

MUNICIPAL MOSQUITO CONTROL GUIDELINES

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DATE:

21 April 2004 (1st Revision),
6 July 2004 (2nd revision),
11 August 2004 (3rd revision)



Table of Contents

1. Biology of Mosquito Vectors	1
1.1 Mosquitoes can be a nuisance and transmit disease-causing organisms	1
1.2 Life History of Mosquitoes.....	1
1.3 Typical Larval Mosquito Habitats	2
1.4 Seasonal Occurrence of Larval and Adult Mosquitoes	2
1.5 Activity and Biting Behaviour of Mosquitoes.....	3
1.6 Resting Sites of Female Mosquitoes	3
2. West Nile Virus Transmission.....	3
2.1 Probable Mosquito Vectors.....	5
2.2 Possible Means of Introduction of WNV into Canada	5
2.3 WNV Transmission Period	5
2.4 Reducing the Risk of Transmission	6
3. Mosquito Control Strategies.....	6
3.1 Public Health Mosquito Control Programs as Relates to the Fisheries Act.....	7
3.2 Source Reduction.....	8
3.3 Mosquito Larviciding.....	9
3.3.1 Rationale for Mosquito Larviciding	9
3.3.2 Monitoring Mosquito Breeding Sites and Larval Populations	9
3.3.3 Mapping Larval Breeding Sites.....	10
3.3.4 Monitoring Mosquito Larvae	11
3.3.5 Monitoring Environmental Factors.....	11
3.3.6 Mosquito Larvicides.....	12
3.3.7 Larviciding Equipment.....	14
3.3.8 Larviciding Permits.....	15
3.3.9 Larviciding Procedures	16
3.3.10 Monitoring the Effectiveness of Larviciding	16
3.4 Mosquito Adulticiding	17
3.4.1 Rationale for Mosquito Adulticiding	17
3.4.2 Mosquito Trap Counts	17
3.4.3 Landing Counts.....	18
3.4.4 Vector Surveillance Traps.....	18
3.4.5 Information Required for Effective Adulticiding	19
3.4.6 Mosquito Adulticides	19
3.4.7 Adulticiding Equipment	19
3.4.8 Adulticiding Permit.....	20
3.4.9 Adulticiding Procedures	21
3.4.10 Public Notice of Spray Operations	21
3.4.11 Monitoring Effectiveness of Adulticiding	22
3.5 Non-chemical Mosquito Control	22

	iii
3.5.1 Water Management	22
3.5.2 Source Reduction.....	23
3.5.3 Public Education	23
3.5.4 Biological Control via Natural Enemies.....	25
4. Record-keeping	25
4.1 Legal Requirements	25
4.2 Computerized Record-keeping System	25
5. Assessing Proposals for Mosquito Control Services.....	26
6. Mosquito Control Resources	27
7. List of Appendices	28
Appendix A. Larval and Adult Mosquito Survey and Management Forms.....	29
Appendix B. Larval Sampling Procedure.....	34
Appendix C. Suppliers of Equipment and Materials Used in Mosquito Control.	35
Appendix D. Mosquito Control Consultants and Companies.....	37
Appendix E. Provincial Government Officials.	39
Appendix F. Federal Government Officials.	42
Appendix G. University Researchers involved in Mosquito Vector Biology and Control....	43
Appendix H. Municipal Mosquito Control Workers.	44
Appendix I. Some Useful Links relating to WNV and Vector Control.....	45
Appendix J. Technical Reports and Publications.	46
Appendix K. Glossary of Technical Terms.....	51

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Because there are wide differences between pesticides and their formulations and because individuals may react differently to them, every pesticide should be handled with extreme care. Label instructions and other literature that accompany a product must be followed at all times. One must always read and carefully follow the pesticide product label because it is the final legal authority as to the use and application of that product.

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Municipal Mosquito Control Guidelines

1. Biology of Mosquito Vectors

1.1 Mosquitoes can be a nuisance and transmit disease-causing organisms

Mosquitoes are important insect pests and control efforts can be justified when they represent a significant "nuisance" or threat to public health. As a nuisance insect, mosquitoes have few rivals in Canada and they can be a burden in certain jurisdictions without posing a threat to public health. Mosquitoes are considered a nuisance because they can 1) decrease the quality of life of local residents by annoying and bother people (including adverse reactions to their bites) in and around their homes or in recreational areas or 2) by reducing property values, slowing economic development of an area, reducing tourism, or adversely affecting livestock production in localities that produce large adult populations.

Although Canada may be fortunate in having relatively few mosquito-borne diseases, several mosquito-borne encephalitis viruses (e.g., Western Equine encephalitis virus and St. Louis encephalitis virus) and various mechanically-transmitted pathogens have periodically represent a risk to the health of Canadians. With the incursion of West Nile virus (WNV) into Canada in 2001 and its rapid spread throughout much of the country, there has never been a greater need to develop municipality- or locally-based mosquito control programs.

Though there are some important differences (e.g., target species, timing of applications, action thresholds, etc.,) between mosquito control programs that are designed to deal with nuisance mosquito species and those that act as vectors of disease-causing agents, many of the basic principles, protocols and methodologies used to control these two groups of mosquitoes are the same.

1.2 Life History of Mosquitoes

Mosquitoes pass through the egg, larval, pupal and adult stages during their life cycle. There are four larval instars. All stages except the egg stage are mobile. Female mosquitoes may lay their eggs either on moist soil or on the surface of water. The 1st-instar larva is very small. As the larvae pass through their four instars, they become larger after each moult.

During the larval and pupal stage, mosquitoes remain in the water. Both these stages are adapted for swimming. The larvae swim as they go to and from feeding to other activities, like swimming to the surface to obtain air. Many people call them 'wigglers' because of the way in which they swim. The larvae of most species can be seen resting at the surface, hanging from the surface film by their respiratory siphon.

The pupal stage looks like an inverted comma. Some people think the pupae look like miniature tadpoles. They use their flattened, paddle-like 'tails' to propel themselves through the water. They do not feed during this transitional stage of development, as they transform from larvae to adults. When mature, the skin of the pupa splits open along its back and the fresh, adult mosquito slowly emerges into the air. After resting on the surface of the water for a few minutes, the adult mosquito usually moves to a sheltered spot close by to allow its outer skeleton and wings to harden.

Soon after emergence, mating takes place. Mating usually occurs in mating swarms, typically within 3 to 5 days after the adults emerge. Females are attracted to the mating swarm and soon fertilized. Females mate once, remain fertilized for life and are the only sex to seek blood from hosts.

1.3 Typical Larval Mosquito Habitats

The typical habitat for mosquito larvae is a snow-melt pool or a summer rain pool. Small pools of water that are created by melting snow in the spring or by heavy rains during the summer produce most of our nuisance species of mosquitoes. A summer rainfall of three or more centimetres can produce a major hatch of mosquitoes from eggs that were lying dormant in grassy depressions in fields or drainage ditches.

Almost anything, whether natural or artificial, that will hold water for about a week or more may breed mosquitoes. These insects have adapted to a wide variety of larval habitats and every one should be checked for larvae.

A few examples of some larval mosquito breeding sites are given below:

- Irrigation ditches, ditches and vehicle ruts along roads, power lines, and railway tracks.
- Low-lying pasture pools and woodlot pools.
- Tree-holes and rock-pools.
- Gutters, barrels, buckets, cans, tires, birdbaths, and boats.
- Vegetated edges of sewage lagoons, storm-water retention ponds and reservoirs.
- Weedy margins of farm dugouts and prairie sloughs.
- Weedy margins of some lakes, ponds, and streams.
- Culverts, open wells, catch basins, ornamental pools, and wading pools.
- Pieces of polyethylene caught up in short vegetation.

1.4 Seasonal Occurrence of Larval and Adult Mosquitoes

Larvae of spring floodwater (also known as snow-melt) mosquitoes hatch from the eggs in pools of water formed by melted snow in the woods. The eggs can be found in the leaf litter lining the pools. These larvae develop slowly because of low water temperatures. They emerge as adults in May, before the pools dry up. The female spring floodwater mosquitoes can be very long-lived and may bite several times. They lay their eggs in the shallow depressions in the woods where they will be flooded by melting snow the following year. Spring snowmelt mosquitoes have only one generation per year. Even if summer rains flood these eggs, they will not hatch until the following spring.

Summer floodwater mosquitoes include several of our common nuisance mosquitoes (e.g., *Aedes vexans*). The larvae hatch from eggs after rainfall in the summer (usually 2.5 cm rains or greater) in shallow flooded areas such as grassy fields, roadside ditches, highway right-of-ways, tire tracks, cow hoof prints, and other habitats. The larvae develop very quickly (7-10 days). Several generations may occur each summer, depending upon the frequency and intensity of rainfall. We cannot predict in advance how bad the summer floodwater mosquitoes will be because we cannot predict rainfall amounts or patterns.

Although there are distinct species differences, generally mosquitoes are most abundant during the summer months. Some species may be more abundant, as adults, during the late spring; others may be most abundant during the late summer. Still others are abundant during the summer months but for only a few weeks after a heavy rainfall.

Heavy snowfall during the winter months, followed by a quick thaw in the spring, tends to favour the development of large populations of the spring floodwater mosquitoes. Heavy rainfalls during the summer months tend to favour massive populations of summer floodwater species.

Temperature is another key factor affecting mosquito populations. During the larval period, warm temperatures speed up larval and pupal development. Warm temperatures, at times when adult mosquitoes are active, facilitate mating and provide favourable conditions for host-seeking by female

mosquitoes. Temperature and relative humidity have a major influence on adult mosquito populations. High temperatures, associated with low relative humidity, tend to shorten the adult period and cause the early death of those mosquitoes unable to find cool, moist areas for shelter.

Winds also have their effect on populations. Low winds facilitate swarming by the males and mating of the sexes. They also facilitate the female mosquito's search for blood. High winds generally have the opposite effects. However, high winds may be a positive factor for mosquitoes in some regards. For example, steady high winds, following a mass emergence of adult mosquitoes, tend to disperse the population widely, sometimes many kilometres.

1.5 Activity and Biting Behaviour of Mosquitoes

Adult mosquitoes are usually found close to their original larval breeding sites. However, the females may disperse from several hundred metres to several hundred kilometres from their source, often aided by wind. Most mosquitoes rest during the day, seeking shelter in dense vegetation that is close to their swarm sites, egg-laying sites, or blood-meal sources.

The adults of most species are active during periods of twilight, which is when winds are relatively low, temperatures are moderate, and the relative humidity is high. In shady areas, mosquitoes may be active throughout the day. Like male mosquitoes, the female mosquitoes feed on nectar from flowers, aphid excretions on leaves, and sap leaking from broken twigs to obtain the carbohydrates that are required for activities like flight.

Unfortunately for humans and other hosts, the females of most mosquito species require a blood-meal for egg development. Each species seems to have its own range of host preferences but most female mosquitoes will feed on a broad range of hosts. Typical hosts include warm-blooded vertebrates, like birds and mammals. However, the females of a few mosquito species feed on reptiles and amphibians.

1.6 Resting Sites of Female Mosquitoes

Most mosquitoes like to rest during the day in cool, moist locations. They are very sensitive to hot, dry weather. A few examples of some adult mosquito resting sites are given below:

- Heavy vegetation near their larval breeding sites or their hosts.
- Areas of high humidity along the shores of streams, rivers and lakes.
- Cool, moist places along roadsides (e.g., in culverts, under bridges, in catch-basins).
- Inside buildings (e.g., houses, livestock barns, poultry houses, outhouses).
- In piles of firewood, lumber, or other stored materials.

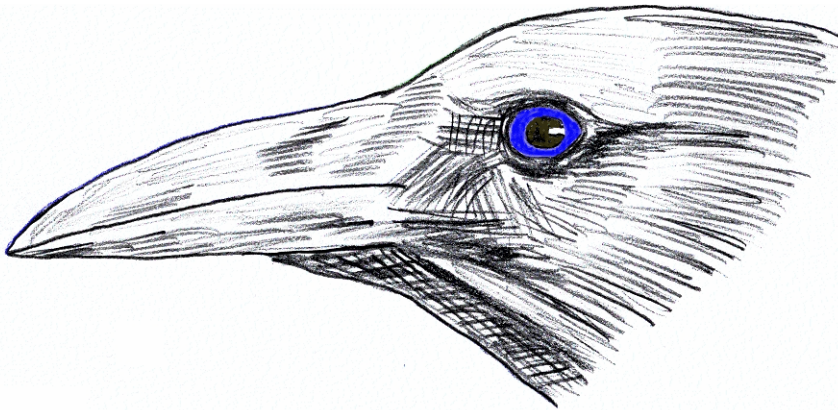
2. West Nile Virus Transmission

West Nile virus has emerged in recent years in temperate regions of Europe and North America, presenting a significant threat to human and animal (wild and domestic animals) health. This virus was first identified in North America in 1999, when it caused an outbreak of viral encephalitis in humans centered in New York City. This virus is a member of the Flaviviridae family of viruses, which includes St. Louis Encephalitis (SLE). Outbreaks of SLE have been reported in Ontario and Manitoba in the past. In addition, outbreaks of another mosquito-borne virus, Western Equine Encephalitis (WEE, family Togaviridae) have been observed in the Prairie Provinces. However, mosquito-borne diseases have been relatively rare in Canada, prior to the incursion of WNV.

The most serious manifestation of WNV infection is fatal encephalitis (inflammation of the brain or spinal cord) in humans and horses, as well as mortality in certain species of domestic and wild birds. However, the symptoms vary.

Approximately 80% of people who are infected with WNV will not show any symptoms at all. Up to 20% of the people who become infected will display mild symptoms, including fever, headache, body aches, nausea, vomiting and sometimes swollen lymph glands or a skin rash on the chest, stomach and back. This flu-like condition is called West Nile fever and symptoms typically last for a few days. In contrast, about one in 150 people infected with WNV will develop severe illness. The severe symptoms can include high fever, headache, neck stiffness, stupor, disorientation, coma, tremors, convulsions, muscle weakness, vision loss, numbness and paralysis. These symptoms may last several weeks, and neurological effects may be permanent. The more severe cases of WNV infection, because they involve the central nervous system, are collectively called West Nile Neuroinvasive Disease (WNND).

West Nile virus is amplified during periods of adult mosquito blood-feeding by continuous transmission between mosquito vectors and bird reservoir hosts. Many different species of birds may act as a reservoir for WNV (up to 138 different species of birds have been reported infected with WNV in North America) and bird surveillance has focused mainly on the Corvidae family that includes crows, ravens, blue jays and magpies. Some bird species (e.g., crows) are very susceptible to infection and often become very ill and/or die as result of an infection.



Infected mosquitoes carry virus in their salivary glands and after a suitable period of incubation (typically 2 to 3 weeks), can infect susceptible bird species during blood-meal feeding. Competent bird reservoirs will sustain an infectious viremia (i.e., have virus circulating in the bloodstream) for 1 to 4 days after exposure, after which these hosts likely develop life-long immunity.

A sufficient number of vectors must feed on an infected reservoir host to ensure the likelihood that some mosquitoes will survive long enough to feed again on a susceptible reservoir host. As a result of this transmission, WNV is "amplified" within this enzootic cycle and under the right conditions, it may "spill-over" into human or other animal populations when infected mosquitoes bite them.

People, horses, and most other mammals are not known to develop levels of viremia that would be high enough to infect feeding mosquitoes and thus are probably "dead-end" or "incidental" hosts. WNV is not transmitted from one person to another and provided appropriate precautions are taken when handling infected birds, is unlikely to be transmitted from birds to people. However, birds (and possibly mosquitoes) likely serve to spread the virus from one geographical area to another.

2.1 Probable Mosquito Vectors

As of January 2004, 43 species of mosquitoes have been identified as possible vectors of WNV in North America by the U.S. Centers for Disease Control. Of these 43 US species, 30 occur in Canada and are listed below. Species in which evidence of WNV infection has been reported in field-collected specimens from Canada are highlighted in bold.

<i>Aedes albopictus</i>	<i>Culex pipiens</i>	<i>Ochlerotatus japonicus</i>
<i>Aedes cinereus</i>	<i>Culex restuans</i>	<i>Ochlerotatus provocans</i>
<i>Aedes vexans</i>	<i>Culex salinarius</i>	<i>Ochlerotatus sollicitans</i>
<i>Anopheles barberi</i>	<i>Culex tarsalis</i>	<i>Ochlerotatus sticticus</i>
<i>Anopheles punctipennis</i>	<i>Culex territans</i>	<i>Ochlerotatus stimulans</i>
<i>Anopheles quadrimaculatus</i>	<i>Ochlerotatus atropalpus</i>	<i>Ochlerotatus triseriatus</i>
<i>Anopheles walkeri</i>	<i>Ochlerotatus canadensis</i>	<i>Ochlerotatus trivittatus</i>
<i>Coquilleltidia perturbans</i>	<i>Ochlerotatus cantator</i>	<i>Orthopodomyia signifera</i>
<i>Culiseta inornata</i>	<i>Ochlerotatus dorsalis</i>	<i>Psorophora ferox</i>
<i>Culiseta melanura</i>	<i>Ochlerotatus fitchii</i>	<i>Uranotaenia sapphirina</i>

Municipalities that are carrying out mosquito control programs would be well advised to map and deal with any breeding sites that are producing these potential vector species. Because *Culex* species of mosquitoes appear to act as the main amplifying vector of WNV, they have been targeted as a priority species for control in many jurisdictions in North America. For a complete list of species in your area, contact the health department in your province. Health officials can put you in contact with persons who are involved in mosquito surveillance and who should have an up-to-date list of mosquito species of concern.

2.2 Possible Means of Introduction of WNV into Canada

It is thought that WNV was introduced into Canada (southern Ontario) by infected mosquitoes or birds in 2001. The likely scenario is that an infected bird moved across the border into Canada from New York or a neighbouring state. That bird would have been a source of virus for local blood-feeding mosquitoes.

Once the virus was introduced into the local mosquito population, the mosquito vectors then infected more birds. Eventually, the mosquito vectors transferred the virus from birds to mammals (e.g., humans and horses). Although WNV-infected birds were reported in parts of Nova Scotia, Quebec, Ontario, Manitoba and Saskatchewan in 2002, locally acquired cases of infection in humans were reported only in Ontario and Quebec.

In 2003, the range of WNV once again expanded, with activity documented for the first time in New Brunswick and Alberta. The focus of human cases in 2003 appeared to shift from Ontario and Quebec to the Prairie Provinces. Although human cases of WNV infection were also reported in persons from BC, Nova Scotia, New Brunswick and the Yukon Territory, these cases were not locally acquired (i.e., they occurred in people with histories of travel to areas where WNV activity was observed). As of January 2004, the only jurisdictions in Canada that have not observed some form of WNV activity are Prince Edward Island, Newfoundland/Labrador, Nunavut and the Northwest Territories.

2.3 WNV Transmission Period

When the enzootic transmission cycle of WNV begins in Canada undoubtedly varies across the country because of regional differences in the timing of: mosquito emergence or activity, seasonal changes in mosquito abundance and incursion or recursion of the virus. Based on dead bird surveillance data, enzootic transmission of WNV has started as early as mid-April (Ontario 2003) and most provinces have

reported their first WNV-infected birds in early June or July. Infected birds continue to be detected throughout the remainder of the summer months, typically until mosquito activity ceases.

Human infections with WNV usually occur in the late summer or early fall in the temperate zone of the world (i.e., between latitudes 23.5° and 66.5° north and south). Symptoms of the disease begin to appear in humans by mid-July and, in horses, by mid-August. Human cases seem to peak in mid-August with the number of horse cases peaking in late-September. In localities where mosquitoes are active year round, WNV may be transmitted throughout the year.

In Canada, as in northern US states, transmission of WNV to horses and humans is likely to begin during the mid- to late-summer period and end with the first hard frost (i.e., sustained overnight temperatures less than -2°C) that typically marks the end of mosquito biting for the season.

2.4 Reducing the Risk of Transmission

People can minimize their risk of mosquito bites by wearing proper clothing and insect repellents and by avoiding times when, and situations where, mosquitoes are most active. Practical tips to pass along to residents are given in the section on public education (see section 3.5.3).

However, many people, including municipal employees, must be outdoors in places where, and during periods of the day when, mosquitoes are active. If there is a risk of WNV transmission in the area, it is important that these people, especially those over 50 years of age, take full precautions to avoid mosquito bites.

3. Mosquito Control Strategies

The goal of a mosquito control program is the control of mosquitoes while preventing any adverse effects on humans, wildlife, or the environment. In general, the most effective mosquito control strategies are ones that are based on sound biological, physical and chemical data and that integrate the best and latest techniques and materials for mosquito control. Mosquito control is achieved within an Integrated Mosquito or Pest Management (IPM) system by addressing each of the core elements of mosquito management namely: surveillance and environmental monitoring, source reduction and other forms of water management, the use of biological control agents, larvicides and adulticides, as well as public relations and education (i.e., how to prevent mosquito bites through use of personal protective strategies). Clearly, developing an IPM-based program should be the "gold standard" for any jurisdiction considering implementing a mosquito control program; however, it takes a considerable amount of planning, lead-time and financial support to achieve a truly integrated mosquito control program.

Most people do not think about a mosquito management program until the adult mosquitoes are present and biting in large numbers. They become quite frustrated when they then seek advice on mosquito control and are told by professionals that it is 'too late'.

Mosquito management requires considerable lead-time. In addition to obtaining a pesticide-use permit (if required), the program requires, at the very least, trained staff, survey maps and tools, vehicles, spray equipment, and insecticides. These requirements are all cost considerations requiring advance budgeting. Before attempting to launch a mosquito management program, those persons who will manage the program should take some preliminary steps:

1. Determine how much support there is for mosquito control in the municipality. You will need the support of residents, business people, and elected officials.

2. Determine the formal steps that must be taken to start a new mosquito control program in your jurisdiction including:
 - Establishing a steering committee for implementing the program.
 - Obtaining the necessary provincial/territorial pesticide-use permits (if required) and applicator licenses.
 - Fulfilling any pesticide-use permit conditions or requirements.
 - Purchasing needed tools, supplies and equipment¹.
 - Renting vehicles and other equipment.
 - Training and assigning staff.
3. Learn as much as possible about mosquito control from government officials, suppliers, university researchers, and consultants and by reading available manuals on mosquito control (see attached appendices).
4. Have key staff and officials attend a mosquito control applicator's course.
5. Determine the costs for the first year of work, including office and communications equipment and supplies, labour, training, vehicles, fuel, spray equipment, pesticides, and program maintenance (allowing for inflation and increased labour costs).
6. Obtain any required applicator licenses and pesticide-use permits, according to provincial regulations, well in advance of the season.
7. Hire responsible, trained, seasonal staff to carry out mosquito breeding site surveys, note environmentally sensitive habitats, maintain mosquito light traps and collections, and carry out any necessary control operations.
8. Record all survey and treatment data, not only to fulfil any permit requirements, but also to help plan for an even better program the following year. An example of the kinds of record-keeping forms that should be kept can be found in Appendix A.
9. Develop some basic policies and standard operating procedures for the mosquito management program and have these approved by senior management and/or elected officials.

3.1 Public Health Mosquito Control Programs as Relates to the Fisheries Act

The implementation of mosquito control programs is a local/provincial/territorial responsibility. However, the federal government plays a role in working with provinces, territories and municipalities to make informed decisions on control measures for their jurisdictions.

It is recognized that the protection of public health is of primary concern. Health Canada's Pest Management Regulatory Agency (PMRA) has the federal responsibility for the Pest Control Products Act. Environment Canada has the lead administrative authority for the pollution prevention provisions of the Fisheries Act; Fisheries and Oceans Canada's Minister is accountable to Parliament for the whole of the Fisheries Act. The Fisheries Act prohibits the deposit of a deleterious substance into water frequented by fish under ss.36(3) and the harmful alteration, disruption or destruction of fish habitat under ss.35(1). In situations where mosquito control is undertaken for the protection of public health, all available means to avoid negative impacts on fish and fish habitat must be taken to meet the legal requirements of the Fisheries Act. This could be done by:

¹ Supplies will include such items as mosquito traps and insecticides; equipment will include such items as a computer and software, a dissecting microscope, and sprayers.

- consulting the National Guidelines for Response to West Nile Virus (currently under revision) and this document (i.e., the Municipal Mosquito Control Guidelines) and choosing, in accordance with recommended best practices, a pest control product currently registered under the authority of the Pest Control Products Act;
- applying such a pest control product in accordance with the product's label instructions and applicable laws; and
- applying an IPM approach which includes reduced-risk chemical and biological pest control products (i.e., products containing methoprene and Bti).

The effective control of mosquito vectors of West Nile virus will require the dedicated cooperation and participation of local, municipal, provincial/territorial and federal agencies, community organizations, and the Canadian public.

3.2 Source Reduction

Ideally, mosquito control should be based on a preventative program, which may include source reduction. This is simply the draining or filling in of mosquito breeding sites where it is reasonable to do so. If draining and filling is not an option, many larval breeding sites (e.g., sewage and dairy lagoons, storm water-retention ponds, farm dug-outs) can be made unsuitable for mosquito breeding through a combination of good design (e.g., steeply-sloped and gravelled shore-lines), water level manipulation, and emergent vegetation control. Bodies of water with sloped, gravelled, rocky, or sandy shorelines will support few mosquitoes as larvae will be exposed to wave action and will have difficulty obtaining food.

Sometimes, the easiest way to prevent mosquitoes from developing is to alter their breeding sites to make them unsuitable for egg laying. In the case of small shallow depressions or unnecessary ditches, this usually equates to improved drainage or filling with clean soil. Even scraping sediment from the bottom of roadside ditches every few years can make the ditches unattractive for mosquito breeding by enhancing proper drainage.

Ditches that are slow to drain may form a series of pocket pools and support lush grasses or weeds, thereby becoming prime larval breeding sites. Regular mowing, every 2 weeks or so, during the summer months will reduce mosquito breeding. When considering ditch drainage improvements, conduct a larval survey after a heavy rain to determine which ditches should receive highest priority for maintenance.

Note that some ditches may be fish habitat or drain directly into fish habitat. Accordingly, any proposed works or undertakings in ditches or waters that may be contiguous to flowing and/or fish bearing waters should be discussed with Fisheries and Oceans Canada (DFO) and Environment Canada (EC) in advance. Often, ditches along main roads and highways are quite wide. They form broad, expansive, grassy pools of shallow water, ideal for mosquito production. One way to reduce the surface area that must be treated with a mosquito larvicide is to run a narrower, deeper ditch through the centre of the broader ditch.

There may be patches of flooded land (occupied by trees, shrubs and weedy vegetation) that are adjacent to roadside ditches. The stagnant water in these depressions can usually be drained into the roadside ditch, eliminating the difficult-to-treat woodland breeding site. If breeding still occurs in the roadside ditch, it is at least more accessible.

In other situations, it may not be possible to drain a man-made breeding site containing standing water. However, it may be possible to fill it with soil, bringing it up to the level of the surrounding land, and eliminating the standing water.

Many small municipalities cannot afford to carry out an annual larviciding program. Funds are unavailable for staff, equipment and insecticide. Yet, most municipalities do own or can get access to

earth-moving equipment of one type or another and could use it to advantage in mosquito source reduction.

Managing or eliminating larval breeding sites can be an economical and effective means of preventing mosquitoes. It is worth considering as either an alternative or a supplement to mosquito larviciding and adulticiding. However, given the legal implications if fish habitat is detrimentally altered, such proposals should be discussed with DFO in advance.

When mosquito source reduction is being considered, consult with both federal and provincial fisheries and wildlife officials before starting. They can determine if the planned water management projects are acceptable from a fish and wildlife habitat point-of-view. A poorly planned drainage project might be in violation of federal and provincial legislation.

3.3 Mosquito Larviciding

3.3.1 Rationale for Mosquito Larviciding

Many people think that the best time to begin a mosquito control program is when the numbers of biting female mosquitoes reach an intolerable level. However, the best time to begin a mosquito management program is before the adult mosquitoes emerge. Control efforts should begin immediately after the mosquito eggs have hatched, the pools have been inspected, and the numbers of larvae present have been quantified to determine whether or not the use of an insecticide is justified. Mosquitoes are most efficiently and economically destroyed when they are in the larval stage and are concentrated in their breeding site.

Preventing the larvae from becoming adult mosquitoes minimizes the area that would have to be treated. It also prevents the development of an annoyance or health problem and it reduces the potential environmental impacts of the adult mosquito control program. Larviciding can reduce overall insecticide use in a mosquito control program by reducing or eliminating the need for ground or aerial application of insecticides to kill adult mosquitoes.

3.3.2 Monitoring Mosquito Breeding Sites and Larval Populations

Mosquito monitoring is a prerequisite to an effective, efficient, and environmentally sound mosquito control program. Monitoring is used to:

- Define the nature and extent of the mosquito problem within the "targeted" control zone, based on larval and adult mosquito surveys.
- Determine if there are any major sources of mosquitoes just outside of your control zone.
- Calculate the amount of larvicide required to treat the total surface area of the infested pools.
- Give direction to daily mosquito control operations.
- Determine the proximity of environmentally sensitive areas, including any fish and wildlife habitat, to the larval breeding sites.
- Determine which larval breeding sites can be eliminated.
- Evaluate the effectiveness of control operations.
- Generate the data needed to comply with provincial/territorial larvicide-use permits (if required).
- Evaluate the potential for transmission of mosquito-borne pathogens.

The first step in determining which mosquitoes must be monitored routinely is to establish which species cause problems (i.e., regardless of whether they are a nuisance or vector species). A list of mosquito species can be compiled from a review of the literature for those species that bite humans or which may transmit disease-causing agents in the area of concern. Once the key target species have been determined, the jurisdiction involved can be surveyed, with special emphasis on the typical breeding sites

of these species. The survey should include the collection of both adults and larvae. Obviously, someone must be trained to correctly identify the adult and larval mosquitoes (may involve attending specialized training at nationally or internationally recognized facilities). That person will require a dissecting microscope, some basic laboratory supplies, and taxonomic keys for mosquito identification (e.g., Wood et al. 1979).

Information from the survey can be used to determine the abundance and seasonal distribution of each species and its relative importance as a target for control efforts. Because mosquito collection methods differ in their effectiveness for sampling different species, more than one collection method should be used to accurately determine the relative abundance of all of the species in an area. Comparing the numbers of a single mosquito species collected in different types of traps can be misleading and should be avoided.

The temporal (seasonal) and spatial (locality-specific) changes in mosquito populations and the problems that mosquitoes can cause are measured by monitoring three factors:

- Telephone requests for mosquito control services (if a program is already established).
- The size of the adult mosquito population.
- The size (and stage of development) of immature mosquito populations.

Both a mosquito-breeding site inventory and a larval surveillance system should be developed. The mosquito-breeding site inventory is a permanent collection of descriptions of all breeding sites. A larval surveillance system describes the numbers of mosquitoes breeding at each site at the time when each site was sampled. Inventory and survey data can provide a record of mosquito breeding activity over time, assisting in the decision to either apply larvicides to the site or eliminate it (recognizing the need to protect fish and fish habitat).

3.3.3 Mapping Larval Breeding Sites

Initially, a systematic survey is made to map all potential mosquito development sites within the municipality. For each mapped site, the surface area (acreage or hectareage) is determined and a reference number and habitat type are assigned.

The site information can then be entered into a database that will contain a detailed breeding history for each site, including:

- Description of the site.
- The time of year when the site is producing mosquitoes.
- The estimated larval density (or abundance) at each sampling date.
- The mosquito species associated with the site.

After a multi-year development period, the municipality can produce a field inspection and control strategy for each site within its jurisdiction. The sites can be split into non-breeding sites and targeted sites. The non-breeding sites are considered a low-priority. Bi-weekly or monthly inspections will maintain the database for these sites. The sites with a history of producing significant populations or species of mosquitoes can be targeted for intensive field inspections and appropriate larval control measures.

A mosquito control program will have maps that show the location of all the mosquito-breeding sites within the jurisdiction. Ideally, the sites should be incorporated into a local geographical information system. These maps are used to maintain a record of the results of larval surveillance and to plan larviciding operations. The map inventory must be updated on a routine basis. For example, as new residential or commercial developments occur, natural drainage patterns will be interrupted and the

characteristics of mosquito breeding sites in those areas may change dramatically. In turn, the species of mosquitoes present at each site may change.

Deciding which characteristics of the breeding site should be recorded in an inventory is difficult. Estimates of various factors will help to determine if treatments are needed. These factors include:

- Water surface area.
- Water depth.
- Water temperature.
- Larval instar and density.
- The presence or absence of significant natural predators or parasites.

Although monitoring mosquitoes is time-consuming, creating and maintaining hard copy maps of breeding sites is even more difficult. A computer-based mapping system is needed, especially for larger municipalities. A computer system will facilitate the compilation and extraction of data. It can even be used to estimate the total surface area of all the breeding sites and, from that, it can be used to ensure that sufficient larvicide is ordered and available to treat all the infested breeding sites permitted by federal and provincial regulators.

3.3.4 Monitoring Mosquito Larvae

Many devices and procedures have been developed to sample mosquito eggs, larvae, and pupae. Larvae can be collected with dippers, nets, aquatic light traps, suction devices, and container-evacuation methods. The most commonly used tool is the mosquito dipper. The dipper can be used simply to determine the presence of larvae. However, standardized sampling methods are required if mosquito abundance is to be quantified.

The most efficient method for larval sampling and ranking of breeding sites is to use a simple sequential sampling technique (Appendix B). Most large control programs rank mosquito-breeding sites (i.e., nil, low, medium or high density) and concentrate larviciding efforts on ones with moderate or high mosquito populations. When there is limited time available for larviciding, it makes more sense to treat the major sources of mosquitoes than to waste time and resources on larval breeding sites that produce only a few mosquitoes.

3.3.5 Monitoring Environmental Factors

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To maximize the usefulness of mosquito surveillance data, key weather events (e.g., rainfall) must be noted. Rainfall will dictate when breeding sites will be flooded and when they will need to be inspected for mosquito larvae.

Rain gauges are important anywhere mosquito production is being monitored. Data from numerous inexpensive backyard-style rain gauges, scattered throughout the municipality, can be supplemented with more precise data from the Environment Canada Weather Service and local weather watchers.

Because rainfall is often highly localized, it is important to record rainfall amounts from as many locations as possible. These data will allow you to pinpoint the areas most likely to have mosquito hatching. When rainfall data is coupled with temperature records, one can predict, almost to the day, when the adult female mosquitoes will emerge. Typically, larviciding will start in the areas having the highest rainfall.

3.3.6 Mosquito Larvicides

a) *Bacillus thuringiensis* subspecies *israelensis*

Bacillus thuringiensis subspecies *israelensis* (Bti) is the active ingredient found in microbial larvicides registered for use in Canada. These products are marketed under the trade names of Vectobac, Aquabac and Teknar. Bti is a naturally occurring bacterium that produces a crystal that is lethal to mosquitoes when eaten. Because mosquito larvae filter out their food as they swim through the water, when Bti is applied to the water, mosquito larvae ingest it. The Bti spores that are consumed contain a crystallized toxin that is dissolved by the larva's alkaline stomach fluids. The toxin then ruptures certain stomach cells of the mosquito larva, causing its death.

The labels of registered Bti products must be referred to for verification of target application sites, which may include:

- Irrigation ditches,
- Floodwater,
- Standing ponds,
- Woodland pools,
- Flooded pastures,
- Marshes and,
- Storm water retention ponds.

The duration of the effectiveness of these larvicides depends on the mosquito species, weather conditions, the formulation of the product, and water quality (i.e., organic content). Although products containing Bti may be expensive, they have the potential to control mosquitoes with minimal impact on most other organisms that might be present in typical larval breeding sites. For this reason, microbial larvicides are well suited for use in an integrated mosquito management program.

Most researchers who have studied the effects of Bti on non-target organisms have concluded that it has minimal impact on most beneficial organisms residing in habitats where mosquito larvae are present. Within the Diptera (biting flies), the toxicity exhibited by Bti is restricted to a few nematoceros families. Apart from larval mosquitoes and black flies, only members of the closely related family Dixidae (non-biting midges) are similarly sensitive to Bti. Before large-scale use of Bti against mosquitoes in the 1980s, numerous safety tests on aquatic organisms were carried out. None of the tested taxa appeared to be affected when exposed in water containing large amounts of Bti (Merritt, 1989; Becker and Margalit, 1993). In addition, Sinigre *et al.* (1979) reported the effects of Bti on non-target organisms in mosquito breeding sites. They found this bacterium to be innocuous on representative test organisms including: water scavenger beetles, cladocerans, copepods, dragonfly larvae, brine shrimp, phantom midge larvae, mosquito fish, and oysters. The only exception was observed with chironomid larvae. Although chironomids are susceptible to Bti, based on laboratory bioassay results, several chironomid species are not susceptible to even high concentrations of Bti (Lacey and Merritt, 2004). Lacey and Merritt (2004) summarized field-derived data from lentic and lotic habitats and noted only slightly reduced or negligible mortality in chironomid larvae treated with Bti at concentrations used to control black flies and mosquitoes. However, studies have shown that nuisance chironomid midges can be controlled with Bti, but the concentrations required are several-fold higher than that permitted for operational mosquito control. A trial conducted in Prince Edward Island with a Bti product, Vectobac 1200L, showed that there was no significant difference between pre-treatment and post-treatment abundance of chironomid and black fly larvae in the streams under study (McCracken and Matthews, 1997). From the available field studies, it can be concluded that when applied at labelled rates, Bti appears to pose little direct or indirect toxic threat to non-target invertebrate species or fish.

Timing of Bti applications is extremely important. Optimal benefits are obtained when treating 2nd or 3rd instar larvae. Treatments against other development stages may provide less than desired results. Therefore, a disadvantage of using Bti is the limited treatment-time window that is available.

b) Methoprene

Methoprene is a compound that was developed after scientists discovered and analyzed a hormone (called juvenile hormone) in insects that kept them in the juvenile or immature stage. Methoprene (which mimics juvenile hormone) is found in several larvicide formulations that are marketed in Canada under the trade name of Altosid. Because the mode of action of methoprene is different from that of active ingredients found in conventional or traditional pesticides, products containing methoprene generally have greater selectivity and present less of a risk to the environment. Rather than controlling target pests through direct toxicity, methoprene interferes with an insect's life cycle and, in the case of mosquito larvae, prevents them from reaching maturity.

Remember that mosquitoes, after hatching from the egg stage, go through four larval instars. While they are in the larval stage, a juvenile hormone is present that stops them from becoming adults. By placing a small amount of these products in habitats containing larvae, the mosquitoes are prevented from properly maturing. They simply die during the pupal stage or as the adult mosquitoes attempt to emerge from the pupal skin.

Altosid is formulated as slow-release briquettes, pellets and granules. The benefit of the slow release is that the materials can be placed in difficult-to-reach locations and continue controlling mosquitoes for a long time. Another benefit of using Altosid, like Bti, is that the larvae remain in the food chain, reducing the impact on other organisms in the habitat. Note that Altosid must be present when the mosquito larvae are in the later stages of development (e.g., later instars) for it to work.

Methoprene used in mosquito control programs does not pose unreasonable risks to wildlife, people, or the environment. For example, the toxicity of methoprene to birds is low; however, methoprene is slightly toxic to some species of coldwater fish. Although reports of frog abnormalities due to Altosid have been widely circulated, most of these reports and other studies are still being evaluated. Other researchers have not been able to reproduce the results of frog abnormalities and have questioned the conclusions on the basis of a number of different points, including lack of geographical correlation between areas of methoprene use and areas of observed effects, amount of material needed to create the effects, and the fact that the type of deformities created have not been observed in the field. Impact studies on the breakdown products of methoprene are ongoing as well.

Methoprene breaks down quickly in water and soil and will not leach into groundwater. Although few mosquitoes breed in habitats that support fish or drain into fish habitats, methoprene is highly toxic to some species of freshwater, estuarine, and marine invertebrates that may be food for fish (see Section 3.0.1). Notwithstanding the high toxicity to aquatic invertebrates, results from field studies with methoprene formulations have shown that there are no lasting adverse effects on populations of invertebrates or other non-target aquatic organisms, when methoprene is used for mosquito control. Where negative impacts on some aquatic invertebrates were observed, they were not permanent as these communities recovered.

c) Diflubenzuron

Diflubenzuron is a chitin-synthesis inhibitor. Each time an insect molts, chitin is required as the hard component of the new outer skin of the larva. A failure to synthesize larval chitin halts molting, leading to physiological problems, and ultimately, the death of the mosquito. Products containing diflubenzuron act on contact with mosquito larvae to disrupt the molting process. For these reasons, diflubenzuron is called an "insect growth inhibitor" or "insect growth regulator".

In Canada, diflubenzuron is available as a wettable powder formulation and is sold under the trade name of Dimilin. Wettable powders are not easy to mix. They must be mixed with water before being applied as a liquid spray. Another drawback is that, because it also affects other arthropods, its use is limited to temporary pools.

d) Chlorpyrifos

Chlorpyrifos is a conventional chemical larvicide. In Canada, its use for the control of mosquito larvae, whether applied by ground or air, remains acceptable, provided that strict limitations are imposed (i.e., limiting its use to temporary pools in outlying areas of municipalities and to situations where the principles of integrated pest management are incorporated into the mosquito control program). The restriction of the use of chlorpyrifos to temporary pools, as opposed to permanent bodies of water such as lakes, dugouts or fishponds, lessens the possibility that non-target aquatic organisms, which are very sensitive to chlorpyrifos, will be affected. Limiting the larviciding use of chlorpyrifos to outlying areas will also lessen the potential for bystander exposure.

e) Malathion

Malathion is another conventional chemical larvicide registered for use in Canada. It appears that malathion is seldom used to control mosquito larvae in Canada, presumably because it rapidly hydrolyzes in water (i.e., its half-life in water is only about one day).

3.3.7 Larviciding Equipment

For the most part, two types of larviciding equipment are used: i.e., granular and liquid spray equipment. These pieces of equipment may be manually or power operated. They may be hand or shoulder carried or mounted on all-terrain vehicles (ATVs), trucks, or aircraft.

3.3.7.1 Granular Application Equipment

Granular larvicides are the most frequently used dry pesticide formulation. Granular larvicides are products in which the active ingredient is applied to the surface of a carrier (the granule). The active ingredient is bound to the surface (whether it is bentonite, vermiculite, or some other inert substance) with some type of binder or sticking agent. This keeps most of the active ingredient on the carrier in transit but allows the active ingredient to release when the granular is applied to the larval habitat.

Granule applicators or spreaders are usually used to apply granules and pelletized larvicides to larval breeding sites. The tank usually consists of a gravity-fed hopper. At the base of the hopper, the granules are ejected through a simple opening or with the aid of a powered auger.

There are several ways to apply granular larvicides. The simplest way is to broadcast them by hand. Many small municipalities use a "belly grinder", a shoulder-carried, crank-operated granule dispenser. These spreaders are supported by straps and look like 20 L pails with a side crank for auguring out the granules. They can hold up to 10 kg of granules. This equipment is useful for small area treatments when the person applying the product can get into the breeding habitat and auger out very small amounts of granules.

If larger areas need to be treated, powered backpack blowers are usually used. These blowers will spread the granules up to 10-15 m from the operator. Backpack blowers (e.g., Solo 400 or 423; Stihl SR420 or SR423; see supplier listing-Appendix C) can also be mounted on ATV's. This enables them to treat relatively large areas more efficiently. Special truck-mounted granular blowers are used for treating wide, roadside ditches.

When hundreds or thousands of hectares of breeding sites need to be treated quickly, aircraft are used to apply the granules. Many aerial applicators use Simplex or similar granule spreader systems. If there is a choice between using helicopter or fixed-wing application services, most municipalities will choose helicopters. Even though more expensive on an hourly basis, they are much more maneuverable and they can be refilled with fuel and larvicide close to the treatment areas. As with any aerial application of insecticide, care should be taken to avoid drift into waters frequented by fish.

3.3.7.2 Liquid Application Equipment

The basic sprayer unit used by pest control technicians to apply liquid sprays for larval mosquito control is the compressed air sprayer. These 'hand sprayers' are made with galvanized metal, stainless steel, or polyethylene tanks. Air is pumped into them with the aid of a plunger-type apparatus or pump. The spray is delivered through an attached hose with a hand shut-off valve and an adjustable or changeable nozzle tip. There are several brands available. One example is the B & G stainless steel sprayer. They are easy to use, efficient, and readily available in 1-, 2-, and 3-US gallon (i.e., 3.8, 7.5 and 11.3 liter) sizes. These small sprayers are used for spot spraying of small larval breeding sites.

The powered, backpack sprayer (comparable to the backpack blower mentioned above) is a more useful unit. It consists of a small engine and gasoline tank, a liquid insecticide tank, and a spray nozzle system. These components are attached to a rigid metal frame and supported by wide shoulder straps and a belt.

Depending on the spray nozzle system used, they are used to produce a solid or variable coarse spray (e.g., for applying mosquito larvicides to narrow ditches or other small larval breeding sites) or to produce an air-driven mist (e.g., used as a mist-blower to apply a spray to larger breeding sites). These units are good for off-road breeding sites and, like the backpack blower, can be carried on one's back or they can be mounted on an ATV for more efficient operations.

There are also a host of different truck-mounted liquid sprayers available. The tank, hose, and reel unit is most common. Municipalities with tree spraying programs may have a large mist-blower that can also be used for liquid applications, particularly along wide roadside ditches. In terms of legal liability, remember that Section 36(3) of the Fisheries Act prohibits the deposit of deleterious substances into waters frequented by fish.

Liquid applications of larvicide are rarely made from the air because most breeding sites are heavily vegetated or occur in wooded areas. Most of the droplets would "hang up" on the vegetation and never make it to the pool where the target mosquito larvae are present.

3.3.8 Larviciding Permits

The pesticide licensing and permit system is the key means by which a province or territory controls pesticide use. Licenses are issued to pesticide applicators that have passed an examination on a particular type of pesticide use (e.g., mosquito and biting fly control). Permits may be required for certain specific types of applications (e.g., application of restricted class mosquito larvicides to water; application of pesticides to public lands).

Any municipality considering a new mosquito control program should contact their provincial/territorial agriculture and/or environment department (well before starting) to determine what licenses and permits may be required. Note that a permit for applying larvicides against mosquitoes may set conditions that restrict the use of a particular larvicide beyond those already specified on the product label.

3.3.9 Larviciding Procedures

For an established, municipal mosquito control program, aimed at controlling nuisance mosquitoes, the mosquito control season may follow the following progression of events:

- Maintenance and calibration of larviciding equipment in the early spring.
- Larval surveys in the spring, once snow melt and hatching begins.
- Assessment of snow-melt breeding sites to determine if they can be filled in or drained to prevent or minimize future mosquito breeding.
- Larviciding of spring floodwater mosquito breeding sites.
- Monitoring of rainfall and temperature to anticipate summer mosquito hatching.
- Larval surveys of summer, floodwater breeding sites.
- Assessment of summer, floodwater breeding sites to determine if they can be filled in or drained to prevent or minimize future mosquito breeding.
- Larviciding of floodwater mosquito larval breeding sites following each significant rainfall, as necessary.

Typically, as mosquito larval breeding sites are identified and ranked, operations crews are assigned to apply the chosen larvicide to the specified sites. The larvicide is then applied, according to any permit conditions and all label directions and precautions. Surveillance or supervisory staff should randomly check the treated breeding sites, within 1-2 days of treatment, to ensure that the larvicide applications were effective.

In some cases, where the larvicide was only partially effective, residual adulticide treatments may be made to vegetation surrounding the breeding site to kill any newly-emerging adult mosquitoes.

In many Canadian jurisdictions, in which mosquito control programs have been put into place to control WNV activity, early season snow-melt mosquitoes are often omitted from treatment because these mosquito species are believed to have little, if any role, in WNV transmission. Instead, efforts are focused on treating breeding sites that produce *Culex* species of mosquitoes; the key WNV amplifying species. The breadth of species targeted for control may be expanded, later in the season, when intensified WNV activity warrants it.

3.3.10 Monitoring the Effectiveness of Larviciding

Individual pools can be selected to assess the effectiveness of a specific larvicide. Larval sampling of the pools is done before and after treatment, to determine the number of larvae per dip or per square metre. With an effective larvicide that is properly applied, one can usually expect >95% control. However, if all label directions were followed, the equipment was properly calibrated, and the product was carefully applied but the larvicide still gave significantly less than 95% control, that batch of larvicide should be tested more rigorously to determine if it meets specifications. Rigorous testing may include controlled field bioassays and chemical or biological laboratory assays, depending on the product involved.

A larviciding program may be evaluated by various methods. Complaints from the public (of intolerable numbers of mosquitoes), or higher than expected numbers of mosquitoes collected during landing counts or in mosquito traps, may indicate a failure of the overall mosquito larviciding program.

Such a failure may be due to weather conditions. Strong winds may have brought mosquitoes into the municipality from outside the control zone immediately following larviciding. This may indicate the need to extend the control effort out further around the municipality. High temperatures, in the days following hatch of mosquitoes (i.e., emergence of larvae from eggs), may have accelerated mosquito development and allowed many adults to emerge before the entire control zone could be treated. This may indicate inadequate staff and equipment for the size of the control zone.

3.4 Mosquito Adulticiding

3.4.1 Rationale for Mosquito Adulticiding

Mosquito adulticiding is normally started if:

- Mosquito larviciding has failed to control the larvae present.
- Adult mosquitoes have blown in from outside the larviciding zone.
- Funds do not permit for an adequate larviciding program.
- Adult mosquitoes reach annoying levels.
- A mosquito-borne pathogen threatens public health.

The number of mosquitoes collected in mosquito light traps and/or the number of mosquitoes caught during landing counts normally determines the need for an adulticiding program for the control of nuisance species. The triggers for implementing an adulticiding program for WNV vector control depend on factors other than numbers alone (for additional guidance, refer to the West Nile Virus National Steering Committee's document entitled *National Guidelines for Response to West Nile Virus*).

3.4.2 Mosquito Trap Counts

Mosquito light traps are an objective measure of mosquito activity. The New Jersey Light Trap (NJLT) is the standard, mechanical, mosquito light trap used in most mosquito control programs. The NJLT was developed at Rutgers University in the 1930s. Because NJLTs usually operate in the same locations for many years (they require 110 VAC power), the historical monitoring data become valuable for documenting the long-term changes in mosquito populations. Although NJLTs are usually operated overnight (using a timer), the number of trap sites and the frequency of trapping vary among mosquito control programs.

Many programs also use Centers for Disease Control light traps (CDC traps) to monitor adult mosquitoes. The CDC trap is a miniature version of the NJLT that can operate on 6 VDC and can be used anywhere. It costs less to purchase than the NJLT, does not require permanent installation, and collects mainly mosquitoes. Most mosquito control programs use carbon dioxide (either dry ice or bottled gas) or octanol as supplemental bait for the CDC trap. As with the NJLTs, there is no standard design for placing or operating CDC traps.

Mosquito traps are generally located in a known mosquito area, out of sight from the public, and in as secure a spot as possible. Some organizations place them in secure areas of parks and golf courses; others place them in the backyards of people who volunteer to assist in the surveillance program.

Long-term monitoring of adult mosquitoes will indicate where mosquitoes are a recurring problem and where preventative measures (including source reduction and larviciding) need more attention. Both of the above-mentioned traps are commercially available in Canada (see supplier listing in Appendix C for full contact details) or can be ordered directly from the manufacturers.

One widely used standard for starting an adulticiding program in terms of nuisance control is that the NJLT collections should average 25 or more female mosquitoes per trap per night for three consecutive nights. This standard recognizes that some traps may collect low numbers and others high numbers of mosquitoes on any given night as a result of their placement. It also recognizes that mosquito activity may be unusually high or low, depending on weather conditions, on any given night.

There does not appear to be a similar standard number of mosquitoes collected per trap per night with the CDC traps. Because there are several different designs, light sources, and baits associated with CDC traps, comparisons are more difficult.

3.4.3 Landing Counts

Mosquito landing counts can also be used as an index of mosquito activity. The counts, carried out according to standard methods, should average 1+ landing mosquito per minute over a 10-minute period at sunset before a mosquito adulticiding program is considered for the control of nuisance species.

Although mainly used to justify mosquito adulticiding, these counts have several other uses:

- Justification for source reduction projects.
- Evaluating the effectiveness of adulticiding.
- Locating major larval habitats.
- Determining the species composition of biting populations.
- Determining where to place light traps.
- Improving larval surveillance.
- Comparing biting populations versus light trap data.

Landing counts are easy to do and require minimal gear. It is best if two people work together as a team. Instructions can be as simple as:

- Wear dark-coloured coveralls, a head net or bug hat, and thin, disposable gloves.
- Do not wear repellents, after-shaves, scented deodorants, or perfumes.
- Go to the location at dusk, selecting a grassy area, in the shade and out of the wind.
- Count the mosquitoes landing on the front of the other person over a 10-minute period.

If the mosquitoes are collected from the other person, as they land, counting is less confusing and enables the collected mosquitoes to be identified at a later time. If only one person is available, that person could simply count the number of mosquitoes landing on the front of their body over a set period of collecting time (i.e., 10-minute period). Dividing the total count by 10 will give an average count of "x mosquitoes/minute" for that time of day and location. Usually, when the numbers exceed one mosquito per minute, they have reached a level that will not be tolerated by most people. Use the sample form provided (Appendix A) for record-keeping.

These NJLT and landing count values (25 females per trap per night and greater than one landing mosquito per minute at dusk, respectively) are comparable and they also seem to match the public's tolerance of nuisance mosquitoes. When these values are exceeded, the public usually demands an adult mosquito control program.

3.4.4 Vector Surveillance Traps

If there is a threat of an encephalitis outbreak, the rationale for adulticiding is slightly different. Mosquito vector surveillance may include the techniques and equipment that are used in the monitoring of nuisance mosquitoes (noted above) plus some specialized methods, equipment and materials.

Live mosquitoes are usually collected to determine the percentage of suspected vector species that are infected with the virus and, sometimes, their reproductive age. Live or dead mosquitoes are collected to obtain an estimate of the population size of the mosquito vectors.

The most commonly used trap for live collections of vector mosquitoes is the CDC miniature light trap (e.g., Hock's New Standard Miniature UV Light Trap Model 1212 or 512) baited with dry ice.

The efficiency of this trap can be enhanced by placing it close to an oviposition site that is attractive to the adult female mosquitoes of *Culex* species. This trap may collect some female mosquitoes that have already laid eggs and may be infected with a virus.

Traps baited with chickens also work well for *Cx. pipiens*. Chicken-baited shed traps have been used to collect *Cx. tarsalis*. Counts of vector mosquitoes can be used to assess their activity throughout the season and to compare their activity over the years.

3.4.5 Information Required for Effective Adulticiding

Mosquito control programs usually use one or more of the above-mentioned methods to measure adult mosquito populations before a decision to start adulticiding is made. Before adulticides are applied for the control of nuisance species, an adult mosquito monitoring program should detect an increase in the population above a pre-determined baseline.

Alternatively, the imminent risk of disease transmission in an area may call for immediate adulticiding, even when the mosquito population is below the normal numerical threshold for taking such action.

3.4.6 Mosquito Adulticides

Applying adulticides or "spraying" for adult mosquitoes, although a component of an IPM strategy, is usually considered to be a "last resort", often when other control efforts (e.g., source reduction or application of larvicides) have not produced the desired reductions in mosquito populations. Most mosquito control work goes on throughout the spring and summer, "behind the scenes", using source reduction and larviciding. Controlling adult mosquitoes is more difficult because they are spread out and moving.

Among the adult mosquito control options available in Canada for use in large-scale mosquito control spray programs, products containing malathion are the preferred choice for ultra-low-volume (ULV) applications. Malathion is preferred to some of the other active ingredients registered for adult mosquito control because it has an updated risk assessment. The use of malathion as a mosquito adulticide has recently been reviewed by the Pest Management Regulatory Agency (PMRA) of Health Canada under its re-evaluation program to ensure that the continued use of products containing malathion for adult mosquito control in residential areas, using ground or aerial ultra-low volume application, will not pose a health concern.

Malathion can be applied at a rate of up to 60.8 grams active ingredient/hectare for ULV ground application, or up to 260 grams active ingredient/hectare for ULV aerial application. The ULV equipment used to apply malathion produces very fine droplets (mostly in the 5-20 microns size range) of concentrated material, which means products containing malathion can be applied at very low application rates. Malathion must contact the flying mosquitoes directly to kill them because it is broken down rapidly after application.

Besides ULV fogging, some adulticides can also be applied as residual sprays to vegetation where mosquitoes rest (discussed in the sections to follow).

3.4.7 Adulticiding Equipment

3.4.7.1 For Residual or Barrier Treatments

One way to control adult mosquitoes is to use residual (or barrier) spray treatments. Residual spraying involves spraying a dilute insecticide onto a band of vegetation surrounding the area to be protected

(e.g., a backyard, a cemetery, a park, a golf course). The treatment leaves the insecticide on plant leaf surfaces. When mosquitoes fly from their harbourage or resting areas (e.g., nearby woods) into this zone, they either land on the treated vegetation and die or they are repelled and do not move into the open to bite. Several different products are available for this use in Canada (see the PMRA's website for information on the currently registered barrier treatments at <http://www.hc-sc.gc.ca/pmra-arla/english/main/contact-e.html>).

Equipment for such applications varies with the size of the area to be protected. It can range from a small hand sprayer to a motorized backpack sprayer to a large Buffalo turbine sprayer or a Myers mist-blower.

3.4.7.2 For Large-Area ULV Treatments

Ultra-low-volume sprayers (often simply called "cold foggers") produce clouds of tiny droplets that slowly drift downwind from the sprayer, killing any mosquitoes that are contacted. The droplets are usually less than 25 microns in diameter (for comparison, a human hair is about 50 microns thick [range of 30-100 microns]). Because the distribution of the droplets depends on air currents and temperature, care must be exercised in determining when to carry out the treatments.

A low level temperature inversion helps to hold the droplets low to the ground and consistent light wind (15 km/h maximum) serves to propel them through the habitat. Under good conditions, such as a temperature inversion with a slight breeze, an effective swath width up to 100 m or more may be obtained with truck-mounted equipment. For large areas, a heavy-duty, skid-mounted, gasoline-powered ULV sprayer is needed. The units are usually truck-mounted to facilitate treatment of large areas. These truck-mounted units are substantial (and expensive) pieces of spray equipment. The ULV liquid tank usually has a capacity of 20 L (usually, the insecticide container itself rather than a special tank). The cold fogger is normally mounted on a half-ton pickup truck. The driver can operate the equipment remotely from the cab of the vehicle.

Flow controllers are available that automatically adjust droplet emission to match vehicle speed. The ULV flow unit can be programmed to stop the flow of insecticide whenever the vehicle stops. Some of the newer flow controllers are GPS-guided. The vehicle speed, path and output can be satellite-guided and monitored. There are several manufacturers of ULV aerosol generators designed for mosquito control (see supplier listing for manufacturers and distributors, Appendix C).

3.4.7.3 For Small-Area ULV Treatments

There are very few good sprayers of this type and size. These small sprayers are either carried using a handgrip and/or shoulder strap or are backpack-mounted. A small, gasoline-fuelled, engine powers them. Using a special nozzle, an air blast breaks the liquid concentrate up into very small droplets. They are most commonly used for adult mosquito control around tents, buildings, and small recreational areas. Few portable cold foggers seem to be designed for rugged use in the field.

Note that some workers, after holding these units for several hours per day, have reported symptoms of carpal tunnel syndrome. If purchasing one of the hand-held units, it would be best to order the optional shoulder sling to minimize this problem. See the supplier listing for manufacturers and distributors (Appendix C).

3.4.8 Adulticiding Permit

As noted above, the licensing and permit system is the key mechanism used by the provinces/territories to monitor and control pesticide use. A permit may be required by the municipality for the application of a mosquito adulticide in public parks and golf courses and/or on residential streets and lanes. A

municipality considering a mosquito adulticiding program should contact their provincial/territorial agriculture and/or environment department (well before starting) to determine if a permit is required.

Note that a provincial permit for mosquito adulticiding may set conditions that restrict the use of the adulticide beyond those already specified on the product label. Conditions may include the publication of an official notice to the public, the setting of distances for an untreated buffer zone around residents not wishing their properties to be included, and the exclusion of certain types of properties (e.g., school grounds, hospital grounds).

Municipalities considering mosquito adulticiding as a possible component of their mosquito control program are advised to determine the conditions for such a permit well in advance of the mosquito season.

3.4.9 Adulticiding Procedures

When a source reduction or larviciding program fails to provide adequate control of adult mosquito populations, two procedures may be followed to reduce adult mosquito levels: residual adulticide treatments and ULV adulticide treatments.

First, residual adulticide treatments may be made to mosquito resting sites. Mosquitoes resting in these areas may be killed for up to 24-48 hours after treatment, depending on the residual activity of the insecticide that is used. Resting sites include:

- Vegetation surrounding larval breeding sites to kill any emerging adult mosquitoes.
- Vegetation surrounding a larval breeding site where treatment with larvicides is not a preferred option (e.g., fish habitat, wildlife refuge).
- Vegetation surrounding an area to be protected (e.g., fish habitat, outer margins of a park).
- Vegetation in wide, grassy ditches where mosquitoes rest during the day.

Second, ULV adulticide spraying may be carried out in recreational and/or residential areas. When objective data indicate a significant nuisance or disease threat, ULV treatments usually begin as soon as possible. A typical sequence of events is as follows:

- Above-tolerable mosquito levels or disease risk is apparent.
- Public notice of the problem and a schedule for the planned spray program is given.
- Crews are assigned areas to treat, usually in the evening hours, between dusk and dawn.
- Areas are treated, usually beginning in recreational areas or the worst infested residential area.
- Areas are treated on a rotational basis until the problem is resolved.

3.4.10 Public Notice of Spray Operations

Requirements vary among jurisdictions but some sort of public notice of planned spray operations is usually required. Organizations usually issue a public notice in local newspapers, stating which insecticides they will be using for which insect problems. Persons may request, and be granted, an untreated buffer zone around their properties.

If some members of the public are concerned about adulticiding (e.g., with malathion), they should be advised to monitor the daily news for spray schedules and to take these precautions:

- Whenever possible, remain indoors when spraying is taking place.
- Close windows during the evening hours.
- If you have to remain outdoors, avoid eye contact with the spray. If you get drops of the malathion spray in your eyes, immediately rinse them with water or eye drops.

- Wash exposed skin surfaces with soap and water if you come in contact with malathion.
- Wash home-grown fruits and vegetables with water before cooking or eating them.
- Cover outdoor tables and play equipment or rinse them off with water after spraying is finished.
- Bring laundry, toys, and pets indoors before spraying begins.
- Cover ornamental fish pools to avoid direct exposure.

Organizations can be proactive with pesticide-related health concerns by using products such as those containing malathion in their ULV adult mosquito control programs and by ensuring that the public is fully aware of the reasons for choosing a given insecticide.

3.4.11 Monitoring Effectiveness of Adulticiding

Small areas can be selected to assess the effectiveness of a specific adulticide. Landing counts are made, before and after treatment, to determine the average number of landing adult mosquitoes per minute. Typically, a ULV mosquito adulticide will give 75-85% control within 8 hours of treatment. If all of the label directions were followed and the adulticide gave less than expected control (e.g., significantly less than 75-85% control), that batch of the adulticide should be tested to determine if it meets chemical specifications. Rigorous testing may also include bioassays using caged mosquitoes.

An adulticiding program may be evaluated by various methods. Continuing complaints from the public of intolerable levels of mosquitoes or higher than expected numbers of mosquitoes collected during landing counts or in mosquito traps, after the ULV treatment, may indicate a failure of the overall mosquito adulticiding program.

Such a failure is often the result of limited operational resources. There may not be as many operators and ULV sprayers available as necessary to treat the entire control zone in a timely manner. Although only one operator-ULV unit may be adequate for a small town, 15-20 operator-ULV units may be required for a large city. Unfortunately, because most mosquito control organizations emphasize larviciding, they are often under-equipped when the need for mosquito adulticiding becomes apparent.

3.5 Non-chemical Mosquito Control

3.5.1 Water Management

Because of the transitory nature and small size of many mosquito floodwater habitats, they often can be altered to prevent or, at least, to minimize mosquito production (see section 3.5.2 on source reduction below). However, there are laws and policies concerning alterations of fish habitats (see Fisheries Act ss.35 (1)). Contact federal and provincial fisheries, wildlife, natural resources, and conservation departments if you are considering such major projects.

In some cases, it may be possible to reduce larval mosquito sources and at the same time preserve or enhance fish, fish habitat, wetlands and other desirable habitats (Chipps et al. 2002). Good land use practices near wetlands (unpolluted by excessive urban storm water runoff or sedimentation) will preserve water quality and favour the increase of diverse populations of aquatic organisms (including predaceous insects) that feed on any mosquito larvae present.

Draining or filling natural wetlands is not a viable control measure for mosquitoes or controlling WNV. If drained, a wetland will still hold water from flooding, rainfall, or snow melt. The shallow depressions may produce more mosquitoes than healthy wetlands. Further, filling wetlands usually just forces the water to move elsewhere, creating flooding or additional wetlands.

Fortunately, wetland management is rarely needed in mosquito management programs because most mosquito breeding sites are small, temporary pools that only hold water for 2-3 weeks following a heavy rain and they do not support fish or, in many cases, macro-invertebrates.

Urban landscape planners should consider carefully the kinds of mosquito habitats they may be creating when natural aquatic habitats are integrated into landscape or neighbourhood designs or when designs are made for storm water retention ponds, sewage lagoons, or ornamental ponds.

3.5.2 Source Reduction

Source reduction of mosquito breeding sites may involve:

- Installation of a catchment (i.e., a small area into which rain water drains).
- Installation of tile leading to a catchment or drain.
- Modification of grade to facilitate drainage.
- Filling and levelling of small water-filled depressions.
- Removal of emergent vegetation from certain potential breeding sites (e.g., golf course water hazard).

3.5.3 Public Education

Fact sheets, posters, school poster contests, media contacts, and formal presentations can all be employed to let residents know what the municipality is doing about mosquitoes and to solicit their cooperation.

a) Source Reduction: One way that citizens can be encouraged to help control mosquitoes is through backyard source reduction. People need to be advised on where mosquitoes breed in their backyards:

Mosquito Sources	How to Reduce Backyard Mosquitoes
Water gardens	Stock with fish or use Bti; remove excess vegetation.
Swimming pools	Keep water off the pool cover; maintain water quality at all times.
Tree holes	Fill hole with sand or mortar.
Plastic pools	Drain water when not in use, or cover so mosquitoes cannot lay eggs.
Containers	Empty water; store in an inverted position; dispose of; or cover.
Bird baths	Change water at least once a week.
Standing water	Eliminate by draining; Fill in low areas.
Livestock watering troughs	Stock with fish or change water weekly.
Street gutter or catch basins	Keep litter and garden debris out of gutters; do not over water yard.
Septic tank fields	Ensure proper drainage so mosquitoes cannot lay eggs.

Roof gutters/eaves trough	Clean once a year to remove debris.
Irrigated lawns or fields	Avoid over-irrigation. Drain standing water.

b) Exclusion:

The use of mosquito screening on all of the doors and windows of homes and other buildings is an obvious means of excluding mosquitoes. Likewise, doors and windows should always be snug fitting along all four edges.

c) Personal Protection:

Citizens should be advised that the most effective method of personal protection from mosquito bites is to avoid places where mosquito densities are high and to avoid being out-of-doors at times of the day when mosquito activity is at its highest (e.g., during calm, warm, and humid evenings).

If people find themselves in situations where they must be exposed to mosquitoes, there are several things they can do. First, they can minimize the exposed skin surface by wearing a hat or head net, long trousers, and a long-sleeved shirt. Some mosquitoes will bite through lightweight clothing, but the number of bites received is definitely reduced if most areas of the body are covered. When mosquito densities become very high or there is a risk of pathogen transmission, people should apply a mosquito repellent.

There are several different active ingredients found in registered personal insect repellents in Canada. DEET, or diethyltoluamide, is the most common active ingredient used in insect repellents and was recently re-evaluated by the PMRA to ensure that its continued use is acceptable from a safety perspective. In addition, a product containing p-methane-3,8 diol and other products containing soybean oil, were also recently registered in Canada and therefore meet all modern safety standards.

Products can contain DEET in different concentrations. It should be noted that products with lower concentrations of DEET are as effective at repelling mosquitoes as products containing higher concentrations of DEET. However, products with less DEET remain effective for shorter periods of time.

It should also be noted that, as a result of the recent re-evaluation of DEET by the PMRA, there are new guidelines for using DEET-containing products. Refer to the PMRA's "Pest Notes" document entitled "Safety Tips on Using Personal Insect Repellents". This document is available on PMRA's webpage: http://www.hc-sc.gc.ca/pmra-arla/english/mosquito/mosquito_e.html.

Repellents have some drawbacks. DEET is an irritant to some people and it may damage synthetic materials such as clothing or plastics. Repellents may lose effectiveness more quickly than anticipated, depending on other factors (e.g., wind, high temperature, high humidity, sweating). When using a personal insect repellent, use only those products that are currently registered in Canada (i.e., under the authority of the Pest Control Products Act (PCPA)). In addition, always read the entire label before using a repellent and apply it according to label directions.

Although most products which make pest control claims (e.g., "repels mosquitoes") do require registration under the authority of the PCPA, there is a vast array of such products that are marketed (illegally) to repel mosquitoes, most of which are totally ineffective. These include wristbands that contain an aromatic repellent, ultrasonic emitters, electric grids, electronic repellents, aromatic plants (the most common one is the so-called mosquito plant), incense coils, vitamins, and even mixtures of brewer's yeast and garlic. Researchers have shown that all these methods are of little or no value in repelling mosquitoes (for more detailed information, see <http://www.rci.rutgers.edu/~insects/proprom.htm>).

3.5.4 Biological Control via Natural Enemies

Mosquitoes are affected by a host of natural enemies, including a wide variety of parasites, predators, and pathogens. Unfortunately, because mosquito numbers can explode after the spring snowmelt or a heavy summer rainfall, natural enemies usually do little to keep mosquitoes at a tolerable level.

There are exceptions to this rule. There have been cases reported in the US literature, where, in individual breeding sites, a parasite (e.g., certain kinds of nematodes) or a predator (e.g., fathead minnows) has kept mosquitoes to a low level. However, the general success of mosquitoes serves to underscore their ability to adapt to widely divergent natural phenomena. They are not likely to succumb in any meaningful way to natural controls.

Further, pursuant to Section 55 of the Fishery (General) Regulations under the Fisheries Act, no person shall release live fish into any fish habitat. Accordingly, mosquito abatement officials must not introduce any predator species (e.g., minnows) into mosquito breeding sites. Some breeding sites are not self-contained or may be subject to flooding and might allow such introduced species to enter fish habitat and pose a serious risk to native fish.

4. Record-keeping

4.1 Legal Requirements

All pesticide use programs in Canada require some record-keeping. Most jurisdictions require detailed records of when and where pesticides are used, the kinds and amounts used, who made the applications, the weather conditions occurring during the treatment, and the specific areas involved. In addition, some agencies require that all treatments be justified through pest monitoring surveys and records.

To facilitate record-keeping by municipalities carrying out mosquito larviciding and adulticiding, several basic record forms have been developed (see Appendix A) that will provide guidance to municipalities regarding how to document larval and adult mosquito activity within their jurisdiction and record relevant operational information.

Most mosquito control agencies maintain a host of other records directly relating to mosquito control operations. These other records may include:

- Employee classroom and on-the-job training.
- Occupational safety and health training and information distribution.
- Employee occupational health records.
- Citizen inquiries and complaints.
- Financial records.

Although forms can be filled out manually, computerized record-keeping is the most efficient means of completing, maintaining, and summarizing mosquito surveillance and control operations.

4.2 Computerized Record-keeping System

Although some mosquito control agencies have developed special databases for their records, a new software program has recently become available that is specially designed for this purpose. It is called the "Vector Control Management System" or VCMS.

It is an integrated database, computer mapping, and field data collection system designed for mosquito control organizations. It includes modules for:

- Logging and tracking of citizen complaints and service requests.
- Mosquito collection and trapping.
- Insecticide applications and regulatory reports.
- Tracking of work assignments, including detailed daily time and task recording.
- Virus testing (sentinel flocks, mosquito pools, etc.) and related lab reporting.
- Mosquito breeding and trap site mapping.

Although this system could be used on a laptop computer in the field, it can also be combined with Palm Pilot and Windows CE devices for ease of field data collection. For further details, see http://www.acrcorp.com:8080/acr_vcms.

5. Assessing Proposals for Mosquito Control Services

Although many municipalities prefer to carry out their own mosquito control program, some municipalities may prefer to hire a professional mosquito control service. Selecting a mosquito control service best suited to a municipality's needs is not an easy task. There are several things to consider.

First, consider the legalities. Anyone performing commercial pest control must be licensed in the jurisdiction involved. Make sure that the company being considered only uses employees that have valid mosquito control applicator licenses to perform the required services. Operators of mosquito control equipment must be trained not only in the proper use and maintenance of the equipment but also in the proper application of the insecticide that they are using.

Second, investigate such services carefully and well in advance of the need. Although mosquitoes can cause a significant problem if left unchecked, do not rush to make a decision about mosquito control services. It is better to spend a few extra days or weeks evaluating the safest, most effective, and economical way to solve the problem.

Conduct a review of the major Canadian mosquito control consultants and companies (Appendix D). Given that there are always new companies providing such services, it may also be useful to consult with your provincial/territorial regulatory officials (see http://www.hc-sc.gc.ca/pmra-arla/english/pdf/fpt/fpt_membership-e.pdf) to determine who else might be licensed to provide the full range of mosquito control services.

Talk with other municipalities to see if they have used mosquito control services or have used the company that you are considering. Find out which companies have done a good job and why. Ask about their particular mosquito problem, the services the company provided, how satisfied they were with the results, and the company's fees. A reputable, experienced company will be glad to provide references to you on work done in other municipalities. Ask for the names and telephone numbers of key contacts in those other municipalities.

Because mosquito control, whether it is larviciding or adulticiding, must be based on sound surveillance data, determine whether it is best if you or the company provide this information. Remember that any recommendations made by the company regarding the need for larviciding or adulticiding, must be supported by valid data.

Reputable firms will give you the names of the products that they intend to use and provide you with information on any required precautionary measures. You should be able to obtain a copy of the Canadian product labels and MSDSs, upon request. If a pest control service is unable, reluctant, or unwilling to provide any of this information, seriously consider hiring another company.

Talk with representatives from several mosquito control companies and get written estimates. Get all of the facts and details straight before signing a contract. You should have several companies assess the problem and present a plan for correcting it. The lowest bidder or firm in your area may not necessarily provide all the services that you need. Check with the Better Business Bureau in their area to see if any complaints have been lodged against the company.

A detailed, written proposal should be obtained, prior to any mosquito control work being undertaken. The written contract should include a complete listing of all of the services that will be provided, including costs. The services to be performed must be fully documented.

Ask for a complete inventory of the mosquito surveillance and spray equipment that the firm intends to use in your municipality (including a detailed description and the number of units of each type). It may also be appropriate to request in the contract that a "dry run" be conducted in advance of the treatment period to ensure that all equipment is properly calibrated (results should be submitted in the form of an interim report).

Don't settle for a contract or an invoice that simply says, for example, "mosquito control". If the mosquito control company needs to treat specific areas, these areas should be listed in detail. The name, concentration, and total amount of any insecticide to be used should also be stated on the contract or invoice.

Determine the steps you need to take (e.g., issuance of a public notice) before the mosquito control program begins. This helps everything go smoothly during the program and ensures that you receive maximum results. Double check that everything is understandable and reasonable, before you enter into a contract.

Good communication with your mosquito control company helps prevent misunderstandings and problems. The mosquito control professional servicing your municipality considers you a valued customer and is there to help you. Never hesitate to ask questions about the service you are receiving.

6. Mosquito Control Resources

There is no shortage of information available on the biology of mosquitoes, methods for conducting surveillance (for nuisance or vector species), and mosquito control operations. In addition to industry, experts in government and universities can be consulted about the various facets of mosquito control (see Appendix F and G). Mosquito control workers in municipalities across Canada can advise on the practical aspects of mosquito surveillance and control (Appendix H). Suppliers can be contacted regarding the prices and availability of services, equipment and materials. Research can be done on the Internet by visiting mosquito control-related websites. Reports and publications on mosquito biology and control can be obtained for in-depth study.

A series of appendices, listed below, has been attached to facilitate the implementation of new mosquito control programs.

7. List of Appendices

To facilitate the implementation of a municipal mosquito surveillance and control program and the location of key resources, a series of appendices have been attached to this report:

- Appendix A. Larval and Adult Mosquito Survey and Management Forms.
- Appendix B. Larval Sampling Procedure.
- Appendix C. Suppliers of Equipment and Materials Used in Mosquito Control.
- Appendix D. Mosquito Control Consultants and Companies.
- Appendix E. Provincial/Territorial Government Officials.
- Appendix F. Federal Government Officials.
- Appendix G. University Researchers involved in Mosquito Vector Biology and Control.
- Appendix H. Municipal Mosquito Control Workers.
- Appendix I. Some Useful Links relating to WNV and Vector Control.
- Appendix J. Technical Reports and Publications.
- Appendix K. Glossary of Technical Terms.

Appendix A. Larval and Adult Mosquito Survey and Management Forms.

Larval and adult survey forms and larviciding and adulticiding forms follow in the next four pages.

LARVAL MOSQUITO SURVEY FORM

COLLECTION DATA	Date: _____	Location No.: _____	Collector's Name: _____
Location Description (if no location no.): _____			

BREEDING SITE DESCRIPTION

Site Type (Check one): Catch Basin <input type="checkbox"/> Tire Dump <input type="checkbox"/> Tire <input type="checkbox"/> Watering Trough <input type="checkbox"/> Artificial Container <input type="checkbox"/> Roadside Ditch <input type="checkbox"/> Right-of-Way Ditch <input type="checkbox"/> Woodland Pool <input type="checkbox"/> Field Pool <input type="checkbox"/> Sewage Lagoon <input type="checkbox"/> Dugout <input type="checkbox"/> Creek <input type="checkbox"/> Culvert <input type="checkbox"/> Slough <input type="checkbox"/> Pond <input type="checkbox"/> Rock Pool: <input type="checkbox"/> Tree Hole: <input type="checkbox"/> Other Type of Site _____	
Pool Length (m): _____ Width (m): _____ Depth (m): _____	Emergent Vegetation: Nil <input type="checkbox"/> Low <input type="checkbox"/> Mod. <input type="checkbox"/> High <input type="checkbox"/>

SEQUENTIAL SAMPLING			Pool rating: Nil <input type="checkbox"/> Low <input type="checkbox"/> Moderate <input type="checkbox"/> High <input type="checkbox"/>		
Dip No.	No. of Larvae	Cumulative No.	Dip No.	No. Larvae	Cumulative No.
1			6		
2			7		
3			8		
4			9		
5			10		

SPECIES IDENTIFICATION

Species Code	No. Identified	Species Code	No. Identified	Species Code	No. Identified

LARVAL MOSQUITO MANAGEMENT FORM

APPLICATION DATA	Date: _____	Location: _____
Applicator's Name: _____ Applicator's Rank: _____ Applicator's Position: _____		

TARGET MOSQUITO LARVAE	<p style="text-align: center;">Aedes: ___ Culex: ___ Culiseta: ___ Anopheles: ___ Coquilletidia: ___ Psorophora: ___</p> <p>Other (specify): _____</p>
------------------------	--

LARVICIDE USED	<p>Active Ingredient: _____ Product Name: _____ PCPA Reg. No.: _____</p> <p>Application Rate Used: _____ Amount Used: _____</p> <p style="text-align: center;">Wind speed: _____ km/h Ambient Temperature: _____ deg. C</p> <p>Spray Equipment Used: _____</p> <p>Specific Areas Treated (indicate number of hectares for each area): _____</p> <p>_____</p>
----------------	---

PERSONNEL INVOLVED	<p>Authorized by:</p> <p>Name: _____ Rank: _____ Signature: _____</p> <p>Application made by:</p> <p>Name: _____ Rank: _____ Signature: _____</p>
--------------------	---

ADULT MOSQUITO SURVEY FORM

COLLECTION DATA	Date: _____	Location No.: _____	Collector's Name: _____
Location Description (if no location no.): _____			

HABITAT DESCRIPTION			
Habitat Type (Check one): Playground ___ Sports Field ___ Golf Course ___ Swimming Pool ___ Backyard ___ Undeveloped Area ___ Woodland ___ Landfill ___ Sewage Lagoon ___ Schoolyard ___ Other Type of Site _____			
Special Characteristics: _____		Weedy Vegetation: Nil ___ Low ___ Mod. ___ High ___	

LANDING COUNTS (10 minutes each)			Time of Day: _____ h		
Count Number	No. of Mosquitoes	Count Number	No. of Mosquitoes	Count Number	No. of Mosquitoes
1		6		11	
2		7		12	
3		8		13	
4		9		14	
5		10		15	

Average No. of Mosquitoes Landing per Minute (based on minimum of 10 minutes)	_____ Mosquitoes/Minute
--	-------------------------

SPECIES IDENTIFICATION					
Species Code	No. Identified	Species Code	No. Identified	Species Code	No. Identified

ADULT MOSQUITO MANAGEMENT FORM

APPLICATION DATA	Date: _____	Location: _____
Applicator's Name: _____ Applicator's Rank: _____ Applicator's Position: _____		

TARGET ADULT MOSQUITOES
Aedes: ___ Ochlerotatus: ___ Culex: ___ Culiseta: ___ Anopheles: ___ Coquillettidia: ___ Psorophora: ___ Other (specify): _____

ADULTICIDE USED
Active Ingredient: _____ Product Name: _____ PCPA Reg. No.: _____ Application Rate Used: _____ Amount Used: _____ Wind speed: _____ km/hr Ambient Temperature: _____ °C Spray Equipment Used: _____ Specific Areas Treated (indicate number of hectares for each area): _____ _____

PERSONNEL INVOLVED
Authorized by: Name: _____ Position: _____ Signature: _____ Application made by: Name: _____ Position: _____ Signature: _____

Appendix B. Larval Sampling Procedure.

A standard system for sampling mosquito breeding sites will save time and simplify record-keeping. A sequential sampling technique, such as that developed by Wada (1965) and used by several Canadian municipalities, can be used to estimate larval abundance and to determine if larviciding is necessary. The method described below enables an inspector to rank a pool as without larvae or with larvae at a low, moderate or high level. Depending on the time and mosquito management resources that are available, this sampling system allows one to decide on which level of pools to treat.

If there was sufficient time and resources, pools that were ranked as medium or high could be treated. If not, only the high-ranked pools would be treated. Unless very large in size, the pools ranked low would contain too few mosquitoes to justify treatment. If the number of pools involved in the control program are all relatively small and few in number (e.g., less than 150), a priority system might be established to treat only those pools with moderate or high numbers of larvae.

The larval survey form (shown in Appendix A) can be used by the person carrying out the survey of larval breeding sites. It is based on the following sequential sampling table:

Cumulative Number of Mosquito Larvae

Number of Dips	Low	Moderate	High
1			> 31
2			> 36
3			> 41
4		2 - 3	> 46
5		4 - 5	> 51
6		5 - 7	> 56
7		7 - 10	> 61
8		7 - 15	> 66
9	1	7 - 20	> 71
10	1 - 2	7 - 30	> 76

Thus, the pool sampled is ranked by the surveyor using the following method:

If the number of larvae collected in at least 5 dips is 31 or more, the site is rated as "high".

If only 1 or 2 larvae are collected in 10 dips, the site is rated as "low".

If no larvae are collected, the site is rated as "nil".

10 dips must be taken to distinguish between "moderate" and "high".

Note that, if the surface area of the larval breeding site is greater than 50 m by 50 m (2500 m²), then the number of dips taken must be doubled.

As a result of the above information sheet and map records, a mosquito abatement operation will become much easier with time. The importance of such larval surveys will diminish as the years pass and the survey approaches completion. However, it must be remembered that each new land development may change the number and location of breeding sites. In addition, there will always be an ever changing number and distribution of container breeding sites that require monitoring, not so much for the number but rather the kinds of mosquitoes present.

Appendix C. Suppliers of Equipment and Materials Used in Mosquito Control.

There are many companies across Canada that supply equipment and materials that are used in mosquito control programs. Some of the well-known firms are listed below. This list is not exhaustive. Check with local government officials and other municipalities in your area for other suppliers.

Adapco, Inc.

2800 South Financial Court, Sanford, Florida 32773-8118 USA

Tel: 407-330-4800, Fax: 866-330-9888

Email: info@e-adapco.com

Website: <http://www.londonfoggers.com/>

Services: Manufactures and distributes a variety of insecticides, misters, foggers, and sprayers.

Beecomist Systems

3255 Meetinghouse Road, Telford, PA 18969, USA

Tel: 215-721-9424, Fax: 215-721-0751

Services: Manufactures and distributes a variety of insecticides, misters, foggers, and sprayers.

Clarke Mosquito Control Products Inc.

P.O. Box 72288, 159 N. Garden Avenue, Roselle, IL 60172, USA

Tel: 708-894-2000, Fax: 708-894-1774

Email: info@clarkemosquito.com

Website: <http://www.cmosquito.com/cmcp/default.asp>

Services: Provides municipal mosquito control services and distributes mosquito surveillance equipment, including traps, and control equipment, including a variety of ULV sprayers.

Curtis Dyna-Products

P.O. Box 297, 17335 U.S. Hwy. 31 North, Westfield, IN 46074, USA

Tel: 317-896-2561, Fax: 317-896-3788

Email: dynafog@iquest.net

Website: <http://www.dynafog.com>

Services: Manufactures and distributes mosquito adulticiding equipment.

Gardex Chemicals Ltd.

7 Meridian Road, Etobicoke, ON M9W 4Z6

Tel: 416-675-1638, Toll Free Canada: 1-800-561-7302, Fax: 416-798-1647,

Email: kmattix@gardexinc.com

Web Site: <http://www.gardex.ca>

Services: Distribute a wide range of insect control equipment and materials.

GDG Environnement Ltee.

375 Vachon, Cap-de-la-Madeleine, QC G8T 8P6

Tel: 819-373-3097, Fax : 819-373-6832

Contact: Christian Back

Email: gdg.environnement@gdg.ca or christian.back@gdg.ca

Website: <http://www.gdg.ca>

Services: Source of mosquito surveillance and control services and BTI.

John W. Hock Company
P.O. Box 12852, Gainesville, Florida 32604 USA
Tel: 352-378-3209, Fax: 352-372-1838
Email: jwhock@acceleration.net
Website: <http://home.acceleration.net/~jwhock/#John%20W.%20Hock%20Company>
Services: Mosquito traps and other sampling devices.

London Fog Inc.
505 Brimhall Avenue, Long Lake, MN 55356, USA
Tel: 952-473-5366, 1-800-448-8525, Fax: 952-473-5302
Email: (see website for direct link).
Website: <http://www.londonfoggers.com>
Services: Manufactures and distributes mosquito control equipment.

Nu-Gro Corp.
10 Craig Street, Brantford, ON N3R 7J1
Tel: 519-757-0077, Fax: 519-757-0080
Email: products@nu-gro.ca
Web Site: http://www.nobite.ca/index_e.php
Services: A supplier of Altosid®, AquaBac, Dursban 2.5G, Malathion ULV, Prox® 120 and mosquito traps.

Pestalto Environmental Products Inc.
400 Elizabeth St., Unit 1, Guelph, ON N1E 2Y1
Tel: 1-866-648-7773 toll-free, Fax: 519- 837-4471
Contact: Barry Tyler
Webpage: <http://www.pestalto.com/>
Email: barry.tyler@pestalto.com
Services: Supplier of mosquito surveillance and control equipment, including backpack sprayers and ULV sprayers; also distributes various mosquito control products.

M.K. Rittenhouse & Sons Ltd.
RR 3, 1402 4th Avenue, St. Catharines, ON L2R 6P9
Tel: 905-684-8122; 1-800-461-1041, Fax: 905-684-1382
Contact: Toni Davies, Sales Manager
Webpage: www.rittenhouse.ca
Email: toni@rittenhouse.ca
Services: Supplier of mosquito control equipment, including sprayers and ULV equipment.

Viceroy Distributors Inc.
65 St. Anne's Road, Winnipeg, MB R2M 2Y4
Tel: 204-925-7939
Contact: Joel Gosselin
Email: viceroy@mts.net
Services: Supplier of mosquito control equipment (including ULV sprayers, flow control equipment, and backpack sprayers) and some insecticides.

Appendix D. Mosquito Control Consultants and Companies.

Several consultants and companies are actively involved in advising municipalities on mosquito control and/or carrying out mosquito control on a contract basis.

Christian Back, Director of Research and Development
 GDG Environnement Ltee.,
 375 Vachon, Cap-de-la-Madeleine, QC G8T 8P6
 Tel: 819-373-3097, Fax: 819-373-6832
 Email: christian.back@gdg.ca
 Services: Can advise on WNV, surveillance and control strategies, and program management.

Roy Ellis, Consultant
 Prairie Pest Management, PO Box 757, Carman, MB R0G 0J0
 Tel: 204-745-6200
 Email: royellis@mts.net
 Services: Consults on all aspects of integrated pest management, including the methods, materials, and equipment used in mosquito surveillance and control.

Randy Gadawski, Consultant
 Black Duck Consultants, Suite 1-277 Arbuthnot Street, Winnipeg, MB R3M 2P8
 Tel: 204-475-5633 or 204-223-1559
 Email: Rgadawski@shaw.ca
 Services: All services related to mosquito management.

Michael Jackson, Consultant
 Culex Environmental Ltd., 5337 Susan Way, Sunshine Coast, BC V0N 1Y2
 Tel: (604) 740-5895
 Email: m.jackson@acroloxus.com
 Services: Mosquito surveillance, species identification, mapping, control, and advisory services

Stephen A. Kells, Entomologist
 Abell Pest Control, Inc., 246 Attwell Drive, Etobicoke, ON M9W 5B4
 Tel: 416-675-3305 ext. 319
 Email: skells@abellgroup.com
 Services: Can advise on mosquito surveillance and control.

Dirk Lewis
 Morrow Engineering Ltd., North Vancouver, BC
 Tel: 604-986-1168, Fax: 604-986-9370
 Email: morrow@telus.net
 Web site: www.morrowengineering.com
 Services: Can advise on mosquito surveillance and control.

Gary Muldoon
 PCO Services Inc., 5840 Falbourne Street, Mississauga, ON L5R 4B5
 Tel: 905-502-9700, Fax: 905-502-9510
 Email: not available
 Web site: www.pco.ca/
 Services: Can advise on mosquito surveillance and control.

Damian Regan
D. G. Regan and Associates Ltd.
201-2605 Clarke Street, Port Moody, BC V3H 1Z4
Tel: 604-931-4565, Fax: 604-931-4563
Email: dgra@telus.net
Services: Can advise on mosquito surveillance and control.

Roger Savignac, Scientific Director
GDG Environnement Ltee.,
375 rue Vachon, Cap-de-la-Madeleine, QC G8T 8P6
Tel: 819-373-3097
Email : roger.savignac@gdg.ca
Services: Can advise on identification of mosquitoes and control operations.

Barry Tyler
Pestalto Environmental Products Inc., 400 Elizabeth St., Unit 1, Guelph, ON N1E 2Y1
Tel: 1-866-648-7773 toll-free, Fax: 519-837-4471
Webpage: <http://www.pestalto.com/>
Email: barry.tyler@pestalto.com
Services: Can advise on mosquito surveillance and control.

Reginald P. Webster
Self-employed Entomologist, 24 Millstream Drive, Charters Settlement, NB E3C 1X1
Tel: 506-459-3166
Email: rwebster@nb.sympatico.ca
Services: Conducting mosquito surveillance and identification of mosquitoes

Appendix E. Provincial Government Officials.

(See also the membership list of the Federal/Provincial/Territorial Committee on Pest Management and Pesticides at <http://www.hc-sc.gc.ca/pmra-arla/english/fpt/fpt-e.html>)

For information on applicator licensing, regulations, and permit requirements associated with vector control and on matters relating to WNV, contact your local provincial officials:

Philip Curry
West Nile Virus Coordinator
Saskatchewan Health, Population Health, 3475 Albert Street, Regina, SK S4S 6X6
Tel: 306-787-2807, Fax: 306-787-3112
E-mail: pcurry@health.gov.sk.ca

Geoff Cutten
Senior Pesticides Regulatory Scientist
Pesticides Section, Standards Development Branch, Ontario Ministry of the Environment, 40 St. Clair Ave.
West 7th floor, Toronto, ON M4V 1M2
Tel: 416-327-5174, Fax: 416-327-2936
Email: geoff.cutten@ene.gov.on.ca

Linda Gilkeson
Environmental Protection, Science, Planning, Analysis and Reporting Section, BC Ministry of Water, Land and Air Protection, PO Box 9335, Stn Prov Govt, Victoria BC V8W 9M1
Tel: 250-387-9410, Fax: 250-387-8894
Website: <http://www.env.gov.bc.ca>
Email: Linda.Gilkeson@gems3.gov.bc.ca

Scott Hartley
Insect/Vertebrate Pest Management Specialist,
Crop Development Branch, Saskatchewan Agriculture, Food & Rural Revitalization, Walter Scott Building,
125 - 3085 Albert Street, Regina, SK S4S 0B1
Tel: 306-787-4669, Fax: 306-787-0428
Email: shartley@agr.gov.sk.ca

Lester Hartling,
Entomologist,
New Brunswick Natural Resources, Forest Management Branch, P.O. Box 6000, Fredericton NB E3B 5H1
Tel: 506-453-2516
Email: Lester.Hartling@gnb.ca
Web Site: <http://www.gnb.ca/0078/index-e.asp>

Syed Jawid
Public Health Consultant,
West Nile Unit, Public Health Division, Ontario Ministry of Health and Long-Term Care, 5700 Yonge St.,
8th Floor, Toronto, ON M2M 4K5
Tel: 416-212-6393, Fax: 416-327-0984
E-mail: syed.jawid@moh.gov.on.ca

Rhona Kurtz
Manitoba Agriculture, Pesticide Licensing, Room 201 - 545 University Crescent, Winnipeg MB R3T 5S6
Tel: 204-945-7706, Fax: 204-945-4327
E-mail: RKurtz@gov.mb.ca
Website: <http://www.gov.mb.ca/agriculture/programs/aaa32s01.html>

Jock McIntosh
Pesticide Specialist,
Alberta Environment, Science and Standards Branch, 4th Flr., 9820 106 Street NW, Edmonton AB T5K 2J6
Tel: 780-427-0031, Fax: 780-422-5120
Email: jock.mcintosh@gov.ab.ca
Web Site: <http://www3.gov.ab.ca/env/protenf/pesticide/service/index.html>

Judy McLinton
Communications Planning Specialist,
Resources, Wildlife and Economic Development, Government of the Northwest Territories, P.O. Box 1320,
Yellowknife, NT X1A 2L9
Tel: 867-873-7379
Email: Judy_McLinton@gov.nt.ca

Jeffrey Ogden
Field Entomologist,
Integrated Pest Management, Nova Scotia Department of Natural Resources, P.O. Box 130 Shubenacadie,
N.S. B0N 2H0
Tel: 902-758 7015, Fax: 902-758 3210
Email: ogdenjb@gov.ns.ca

Joe Muldoon
Saskatchewan Environment, Environmental Protection, Rm. 224, 3211 Albert Street, Regina, SK S4S 5W6
Tel: 306-787-6178, Fax: 306-787-0197
Email: joe.muldoon.erm@govmail.gov.sk.ca

Ontario Ministry of Environment and Energy
(Pesticide Applicator/Operator Licensing)
Approvals Branch - Approvals & Client Services, 2 St. Clair Ave. W., 12A Floor, Toronto, ON M4V 1L5
Tel: 416-314-8292, Fax: 416-314-7271
Website: <http://www.ene.gov.on.ca>

Ken Plews
Pesticide/Fertilizer Approvals, Environmental Stewardship Branch, Manitoba Conservation, 123 Main
Street, Suite 160, Winnipeg, MB R3C 1A5
Tel: 204-945-7482, Fax: 204-945-1211
Email: kplews@gov.mb.ca
Website: <http://www.gov.mb.ca/environ>

PEI Agriculture & Forestry
Pesticide Regulatory Program, P.O. Box 306, Kensington, PE C0B 1M0
Tel: 902-836-8925, Fax: 902-836-8921
Email: dreeves@agric.gov.pe.ca
Website: <http://www.gov.pe.ca>

Quebec Ministère de l'Environnement
Direction régionale de Montréal, 5199, rue Sherbrooke Est, Bureau 3860, Montréal, PQ H1T 3X9
Tel: 514-873-3636, Fax: 514-873-5662
Email : dr06@menv.gouv.qc.ca

Brad Skinner, Amherst District Manager
Nova Scotia Department of Environment and Labour, 32 Church Street, Amherst, NS B4H 4A8
Tel: 902-667-6205, Fax: 902-667-6214
Email: skinnebl@gov.ns.ca

Kathy Stapleton
Pesticide Management Unit, New Brunswick Department of Environment and Local Government, P.O. Box
6000, Fredericton, NB E3B 5H1
Tel: 506-453-7945, 1-800-561-4036, Fax: 506-453-2390
E-mail: pesticides@gnb.ca

Appendix F. Federal Government Officials.

Federal officials can advise on legislation, regulations, issues, and policies associated with mosquito vector control and/or WNV.

Peter Buck

Foodborne, Waterborne and Zoonotic Infections Division, Centre for Infectious Disease Prevention and Control, Population and Public Health Branch, Health Canada, PL 0603E1, 2nd Floor, Bldg. 6, Tunney's Pasture, Ottawa, ON K1A 0L2

Tel: 613-954-9729, Fax: 613-946-0798

Email: Peter_Buck@hc-sc.gc.ca

Web Site: <http://www.hc-sc.gc.ca/pphb-dgspsp/wnv-vwn/index.html>

Pierre-Yves Caux

Chief, Science Programs Coordination Division, Conservation Priorities Branch, Conservation Strategies Directorate, Environmental Conservation Service, Environment Canada, 351 St-Joseph Blvd., Gatineau Hull, QC, K1A 0H3

Tel: 819-953-0602, Fax: 819-953-0461

Email: pierre-yves.caux@ec.gc.ca

Rob Kent

Manager, Water Quality Monitoring Branch, National Water Research Institute, 351 boul St-Joseph, 8e étage, Gatineau PQ K1A 0H3

Tel: 819-953-1554, Fax: 819-953-0461

Email: Robert.Kent@ec.gc.ca

Website: <http://www.nwri.ca>

Robbin Lindsay

Zoonotic Diseases and Special Pathogens, National Microbiology Laboratory, Health Canada, Rm 4770, 1015 Arlington Street, Winnipeg, MB R3E 3R2

Tel: 204-789-6060, Fax: 204-789-2082,

Email: Robbin_Lindsay@hc-sc.gc.ca

PMRA's Pest Management Information Service

Health Canada, 4th Floor, Tupper Building, 2720 Riverside Drive, Ottawa, ON K1A 0K9

Tel: 1-800-267-6315

Steve Samis

A/Sr. Advisor, Regulatory Affairs (National), Habitat Management, Fisheries and Oceans Canada, 401 Burrard Street, Vancouver, BC V6C3S4

Tel: 604-666-8171, Fax: 604-666-0417

Email: samisst@pac.dfo-mpo.gc.ca

Web Site: http://www.dfo-mpo.gc.ca/canwaters-eauxcan/habitat/index_e.asp

Steve Schofield

Senior Advisor Pest Management/Entomology, Communicable Disease Control Program, Force Health Protection, Director General Health Services, Department of National Defence, 1745 Alta Vista Drive, Ottawa, ON K1A 0K6

Tel: 613-945-8062 ext. 3185

Email: schofield.sw@forces.gc.ca

Appendix G. University Researchers involved in Mosquito Vector Biology and Control.

Robert Anderson
 Biology Department, University of Winnipeg, 515 Portage Avenue, Winnipeg, MB R3B 2E9
 Tel: 204-786-9296, Cell: 204 791-3568, Fax: 204-774-4134
 Email: r.anderson@uwinnipeg.ca

Jacques Boisvert, Professeur
 Département de chimie-biologie, Université du Québec à Trois-Rivières, 3351 boul. des Forges,
 Trois-Rivières, QC G9A 5H7
 Tel: 819-376-5011 ext 3372
 Email address: jacques_boisvert@uqtr.ca

Jean-Pierre Bourassa
 Département de chimie-biologie, Université du Québec à Trois-Rivières, 3351 boul. des Forges,
 Trois-Rivières, QC G9A5H7
 Tel: 819-376-5053 ext 3361, Fax: 819-376 5084
 Email: jean-pierre_bourassa@uqtr.quebec.ca

Murray Colbo
 Department of Biology, Memorial University, St. John's NF A1B 3X9
 Tel: 709-737-8004, Fax: 709-737-3018
 Email: mcolbo@mun.ca

Terry Galloway
 Department of Entomology, University of Manitoba, 214 Animal Sciences Bldg., Winnipeg, MB R3T 2N2
 Tel: 204-474-6024, Fax: 204-474-7628
 Email: Terry_Galloway@umanitoba.ca

Fiona Hunter
 Department of Biological Sciences, Brock University, 500 Glenridge Ave., St. Catharines, ON L2S 3A1
 Tel: 905-688-5550 ext. 3394, Fax: 905-688-1855
 Email: hunterf@spartan.ac.Brocku.ca

David Lewis
 Macdonald Campus, McGill University, Nat. Res. Sci., Ste. Anne-de-Bellevue, QC H9X 3V9
 Tel: 514-398-7909, Fax: 514-398-7990
 Email: lewisd@nrs.mcgill.ca

Carl Lowenberger
 Dept. of Biological Sciences, Simon Fraser University, 8888 University Drive, Burnaby BC V5A 1S6
 Tel: 604-291-3985 (office)/604-291-4391 (lab), Fax: 604-291-3496
 Email: clowenbe@sfu.ca

Gord Surgeoner,
 President, Ontario AgriFood Technologies, 1 Stone Road, Guelph, ON N1G 4Y2
 Tel: 519-826-4195, Fax: 519-826-3389
 Email: oaft@sentex.net

Appendix H. Municipal Mosquito Control Workers.

In Canada, there are a number of people with expertise in mosquito biology and control, working in established mosquito control organizations, who can provide advice on mosquito control methods, materials and equipment.

Jeffrey Balone, Foreman, Pest Management
 City of Saskatoon Infrastructure Services Department
 1101 Ave. P North, Saskatoon, SK Canada S5L 7K6
 Tel: 306-975-2766
 Email: jeffrey.balone@city.saskatoon.sk.ca

Bill Boieieie
 City of Port Coquitlam, 2580 Shaughnessy Street
 Port Coquitlam, BC V3C 2A8
 Tel 604-944-5447, Fax 604-944-5448
 Email: wboieieie@hotmail.co

Wade Morrow
 Supervisor, Integrated Pest Management,
 Community Services Department, City of Regina, PO Box 1790
 Regina, SK S4P 3C8
 Tel: 306-777-7731
 Email: wmorrow@regina.ca

Chris Saunders
 Biological Sciences Technician,
 River Valley, Forestry & Environmental Services
 Edmonton Community Services, Pest Management Services
 P.O. Box 2359, Edmonton, AB T5J 2R7
 Tel: 780-496-6395, Fax: 780-496-4978
 E mail: chris.saunders@edmonton.ca
 Web site: www.gov.edmonton.ab.ca/parksnpests

Appendix I. Some Useful Links relating to WNV and Vector Control.

General information on West Nile Virus

<http://www.hc-sc.gc.ca/english/westnile/index.html>
<http://www.hc-sc.gc.ca/pphb-dgspsp/wnv-vwn/index.html>
<http://environmentalrisk.cornell.edu/WNV>

Provincial and Territorial Links <http://www.hc-sc.gc.ca/english/westnile/links.html>

US CDC Web Site http://www.cdc.gov/ncidod/dvbid/westnile/site_index.htm

Reporting Dead Birds

Canadian Cooperative Wildlife Health Centre Web site
<http://wildlife.usask.ca/WestNileAlertHTML/WestNileAlertProvinceContact.htm>

Information on Personal Insect Repellents including DEET

Health Canada <http://www.hc-sc.gc.ca/pmra-arla/english/mosquito/mosquito-e.html>

Larvicides -Bti

Health Canada <http://www.hc-sc.gc.ca/pmra-arla/english/mosquito/mosquito-e.html>

Larvicides – Methoprene

Health Canada <http://www.hc-sc.gc.ca/pmra-arla/english/mosquito/mosquito-e.html>

Larvicides – Chlorpyrifos

Health Canada <http://www.hc-sc.gc.ca/pmra-arla/english/mosquito/mosquito-e.html>

Adulticides – Malathion

Health Canada <http://www.hc-sc.gc.ca/pmra-arla/english/mosquito/mosquito-e.html>

Homeowner Control of Mosquitoes

Health Canada - Effective Control of Mosquitoes around your Home
<http://www.hc-sc.gc.ca/pmra-arla/english/pdf/pnotes/mosquitos-e.pdf>

Mosquito - General Information

American Mosquito control association: <http://www.mosquito.org>

Mosquito-related Lists

Mosquito-L, maintained by the University of Iowa <http://www.ent.iastate.edu/maillinglist/mosquito-L/>
<http://www-rci.rutgers.edu/~insects/njmos.htm>

Mosquito identification

University of Florida Medical Entomology Laboratory <http://mosquito.ifas.ufl.edu/>

Appendix J. Technical Reports and Publications.

There are hundreds of thousands of technical publications on mosquito biology and control. A few key publications are listed below. A municipality that is just beginning to develop a mosquito control program is advised to obtain a copy of the publications marked with an asterisk (*) below.

Akesson, N.B., and W.E. Yates, 1982. The use of aircraft for mosquito control. AMCA Bull. 1:1-96.

Anonymous, 1974. Equipment for vector control. WHO Manual, Geneva, Switzerland. 179 p.

Anonymous, 1977. Guidelines for municipal mosquito abatement programs. Ont. Ministry Envir., Facts About Pesticides 20-02-15. 7 p.

Anonymous, 1990. Equipment for vector control. World Health Organization, Geneva. 310 p.

Artsob, H., and L. Spence, 1979. Arboviruses in Canada. p. 39-65 In Kurstak, E. (Ed.). Arctic and tropical arboviruses. Academic Press.

Artsob, H., L. Spence, and C. Th'ng, 1979. Horses as monitors for arboviral activity in southern Ontario. p. 233-243 In M.S. Mahdy, L. Spence, and J.M. Joshua (Eds.). Arboviral Encephalitides in Ontario With Special Reference to St. Louis Encephalitis. Ontario Ministry of Health.

Becker, N., and J. Margalit. 1993. Use of *Bacillus thuringiensis israelensis* against mosquitoes and blackflies. In: *Bacillus thuringiensis*, an environmental biopesticide: theory and practice. Wiley, New York. pp. 147-170.

Berry, R.A., and K.W. Ludlam, 1976. Field evaluations of ULV applications to control adult mosquitoes in Maryland. Proc. NJ Mosquito Exterm. Assoc., p. 194-196.

Brust, R.A., and R.A. Ellis, 1976b. Assessment of the emergency mosquito control operation in Manitoba, 1975. Can. J. Publ. Hlth. 67 (Suppl.):69-71.

Brust, R.A., and R.A. Ellis, 1976a. Mosquito surveys in Manitoba during 1975. Can. J. Publ. Hlth. 67 (Suppl.):47-53.

Brust, R.A, 1982. Population dynamics of *Culex tarsalis* Coquillett in Manitoba. In Sekla, L. (Ed.), 1982. Western Equine Encephalitis in Manitoba. Manitoba Health Services Commission. p. 21-30.

Brust, R.A, 1984. Mosquito Control Evaluations. In Final Technical Report Volume Environmental Monitoring Program for the 1983 Aerial Spraying of Malathion to Combat Western Equine Encephalitis. Manitoba Environment, Workplace Safety and Health. p. 189-225.

Brust, R.A., R.A. Ellis, and K.W. Plews, 1976. Guidelines for mosquito control in Manitoba. Manitoba Mines, Resources, and Environmental Management, 19 p.

Buth, J.L, 1983. The bionomics of three potential vectors of Western Equine Encephalitis in Manitoba. M.Sc. Thesis, University of Manitoba. 112 p.

CDC, 1979. Mosquitoes of public health importance and their control. USHEW/CDC, Atlanta.

Chapman, H.C. (Ed.), 1985. Biological control of mosquitoes. Bull. Amer. Mosquito Control Assoc. 6.

Chippis, S.R., D.E. Hubbard, K.B. Werlin, N.J. Haugerud, and K.A. Powell, 2002. Development and application of biomonitoring indicators for floodplain wetlands of the Upper Missouri River Basin, North Dakota. Final report to the U.S. EPA. Region 8. USGS South Dakota Cooperative Fish and Wildlife Research Unit, South Dakota State University, Brookings, SD

Clarke, J.L, 1943. Studies of the flight range of mosquitoes. J. Econ. Ent. 36:121-122.

Copps, P.T., G.A. Surgeoner, and B.V. Helson, 1984. An assessment of sampling techniques for adult mosquitoes in southern Ontario. Proc. Ent. Soc. Ont. 115:61-70.

Darsie, R.F., and R.A. Ward, 1981. Identification and geographical distribution of the mosquitoes of North America, north of Mexico. Amer. Mosquito Control Assoc., Fresno. 313 p.

Donogh, N.R, 1976. Public information on Western Encephalomyelitis and emergency mosquito control in Manitoba, 1975. Can. J. Publ. Hlth. 67 (Suppl. 1):61-62.

Eldridge, B.F, 1987b. Strategies for vector surveillance, prevention, and control of arboviruses in western North America. Am. J. Trop. Med. Hyg. 37 (suppl.):77-86.

Ellis, R.A, 1982. Emergency mosquito vector control in Manitoba. Part 1. Aerial ULV application of insecticide for large area vector control. Prairie Pest Management. 188 p.

Ellis, R.A., and R.A. Brust, 1982. Effectiveness of the emergency mosquito vector control operations. In Sekla, L. (Ed.), 1982. Western Equine Encephalitis in Manitoba. Manitoba Health Sciences Commission. p. 209-222.

Ellis, R.A, 1976. Emergency measures and mosquito control operations during the 1975 Western encephalomyelitis outbreak in Manitoba. Can. J. Publ. Hlth. 67(Suppl.):59-60.

Ellis, R.A., 1976. Emergency measures and mosquito control operations during the 1975 western encephalomyelitis outbreak in Manitoba. Can. J. Public Hlth 67(Suppl.):59-60.

*Gray, H.F., 1961. Organization for mosquito control. Amer. Mosquito Control Assoc. Bull. 4.

Harwood, R.F., and M.T. James, 1979. Entomology in human and animal health. Macmillan, New York. 548 p.

Helson, B.V., G.A. Surgeoner, R.E. Wright, and S.A. Allen, 1978. *Culex tarsalis*, *Aedes sollicitans*, *Aedes grossbecki*: new distribution records from southwestern Ontario. Mosquito News 38:137-138.

Helson, B.V., G.A. Surgeoner, and R.E. Wright, 1979. Mosquitoes of southwestern Ontario, their seasonal distribution, prevalence and new records. In Mahdy, M.S., L. Spence, and J.M. Joshua, (Eds.). Arboviral Encephalitides in Ontario With Special Reference to St. Louis Encephalitis. Ontario Ministry of Health. p. 181-198.

Kent, R.A. 2003. West Nile Virus in Canada - Environmental Issues and Considerations: A Case Study on Wildlife-Related Diseases. Environment Canada, Gatineau Quebec Canada.

Kettle, D.S., 1984. Medical and veterinary entomology. John Wiley and Sons, New York. 658 p.

Lacey, L. A., and R.W. Merritt. 2004. The safety of bacterial microbial agents used for blackfly and mosquito control in aquatic environments. Kluwer Academic Press (date of publication: June 30, 2004).

- Lofgren, C.S., 1972. Ultralow volume application of insecticides. *Amer. J. Trop. Med. Hyg.* 21:819-824.
- *Lofgren, C.S., 1970. Ultralow volume applications of concentrated insecticides in medical and veterinary entomology. *Annu. Rev. Ent.* 15:321-342.
- *Lowe, R.J., 1977. Starting a mosquito control program. *Mosquito News* 37(1):141-142.
- MacKenzie, D.L., 1979. Mosquito control in Ontario prior to, during and following the St. Louis encephalitis outbreak. In Mahdy, M.S., L. Spence, and J.M. Joshua (Eds.). *Arboviral Encephalitides in Ontario With Special Reference to St. Louis Encephalitis*. Ontario Ministry of Health. p. 282-332.
- Madder, D.J., G.A. Surgeoner, and B.V. Helson, 1983b. Number of generations, egg production, and developmental time of *Culex pipiens* and *Culex restuans* (Diptera: Culicidae) in southern Ontario. *J. Med. Ent.* 20:275-287.
- Madder, D.J., R.S. MacDonald, G.A. Surgeoner, and B.V. Helson, 1980. The use of oviposition activity to monitor populations of *Culex pipiens* and *Culex restuans* (Diptera: Culicidae). *Can. Ent.* 112:1013-1017.
- *Magu, M.R., 1981. A survey of the administration, organization and operation of American mosquito control agencies. *Mosquito News* 41(1):13-17.
- Mahdy, M.S., L. Spence, and J.M. Joshua (Eds.), 1979. *Arboviral Encephalitides in Ontario With Special Reference to St. Louis Encephalitis*. In The Committee on Programs for the Prevention of Mosquito-borne Encephalitis. Ontario Ministry of Health. xiii + 364 p.
- McCracken, I.R., and S.L. Mathews. 1997. Effect of *Bacillus thuringiensis* subsp. *israelensis* applications on invertebrates from two streams on Prince Edward Island. *Environ. Contamin. Toxicol.* 58: 291-298.
- McLean, D.M., 1975. Arboviruses and human health in Canada. Associate Committee on Scientific Criteria for Environmental Quality. National Research Council of Canada, No. 14106. p. 1-35.
- McLintock, J., and J. Iversen, 1975. Mosquitoes and human disease in Canada. *Can. Ent.* 107:695-704.
- McLintock, J., 1978. Mosquito-virus relationships of American encephalitides. *Ann. Rev. Ent.* 23:17-37.
- McLintock, J., 1976. The arbovirus problem in Canada. *Can. J. Publ. Hlth. (Suppl. 1)*:8-12.
- Merritt, R.W. 1989. A broad evaluation of B.t.i for black fly (Diptera: Simuliidae) control in a Michigan river: efficacy, carry and nontarget effects on invertebrates and fish. *J. Am. Mos. Contr. Ass.* 5: 397-415.
- Monath, T.P., 1979. Arthropod-borne encephalitis in the Americas. *Bull. W.H.O.* 57:513-533.
- Monath, T.P. (Ed.), 1980. *St. Louis Encephalitis*. Amer. Public Health Assoc., Washington, D.C., 680 p.
- Monath, T.P., 1984. Ecology and control of mosquito-borne arbovirus disease. In Kurstak, E., and R.G. Marusyk (Eds.), 1984. *Control of Virus Diseases*. Marcel Dekker, Inc., New York. p. 115-134.
- Mount, G.A., 1979. Ultra-low volume application of insecticides: a guide for vector control programs. WHO/VBC/79.734.
- Ofiara, D.D., and J.R. Allison, 1986. A comparison of alternative mosquito abatement methods using benefit-cost analysis. *J. Amer. Mosquito Control Assoc.* 2(4):522-528.

- *Ofiara, D.D., and J.R. Allison, 1986. On assessing the benefits of public mosquito control practices. J. Amer. Mosquito Control Assoc. 2:280-288.
- Pal, R., and R.H. Wharton (Eds.), 1974. Control of arthropods of medical and veterinary importance. Plenum, New York. 138 p.
- Panetta, J. (Ed.), 1980. DEET pesticide registration standard. U.S. EPA, Office of Pesticides and Toxic Substances, 136 p.
- Raddatz, R.L., 1985. A biometeorological model of an encephalitis vector. Boundary Layer Meteorol. 34:185-199.
- Raddatz, R.L., 1982. Forecasts of *Culex tarsalis* populations in Winnipeg. In Sekla, L. (Ed.) Western Equine Encephalitis in Manitoba. Manitoba Health Services Commission. 296 p.
- Rathburn, C.B., A.H. Boike, C.F. Hallmon, and R.L. Welles, 1981. Field tests of insecticides applied as ULV sprays by ground equipment for the control of adult mosquitoes. Mosquito News 41(1):132-135.
- Reeves, W.C., 1974. Overwintering of arboviruses. Progr. Med. Virol. 17:193-220.
- Reeves, W.C., 1965. Ecology of mosquitoes in relation to arboviruses. Ann. Rev. Ent. 10:25-46.
- *Sekla, L.H. (Ed.), 1976. Special Supplement - Western Encephalitis. Can. J. Publ. Hlth 67 (Suppl.). 75 p.
- Sekla, L. (Ed.), 1982. Western equine encephalitis in Manitoba. Manitoba Health Services Commission. 296 p.
- Sekla, L., and W. Stackiw, 1982. Arbovirus isolations from mosquitoes in Manitoba: value in decision making. In Sekla, L. (Ed.). Western Equine Encephalitis in Manitoba, Manitoba Health Services Commission. p. 50-60.
- *Service, M.W., 1976. Mosquito ecology - field sampling methods. John Wiley and Sons. New York, Toronto. xii + 583 p.
- Service, M.W., 1983. Biological control of mosquitoes - has it a future? Mosquito News 43(2):113-120.
- Sinegre, G., B. Gaven, and J.L. Jullien, 1979. Safety of *Bacillus thuringiensis* serotype H-14 for non-target organisms in mosquito breeding sites of the French Mediterranean coast. WHO/VBC/79.742, 5 p.
- Smith, A., 1982. Chemical methods for the control of vectors and pests of public health importance. WHO/VBC/82.841, 69 p.
- Stelman, C.D., J.M. Gassie, and B.R. Craven, 1967. Laboratory and field studies on mosquito control in waste disposal lagoons in Louisiana. Mosquito News 27(1):57-59.
- Steickman, D., 1979. Malathion as ground-applied ULV evaluated against natural populations of *Culex pipiens* and *Cx. restuans*. Mosquito News 39:64-67.
- Surgeoner, G.A., and B.V. Helson, 1978. An oviposition trap for arbovirus surveillance in *Culex* species mosquitoes (Diptera: Culicidae). Can. Ent. 110: 1049-1052.
- Trimble, R.M., 1972. Occurrence of *Culiseta minnesotae* and *Aedes trivittatus* (Diptera: Culicidae) in Manitoba, including a list of mosquitoes from Manitoba. Can. Ent. 104:1535-1537.

Wada, Y., 1965. Population studies on Edmonton mosquitoes. *Quaestiones ent.* 1:187-222.

West, A.S., and A. Hudson, 1960. Notes on mosquitoes of eastern Ontario. *Proc. NJ Mosquito Exterm. Assoc.* 47:68-74.

Wong, F., and J. Neufeld, 1982. Sentinel flock monitoring procedures for Western Equine Encephalitis in Manitoba, 1976-1981. In Sekla, L. (Ed.), 1982. *Western Equine Encephalitis in Manitoba*, Manitoba Health Services Commission. p. 86-97.

Wood, D.M., 1977. Notes on the identities of some common nearctic *Aedes* mosquitoes (Diptera, Culicidae). *Mosquito News* 37:71-81.

*Wood, D.M., P.T. Dang, and R.A. Ellis, 1979. The insects and arachnids of Canada, Part 6. The Mosquitoes of Canada (Diptera: Culicidae). Canadian Government Publishing Centre, Supply and Services Canada, Hull, Quebec. 390 p.

Appendix K. Glossary of Technical Terms.

Active Ingredient — The component of a pest control product to which the insecticidal effects are attributed (listed under the "Guarantee" statement on the label of a registered pest control product)

Adulticide — Pesticides used to control insects at the adult stage of their development. In mosquito control, any insecticide used to kill adult mosquitoes.

Adulticiding - The application of chemicals to kill adult mosquitoes by ground or aerial applications. Nevertheless, adulticiding, based on surveillance data, is an extremely important part of any IPM program. Adulticides are typically applied as an Ultra-Low-Volume (ULV) spray where small amounts of insecticide are dispersed either by truck-mounted equipment or from fixed-wing or rotary aircraft. Ground or aerial applied thermal application of adulticides is also used in some areas but to a much lesser degree. Mosquito ULV adulticiding differs fundamentally from efforts to control many other adult insects. For good adult mosquito control, the fine ULV droplets must drift through the habitat and impinge on flying mosquitoes for effective control.

Application Rate — The average volume or weight of either the end-use product or the field formulation (including both end-use product and diluent), depending on how the application rate is expressed on the label which is applied per unit of area or volume treated.

Arbovirus — Arthropod-borne virus. 'Arboviruses' are a large group (more than 400) of enveloped RNA viruses which are transmitted primarily (but not exclusively) by arthropod vectors (mosquitoes, sand-flies, fleas, ticks, lice, etc). They were previously grouped together under the name 'arboviruses' but "arbovirus" is not a taxonomic classification. This grouping has now been split into four virus families.

Arthropod — Invertebrate animals in the phylum Arthropoda, a group that has a segmented body, jointed appendages, a usually chitinous exoskeleton molted at intervals, and a dorsal anterior brain connected to a ventral chain of ganglia. Includes insects, arachnids, and crustaceans.

Blood-feeding — Some arthropods take blood, a behaviour known as 'blood-feeding'. The blood that they ingest is known as a 'blood-meal'. They use the protein in the blood-meal to mature their eggs. Some biting arthropods also require a sugar source to meet their energy requirements for mating, locating their hosts, and egg laying.

Breeding sites — Technically, any body of water that contains or produces mosquitoes (in one of the aquatic stages). Mosquito breeding sites have been precisely defined in the laws and regulations and in the scientific literature and some workers prefer the term "mosquito source" as it is more descriptive.

Concentrate — A form of commercially available end-use pesticide formulation which requires further dilution before it is applied in the field.

DEET — DEET (chemical name = N,N-diethyl-meta-toluamide) is the active ingredient in many insect repellent products.

Diapause — A period of suspended development or growth, characterized by inactivity and decreased metabolism.

Disease — 'Lack of ease' or the condition of "ill health". Departure from the state of health or normality. A condition in which bodily health is impaired; sickness; illness; a malady; an ailment; a condition which adversely affects survival. An archaic form, "dis-ease", means discomfort.

Ecology — The interrelationships of living organisms to one another and to their environment, or the study of science of such interrelationships.

Ecosystem — A unit of biological organization made up of all the organisms in a given area (community) interacting with the physical environment and with each other; an ecological system.

Encephalitis — An inflammation of the brain that can be caused by viruses and bacteria, including viruses transmitted by mosquitoes.

Endemic (adjective) — Belonging or native to a particular people or country and thus continuously present at the expected frequency of occurrence; restricted or peculiar to a locality or region (endemic diseases; an endemic species). Synonym=Native.

Entomology — The science that deals with insects.

Enzootic — Referring to animal diseases that are peculiar to or constantly present in a locality.

Epidemic (adjective) — Affecting or tending to affect a disproportionately large number of individuals within a population, community or region at the same time; i.e., at a higher than expected frequency. Used to refer to diseases that are not consistently present in an area, and which are brought in from the outside or a temporary increase in the number of cases of an endemic disease.

Formulation — A pest control product comprised of a mixture of one or more active ingredients plus other materials needed to make the formulation easy to store, dilute, and apply. Properties of spray formulations can affect effectiveness of pesticides (toxicity and residual life). Insecticide mixture as produced and delivered by the manufacturer is a formulation. If dilution is required, once the formulation is diluted with oil or water for spraying, it is referred to as the tank mix. Examples of formulations are solutions, emulsions, granules, and wettable powders.

Habitat — The natural region or abode which an organism inhabits. The term as applied to particular surroundings may be made more specific or critical by adding qualifying expressions (e.g., sand dune habitat, flood plain habitat, and rock pool habitat). The place where the organism lives; "address". Habitat is not equivalent to niche.

Host — This term has several different meanings that can include: 1) individuals fed upon by mosquitoes (i.e., the host for the blood-meal); 2) Dead-end (or incidental) host are (usually) vertebrates that may harbour the pathogen being considered, may even be severely affected by it, yet the level of the pathogen in the blood or peripheral tissues may be too low for a blood-sucking arthropod to become infective after feeding on this host and; 3) an amplifying host is one in which the level of the pathogen is high enough that a feeding vector will likely become infectious (capable of transmitting the pathogen after a suitable incubation period). For WNV specifically, examples of dead-end hosts are horses and people while amplifying hosts would include many different species of birds. All of which often serve as hosts for blood-feeding adult mosquitoes.

Instar — The form assumed by insects between larval moults. Mosquitoes develop through four larval instars. The first is formed when the larva hatches from the egg, the second follows the first moult, the third larval instar follows the second moult, and the fourth instar occurs prior to and ceases to exist when the pupa is formed.

Integrated (Mosquito) Pest Management — Mosquito control programs that integrate a variety of different strategies to suppress or destroy mosquitoes. The principle activities undertaken in an IPM program for mosquito control include: surveillance and environmental monitoring, source reduction and other forms of

water management, the use of biological control agents, larvicides and adulticides, and education of the public.

Larva (plural = larvae) — The immature stages between the egg and the pupa, of an insect with complete metamorphosis. The form of the insect during the larval stage differs radically from the adult.

Larvicide — Pest control products that are used to destroy or kill mosquito larvae.

Larviciding — A general term for the process of applying larvicides to aquatic habitats containing mosquito larvae. Larvicide treatments can be applied from either the ground or air.

Mosquito Abatement or Control — Refers to the programmed efforts of local mosquito abatement or control districts or other agencies to eliminate the sources or to suppress the population of the target mosquitoes to a level which can be tolerated.

Multivoltine (adjective) — Having several broods or generations in a season, as in "multivoltine species of mosquito".

Overwintering — A period of rest or hibernation by which mosquitoes survive the winter.

Pathogen — Any organism that causes disease (e.g., WNV). The most common arthropod-transmitted pathogens are protozoa, helminthes, bacteria, and viruses.

Pest — Any organism (usually a plant or animal species) that is considered unacceptably abundant.

Pupa (plural = pupae) — The immature stage, between the larva and adult, of an insect with complete metamorphosis.

Reservoir — this term is applied to maintenance infections, that is, to any animal system, whether vector or vertebrate, capable of maintaining a pathogen for considerable periods of time. Such a system may involve vertebrates that show no evidence of serious disease (e.g., many species of birds in the case of WNV) or a reservoir of infection may be maintained by continuous transmission among a group of severely infected animals (e.g., most members of the Corvidae family acts as reservoirs for WNV and suffer high rates of mortality because of infection).

Source Reduction — The elimination of larval mosquito breeding sites; ranges from removing containers that collect water and simple drainage, using pumps or creating ditches, to actual filling of the site.

Ultra-low-Volume (ULV) — The application of a pesticide, usually a more concentrated formulation, by spraying relatively small amounts over a large area (usually less than 1 litre of product per hectare). A method of insecticide distribution in which a small portion of the compound is fragmented into extremely fine droplets for aerial dispersal.

Vector — Any organism that is capable of transmitting a disease-causing agent or pathogen from one animal to another. An organism, as an insect, that transmits pathogens to plants or animals.

Virus — A non-cellular infectious organism that can only reproduce within living cells.

Viremia — The presence of virus in the blood or peripheral tissues of a host.

Zoonoses — Diseases of animals transmissible to humans. An arthropod vector may (e.g., WNV) or may not (e.g., rabies) be required for zoonotic disease-causing agents to be transmitted from animals to people.