

# Mosquito Biology for the Homeowner

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## Introduction

Mosquitoes are flies in the insect family Culicidae. Over 3,000 known species of mosquitoes exist worldwide. More than 160 species have been documented in North America; at least 62 species occur in New York State.

Adult mosquitoes are characterized by having long, slender, needle-like mouthparts (proboscis), antennae, and legs. Their narrow wings are often covered with minute scales, and are characteristically folded over their abdomen at rest. Fine scales, bristles and setae cover the mosquito body and vary in coloration from white, silver, or gold, to very dark. Pattern arrangement and scale coloration, among other traits, are often useful for identifying mosquito species.



Left: An adult female *Culex restuans*.

Right: Close-up of a mosquito wing (*Aedes* sp.).

Despite their delicate appearance, mosquitoes are notorious pests of humans and other animals. Bites from mosquitoes can cause severe discomfort. The resulting intense itching is due to an immunological reaction to mosquito saliva injected into the bite wound.<sup>34</sup>

The real danger, however, is that mosquitoes may vector and transmit disease-causing organisms. Mosquitoes are capable of transmitting viruses (e.g. dengue, yellow fever), protozoans (e.g. malaria), and filarial nematodes (e.g. dog heartworm). The most important mosquito-borne diseases in the United States are caused by viral pathogens and include West Nile fever, eastern equine encephalomyelitis, St. Louis encephalitis, western equine encephalomyelitis, and La Crosse encephalitis; all are flu-like diseases but are usually accompanied by inflammation of the brain. Recently, new mosquito-borne viruses, such as dengue fever, have caused local outbreaks in the USA (Florida), after a hiatus of nearly 40 years. Introduction of other exotic mosquito-borne viruses such as Chikungunya into the USA is a future threat.

## Biology

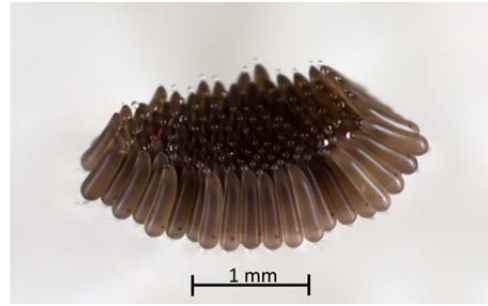
Mosquitoes have four distinct developmental stages: egg, larva, pupa, and adult. Immature stages of mosquitoes require water to complete their life cycle. Mosquitoes, as all insects, are cold-blooded (poikilothermic) animals and, therefore, are highly dependent on temperature for development and survival. Their growth rate and other aspects of their physiology are temperature-dependent. As the temperature increases, their development time shortens.<sup>35</sup>

## Eggs

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Left: Clustering of *Aedes aegypti* eggs



Right: An egg cluster or “raft” of *Culex p.pipiens* viewed sideways.

A freshly laid egg is light in color and darkens within a few hours. Mosquito eggs are oval and about  $1/40^{\text{th}}$  of an inch (0.635 mm) long. Eggs are either deposited singly or as an egg raft depending on the mosquito species. For mosquitoes that lay eggs in clusters or “rafts”, a standard egg raft is about  $1/4$  inch (6.35mm) long and contains 100-200 eggs. Some species of mosquitoes lay their eggs singly and deposit them directly on water or floating aquatic vegetation. Others will lay their eggs on moist soil that is subject to periodic flooding, or above the water line in natural and artificial containers. These eggs can survive dry in a dormant state for days or months until they are submerged by water. The number of single eggs laid per batch varies within and between mosquito species, and is dependent on the body size of the mosquito and the amount of engorged blood they ingest, and can range from 60 to 200.

## Larvae

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Most eggs will hatch within 2-3 days when environmental conditions are suitable. The immature mosquito (or “larva”) goes through four growth or developmental stages called “instars”. First instar larvae are barely noticeable to the human eye. Last larval instars ( $4^{\text{th}}$  instars) of some species can be approximately  $1/2$  inch (12.7mm) long. Larvae move through the water in a serpentine motion. When they sense a shadow or movement in their habitat, larvae will quickly dive to the bottom to avoid predation (Video 1).

[Video 1. \*Cx. pipiens\* larvae in motion](#)



Third (left) and fourth (right) instar larvae of *Cx. pipiens*.

Mosquito larvae are worm-like. They have a distinguishable head and lack legs. Upon close inspection one can distinguish the wider thorax (body segment next to the head) from the long and slender abdomen. A tube-like structure, called a siphon, is located at

the tip of the abdomen. Larvae use the siphon to breathe air from the water surface. Larvae possessing a siphon (Culicine) hold their body roughly at a 45-degree angle from the surface. Species of mosquitoes lacking a respiratory siphon (Anopheline) hold their body horizontal to the water surface. Mosquito larvae lacking a siphon breathe air through openings located on the dorsal surface of the abdomen. A few species will bore their siphon into stems of aquatic plants, allowing them to breathe without coming to the water surface.



*Anopheles punctipennis* larva; note the absence of a siphon. (scale in mm)

Mosquito larvae can be found in a wide variety of habitats, including temporary floodwater and snowmelt pools; more permanent water habitats like marshes, swamps, lagoons, and ponds; stagnant waters; and natural and artificial containers. Shallow water is ideal for larval survival because there is less turbulence and wave action. Upper water movement interferes with the surface

feeding of some mosquito species, and in most species, it hinders the larvae and pupae from obtaining oxygen at the air-water interface. A deep-water environment prevents bottom-feeding larvae from reaching food that has accumulated at the lower levels of the water column. Water quality in larval habitats can vary from fresh to saline,<sup>36</sup> to high in organic wastes. Different species can tolerate and thrive in water with varying degrees of organic content.<sup>38</sup>

Mosquito larvae eat a variety of dead and living organisms, including detritus, algae, bacteria, and fungi.<sup>38</sup> Some mosquito species are predaceous and feed on other mosquito larvae and small invertebrates. Depending on water temperature, crowding, and food availability, the larval stage is typically completed in 5-6 days.<sup>5,7</sup>

## Pupae

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Mosquito pupae are active when compared to other insect pupae. Pupae move in a somersault fashion through the water (Video clip 2). Pupae breathe through tubes located on the thorax and will remain at the water surface unless they are disturbed. This non-feeding stage can be completed in as few as 2-3 days.<sup>5,7</sup>

[Video 2. \*Cx. pipiens\* pupae in motion](#)



Mosquito pupae in their natural breathing posture beneath the water surface.

## Adults

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Both male and female mosquitoes can feed on sugar sources such as plant nectar and honey dew, but only females feed on blood. Female mosquitoes use proteins and lipids from the blood meal to develop a batch of eggs. There are a few exceptions to this rule. Some species are "autogenous", meaning a female is able to utilize energy reserves accumulated in her larval stage to produce eggs without a blood meal.



Female *Aedes j. japonicus* blood feeding on a human arm.

Many species of mosquitoes have narrow host preferences. Some prefer to feed only on birds or mammals, or cold-blooded vertebrates such as reptiles and frogs. Consequently, various mosquito species use a wide variety of cues to find a suitable host, often involving a variety of complex interactions that are optimal for their host preference. This complex of cues is still not fully understood by scientists. Odors emanating from skin or breath, or visual cues such as movement or contrast of a potential host with the surrounding background can be attractive. Carbon dioxide is a major cue for host-seeking mosquitoes and is often utilized as bait in mosquito traps. Lactic acid, acetone and 1-Octen-3-ol and substances found in human and bovine sweat also act as strong attractants of several mosquito species.<sup>21, 22</sup>

Several hundred compounds found in human breath, secretions, and sweat glands have been identified and vary in their degree of attractiveness to female mosquitoes.<sup>6, 22</sup> Some of the more attractive odors include: carbon dioxide, alanine, lysine, lactic acid, and estrogen. Some chemicals emanating from a potential host may be more important for certain species of mosquitoes. In other mosquito species, these very same odors may play a secondary role, no role, or act to repel mosquitoes.<sup>6, 22</sup>

The distance that mosquitoes can fly is difficult to generalize because mosquito species vary in their flight range. Some species can fly long distances (up to 10 km), but most are weak fliers, and do not travel more than several meters.<sup>6, 7, 15</sup>

## Management

New York State has specific environmental laws, rules, regulations, and policies relating to mosquito control and management. For detailed information see:

[http://www.health.ny.gov/diseases/west\\_nile\\_virus/docs/2012\\_mosquito-](http://www.health.ny.gov/diseases/west_nile_virus/docs/2012_mosquito-borne_illness_surveillance_and_response_plan.pdf)

[borne\\_illness\\_surveillance\\_and\\_response\\_plan.pdf](http://www.health.ny.gov/diseases/west_nile_virus/docs/2012_mosquito-borne_illness_surveillance_and_response_plan.pdf)). Area-wide control of adult mosquitoes and control of mosquito larvae and pupae in wetlands, waterways, catch basins, and public areas fall under these regulations and cannot be performed by the general public. Integrated Pest Management (IPM) uses a strategic approach to controlling mosquitoes. IPM is most likely to be effective when several techniques are used together. The



following mosquito IPM recommendations are applicable to homeowners and include measures you can take only with your own property.

## Larvae

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### Source reduction

An effective, long-term method of minimizing mosquito problems is reducing or eliminating potential breeding sites around the home. Water is necessary for mosquito development. Containers of all types can hold water and potentially serve as larval habitat for certain peridomestic species. Properly dispose of old tires, cans, bottles, water-collecting rubbish, flower pots and other unused or unwanted containers. Eliminate standing pools of water created from tire ruts or similar sites that hold water for more than one week. Avoid excess watering of lawns and gardens. Control seepage from air-conditioning units and ill-fitting garden hoses.



Water holding tire ruts are another example of mosquito larval habitat.



A tree hole collecting rain water; a potential breeding site for mosquitoes.

Periodically clean birdbaths, pet dishes, plant pots, rain barrels, and kiddie pools and monitor them for mosquito production. Keep an eye out for small black mosquito eggs pasted around the rim of these containers or black egg rafts floating on water. When cleaning containers, be sure to thoroughly scrub the sides in order to dislodge any attached eggs. Survey your yard for mosquito larvae in other types of water-holding containers such as tree holes, ornamental ponds, and clogged rain gutters.



A clogged rain gutter on a house provides the conditions for mosquito larvae to develop.

## Predators

Mosquito larvae confined to containers, ornamental ponds, or small temporary pools may be controlled in certain situations by biological predators (although the efficacy of this approach has not been fully investigated by scientists). Larvae-eating fish (e.g. *Gambusia* or “mosquito fish”), immature dragonflies and damselflies, aquatic beetles, cannibal mosquito larvae, and certain aquatic organisms such as copepods and planaria (a type of flatworm) will feed on mosquito larvae and may help reduce larvae in breeding sites if initial larval numbers are not high. Consider encouraging the establishment or conservation of these predators. Distributors of some of these predators may be found online. Note that stocking of mosquito-eating fish requires a special permit from the New York State Department of Environmental Conservation.

## Larvicides

Larvicides are products that kill mosquito larvae. Targeting larvae is more desirable than controlling adults because the larvae are concentrated in a relatively small area. Products containing *Bacillus thuringiensis* variety *israelensis* (Bti, a microbial compound), *Bacillus sphaericus* Serotype H5a5b, strain 2362 (Bs, a microbial compound) and methoprene (an insect growth regulator) are either approved for use by NYS or currently available over-the-counter for homeowner use in New York state. Advantages of these compounds are their specific action against insects and minimal impact on non-target organisms such as fish and other aquatic animals.

The microbial insecticides, *Bti* and *Bs*, need to be consumed by mosquito larvae and must be applied well before the last larval instar (stage). Their effectiveness depends upon the mosquito species present, water quality, and size of the initial larval population. The products are made from a dormant spore of a soil-inhabiting bacterium. Ingestion of the spore disrupts the gut wall of larvae, causing death. According to the Environmental Protection Agency and others, both bacteria do not pose risks to wildlife, non-target species, or the environment.<sup>18, 23</sup>

Mosquito larvae in water treated with the insect growth regulator methoprene continue to feed and grow normally until the pupal stage. Exposure of larvae to methoprene disrupts normal molting into the pupa and results in death. The Environmental Protection Agency and other researchers state that, at the recommended use rates, methoprene toxicity to mammals, fish, crustaceans, birds, protozoa, annelids, mollusks, amphibians, damselflies, mayflies, water beetles, or waterfowl is low to non-existent, and methoprene is nontoxic to honeybees.<sup>18, 24</sup> Methoprene undergoes rapid degradation and metabolizes in plants, animals, aquatic microorganisms and soil bacteria and will not bioaccumulate in fish.<sup>24</sup>

## Adults

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### Physical exclusion



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An often overlooked but highly effective means of controlling mosquitoes is the use of tight-fitting and well-maintained window and door screens with a 16-inch mesh. Make sure there are no holes in screens, because mosquitoes can easily find these and enter your home. Also make sure there are no gaps between the screen and window frame. Be sure to caulk and seal all cracks around windows. Some mosquito species are attracted to outdoor lights. Reduce unnecessary lighting, or move the lights away from sensitive areas such as doorways. Replace outdoor lights with yellow bug lights. Bug lights are less attractive to many kinds of insects and can be found wherever household light bulbs are sold. Refrain from spraying window screens with insecticides as this has limited-to-no efficacy against biting insects and instead may be harmful to humans close by at the time of application (see next section).

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### **Adulticides**

Adulticides are substances that kill adult mosquitoes. Yard foggers or sprays are available to homeowners for temporary control of adults in the yard. These products contain various formulations of chemical insecticides such as sumithrin (synthetic pyrethroid), resmethrin (synthetic pyrethroid), or piperonyl butoxide (pesticide synergist increasing pyrethroid potency). Malathion (organophosphate) is also used occasionally. The duration of their activity depends on the method of application and environmental conditions such as rain, sunlight, and high temperature. Furthermore, they are much more toxic to humans, pets, and other animals than the larvicidal compounds. In recent years novel and effective compounds have been developed to fight adult mosquitoes among others. These include diafenthiuron (sold as Polo® or Pegasus®) and chlorfenapyr (sold as Pirate® or Alert®) which metabolize inside the insect gut only then becoming toxic to it.<sup>26</sup> These insecticides are not approved for public use as of yet. Always read and follow directions on the label of any insecticide/repellent; remember, it is the law when applying pesticides.

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### **Personal protection**

You can take individual measures to minimize your exposure to mosquito bites. If possible, modify your routine or other outdoor activities to minimize your time outdoors during peak mosquito activity. Predicting "peak mosquito activity" is difficult because it varies locally and seasonally, and it depends on the mosquito species present in your area. Many species are active during early evening hours. Some mosquitoes are active during night,<sup>28</sup> while others will readily bite during daylight hours.<sup>29</sup> There also seems to be a difference in individual human attraction to mosquitoes.<sup>27</sup> Be sure to pay attention to the biting pressure your children may receive while they are outside playing. Wear protective clothing such as long sleeve shirts, long pants, socks and shoes. Consider using an insect repellent while outdoors to reduce your chances of being bitten. If you use a repellent, make sure you read and understand the label prior to each use. Some repellent formulations can be applied only to skin, on both skin and clothing, or only on clothing! Insect repellents come in a variety of

formulations: aerosol sprays, pump sprays, lotions, wipes, liquids, and with sunscreen. Common ingredients found in over-the-counter repellents belong to two broad categories: synthetic chemicals and biopesticides.

### Synthetic Repellents

Two common synthetic repellents have DEET (*N,N*-Diethyl-*m*-toluamide) ( $C_{12}H_{17}NO$ ) or permethrin ( $C_{21}H_{20}Cl_2O_3$ ) (pyrethroid) as active ingredients. DEET can be applied directly to the skin or clothing. However, DEET can damage some types of fabrics, watch faces, and painted and varnished surfaces. DEET cannot be applied to skin that is covered with clothing. The United States Environmental Protection Agency (EPA) has completed an extensive reevaluation of DEET and has "*concluded that as long as consumers follow label directions and take proper precautions, insect repellents containing DEET do not present a health concern.*"<sup>19</sup> Overall, studies have shown that higher concentrations of DEET are correlated with a greater length of protection<sup>30</sup> but products containing lower concentrations of DEET in the 15-25% range afford good protection.<sup>2,3,8,9</sup> The length of protection provided will depend on various conditions such as how much you sweat, environmental temperature, and mosquito species present. Starved mosquitoes are not as easily deterred by DEET.<sup>20</sup> Do not overuse products containing DEET, and be sure to wash treated skin with soap and water upon returning indoors. The American Academy of Pediatrics (AAP),<sup>1</sup> the Environmental Protection Agency (EPA),<sup>17</sup> and the National Pesticide Information Center (NPIC)<sup>14</sup> provide additional information on DEET. The Internet address for these organizations can be found in the reference section. Persons concerned with using DEET-based products on their children should contact their health care provider.

Permethrin (0.5% active ingredient) cannot be applied directly to the skin. It is applied to clothing and dried before the clothes are worn. The advantage of permethrin is that it is a toxicant and will kill any mosquitoes landing on treated clothing. In recent years, pyrethroid-resistance has been detected in several mosquito species signaling a possible reduction in its effectiveness against mosquitoes in general.<sup>31</sup>

### Biopesticide Repellents

There are non-DEET and non-permethrin repellents labeled for use against mosquitoes; however most biopesticide repellents do not provide the same degree of complete protection as synthetic repellents.<sup>2,3</sup> A laboratory based study found that protection afforded by a soybean oil repellent (2% active ingredient) was not significantly different from the complete protection time of a product with a low concentration of DEET (4.75% active ingredient).<sup>9</sup> A more recent study on DEET alternatives evaluated the repellency of 33 essential oils against *Culex pipiens pallens* females on human volunteers. Clove bud, clove leaf, juniper berry and marjoram were the four most effective oils expressing acceptable repellency at 0.005 mg/cm<sup>2</sup>. Clove bud oil had the longest lasting effect and exhibited better repellency than other commercial products.<sup>32</sup> Active ingredients of other biopesticide repellent products include: oil of citronella, oil of eucalyptus (p-menthane-3, diol), and IR3535 (found in products sold through catalog cosmetic distributors).

## Other Management Measures

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Contrary to popular belief, bug zappers do very little in controlling adult mosquitoes. Studies have shown that far more beneficial insects are killed by bug zappers than are pest species.<sup>10</sup> There is evidence from at least one backyard study that electric bug zappers increased the number of female mosquitoes present in the yards as opposed to yards without the devices, and were not effective in reducing the number of female mosquitoes landing on people.<sup>13,16</sup> Similar results were found with electronic mosquito repellents. Persons using the devices recovered more female mosquitoes landing on them when compared to those not using them.<sup>11</sup> The repellents did not afford any protection against bites.<sup>11</sup>

Scientific studies to date have demonstrated that propane-powered mosquito traps do collect adult mosquitoes.<sup>4,12</sup> However, very few studies exist that document the efficacy of these types of traps in significantly reducing mosquito populations to the level that they prevent bites, or decrease the risk of contracting a mosquito-borne disease. In a paper published in 2013 the authors were able to reduce the numbers of mosquitoes in a defined area by placing four propane activated traps. Concomitantly, they also recorded an increase in mosquito landings on human volunteers a short distance from the traps.<sup>33</sup>

Please contact your local [Cornell Cooperative Extension](#) office for current chemical control recommendations for mosquito larvae and adults. **Remember, the label is the law.** Contact the New York state Department of Environmental Conservation for any regulations that may apply to your particular situation.

## Using Insect Repellents Safely

(From: <http://epa.gov/pesticides/insect/safe.htm>)

For the safe and effective use of pesticide products, always read the product label before using the product. Apply just enough repellent to cover exposed skin and/or clothing. Remember these important points to use repellents safely:

- Follow the label directions to ensure proper use.
- Repellents should be applied only to exposed skin and/or clothing. Do not use under clothing.
- Store insect repellents safely out of the reach of children, in a locked utility cabinet or garden shed.
- Do not apply near eyes and mouth, and apply sparingly around ears.
- When using sprays, do not spray directly into face; spray on hands first and then apply to face.
- Never use repellents over cuts, wounds, or irritated skin.
- Do not spray in enclosed areas. Avoid breathing a spray product, and do not use it near food.
- After returning indoors, wash treated skin and clothes with soap and water.
- Do not use any product on pets or other animals unless the label clearly states it is for animals.
- Most insect repellents do not work on lice or fleas.

- [Use other preventive actions to avoid getting bitten](#) .
- [Read more about active ingredients](#).

## Repellents and Children

EPA does not recommend any additional precautions for using registered repellents on pregnant or lactating women, or on children, other than those listed on the label. For example, some repellents are eye irritants and those labels would have a specific caution about keeping the product away from your eyes.

Because children frequently put their hands in their eyes and mouths, [EPA recommends that all repellent products](#) have the following precautionary statements related to children on their labels:

- "Do not allow children to handle this product, and do not apply to children's hands. When using on children, apply to your own hands and then put it on the child.
- After returning indoors, wash your child's treated skin and clothes with soap and water or bathe."

According to the label, oil of lemon eucalyptus products should not be used on children under the age of three.

Always store insect repellents safely out of the reach of children.

If you are concerned about using repellent products on children you may wish to consult a health care provider for advice or contact the National Pesticide Information Center (NPIC) through their toll-free number, 1-800-858-7378 or [npic.orst.edu](http://npic.orst.edu)

This publication contains pesticide recommendations. Changes in pesticide regulations occur constantly and human errors are still possible. Some materials mentioned may no longer be available and some uses may no longer be legal. All pesticides distributed, sold or applied in New York State must be registered with the New York State Department of Environmental Conservation (DEC). Questions concerning the legality and/or registration status for pesticide use in New York State should be directed to the appropriate Cornell Cooperative Extension Specialist or your regional DEC office. **READ THE LABEL BEFORE APPLYING ANY PESTICIDE.**

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