Mosquitoes, West Nile Virus, and Procedures Used for Mosquito Surveillance and Control

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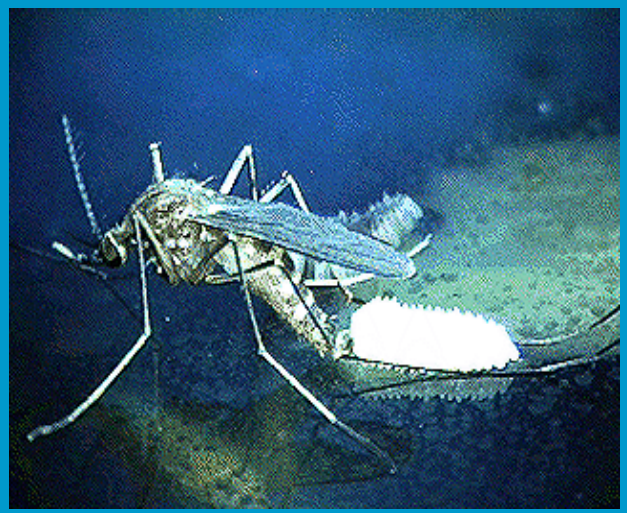
VDH VIRGINIA DEPARTMENT OF HEALTH
Protecting You and Your Environment

Basic

Mosquito

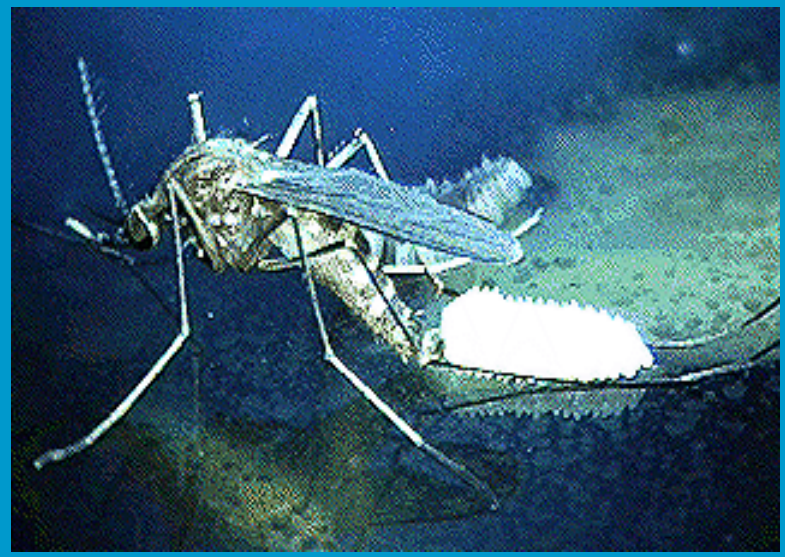


Biology

Mosquito biology and behavior

As with most insects, mosquitoes go through four stages of life that include: egg, larva, pupa and adult.

Adult mosquitoes lay their eggs in water or in places that will become aquatic habitats as soon as rain falls or there is a flood.



Once in contact with water, eggs may hatch and become larvae.

Larvae feed on microorganisms in the water, and go through 4 growth stages until they pupate to become comma-shaped pupae.

Adult mosquitoes soon exit the pupal skin and fly off to find a blood meal and then to lay eggs.

Most mosquito species breed in shallow, temporary bodies of water.

Permanent bodies of water (ponds and permanent marshes or swamps) develop resident populations of predatory species (fish, amphibians and insects) that prey upon and eliminate the mosquitoes that hatch from eggs laid in those environments.

In temporary bodies of water (puddles, residual ditch water or artificial containers) mosquitoes are able to complete their development before predators can become established.

Only a few mosquito species have evolved predator evasion strategies needed to complete their development in permanent bodies of water.

Most mosquito larvae like shallow water and are mostly found along the edges of aquatic habitats in places where the water is less than 3 inches deep.

Mosquito larvae feed on organic debris and microorganisms that are suspended in water or are found on the bottom of their aquatic habitat.

If they are in deep water they will need to swim too far to reach the bottom to feed.

If they are in deep water they cannot quickly swim to the bottom to hide from predators. They may also be easily picked off by predators when they are swimming to and from the bottom.

Mosquito Development Time (the time from egg hatch through the larval/pupal stages to adult emergence) varies with species as well as with water temperature and nutrient levels. Higher temperatures and nutrient levels yield faster development rates.

At normal water temperatures most mosquito species take 10 to 14 days to complete their development.

A few mosquito species can complete their development in 7 to 8 days if water temperatures and nutrient levels are favorable.

One mosquito species can complete its development in as little as 5 days if conditions are ideal, but it normally requires 6 to 7 days for development.

One mosquito species requires a whole year to complete its development.

Approximately 55 species of mosquitoes can be found in Virginia. Each of these mosquito species is hard wired with its own unique behavior and biology.

Variation among mosquito species plays a big role in whether they are important pests or disease vectors.

This variation includes:

Feeding preferences - the source of blood meals (e.g., birds, rodents, large mammals, frogs, people, or a combination of several, or many animal types).

Activity / feeding times - the time when they fly in search of blood e.g., day, evening, night, morning, evening and morning, etc.).

Variation among mosquito species:

Flight range - how far a mosquito species will fly from their breeding habitat in search of blood (e.g., 100 yards, ½ mile, 5 miles).

Domestic affiliation - a mosquito's attraction to human structures and tendency to enter homes to feed.

Overwintering stage - stage that overwinters (i.e., egg, larva, or adult mosquito).

Vector competence – ability for an adult mosquito to become infected by a disease and be able to spread it while feeding.

Breeding habitat – where adult mosquitoes prefer to lay their eggs.

Mosquito breeding habitats

Breeding Habitats of Common Pest and WNV Vector Species:

Containers and Other Habitats

Culex pipiens *	Small and # large containers, puddles, grassy flood pools, stagnant ditches, * water with high organic content.
Culex restuans *	
Culex salinarius #	
Anopheles punctipennis	

Containers Only (Artificial and Natural)

Aedes albopictus	Small and large containers, tree holes, natural rock pools.
Ochlerotatus triseriatus	
Ochlerotatus japonicus	
Ochlerotatus atropalpus	

Species that fly and bite only during daylight hours.

Breeding Habitats of Common Pest and WNV Vector Species:

Salt Marsh Environment

Ochlerotatus sollicitans
Ochlerotatus taeniorhynchus
Culex salinarius #

Temporary puddles, pools or flooded ditches in salt marsh habitats, or areas of # brackish water.

Flood Pools

Aedes vexans
Psorophora columbiae
Ochlerotatus canadensis
Ochlerotatus trivittattus
Ochlerotatus sticticus

Temporary flood pools in open fields or shaded locations.

Species that will commonly fly and bite during daylight hours.

Breeding Habitats of Common Pest and WNV Vector Species:

Woodland Pools

Aedes vexans

Ochlerotatus atlanticus

Ochlerotatus canadensis

Ochlerotatus sticticus

Ochlerotatus tormentor

Psorophora ferox

Temporary or seasonal woodland pools containing dead leaves.

Species that will commonly fly and bite during daylight hours.

Breeding Habitats of Common Pest and WNV Vector Species:

Permanent and Semi-permanent Aquatic Habitats

Anopheles crucians [#]
Anopheles punctipennis [#*]
Anopheles quadrimaculatus [#*]
Coquilletidia perturbans [@]
Culex erraticus [#]
Culex salinarius [#]

[#] Grassy or vegetated margins of semi permanent pools, ponds, marshes, swamps; @cattail marshes; *margins of slow moving streams, or stream pools and/or ponds having floating debris or emergent vegetation.

Some Pest and WNV Vector Mosquito Species that Might Potentially Breed in Temporarily of Permanently Flooded Storm-water Management Basins

1. *Aedes vexans* — Temporary puddles
2. *Anopheles crucians*
3. *Anopheles punctipennis* — Permanent ponds
4. *Anopheles quadrimaculatus*
5. *Coquilletidia perturbans*
6. *Culex erraticus*
7. *Culex pipiens*
8. *Culex restuans* — Temporary puddles
9. *Culex salinarius* — Temporary and Permanent ponds
10. *Ochlerotatus canadensis*
11. *Ochlerotatus sticticus*
13. *Psorophora columbiae*

Species that are most commonly found in storm-water management basins

2003 study by Dr. J. B. Gingrich, University of Delaware

Species that will commonly fly and bite during daylight hours.

Mosquitoes as Vectors of West Nile Virus

Vector competence – a mosquito's tendency to become infected with a virus, harbor it, and transmit it to other hosts.

Mosquito species that serve as WNV vectors can only do so by having a completely disseminated WNV infection.

Disseminated infections occur when the WNV virus moves from blood in a mosquito's gut, through the gut wall, and infects tissues throughout the mosquito's body.

The mosquito can only become a WNV vector when its salivary glands have become infected.

The time required for completion of a disseminated infection may be days or weeks depending on mosquito species and environmental conditions.

In the transmission of WNV, a mosquito's level of vector competency may not be as important as its feeding preferences.

Birds are the only animals thought to serve as reservoirs where feeding mosquitoes can pick up WNV. So, a mosquito species could be proven to be a highly competent WNV vector in the laboratory, but if it rarely bites birds in nature, it would not pick up the virus, and thus, would not be an important WNV vector.

A mosquito species that commonly bites both birds and mammals may be an important WNV vector even if its vector competency is somewhat low.

Mosquito species that feed only on birds, pick up WNV, and only pass it on to other birds are known as primary vectors .

Mosquito species that feed on both birds and humans or other mammals are known as bridge vectors. They serve as a bridge for the virus to move from bird to mammal.

WNV vector competence test results for 15 mosquito species found in Virginia.

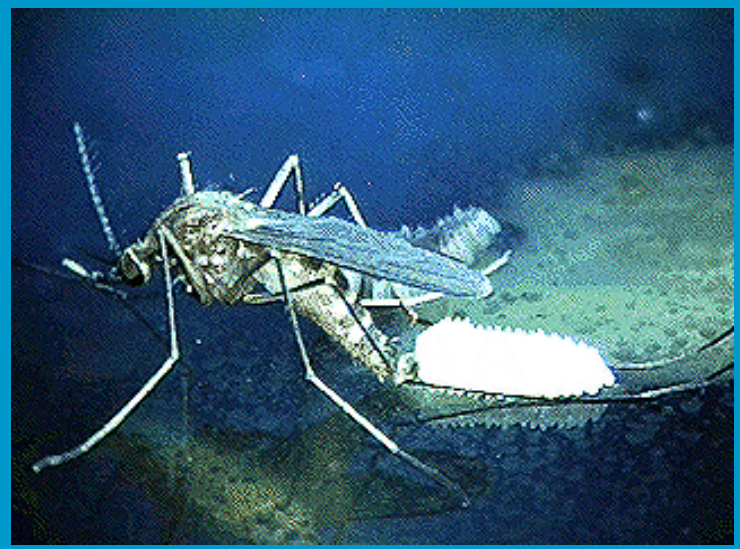
Vector Competence		
Efficient	Moderately Efficient	Not Efficient
Ae. albopictus * *Cx. salinarius* @ * *Oc. atropalpus* *Oc. japonicus* *	*Ae. aegypti* *Ae. vexans* * *Cx. pipiens* @ * *Cx. restuans* @ *Oc. triseriatus* *	*Cq. perturbans* *Oc. canadensis* *Oc. cantator* *Oc. sollicitans* *Oc. taeniorhynchus* *Ps. ferox*

Species that are most likely to be important WNV primary vectors @ and/or bridge vectors * in Virginia

Habitats of the seven mosquito species that are considered to be the most important WNV vectors in Virginia .

Culex salinarius	Marshes, ditches, puddles and large artificial containers
Aedes albopictus	Large and small artificial or natural containers
Ochlerotatus japonicus	
Ochlerotatus triseriatus	
Culex pipiens *	Artificial containers, sewers*, ditches and puddles
Culex restuans	
Aedes vexans	Floodwater (ditches, puddles, field and woodland flood pools)

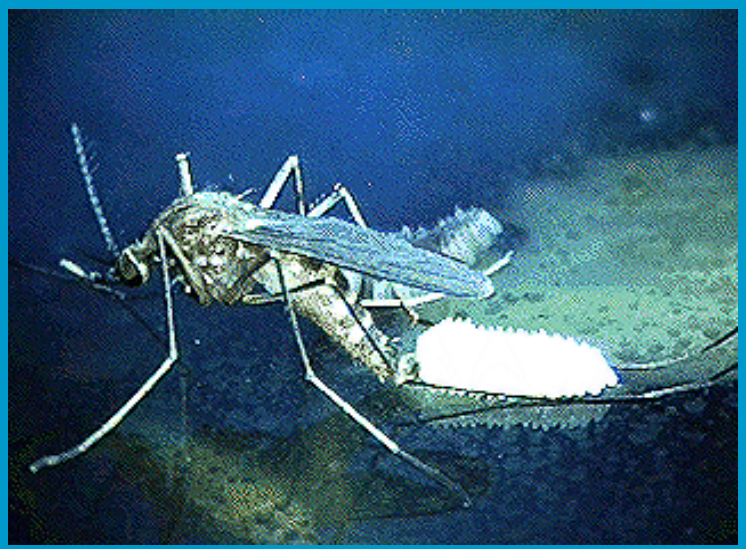
Among Virginia mosquito species, the two most important primary vectors and bridge vectors for WNV are *Culex pipiens* and *Culex salinarius* . These two species bite only at night, so they are mostly a threat to people that sit out at night, or do not have screened windows.



***Culex pipiens*, the "northern house mosquito" feeds mostly on birds and is the most important primary vector for WNV. It may play a role as a bridge vector because of its habit of entering homes and biting people indoors. It breeds in polluted water such as agricultural run-off, storm drains, sewage, and in artificial containers. These are habitats that are often found near homes and in urban settings.**

Culex salinarius "the marsh Culex" is common throughout all parts of the Eastern U.S. and may be locally abundant near marshes. It often breeds in stagnant water in ditches and puddles containing grass, weeds or other plant matter.

This mosquito feeds equally on birds, large mammals, and humans, and may fly several miles from its breeding habitat. It may also breed in any large container that contains water polluted with grass or other dead vegetation. Like *Culex pipiens*, this mosquito feeds only at night and will enter homes through any open window or door, and bite indoors.

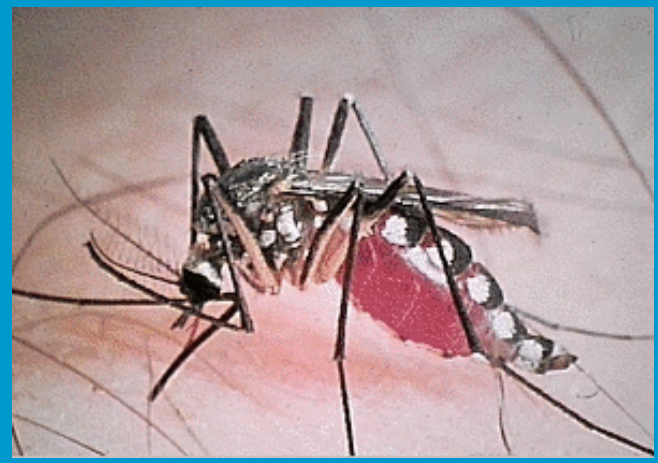


Among the most important WNV bridge vector species are the other container breeders. That is because they are competent WNV vectors, they bite people during the daylight hours, and are often found close to homes. These mosquitoes include:

Ae. albopictus **- the Asian tiger mosquito**

Oc. triseriatus **- the eastern tree hole mosquito**

Oc. japonicus **- a new Asian rock pool mosquito**



These daytime biting species only breed in containers and will not come from any ground pool, ditch, or puddle having a soil substrate. If citizens are being bitten by these mosquitoes, containers are the source of the problem!

Mosquito Surveillance

Mosquito surveillance is the cornerstone of mosquito control. No mosquito control program can operate effectively without a surveillance program.

Mosquito surveillance reveals:

- **The species of mosquitoes that are active in a community**
- **The presence of disease vector species**
- **The presence of mosquitoes infected with arboviral diseases**
- **The breeding habitats of the local species**
- **The size of the local mosquito population**
- **The best time and place to apply pesticides to control the mosquito population.**

Mosquito surveillance uses several methods. The two most important methods are:

Trapping and collection of adult mosquitoes

Dip sampling for larval mosquitoes

Trapping and identification of adult mosquitoes reveals what species are present locally and provides information on their local abundance.

Adult mosquito control programs rely on adult trapping to indicate when and where to apply pesticide fogs, and to measure the effectiveness of control efforts.

Identified mosquitoes can also be submitted to a laboratory for arboviral testing.

CDC Type Trap

Investigative mosquito trapping may be conducted to determine whether mosquito population are present near to suspected local mosquito breeding habitats, or to determine the source or cause of a citizen complaint.

Investigative mosquito trapping should be conducted on several different nights over a period of several weeks.

Once a local mosquito problem area is identified, one can then conduct regular mosquito trapping to monitor the local mosquito populations and plan control efforts.

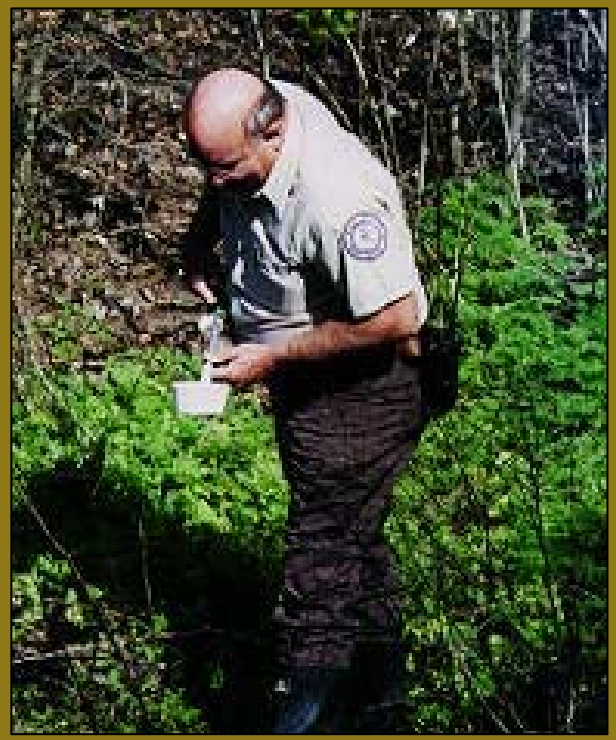
Regular mosquito trapping is generally conducted at fixed trap sites on a weekly basis. Several years of regular surveillance will provide a picture of the seasonal abundance of the local mosquitoes.

Trapping and identification of adult mosquitoes may also indicate location(s) of the mosquito breeding habitats. This is because each mosquito species has a characteristic breeding habitat and flight range.

Identification of larval breeding habitats facilitates the application of larval mosquito control.

Gravid Trap

Larval surveillance:

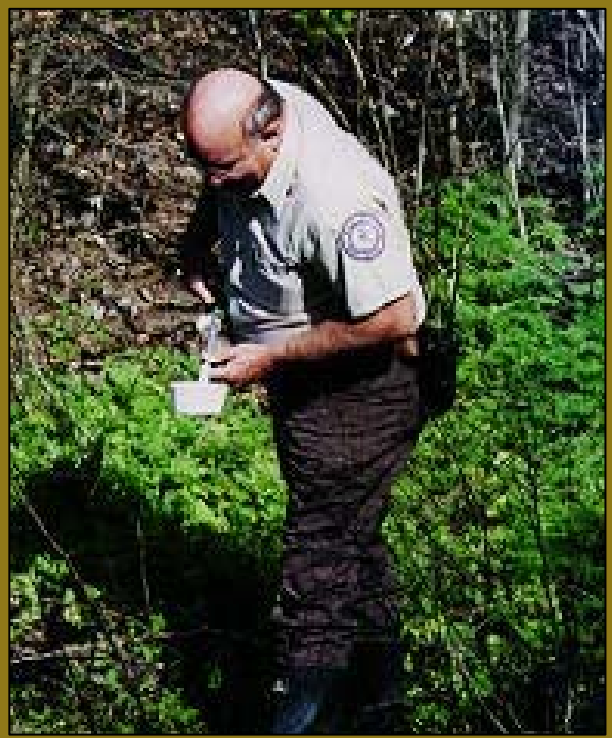


Larval surveillance is used to identify new breeding habitats, to check suspect habitats, or to regularly monitor mosquito populations in identified breeding habitats.

Dip sampling indicates if larvae are present in a suspected habitat. Collected larvae can be identified to determine what species are present.

Larval surveillance:

Dip sampling also provides indications on the number of mosquitoes in a breeding habitat and whether they are in a growth stage that can be controlled with larvicides.



Citizen Complaints:

Citizen complaints can be a useful aid in mosquito surveillance. Citizen complaints can provide indications of where and when mosquitoes are active and where potential breeding habitats occur.

However, Citizens are not mosquito experts so their complaints are often unfounded or misleading.

Responding to unfounded or misleading mosquito complaints can be a waste of time for mosquito surveillance and control personnel.

Citizen complaint calls should always be screened by a person with knowledge of mosquitoes so that the facts can be sorted out from assumptions. Complainers should always be questioned to determine the validity of the complaint.

Citizen Complaints:

Some screening questions to ask of citizens complaining of mosquito activity:

1. **Are the mosquitoes actually biting, or trying to bite?**
2. **Are the mosquitoes biting during daylight hours (sun-up to sundown), or do they only bite at night (after sundown)?**
3. **Are there areas of flooded forest (woodland pools), forest clear-cut (timber harvest), or salt marsh habitats near the residence?**
4. **Are the mosquitoes persistently aggressive (try to bite you on your face or upper body as you are moving), or are they sneaky (bite mostly on the ankles, lower legs and the backs of your arms while you stand still).**

Citizen Complaints:

Some screening questions to ask of citizens complaining about standing water:

1. **Is the water on private property or is it on county or city land?**
2. **Is the standing water a permanent body of water, or a temporary body of water?**
3. **Does the water stand in the puddle less than a week, or more than a week?**
4. **Is there currently a mosquito problem in the area and/or has there been a problem in the past?**

Mosquito Control

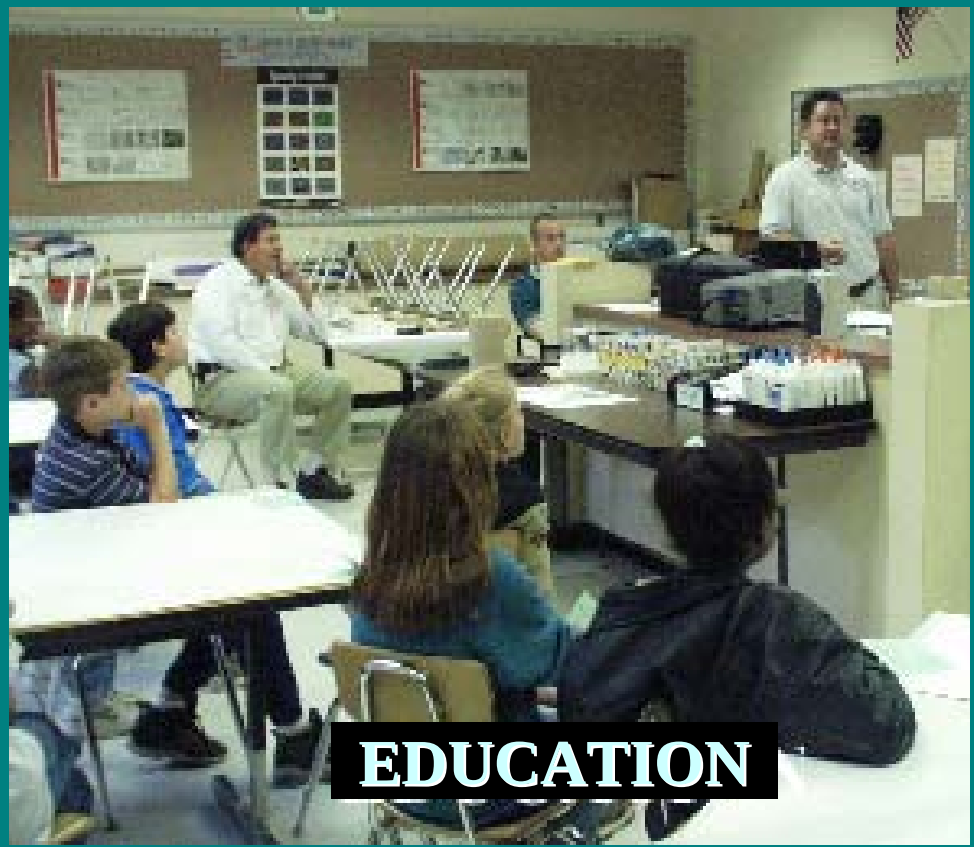
Tactics Used :

1. **Adult mosquito surveillance**
2. **Larval mosquito surveillance**
3. **Public Education**
4. **Larval mosquito control**
5. **Drainage control (breeding habitat elimination/modification)**
6. **Adult mosquito control**

Mosquito control programs should always rely on adult and larval mosquito surveillance.

Public education should be used when the problem mosquitoes originate from artificial breeding habitats (water containers) found around homes.

Public education informs people in rural or untreated areas how to protect themselves against mosquito bites and how to treat larval habitats on their own property.



Adult mosquito control should be used to control mosquitoes that have escaped larval control, or to control mosquitoes that originate from breeding habitats that are too large, distant or sheltered to allow effective larval control operations.

Adult mosquito control should be based on mosquito surveillance data

Adult Mosquito Control is subject to many factors that can reduce its effectiveness. Spraying can also impact the environment if done improperly.

Factors that affect adult mosquito control include:

- **Mosquito flight – Mosquitoes must be in flight for fog to be effective.**
- **Mosquito species – Not all species fly during the same time of day. Applicators must know their target species and apply their fog at the appropriate time!**
- **Air Temperature – Low temperatures discourage mosquito flight.**

Other factors that affect adult mosquito control:

Wind Speed – High wind discourages mosquito flight activity. High wind also dilutes the pesticide fog too quickly. Absence of wind prevents the pesticide fog from reaching target areas.

Wind Direction –Wind must be blowing in the right direction to carry the insecticide fog into the target area from road/sprayer.

Spacing and Layout of Roads – Road spacing and layout must allow fog to reach areas between roads.

Vegetation Density – Pesticide fogs will not penetrate areas of dense vegetation.

Other factors that affect adult mosquito control:

Calibration of Fogging Device – Insecticide fogs must be of the proper droplet size.

If droplets are too large they will drop out of the air too quickly and contaminate surfaces, and/or kill non-target animals.

If droplets are too small they will float away and will not impact the target mosquitoes.

Foggers must be calibrated frequently ! Misapplication of insecticide fogs is a violation of the label, and the law!

Mosquito Adulticides – When applied correctly as fogs, adulticide concentrations are too low to harm anything but small flying insects. Adulticide fog concentrations are typically $^{1}/_{1,000}$ to $^{1}/_{10,000}$ of the concentration that would affect larger mammals or people.

Adulticide Types

Pyrethroids – Have very low mammalian and avian toxicity, but very high toxicity to fish, aquatic arthropods, and honeybees.

- **Permethrin**
- **Resmethrin (Scourge)**
- **Sumithrin (Anvil)**

Adulticide Types

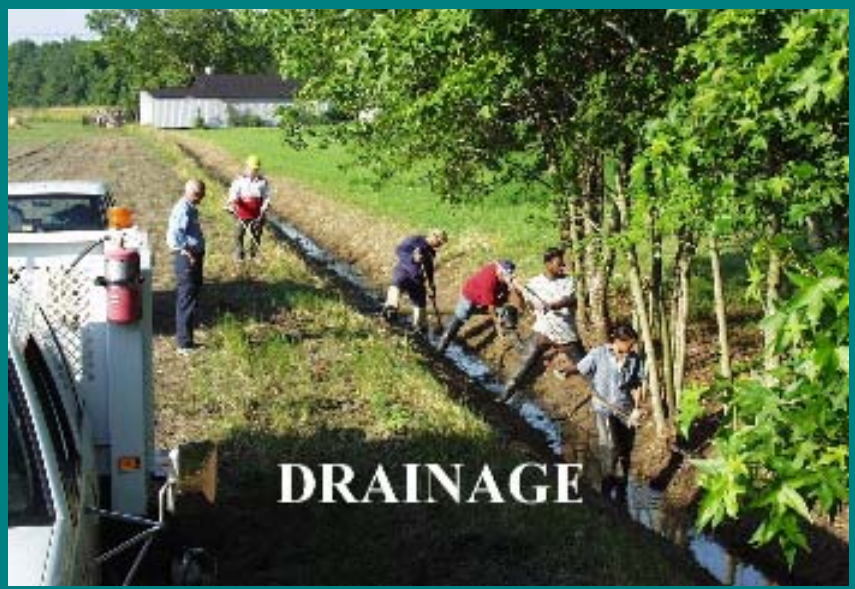
Organophosphates – Have moderate to high mammalian toxicity, moderate to high avian and fish toxicity, very high honeybee toxicity.

Malathion – Low to moderate mammalian toxicity

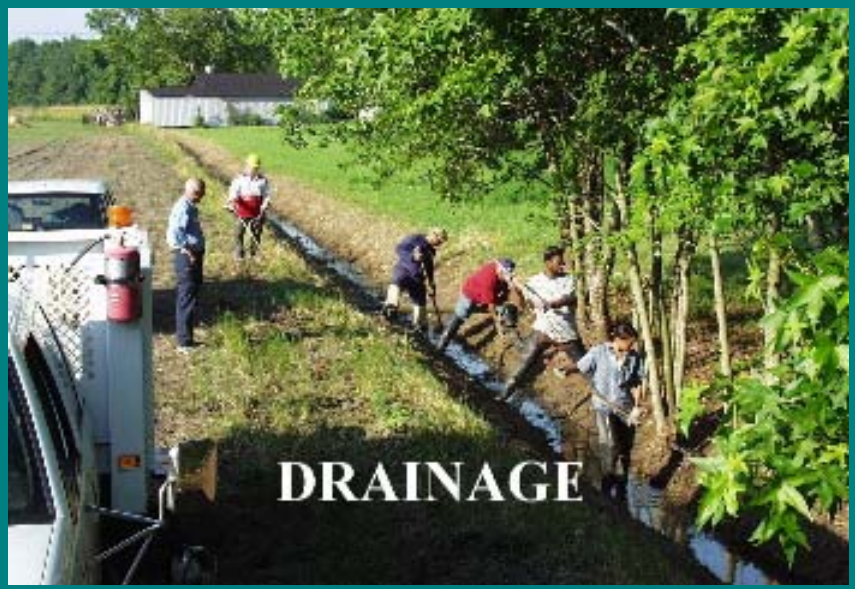
Naled (Dibrome) – Moderate to high mammalian toxicity

Drainage maintenance (habitat modification) is a tactic that should be used on mosquito breeding habitats that can be drained.

Mosquito larvae breed in stagnant water, such as clogged ditches and cannot breed successfully in running water.



Drainage maintenance is generally directed towards unnatural and stagnant impoundments of water (clogged ditches, puddles, areas of poor drainage, etc.) that occur on public land.



Drainage maintenance is one of the key tactics used by most mosquito control programs.

Larval mosquito control is used on mosquito breeding habitats that are treatable and within close proximity to towns or suburbs.

Larval mosquito control should be the mainstay of any mosquito control operation.

Larval mosquito control should always be based on larval surveillance

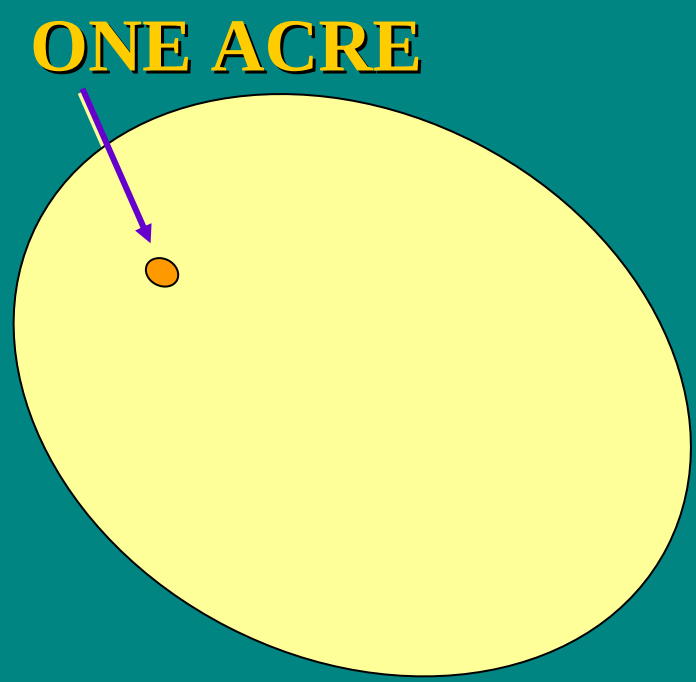
The activity of larval control is frequently combined with larval surveillance.

It is always useful to carry some mosquito larvicide (briquettes, or granules) into areas being surveyed so that applications can be made to breeding habitats when larvae are detected.

Larval Mosquito Control

Larval mosquito control has the lowest environmental impact and is the most efficient method of mosquito control.

For example, if you had one acre of mosquito breeding habitat you could either larvicide it or wait for adult mosquitoes to emerge and fog them with adulticides to kill them.

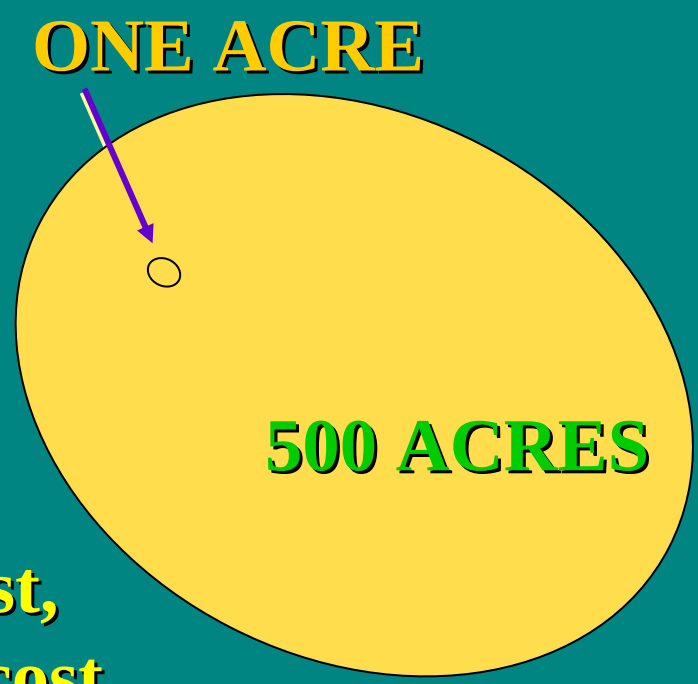


Larval Mosquito Control

However, mosquitoes disperse and some can travel long distances, so one acre of larvae can quickly become 500 acres of adult mosquitoes.

Larvicide Option – If you treat one acre of larval habitat, you could eliminate the local mosquito population.

Adulticide Option – If you fog 500 acres of land, you might kill 85-90% of the mosquitoes, at best, and at a greater environmental cost.



Larval Mosquito Control: There are only a few factors that can reduce its effectiveness of larval control.

Factors that affect larval mosquito control:

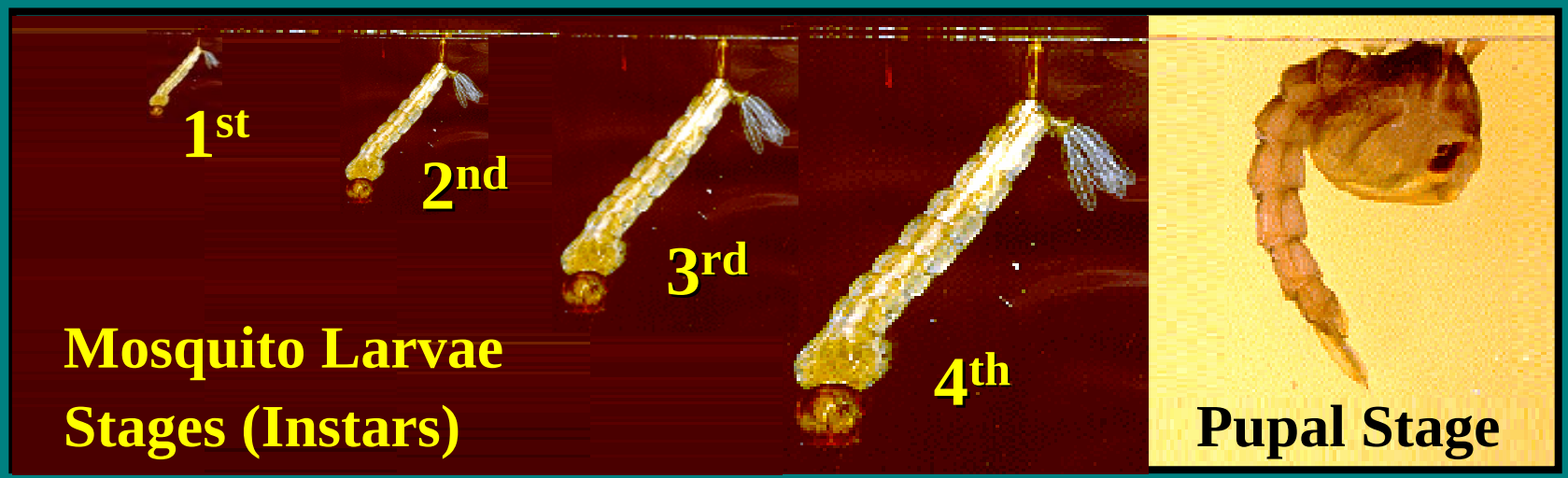
Larval Development Stage –

Immature mosquitoes must be in the right stages of growth for the most widely used larvicides to be effective; larvicides kill the early larval stages of growth. but have little effect on late stages of growth and no effect on the pupal stage.


LARVAE


PUPAL STAGE

All mosquitoes go through four larval stages and one pupal stage in their aquatic habitat before they become adult (flying/biting) mosquitoes.



The most commonly used larvicides (bacterial larvicides and insect growth regulators) only work on the 1st through early 4th larval growth stages. They have no effect on late 4th and pupal stages.

Other factors that affect larval mosquito control:

Larval Habitat – Some mosquito species breed in habitats that are very difficult to find or hit with larvicides. Other mosquito species breed in very large habitats and can fly long distances, so, their habitat may be too costly to treat, and may be outside of a program's jurisdiction.

Mosquito species – Certain larvicides do not affect all species equally. Applicators must know their target species and apply larvicides appropriate for that species!

Other factors that affect larval mosquito control:

Organic Content of Water – Habitats that are heavily polluted or contain much organic matter may require a heavier dosage of larvicides than habitats that contain relatively clear water. Certain larvicides may be more effective than others in water that is polluted or contains heavy organic content .

Mosquito Larvicides – Most are relatively target specific and do not harm non-target organisms.

Types – Biological Insecticides, Insect Growth Regulators, Chemical insecticides, Water Surface Disruptors.

Biological Insecticides – highly target specific (affect only primitive flies) - are most effective on early stage mosquito larvae

Bacillus thuringiensis Israelensis **(BTI) – very target specific**

Bacillus sphaericus **(Vectolex) – highly target specific (species specific)**

Mosquito Larvicides

Types

Insect Growth Regulators – relatively target specific (affect only aquatic insects that have complete metamophosis [flies, beetles], but may also have effects on non-insect aquatic invertebrates [shrimp, crawfish, moluscs], and can be toxic to birds that consume pellets) - are most effective on early stage mosquito larvae; not effective against late 4th stage larvae or pupae)

Methoprene (Altosid)

Mosquito Larvicides

Types

Chemical Insecticides – may affect many non-target species (e.g., fish, frogs, aquatic invertebrates, other aquatic insects, etc; may cause dependence on insecticide use by eliminating natural predator population) – **are effective against all larval stages of mosquitoes but will not control pupae.**

Temephos (Abate)

Mosquito Larvicides

Types

- **Water Surface Disruptors – relatively target specific – are effective against all immature mosquito stages**
  - **Agnique (monomolecular layer) – relatively specific (may affect other insects and invertebrates that rely on the water surface for respiration or locomotion)**
  - **Surface Oils (mineral oils) – somewhat indiscriminate (can affect some aquatic insects and invertebrates, and may be slightly toxic to frogs and fish)**

Mosquito Larvicides

The effectiveness of an insecticide is governed by both its active ingredient and its formulation.

Most mosquito larvicides can be obtained in the following formulations:

- **Liquids**
- **Granulars**
- **Briquets (dunks)**

Always read the insecticide label to be sure you are selecting a pesticide with the correct ingredient and formulation for your job!

Mosquito Larvicides

Some advantages and disadvantages of different larvicide formulations:

Liquid Formulations –

Advantage – become effective as soon as they hit the aquatic habitat; can be applied with ordinary sprayers.

Disadvantage – cannot be applied effectively to aquatic habitats that are hidden beneath foliage or vegetation.

Mosquito Larvicides

Some advantages and disadvantages of different larvicide formulations:

Granular Formulations –

Advantage – may have longer residual effect than liquid formulations; will bounce down through vegetation, foliage, or other obstructions to reach the aquatic habitat; are easily carried into the field in a shoulder bag or pocket.

Disadvantage – require specialized equipment for dispensing large quantities.

Mosquito Larvicides

Some advantages and disadvantages of different larvicide formulations:

Briquet (dunk) Formulations –

Advantage – may have very long residual effect; will bounce down through vegetation or foliage to reach the aquatic habitat; are easily carried into the field in a shoulder bag or pocket.

Disadvantage – may be too large to use on some small aquatic habitats.

The End