Municipal Mosquito Control Guidelines

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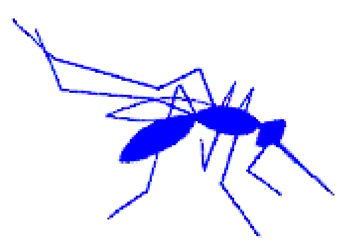

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1. Mosquito Vector Biology

1.1 Nuisance Mosquitoes and Disease Vectors

Mosquitoes are important insect pests from both a nuisance and a health point-of-view. Although Canada may be fortunate in having relatively few mosquito-borne diseases, there remain the risk of several mosquito-borne encephalitides viruses and various mechanically-transmitted pathogens.

As a nuisance insect, mosquitoes have few rivals across southern Canada. Most people do not think about a mosquito control 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 control requires considerable lead-time. Besides a provincial pesticide use permit, the program requires, at the very least, trained staff, mosquito survey maps and tools, vehicles, spray equipment, and insecticides. These requirements are all cost considerations that require advance budgeting, purchasing, and hiring or contracting.

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 eggs 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 'wrigglers' because of 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 are shaped like commas. Some people think they 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, usually within 3 to 5 days after the adults emerge. Females are attracted to the mating swarm and are quickly fertilized. Females mate once and remain fertile for life.

1.2.1 Typical Larval Mosquito Habitats

The typical habitat for mosquito larvae is a snow-melt pool or a summer rain pool. Pools that are created by melting snow in the spring or by heavy rains during the summer produce most of our pest 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:

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

1.2.2 Seasonal Occurrence of Larval and Adult Mosquitoes

Larvae of spring floodwater mosquitoes hatch from the eggs in pools of water formed by melted snow in the woods. The eggs occur in the leaf litter at the bottom of 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 woods where they will be flooded by melting snow the following year. Spring floodwater 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 pest mosquitoes (e.g., *Aedes vexans*). The larvae hatch from eggs after rainfall in the summer (usually 2.5 cm 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 snowmelt 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 during the adult stage favour mating between the sexes and host seeking by the blood-feeding adult females.

Temperature and relative humidity have a major influence on adult mosquito populations. High temperatures, associated with low relative humidities, 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 affect on populations. Low winds facilitate swarming by the males and mating of the sexes. They also facilitate the adult female's search for blood. High winds, on the other hand, generally have the opposite effects although they 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.

1.2.3 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 site, oviposition site, or blood-meal source(s).

The adults of most species are active during periods of twilight, which is when winds are relatively low, temperatures are moderate, and relative humidities are high. In shady areas, mosquitoes may be active throughout the day. Like male mosquitoes, the female mosquitoes feed on nectar from flowers, aphid honeydew (i.e., sugar solution produced by aphids), and sap leaking from broken twigs to obtain the carbohydrates that they require for their energy.

Unfortunately for humans and other hosts, the adult females of most mosquito species require a blood meal. 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 some mosquito species feed on reptiles and amphibians.

1.2.4 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.
- In culverts, under bridges, above catch-basins.
- Inside buildings (e.g., houses, livestock barns, poultry houses, outhouses).
- Under piles of firewood, lumber, or other materials.

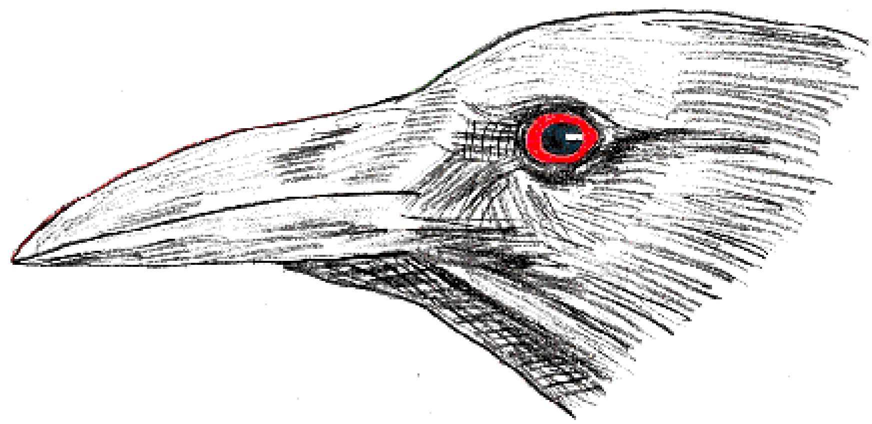
2. Transmission of viruses by mosquitoes in North America

Mosquito control programs are typically instituted in areas where local mosquito populations consistently represent a significant annoyance or potential public health threat or both. The objective of this section is to provide basic information on how viruses, specifically West Nile virus (WNV), are transmitted between mosquitoes and other host (i.e., humans) or reservoir animals (i.e., birds). Although the vectors, hosts and reservoir species involved in transmission cycle of the different mosquito-borne viruses vary, the objectives and approaches used to minimize human or animal infection through mosquito control programs are similar. However, it should be remembered that control programs designed to suppress the numbers of nuisance mosquitoes may differ significantly from ones aimed at reducing the abundance of disease-carrying mosquito populations.

2.1 West Nile virus Transmission Cycle

West Nile virus is spread to humans by the bite of an infected mosquito and can cause encephalitis (inflammation of the brain) or meningitis (inflammation of the lining of the brain and spinal cord). West Nile encephalitis (WNE) has been documented in parts of Africa, West Asia, and the Middle East and WNV has been in northeastern USA since, at least, 1999. West Nile virus is closely related to the viruses that cause St. Louis Encephalitis (SLE) and Western Equine Encephalitis (WEE). Outbreaks of WEE (in humans and horses) in Manitoba and Saskatchewan and SLE (in humans) in Ontario have occurred in the past.

Wild birds are the principal reservoirs of mosquito-borne encephalitis viruses. Mosquitoes feed on infected birds, picking up the virus with the blood meal.



The virus may circulate in the blood of the mosquito for a few days. After laying their eggs, the infected mosquitoes may then transmit the virus to other birds (at least 70 species; mainly corvids, such as crows and blue jays), mammals (e.g., horses, cats, bats, chipmunks, skunks, squirrels, and domestic rabbits), and humans when they take their next blood meal. Some newly infected hosts (e.g., American crows) may become ill and/or die as result of an infection.

The virus is located in the mosquito's salivary glands. During blood feeding, the virus may be injected into the new host animal where it may multiply, possibly causing illness. Some of these newly infected hosts may allow the buildup or amplification of the virus in their blood with or without showing any signs of illness. WNV is not transmitted from one person to another or from birds directly to people. Birds may serve to spread the virus from one geographical area to another. One of the keys to the prevention of WNE or other infections caused by arboviruses is the suppression of vector mosquito populations.

2.2 Probable Mosquito Vectors

Thirteen species of mosquitoes have been identified as possible vectors of WNV in northeastern USA. The distribution of these 13 species across southern Canada has been summarized in the table below. In addition, two other potential vectors of WNV have been added. These two species do not occur within the present range of WNV but will likely be competent vectors of this virus, based on their efficiency in transmitting other viruses in Canada. Although it has been well established that *Culex* species are primarily responsible for transmission of WNV to birds, the specific role that the other mosquito species will play in the transmission of WNV to humans has not been clearly defined. The mere presence of probable WNV vectors in a province does not mean that WNV activity or outbreaks of WNE in humans are imminent.

Mosquito Species	Species Present

	MB	ON	QC	NB	NS	PEI
Culex pipiens	-	+	+	+	-	-
Culex restuans	+	+	+	+	+	-
Culex salinarius	-	-	-	-	-	-
Culiseta melanura	-	+	+	-	-	-
Ochlerotatus japonicus	-	-	-	-	-	-
Ochlerotatus triseriatus	-	+	+	+	-	-
Ochlerotatus trivittatus	+	+	+	-	-	-
Aedes vexans	+	+	+	+	+	+
Aedes albopictus	-	-	-	-	-	-
Ochlerotatus atropalpus	-	+	+	-	-	-
Ochlerotatus cantator	-	-	+	+	+	+
Psorophora ferox	-	-	+	-	-	-
Anopheles punctipennis	0	+	+	+	+	-
Other Potential Vectors[1]						
Culex tarsalis	+	+	-	-	-	-
Culiseta inornata	+	+	-	-	-	-

Note that some of these species may be more widely distributed in southern Canada than the published reports indicate. Intensive sampling, especially in the Atlantic Provinces where mosquitoes have not been intensively studied, may extend the known range of several *Culex* and *Culiseta* species.

Obviously, from the above table, the provinces of Ontario and Quebec have the greatest numbers of possible WNV vectors. Municipalities that are initiating new mosquito surveys would be well advised to note and deal with any breeding sites that are producing these species.

2.3 Means of Introduction of WNV into Canada

West Nile virus could be (and, perhaps, has already been) introduced into Canada by infected mosquitoes or birds in 2000. The likely scenario of introduction is that infected bird(s) would move across the border into Canada from New York or other neighbouring states. These birds would then serve as a source of virus

[1] Known vectors of SLE and/or WEE are potential vectors of WNV.

for local blood-feeding mosquitoes.

Once the virus was introduced into the local mosquito population, the mosquito vectors could infect more birds. Eventually, mosquitoes would transfer the virus from birds to mammals, including horses and people.

2.4 WNV Transmission Period

WNE cases usually occur in the late summer or early fall in the temperate zone of the world (i.e., between latitudes 23.5E and 66.5E north and south). In the NE USA, 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; horse cases peak in late-September. In more southern climatic zones, WNV is reported to be transmitted by mosquitoes throughout the year.

In Canada, as in northeastern USA, transmission from mosquitoes to people is likely to begin during the mid- to late-summer period and to end with the first hard or severe frost that typically marks the end of mosquito biting for the season.

2.5 Reducing the Risk of Transmission

People can minimize their risk of mosquito bites through wearing proper clothing and a repellent and avoiding times and situations when and where mosquitoes are most active. Practical tips to pass along to residents are given in the section on public education below.

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

3. Mosquito Control Strategies

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 government permit, 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, merchants, and councilors.

Determine the formal steps that must be taken to start a new mosquito control program in your province, including:

- Establishing a steering committee for implementing the program and consider developing a mosquito control by-law which would give municipalities right to access private property for the purposes of mosquito control.
- Obtaining provincial pesticide applicator licenses.
- Fulfilling pesticide-use permit requirements.

- Purchasing of tools, supplies and equipment[2].
- 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 [e.g., courses such as that offered by Clarke Environmental Mosquito management (http://www.cmosquito.com/inside/mu_objectives.asp) or those offered by the Florida Medical Entomology Laboratory (http://fmel.ifas.ufl.edu/index.htm)]

5. Determine the costs for the first year of work, including labour, equipment, and materials (allowing for inflation and increased labour costs).

6. Obtain applicator licenses and pesticide use permit, according to provincial regulations, well in advance of the season.

7. Hire responsible, trained, seasonal staff to carry out mosquito breeding site surveys, maintain mosquito light traps and collections, and carry out any necessary spray operations.

8. Record all survey and spray data to fulfill permit requirements and to plan for an even better program the following year.

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 Non-chemical Mosquito Control

3.1.1 Water Management

Because of the temporary nature and small size of many mosquito floodwater habitats, they often can be altered to prevent or, at least, minimize mosquito production (see section on source reduction below). However, there are laws and policies regulating alterations of larger habitats such as wetlands. Contact your Department of Natural Resources or Conservation if planning such major projects. Although compromises must be made, it is usually possible to reduce larval mosquito sources and at the same time preserve wetlands and other desirable habitats. In some instances, water management can even enhance certain types of wetland habitats. For example, it is possible to change many very temporary, scattered pools into more permanent wetland habitats.

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

[2] Supplies will include such items as mosquito traps and insecticides; equipment will include such items as a computer, dissecting microscope, and sprayers.

3.1.2 Source Reduction Prevents Mosquitoes

Ideally, mosquito control should be based on a preventive program. This is simply the removal of mosquito breeding sites. Many breeding sites (e.g., salt-marshes, sewage and dairy lagoons, storm water-retention ponds, farm dug-outs) can be made unsuitable for mosquito breeding. This is done through a combination of good design (e.g., steeply-sloped and graveled shore-lines), water level manipulation, and emergent vegetation control. Sloped, graveled, rocky, or sandy shorelines will support few mosquitoes. Larvae will be exposed to wave action and have difficulty obtaining food.

Sometimes, the easiest way to prevent mosquitoes is to alter their breeding sites to make them unsuitable for egg laying. In the case of 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.
Ditches that are slow to drain, form a series of pocket pools, and support lush grasses or weeds are 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.

Often ditches along main roads and highways are quite wide. They form broad, expansive breeding sites. One way to restrict the size of the habitat and 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 occurs in the roadside ditch, it is at least more accessible.

In other situations, it may not be possible to drain an open breeding site. 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 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.

When mosquito source reduction is being considered, it is advisable to consult local wildlife officials before starting. They can determine if the planned water management projects are acceptable from a wildlife habitat point-of-view. A poorly planned drainage project might cause more problems than it is worth.

Source reduction of larval mosquitoes may involve:

- Installation of a catchment.
- Installation of tile leading to a catchment or drain.
- Modification of grade to permit drainage.
- Filling and leveling of small water-filled depressions.
- Conversion of a mosquito-producing area to a non-mosquito-producing body of water such as an ornamental pond, water hazard, or permanent wetland.
- Elimination of artifical breeding containers (critical for control of *Culex* species).
- Reduction or elimination of emergent vegetation around storm-water retention ponds thus making them less suitable for mosquito development.

3.1.3 Exclusion

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

3.1.4 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. 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
Ponds	Stock with fish or use BTI; remove excess vegetation.
Swimming pools	Keep water off 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.
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	Clean once a year to remove debris.
Rain Barrels	Cover with screening or empty weekly.
Irrigated lawns or fields	Avoid over-irrigation. Drain standing water.

3.1.5 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 (during calm, warm, humid evenings).

If people find themselves in situations where they must be exposed to biting 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 disease transmission, people may want to apply a mosquito repellent.

Most effective repellents contain DEET (N,N-diethyl-meta-toluamide). Commercial repellents contain varying concentrations of DEET, usually between 10 and 50%. In general, the higher the concentration of DEET in a product the longer the duration of protection with a single application. Thus the lower concentration products provide 1 or 2 hours of protection, whereas higher concentration products are effective for 4 to 6 hours. The duration of protection of lower concentration DEET products can match that of higher concentration products, if they are reapplied at regular intervals (e.g., hourly). The efficacy of any repellent will depend on weather conditions (i.e., strong wind speeds and high temperatures or relative humidity will decrease the duration of protection) and amount of physical activity of the user (i.e., sweating will result in rapid declines in protection times).

DEET-based repellents do have some minor drawbacks. DEET can be an irritant to some people and it may damage synthetic materials such as rayon, nylon or certain plastics. When applying repellents, always read the label instructions carefully and thoroughly apply the material to all exposed skin, including behind the ears. If people wish to avoid using DEET, there are few, if any, effective alternatives. Plant oils, such as oil of lavender or citronella, have been shown to be somewhat repellent to mosquitoes. However, most other plant oils are not available as commercial mosquito repellents. More detailed information concerning the selection of a repellent and safe use of insect repellents can be obtained from Health Canada's Pest Management Regulatory Agency (PMRA) at http://www.hc-sc.gc.ca/hpb/lcdc/publicat/info/repell_e.html.

There is a vast array of other products that are marketed to repel mosquitoes, most of which are totally ineffective. These include wristbands that contain an aromatic repellent, ultrasonic emitters, electric grids, electronic repellers, aromatic plants (the most common one is the so-called mosquito plant), incense coils, vitamins, and even mixtures of brewer's yeast and garlic. Research has shown that all of these methods are of little or no value in repelling mosquitoes.

3.1.6 Biological Control

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 do little to keep mosquitoes at a tolerable level.

There are exceptions to this rule. There have been cases where, in individual breeding sites, a parasite (e.g., certain kinds of nematodes) or a predator (e.g., fathead minnows) have 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.

Fortunately, one natural enemy can be easily manipulated to control mosquito larvae. The microbial insecticide, BTI (see section 3.2.3.1 below) is an example of a natural mosquito pathogen that has been commercialized and is now widely used in mosquito control programs across Canada. Because BTI has no effects on other natural enemies, it is the ideal mosquito larvicide.

3.2 Mosquito Larviciding

3.2.1 Rationale for Mosquito Larviciding

Mosquito control programs are typically instituted in areas where local mosquito populations consistently represent a significant annoyance or potential public health threat or both. It should be clear that mosquitoes are involved in one or both of these activities before implementing a control program, since it may not be necessary to use larvicides (or other mosquito control measures) in areas where mosquito populations rarely reach annoying levels or where mosquito-borne diseases are not present or expected to be present.

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 mosquitoes emerge. Prevention should begin immediately after the mosquito eggs have hatched, the pool has been inspected, and the numbers of larvae present justify the use of an insecticide. The larvae are most efficiently and economically destroyed when they are concentrated in their breeding site. Preventing the larvae from becoming adult mosquitoes minimizes the area that would have to be treated. It prevents the development of an annoyance or health problem. 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 widespread adult mosquitoes.

3.2.2 Information Required for Effective Larviciding

3.2.2.1 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 by determining the species composition of mosquitoes and the age structure of immature mosquitoes (i.e., early or late larval instars or pupae).
- Calculate the amount of larvicide required.
- Give direction to daily mosquito control operations.
- Determine the proximity of environmentally sensitive areas to 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 larvicide use permits.
- Evaluate the potential for transmission of mosquito-borne diseases.

The first step in determining which mosquitoes must be monitored routinely is to establish which species cause problems. Control efforts can be justified when certain mosquitoes pose a nuisance or are an economic or health-related pest. A nuisance mosquito bothers people, typically in and around homes or in recreational areas. An economically important mosquito reduces property values, slows economic development of an area, reduces tourism, or adversely affects livestock production. Health-related mosquito problems include adverse reactions to mosquito bites and the transmission of infectious diseases (e.g., West Nile Encephalitis).

A list of mosquito species can be compiled from a review of the literature for species that bite humans or that may vector disease in the area of concern. For example, in southern Ontario, the main nuisance species might be *Ae. vexans* and the main disease vector species might be *Cx. pipiens*. Once the key target species have been determined, the jurisdiction involved can be surveyed, with special emphasis on the breeding sites of these species. The survey should include the collection of adult mosquitoes and larvae. Obviously, someone must be trained to identify the larval and adult mosquitoes. That person will require a dissecting microscope, processing supplies, and a key to identify mosquitoes[3].

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 may be used to accurately determine the relative abundance of all 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 and spatial changes (when and where) in mosquito populations and the problems that mosquitoes cause are measured by monitoring four factors:

- Telephone requests for mosquito control services.
- Adult mosquito population studies.

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[3] 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.

- Immature mosquito population studies.
- Long- and short-term weather patterns (e.g., rainfall and temperature)

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 when it was sampled. Inventory and survey data can provide a record of mosquito breeding over time, assisting in the decision to either larvicide the breeding site or eliminate it.

3.2.2.2 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 acreage (or hectarage) is determined and a reference number and habitat type are assigned.
The site information can then be entered into a database which will contain a detailed breeding history for each site, including:

- A map reference location (e.g., street address or concession roads, sections or GPS coordinates).
- Description of sites that have produced larvae.
- The time of the season when the sites have mosquitoes.
- The larval density at each site.
- The species associated with in each site.
- Type of equipment most appropriate to dispatch to the location (i.e., helicopter, backpack, truck-mounted units, etc.).
- Any restrictions associated with the site (e.g., permission required, phone ahead, BTI only, close gate, 24 hours notice required).

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 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 in its jurisdiction. These maps are used to maintain a program for 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 in those areas will change. In turn, the species composition of the mosquitoes 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. The factors include:

- Water surface area.
- Water depth.
- Water temperature.
- Mosquito stage and density.
- The presence or absence of 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, be used to ensure that sufficient larvicide is ordered and available to treat all the infested breeding sites.

3.2.2.3 Monitoring Mosquito Larvae

Many devices and procedures that 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 densities are to be quantified.

The most efficient method for larval sampling and ranking of breeding sites is to use a simple sequential sampling technique (see appendix D). Most large control programs rank mosquito breeding sites (nil, low, medium or high density) so they can plan their larviciding efforts, concentrating on breeding sites with moderate or high mosquito populations.

When there is limited time available for larviciding, it is makes more sense to treat the major sources of mosquitoes than waste time and resources on larval breeding sites that produce only a few mosquitoes.

3.2.2.4 Monitoring Environmental Factors

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 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 crews will start in the areas having the highest rainfall.

Weather conditions are important considerations during aerial or ground application of mosquito larvicides and adulticides. High winds, low temperatures, rainfall, and high humidity can affect adult mosquito activity, as well as the effectiveness of the mosquito control operations.

3.2.3 Mosquito Larvicides

3.2.3.1 Microbial Larvicides

Microbial larvicides are bacterium that have been registered with Health Canada as insecticides for the control of mosquito larvae. The target application sites include:

- Irrigation ditches.
- Flood water.
- Standing ponds.
- Woodland pools.
- Flooded pastures.

- Marshes.
- Storm water retention ponds.

Though the duration of the effectiveness of these larvicides depends on the mosquito species, weather conditions, product formulation, and water quality, generally these larvicides have short residual activity (i.e., less than 24 hours). Microbial larvicides are well suited for use in an integrated mosquito management program.

The only microbial larvicide use in Canada is *Bacillus thuringiensis israelensis* or BTI. It is currently sold under the trade names of Vectobac, Aquabac or Teknar. BTI is a naturally occurring bacteria that produces a crystal that is fatal to mosquitoes when eaten. It is harmless to beneficial organisms in the mosquito environment. Extensive testing shows this microbial larvicide does not pose a risk to wildlife, non-target species, or the environment.

Mosquito larvae move through the water, filtering out food as they go. When BTI is applied to the water, the mosquito larvae eat it. The BTI spores that contain a crystallized toxin are released by the larva's stomach fluids. The toxin then ruptures the stomach of the mosquito, causing the larva's death.

Timing of BTI applications is extremely important. Optimal benefits are generally obtained when treating 2^{nd} or 3^{rd} instar larvae. Although 1^{st} instar larvae are susceptible to BTI, treatment is usually targeted at these later instars to ensure that hatch is complete. Treatments at other developmental stages may provide less than desired results because the hatch is incomplete (1^{st} instar) or larvae stop feeding (4^{th} instar larvae prior to moulting to pupae). Therefore, a disadvantage of using BTI is the limited treatment window available.

3.2.3.2 Biorational Larvicides

Methoprene (sold as Altosid) is a compound that was developed after scientists discovered and analyzed a hormone in mosquitoes that kept the mosquitoes in the juvenile or immature stage. Altosid is one of the so-called "biorational" compounds, meaning the impact on the environment is minimized by using natural products or chemicals that are similar to these natural products.

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. Altosid is formulated as a slow-release briquette. The benefit of the slow release is that the briquettes can be placed in difficult to reach locations and continue controlling mosquitoes for a long time. By placing a small amount of this compound in the water (less than 70 g/ha), the mosquitoes are prevented from maturing. They simply die during the pupal stage. Another benefit of using Altosid is that larvae remain in the food chain, reducing the impact on other organisms sharing the aquatic habitat. Note that Altosid must be present when the mosquito larvae are in the later stages of larval development for it to work.

Methoprene used in mosquito control programs does not pose unreasonable risks to wildlife, people, or the environment. The toxicity of methoprene to birds and fish is low. It is non-toxic to bees. Reports of frog abnormalities due to Altosid have been widely circulated but these reports have not stood up to scientific scrutiny.

Methoprene breaks down quickly in water and soil and will not leach into groundwater. However, methoprene is highly toxic to some species of freshwater, estuarine, and marine invertebrates such as crayfish, if misused. For that reason, PMRA has included special precautions on the container label to reduce such risks. Although BTI and methoprene are expensive, they work to control mosquitoes without harming other organisms present in the breeding site.

Diflubenzuron is a chitin-synthesis inhibitor. It acts on contact with mosquito larvae to disrupt the moulting process. At the end of an insect moult, chitin is required as the hard component of the new outer skin of the larva. A failure to synthesize larval chitin halts moulting, leading to physiological difficulties, desiccation, and ultimately death. For these reasons, it is variously called an "insect growth inhibitor" or "insect growth regulator".

Diflubenzuron is available as Dimilin, a wettable powder formulation. 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, it cannot be used in habitats in which crustaceans are a valuable component (e.g., in marshes). A granular formulation of Dimilin is actively being pursued and is currently in the developmental stages.

3.2.3.3 Chemical Larvicides

Conventional chemical larvicides that can currently be used in Canada include chlorpyrifos, fenthion, and malathion. Chlorpyrifos has, for decades, been the chemical larvicide of choice. It has had a good record as a relatively safe, effective, and environmentally acceptable mosquito larvicide. It also is much less expensive to use than any of the microbial or biorational products. However, as a result of a recent PMRA review, the use of chlorpyrifos will be restricted in the future, especially in and around residential areas.

Fenthion, although registered as a mosquito larvicide, is rarely used for this purpose because of its toxicity to birds. No municipalities in Canada are currently known to use this product as a mosquito larvicide and its future is uncertain.

Malathion is an effective larvicide but has essentially no residual activity. It is rapidly hydrolyzed in water. Studies have shown it to be ineffective 24 hours after treatment. However, its use may increase in future years unless new chemical larvicides or more inexpensive non-chemical larvicides become available to replace those being lost. Even so, because there are no granular formulations of this product available, the use of malathion will be limited to ground-based application equipment.

3.2.4 Larviciding Equipment

3.2.4.1 Granular Application 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 (ATV), trucks, or aircraft.

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 be 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 pesticides 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. These 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 often 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) can also be mounted on ATVs. 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.

3.2.4.2 Liquid Application Equipment

The basic sprayer unit used by pest control technicians to apply residual sprays for insect 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 sizes. These small sprayers are used for spot spraying of small larval breeding sites.

The powered, backpack sprayer (comparable to the backpack blower above) is a more useful unit. It consists of a small engine and gasoline reservoir, 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 ditches or other small larval breeding sites) or to produce an air-driven mist (e.g., used as a mist-blower to apply a residual spray and control adult mosquito in their daytime resting 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. 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.

3.2.5 Larviciding Permit

The pesticide licensing and permit system is the key means by which a province 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 by municipalities for certain specific types of applications (e.g., application of restricted mosquito larvicides to water; application of pesticides to public lands).

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

3.2.6 Larviciding Procedures

For an established municipal mosquito control program, 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.
- Larviciding of snowmelt mosquito breeding sites.
- Monitoring of rainfall and temperature to anticipate summer mosquito hatching.
- Larval surveys of summer, floodwater breeding sites.
- Larviciding of floodwater mosquito larval breeding sites following each significant rainfall.

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 a few 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 emerging adult mosquitoes. In other cases, the breeding site may be assessed to determine if it can be filled or drained to prevent or minimize future mosquito breeding.

3.2.7 Monitoring the Effectiveness of Larviciding

Individual pools can be selected to assess the effectiveness of a specific larvicide. Larval sampling is done on the pools, before and after treatment, to determine the number of larvae per dip or per square meter. Typically, a larvicide will give >95% control within 24 hours of treatment. If all label directions were followed and the larvicide still gave significantly less than 95% control, that batch of the larvicide should be tested more rigorously to determine if it meets specifications. Rigorous testing may include controlled bioassays and chemical or biological assays, depending on the product involved.

A larviciding program may be evaluated by various methods. Citizen complaints of intolerable levels of mosquitoes or higher than expected numbers of mosquitoes collected in landing counts or 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 out further around the municipality. High temperatures, in the days following the mosquito hatch, 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. In addition, operator error or improper calibration of insecticide application equipment can result in less than optimum levels of larval control.

3.3 Mosquito Adulticiding

3.3.1 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 an adequate larviciding program.
- Adult mosquitoes reach annoying levels.
- A mosquito-borne disease threat was apparent.

Mosquito light trap collections and/or mosquito biting counts would normally determine the need for adulticiding.

3.3.1.1 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 the Centers for Disease Control and Prevention light traps (CDC traps) to monitor adult mosquitoes. The CDC trap is a miniature version of the NJLT that operates on 6 VDC and can be used anywhere. It costs less to purchase than the NJLT, does not require permanent installation, and collects only mosquitoes. Some mosquito control programs use carbon dioxide (either dry ice or bottled gas) or octanol as a 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 parks and golf courses; others place them in the backyards of people who volunteer to assist in the program.

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

Before adulticiding campaigns are undertaken to control nuisance mosquitoes, the NJLT collections should average more than 25 adult female mosquitoes per trap per night for 3 consecutive nights. This value 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 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 these traps, comparisons are difficult.

3.3.1.2 Landing Biting Counts

Mosquito landing and/or biting counts can also be used as an index of mosquito activity. The counts, carried out according to standard methods, should average 1^+ bite per minute over a 10-minute period at sunset before application of adulticides to control nuisance mosquitoes are started.

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.
- Assessing the vector potential of biting populations.
- Determining where to place light traps.
- Improving larval surveillance.
- Comparing biting populations versus light trap data.

When arbovirus activity has been documented in an area, counts should be restricted to landing counts only (i.e., subjects do not allow the mosquitoes to bite). 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 bee veil (over a hat), and thin disposable gloves.
- Do not wear repellents, after-shaves, 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, making counts is less confusing and enables the collected mosquitoes to be identified at a later time. If only one person is available, simply count the mosquitoes landing within view. Use the sample form for record-keeping. Mosquitoes coming to bite and landing on the front of the body can be counted over a 10-minute period.

Dividing the total count by 10 will give an average landing count of "x mosquitoes/minute" for that time and location. Usually, when mosquitoes exceed 1 mosquito/minute, they have reached a level that will not be tolerated by most people.

These NJLT and landing count values (25 females per trap per night and 1 landing/biting count per minute at dusk) are comparable and they also seem to match the public's tolerance of nuisance mosquitoes, in areas where mosquito control is routinely undertaken. Likewise, when these values are exceeded, the public usually demands an adult mosquito control program. The exact abundance of adult mosquitoes that would result in adulticiding, when arbovirus activity is detected in an area, is unknown; however, the “trigger values” for nuisance adult mosquito control can be used as a guide.

3.3.1.3 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 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) 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 will collect some female mosquitoes which have already laid eggs and may be infected with a virus.

Female mosquitoes of the *Cx. pipiens* complex are less readily attracted to a CDC trap, baited with dry ice, than they are to a NJLT. Other collecting methods must be used. Traps baited with chickens work well for

Cx. pipiens. In areas where arbovirus activity is documented, the use of CDC gravid traps (i.e., traps that collect egg-laying female mosquitoes) would be useful for assessing the prevalence of infection in *Culex* species mosquitoes. Chicken-baited shed traps have been used to collect *Cx. tarsalis* in southern Canada. Counts of vector mosquitoes can be used to assess their activity throughout the season and to compare their activity over the years.

3.3.2 Information Required for Effective Adulticiding

Mosquito control programs use one or more of the above methods to measure adult mosquito populations before a decision to control adult mosquitoes is made. Before adulticides are be applied, an adult mosquito-monitoring program should detect an increase in the population above a predetermined baseline (e.g., 25 female mosquitoes per NJLT for three consecutive nights), though this threshold may not be precisely known for all mosquito-borne diseases. Alternatively, the risk of disease transmission in an area may call for immediate adulticiding, even when the nuisance mosquito population is below the normal numerical threshold for taking such action.

3.3.3 Mosquito Adulticides

In nuisance mosquito control operations, applying products to control adult mosquitoes is a "last resort". 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. When there is a serious threat to public or animal health because of a mosquito-transmitted virus, applying adulticides may be a necessary first course of action, to reduce the abundance of potentially infected host-seeking females.

Although there are a number of factors to consider when selecting an adulticide (e.g., method of application, efficacy under certain environmental conditions, impact on the environment and non-target organisms, cost and availability, etc.), it is recommended that only products with a history of use in Canada and recent human health and environmental risk assessments, conducted by the US Environmental Protection Agency or the PMRA of Health Canada, be used. When applied using ground-based equipment, malathion and chlorpyrifos meet these criteria. However, malathion is the only product currently registered for aerial application which satisfies these criteria. Alternative application techniques (e.g., thermal fogging or residual sprays) or other registered adulticides (e.g., resmethrin or propoxur) could be used, if the recommended ones are not readily available. Appendix C provides a list of adulticides currently registered in Canada.

3.3.4 Adulticiding Equipment

3.3.4.1 Equipment Used for Residual or Barrier Treatments:

One way to control adult mosquitoes is to use barrier spray treatments. This involves spraying a dilute insecticide onto a band of vegetation surrounding the area to be protected (e.g., a backyard, a cemetery, a park, or a golf course). The treatment leaves the insecticide on plant leaf surfaces. When mosquitoes fly from the harborage or resting areas (e.g., nearby woods) through this zone, they land on the treated vegetation and die or they are repelled and do not move into the open to bite. Only chlorpyrifos, methoxychlor and permethrin are registered for this type of application in Canada, and permethrin is not intended for perimeter control around large areas such as parks.

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 larger truck or aircraft-mounted units.

3.3.4.2 Equipment Used for Large-Area ULV Treatments

Ultralow volume sprayers (sometimes 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 (5-20 micron range) in diameter (human hair is about 100 microns thick) and typically are broken down rapidly (within hours) after insecticide application. Because the distribution of the droplets depends on air currents and temperature, care must be exercised in determining when to carry out the treatments. Likewise, to maximize the efficiency of an adulticiding program, spray programs should be conducted under conditions that favour mosquito activity (i.e., low winds and warm temperatures) and when mosquitoes are most active (i.e., during the evening or early morning hours prior to dawn and shortly after dusk).

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 it 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 can be 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. It 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 flow rates to match vehicle speed. The ULV flow unit can be programmed to shut off whenever the when 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 Appendix G for supplier listings).

3.3.4.3 Equipment Used 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 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 seem to be designed for rugged use in the field.

Note that some workers, after hand 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 Appendix G for supplier listings).

3.3.5 Adulticiding Permit

As noted above, the licensing and permit system is the key mechanism used by the provinces to control pesticide use. A permit may be required by the municipality for the application of a mosquito adulticide in public parks and golf courses or on residential streets and lanes. A municipality considering a mosquito adulticiding program should contact their provincial 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 and/or the setting of distances for an untreated buffer zone around residents not wishing their properties to be included, exclude 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.

3.3.6 Public Notice of Spray Operations

Requirements vary between provinces 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 with sensitive medical conditions may request and be granted an untreated buffer zone around their properties.

If the public is concerned about insecticides, they should monitor the daily news for spray schedules and they can be advised 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 insecticide 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 insecticide.
- Wash homegrown 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 ponds to avoid direct exposure.

Organizations can be proactive with pesticide-related health concerns by using the least-toxic materials in their mosquito control programs and by ensuring that the public is fully aware of the reasons for choosing a given insecticide.

3.3.7 Adulticiding Procedures

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

First, residual adulticide treatments may be made to mosquito resting sites. Mosquitoes resting in these areas may be killed for several days 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 breeding sites that cannot be treated with larvicide (e.g., wildlife refuge).
- Vegetation surrounding an area to be protected (e.g., outer margins of a park).
- Vegetation in wide, grassy ditches where mosquitoes rest during the day.

Second, ULV spraying may be carried out in recreational and/or residential areas. When objective data indicates an adult mosquito nuisance or disease problem, 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.

3.3.8 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 number of landing adults per minute. Typically, a mosquito adulticide will give >85% control within 8 hours of treatment. If all label directions were followed and the adulticide gave significantly less than 85% control, that batch of the adulticide should be tested to determine if it meets chemical specifications. Reduced levels of control can be caused by reduced potency of insecticide due to poor (or extended) storage conditions. Rigorous testing may also include caged mosquito bioassays.

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

Such failures are usually 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. Similarly road access may have an impact on effectiveness of control when truck-mounted adulticiding equipment is used. Spray equipment mounted on ATVs can provide access to remote areas (i.e., bicycle pathways, walking trails, golf courses, etc.) that may harbour significant numbers of adult mosquitoes. As with application of larvicides, operator error that results in improper application rates or calibration of spray equipment can also lead to reduced levels of adult mosquito control. Unfortunately, because most mosquito control organizations emphasize larviciding, they are under-equipped when the need for adulticiding becomes apparent.

4. Record-keeping

4.1 Legal Requirements

All pesticide use programs in Canada require some record-keeping. Most provinces 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 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 allow municipalities to record larval and adult mosquito surveys and larviciding and adulticiding operations.

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 health records.
- Citizen inquiries and complaints.

All of the forms that are used can be filled out manually or be converted so they can be used to make computer records directly in the office or field. 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"[4] 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.

5. Assessing Proposals for Mosquito Control Services

Although most 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 province involved. Make sure that the company that you deal with uses only employees that have valid mosquito control applicator licenses to perform services that you need. 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.

Review the listing of the major companies in Canada involved in mosquito control provided in Appendices E and G. Also, consult with provincial regulatory officials to determine who else might be licensed to provide the full range of services that you require in your area of the province.

Talk with mosquito control workers in other municipalities to see if they have used such services or have used the company that you are considering. Find out which companies have done a good job and why.

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[4] For more information, contact
sales@htex.com or telephone 1-866-425-5832).

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 for 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 be mosquito larviciding or mosquito adulticiding, must be based on good surveillance data, determine who is best suited to provide this information (i.e., the municipality, another independent company, or the company paid to conduct the adulticiding or larviciding). Remember that any statements made by the company that larviciding or adulticiding is necessary 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 material safety data sheets 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 quotations. 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 the firm in your area may not necessarily provide all the services 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. The written contract should include a complete listing of all of the services and costs included. 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 of the type and number of units in good working condition).

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. The name, concentration, and total volume 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 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 mosquito biology and control or disease vector surveillance and control. Experts in government, industry, and universities who can be consulted about mosquito control. Mosquito control workers in municipalities across Canada can advise on the practical aspects of mosquito surveillance and control. 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 Control Forms.
Appendix B. Mosquito Larvicides in Canada.
Appendix C. Mosquito Adulticides in Canada.
Appendix D. Larval Sampling Procedure.
Appendix E. Mosquito Workers.
Appendix F. Government Officials.
Appendix G. Suppliers Of Services, Equipment And Materials.
Appendix H. Mosquito Control Related Websites.
Appendix I. Technical Reports and Publications.
Appendix J. Glossary of Technical Terms.

Appendix A. Larval and Adult Mosquito Survey and Control Forms

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 __ Tire Dump __ Tire __ Watering Trough __ Artificial Container __ Roadside Ditch __ Right-of-Way Ditch __ Woodland Pool __ Field Pool __ Sewage Lagoon __ Dugout __ Creek __ Culvert __ Slough __ Pond __ Rock Pool: __ Tree Hole: __ Other Type of Site _________________________________	

SEQUENTIAL SAMPLING			Pool rating: Nil ____ Low ____ Moderate ____ High ____		
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

Aedes: ___ Culex: ___ Culiseta: ___ Ochlerotatus:_____ Anopheles: ___ Coquillettidia: ___ Psorophora: ___

Other (specify): ____

LARVICIDE USED

Active Ingredient:: _________________________ Product Name: ______________________ PCPA Reg. No.: _________________

Application Rate Used: ____ Amount Used: ______________________________

Wind speed: _____ km/h Ambient Temperature: _____ deg. C

Spray Equipment Used:____

Specific Areas Treated (indicate number of hectares for each area): ____

____

PERSONNEL INVOLVED

Authorized by:

Name: ______________________________ Rank: ______________________________ Signature: __________________

Application made by:

Name: ______________________________ Rank: ______________________________ Signature: ___________________

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-BITING 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 Landing or Biting Mosquitoes 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 CONTROL 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/h Ambient Temperature: _____ deg. 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. Products registered for larval mosquito control in Canada.

Active Ingredient	Registrant	Reg. no.	Product Name[5]
BTI[6]	Abbott Laboratories Ltd.	19455	Vectobac 600L Biological Larvicide
		19466	Vectobac-200G Biological Larvicide
		21062	Vectobac 1200L Biological Larvicide
	Pestalto	26860	Aquabac xt
		26863	Aquabac 200G (18.1 kg bag)
		26862	Aquabac 200G (5 kg bag)

[5] Some of the products in this listing are currently under re-evaluation by Health Canada's Pest Management Regulatory Agency (e.g., chlorpyrifos and fenthion) and may cease to be available or may become highly restricted in the near future.
[6] BTI = *Bacillus thuringiensis israelensis.*

Active Ingredient	Registrant	Reg. no.	Product Name[5]
	Thermo Trilogy Corporation[7]	19241	Teknar HP-D Larvicide for Mosquito and Blackfly Control
		19239	Teknar Granules Larvicide for Mosquito Control
Chlorpyrifos	Dow Agrosciences Canada Inc.	12223	Dursban 2½ G Insecticide Granules
	Makhteshim Agan N.A.	23704	Pyrate 480 EC for Non-Food Uses
	United Agri Products	24649	Klor 2.5 G Insecticide Granules
Diflubenzuron	Uniroyal Chemical Ltd.	13816	Dimilin 25% WP Insecticide Insect Growth Regulator
Fenthion	Ditchling Corp. Ltd.	10146	Fenthion 50E EC Insecticide
Malathion	Cheminova Inc.	4590	Fyfanon Emulsifiable Concentrate Insecticide
	Ditchling Corp. Ltd	9975	Malathion 50E Emulsifiable Liquid Insecticide
	Sanex Agro Inc.	16099	Wilson Malathion 50 E.C. Liquid Insecticide
Methoprene	Wellmark International	21809	Altosid Pellets Mosquito Growth Regulator

[7] GDG Environnement Ltée., 375, rue Vechon, Cap-de-la-Madeleine, QC G8T 8P6, Tel 819-373-3097, Fax 819-373-6832, supply Vectobac. Pestalto (Dr. Barry Tyler), R.R. #2, Erin, Ontario, N0B 1T0, Telephone 519-833-0084, Fax 519-833-0084, http://www.pestalto.com, supply Aquabac. Sylvico Inc., 195 St. Charles Street West, Suite 305, Longueuil, QC J4H 1C8, Tel 450-646-4746, Fax 450-646-5532. Email: rejean.bergevin@sylvico.com, supply Teknar.

Appendix C. Products registered for adult mosquito control in Canada

Active	Class*	Number of products & registration numbers[a]	Method of application
Ultralow volume (ULV) sprays			
Malathion	OP	(5). Reg. Nos. 9337, 16099, 16198, 23840,	ground or air
Propoxur	CA	(6). Reg. Nos. 11029, 11313, 13212, 15565,	ground or air
Dichlorvos	OP	(5). Reg. Nos. 13349, 16476, 19680, 22761,	ground only
Resmethrin	PY	(1). Reg. No. 15187	ground only
Pyrethrins	PY	(3). Reg. Nos. 11855, 13378, 14632	ground only
Fogs or residual sprays			
Malathion	OP	(3). Reg. Nos. 4590, 9975, 16099	fog (ground)
Chlorpyrifos	OP	(3). Reg. Nos. 23704, 24414, 24945	residual spray (ground)
Dichlorvos	OP	(8). Reg. Nos. 11819, 13349, 16476, 19680,	thermal fog (ground)
Propoxur	CA	(7). Reg. Nos. 13212, 13934, 14832, 15565,	thermal fog (ground)
Methoxychlor	OC	(1). Reg. No. 13727	thermal fog (ground),
Pyrethrins	PY	(1). Reg. No. 21384	fog (ground)

* CA = carbamate; OC=organochlorine; OP = organophosphate; PY = pyrethroid

[a] The registration numbers of these products are provided as examples only. This list will soon become outdated because many of the insecticides are currently under re-evaluation.

Appendix D. 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 m^2), 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 E. Mosquito Workers

There are a number of mosquito biology and control experts in Canada. Some are private consultants while others are municipal officials or university researchers. Possible contacts include:

Consultants

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

Municipal Mosquito Control Workers

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
Services: Can advise on mosquito control methods, materials, and equipment.

Bill Boieeie
City of Port Coquitlam
2580 Shaughnessy Street
Port Coquitlam, BC V3C 2A8
Tel 604-944-5447, Fax 604-944-5448
Email: wboieeie@hotmail.com
Services: Can advise on mosquito control methods, materials, and equipment.

Randy Gadawski
City of Winnipeg Insect Control Branch
15 Conservatory Drive
Winnipeg, MB R3P 2N5
Tel 204-986-3794
Fax 204-986-4050
Email: rgadawsk@city.winnipeg.mb.ca
Services: Directs the largest mosquito control program in Canada and can provide advice on methods, materials, and equipment used in mosquito surveillance and control.

Grant Moir
City of Red Deer
PO Box 5008
Red Deer, AB T4N 3T4
Tel 403-342-8159
Email: Not available
Services: Can advise on mosquito control methods, materials, and equipment.

Wade Morrow
City of Regina
2476 Victoria Avenue
Regina, SK S4P 3C8
Tel 306-777-7731
Email: wmorrow@cityregina.com
Services: Can advise on mosquito control methods, materials, and equipment.

Todd Reichardt
Park Development & Operations #82
Community Vitality & Protection
P.O. Box 2100 Stn "M"
Calgary, Alberta CA
Tel 403-221-3977, Fax 403-221-3982
Email todd.reichardt@gov.calgary.ab.ca
Services: Can advise on mosquito control methods, materials, and equipment.

Chris Saunders
City of Edmonton Community Services
River Valley, Forestry & Environmental Services
PO Box 2359
Edmonton, AB T5J 2R7
Tel 403-496-6395, Fax 403-496-4978
Email: chris.saunders@gov.edmonton.ab.ca
Services: Can advise on mosquito control methods, materials, and equipment.

Jeff Scott, Assistant General Director,
Greater Moncton Mosquito Control Commission
City Hall, 655 Main Street Moncton, NB Canada, E1C 1E8
Tel: (506) 859-2605 (506) 859-2670 Fax: (506) 853-3543
Email: jeff.scott@moncton.org
Services: The Greater Moncton Pest Control Commission follows an Integrated Pest Management model in its efforts to control mosquitoes. The Commission has information on its mosquito control program annually conducted in the greater Moncton area.

University Researchers

Dr. Rob Anderson
Department of Biological Sciences
Simon Fraser University
Burnaby, BC, V5A 1S6
Tel 604-291-4462, Fax 604-291-3496
Email: raa@sfu.ca
Services: Can provide advice on methods, materials, and equipment used in mosquito surveillance and control. (Note: Assistant Professor, Department of Biology, University of Winnipeg, 515 Portage Avenue Winnipeg, Manitoba, Canada, R3B 2E9, as of July 1, 2001)

Dr. Jacques Boisvert
Department of Biology
University of Quebec
Trois-Rivieres, QC G9A 5H7
Tel 819-376-5053, Fax 819-376-5084
Email: jacques_boisvert@uqtr.uquebec.ca
Services: Can provide advice on methods, materials, and equipment used in mosquito surveillance and control.

Dr Jean-Pierre Bourassa
Département de chimie-biologie,
Université du Québec à Trois-Rivières,
3351 boul. des Forges,
Trois-Rivières, Québec G9A-5H7
Tel 819-376-5053 poste 3361
Fax 819-376 5084
Email: jean-pierre_bourassa@uqtr.uquebec.ca
Services: Can provide advice on mosquito surveillance methods and materials.

Dr. Donna Giberson
Department of Biology
University of Prince Edward Island
550 University Avenue
Charlottetown, PE C1A 4P3
Tel 902-566-0797, Fax 902-566-0740
Email: dgiberson@upei.ca
Services: Can provide advice on mosquito surveillance methods and materials.

Dr. 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
Services: Can provide advice on mosquito surveillance methods and materials.

Dr. 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
Services: Can provide advice on mosquito surveillance methods and materials.

Appendix F. Provincial Government Officials

For information on applicator licensing, regulations and permit requirements associated with mosquito control, contact your provincial representative:

Karen Ryan
Manager, Pesticides Control Section
NF Department of Environment and Labour
4th Floor, West Block, Confederation Building
P.O. Box 8700
St. John's, NF A1B 4J6
Tel 709-729-5707, 1-800-563-6181, Fax 709-729-6969
Email: kryan@mail.gov.nf.ca

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/

NS Department of the Environment and Labour
5151 Terminal Road, 5th Floor
P.O. Box 697
Halifax, NS B3J 2T8
Tel 902-424-5300, Fax 902-424-0503

Centre for Continuing & Distance Education, Pesticide Applicator Training
Nova Scotia Agricultural College
PO Box 550
Truro, NS B2N 5E3
Tel 902 893-6666, Fax 902-895-5528
Email: cde@nsac.ns.ca

Brad Skinner, Amherst District Manager
NS 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
NB 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

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

Ministere de l'Environnement
Direction des politiques du secteur agricole
675, boul. Rene-Levesque, Est,
8e etage, boite 26
Quebec (Quebec) G1R 5V7
Tel 418-521-3829, Fax 418-528-1035
E-mail: cecile.laverdiere@menv.gouv.qc.ca
Website: http://www.mef.gouv.qc.ca

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

ON 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

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: r.kurtz@agr.gov.mb.ca
Website: http://www.gov.mb.ca

Scott Hartley
Saskatchewan Agriculture
Sustainable Production Branch
Room 125, 3085 Albert Street
Regina, SK S4S 0B1
Tel 306-787-4669, Fax 306-787-0428
Email: n/a

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

Neil Wandler
Alberta Environment
5th Floor, Oxbridge Place
9820 - 106 Street
Edmonton, AB T5K 2J6
Tel 780-427-0054, Fax 780-422-5120
Email: neil.wandler@gov.ab.ca
Website: http://www.gov.ab.ca/env/protenf/pesticide/

Jock McIntosh
Alberta Environment
5th Floor, Oxbridge Place
9820 - 106 Street
Edmonton, AB T5K 2J6
Tel 780-427-0031, Fax 780-422-5120
Email: jock.mcintosh@gov.ab.ca

Linda Gilkeson
BC Ministry of Environment, Lands & Parks
Pollution Prevention & Remediation Branch
P.O. Box 9342 STN. PROV. GOVT
Victoria, BC V8W 9M1
Tel 250-387-4441, Fax 250-387-9935
Website: http://www.env.gov.bc.ca/
Email: linda.gilkeson@gems3.gov.bc.ca

Appendix G. Suppliers of Services, Equipment and Materials

Major Canadian suppliers of services, equipment, and materials relating to mosquito control are listed below. The listing should only be considered as a starting point for purchasers. Provincial applicator licensing officials can also provide the names of local pest control firms that offer some level of mosquito control service.

Forest Protection Limited
Fredericton Airport
2502 Route 102 Hwy.
Lincoln, NB E3B 7E6
Tel 506-445-6930, Fax 506-446-6934
Contact: David Davies
Email: Ddavies@forestprotectionltd.com
Services: Large fleet of fixed wing aircraft (TBM, AT802, M18 Dromader, Cessna 188 AgTruck) available for aerial application of adulticides and larvicides. Use latest technology including DGPS, AIMMS, Micronair rotary nozzle systems for UULV applications, spreaders for granulars. Have carried out numerous large-scale pest control operations in central and eastern Canada.

GDG Environnement Ltee.
375, rue 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: Have carried out mosquito control for several municipalities in eastern Canada, using Vectobac.

Sylvico Inc.
195 St. Charles Street West, Suite 305
Longueuil, QC J4H 1C8
Tel 450-646-4746, Fax 450-646-5532
Contact: Rejean Bergevin, President
Email: rejean.bergevin@sylvico.ca
Services: Provide both mosquito surveillance and larval control programs, using Teknar.

Caledon Helicopters Ltd.
RR #3
Dundalk, ON, N0C 1B0
Tel 519-923-3563
Contact: Andrew Dobb
Services: Have carried mosquito control for municipalities and military bases in Ontario.

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

Pestalto Environmental Products Inc.
Dr. Barry Tyler
5476 Wellington Road 24
R.R. 2
Erin, ON N0B 1T0
Tel 519-833-0084, Cell: 519-829-8373
Webpage: http://www.pestalto.com/
Email: info@pestalto.com
Services: Supplier of mosquito surveillance and control equipment, including Stihl backpack sprayers, ULV sprayers; also distributes Aquabac larvicide.

Zimmer Air Services Inc.
9706 Burk Line
RR 7
Blenheim, ON N0P 1A0
Tel 519-676-9550, Fax 519-676-9552
Webpage: www.zimmerair.com
Email: info@zimmerair.com
Services: Have carried out mosquito control programs in Ontario and Labrador.

Viceroy Distributors Inc.
Joel Gosselin
65 St. Anne's Road
Winnipeg, MB R2M 2Y4
Tel 204-925-7939, 1-800-565-9995, Fax 204-231-8507
Email: jgosselin@viceroydistributors.mb.ca
Services: Supplier of mosquito control equipment, including ULV sprayers.

Alpine Helicopters Limited
165 George Craig Blvd N.E.
Calgary, Alberta T2E 7H3
Tel 403-291-3100, Fax 403-250-7074, Cell 403-620-3763
Contact: Jim Reid
Email: Not available
Services: They have extensive experience with conventional, accuflow, micro foil and Thru Valve boom spraying systems. Their current spray fleet consists of Bell 212, 206B and 206L-3 helicopters.

Conair Aviation
Rick Pedersen, Vice President
P.O. Box 220
Abbotsford, BC, V2S 4N9
Tel 604-855-1171, Fax 604-855-1189
Contacts: George Simon or Rick Pederson
Email: rpedersen@aviation.conair.ca
Services: Large fleet of helicopters and fixed wing aircraft (DC-6s and 802 Tractors) available for aerial application of insecticide. Use latest technology, including GPS and Beecomist nozzle systems for ULV applications. Have carried out numerous large-scale emergency mosquito control operations and spruce budworm spray programs in central and eastern Canada.

Western Aerial Applications Ltd.,
Hangar 1, 8409 Lockheed Place,
Chilliwack, BC V2P 8A7
Tel 604-792-3354, Fax 604-972-3358, Toll Free : 1-800-969-2991
Contact: Jim Cooper
Email: ops@western-aerial.com
Services: Western Aerial Applications has a fleet of Hiller/Soloy 1helicopters that are well suited for aerial application work. They have many years of experience in mosquito control, forestry applications, and agricultural work. They have carried out the City of Winnipeg's aerial mosquito larviciding for many years.

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.

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.

Appendix H. Mosquito Control Related Websites

There are literally hundreds of web pages on the Internet that deal specifically with mosquitoes. Unfortunately, very few of them are Canadian. When visiting non-Canadian web pages, remember that many of the insecticides mentioned are not registered in Canada.

Some of the more informative web pages are listed below and have links to additional mosquito biology and control web pages:

- City of Winnipeg's Mosquito Control Program
- City of Regina's Mosquito Control Program
- American Mosquito Control Association
- Michigan Mosquito Control Association
- Mid-Atlantic Mosquito Control Association
- New Jersey Mosquito Control Association
- Northeastern Mosquito Control Association
- Northwest Mosquito &Vector Control Association
- US EPA mosquito pesticide information
- EXTOXNET, The EXtension TOXicology NETwork
- Florida Medical Entomology Lab
- Harvard School of Public Health, Mosquito-Borne Viruses
- US CDC's Home Page
- World Health Organization
- Mosquito-L Mailing List
- Iowa State University Entomology Image Gallery
- Key to the Mosquito Genera of North American and Mexico
- Mosquito-Borne Diseases
- West Nile Fever
- Greater Moncton Pest Control Commission

Appendix I. 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.

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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.

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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.

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MacKenzie, D.L, 1979. Mosquito control in Ontario prior to, during and following the St. Louis encephalitis outbreak. In Mhady, 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.

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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.

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.

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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.

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ULV sprays by ground equipment for the control of adult mosquitoes. Mosquito News 41(1):132-135.

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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 J. Glossary of Technical Terms

Active Ingredient — An ingredient which provides either stimulating or killing action. In pesticide use, this generally is equivalent to the amount of technical material in a formulation or amount of technical material (AI) applied per hectare.

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, is usually the least efficient mosquito control technique. 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 the field formulation of chemical material (including both toxicant and diluent) 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 have a segmented body, jointed appendages, a usually chitinous exoskeleton moulted at intervals, and a dorsal anterior brain connected to a ventral chain of ganglia. Includes insects, arachnids, crustaceans.

Blood-feeding — Some arthropods take blood, a behaviour known as 'blood-feeding'. The blood they that they ingest is known as a 'blood-meal'. They use 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 oviposition.

Breeding Place — Any body of water which contains or produces mosquitoes. "Breeding place" has been finally established in the laws and regulations and in the scientific literature. Some workers prefer the term "mosquito source" as more descriptive.

Concentrate — A form of commercial pesticide preparation which generally requires further dilution to decrease the concentration of its active ingredient before it is applied.

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

Dead-end Hosts — People and animals that become diseased as a result of being infected by an arbovirus usually are "dead-end" hosts. They may suffer disease but the virus does not spread from them to other vertebrates or to other mosquitoes.

Diapause — A period of suspended development or growth, characterized by inactivity and decreased metabolism. *Culex* species enter reproductive diapause late in the summer or fall and seek overwintering sites rather than blood-feeding.

Disease — ‘Lack of ease’. 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.

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 mixture of one or more pesticides plus other materials needed to make it safe and easy to store, dilute, and apply. Properties or spray formulation can affect effectiveness of pesticides (toxicity and residual life). Insecticide mixture as produced and delivered by the manufacturer is a formulation. Once the formulation is diluted with oil or water for spraying, it is referred to as the tank mix. Examples 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 — An individual infested by or upon which a parasite grows. An individual preyed upon. Regarding mosquitoes, the plants and animals from which they obtain nectar or blood. Regarding disease, the source of the disease organism.

Instar — The form assumed by insects between larval moults. Mosquitoes develop through 4 larval instars. The first is formed when the larva issues 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 Control — Applied mosquito control which combines any two or more measures that tend to suppress or destroy mosquitoes (e.g., source reduction and chemical control). The manipulation of pest or vector populations, taking advantage of natural occurring mortality. The integration of all suitable management techniques with the natural regulating and limiting elements of the environment.

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 — Pesticides used to control insects at the larval stage of their development. Mosquito larvicide refers to the insecticides that are used to control mosquito larvae.

Larviciding — A general term for the process of killing mosquitoes by applying natural agents or commercial products designed to control larvae and pupae (collectively called larvicides) to aquatic habitats. 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 in a season, as in "multivoltine species of mosquito".

Overwintering — A period of rest or hibernation by which mosquitoes survive the winter. The stage that mosquitoes overwinter varies with mosquito species. *Culex* species overwinter as unfed females, most of the floodwater *Ochlerotatus* or *Aedes* species get through winter as eggs while others overwinter in as larvae (e.g., *Coquillettidia* species).

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 — A population or group of populations of vertebrate or invertebrate hosts in which the pathogen is endemic (i.e., permanently maintained). Although human populations can form reservoirs of this kind, the concept is usually applied to non-human populations from which the pathogen periodically escapes, causing individual infections or epidemics in humans or epizootics in other animals.

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. A wide variety of equipment and materials may be used. Usually, a municipality will already have all the required gear to carry-out the work.

Ultralow Volume — 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. Abbreviated as 'ULV'.

Vector — Any mosquito that is capable of transmitting a disease agent (pathogen) from an infected animal to a susceptible human or animal. An organism, as an insect, that transmits pathogens to plants or animals. Any disease carrier.

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

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

Zoonoses — Diseases in which pathogens are harbored by other animals as well as by humans, and which are communicable from animals to humans under natural conditions.