Mosquitoes

Glossary/Terminology

There are more than 3,000 species of mosquitoes, but the members of three bear primary responsibility for the spread of diseases that can cause deaths worldwide each year. Anopheles mosquitoes are the only species known to carry malaria. They also transmit filariasis (also called elephantiasis) and encephalitis. Culex mosquitoes carry encephalitis, filariasis, and the West Nile virus, and Aedes mosquitoes, of which the voracious Asian tiger is a member, carry yellow fever, dengue, and encephalitis. Approximately 150 species of mosquitoes are found in the United States and their irritating bites and nearly ubiquitous presence can ruin a late afternoon ride or a trail ride through the woods.

Mosquitoes transmit disease in a variety of ways. In some instances, parasites attach themselves to the gut of a female mosquito and enter a host as she feeds and in others a virus enters the mosquito as it feeds and is transmitted via the mosquito's saliva to a subsequent victim. While mosquitos feed on humans, they usually prefer horses, cattle, or birds, which is why we need to understand their life cycles to help protect our horses.

All mosquitoes must have water in which to complete their life cycle. This water can range in quality from melted snow water to sewage effluent and it can be in any container imaginable. The type of water in which the mosquito larvae is found can be an aid to the identification of which species it may be. Adult mosquitoes show a very distinct preference for the types of sources in which to lay their eggs. They lay their eggs in such places such as tree holes that periodically hold water, tide water pools in salt marshes, sewage effluent ponds, irrigated pastures or rain water ponds. Each species has unique environmental requirements for the maintenance of its life cycle.

Mosquitoes use exhaled carbon dioxide, body odors, temperature and movement to home in on their victims. Only female mosquitoes have the mouth parts necessary for sucking blood. When biting with their proboscis, they stab two tubes into the skin: one to inject an enzyme that inhibits blood clotting; the other to suck blood into their bodies. They use the blood not for their own nourishment but as a source of protein for their eggs. For food, both males and females eat nectar and other plant sugars. Some mosquitoes prefer to feed on only one type of animal or they can feed on a variety of animals. In addition to horses, mosquitoes feed on man, other domesticated animals and wild animals, all types of birds, and snakes, lizards, frogs, and toads.

The flight habits of mosquitoes depend on the species. Most domestic species remain fairly close to their point of origin, but there are some species that migrate far from their breeding place. The flight range for females is usually longer than that of males. Many times wind is a factor in the dispersal or migration of mosquitoes. Most mosquitoes stay within a mile or two of their source. However, some have been recorded as far as 75 miles from their breeding source.

The length of life of the adult mosquito depends on several factors: temperature, humidity, sex of the mosquito and time of year. Most males live for about a week and females live about a month depending on the above factors.

Lifecycle/Biology

The mosquito goes through four separate and distinct stages of its life cycle and they are as follows: Egg, Larva, pupa, and adult. Each of these stages can be easily recognized by their special appearance.

Egg: Eggs are laid one at a time and they float on the surface of the water. In the case of

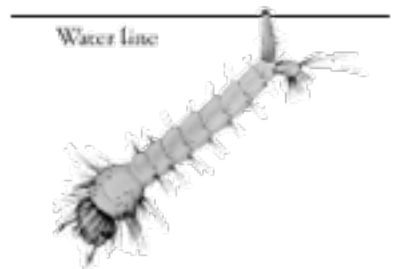
Culex and *Culiseta* species, the eggs are stuck together in rafts of a hundred or more eggs. *Anopheles* and *Aedes* species do not make egg rafts but lay their eggs separately. *Culex*, *Culiseta*, and *Anopheles* lay their eggs on water while *Aedes* lay their eggs on damp soil that will be flooded by water. Most eggs hatch into larvae within 48 hours.

Mosquito Egg Raft

Culex mosquitoes lay their eggs on the surface of fresh or stagnant water, usually at night. The water may be in tin cans, barrels, horse troughs, ornamental ponds, swimming pools, puddles, creeks, ditches, or marshy areas. The female will lay her eggs one at a time, sticking them together to form a raft of 200- 300 eggs. A raft of eggs looks like a speck of soot floating on the water and is about 1/4 inch long and 1/8 inch wide. Tiny larvae emerge from the eggs within 24 hours. Mosquitoes prefer water sheltered from the wind by grass and weeds. A mosquito may lay a raft of eggs every third night during its life span.

Anopheles mosquitoes lay their eggs singly on the water, not in rafts. Aedes mosquitoes lay their eggs singly on damp soil. These eggs will hatch only when flooded with water (salt water high tides, irrigated pastures, treeholes, flooded stream bottoms, etc.).

Larva: Mosquito larvae live in the water and come to the surface to breathe. They shed their skin four times growing larger after each molting. The stages between molts are called instars. At the 4th instar, the larva reaches a length of almost 1/2 inch. Most larvae have siphon tubes for breathing and hang from the water surface. *Anopheles* larvae do not have a siphon and they lay parallel to the water surface. The larva feed on micro-organisms and organic matter in the water. On the fourth molt the larva changes into a pupa.



Mosquito Larva

Mosquito larvae are commonly called "wigglers" or "wrigglers" and they must live in water from 7 to 14 days depending on water temperature.

Larvae must come to the surface at frequent intervals to obtain oxygen through their siphon. The larva eats algae and small organisms which live in the water.

Pupa: The pupal stage is a resting, non-feeding stage. At this stage of life the pupa are called "tumblers", and they must live in water from 1 to 4 days, depending upon species and temperature. The pupa is lighter than water and therefore floats at the surface. It takes oxygen through two breathing tubes called "trumpets". When it is disturbed it dives in a jerking, tumbling motion and then floats back to the surface. This is the time the mosquito turns into an adult. When development is complete, the pupal skin splits and the adult mosquito emerges to the surface of the water where it rests until its body can dry and harden.

Mosquito Pupa

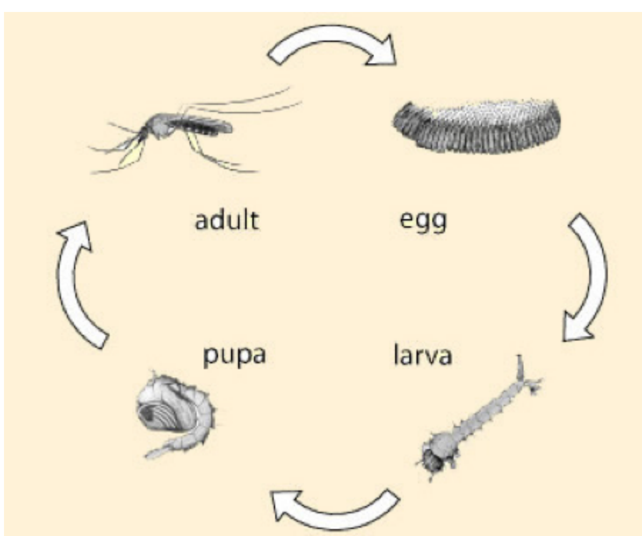
Mosquito Adult

Aedes mosquitoes are painful and persistent biters, attacking during daylight hours (not at night). They do not enter dwellings, and they prefer to bite mammals. They are strong fliers and are known to fly many miles from their breeding sources.

Culex mosquitoes are painful and persistent biters also, but prefer to attack at dusk and after dark, and readily enter dwellings for blood meals. Domestic and wild birds are preferred over horses. *Culex tarsalis* is known to transmit encephalitis (sleeping sickness) to man and horses. This genus is generally a weak flier and does not move far from their breeding ground, although they have been known to fly up to two miles. *Culex* species usually live only a few weeks during the warm summer months. However, the females that emerge in late summer search for sheltered areas where they "hibernate" until spring. Warm weather brings them back out in search of water on which to lay eggs.

Culiseta mosquitoes are moderately aggressive biters, attacking in the evening hours or in shade during the day.

Mosquito Life Cycle



Associated disease/condition

Mosquito borne viruses	Transmission	Vector	Equine Amplifiers	Equine Mortality %	Equine Morbidity/year
WEE	Birds	Culex tarsalis	No	3-5o	0-5
EEE	Birds	Aedes and Coquillecttidia	1 out of 20	70-90	120
VEE	Rodents	Culex	Unknown	Rare	Unknown
SLE	Birds	Culex	No	None	None
JE	Birds	Culex	No	Rare	Unknown
WNV	Birds, Horses, Alligators	Aedes, Culex, Anopholes	No	30	~200

Information on Arboviral Encephalitides

Arthropod-borne viruses or arboviruses are maintained in nature through biological transmission between susceptible vertebrate hosts by blood feeding arthropods (mosquitoes, psychodids, ceratopogonids, and ticks). Vertebrate infection occurs when the infected arthropod takes a blood meal. Togaviridae are small, lipid- and protein-enveloped RNA viruses. Arboviruses of the genera *Alphavirus* and *Flavivirus* have been associated with encephalitis in horses. The *Alphavirus* species tend to be more infectious and more often associated with epidemics compared with the *Flavivirus* species.

Arboviral encephalitides have a global distribution, but the main virus agents of encephalitis in the United States are eastern equine encephalitis (EEE), western equine encephalitis (WEE), and St. Louis encephalitis (SLE), all of which are transmitted by mosquitoes. Most cases of arboviral encephalitis occur from June through September, when arthropods are most active. In milder parts of the country, where arthropods are active late into the year, cases can occur into the winter months.

All arboviral encephalitides are zoonotic, being maintained in complex life cycles involving a nonhuman primary vertebrate host and a primary arthropod vector. Humans and domestic animals can develop clinical illness but usually are "dead-end" hosts because they do not produce significant viremia, and do not contribute to the transmission cycle. Many arboviruses that cause encephalitis have a variety of different vertebrate hosts and some are transmitted by more than one vector. Maintenance of the viruses in nature may be facilitated by vertical transmission.

Eastern Equine Encephalitis is caused by a virus transmitted to humans and equines by the bite of an infected mosquito. EEE virus is an *Alphavirus* that was first identified in the 1930's and currently occurs in focal locations along the eastern seaboard, the Gulf Coast and some inland Midwestern locations of the United States. Equine epizootics can be a common occurrence during the summer and fall.

EEE virus can produce severe disease in horses, some birds such as pheasants, quail, ostriches and emus, and even puppies. Because horses are outdoors and attract hordes of biting mosquitoes, they are at high risk of contracting EEE when the virus is present in mosquitoes. Human cases are usually preceded by those in horses and exceeded in numbers by horse cases which may be used as a surveillance tool.

EEE virus occurs in natural cycles involving birds and *Culiseta melanura* and *Aedes* spp., in some swampy areas nearly every year during the warm months. Where the virus resides, or how it survives in the winter, is unknown. It may be introduced by migratory birds in the spring or it may remain dormant in some yet undiscovered part of its life cycle. With the onset of spring, the virus reappears in the birds (native bird species do not seem to be affected by the virus) and mosquitoes of the swamp. In this usual cycle of transmission, virus does not escape from these areas because the mosquito involved prefers to feed upon birds and does not usually bite humans or other mammals.

For reasons not fully understood, the virus may escape from enzootic foci in swamp areas in birds or bridge vectors such as *Coquilletidia perturbans* and *Aedes sollicitans*. These species feed on both birds and mammals and can transmit the virus to humans, horses, and other hosts. Other mosquito species such as *Aedes vexans* and *Culex nigripalpus* can also transmit EEE virus.

Western Equine Encephalitis was first isolated in California in 1930 from the brain of a horse with encephalitis, and remains a cause of encephalitis in horses and humans in North America, mainly in western parts of the USA and Canada. In the western United States, the enzootic cycle of WEE involves passerine birds, in which the infection is unapparent, and culicine mosquitoes, principally *Culex tarsalis*, a species that is associated with irrigated agriculture and stream drainages. The virus has also been isolated from a variety of mammal species. Other important mosquito vector species include *Aedes melanimon* in California, *Aedes dorsalis* in Utah and New Mexico and *Aedes campestris* in New Mexico. WEE virus was isolated from field collected larvae of *Aedes dorsalis*, providing evidence that vertical transmission may play an important role in the maintenance cycle.

Expansion of irrigated agriculture in the North Platte River Valley during the past several decades has created habitats and conditions favorable for increases in populations of granivorous birds such as the house sparrow and mosquitoes such as *Culex tarsalis*, *Aedes dorsalis* and *Aedes melanimon*. All of these species may play a role in WEE virus transmission in irrigated areas.

Venezuelan Equine Encephalitis (VEE) like EEE and WEE, is an alphavirus and causes encephalitis in horses and humans and is an important veterinary and public health problem in Central and South America. Occasionally, large regional epizootics and epidemics can occur resulting in thousands of equine and human infections. Epizootic strains of VEE virus can infect and be transmitted by a large number of mosquito species. The natural reservoir host for the epizootic strains is not known. A large epizootic that began in South America in 1969 reached Texas in 1971. It was estimated that over 200,000 horses died in that outbreak, which was controlled by a massive vaccination program using an experimental live attenuated VEE vaccine.

Enzootic strains of VEE virus have a wide geographic distribution in the Americas. These viruses are maintained in cycles involving forest dwelling rodents and mosquito vectors, mainly *Culex* species.

An equine vaccine is available for EEE, WEE and VEE. Arboviral encephalitis in horses is best prevented by ensuring that horses are immunized appropriately and steps are taken to reduce the population of infected mosquitoes.

West Nile Encephalitis (WNV) is a flavivirus belonging taxonomically to the Japanese encephalitis serocomplex that includes the closely related St. Louis encephalitis (SLE) virus. WNV has the most widespread geographical distribution and the largest vector and host range of all mosquito-borne flaviviruses. WNV was first isolated in the West Nile Province of Uganda in 1937. The first recorded epidemics occurred in Israel during 1951-1954 and in 1957. Epidemics have been reported in Europe in the Rhone delta of France in 1962 and in Romania in 1996.

An outbreak of arboviral encephalitis in New York City and neighboring counties in New York state in late August and September

1999, was initially attributed to SLE virus based on positive serologic findings in cerebrospinal fluid and serum samples using a virus-specific IgM-capture ELISA. The outbreak was subsequently confirmed as caused by West Nile virus based on the identification of virus in human, avian, and mosquito samples. SLE and WNV are antigenically related, and cross reactions are observed in most serologic tests. The limitations of serologic assays emphasize the importance of isolating the virus from entomologic, clinical, or veterinary material.

Although it is not known when and how WNV was introduced into North America, international travel of infected persons to New York or transport by imported infected birds may have played a role. WNV can infect a wide range of vertebrates; in humans it usually produces either asymptomatic infection or mild febrile disease, but can cause severe and fatal infection in a small percentage of patients. Migratory birds may play an important role in the natural transmission cycles and spread. Like SLE virus, WNV is transmitted principally by *Culex* species mosquitoes, but also can be transmitted by *Aedes*, *Anopheles*, and other species. The predominance of urban *Culex pipiens* mosquitoes trapped during this outbreak suggests an important role for this species (Weissenböck et al 2010).

Widespread use of equine WNV vaccines decreases the incidence of equine WNV disease.

St. Louis Encephalitis virus is the leading cause of epidemic flaviviral encephalitis in the United States. During the summer season, SLE virus is maintained in a mosquito-bird-mosquito cycle, with periodic amplification by peridomestic birds and *Culex* mosquitoes. The principal vector is in the Midwest is *Culex pipiens* and *Culex tarsalis*. Infected wild birds and mammals do not exhibit clinical signs (Reisen 2003). Experimental inoculation in horses produces viremia but no clinical signs

Japanese Encephalitis (JE) virus is a flavivirus, related to St. Louis encephalitis and is widespread throughout Asia. Worldwide, it is the most important cause of arboviral encephalitis with over 45,000 human cases reported annually. The virus is maintained in a cycle involving culicine mosquitoes and wading waterbirds such as egrets. The virus is transmitted to man primarily by *Culex tritaeniorhynchus* and *Culex pipiens*, which breed in rice fields. Pigs are the main amplifying hosts of JE in peridomestic environments. In most cases JE is a disease of humans and they are the source for horses. When JE was still widespread in Japan, epizootics of encephalitis in horses tended to coincide with human epidemics, but nowadays equine disease has become rare (Halstead and Jacobson, 2003). Clinical signs of the disease in horses vary widely in presentation and severity. Mild signs are pyrexia, depression and icterus for a few days. In most cases complete recovery occurs in 5-10 days.

Diagnosis

The usual method of diagnosing viral infections is by complement fixation, hemagglutination inhibition and cross serum neutralization assays. A combination of these techniques increases the likelihood of a positive diagnosis. A four-fold increase in antibody titer in convalescent sera commonly is recommended for a diagnosis. However, viral antibodies are commonly present within 24 hours after the initial viremia and their presence often precedes clinical encephalitis. Therefore an initial sample taken when encephalitic signs are present may be after the titers have peaked and a second sample may actually have a decreased titer compared to the first one. Viral cultures are unlikely to be of use except in the case of acute VEE.

Specific Control & Treatment Measures

Owners should use insecticides and repellents when possible and practical and eliminate standing water. Selection of mosquito control methods depends on what needs to be achieved; but, in most situations, the preferred method to achieve maximum results over a wide area is aerial spraying. In many states aerial spraying may be available in certain locations as a means to control nuisance mosquitoes. Such resources can be redirected to areas of virus activity. When aerial spraying is not routinely used, such services are usually contracted for a given time period.

Pesticides for adult mosquito control can be applied from hand-held application devices or from trucks or aircraft. Hand-held or truck-based applications are useful to manage relatively small areas, but are limited in their capacity to treat large areas quickly during an outbreak. In addition, gaps in coverage may occur during truck-based applications due to limitations of the road infrastructure. Aerial application of mosquito control adulticides is required when large areas must be treated quickly, and can be particularly valuable because controlling WNV vectors such as *Cx. quinquefasciatus* or *Cx. pipiens* often requires multiple, closely spaced treatments (Andis et al. 1987). Both truck and aerially-applied pesticides for adult mosquito control are applied using ultra-low-volume (ULV) technology in which a very small volume of pesticide is applied per acre in an aerosol of minute droplets designed to contain sufficient pesticide to kill mosquitoes that are contacted by the droplets. Information describing ULV spray technology and the factors affecting effectiveness of ground and aerially-applied ULV pesticides is reviewed in Bonds 2012.

Key active ingredients

Control of adult mosquitoes is attempted by the use of pesticides registered by the environmental protection agency as adulticides. These compounds are applied either by aircraft of truck-mounted sprayers. Two organophosphates are in use, Malathion and Naled. In addition to these compounds pyrethroids are widely used for controlling various insects. Pyrethroids are synthetic chemical insecticides that act in a similar manner to pyrethrins, which are derived from chrysanthemum flowers. Permethrin, resmethrin, and d-phenothrin are synthetic pyrethroids commonly used in mosquito control programs to kill adult mosquitoes. More information regarding their use and methods of distribution are available at http://www2.epa.gov/mosquitocontrol/controlling-adult-mosquitoes

Environmental control options
Integrated Vector Management

Mosquito abatement programs successfully employ integrated pest management (IPM) principles to reduce mosquito abundance, providing important community services to protect quality of life and public health (Rose 2001). Prevention and control of zoonotic arboviral diseases is accomplished most effectively through a comprehensive, integrated vector management (IVM) program applying the principles of IPM. IVM is based on an understanding of the underlying biology of the arbovirus transmission system, and utilizes regular monitoring of vector mosquito populations and viral encephalitic activity levels to determine if, when, and where interventions are needed to keep mosquito numbers below levels which produce risk of human disease, and to respond appropriately to reduce risk when it exceeds acceptable levels.

Change the water in water troughs is changed at least twice a week to discourage mosquito breeding. Have secure screens on windows and doors to keep mosquitoes out.

Get rid of mosquito breeding sites by emptying standing water from flower pots, buckets, barrels and other containers. Drill holes in tire swings so water drains out and keep children's wading pools empty and on their sides when they aren't being used.

Insecticide active ingredients labeled for topical application to control mosquitoes

Active ingredients and concentrations	Application options	Precautions
Cypermethrin 0.075%	Dust	
Cypermethrin 0.15% + Pyrethrins 0.20%	Spray or wipe	
Cypermethrin 1%	Spray or wipe	Do not use on foals under 3 weeks old
Permethrin 0.5%	Spray	
Permethrin 0.10% to 0.50% + Pyrethrins 0.05% to 0.50%	Spray, spot spray or wipe	Do not use on foals under 3 months old
Permethrin 0.20% + 0.13% Prallethrin	Spray	
Permethrin 0.90% + Tetramethrin 0.25% + Cypermethrin 0.10%	Spray or wipe	Do not use on foals under 3 months old
Permethrin 1.0% + 0.50% Pyrethrins	Spray or wipe	Do not use on foals under 3 months old
Permethrin 0.9% + Tetramethrin 0.25% + Cypermethrin (0.10%)	Spray or wipe-on	Do not use on foals under 3 months old
Permethrin 5% + 5% Diflubenzuron	Pour-on, Spray, or Wipe	Do not use pour-on application on foals
Permethrin 7.4% to 10%	Pour-on, paste or wipe	Do not use on foals under 3 months old Do not ride within 24 hours of use
Permethrin 10% to 40%	Spray or wipe	Dilute before use
Permethrin 45%	Spot-on	Do not use on foals under 3 months old Suppression only
Pyrethrins 0.10% to 0.20%	Spray or wipe-on	

Check the product label for treatments intervals, application rates, and precautions prior to application.

Brush animals before treatment to remove dirt and dust which can reduce insecticide effectiveness.

Be familiar with pest feeding sites and thoroughly treat areas where the pests feed.

Select Ready-To-Use products with higher percentages of active ingredient for longer duration of protection or for more effective protection when pest pressure is high.

Some animals may be sensitive to ingredients any product, especially if the concentration of active ingredients is high. Reactions may include skin sensitivity, itchiness, rash and hair discoloration or hair loss at the application site. Bathe your horse with a mild, non-insecticidal shampoo and rinse with large amounts of water if you see signs of sensitivity. Contact your veterinarian immediately if the signs persist.

Insecticide active ingredients labeled for application mosquitoes breeding sites to control larvae

Active ingredients and concentrations	Application options	Precautions
Bacillus thuringiensis israelensis(Bti) toxin 10.31%	Standing water where mosquitoes breed,	Do not treat drinking water including animal watering troughs.
(S)- Methoprene 8.62%	Standing water where mosquitoes breed,	Do not apply to water that may drain into public waterways, such as streams or lakes including animal watering troughs.

Mosquito control alternatives

Remove or drain sites where water can collect and stand long enough to serve as a breeding site.

If practical, stock mosquito fish, such as *Gambusia affinis* or *G. holbrooki*, in ponds and standing water that cannot be drained or treated.

Mechanical aerators can create wave action that discourages mosquito breeding and helps to increase oxygen content that to a level that allows fish to survive.

Non-Toxic Pheromone Mosquito Trap uses an egg pheromone to entice gravid mosquitoes to lay their eggs in the container. It attracts species that prefer stagnant water in artificial containers and are vectors of encephalitis virus. The mosquitoes can enter the trap but cannot escape.

Mosquito proof barns and stables by installing window and doors screens, using air screens or fans to keep mosquitoes from entering. Replace incandescent lights with fixtures that are less attractive, such as fluorescent.

Protective fly sheets may be useful in protecting pastured horses from mosquitoes, when practical.

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