a rain event. TPH surveillance efforts in 2002 confirmed that storm water catch basins in the City harboured mosquito larvae. This is in keeping with similar findings from a survey conducted in neighbouring Peel Region and in other urban areas. Given that catch basins are important breeding grounds that are directly under the City's control, TPH is recommending the adoption of measures to reduce mosquito breeding in these catch basins across the City in 2003.

(b) Choice of Control Measures

(i) Environmental management (Step 7, Appendix B)

Various non-chemical methods have been considered for catch basins, including flushing, vacuuming and possibly the injection of air or steam. As part of its regular maintenance, WES periodically removes the water in catch basins. TPH monitoring in 2002 showed that there was no long-term impact on the number of larvae, which returned to pre-cleaning levels after a few days. Catch basins would therefore need regular cleaning (every two weeks). This would be extremely labour intensive and require the acquisition of a large amount of new equipment.

The flushing of catch basins involves hosing water into the storm sewer system and thus replacing the water in them with fresh water, much as would happen after a heavy rain. This will disturb the larvae causing them to be washed away. However, this would also disturb the sediment that has accumulated in the wells, which can release pollutants into the storm sewer system and, in some cases, directly into streams and other bodies of water with no long-term impact on the number of larvae. Therefore, although in theory this could reduce the number of larvae, regular flushing would be required.

Some devices are being developed to control mosquitoes without the use of pesticides. For example, Larvasonic is a device that uses sound waves to kill larvae. This tool is in the process of being commercialized and has been tested in Quebec. However, it is not well suited to use in Canadian style catch basins – each lid must be lifted which would greatly increase staffing requirements and associated costs.

A major disadvantage of these physical methods described above is that they do not have any residual action and must be used repeatedly to effectively reduce the number of larvae. TPH will continue to explore these and other mechanical methods in collaboration with WES to reduce or eliminate the use of chemicals in the stormwater management system, so as to avoid the discharge of chemical larvicides into natural watercourses.

(ii) Natural Predators (Step 7, Appendix B)

Toronto Public Health also reviewed the use of predator species. The mosquito fish Gambusia affinis has been used successfully in some situations in the United States, but never in catch basins. No effective Canadian mosquito eating fish has yet been identified. Given that the Gambusia is not native to Canada, there are ecological risks to introducing this predator. In addition, given the low quality of water in catch basins it is unlikely that fish would survive long enough to effectively control mosquito larvae. As well, it is likely that the fish would be transported out of the catch basins after a rain, which would require regular restocking.

Although dragonfly larva or naiads also eat mosquito larvae, there is no data on their suitability in catch basins. However, the low quality of water in catch basins is likely to limit the viability of the dragonfly naiads plus the fact that rains would wash them away. In consultation with other City departments (for example, WES and, once convened, the Water and Wastewater Committee) as well as with local conservation authorities, TPH will continue to consider whether viable alternative mosquito control methods can be incorporated as part of the City's mosquito abatement program in future. This would be particularly important for the treatment of mosquito sources in ecologically sensitive areas.

(iii) Low-impact pesticides (Step 11, Appendix B)

In cases where non-pesticide alternatives are not able by themselves to sufficiently reduce mosquito populations, TPH will consider supplementing these methods with the use of the lowest-impact pesticide available. The choice of product will be guided by the criteria listed in Appendix B. Using these criteria, two pesticides can be considered acceptable in terms of availability, efficacy, human health impact and environmental impact: Bacillus thuringiensis var. israelensis (Bti) and methoprene (see Appendix D).

An IPM approach will consider first if a natural product is available. Bti is a biological pesticide that has the fewest adverse impacts on human health and the environment compared to other pesticides. However, data suggest that it is less effective against Culex pipiens (the most common species found in catch basins) than other products. In addition, given that a long-lasting formulation is not available in Canada, Bti would need to be applied more often to effectively reduce the number of larvae. Another biological pesticide currently used in the United States is Bacillus sphaericus. It is more effective against Culex pipiens, however it is not registered for use in Canada.

Of the other products available in Canada, methoprene has very low toxicity for humans and has fewer potential adverse impacts on the environment than other pesticides. It is available in a longer-lasting formulation and is effective against Culex pipiens, thus making it suitable for controlling mosquitoes in catch basins. At this time, TPH is not considering the use of other products to control mosquito larvae because of their higher toxicity to humans and the environment. However, TPH will consider the use of low-impact pesticides under Federal experimental-use permits as appropriate. See Appendix B for criteria used in choosing a larvicide.

(c) Application of control measures (Steps 8 & 12 Appendix B)

Implementation of mosquito control measures will take into account a number of factors, such as the following:

(i) Population peaks of mosquitoes during the season
(ii) Optimum time for mosquito control intervention
(iii) Nature of the habitat of the mosquitoes to be targeted
(iv) Product applicators: availability, reliability, safe application and quality assurance
(v) Evaluation of effectiveness and environmental impact

(d) Communication (Steps 8 & 12 Appendix B)

The Pesticides Act requires that public notice be provided in advance of any application of pesticides in residential areas. A public communications plan must be submitted to the MOE for approval. Before any decision is made to apply pesticides, TPH will consult with the Ministry and develop an appropriate communications strategy designed for maximum reach to all Toronto residents. In addition to paid advertising, this strategy will make use of all available outlets and channels, including the City's web site, Access Toronto and all public service announcement vehicles. Resources will also be made available in advance to the councillors of the appropriate wards and members of the Board of Health to assist in responding to inquiries from residents.

(e) Evaluation (Steps 9 & 13 Appendix B)

Mosquito surveillance will provide an indication of the immediate effectiveness of control. A long-term assessment of the effectiveness of the use of larvicides on mosquito populations would require a more thorough environmental study. An evaluation of the environmental impact of larviciding would be on a similarly large scale and is beyond the expertise and resources of TPH. In the October 2003 staff report to the Board of Health, TPH therefore recommended that the Board request the province and federal authorities to undertake such studies, should larvicides be used as a tool to control mosquitoes.

Conclusions:

Toronto Public Health has outlined a protocol for the control of mosquito larvae to prevent and control human disease by the WNV in Toronto. This protocol is based on an integrated pest management (IPM) approach that seeks to minimize the use of pesticides and uses methods that have the least adverse impacts on human health and the environment. Toronto Public Health will prepare a complimentary protocol that will address the use of pesticides to control adult mosquitoes (adulticides) in Spring 2003.

Of the methods available, the use of adulticides to control mosquitoes is the least desirable as a result of potential adverse impacts on human health and the environment. The best way to reduce the need for adulticides is to implement a comprehensive mosquito control program early in the WNV season that removes breeding sites and mosquitoes while they are still larvae. TPH has identified storm water catch basins as a major breeding ground for mosquitoes in Toronto and, in consultation with WES, is investigating various methods and as a last resort the use of larvicides in 2003 to control mosquito larvae. Of the products currently available in Canada, methoprene is the product judged to be the most effective against mosquitoes found in catch basins, while presenting the least risk to human health and the environment.

To allow sufficient time to prepare for the WNV season and to implement its mosquito control program, TPH is recommending that the Board of Health endorse the protocol for the control of mosquito larvae to prevent and control human disease by the WNV in Toronto. The resources required to accomplish the mosquito control measures for 2003 will be considered through the 2003 budget process.

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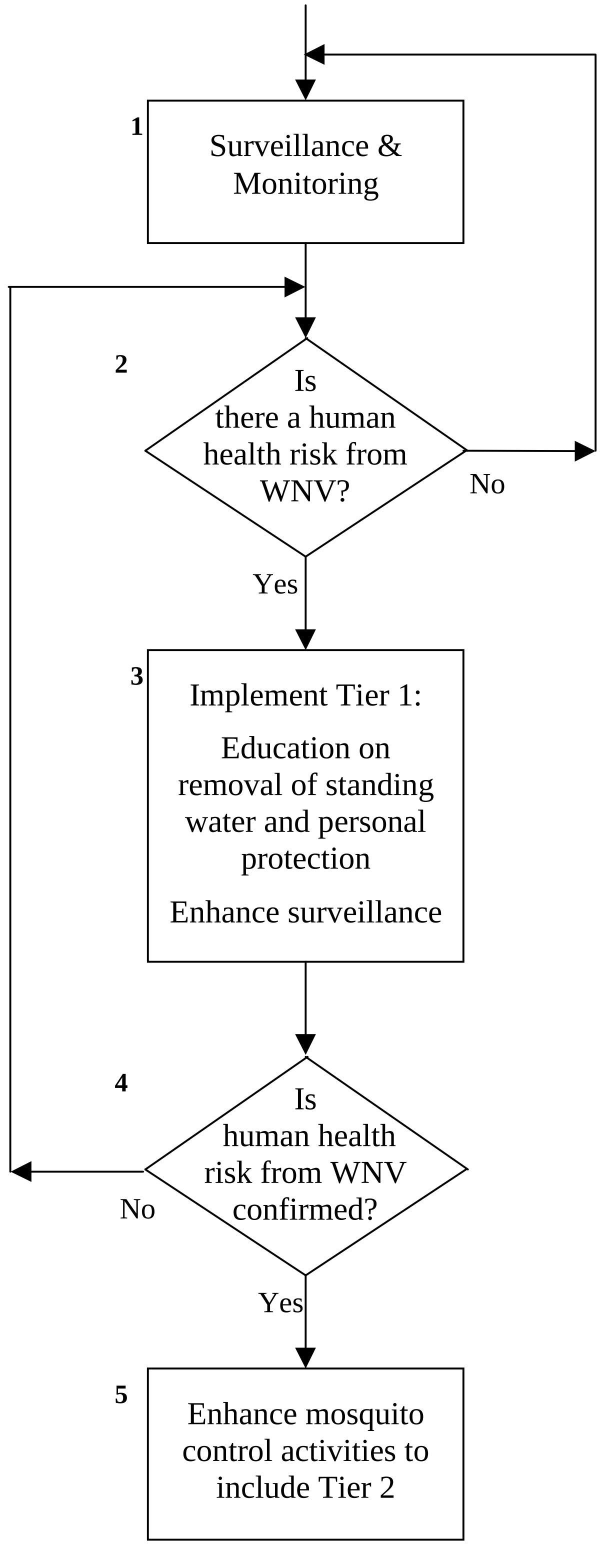
List of Attachments:

Appendix A: Flow Chart for the Control of Mosquito Larvae to Prevent the Spread of WNV Using Integrated Pest Management Principles
Appendix B: Protocol for the Control of Mosquito Larvae to Prevent the Spread of WNV
Appendix C: Alternative Methods of Mosquito Control
Appendix D: Comparison between Bti and Methoprene

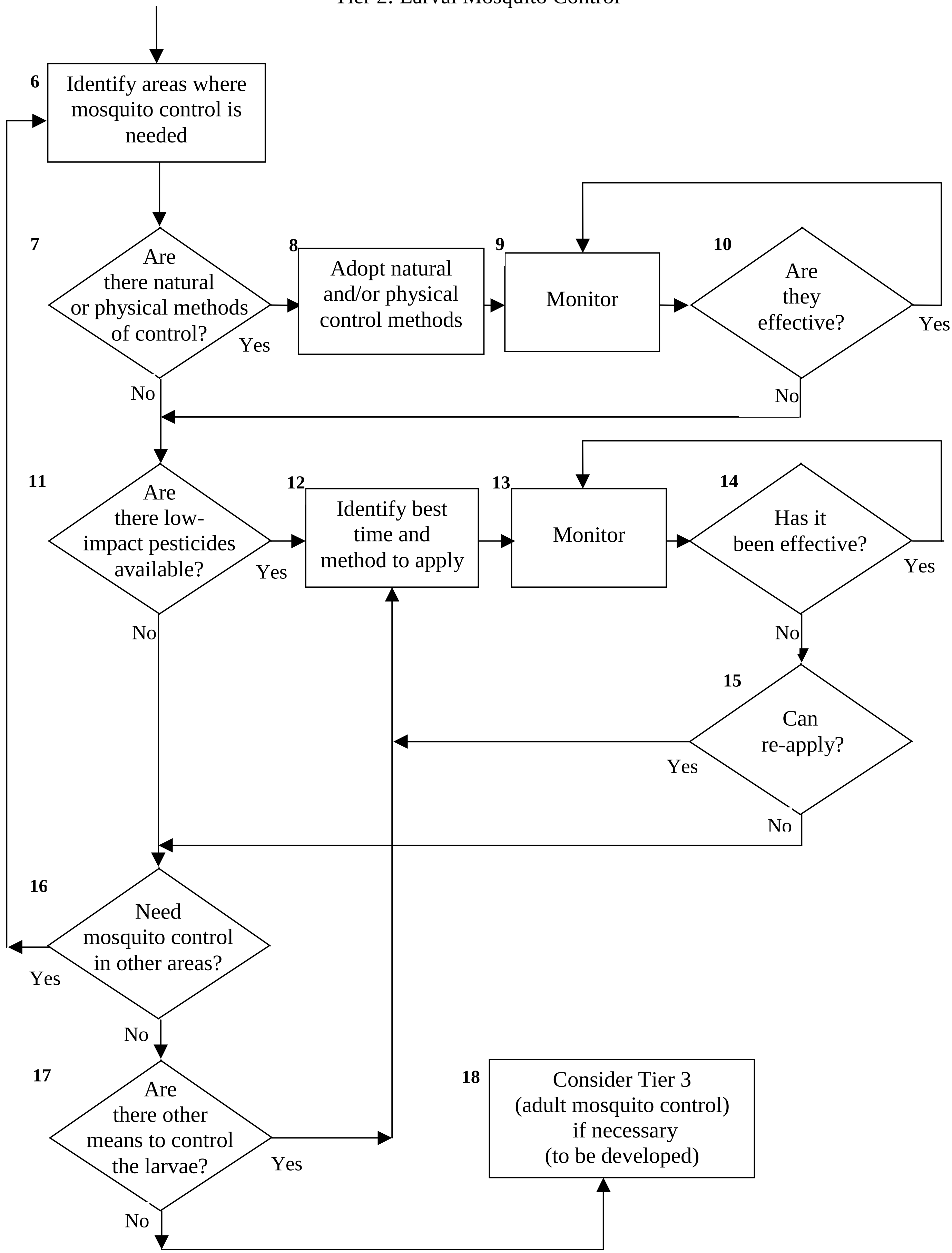
Appendix A

Flow Chart for the Control of Mosquito Larvae to Prevent the Spread of WNV
Using Integrated Pest Management Principles

Tier 1: Environmental Management, Public Education and Surveillance



Tier 2: Larval Mosquito Control



Appendix B

Protocol for the Control of Mosquito Larvae to Prevent the Spread of WNV

Toronto Public Health is committed to using an approach that is effective at reducing the risk of human illness due West Nile Virus (WNV) and at the same time has a minimal impact on the environment and human health. TPH is therefore emphasizing an integrated pest management (IPM) approach in its WNV program.

IPM uses a tiered approach to mosquito control. This places primary emphasis on preventive approaches that have the least negative impact on human health and the environment, followed by additional methods that are applied only if the initial efforts do not sufficiently reduce mosquito populations. TPH has developed a 3-tier framework to guide decision-making on mosquito control for WNV risk management. Table 1 summarizes the major elements of the framework.

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		c) Other Larvicides e.g. Fenthion, Chlorpyrifos
Tier 3	Adult Mosquito Control	Adulticides e.g. Malathion

Tier 1:

The IPM framework emphasizes preventive measures. Surveillance and monitoring activities are undertaken to guide decision-making on the adoption of additional control measures. Educational programs encourage the reduction of mosquito breeding habitats, the adoption of personal protection and mosquito avoidance measures. Tier 1 strategies are the basic tools that are implemented throughout the season even when additional strategies from other tiers are adopted.

Tier 2:

In this framework, Tier 2 strategies aim at reducing mosquito numbers by controlling larvae. Tier 2 strategies are used only when the risk of human disease from WNV is likely and when Tier 1 activities have not reduced mosquito populations sufficiently to address the risk.

There are a number of biological control mechanisms that capitalize on the natural predators of mosquitoes in the wild. However, experts emphasize that while biological and environmental control methods can be important aspects of any integrated strategy for abatement of mosquitoes, will rarely function as the sole method of control. The ability of mosquito populations to adapt rapidly to different natural phenomena means that natural control methods are less effective and less predictable than other control methods, particularly in complex environments. In addition, in most cases, there is insufficient information from field studies to determine whether different biological control methods will be sufficiently effective to reduce disease transmission.

Tier 2 identifies three types of interventions: (a) mechanical methods or natural predators; (b) larvicides with the lowest negative impact on human health and the environment; and (c) and other larvicides. When available and effective, natural, physical, and mechanical control methods, such as the use of predators or cleaning of catch basins, are generally preferred to other interventions. If these are not available or suitable, or are not capable of sufficiently reducing mosquito populations on their own, then the next preferred choice is use of a larvicide that has the lowest toxicity to humans and is most specific to mosquitoes. Finally, there are other pesticides that may be more effective, but may also have greater negative impact on human health or the environment. These may be considered in a situation when other products are not available or effective or if the use of these larvicides would help avoid the need for Tier 3 interventions.

Tier 3:

Tier 3 control uses pesticides applied by air or through the use of ultra-low volume sprayers over large areas to control adult mosquitoes. The use of adulticides poses a higher risk to human health and the environment than do larvicides. The best way to minimize the use of adulticides is to implement Tier 1 and Tier 2 strategies. Thus adulticides will only be considered if Tier 1 and Tier 2 efforts have not been successful in reducing the risk to human health from WNV. Specific details of Tier 3 are currently being developed in consultation with other health units in Ontario, the Ontario Ministry of Health and Long-term Care and Health Canada.

The following section outlines the steps as found in the chart (Appendix A).

Tier 1:

(1) Surveillance and monitoring: Routine monitoring of dead birds, adult and larva mosquito surveillance, human surveillance, WNV testing in bird, mosquitoes and humans.

(2) If there is the potential for WNV to be transmitted to humans, Tier 1 strategies are the first line of defence. These are implemented when WNV has been detected in sentinel species such as crows in Toronto and/or WNV has been detected in a neighbouring jurisdiction during the current or previous year. If surveillance data does not indicate a risk, then routine monitoring continues.

(3) Tier 1 activities are implemented. These include the following:

(a) Enhanced surveillance and monitoring: monitoring of dead birds, adult and larva mosquito surveillance, human surveillance, WNV testing in bird, mosquitoes and humans. Areas where mosquito species of greatest concern in the WNV transmission cycle help identify the type of breeding ground of most concern. Mosquito surveillance data, which includes larval dipping, survey of potential breeding sites, reports of standing water, and adult mosquito surveillance data, guide the selection of areas that may need mosquito control.

(b) Environmental management methods: measures such as removal of standing water in artificial containers (e.g., eaves troughs, debris, awnings) improved drainage, replenishing water in birds baths, aerating water in ponds.

(c) Personal protective measures: installation and repair of mosquito screens, avoidance of areas with large numbers of mosquitoes, use of mosquito repellents, and use of long sleeves and long pants.

(d) Education: activities undertaken to encourage the adoption of the above environmental management and personal protective measures as well as promote co-operation with surveillance activities such as reporting of human illness, dead birds, standing water or other mosquito breeding sites. Selection of areas for mosquito control (Step 6):

(4) If the surveillance data in (3) above confirms that a risk of human illness exists in Toronto, then mosquito control activities are enhanced to Tier 2 (Step 5), otherwise Tier 1 activities continue (Step 3). If data suggests that there is no longer a risk of WNV then emphasis is placed on surveillance and monitoring activities (Step 1)

(5) Consider the adoption of Tier 2 methods to control mosquitoes

Tier 2:

Within Tier 2, three options for intervention have been identified. Using IPM principles, TPH will give preference to the option that is effective and is of lowest risk to human health and the environment. Tier 1 activities continue even with the adoption of Tier 2 methods. Tier 2 outlines the criteria used in the selection of the additional control strategies.

(6) Using data from the surveillance and monitoring, and taking into consideration the experience form other areas in controlling the risk to human health from WNV, identify areas where mosquitoes need to be controlled.

(7) Information on possible natural predators or physical or mechanical methods is evaluated to identify the ones applicable to the specific types of breeding sites. (Examples of physical or mechanical methods include vacuuming or flushing of catch basins, or alteration of water levels in wetlands.) TPH will involve appropriate other City departments and stakeholders in the assessment of methods. When choosing a method to control larva, first consideration is given to the use of mechanical, predators and/or other non-pesticide approaches. If the review indicates that alternatives are available which are effective, feasible and would not result in adverse or undesirable environmental consequences, then preference is given to these approaches (Step 8). If the review indicates that non-pesticide options are either not available, not feasible, or could result in undesirable environmental consequences, then the use of larvicides is evaluated (Step 11).

(8) The Board of Health, City Councillors and the public are advised of the choice of control measures and the selected method of control (natural / mechanical) implemented.

(9) Using the data from mosquito surveillance, the schedules and geographical area for control are determined. Monitoring is also undertaken to assess the effectiveness of the measures adopted. To the extent that it is possible, TPH and other partners as appropriate will assess any potential environmental impacts.

(10) If non-pesticide methods are effective, then mosquito control monitoring will continue to ensure that mosquito populations remain low (Step 9). If monitoring suggests that these methods do not reduce mosquito populations sufficiently, then consideration will be given to supplementing these using larvicides (Step 11). If these efforts are not effective, they will be discontinued and other methods considered (Step 11)

(11) If alternative methods are not available or do not reduce mosquito populations sufficiently, then consideration is given to the application of larvicides. The following factors are considered when selecting a larvicide:

   (a) Available products: Not all products that have been shown effective to control mosquitoes are registered for use in Canada. Products that are currently registered for use in Canada and classified in Ontario will be chosen.

   (b) Human toxicity: Preference will given to products that have been recently reviewed and are the least likely to pose a poisoning hazard to humans and are not known or suspected to cause adverse long-term health impacts such as cancer, birth defects, nervous system disorders.

   (c) Environmental impacts: Preference will be given to products that have been recently reviewed and are shown to be least persistent in the environment and least likely to have an adverse effect in the environment (wildlife, birds, fish, other aquatic organisms, other non-target species)

(d) Efficacy: Different species of mosquitoes have varying susceptibility to specific pesticides. Residual activity of the formulation can also impact the efficacy of a certain product. Preference will be given to products that are of low human and environmental toxicity (as determined in b) and c) above), have sufficient residual activity, and are the most effective for the targeted species.

(e) Resistance: The continual use of the same pesticide over large areas and for multiple years can build resistance in the target species. Preference will be given to products that are least likely to build resistance and products will be rotated as needed to limit any build-up of resistance.

(f) Location: Consideration will be given to the type of breeding site that is targeted, for example natural habitat or catch basin. Not only does the type of habitat determine the species of mosquitoes present (see d) above), it also has an impact on the choice of application method and potential adverse effect on non-target organisms and the environment. Preference will be given to products that are most effective and easily applied and that are the least likely to cause adverse effects on human health or the environment.

(g) Logistics and feasibility: Such factors such as the number of times a product would need to be applied, the method of application, permit requirements, timelines, and the need for special measures have an impact on the feasibility of using a certain product. Preference will be given to products that have the lowest potential of adverse effects to human health and the environment, but if two products have similar impacts, then the product that is the most easily applied will be favoured.

(h) Cost of product and application: The cost of various available products, including the cost of application, will be considered. Preference will be given to products that have the lowest potential for adverse effects to human health and the environment, but if two products have similar impacts, then the lower cost of these will be favoured.

Using these considerations, the pesticide (larvicide) that has the lowest negative impact on health and the environment and that can effectively control mosquitoes in the location of concern (for example, catch basin or wetland) is chosen (Step 12). If there are no low-impact alternatives available, then other control options are considered (Step 16)

(12) Using the data from mosquito surveillance, the schedules and geographical area for the application of pesticides are determined. Adequate public notification is also part of the requirements for applying pesticides for mosquito control. This involves advising the public through newspaper or radio advertisements or other appropriate means at least 48 hours, but no more than 7 days, in advance of the nature of the treatment. TPH will

provide MOE with plans and copies of any proposed notification at least 7 days in advance of any pesticide application. Once the public notification plan is approved and the scheduling finalized, TPH will advise the Board of Health and the councillors of the affected Wards of the specific plans in advance of public notification.

The implementation of the TPH plan for mosquito control will take into account a number of factors, such as the following:

(a) Population peaks of mosquitoes during the season: The most important mosquito vectors for the transmission of WNV to humans in Toronto are Culex pipiens and Aedes vexans. The peak number of adult Culex pipiens mosquitoes occurs in early August and the peak number of Aedes vexans occurs in late August.

(b) Optimum time for mosquito control intervention: To reduce the peak numbers of Culex pipiens and Aedes vexans, the application of larvicides must be timed to occur prior to these peaks. The exact dates and areas to be treated are set according to the type of pesticide used, mosquito surveillance data and weather information.

(c) Nature of the habitat of the mosquitoes to be targeted: The pesticide used may differ depending on the type of habitat and the effectiveness of the product to control mosquitoes that breed in different habitats. Habitat may also influence the method and timing of application.

(d) Product application: Larvicides may be applied by City staff or by a contracted pesticide applicator, depending on a cost-benefit analysis of the two options. Regardless of who performs the applications, application must follow provincially mandated and recommended guidelines that govern the approved use of pesticides. In addition, TPH will write into the contract (or the scope of work document if larviciding is done by City staff) any additional safety measures that may be deemed necessary based on the advice of the City's occupational health and safety staff, conservation authorities and other appropriate stakeholders. Provision for an on-going evaluation of the application of larvicides in catch basins is part of a process of continuous quality assurance. The details are currently being determined in conjunction with the Central East WNV Task Group.

(13) Evaluation of effectiveness: An evaluation of the effectiveness of the mosquito control program will be carried out partly by the applicators themselves; the MOE recommends an evaluation of the number of larvae in a body of water pre- and post-pesticide application. This gives an immediate indication of whether the pesticide has effectively controlled the mosquito larvae.

A long-term assessment of a larvicide's effectiveness in reducing mosquito populations would require a more thorough environmental study than the data obtained from pre- and post-application monitoring. The evaluation of ecological impacts and potential negative impacts on sensitive non-target species would also be desirable. However, the scale of this type of evaluation is beyond the expertise and resources of TPH and should be taken on by the province or the federal authorities.

TPH will work with Works and Emergency Services (WES), other relevant City departments and local conservation authorities to assess any potential environmental impacts of applying larvicidal products to storm water catch basins, particularly where water from these basins flows directly into natural bodies of water.

(14) If mosquito monitoring data shows that the application of the larvicide has been effective, then monitoring is continued (Step 13). If it has not been effective, then the need to re-apply is considered (Step 14).

(15) If the evaluation determines that re-application of the pesticide is feasible and would likely be effective, then a decision is made to re-apply (Step 12). If not, further control measures are considered (Step 16)

(16) If low-impact pesticides are not available or have not been effective, then consideration is given to other areas where mosquitoes breed that may need to be controlled (Step 6). If no such areas are identified, then alternative means of control are considered (17)

(17) If extending mosquito control to other areas is not an option and low-impact pesticides are not available or have not been effective, then the use of other larvicides that may be more effective are considered. Application of such a pesticide is undertaken only if it will reduce the likelihood that Tier 3 intervention (adulticide) will be needed. Preference is given to the pesticide with the lowest human health and environmental impact determined using the criteria outlined in Step 11. If all methods of larval control are no longer possible or effective, then consideration is given to Tier 3 intervention.

(18) Tier 3 interventions are considered only when control of mosquito larvae is no longer an option to prevent human illness and the spread of WNV. Tier 3 protocols are being developed jointly with other health units in Ontario and in consultation with the Ontario Ministry of Health and Long-term Care and Health Canada.

Appendix C

Alternative Methods of Mosquito Control

In terms of alternatives, research has identified a number of biological control mechanisms that capitalize on the natural predators of mosquitoes in the wild. However, experts emphasize that while biological and environmental control methods can be important aspects of any integrated strategy for abatement of mosquitoes, rarely will they function as the sole method of control (Lacey & Orr, 1994; NYCDOH, 2001). The ability of mosquito populations to adapt rapidly to different natural phenomena means that natural control methods are less effective and less predictable, particularly in complex environments (Health Canada, 2001). In addition, in most cases, there is insufficient information from field studies to determine whether different biological control methods will be satisfactorily effective for reducing disease transmission.

Several organisms have been considered as biological control agents for mosquitoes. They include certain aquatic plants, fish, insects and other invertebrate organisms, parasites and bacterial pathogens. Each biological agent varies in terms of efficacy, feasibility and practicality of use. Predation on larval or pupal stages (versus egg or adult stages) of mosquitoes is most likely to yield greatest effects on adult mosquito populations (Lacey & Orr, 1994). Use of biological control methods must also include consideration of the potential negative ecological effects from altering the species balance. It would not be advisable to introduce non-native species that prey on mosquitoes because of concerns that these introduced species might outcompete indigenous species or disrupt predator-prey relationships.

Larval mosquito control

Predators:

There are some biological alternatives for control of mosquitoes at the larval stage. However, these are not without inherent limitations. One of the major challenges is that mosquitoes are highly adaptable and their larvae will breed easily in temporary pools of water (no matter how small) and these are often not easily accessible in a timely manner.

Some predator fish species appear to be useful control agents in specific circumstances. For example, the mosquito fish, Gambusia (also known as the fathead minnow) has been effective in contained waters such as artificial and stormwater retention ponds. Gambusia may have an impact on mosquito populations and could probably be adapted to Ontario, although they have not been used here before. As Gambusia are not native to Canada, there are risks posed from their introduction. Gambusia are highly aggressive, fecund fish and they could out-compete native fish species. It is unlikely that Gambusia could be used in local wetlands or other natural waterways. It is also unlikely that by themselves, mosquito fish would control mosquitoes sufficiently to prevent transmission of WNV.

While dragonfly naiads (larvae) are known to feed on mosquito larvae from container breeding experiments, this is described as a highly labour-intensive and therefore costly larval control effort for field application (Lacey & Orr, 1994). There has been some research on other organisms and parasites; however, there is minimal research on their effectiveness in the Canadian climate and they do not seem to be commercially available in Canada.

Mechanical devices:

Various devices are being developed as alternatives to pesticides. For example, Larvasonic is a device that uses sound waves to kill larvae by destroying the swim bladder. This tool is in the process of being commercialized and has been tested in Quebec. However, it is not well-suited to use in Canadian style catch basins, meaning that each lid must be lifted. As well, there is no residual activity, meaning that effective control needs repeated application, greatly increasing the need for labour.

Larvicidal oils or films:

Larvicidal oils or monomolecular films can be considered a physical method of controlling larvae. They work by creating a small film of oil on the surface of the water which then prevents larvae from breathing through the surface. These products work well where the film will not be destroyed by the movement of water, however they do have an impact on other aquatic life and are unaesthetic. Larvicidal oils are not currently registered for use in Canada.

Adult mosquito control

For control of adult mosquitoes the list of possible biological agents is short. Many organisms eat mosquitoes (e.g. bats, birds, dragonflies among others) but typically most would not lead to an appreciable control of adult populations. For a biological control agent to influence transmission of disease by mosquitoes, it should provide more than just partial control. Generally use of these predators alone is not very effective.

There is a longstanding misconception that purple martins are useful for mosquito control. Other studies have come to similar conclusions. Martins and mosquitoes are not active at the same time or same location: martins are active during the day and feed high in the sky, while mosquitoes stay low in damp places during the day, or only come out at night.

Dragonflies do eat mosquitoes, however they also are active during the day whereas mosquitoes are most active at dusk and dawn. In addition, dragonflies are normally resident in larger ponds and creeks that do not support large populations of mosquitoes; therefore one cannot rely on natural dragonfly populations to control mosquitoes to any large extent. Dragonflies have been used in some areas for nuisance mosquito control. Review of the efficacy of the use of dragonflies for mosquito control indicates that they do not result in sufficient adult mosquito mortality for controlling the spread of mosquito-borne disease (NYCDOH, 2001).

Bats are also natural mosquito predators. However, research indicates that their primary food items are larger insects such as beetles or moths (Anthony & Kunz, 1977; Whitaker, 1972). It is not clear whether the urban environment provides enough other insects to sustain an enhanced population of bats. Enhancing the existing population of bats is of potential concern since bats can carry rabies.

Physical or mechanical devices:

Mosquito magnets or mosquito traps emit CO_2 or other chemicals which attracts mosquitoes. A fan or vacuum then sucks mosquitoes into the trap once they hone in on the device. They appear to collect a lot of mosquitoes, but no one has shown that they effectively reduce the number of mosquitoes or the number of bites in a backyard setting. Most claims that electronic devices control mosquitoes are not bona fide. For example, bug zappers kill a lot of insects, including beneficial ones, but are not particularly effective against mosquitoes alone (Frick & Tallamy, 1996).

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Appendix D

Comparison between Bti and Methoprene

Of the larvicides currently registered for use in Canada, two are considered or low-impact pesticides: Bacillus thuringiensis var. israelensis (Bti) and methoprene. A short summary on the properties of methoprene, the pesticide that has been selected for use in catch basin in Toronto in 2003, is provided below. Table 1 compares Bti and methoprene.

Methoprene

(a) Human Toxicity

Methoprene is a synthetic mosquito growth hormone, which is variously described as a biorational or biochemical pesticide. It controls mosquito populations by preventing the larvae from becoming adults. Methoprene is of low toxicity to people (U.S. EPA, 1991; PMRA, 2001). It has very low acute oral, dermal and inhalation toxicity potential and is not an eye or skin irritant, nor is it a human-skin sensitizer. Toxicological screening tests have not found any significant adverse toxicological effects. The necessary safety precautions, such as wearing gloves, will be taken to minimize exposure to the applicators. The use of methoprene in the City's catch basins is unlikely to pose an exposure risk to the general public.

(b) Environmental Impacts

Methoprene and other pesticides that are applied directly to water are classified as "Restricted" by the Pest Management Regulatory Agency (PMRA) and by the Ontario Pesticides Advisory Committee (OPAC). Because methoprene has a non-toxic mode of action, that is, it does not kill the larvae but prevents their maturation into adults, it has relatively low impact to the environment and is generally of low ecological toxicity. Methoprene breaks down quickly in water particularly in the presence of sunlight and microorganisms. Although it is non-persistent, water quality, salinity and temperature influence its level of activity. It is moderately to slightly toxic to some fish species. It is highly toxic to certain aquatic invertebrates (e.g. benthic organisms) however, effects observed were temporary and invertebrate populations have shown rapid recovery a short time after methoprene treatments. The above potential adverse effects are of limited concern given that TPH is recommending that applications for the year 2003 be restricted to storm water catch basins.

Methoprene is available in long-lasting formulations that make it more effective, but may have some impact on other insects and aquatic life. The potential for effects from application of larvicidal products to catch basins that flow directly into natural bodies of water (that is, the "yellow fish" catch basins) will be assessed prior to applications in these particular catch basins. TPH will work with Works and Emergency Services (WES), other City departments and local conservation authorities to assess any potential environmental impacts of applying larvicidal products to storm water catch basins, particularly where water from these basins flows directly into natural bodies of water.

Table 1 - Comparison Between Bti and Methoprene

Active Ingredient	Type & Mode of Action	Human toxicity	Ecological toxicity	Pros	Cons
Bacillus thuringiensis var. Israelensis (Bti) (Sold as Vectobac)	Bacteria Contains protein crystals (delta endotoxin) that rupture digestive cells when ingested by larvae Applied in granular or liquid form	ACUTE: No human organ toxicity (high dosage) CHRONIC: No known reproductive, teratogenic, mutagenic or carcinogenic effects	Non-toxic to wildlife and organisms in sensitive areas Can affect other insect species Low persistence in water (binds to organic debris)	Lowest ecological toxicity Low risks for non-target species	Less effective for control of <u>Culex</u> species (40% kill rate)∴ high doses needed No slow release formulations ∴ requires more frequent applications (8 to 10 per season) Limited treatment window available (optimal benefits from applying to 2^{nd} or 3^{rd} larval instars)
Methoprene (Sold as Altocid)	Insect growth regulator Synthetic insect hormone Prevents metamorphosis from pupa to adult Applied as slow release granules or pellets	ACUTE: Oral LD_{50} (rats) 34600 mg/kg Toxic to human liver (high dosage) CHRONIC: No known reproductive, teratogenic, mutagenic or carcinogenic effects	Low toxicity to birds, wildlife Moderately toxic to fish Highly toxic to some invertebrates if misused Non-toxic to bees, but can affect other insect species Low persistence in water (half-life 30 to 40 hr)	Available in slow-release product (about 3 wks) ∴fewer applications needed High efficacy (up to 100%) against <u>Culex</u> species	Must be applied when larvae are in 2^{nd}, 3^{rd} or 4^{th} instars Not for use in waters which are fish and wildlife habitat Cannot be certain of effectiveness until too late to re-treat

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