
MOSQUITOES

Integrated Pest Management Around the Home

More than 50 species of mosquitoes occur in California, with habitats ranging from deserts at or below sea level to mountain meadows with elevations of 10,000 feet or higher. Many of these species are relatively uncommon and seldom pose a threat to human health or well-being.

However, several species readily attack people and can transmit microbial organisms that cause human diseases such as encephalitis and malaria. The mosquitoes of major concern in California belong to the genera *Culex*, *Aedes*, and *Anopheles*.

IDENTIFICATION

Mosquito adults are small, delicate, two-winged flies. At first you might mistake them for the widely distributed, nonbiting midges. However, female mosquitoes differ from similar insects because of their long, slender proboscis, a tubular feeding organ adapted for piercing skin and sucking blood.

If you were to view a mosquito with a hand lens, you would see another characteristic that distinguishes mosquitoes from closely related flies—small scales cover their long, slender wings. Male mosquitoes also have scale-covered wings, but they use their proboscises, or “beaks,” only for sucking plant juices and other sources of sugar rather than blood.

Mosquito larvae, or wigglers, usually are black or brown and occur in stagnant or nearly still water in surface pools, tree holes, or man-made containers such as abandoned tires. *Culex* and *Aedes* larvae have a distinctive siphon, or air tube, at the rear of their bodies, which is lacking in *Anopheles*.

The next immature stage, the pupa, or tumbler, is aquatic, small, comma-shaped, and usually a dark color.

LIFE CYCLE

The life cycle of mosquitoes varies widely among species. Some female mosquitoes lay single eggs on water surfaces, while others lay batches of 100 or more eggs, called rafts (Fig. 1). Other species lay single eggs on moist soil where later flooding is likely. Eggs deposited on water surfaces usually hatch within a day or so, but eggs laid on soil surfaces won't hatch until flooding occurs, which can be months or even years later.

First instar larvae, which are nearly invisible to the naked eye, hatch from the eggs. Larvae molt 3 more times growing larger after each molt (Fig. 2). The fourth instar larvae molt again to become pupae (Fig. 3).

Adult mosquitoes (Fig. 4) emerge from pupae 1 to 2 days after that, with male mosquitoes always emerging first. In summer the entire life cycle, from egg to adult, can be completed in a week or less depending upon water temperature. Adult mosquitoes mate soon after emergence. Soon after, females will seek a blood meal from a vertebrate animal. Females require this extra nutrition to mature the large number of eggs they will lay to complete the life cycle.

PUBLIC HEALTH AND VETERINARY IMPORTANCE

Female mosquitoes of nearly all species require blood from vertebrate animals such as people, pets, and livestock. The most important consequence is the acquisition and later transmission of microorganisms that cause diseases including Western equine encephalomyelitis, St. Louis encephalitis, and West Nile encephalitis. These viruses

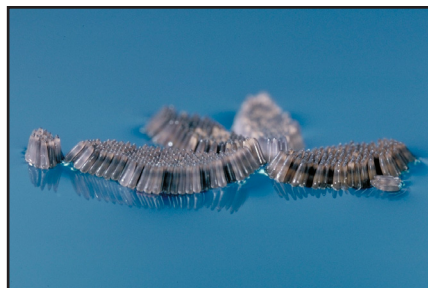


Figure 1. Egg rafts of *Culex tarsalis*.



Figure 2. Larvae of *C. tarsalis*.



Figure 3. Pupal stage.



Figure 4. Adult *C. tarsalis*.

PEST NOTES

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can cause serious, sometimes fatal, neurological ailments in people. Western equine encephalomyelitis and West Nile viruses also can affect horses and occasionally other domestic animals.

Most people infected with viruses that mosquitoes transmit show no symptoms or only mild, flulike ones. However, severe symptoms following infection occur in a small percentage of people. Western equine encephalomyelitis infections tend to be more serious in infants, whereas St. Louis encephalitis affects older people. West Nile Virus infections can range in severity from no detectable symptoms to West Nile fever to comparatively severe neuroinvasive diseases such as West Nile encephalitis, West Nile meningitis, or West Nile meningoencephalitis. For more information, see the sidebar on West Nile Virus.

Some *Anopheles* mosquitoes found in California can transmit human malaria. If these mosquitoes suck the blood of a person who has malarial parasites, the insects can pass on the infection when they bite other people. Endemic malaria was eradicated from California by the 1940s; however, travelers have constantly reintroduced the parasite, which has led to several small outbreaks.

Mosquitoes also can vector, or carry, dog heartworm in California. Oak trees, common in the foothill areas of the state, provide tree holes that fill with water and harbor the larvae of the principal *Aedes* vector of this disease.

Even when mosquitoes don't transmit the causative agents of infectious diseases, they can be a serious nuisance and a health problem to people and livestock. Mosquito bites can result in secondary infections, allergic reactions, pain, irritation, redness, and itching.

MANAGEMENT

The objective of mosquito management is to keep populations below levels where they become a nuisance or a public health problem leading to an outbreak of disease. Mosquito manage-

WEST NILE VIRUS

West Nile Virus (WNV) is a virus that infectious mosquitoes transmit to susceptible vertebrate hosts such as humans and birds. More than 60 species of mosquitoes have been found to be infected with WNV, although most of these species don't play a significant role in the cycling of WNV in nature. Mosquitoes in the genus *Culex* are the most important vectors, or carriers, of WNV in the United States.

The primary cycle (Fig. 5) involves the transmission of WNV between some species of birds and *Culex* mosquitoes. Humans and domestic animals can develop serious symptoms from WNV infection but usually are "dead-end" hosts, because they don't produce enough virus to infect mosquitoes that feed on them.

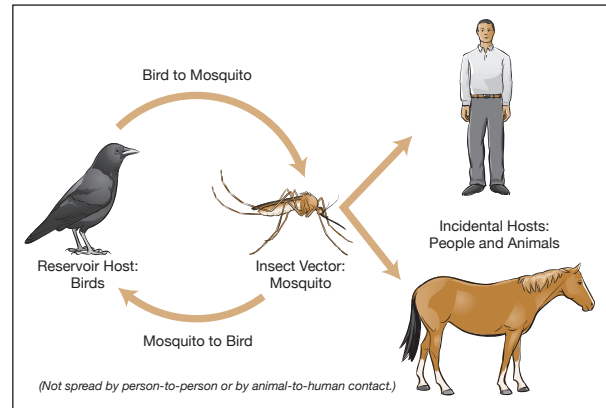


Figure 5. Transmission cycle of West Nile Virus. Mosquitoes spread the virus from birds to humans, animals, or other birds.

WNV infections have been documented to occur through other pathways such as blood transfusion, organ transplants, and breast milk, but enhanced screening methods have virtually eliminated transmission by sources other than mosquito vectors.

In North America WNV outbreaks usually start in the summer and continue into autumn. About 80 percent of people who are infected with WNV won't show any symptoms. Mild symptoms, which appear in about 20 percent of the people who become infected, include fever, headache, body aches, nausea, vomiting, and sometimes swollen lymph glands or a skin rash on the chest, stomach, and back. The symptoms can last for only a few days up to several weeks.

About one in 150 people infected with WNV will develop a neurological illness that sometimes results in death. Symptoms include high fever, headache, neck stiffness, stupor, disorientation, coma, tremors, convulsions, muscle weakness, vision loss, numbness, and paralysis. These symptoms can resolve themselves in several weeks or be permanent.

Currently no vaccine against WNV is available for humans. Even though a vaccine for WNV is available for horses, they still aren't routinely vaccinated across the United States, and mortality rates can be as high as 40% for clinical WNV infections.

People can protect themselves from WNV infection in two key ways—personal protective measures to reduce contact with mosquitoes and public health measures to reduce the population of infected mosquitoes in the environment. The Centers for Disease Control and Prevention (CDC) recommends personal protection measures such as:

- Maintaining conditions around the home to reduce contact with mosquitoes;
- Repairing broken window and door screens;
- Eliminating small pools of standing water;
- Reducing time outdoors, particularly in early morning and evening hours when host-seeking *Culex* mosquitoes are most active;
- Wearing long pants and long-sleeved shirts; and
- Applying mosquito repellent to exposed skin and to clothing.

Public health measures include reducing environmental conditions in aquatic habitats conducive to producing mosquitoes and eliminating standing water, which mosquito larvae require to survive. Insecticides might be needed to kill adult mosquitoes, especially if WNV activity in large mosquito populations has a high probability of spilling over into the human population. In emergency situations, wide area aerial spraying is used to quickly reduce the number of adult mosquitoes. The methods selected for a mosquito control program depend on the time of year, the type of mosquitoes that need to be controlled, and landscape features.

ment often occurs on an areawide basis by public agencies that either are part of local health departments or are independent districts organized specifically for mosquito control. California has more than 60 mosquito and vector control districts. Some are small and have responsibility for mosquito abatement in a few hundred square miles, while the activities of others can encompass one or two entire counties.

Vector control technicians search out mosquito larvae in standing water and use appropriate control measures that are cost-effective and environmentally friendly. Control measures include environmental manipulation to reduce aquatic habitats such as removing dense patches of decaying vegetation conducive to mosquito production, applying mosquito-specific control agents, and stocking fish that feed on the larvae. Many materials currently in use are biological in origin and are highly specific for mosquitoes while having little or no effect on other organisms.

Controlling irrigation water in agricultural areas to avoid excess runoff also is an important mosquito control method. However, eliminating natural bodies of water such as vernal pools that also serve as wildlife habitat has ceased to be a mosquito control option because of habitat preservation concerns.

Occasionally mosquito abatement agencies also might have to use chemical pesticides to kill adult mosquitoes, but ordinarily this occurs only when adult populations become so large they cause extreme annoyance to many people or when the threat to people of an outbreak of a disease-causing pathogen is high.

Around the Home

In many areas of California, public mosquito and vector control agencies keep mosquito numbers down to tolerable levels all or most of the time. However, some Californians live in areas where no organized mosquito control exists. These usually are low-density areas in foothill, mountain, or desert regions.

Table 1.

Checklist of Possible Mosquito Sources Around the Home.

Mosquito Sources	What to Do to Reduce Mosquitoes
Bird baths	Change water at least once a week.
Cesspool or septic tanks	Seal and cover openings, so mosquitoes can't lay eggs in them.
Containers	Empty water. Store in an inverted position. Dispose. Cover so mosquitoes can't lay eggs in them.
Cooler drains	Prevent water from standing.
Irrigated lawns or fields	Avoid excessive irrigation. Drain standing water.
Plastic pools	Drain when not in use, or cover so mosquitoes can't lay eggs in them.
Ponds	Stock pond with fish, or use <i>Bacillus thuringiensis</i> subspecies <i>israelensis</i> . Remove excess vegetation.
Roof gutters	Clean once a year to remove debris.
Standing water	Eliminate by draining. Fill in low areas.
Street gutter or catch basins	Remove litter and garden debris. Don't overwater lawns.
Swimming pools	Keep water off of the cover. Maintain water quality at all times.
Tree holes	Fill hole with sand or mortar.
Watering troughs	Stock with fish, or change water weekly.

Adapted from the Sacramento-Yolo Mosquito and Vector Control District.

People living in these areas or in other locations where mosquito populations become bothersome can protect themselves from mosquitoes by using a variety of strategies. These include keeping fine mesh screens on windows and doors in good repair, draining standing water or treating it with the microbial control agent *Bacillus thuringiensis* subspecies *israelensis* (Bti), incorporating mosquito-eating fish, and wearing repellents and protective clothing when outdoors during the mosquito season.

The most effective control methods are those targeted against the larval stage of the life cycle. If you have an area or object that can hold water for more than a few days, drain it or fill it with soil or cement, treat it with Bti, or stock it with mosquito-eating fish. Even small containers such as soda cans, glass jars, flower pot saucers, or tree holes can provide a habitat for mosquito development.

Keep in mind adult mosquitoes can fly several miles from where they develop. Even successful control of mosquito larvae on your premises might not result in eliminating mosquito numbers or biting activity. See Table 1 for ways to reduce mosquito populations in a given situation.

Mosquito-eating fish. Mosquito-eating fish can be an important control agent for immature mosquitoes. People worldwide have used the mosquito-fish, *Gambusia affinis*, for mosquito control. These fish are most effective in man-made bodies of water that don't connect with natural waters and don't contain dense stands of emergent vegetation. You can obtain mosquitofish from most vector control districts.

You never should release mosquitofish into streams, ponds, and lakes, because these fish aren't native to California. Fish native to California are being

considered for use as mosquito control agents in habitats where mosquitofish no longer can be released. Your local vector control district is a good source of additional information for mosquito-fish alternatives.

Bacillus thuringiensis subspecies *israelensis*. Proteins produced when the bacterium *Bacillus thuringiensis* subspecies *israelensis* (Bti) forms spores will kill mosquito larvae. To be effective, mosquito larvae must eat the compounds, which act as a stomach poison that damages mid-gut cells. Like the closely related forms of Bt used by gardeners to control specific insect pests, Bti is highly selective, killing only mosquitoes and the larvae of a few other related flies. This biopesticide is not effective against pupae, since they don't feed. Bti is marketed in a variety of formulations for the homeowner, the most common being the Mosquito Dunk, a doughnut-shaped float that lasts for about 30 days in water.

Outdoor Sprays. Using insecticide sprays or outdoor foggers for controlling adult mosquitoes has limitations. While they can provide a temporary reduction of the adult population—which can be useful if you make the application shortly before a backyard picnic or family gathering—alternative, more long-term approaches for controlling mosquitoes are preferable. Equipment for applying outdoor sprays is expensive and complex.

Personal Protection

Probably the most effective method of personal protection from mosquito bites is to avoid places where their densities are high and avoid being outside when mosquito activity is at its highest. In mountainous areas, most mosquito species bite during morning and afternoon hours and often not at all when it is dark. In some low-elevation areas, such as the Central Valley, some mosquitoes tend to bite at night, while others bite during the day.

Repellents. If you find yourself in a situation where you can't avoid mosquitoes, first minimize the amount of

exposed skin surface by wearing a hat or head net, long trousers, and a long-sleeved shirt. Some mosquitoes will bite through lightweight clothing, but the number of bites you receive will decrease if you cover most areas of your body.

When mosquito densities become very high, you might want to apply a mosquito repellent. The Centers for Disease Control and Prevention (CDC) recommends using products containing active ingredients registered by the U.S. Environmental Protection Agency (EPA) for use as repellents applied to skin and clothing. An EPA registration indicates the active ingredients of repellents have been tested for human safety when applied according to the instructions on the label.

The CDC currently recommends two general types of repellents for use on skin, conventional and biopesticide. Conventional repellents include compounds such as DEET (N,N-diethyl-m-toluamide or N,N-diethyl-3-methyl-benzamide) and Picaridin (KBR 3023: 2-[2-hydroxyethyl]-1-piperidine-carboxylic acid 1-methylpropyl ester). Biopesticide repellents are derived from natural materials and include Oil of Lemon Eucalyptus (OLE) and IR3535 (3-[N-Butyl-N-acetyl]-aminopropionic acid, ethyl ester). A synthetic (p-Menthane-3,8-diol) alternative to natural OLE also is available.

New repellents are continually being developed and tested. The federal government's latest recommendations for mosquito repellents can be found on the CDC's (<http://www.cdc.gov/ncidod/dvbid/westnile/RepellentUpdates.htm>) and EPA's (http://www.epa.gov/pesticides/health/mosquitoes/ai_insectpr.htm) Web sites.

A repellent's effectiveness and duration of protection vary considerably among products and mosquito species. Effectiveness typically lasts 4 or fewer hours depending on wind, high temperatures, high humidity, and perspiration amounts.

In general, higher concentrations of active ingredient provide a longer protection time, regardless of the active ingredient, although concentrations greater than 50% don't offer a marked increase in protection time. Products with less than 10% active ingredient might offer only limited protection, often only 1 to 2 hours.

Products that offer sustained release or controlled release (micro-encapsulated) formulations, even with lower active ingredient concentrations, might provide longer protection times. Regardless of what product you use, if you start to get mosquito bites, reapply the repellent according to the label instructions, or remove yourself from the area if possible.

DEET is the most effective mosquito repellent if you will be outside for long periods where mosquitoes are abundant. However, DEET is an irritant to some people, and repellents containing high DEET concentrations can damage synthetic materials such as clothing or plastics. Apply sparingly to all exposed skin. Special formulations for children contain low concentrations of the chemical in an oil-based medium that slowly releases the compound and limits its absorption through the skin; these formulations also work well for adults.

If you wish to avoid DEET, many of the EPA-approved alternative repellents are as effective or are more effective for some people than are low concentrations of DEET, especially when only short-term repellency (fewer than 2 hours) is desired and mosquitoes aren't very abundant.

In addition to the previously mentioned repellents, plant oils such as those from birch, bluestem grass, geranium, pine, rosemary, spearmint, yarrow, lantana, and neem somewhat repel mosquitoes, but most aren't available in commercial mosquito repellents. Oil of Lemon Eucalyptus isn't recommended for use on children younger than 3 years old. The insecticide permethrin functions as a repellent when you apply it to cloth-

ing, but you shouldn't use it directly on your skin.

The EPA recommends several precautions when using insect repellents.

- Apply repellents only to exposed skin and clothing; never use repellents underneath clothing.
- Don't apply repellents over cuts or irritated skin.
- Never spray repellents directly onto your face; apply the repellent onto your hands first, then use your hands to apply the product sparingly onto your face and head.
- Never let children handle repellents.
- A small amount of repellent is sufficient to effectively deter mosquitoes.
- After returning indoors, wash treated areas with soap and water.
- If you develop a rash after using a repellent, wash the affected area with mild soap and water, and seek guidance from a physician or poison control center.
- Always read and follow the directions on the product's label.

Other Products. Research has shown that the effectiveness of most other products marketed to repel mosquitoes differs appreciably. Wristbands that contain an aromatic repellent, ultrasonic emitters, electric grids, electronic repellents, aromatic plants (the most common one is the so-called mosquito plant, *Pelargonium x citrosum*), incense coils, vitamin B₁, and mixtures of brewer's yeast and garlic are ineffective.

Oil of citronella, which is extracted from *Andropogon nardus*, has a reputation for repelling mosquitoes. Burning citronella candles or mosquito coils containing allethrin works best if there is relatively little air movement, but these products are for use only outdoors.

Electric bug zappers used to kill pest insects probably are counterproductive, because many of the insects these traps kill are those that prey on mosquitoes. Manufacturers claim that clip-on, battery-operated dispensers for the pyrethroid pesticide metofluthrin repel mosquitoes for up to 12 hours per refill,

but like most repellents, effectiveness varies among users.

You can trap mosquitoes using products such as the Mosquito Magnet, which releases attractants such as carbon dioxide. However, you'll want to weigh the cost of the trap and its operation against the fact that although the trap attracts mosquitoes searching for a host to feed on, it captures only a small proportion of the attracted insects. Also a single trap might not be effective enough for controlling adult mos-

quitoes, which often disperse across a broad geographic area.

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To simplify information, trade names of products have been used. No endorsement of named products is intended, nor is criticism implied of similar products that are not mentioned.

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WARNING ON THE USE OF CHEMICALS

Pesticides are poisonous. Always read and carefully follow all precautions and safety recommendations given on the container label. Store all chemicals in the original, labeled containers in a locked cabinet or shed, away from food or feeds, and out of the reach of children, unauthorized persons, pets, and livestock.

Pesticides applied in your home and landscape can move and contaminate creeks, rivers, and oceans. Confine chemicals to the property being treated. Avoid drift onto neighboring properties, especially gardens containing fruits or vegetables ready to be picked.

Do not place containers containing pesticide in the trash or pour pesticides down the sink or toilet. Either use the pesticide according to the label, or take unwanted pesticides to a Household Hazardous Waste Collection site. Contact your county agricultural commissioner for additional information on safe container disposal and for the location of the Household Hazardous Waste Collection site nearest you. Dispose of empty containers by following label directions. Never reuse or burn the containers or dispose of them in such a manner that they may contaminate water supplies or natural waterways.

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