

Learning Objectives

When you have completed this module you should be able to:

- describe why mosquitoes and black flies can be pests
- describe the biology of mosquitoes and black flies
- identify mosquitoes and black flies to genus
- describe the control measures used to manage these pests

Introduction

The biting activities of mosquitos and black flies can result in significant effects on human health. Intense scratching of black fly and mosquito bites may result in open wounds and secondary infection. In addition, mosquitoes are also capable of carrying West Nile virus to humans and heartworm to dogs. Dog heartworm is a nematode that resides in the heart of dogs resulting in restricted blood flow, reduced endurance and reduced longevity. West Nile virus infection is caused by a virus. It is spread by mosquitoes that have fed on the blood of infected birds. Birds are usually the natural hosts for West Nile virus. Most people infected with the virus have no symptoms at all, or only mild symptoms that can begin three to 14 days following a bite from an infected mosquito. One in five people infected with West Nile virus may develop symptoms. These symptoms are usually mild, and can include fever, headache, muscle aches, tiredness, joint pain, swollen glands and rash. One in 150 people infected with the virus will develop serious health problems including paralysis, meningitis, encephalitis or even death.

The evidence to date, shows that most people infected with West Nile virus got it from the bite of an infected mosquito. A mosquito becomes infected when it feeds on the blood of a bird that is infected with the virus. About two weeks later, the mosquito becomes capable of passing the virus to people and animals by biting them.

While preventing the transmission of disease by mosquitoes is of significance, any control program must be seriously evaluated. Mosquito and Black fly larvae may be a food source for insects, fish and other animals. Applications of pesticides made to standing or flowing water may harm other organisms living in the water and alter the ecosystem. There are a variety of techniques that can be used to control mosquitoes and black flies; these are discussed in this chapter.

Mosquitoes

Identification

Mosquitoes belong to the family Culicidae. All members of this family have piercing and sucking mouthparts as well as fine scales on their body and wings (Figure 9). The scales are visible as dust that easily rubs off the wings or body. There are over 70 species of mosquitoes in Canada with more than 27 species in Nova Scotia. These species differ in their size, colour, body features, habitat and host preference. The blood feeding habits of mosquitoes has led to many studies of their biology and identification including Wood, et al. (1979); McAlpine et al. (1981); and Anonymous (1984).

Adult mosquitoes and black flies like most other adult insects have three major body parts (head, thorax and abdomen) six legs and are winged. Like most other insects of the Order Diptera, they have a single pair of membranous wings in the adult stage. A pair of knobbed structures on the thorax, called halteres, are the remnants of the second set of wings. These flies have relatively large heads with large compound eyes. The mouthparts are adapted for piercing and sucking fluids. The male members of these species are not blood feeders but rather feed exclusively on plant fluids such as nectar. The females often feed on nectar as well, but also require blood to obtain the nutrients necessary for egg development. When feeding on a host, salivary fluid is pumped into the wound to prevent coagulation of the blood and stimulates blood flow. This saliva often causes local allergic reactions that include redness, swelling, discomfort and pain at the site of feeding. The saliva is also often the way disease organisms travel from the mosquito to the host.

It is necessary to be able to identify the larval and adult stages as well as understand the biology of these pests to select and use appropriate control measures.

This section does not include identification of individual mosquito species. However, the identification and biology of the most significant mosquito genera will be outlined here since the timing and type of control measures vary among different genera.

Mosquitoes have four stages in their development, namely the egg, larva, pupa and adult. The larvae and adults of mosquitoes can be identified to genus using the key on the following pages.

Key to the Genera of Mosquitoes of Nova Scotia

1. Scutellum rounded (Fig 1a); palpi as long as proboscis (Fig.2a)*Anopheles*
 Scutellum tri-lobed, each with a tuft of setae (Fig 1b); palpi much shorter than proboscis (Fig 2b)..... 2

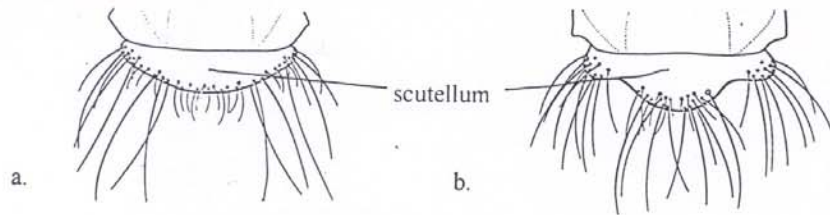


Figure 1: Dorsal view of scutellum. a. *Anopheles*; b. *Aedes*.

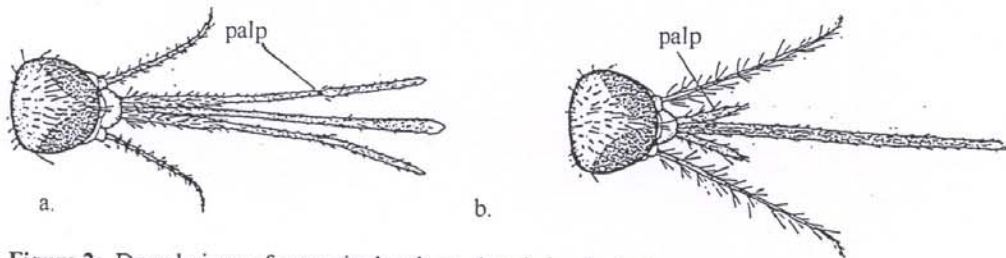


Figure 2: Dorsal views of mosquito heads. a. *Anopheles*; b. *Aedes*.

2. Postspiracular setae present (Fig. 3a); female abdomen tapered to apex (Fig. 4a).....*Aedes*
 Postspiracular setae absent (Fig. 3b); female abdomen rounded at apex (Fig. 4b).....3

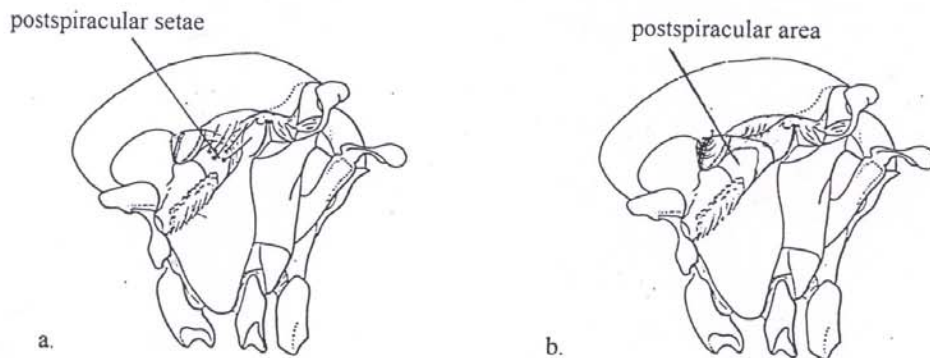


Figure 3 : Left lateral view of thorax. a. *Aedes*; b. *Culiseta*

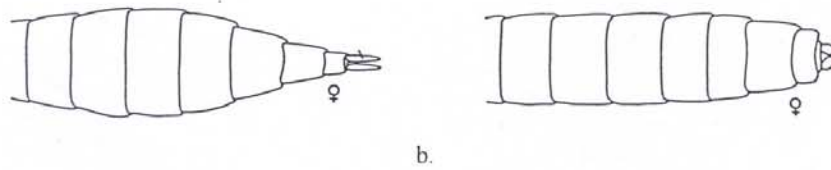


Figure 4 : Dorsal view of female abdomens. a. *Aedes*; b. *Culiseta*

3. Spiracular area with setae (Fig. 5a).....4
 Spiracular area without setae (Fig. 5b).....5

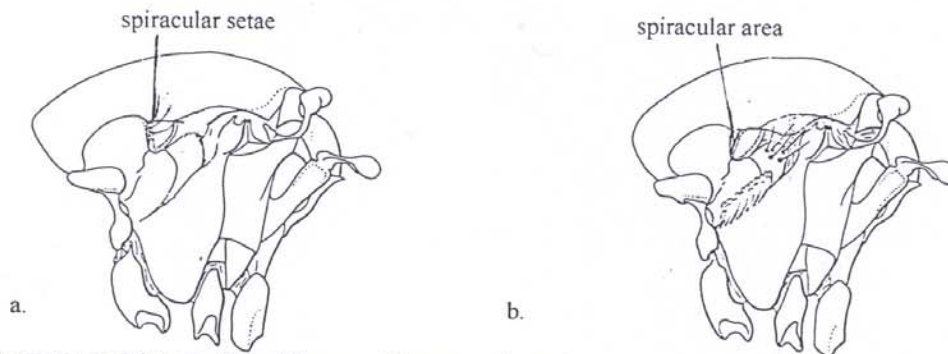


Figure 5 : Left lateral view of thorax a. *Wyeomyia*; b. *Aedes*.

4. Abdominal segments banded or with lateral spots (Fig. 6a); postnotum without setae (Fig. 7a).....*Culiseta*
 Abdominal segments unbanded and without lateral spots (Fig. 6b); postnotum with setae (Fig. 7b).....*Wyeomyia smithii* (Coqu.)

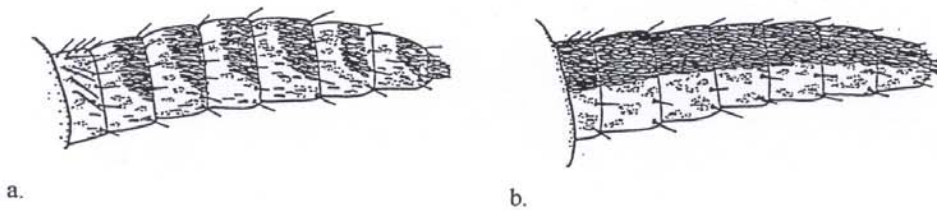


Figure 6 : Lateral view of abdomen a. *Culiseta*; b. *Wyeomyia*.

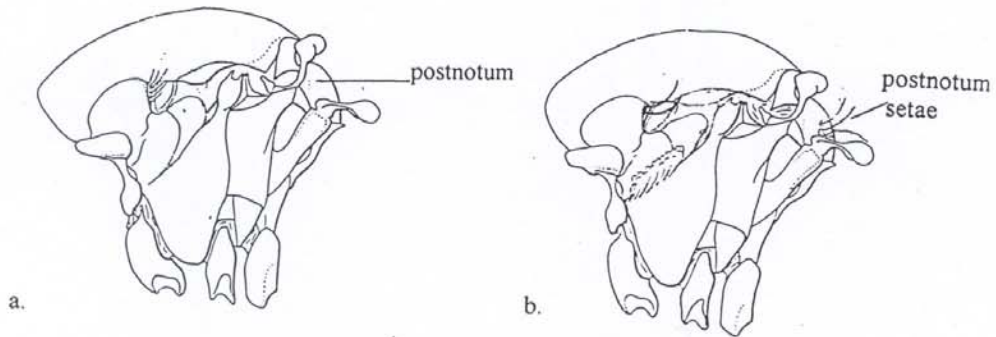


Figure 7 : Left lateral view of thorax a. *Culiseta*; b. *Wyeomyia*.

5. Hind tibiae with wide ring of pale scales; basal half of tarsal segments with pale scales
 (Fig. 8a) *Mansonia*(=*Coquillettidia*)
perturbans (Walker)

Hind tibiae without wide ring of pale scales; tarsal segments with pale scales on both base
 and apex or all dark scaled.(Fig. 8b).....*Culex*

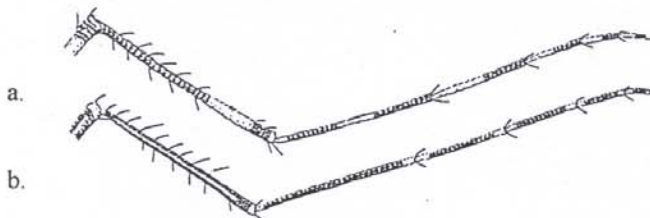
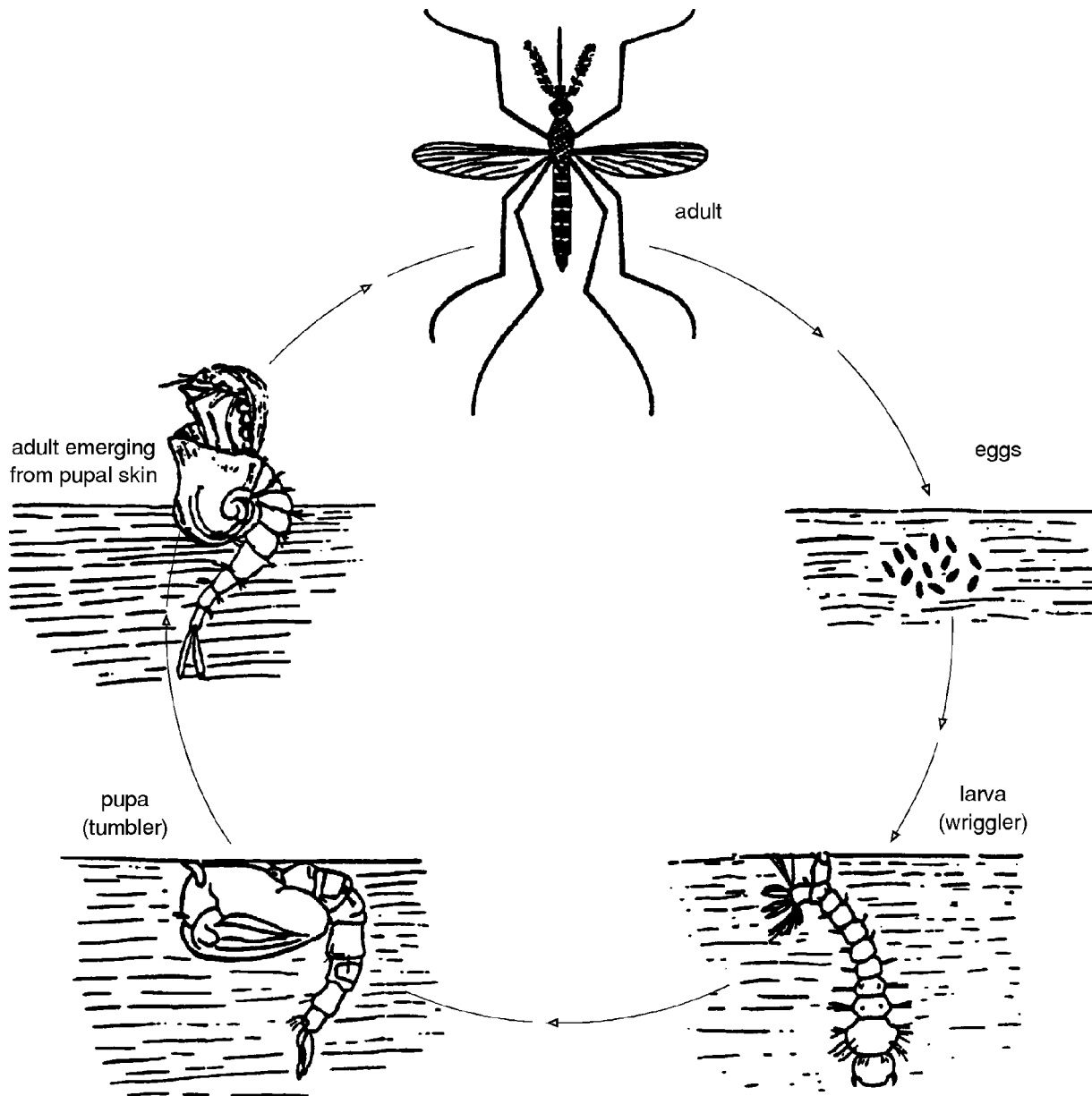


Figure 8 : Hind tibiae and tarsus a.*Mansonia*; b.*Culex*.

Figure 18. Generalized life cycle of a mosquito.



It may be necessary to identify the exact species of mosquito present. In these instances it is strongly recommended that you consult a specialist in mosquito identification to help identify the mosquitoes.

Life Cycle and Behaviour

A female mosquito usually lays from one hundred to several hundred eggs. The eggs will hatch, and the larva and pupa develop, only in water (Figure 18). To ensure that water is present, the female will lay her eggs either directly on water, or on moist soil, sod or leaf litter that may be subsequently flooded.

The eggs hatch to produce “wrigglers” or larvae. Standing or very slowly moving water that is high in organic matter is preferred for egg laying and larval development. Such locations include:

- edges of swamps
- temporary flood water pools
- shallow ponds
- weedy margins of deeper ponds
- woodland pools.

Woodland pools are a common habitat for larval development.

Mosquitoes may also develop in any standing water which accumulates around culverts, and highways and in storm water catch basins; eavestroughs; discarded tires; tin cans; bird baths and ornamental pools.

Mosquitos develop only in stagnant water and cannot survive the wave action of open bodies of water or the movement of water in flowing streams. Therefore locations such as large ponds and lakes are not suitable breeding sites except possibly around a shallow perimeter where vegetation will reduce water movement.

The larvae feed (filter feed or graze) on tiny particles of plant or animal matter in the water. A larva grows by shedding its skin three times and developing into progressively larger stages. Each of these four larval stages is known as an **instar**. The larva breathes at the water surface by means of a slender tube, known as a **siphon**.

When fully grown, the fourth instar larva moults into the **pupa** stage which resembles a large headed black comma. The pupa obtains air at the water surface through breathing tubes. When the adult has formed the pupal skin splits at the back of the thorax and the adult emerges from the pupal skin. The adult rests on the empty skin on top of the water while its body and wings stiffen. Several minutes later the tanning process is complete and the adult flies away.

The adult is an active flying insect, but is relatively fragile. Some species may die from drying after a few hours' exposure to sunshine or in conditions of relatively low humidity. Therefore,

adults tend to seek shelter from the sun during the day in woods or in dense vegetation such as hedges or tall grass. For a few days after emergence the adult male and female mosquitoes feed on plant nectar. During this period mating occurs.

The female mosquito bites and feeds on the blood of humans, other mammals, birds and even some reptiles to obtain sufficient nutrients for egg development. A few days after her blood meal, the female lays eggs. In general, the females of most species do not live long after this, but some are able to repeat the cycle of blood feeding and egg laying several times (up to 20 times).

It is important to note that male mosquitoes feed on plant nectar throughout their lives and are important pollinators. Typically adult mosquitoes are most active around sunset and sunrise when winds are low, relative humidity is high and temperatures are warm. Biting activity peaks during these times. Mosquitoes may be dispersed from the larvae habitat up to about 20 km depending on the species, habitat and weather conditions.

The genera of mosquitoes found in Nova Scotia that are of annoyance to humans or may carry disease are:

Aedes (spring and summer groups)
Culex,
Mansonia

The above groups may differ in:

- the preferred source of their blood meal
- the number of generations in a year
- which stage and where they survive the winter
- the type of habitat preferred for larval development
- ability to carry disease

These factors influence the necessity for control, the timing of control methods, and the selection of the control method that is most appropriate.

Aedes Genus

- **Spring *Aedes*:** The most common group of mosquitoes in most of Nova Scotia is a species in the spring *Aedes* group (approximately 15 species). Examples of the spring *Aedes* group include:

<i>Aedes communis</i>	<i>A. canadensis</i>
<i>A. excrucians</i>	<i>A. punctor</i>
<i>A. fitchii</i>	<i>A. provocans</i>
<i>A. stimulans</i>	

All of these vary subtly in physical characteristics and biology. In any one area usually four or five species are dominant. This group is not only annoying but may also carry West Nile virus to humans and heartworm to dogs.

These species survive the winter as eggs in damp depressions containing decaying vegetation, most often deciduous leaves. These locations are typically in a deciduous woodlot or forest. In the spring, the eggs hatch as snow melt creates water pools over the eggs (snow-melt pools). As a consequence these mosquitoes are also referred to as snow-melt *Aedes*. The eggs may hatch as early as April or as late as early June, depending on local weather conditions.

The larvae grow from 1st to 4th instar in 3 to 8 weeks depending on temperature conditions. Snow or colder weather will slow the metabolism of these larvae, but will not kill them. They will usually survive even if the water freezes.

Following larval development, the mosquitoes pupate. The pupal stage lasts up to one week depending on temperature conditions with warmer temperatures reducing the development time. Adult mosquitoes emerge in late April through May.

The adult females take blood from a wide variety of animals: humans, pets, other mammals and birds. Biting activity from this group typically is maximum in June with adult populations declining markedly by late July. After the female has taken blood she rests in areas of high humidity until the eggs develop. She will then lay eggs in moist soil and leaf litter where they will stay until the next spring snow-melt when hatching will occur. There is only 1 generation per year (Figure 19).

- **Summer *Aedes***

There are three species (*A. cantor*, *A. sollicitans* and *A. vexans*) in this group, that are common in Nova Scotia, especially where drainage is poor. This group can carry heartworm to dogs and cause significant annoyance to humans. They survive the winter as eggs in moist depressions containing decaying vegetation, usually grass. Typical habitats include golf course “roughs”, powerline rights-of-way, and grassed ditches that are flooded following precipitation. Eggs hatch as a result of being wetted, dried, and wetted again. Spring snow melt can be considered the first “wetting” after a dry spell. A subsequent heavy rain in late May or June can cause eggs to hatch. Usually 2.5 cm of rain within 24 hours will cause eggs to hatch. *A. cantor* and *A. sollicitans* prefer roadside ditches where salinity from winter road salt is present and natural salt marshes, while *A. vexans* are found in any area that has grassy vegetation and frequent summer flooding. The larvae develop from 1st to 4th instar in 10 days or less, depending on water temperature (faster when warmer). If the larval habitat dries within this time, as commonly occurs, the larvae will be killed. Pupation occurs and lasts for a maximum of 3 days, often less. Adult mosquitoes may emerge within a week of the eggs hatching. The adults mate, and the females obtain blood from a variety of hosts, often mammals

including humans. The blood fed females rest in areas of high humidity during which time the eggs develop. The eggs are laid in grassy moist areas. These eggs will hatch after 2 consecutive wettings during the same summer.

The number of generations per year is related strictly to weather conditions. There may be one to many generations per year with more precipitation resulting in more generations. Biting activity from this group may be maximum anytime from June through September. However, if precipitation is common through the summer, populations of adults will increase through the summer and into September until there is significant frost (Figure 19).

- ***Culex***

Culex mosquitoes prefer to feed on birds but can be an annoyance to mammals including humans. While they can be of annoyance to humans, they are of greatest significance as carriers of West Nile virus (WNV) to birds. They amplify the virus in the bird population.

WNV is known to be primarily an infection of birds, both those which migrate from the far south and those which remain here throughout the winter. Once a mosquito has fed on an infected bird, and the virus has multiplied in its body, the mosquito remains capable of transmitting the disease for the rest of its life.

Culex mosquitoes survive the winter as adults, under houses, in barns, sewers, and road culverts as well as natural sites such as caves or hollow trees. They leave their overwintering sites when average daily temperatures reach 21°C (usually mid-May). The adult females take blood, develop eggs and lay them in early June. The eggs are laid in boat-shaped rafts that float on the water surface. Each raft is the result of one blood meal and contains several hundred eggs. The eggs are laid in habitats with high organic content that contain water for an extended period of time. These habitats are typically:

- storm sewer catch basins
- sewage lagoons
- abandoned tires
- abandoned or poorly maintained swimming pools
- small containers such as tin cans, bird baths, rain barrels, etc.
- dykeland ditches

When populations are high, flooded ditches may also be used for larval development. The eggs hatch 24 to 48 hours after being laid and the larvae develop from first to fourth instar in 7 to 21 days depending on temperature. Pupation occurs and the pupal stage

lasts several days. Adults emerge, mate, take a blood and return to lay egg rafts in the same type of habitat.

While there are typically three generations per year there is significant overlap in the development of these generations. Eggs, the four larval instars and pupal stages of *Culex* may be found in the same breeding site at the same time. Biting activity from this group typically is maximum in late July and late August. From early August on, some emerging adults will not seek a blood meal to develop eggs, but rather begin to prepare to go into “hibernation” by feeding on nectar to develop fat bodies. These adult mosquitoes will enter overwintering sites and survive until the next spring (Figure 19).

- ***Mansonia perturbans* (*Coquillettidia perturbans*)**

This is a single species that is known as either *Mansonia perturbans* or *Coquillettidia perturbans*. The adults of this species are strong fliers and voracious biters. They can be an extreme nuisance in areas adjacent to larval habitats. This species survives the winter as larvae buried in the mud at the bottom of permanent water swamps. The larvae breathe air by inserting specially adapted siphons into porous tissue of emergent aquatic plants such as pickerelweed, bulrushes and cattails. The larvae remain attached to the roots from first to fourth instar larval and pupal development. When fully developed, the pupae detach from the roots of the aquatic vegetation, swim to the surface and emerge from July through August. Several emergences of adults may occur during the summer. This is a result of larvae overwintering in different instars and requiring different development periods to complete development the next spring and summer.

After mating and taking blood, the female lays eggs on the water surface in boat-shaped rafts similar to those laid by *Culex*. After hatching, the first instar larvae swim down to the mud substrate in the marsh and attach themselves to the roots of aquatic plants with their syphon. They will remain attached to the roots until the next summer when they will pupate and emerge.

There is only 1 generation per year with most biting activity occurring in July through August (Figure 19).

This species is very difficult to control with larvicides or biocontrol agents focussed against the larvae as they are buried in the mud for most of the year. Control of this species usually focuses on control of the adult stage.

- **Other Genera**

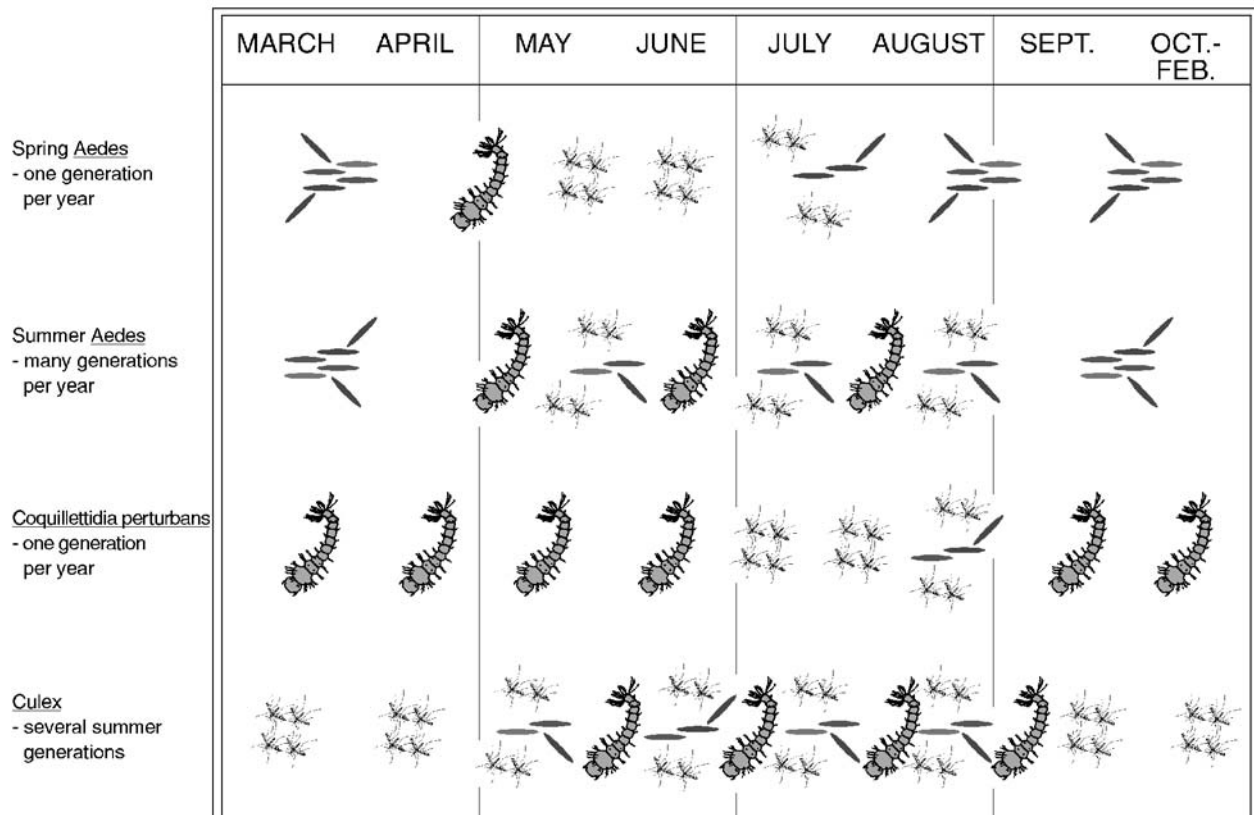
In addition to the above groups, there are other mosquito species in Nova Scotia that may occasionally be annoying including species in the genera *Culiseta*, and *Anopheles*. These are rarely of significance on a large scale. If further information is required concerning these groups please refer to the Additional Readings section of this module.

Monitoring Mosquito Populations

During the planning phase of a mosquito control program it is necessary to monitor mosquito populations to establish the:

- mosquito species of significance in the area
- proximity of larval habitats to humans
- relative importance of each species
- presence or absence of carriers of disease
- size of the larval habitats that require treatment

Figure 19: Summary of Lifecycle of Mosquito Genera



- control methods most suitable to the situation
- type and amount of application equipment required
- type and amount of control agent required

During the control program, monitoring information is used to establish the:

- timing of control methods
- effectiveness of control methods
- most cost-effective components of the program

Both larval and adult populations should be monitored as described below.

- **Monitoring Larval Mosquito Populations:** The monitoring of larval populations includes:

- identification of the larvae present in the area
- surveys to establish where the larvae are found
- development of site maps indicating where control measures should be used, adjacent sensitive areas, etc

Surveys of larval habitats may be either subjective to determine the location and kind of mosquitoes present, or objective to determine the relative abundance of each species present.

Subjective surveys require much less sampling and time than objective surveys, but are not as accurate. In either case, the survey must be systematic to ensure that no areas will be missed.

The equipment used to conduct larval surveys include:

- a white dipper (500 ml capacity) made of metal or plastic
- small dip nets to collect larvae for preservation
- containers to hold larvae (eg. polystyrene or paper cups with lids);
- maps to record the location of the larval habitat
- pen and paper to record the information
- boots or hip waders

Larval monitoring should be conducted regularly at designated locations. The scheduling of observations depends on the species of mosquitoes present:

- monitoring for spring *Aedes* requires the regular sampling of snow- melt pools from when snow-melt begins until hatching and larvae have developed to the second or third instar when treatment should occur. Sites that melt early, and those that contain snow and ice for an extended period should be monitored to ensure that all eggs have

hatched before treatment. Similarly, monitoring should ensure that the larvae are treated prior to pupation when larvicides are not effective.

- monitoring for summer *Aedes* requires sampling of sites which are likely to hold water for a minimum of four days following summer rains. They should be sampled 24 hours after a significant rainfall. A significant rainfall is considered 2.5 cm or more of rain within 24 hours. Flat clay terrain will not permit much water percolation and so summer *Aedes* eggs may hatch when less than 2.5 cm of rain falls on clay soils. Grassy ditches and ditches associated with multilane highways should be checked after every summer rainfall to see if sufficient precipitation has occurred to hatch eggs. Similarly, check around the edges of ponds receiving water from urban storm sewer and ditch systems for *A. vexans* production. Monitoring should continue after hatching to ensure that treatment occurs before pupation.
- monitoring for *Culex* requires sampling of storm sewer catch basins, and permanent water ditches especially those high in organic content should be checked from June 1st on a weekly basis for production of *Culex* and *Culiseta* mosquitoes. Containers such as rain barrels, bird baths, flat roofs, discarded pans, swimming pool covers and old rubber tires should also be monitored at least twice per month during the summer season. Monitor sewage lagoons containing stagnant water for production of *Culex* and other mosquito species.

You should indicate the location of larval habitats, as well as the type of mosquito present on a topographical map or aerial photograph. In large control programs the control area should be divided into sections and each potential mosquito habitat indicated and numbered on the map. If possible, the pools should be coded to indicate the types of mosquitoes present. The scale of the maps should be sufficiently large to indicate each individual larval habitat.

Data concerning the mosquito species should be recorded and includes the following:

- the species present (collect larvae for later identification)
- their relative abundance
- when larvae were present
- the presence of natural enemies

Other data that may be recorded concerning the site includes:

- site permanency (spring snow melt, summer intermittent, summer permanent)
- substrate type
- average depth
- dimensions or area of the site
- the type and amount of vegetation present

To collect and preserve larvae for identification skim the surface of the water with the dipper or dip net. Choose places where aquatic vegetation or floating debris offer protective cover for the larvae. When disturbed, larvae of many species sink to the bottom rapidly and remain there for several minutes. You may need to wait until the larvae come back to the surface to collect them.

The key provided in this section is for mature larvae (fourth instar larvae). However, you can collect immature larvae and raise them to fourth instar by keeping them in containers at room temperature and feeding the larvae small amounts of fish food.

For the best preservation, place the mature larvae in small vials in 70-95% ethanol to preserve them. No more than 25 larvae should be placed in one vial. Place a label containing the locality, date and name of collector inside the vial; it is advisable to use water proof paper and a pencil to record the appropriate information. The vial should be tightly sealed with a stopper.

Monitoring Adult Mosquito Populations

Monitoring of adult populations includes:

- identification to establish the species that are actually causing the biting activity in the area
- surveys to establish where biting activity is most severe
- the development of thresholds to establish when control measures should be taken

NOTE: DO NOT PRESERVE ADULT MOSQUITOES IN LIQUIDS such as ethanol because the scales cannot be easily seen, making species identification impossible. Instead place mosquitoes in a soft packing material (e.g. tissue paper) and place in a protective container.

Adult mosquito populations should be monitored in areas where information on annoyance levels is needed (usually in a residential area). A good spot is the backyard of a home on a quiet street away from highly-illuminated areas and close to shrubbery. The proximity of larval breeding sites will significantly influence the data.

There are many methods of surveying adult mosquito populations. In Nova Scotia surveys have been conducted with:

- New Jersey Light Traps
- CDC Miniature Light Traps Baited with Dry Ice

The methods used to measure adult mosquito populations are not without bias. The number of mosquitoes collected will depend on:

- the time of day when monitoring is conducted
- the duration of monitoring
- location of the trap
- weather conditions (temperature, wind, humidity)
- attractiveness of the trap for each species of mosquito

The best means is to use a combination of monitoring methods that together will overcome any one bias. Some of the advantages and disadvantages of the most commonly used methods are discussed below.

- **New Jersey Light Traps:** These traps are standard traps which have been used for many years to monitor adult mosquito populations. They use a light bulb to attract mosquitoes and an electric fan to draw them into a container. Light is supplied by a 25 or 40 watt electric light bulb. Do not use a stronger wattage.

Advantages

- traps can be set up and run 24 hours a day, or on a timer
- collections can be made on a daily 2, 3, 4 or 7 day cycle
- rugged construction minimizes breakdown, vandalism and theft
- traps need not be baited with dry ice
- it is effective for monitoring many different species of mosquito
- comparisons can be made of data from other New Jersey light traps in different geographical locations, different times of the season and from year to year

Disadvantages

- the trap must be located within 30 metres of a hydro outlet
 - it collects a wide variety of insects as well as mosquitoes and much labour is required to sort mosquitoes from other insects
 - mosquito specimens often are damaged in the trap or during sorting
 - the traps cost several hundred dollars
- **CDC Miniature Light Traps:** These traps use a combination of light, and a carbon dioxide source to attract mosquitoes and a fan to suck the mosquitoes into a mesh bag. Dry ice is usually used as the source of carbon dioxide. Because of differences in the attractiveness of this trap and that of the New Jersey trap, the data from these two traps cannot be compared.

The trap should be set out between 6:30 - 7:30 p.m. with collection. It should be disassembled the next morning, between 6:30 - 7:30 a.m. The trap should be suspended from

a tree 1.5 m from the ground, at the edge of, or inside a wooded area. It should not be visible from any well travelled road or theft will be likely.

Advantages

- traps can be set up and operated away from sources of electricity because the power source is a portable battery
- at morning pick-up, the specimens are usually still alive and may be used for encephalitis surveillance
- only minimal sorting of collected insects is required

Disadvantages

- the apparatus is quite portable and easily stolen
- when collections are made over more than 12 hours, the specimens become badly damaged
- traps should be baited with dry ice as the light source alone is not an effective attractant
- the mesh bag can be easily torn
- while less expensive than New Jersey light traps, the CDC traps may be costly

Adult mosquitoes collected in a CDC light trap or during biting counts, can be killed with minimal damage by placing the collecting vial or bag in a freezer for several hours. Provide a label which defines when the sample was collected, location of the collection, and the name of collector.

Control Of Mosquitoes

The selection of a control method or a combination of control methods for mosquito control depends on:

- size of the area to protect
- financial resources
- acceptability of the control method to the public
- availability of application equipment
- effectiveness of the control method

These factors are critical in deciding which combination of control measure should be used. With few people and limited financial resources, personal protection methods are the most feasible method of control. However, if a large area is to be protected and sufficient financial

resources are available a much greater variety of control measures with greater effectiveness are possible. An integrated mosquito control program may involve a combination of the following techniques:

- **Habitat modification:** Virtually all mosquito larval habitats have one factor in common, i.e. standing water. The elimination of water from the site will result in complete control. However, the practicality and environmental effects of such activities rarely make this a viable option on a large scale.

Low areas and ditches where water accumulates in the spring or after precipitation during the summer may be dredged to ensure that they drain quickly.

The alteration of a watercourse (ponds, rivers lakes etc) or water resource (wetland, marsh, bog etc), including infilling or draining the water therein, requires an Approval from the Nova Scotia Department of Environment & Labour. The draining or infilling of a watercourse or water resource is not permitted for the purposes of “private gain”.

Plans which involve drainage of wetlands should also consider the effect on fish, waterfowl, other wildlife and the environment in general. Natural swamps are important as reservoirs; they help to maintain adequate water levels in tributaries and streams over dry summer periods. Manipulating drainage systems may also have a significant impact on the availability of water for recreation, domestic water supplies and agriculture. Therefore, all these factors must be considered before significant changes in drainage of natural swamps are attempted.

On a small scale, property owners should be encouraged to eliminate sites that may be mosquito larval habitats such as:

- abandoned swimming pools
- precipitation and snow-melt left in swimming pool covers
- ornamental ponds
- rain barrels
- troughs
- other small containers and debris

Old tires often contain water and provide an excellent habitat for the development of several mosquito species.

Storm water retention ponds, dugouts and ornamental ponds should be kept free of emergent aquatic vegetation. If possible no vegetation should be present around the edges of these ponds to discourage female mosquitoes from egg-laying.

- **Mechanical exclusion (protective clothing, building maintenance):** If people must be in areas with high mosquito populations, they should wear clothing designed to exclude mosquitoes, e.g. long-sleeved shirts, light coloured jackets, trousers and socks. Some clothing (often available in fishing and hunting stores) is specifically designed to exclude mosquitoes and black flies. Remember that lighter coloured clothing is less attractive to biting flies than dark clothing.

The use and maintenance of screens on windows and doors, door closures, and proper building maintenance will reduce the number of mosquitoes entering buildings. If a shipping door must be left open for a long period, an air curtain or plastic strip curtain will reduce the number of mosquitoes and other flying insects from entering the building.

Reducing the number of and type of lights used in the evening, in areas frequented by people, will reduce the number of mosquitoes attracted to the area.

- **Light traps:** Many varieties of light traps are now being marketed as a method of insect control. Although two types of light traps (CDC and New Jersey Light Traps) are commonly used in monitoring mosquito populations, neither of these, nor any light trap is particularly effective for reducing mosquito populations outdoors. Studies conducted in Ontario indicated that less than 4.1% of the insects killed in these traps were mosquitoes. These devices do not reduce the number of mosquitoes biting people in yards. The operation of these devices for several days does not reduce the mosquito populations.
- **Biocontrol agents:** Biological control or biocontrol includes the use of predators, parasites and pathogens for control. The only commercially available biocontrol agent for mosquitoes in Nova Scotia is the bacteria *Bacillus thuringiensis israelensis* (BT H-14).

Commercial formulations of BT H-14 contain the bacterial spores and crystalline endotoxins that are toxic to larvae of mosquitoes. Applied as a liquid solution or granules, BT H-14 is active against the larvae. There is no significant residual activity. While BT H-14 is highly effective against spring and summer *Aedes*, it may not be the product of choice to control *Culex* mosquitoes because of its brief residual activity.

- **Repellents:** A variety of effective mosquito repellents is available. How long the repellent works depends on:

- the active ingredient in the repellent
- the concentration of the active ingredient in the formulation
- the completeness of the application
- any factor that will dilute or cause the repellent to evaporate faster

Please note: the fact sheet from the PMRA on the use of insect repellents can be found at <http://www.hc-sc.gc.ca/pmra-arla/english/pdf/pnotes/deet-e.pdf>.

Compare the concentrations of the effective ingredients listed on the label of different brands. A repellent should be applied thinly, but evenly to all exposed skin. **Keep it out of your eyes.** Treat your clothing, especially, around the collar, cuffs and front openings on shirts or jackets. Always read the instructions on the label before use. Remember that all repellents are solvents of plastics and can damage eyeglass frames, watch crystals and synthetic fabrics such as nylon. Repellents with a high percentage of active ingredient tend to have more of an effect on plastics than formulations that are less concentrated. Hooded jackets already treated with repellent are available commercially. Any physical activity that results in perspiration will shorten the effective life of the repellent. Swimming, bathing or exposure to precipitation will quickly remove most repellents.

Sonic repellents do not repel mosquitoes.

- **Larvicides:** Generally, most mosquito control programs rely on larvicides (chemical or BT H-14). Since the larvae can live only in water, they are easier to control than the adults which are free to fly about over a wide area.

Larvicides are available in a variety of formulations (Table 1). These formulations are better adapted to some situations than others.

Table 1. Group and method of application of mosquito larvicides

COMMON NAME	CHEMICAL GROUP*	FORMULATION**
BT (H14)	Bacteria	S, G
methoprene	IGR	S, B
diflubenzuron	IGR	WP
chlorpyrifos	OP	EC, G
malathion	OP	EC

* OP=organophosphate; B=botanical; IGR=insect growth regulator

** S=solution; G=granular; B=briquette; WP=wettable powder; EC=Emulsifiable Concentrate; C=capsules

Capsules: Capsules contain an active ingredient held inside a covering. The covering breaks open after several hours of exposure to water releasing the active ingredient into the larval habitat. These are useful when a small area needs treatment. No application equipment is needed and they can be easily applied.

Briquettes: This type of formulation results in the active ingredient being slowly released into the larval habitat over a period of time. The residual activity of this formulation depends to a significant extent on the change over of water in the site because of precipitation. Briquettes are especially useful in a situation such as the control of *Culex* larvae found in small containers, or catch basins.

Emulsifiable concentrates, Wettable Powders, Solutions: The control of larvae in sites with no or minimal vegetation (catch basins, open ditches etc.) can be conducted with any of these formulations. They are mixed in water and applied with a variety of equipment ranging from back-pack sprayers through skid-truck mounted sprayers and mist blowers.

If there is a significant amount of vegetation in the treated sites, the insecticide may adhere to the vegetation and not reach the standing water. Off target drift may also be a problem and limit work when winds are significant. You must ensure that wettable powder formulations receive sufficient agitation for the product to remain in suspension during application.

Granules: Granular formulations are commonly used for the control of spring *Aedes* mosquitoes. The larval habitat is often under vegetation. The granules are used so that the active ingredient does not adhere to the vegetation, but falls to the standing water below. The use of granules minimizes drift and reduces user exposure during mixing and loading. Because the granules are very visible, it is easy to distinguish between treated and untreated sites. Granules can be applied with manual, powered back-pack blowers or vehicle-mounted equipment.

Larvicides should be applied when the majority of larvae are mid-way through their development (second and third instar). **Because larvicides do not control pupae, treatment must be made before the pupal stage.** The treated sites should be surveyed 24 to 48 hours after the application to establish whether the larvicide has been effective.

If there is significant precipitation immediately following the larvicide application, effectiveness may be reduced. Also, additional precipitation may cause another hatch of mosquito eggs, that may not be controlled by the initial larvicide application. A second treatment may be required to control these mosquitoes.

- **Adulticides:** A properly conducted larvicide program will reduce the mosquito population so that killing adults may not be required. However, occasionally adults may migrate into the area from untreated locations, or it may not be practical to conduct a larviciding program. The latter situation may occur in small northern communities or at work camps, summer camps, tourist resorts and cottages. Adulticiding alone is an activity which provides only temporary relief. Within a few hours, or perhaps a few days if the treated area is large, re-infestation will take place from the surrounding area.

Table 2. Chemical group and method of application for mosquito adulticides

COMMON NAME	CHEMICAL GROUP	APPLICATION METHOD*		
dichlorvos	OP		TF	ULV
propoxur	C	RS	TF	ULV
chlorpyrifos	OP	RS	TF	
naled	OP	RS	TF	ULV
resmethrin	SB		TF	
malathion	OP		TF	ULV
pyrethrin	B		TF	ULV
methoxychlor	CH	RS	TF	

* OP=organophosphate; CH=chlorinated hydrocarbon; B=botanical; SB=synthetic botanical; C=Carbamate.

** RS= residual spray; TF=thermal fog; ULV=ultra low volume

Mosquito adulticides may be applied as residual sprays, thermal fogs or as ultra low volume applications. The products available for use are listed in Table 2. The following provides a discussion of these application techniques:

Residual Spray

Back-pack, truck-mounted mist or high pressure sprayers are used to deliver a variety of insecticides (Table 2) to kill mosquitoes where they rest during the day. This equipment typically produces a droplet size of 50 to 400 microns depending on the pressures and nozzles used. This droplet size is significantly greater than that used for thermal fogging or ULV applications described below. Therefore, drift is usually a less significant problem with this type of application.

Residual sprays may be applied where specific areas are to be protected, or as a barrier treatment to prevent the migration of mosquitoes into an area. Areas such as industrial work areas, private yards, playing fields, parks and golf courses are areas where such sprays can be effective.

Areas where mosquitoes rest during the day should be treated. This is typically in areas of dense vegetation with high humidity. For greatest effectiveness, applications should be done in late afternoon or early evening shortly before mosquitoes become active. Some emulsifiable concentrate formulations may be phytotoxic. Avoid direct application of these formulations to foliage and consult the label as to whether or not foliage should be treated.

Thermal Fog

Thermal fogs are produced by introducing an insecticide mixed with diesel fuel, fuel oil or kerosene on to a warm manifold and subsequently into a stream of air. This results in the production of a dense grey fog consisting of droplets ranging in size from 0.5 to 50 microns. This fog or cloud of extremely fine spray droplets lingers near the ground, penetrating the area inhabited by adult mosquitoes. The insecticide enters the mosquito through the exoskeleton or through the breathing system. Residual deposits are minimal and insufficient to kill mosquitoes landing later on. Thermal fogging will reduce biting activity for several hours to several days depending on the environmental conditions during and following the application, the size of the mosquito population, and the effectiveness of the active ingredient chosen.

Experience has shown that mosquitoes must be in a fairly dense fog for a minimum of 20 - 30 seconds to be killed. If the fog is intermittent and the mosquitoes are exposed to it for a lesser period of time, they are likely to survive. Fog density and exposure time are the two important factors. Unless atmospheric conditions (wind and temperature), and the fog produced are such that a dense fog moves slowly through the area to be protected from 0-5 m above the ground the effectiveness of the treatment will not be satisfactory.

Fogging is most effective when conducted during the evening or early morning hours. At this time a temperature inversion may occur and is desirable (cooler air at ground level with a warmer air above). Fogs tend to rise and are dispersed too rapidly during the heat of the day. An inversion causes the warm fog containing the insecticide to stay near the ground.

Although some air movement is desirable to carry the fog through the area, the wind should not be greater than 15 kph and ideally should be 5 - 8 kph.

An additional advantage to fogging during the evening is that, at this time, usually the greatest number of mosquitoes are starting to move from their resting places and thus more likely to be contacted by fog.

The fogging machine should be moved in a direction at right angles to the wind direction. Additional passes should be made through the area, still moving across the direction of the air movement. The distance between passes is governed by the necessity that all parts of the area should be exposed to a dense fog for the required period of time. This will regulate the rate of travel of the fogging machine.

The best results are produced from fogging machines when the instructions for operating, cleaning and maintaining the particular machine are followed. It is preferable to have one person responsible for operating and maintaining the machine. Straining the insecticide as it is poured into it may avoid clogging. It may also be advantageous to flush out the machine at the end of each fogging season by running fuel oil through it.

Problems associated with the use of thermal fogging include:

- weather conditions that are inappropriate for the fogging; (often wind speed is too high)
- inadequate access to the area where most of the mosquitoes are resting
- it may be impractical to apply the fog at right angles to the wind;
- the swath width is too wide because of dense vegetation
- the fog produced may impair the safe driving of vehicles
- be certain to “warm up” the thermal fog generating equipment before application or a “wet” fog will be produced. This “wet” fog may be phytotoxic.
- fogging may have an adverse effect in off target drift.

Ultra Low-Volume

Ultra low volume machines break specially concentrated formulations of insecticides into very small droplets and disperse them by means of a powerful air blast system. The formulations used have a relatively high percentage of active ingredient and are often used undiluted. This significantly reduces the size of the tank required on the sprayer. The size of droplets produced is in the 5 to 20 micron range. The ideal range for mosquito control is 5-15 microns. This technology was developed in part to eliminate some of the problems associated with the use of thermal fogs. The aerosol produced is almost invisible, and drift is more controlled than with thermal fogs.

The insecticide droplets kill mosquitoes by direct contact and should be applied in the late afternoon and early evening hours when mosquitoes are active. A low wind velocity usually aids in dispersing ULV aerosols.

Larvicides And Adulticides

Mosquito larvicides and adulticides may be divided into four groups:

- insect growth regulators
- botanical and synthetic botanical
- chlorinated hydrocarbon
- organophosphate and carbamate

Insect Growth Regulators

Methoprene is an insect growth regulator used to control mosquito larvae. It causes abnormal development in larvae, pupae and adult insects when applied during the larval stage. Death usually occurs when the pupa attempts to moult to the adult. Methoprene itself has a residual life of only several hours. Therefore the formulations sold, slowly release methoprene into the larval habitat. It is sold in a slow release liquid formulation or as briquettes. The briquettes are especially suited for the control of *Culex* mosquitoes in permanent water sites while the liquid formulation is effective against *Aedes* larvae.

Diflubenzuron is an insect growth regulator that prevents the chitin from forming in the insect's exoskeleton. As a result the mosquito is killed at its next moult. It is not effective against pupae or adult mosquitoes. The residual life is a maximum of several days. It has little residual activity and is not suitable for the control of *Culex* mosquitoes in its wettable powder formulation.

Botanical and Synthetic Botanical

Pyrethrins (the pyrethrum extracts from chrysanthemums) are the only botanical insecticides used for mosquito control. Various formulations of pyrethrins are available for the control of many insect pests, including larval and adult mosquitoes. They are often formulated with piperonyl butoxide, a synergist, or other active ingredients to increase their insecticidal activity. They work faster at lower temperatures, a property known as a negative temperature co-efficient.

Capsules containing pyrethrins are used to treat small, mosquito larval habitats. They are easy to apply with no application equipment and are ideal for the treatment of small spring or summer *Aedes* sites. The negative temperature coefficient results in pyrethrum being especially effective against spring *Aedes* mosquitoes.

Both thermal fog and ultra low volume formulations of pyrethrin are available for the control of adult mosquitoes.

Resmethrin is a synthetic botanical used for the control of adult mosquitoes. It is similar to pyrethrum in many ways but is generally more effective and has a longer residual activity. It is applied as a thermal fog.

Both **pyrethrin** and **resmethrin** are known for their rapid “knock-down” of flying insects including mosquitoes.

Chlorinated Hydrocarbons

Methoxychlor is the only chlorinated hydrocarbon used to control mosquitoes. It is available as an emulsifiable concentrate for the control of adult mosquitoes.

Organophosphates and Carbamates

Two organophosphate insecticides are currently used to control mosquito larvae, namely: **chlorpyrifos** and **malathion**. In mosquito larval habitats chlorpyrifos has a residual life of several weeks; malathion shows residual activity for several days. Chlorpyrifos is available in granular formulations that make them especially suitable for use in habitats that have dense vegetation. Malathion does not show sufficient residual activity to control *Culex* mosquitoes. However, chlorpyrifos with a longer residual life may be an effective agent for the control of mosquitoes in this genus.

Four organophosphate and one carbamate insecticide are used to control adult mosquitoes (Table 2). These vary in residual activity from virtually none to several days, depending on the method of application and product used.

Record Keeping

The collection of data and accurate record keeping provides information that will help to:

- identify areas consistently requiring treatment
- monitor costs and develop future budgets
- establish the effectiveness of the program
- identify where improvement may be made
- defend any liable action directed at the program

Detailed records should be maintained concerning:

- **Larval Surveillance:** The maps, aerial photographs, and related information discussed in the monitoring should be maintained on an ongoing basis.
- **Larval Treatment:** Details of the control method used together with data on effectiveness should be kept with the pond number. This includes information concerning any habitat alteration that has been done, and the use of biocontrol agents and insecticides etc.
- **Adult Surveillance:** Records concerning all the monitoring of adult mosquito populations should be maintained.
- **Application Equipment:** Type and number of equipment used, repair or replacement time and costs; vehicle allocation and depreciation should all be recorded to help plan budgets and maintenance schedules.
- **Notification:** Records must be maintained concerning the methods of notification used to inform people regarding the details of the mosquito control program.

Black flies

Black flies belong to the family *Simuliidae*. Black flies are also known as buffalo gnats, turkey gnats, ear flies and sand flies. Adult female black flies feed on blood causing irritation and discomfort to humans, domestic and wild mammals and birds.

Female black flies have short, piercing-rasping mouthparts which slash the skin before sucking blood. The males, which do not blood-feed, have sponging mouthparts. They feed on the nectar of flowers to meet their energy requirements. Both sexes of black flies feed on moisture released through pores on the underside of leaves. The female starts looking for her blood meal approximately two weeks after emerging. Unlike the mosquito, the black fly bites only during the day. On animals they bite not only the exposed skin but also invade the ears and nostrils. On humans, in addition to biting exposed areas, they also crawl through openings in clothing. Although the actual bite may not be painful, swelling may occur later and the area may remain sore and itchy for several days. Some species that seldom bite can nevertheless be very annoying because of their habit of flying about the head and face.

Identification

Adult black flies are small (1-5 mm in length), stout-bodied, hump-backed flies with short, broad wings and short legs. They have short, thick antennae with 9-11 segments. There are about 150 species of black flies in Canada. Only 6 or 7 species are major pests of humans.

In Eastern Canada, only two species complexes are severe pests. The first of these to appear (with the bursting of the buds of forest trees) is the *Prosimulium fuscum-mixtum* species complex. Adults are pale to dark brown and have uniformly brown legs, without white bands. The species of *Prosimulium* last only 1-2 weeks before being largely supplanted by the *Simulium venustum-verecundum* species complex, a group of blacker species with black and white banded legs. The peak of abundance of the *venustum* species complex is in June or early July, depending on latitude. Thereafter, the problem usually subsides, although a few species continue to create local problems. *Simulium decorum* may become noticeable in autumn (though present all summer, this species either does not attack humans or is so outnumbered by the *venustum* complex that it escapes detection).

Many black fly genera do not bite humans and do not need to be controlled. Proper identification will minimize the number of sites requiring treatment. A key to help identify the larvae and adults of the major genera of black flies is included on the following pages. The groups that do not bite humans are indicated on the key.

It is strongly advised that you consult a specialist in this field if you need to identify black flies to species.

Adult Black flies

- 1) Dorsal surface of stem of wing vein R with no setae (fig. 20)
 - biting species of *Simulium*
 - Dorsal surface of R with setae 2
- 2) Rs wing vein deeply forked; stem same length as or shorter than branches (fig. 21)
 - 3
 - Rs unforked or shallowly forked; stem much longer than branches (fig. 22)
 - *non-biting spp. of *Simulium*, *Greniera*, *Cnephia*, *Mayacnephia*, *Metacnephia*, *Stegopterna*, *Ectemnia*
- 3) Wing smoky brown, opaque **Gymnopsis*
 - Wing clear or, if tinted, transparent 4
- 4) Antennal flagellum 7-segmented, 9 segments in all (fig. 24) 5
 - Flagellum 9-segmented, 11 segments in all most spp. of *Prosimulium*
- 5) Vein R₁ joining C at or beyond midlength of wing. Vein C extending around margin of wing well beyond its junction with R₄₊₅. Setae on C and all branches of R as long as cross-vein r-m (fig. 23) **Parasimulium*
 - Vein R₁ joining C beyond midlength of wing. Vein C ending close to junction with R₄₊₅. Setae on veins much shorter than length of r-m 6
- 6) Shiny spherical protrusion behind eye (fig. 24,a) **Twinnia*
 - No-shiny spherical protrusion behind eye *Prosimulium gibsoni*

* Genera not known to bite humans

These keys are from the publication Insect Identification; Supplement No.1; Third Edition; To Canadian Forces Manual On Pest Control (A-MD-115-001/FP-Z01) 94 pp.

Late-Stage Larvae

- 1) Lateral margins of head capsule convex, labral fans absent (fig. 25)
 **Gymnopais*, *Twinnia*

- Lateral margins of head capsule more or less parallel, labral fans present (fig. 26)
 2

- 2) Basal 2 segments of antenna pale, contrasting with dark pigmented distal portion.
 Median tooth of hypostome, on underside of head (fig. 27), prominent and clearly trifold
 (fig. 28) 3

- Basal 2 segments of antenna pigmented, as dark or almost as dark as distal segments.
 Median tooth of hypostome not trifold 4

- 3) Cervical sclerites strap-shaped (as in fig. 26) *Prosimulium*

- Cervical sclerites reduced to dots of pigmented cuticle **Stegopterna mutata*

- 4) Median tooth of hypostome projecting as far anteriorly as largest lateral teeth (fig.
 29) *Simulium*

- Median tooth either small and similar to other teeth of hypostome or flanked by 2
 prominent groups of lateral teeth 5

- 5) All teeth on hypostome small (fig. 30) **Ectemnia*, *Cnephia*, *Metacnephia*

- Lateral teeth of hypostome in prominent groups, projecting much further forward than
 median tooth (fig. 31) **Greniera*, *Mayacnephia*, *Stegopterna emergens*

* Genera not known to bite humans

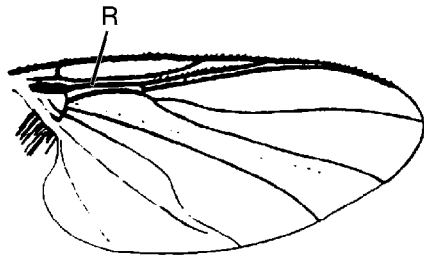


Figure 20

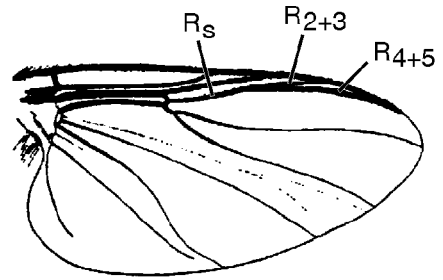


Figure 21

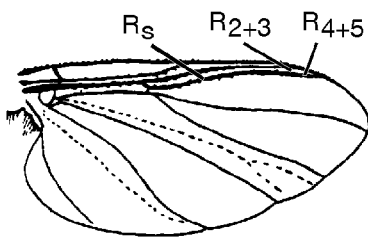


Figure 22

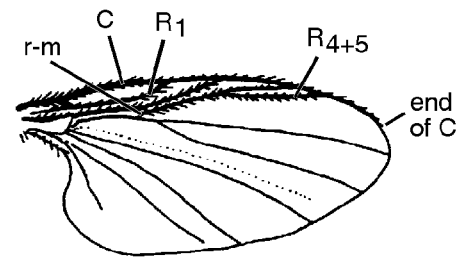


Figure 23

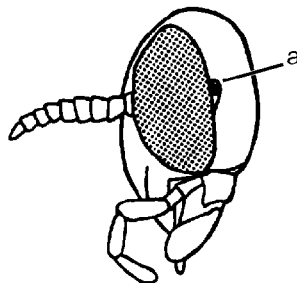


Figure 24

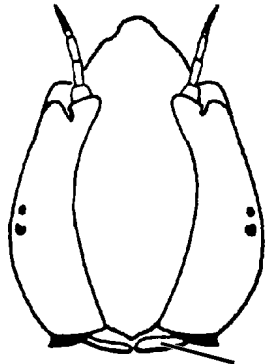


Figure 25
cervical sclerite

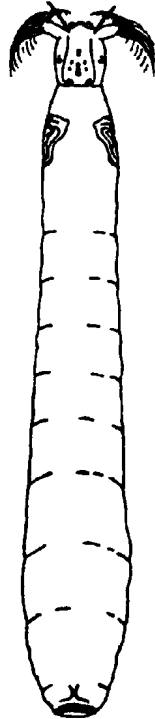


Figure 26

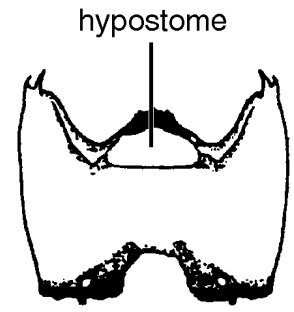


Figure 27
hypostome

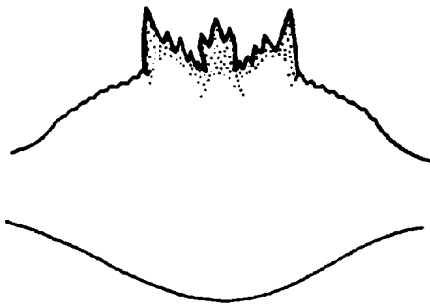


Figure 28

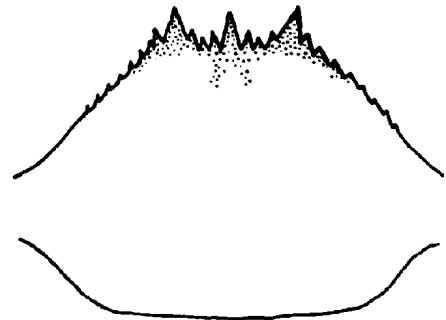


Figure 29

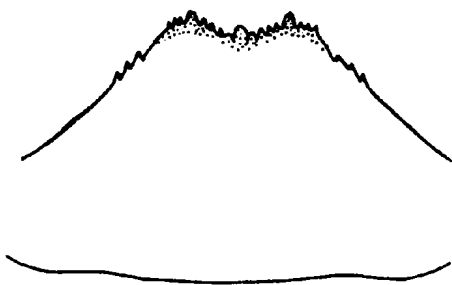


Figure 30

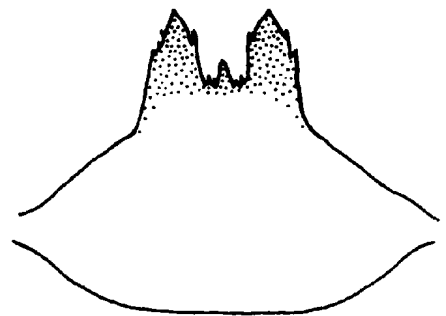


Figure 31

The Life Cycle and Behaviour

Like the mosquito, the black fly also has four life stages: egg, larva, pupa, and adult (Figure 32). The first three stages are found in fast-flowing water. They are in rapids, beaver dams and even below waterfalls. In the spring, every stream and rivulet is a potential breeding place for black flies. Unlike the mosquito which breathes at the water surface, the black fly larva and pupa obtain their oxygen directly from the water. This explains the need of black fly larvae for flowing water which is well aerated, while the mosquito larvae live in standing waters.

Different species of black flies differ greatly in details of their development including:

- the stage in which they overwinter
- preferred water temperature for development
- types of streams in which they live
- number of generations per year

Depending on the species, black flies may have one or several generations per year. In the latter case, the number of generations may overlap so that at a given time any of the four life stages of a species may be present.

The adult females lay eggs on or in moving water, or on rocks, weeds or other materials at or just under the water's surface. Depending on species, each female can lay 200 to 500 eggs. The eggs may hatch within a few days or several months. Some species overwinter in the egg stage.

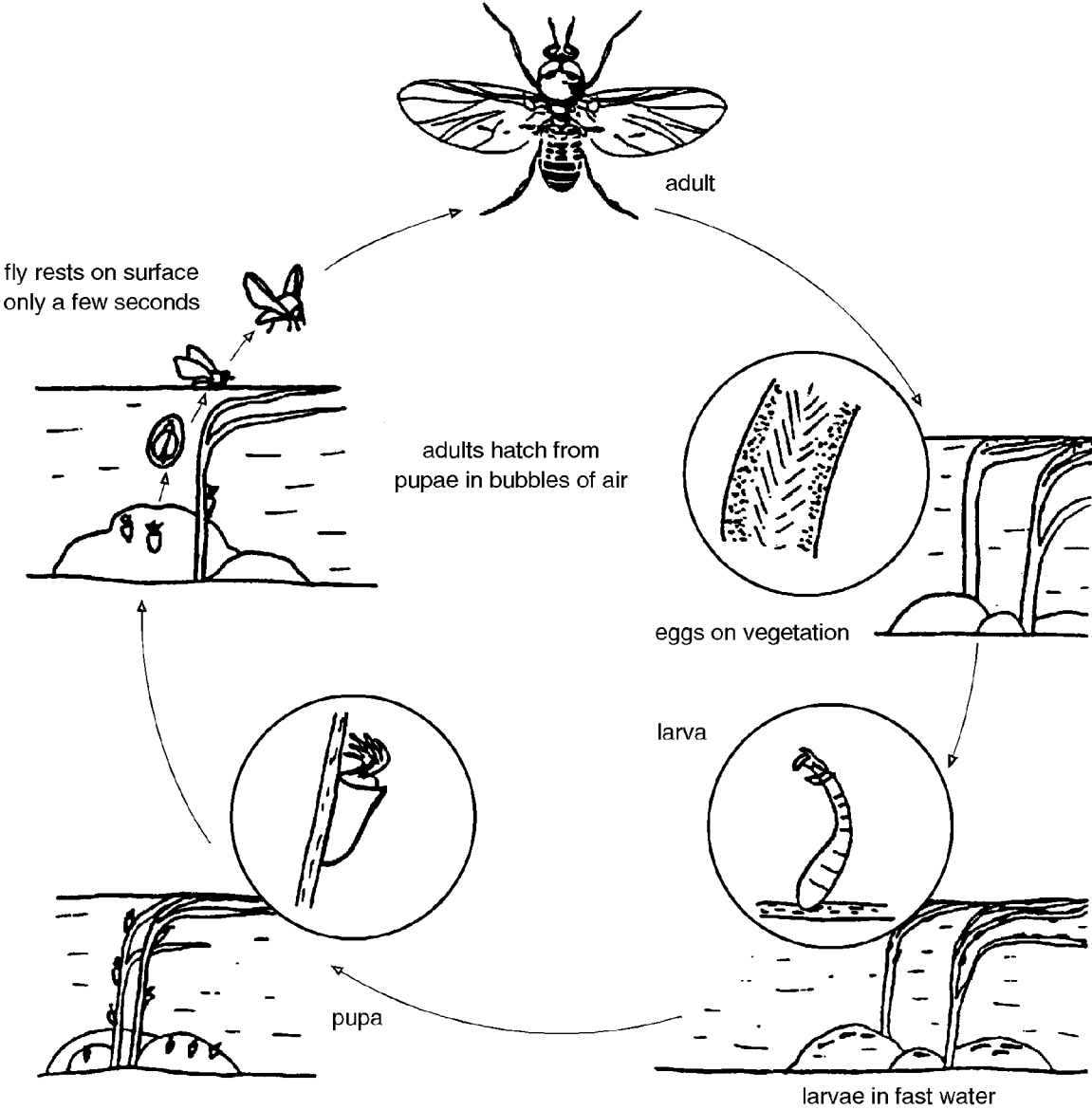
The eggs hatch into larvae which attach to stones, sticks or vegetation under the water. The larvae may be dark brown, green or pale in colour. When very numerous, they cause the object to which they cling to have a slimy appearance. The larvae feed by filtering organic matter from the passing water. The larvae moult 5 to 8 times before pupating and when full grown are about 1 centimetre long. The larval period varies from 2 weeks to several months depending on the species and water temperatures. Some species may overwinter in the larval stage.

The larvae spin cocoons which are attached to objects in the water. Cocoons vary in form. In some species they may be of loosely woven silk-like material; in others they may be firmer and slipper-shaped. The larvae change into pupae within the cocoons. The adult emerges from the pupal skin, rises to the water surface and takes flight almost immediately. Mating usually occurs soon after emergence. The females then begin to search for a blood meal.

The adult black fly may live for a few days to several weeks. For some species several generations may occur in one year. Biting activity may continue into October.

Some black fly species are very active fliers commonly dispersing 30-40 km. They may be carried by the wind more than 100 km.

Figure 32. Generalized life cycle of black flies.



Black flies are most active when the wind is less than 5 km/h. They will attack during daylight with more activity at dawn or dusk. They become more aggressive on cloudy days and when storms are approaching. They usually do not bite when in buildings, tents or vehicles.

Monitoring Black fly Populations

Preparation for a successful black fly management program begin well before the black fly season. Monitoring for black fly control must include records of:

- dates, times and severity of biting activity
- weather records
- preserved samples of adult flies
- preserved samples of larvae and pupae from as many sites as possible in rivers and streams within a minimum 8 kilometre radius of the proposed areas where control is desired (refer to the mosquito control section for directions on labelling and preservation of larvae and pupae)
- maps indicating the location of all larval breeding sites (stream riffles, dam spillways, beaver dams, etc.)

Monitoring larval populations

A survey of larval habitats should extend as far as possible and practical since the adult can disperse significant distances. The survey of streams and rivers should begin as soon as the ice breaks up in the spring. It should be repeated at 10 day to 2 week intervals for as long as the black flies are bothersome.

Survey larval breeding sites by checking rocks, twigs, and other vegetation in the water for larvae or pupae. Artificial substrates such as light coloured ceramic tiles or weighted survey tape may be placed in the stream bottom to collect larvae for identification. These artificial substrates may also be used to determine the effectiveness of the program.

Since some pest species of black fly overwinter as larvae, it may not be possible to conduct the larval survey and make a treatment the same year. In addition it may require several months to obtain proper species identification of the larvae and adults collected. Sampling of larvae throughout the first survey season will help to determine proper treatment timing and site locations for the following year.

Monitoring adult populations

Surveys of adult black fly populations may be made using a sweep net. Use the sweep net to gather resting black flies in vegetation near larval breeding habitats or where significant adult biting activity is present. The sweep net can also be used to collect adult black flies that are flying around your body, especially your head.

A dark blue cloth (30.5 cm square) may also be used to estimate adult black fly populations. Place the cloth in your lap and following a two minute interval, record the number of black flies which land on the cloth and fold their wings during the two minutes. The identification of these adults will indicate which species are actually a problem in the area. It may not be the most common larvae found in the area.

Control of Black flies

As discussed for mosquitoes, the selection of a control method or a combination of control methods for black flies depends on the:

- size of the area to protect
- financial resources available
- acceptability of the control method to the public
- availability of application equipment

Some of the options available to control mosquitoes are not effective or practical for the control of black flies. For example, since black fly larvae live in fast-moving streams or rivers, it is not practical or desirable to eliminate these habitats.

As discussed for mosquitoes, light traps are not effective for the control of either mosquitoes or black flies.

Black fly Larvae

The most practical control methods for black flies include:

- **Protective clothing:** If people must be in areas with high black fly populations they should wear clothing designed to exclude black flies, e.g. long-sleeved shirts, light jackets, trousers and socks. Some clothing (available in fishing and hunting stores) is specifically designed to exclude black flies. Keep in mind that black flies will land and crawl under clothing to obtain a blood meal. Therefore clothing should be sealed with elastic at the wrists and ankles. Head nets are also available that will exclude black flies. Remember that lighter coloured clothing is less attractive to biting flies than dark clothing.

Black flies will rarely bite indoors; therefore, work indoors if at all possible when black fly populations are severe.

- **Biocontrol agents:** This includes the use of predators, parasites and pathogens for control. The only commercially available biocontrol agent in Canada is the bacteria *Bacillus thuringiensis israelensis* (Bt H-14). It is a highly effective and selective biocontrol agent. The application methods discussed for chemical larvicides apply to BT H-14
- **Repellents:** The same repellents used against mosquitoes will work against black flies. However, they are usually effective for a shorter period.

The following factors are important in the use of biocontrol agents and larvicides:

- **Timing:** Since the recommended larvicides are effective only against the larvae, treatment should be made when the greatest number are in the larval stage. This may be immediately after ice starts to leave, or as late as mid-May depending upon species, and local weather. Thus, to ensure the best timing, monitoring of breeding sites should begin early in the spring. Treatment should be timed for when the larvae are very numerous and are about 6 mm long. Treatments are not effective against pupae; therefore, application must occur before pupae are present.
- **Application:** In general, the larvicide should be applied to the streams or rivers at intervals of 400-800 metres. However, the optimum spacing should be determined by past experience. Where possible, treatment sites should be located above rapids, below dams, or pond or lake outlets where the water is highly oxygenated. Stream turbulence is needed to ensure adequate mixing. Wide streams will need more than one injection point across their width. Back-pack sprayers or other application devices may be used to apply the larvicide and ensure good mixing of the larvicide in the water.

Because black flies are excellent fliers, the area in which larvae should be controlled may be significantly larger than that required for mosquito control. It is not possible to state the area required for good control. Certainly, the larger the area treated, the lower the biting activity in the treated area. Cost usually limits the amount of time and labour available, and thus the size of the area in which larvae can be controlled.

- **Assessment:** The effectiveness of the treatment should be assessed 24 to 48 hours after application by counting the number of larvae remaining on natural stream substrates or artificial substrates used in the initial surveys. Several treatments may be required in one year depending on the species present. Species with several generations each summer may re-infest a larval breeding habitat.

The effectiveness of the control program should also be monitored on the basis of adult populations within the control area. This could be done using sweep nets or monitoring biting activity. However, the biting activity of adult black flies is very weather dependent and assessments of biting activity difficult.

Adulticides

Black flies bite only during daylight hours. Usually the peak time of activity is during the late afternoon and evening. However, in wooded areas especially on cloudy warm days, they bite throughout the day. Black fly activity is suppressed by winds of 5 kph or more, especially in open areas.

Methoxychlor, and **propoxur** are the only registered black fly adulticides. The formulations that are available are the same as mosquitoes (Table 2). Refer to the discussion of these active ingredients and their formulations in the mosquito section of this module.

Similar to mosquitoes, black fly adulticides may be applied as:

- residual sprays
- thermal fogs
- ultra low volume applications

Refer to the discussion of these application methods in the mosquito section.

The control of adult black flies usually provides only several hours, or at best several days of reduced biting activity. Application should be done when the black flies are most abundant, ie. early morning or during the late afternoon or throughout warm, still, overcast days. Generally adult black fly control must be conducted on a consecutive daily basis over a large area to reduce biting activity significantly. Repeat applications at dawn and dusk are necessary if adults continue to emerge and move into the treated area.

Record Keeping

As discussed with mosquito control, the collection of data and accurate record keeping provides information critical to the success of your program. Refer to the discussion concerning mosquitoes for what types of information should be recorded.

Review Questions

1. What do adult male mosquitoes and black flies feed on?
2. What do adult female mosquitoes and black flies feed on?
3. Where are the larvae of mosquitoes found?
4. List the three genera of mosquitoes commonly found in Nova Scotia.
5. What stage of the life cycle of the *Culex* mosquito survives the winter?
6. How much precipitation is usually required for a hatch of summer *Aedes* mosquitoes?

