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Michigan State University Extension Service
Joy Neumann Landis, Pesticide Education and Pest Management Assistant; Larry G. Olsen, MSU Pesticide Coordinator.
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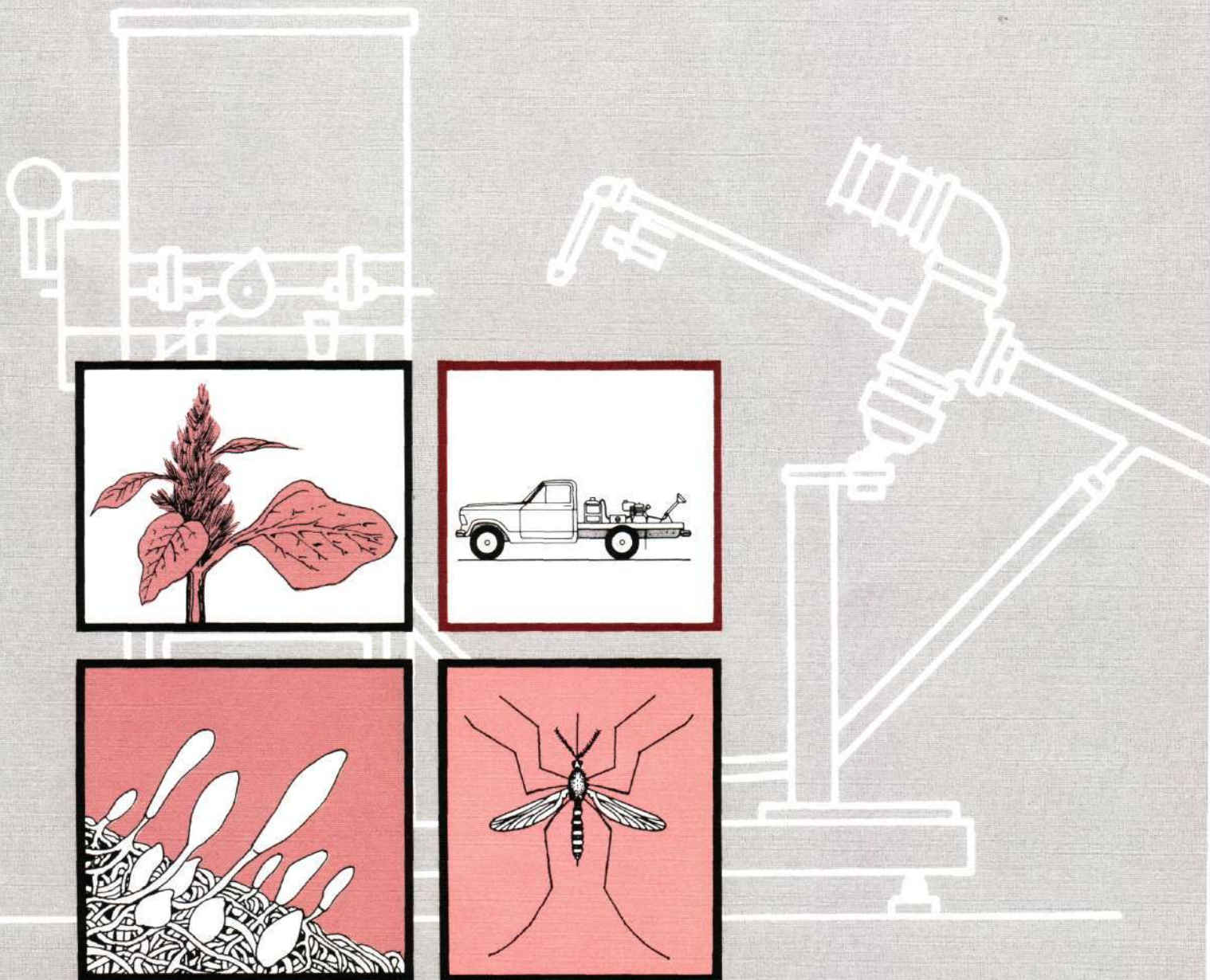
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Mosquito Control

A Manual for Commercial Pesticide Applicators



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MOSQUITO CONTROL

A Manual For Commercial Pesticide Applicators

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PREFACE

This manual is intended to prepare pesticide applicators in mosquito control for certification under the Michigan Pesticide Control Act of 1988. The "Commercial and Private Pesticide Applicator Manual: Core Certification" which explains safety considerations, pesticide laws, and integrated pest management principles, should also be studied to prepare for certification.

After reading each chapter of this manual, answer the review questions. Write out the answers to receive the maximum benefit from your studying. Compare your responses with the correct answers listed in the back of the manual. After completing your study of this manual and the "core" manual, take the exam administered by the Michigan Department of Agriculture to become a certified commercial pesticide applicator for mosquito control.

ACKNOWLEDGEMENTS

This manual is based on information from "The Michigan Mosquito Manual" published by the Michigan Department of Public Health, Insect and Rodent Control Section. We would also like to express our appreciation to Mark Harten and Peter Carrington for providing illustrations.

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CHAPTER 1

INTRODUCTION: THE HISTORY OF MOSQUITOES IN MICHIGAN

The Impact of Mosquitoes

Michigan probably has had mosquito problems since humans first moved into the region. There are stories about Indian trails, developed long before the Caucasian invasion, that wound around and about high ground to avoid areas where mosquitoes lay in wait for a suitable warm-blooded donor. Humans, being less hairy than other mammals, were favorite targets.

Although written accounts are few, it doesn't take much imagination to believe that these same adversaries were encountered by the early fur traders, missionaries and their aboriginal associates who worked in the areas near Lakes Michigan, Superior, Huron and Erie. In fact, U.S. military documents show that a fort was established on the banks of the Saginaw River in 1822 only to be decommissioned three years later because over 90% of the garrison had contracted malaria.

The mosquito-borne disease, viral equine encephalitis, also is no newcomer to this state. Techniques needed to diagnose eastern and western equine encephalitis did not become available until the 1930's, so there are no reliable records to indicate the incidence of these diseases prior to that time. Records of the Michigan Department of Agriculture (MDA) indicate that sporadic equine infections with this disease are the norm, and that more extensive outbreaks have occurred periodically. In 1942 and 1943, a total of 469 equine cases, were reported in Michigan by the U.S. Department of Agriculture Bureau of Animal Industry. Until 1980, however, no human infections of equine encephalitis were reported in Michigan. During an extensive epizootic in that year, a young boy in St. Joseph County became the first human known to have contracted eastern equine encephalitis in Michigan. He was hospitalized in August 1980, became comatose, and died in March 1982. This event raised public awareness of the seriousness of the disease and its potential hazard to humans.

Two other mosquito-borne encephalitides also occurred in Michigan, St. Louis (SLE) and Califor-

nia Group (CE), but recognition of their presence here is much more recent than that of eastern and western equine encephalitis. The first known human infections with SLE were reported in Michigan in 1975, part of a widespread epidemic that extended from the southern Mississippi Valley in the United States into southern Ontario. In this epidemic, 93 human cases with 3 deaths were reported in Michigan. In the years following the 1975 epidemic, only sporadic human SLE infections have been reported.

The first evidence of the existence of CE viruses in Michigan was reported in 1963 when neutralizing antibodies were found in the blood of snowshoe hares collected in the Upper Peninsula. The first diagnosed human case of CE in Michigan was in 1968. CE infection symptoms may be relatively mild, so it is quite probable that many of the cases go undiagnosed and therefore, underreported. Studies in 1986 by Grimstad at Notre Dame University revealed that approximately 20% of premarital blood samples drawn from Michigan residents of the Lower Peninsula contained antibodies to the California group virus named Jamestown Canyon (JC).

Dog heartworm, *Dirofilaria immitis*, another mosquito-borne disease appears to be a relative newcomer to Michigan, although it has been a major problem in the southeastern United States for many years. From the mid- 1960's until the end of the 1970's there was an explosive spread of dog heartworm throughout Michigan. It now is transmitted throughout the summer months in virtually all counties in the Lower Peninsula. It is present in some dogs in the Upper Peninsula as well, but the degree to which it may be transmitted in this part of the State presently is unknown. Although this is primarily a canine disease, a small number of human infections have been reported in the United States, one in Michigan.

None of these mosquito-borne diseases have been as numerous in Michigan as many other pathogenic infections, but the physical and emotional stress associated with them and the media publicity that inevitably comes with them create intense public concern that must be dealt with by health professionals.

CHAPTER 2

MOSQUITO LIFE CYCLE

Mosquitoes are small, long-legged, two-winged insects belonging to the order Diptera (flies) and the family Culicidae. The adults differ from other Diptera in that they have both elongated mouthparts and scales on the wing veins and wing margins. Worldwide there are over 2,600 known species. About 150 species representing 13 genera and three subfamilies occur in the United States. These are:

- Subfamily Anophelinae – Genus *Anopheles*
- Subfamily Culicinae – Genus *Aedes*,
Coquillettidia, *Culex*, *Culiseta*, *Deinocerites*,
Haemogogus, *Mansonia*, *Orthopodomyia*,
Psorophora, *Uranotaenia*, and *Wyeomyia*;
- Subfamily Toxorhynchites – Genus *Toxorhynchites* (formerly *Megarhinus*).

Nine of the 13 genera that exist in North America are present in Michigan, and over 60 species at this time are known to exist here.

LIFE HISTORY

Mosquitoes have four distinct stages of development (complete metamorphosis): egg, larvae, pupa, and adult (Figure 1). Eggs must be in water to hatch but may be deposited initially either directly on water or in locations subject to periodic flooding. Larvae and pupae are aquatic but the adults are active, free-flying insects. Overall, the aquatic and terrestrial habitats used by immature and adult mosquitoes are diverse but are relatively specific for each species.

Eggs

Adult females select locations for egg laying that will provide suitable conditions for larval development after the eggs hatch. Egg laying characteristics follow one of three patterns: (1) eggs laid singly on the water surface; (2) eggs glued together to form rafts which float on the water surface; and (3) eggs laid singly out of the water.

To a degree, the physical characteristics of the eggs of each species are adaptations that reflect the egg laying pattern. *Anopheles* and *Toxorhynchites*

eggs are deposited singly on the water surface and float until they hatch two or three days later. The *Anopheles* eggs have lateral extensions that serve as floats while the *Toxorhynchites* eggs have projecting spines that trap air bubbles which keep them on the water surface. *Culex*, *Culiseta*, *Mansonia*, *Coquillettidia*, and *Uranotaenia* species glue individual eggs together to form a floating raft. As the eggs hatch two or three days later, the raft breaks up and individual egg cases – up to 300 or more – remain floating on the water. The eggs of *Aedes*, *Psorophora*, and *Orthopodomyia* species are deposited out of the water so they are adapted to withstand dryness until the area is later flooded and the eggs hatch.

Within these three genera there is a wide variety of habitats used, and the environmental conditions needed for egg survival and hatching vary. *Orthopodomyia* and some *Aedes* species lay their eggs on the sides of tree rot holes or other water containers just above the water surface. *Orthopodomyia* eggs hatch within two to three days and then the larvae slide down into the water. Hatching occurs in *Aedes* species only when the water level rises and eggs are flooded.

Other *Aedes* and all *Psorophora* species deposit their eggs on moist soil where they remain until exposed to certain environmental conditions and then are covered with water. *Psorophora* and some of the soil-deposited *Aedes* eggs hatch shortly after flooding, but other *Aedes* must be exposed to cold weather for a time before flooding causes them to hatch. In the former groups there may be several generations each year while the latter group has only one. In Michigan, all *Psorophora* and *Aedes* species overwinter in the egg stage.

Larvae

Mosquito larvae have three distinct body regions: head, thorax, and abdomen (Figure 2). The head is broad and somewhat flattened with lateral antennae. Mouthparts usually consist of a series of brushes and grinding structures, but in some predaceous species, they are adapted for grasping their prey.

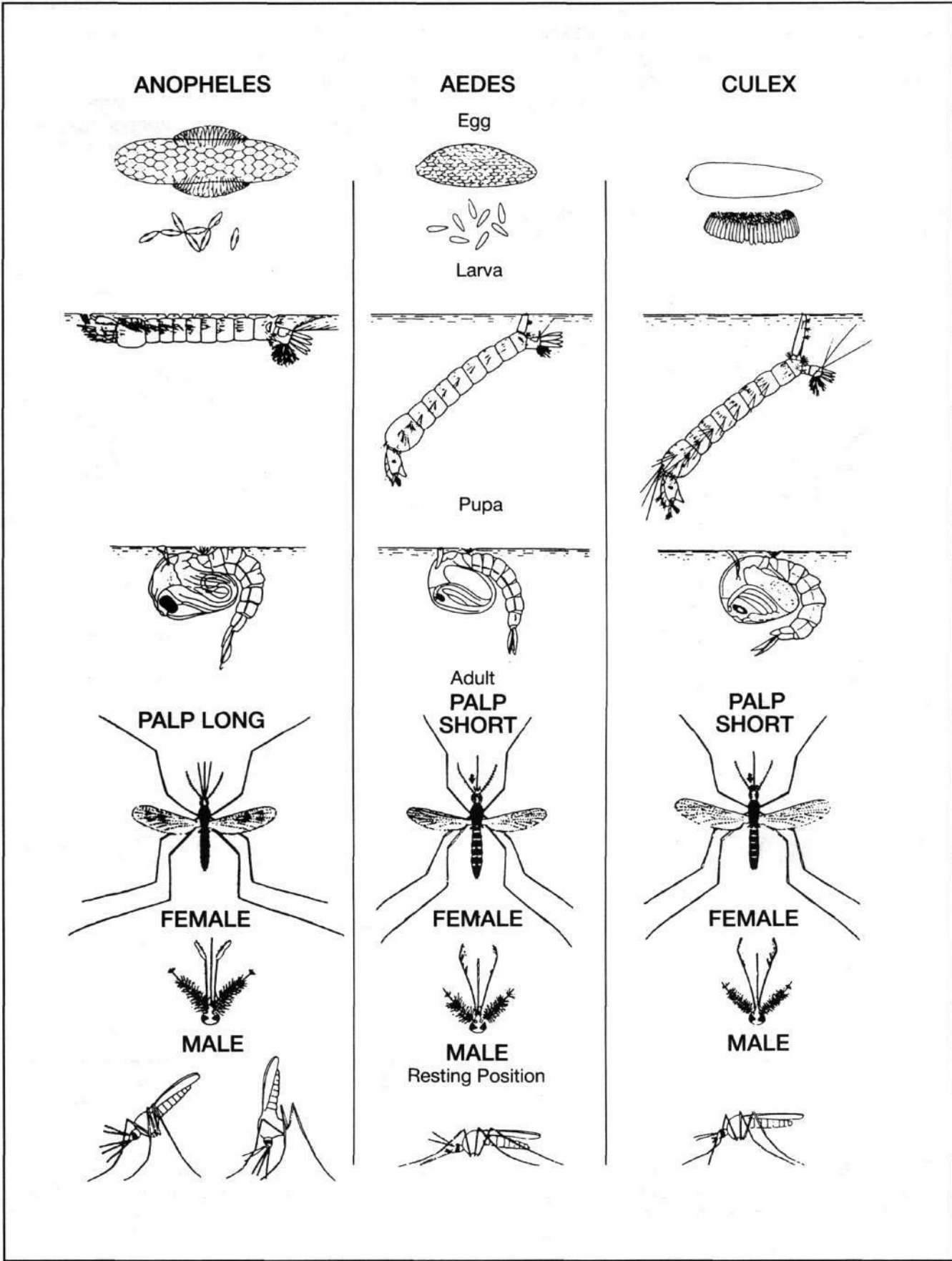


Figure 1. Four Stages of *Anopheles* and *Culex* Larvae.

The thorax is broader than the head and somewhat flattened. The structure and number of hairs on both the head and thorax are used to identify species. The abdomen is elongate and cylindrical, consisting of nine well defined segments. The first seven are similar, but the eighth and ninth are considerably modified. The eighth contains the respiratory openings which in *Anopheles* are a pair of breathing holes, while in all others, a prominent air tube. The ninth segment is the anal segment.

mosquito larvae are found are highly variable but have three common characteristics. The water is: 1) either stationary or very slow moving; 2) has a suitable food source for the larvae (bacterial, fungal, or algal growth or suspended organic particles); and 3) provides some protection from wind and waves either in the form of vegetation or other wind shielding features.

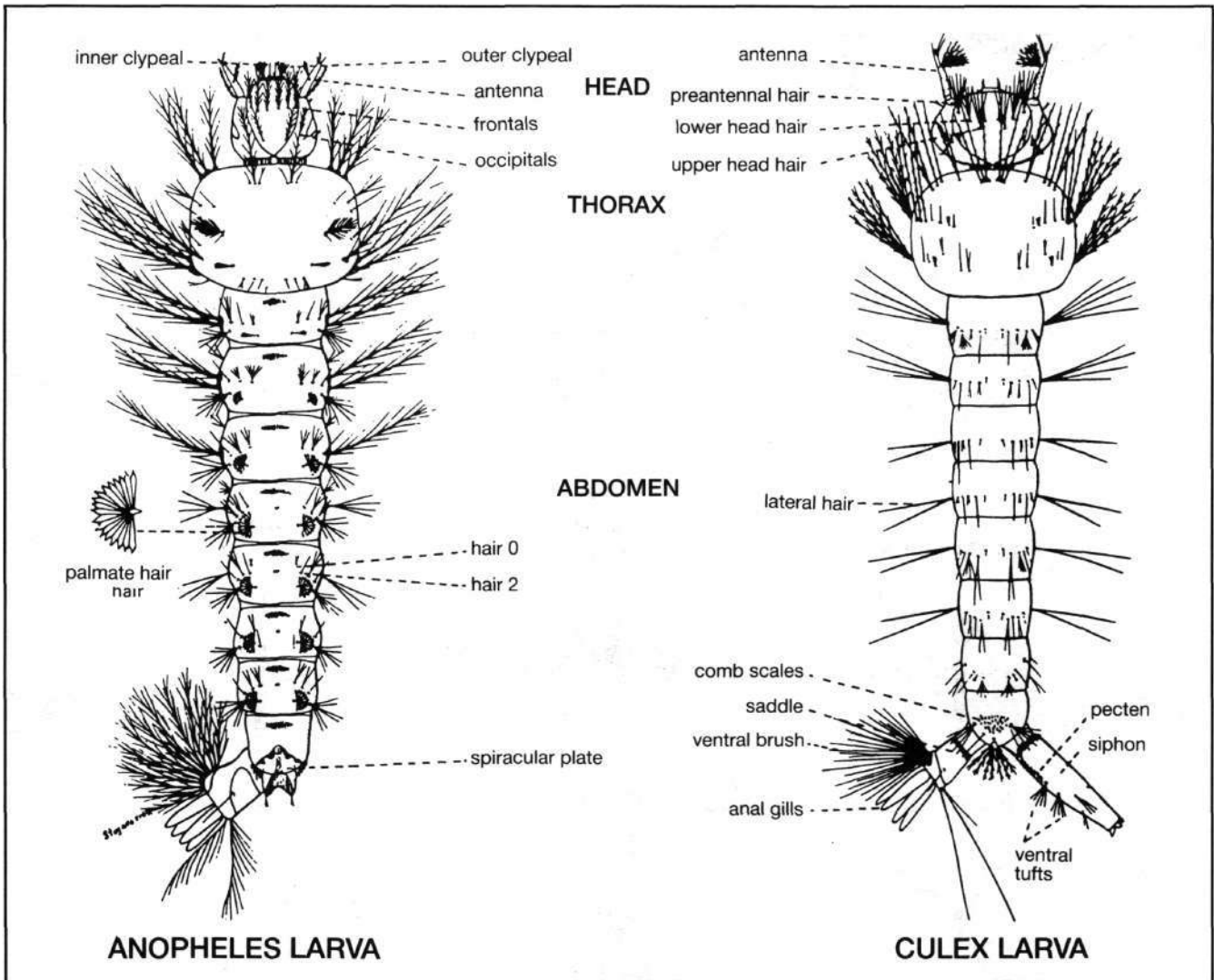


Figure 2. Fourth Stage of *Anopheles* and *Culex* Larvae.

The location in which mosquito larvae occur are determined by the sites selected for egg laying by the female mosquitoes. Without exception, water is required during larval and pupal development because neither of these two stages can survive out of water. The size and type of water accumulations (called breeding sites) in which

Within these broad requirements the specific type of water used by mosquito larvae is characteristic for each species but may vary widely from one species to another. Common larval habitats in Michigan are temporary pools, caused by rain or stream overflow (flooded fields, flooded woodlots, river floodplains), used tires, tin cans, and

other water collecting containers, storm sewer catch basins, roadside drainage ditches, rot cavities in trees, sewage lagoons, and permanent ponds, marshes, and lakes with emergent vegetation. The water may vary from fresh to highly polluted and have a broad spectrum of dissolved chemical concentrations.

During larval development mosquitoes pass through four stages called instars. At the end of each stage they shed their skins (molt) and increase in size. The average size of a fourth instar larva is 1/4-1/2 inch long. At the end of the fourth instar, larvae molt again and become pupae. Complete larval development at normal summer temperatures in Michigan occurs in seven to ten days but may take much longer at lower temperatures or if food is not adequate. Larvae are indiscriminate feeders that ingest all suspended particular matter that is small enough to be swallowed. Most species also browse on algae, bacteria, and fungi growing on submerged surfaces. Some species feed on other mosquito larvae and small aquatic invertebrates.

All mosquito larvae are air breathers and with some exception, spend a great deal of time suspended from the water surface in characteristic positions. *Anopheles* rest parallel to the surface, suspended by float hairs inserted into the surface film, with their respiratory openings exposed to the air. All other Culicinae, except *Mansonia* and *Coquillettidiae*, hang at an angle from the surface with the tip of their air tube (siphon) inserted into the surface film. *Mansonia* and *Coquillettidiae* obtain air by inserting their tubes into the hollow roots of aquatic plants and never need to surface to breathe.

Pupae

The pupal stage is a relatively short (two to three days), nonfeeding, transitional stage in which the adult develops within the pupal covering. There are two body regions: an expanded cephalothorax and an elongate abdomen consisting of eight movable segments terminating in a pair of paddles. Projecting from the cephalothorax are two short, flared tubules "trumpets" surrounding the openings to the respiratory system. The trumpets are inserted through the water surface film which allows the pupae to breathe air directly. As with the larvae, exceptions to this are the *Mansonia* and *Coquillettidiae* pupae which insert their trumpets into the hollow, air-filled roots of aquatic plants. Pupae in other genera are lighter than water due to an air bubble in the cephalothorax so they normally remain suspended

at the water surface. If disturbed, they can move quickly by rapidly flexing the abdomen and its paddles, producing a diving, tumbling movement which is the source of their common name, tumblers. When pupal development is completed the skin splits along the dorsal side, and the adult crawls out and rests on the floating skin until able to fly away.

Adults

The adult mosquito (Figure 3) is a small, fragile insect with a slender abdomen, one pair of narrow wings, three pairs of long, slender legs and an elongated proboscis. This stage varies in length from slightly over 1/16 inch to about 1/2 inch. Three body regions: head, thorax, and abdomen are distinct.

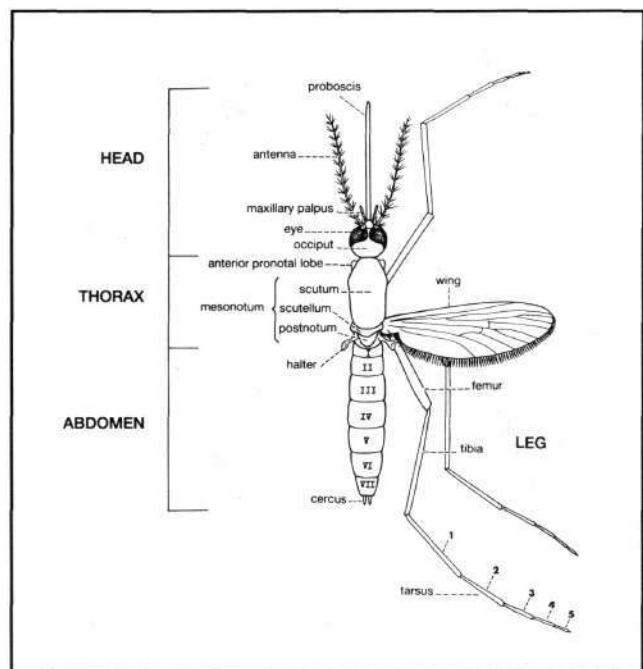


Figure 3. Diagram of Adult Mosquito and Body Parts. (Courtesy: Indiana State Board of Health)

The antennae, arising on the front of the head between the eyes, are long, slender structures with 15 segments, only 14 of which are readily visible. Each segment, except the nearest two, bears a whorl of hairs which are short and sparse in females but long and bushy in males. This characteristic identifies males from females. Antennae are believed to be organs of hearing and smell. The five segmented (Figure 4) palpi originate at the lower anterior margin of the head near the proboscis and vary in size and shape. In female *Anopheles* they are about the same length as the proboscis and straight-sided. In male *Anopheles*, they are enlarged at the tip. Palpi of

female Culicinae are very much shorter than the proboscis while the male palpi are longer than those of the female, are more densely haired and have the last two segments bent upwards. The proboscis projects downward and forward from the lower front margin of the head and consists of a sheathlike labium enclosing six stylets. The labium is a protective sheath for the stylets and acts as a guide at the skin surface when they are inserted into a host during blood feeding (Figure 4).

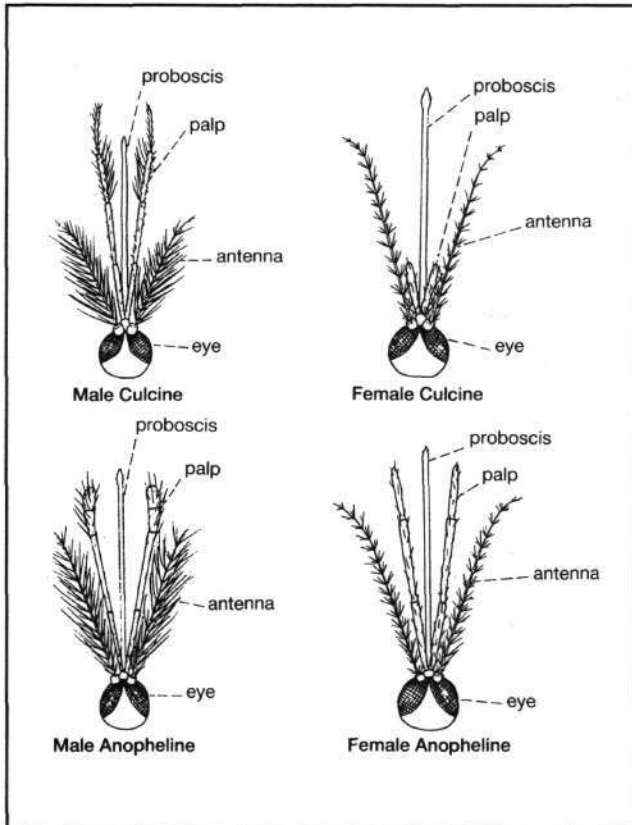


Figure 4. Diagram of Anopheline and Culicine Mosquito Heads. (Courtesy: Indiana State Board of Health)

The close-fitting stylets also form two narrow channels, one to deliver saliva into the hosts while the female mosquito takes a blood meal and the other two withdraw either blood or plant fluids. Male and female mouthparts are similar but only the female feeds on blood.

Scales and scale patterns on the thorax, legs, and wings, and the hairs and bristles on the sides of the thorax are all used in species identification. The thorax bears the wings and legs and has a variety of scales and hairs or bristles on the upper surface and sides. The long, slender legs arise from the lower sides of the thorax and consist of five sections. All segments of the leg are covered with scales. The wings are long and narrow with

longitudinal reinforcement structures called veins. They have a close-set row of long, slender fringe scales on the posterior margin. The wing veins also are clothed with scales, often of different colors that form distinct patterns. A pair of small, knobbed structures, known as halteres, is behind the wings. These vibrate rapidly during flight and function as organs of equilibrium.

The elongate abdomen is nearly cylindrical and consists of ten segments, only eight of which are readily visible. The ninth and tenth segments are greatly modified for sexual function in both males and females. In Culicinae and Toxorhynchitinae species, the abdomen is covered with scales which often form characteristic markings. In Anophelinae species, abdominal scales are either absent or very sparse. The abdomens of *Aedes* and *Psorophora* females are tapered apically, with the eighth segments withdrawn into the seventh, while in all other U.S. genera, they are bluntly rounded at the apex (Figure 5). The terminal abdominal segments of all male mosquitoes are greatly modified for copulation and help identify the species.

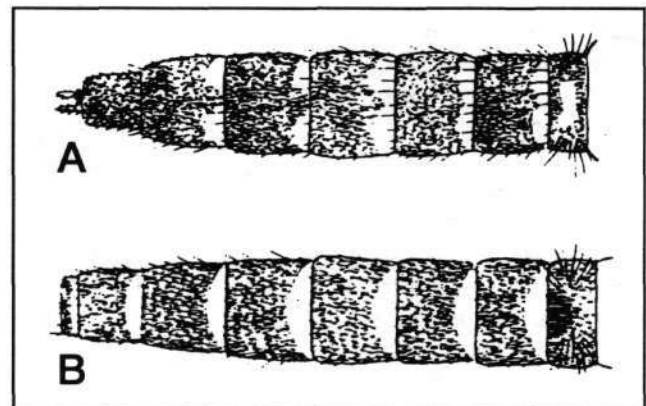


Figure 5. Comparison of *Aedes* abdomen (A-pointed) and *Culex* abdomen (B-blunt).

ADULT MOSQUITO CHARACTERISTICS

There are some behavioral characteristics that are common to most mosquito species, but by and large there are few generalizations that can be made. The male-female ratio in adult mosquitoes is normally about 1:1. Males emerge from the pupal stage about 24 hours before the females and stay in the immediate vicinity until the female emergence so the majority of females in any population is fertile.

Both females and males drink nectar and other plant juices as energy sources; but only females take a blood meal, utilizing the protein from blood

to produce eggs. In a few species females acquire enough protein during the larval stage to produce eggs when they become adults and so do not require a blood meal to reproduce. The mosquito life-span is highly variable and dependent upon a number of environmental conditions. In general males are much shorter lived than females, surviving for a few days to a week, while females may live for several weeks to months, depending upon the species and local conditions. Generally mosquitoes remain inactive during the day, resting in cool, humid locations to minimize moisture loss. Feeding and mating activity occurs from dusk through the night until just after dawn.

Knowing specific behavior of individual species is very important for controlling or preventing both mosquito-borne diseases and pest mosquito problems. To understand the dynamics of mosquito-borne disease transmission and plan effective control measures for either disease or pest problems, you need to know an impressive number of facts about the mosquito species in the area of concern. This information includes:

- the types of larval breeding sites used;
- biting preference of females — birds, mammals, reptiles, or combinations;
- seasonal population levels;
- how far mosquitoes fly from their sites of origin;
- whether or not a given species can become infected with and later transmit the pathogen involved;
- whether a given species in the area is actually infected with pathogen at the time the disease is present in vertebrate hosts;
- many other related specific items of information.

These types of specifics usually are unique for a given area so the information that may have been assembled at other times and places may not be accurate for your area. Some of this type of information is given in the table in Chapter 3. Select the genus and species (left two columns of the table) for the particular mosquito and check the remaining columns for behavioral information. See Figure 6 for an illustration of insects most often mistaken for mosquitoes.

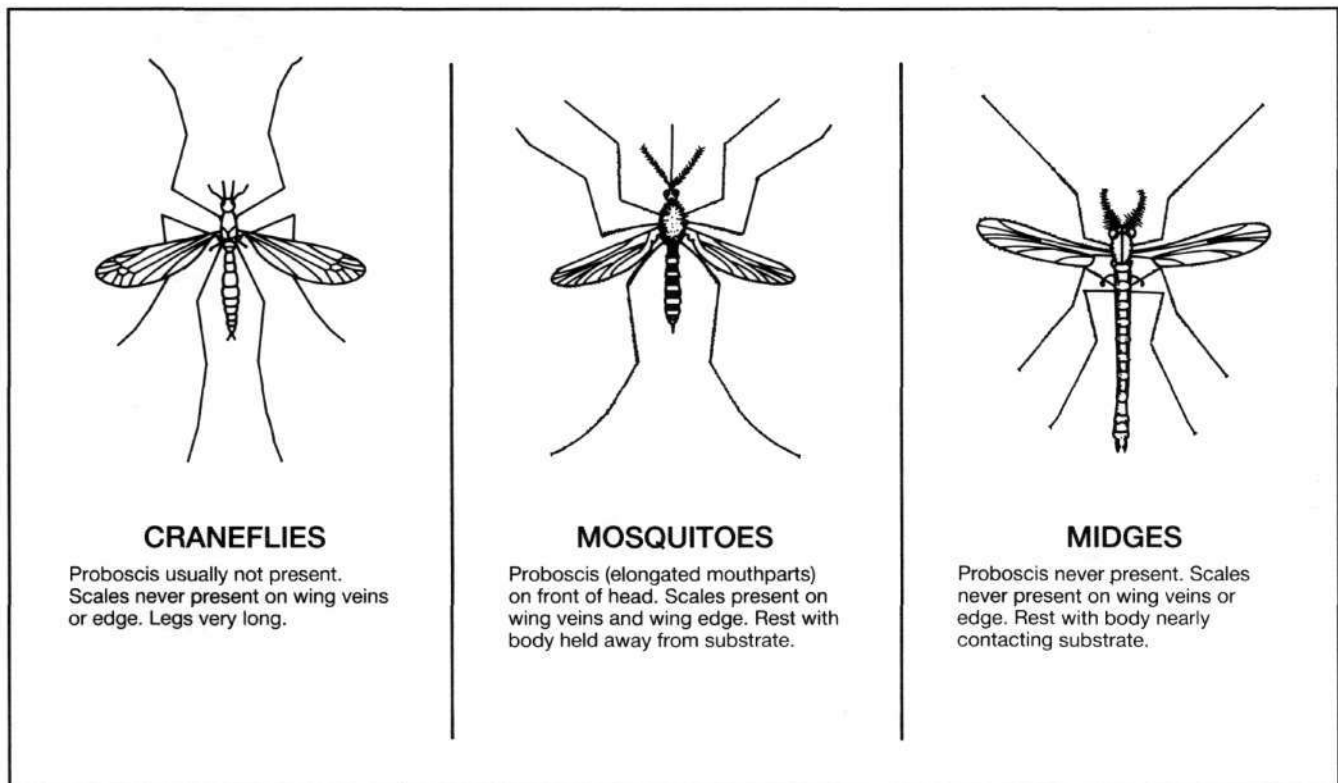


Figure 6. Insects Commonly Confused With Mosquitoes.

REVIEW QUESTIONS – CHAPTER 2: MOSQUITO LIFE CYCLE

1. Mosquito development is a complete metamorphosis which means it passes through the following stages:
 - a. Egg, larva, adult.
 - b. Egg, larva, pupa, cocoon, adult.
 - c. Egg, larva, pupa, adult.
 2. Name three ways mosquitoes lay eggs.
 3. All mosquito larvae and pupae cannot survive out of water. True or False?
 4. The three distinct body regions of the mosquito larvae and adults are the head, thorax, and abdomen. True or False?
 5. During pupal development, pupae shed their skin several times between growth stages. True or False?
 6. Which of the following statements describe common characteristics of mosquito breeding sites:
 - a. The water is stationary or slow moving.
 - b. The area is protected from wind and waves.
 - c. There is a larval food source such as bacterial, fungal or algal growth or suspended organic particles.
 - d. a and c
 - e. a, b, and c
 7. Which mosquitoes bite and why do they bite?
 8. Why is it necessary to identify mosquito species and know as much as possible about the life history of mosquitoes present in your area?
-

CHAPTER 3

CHARACTERISTICS OF COMMON MICHIGAN MOSQUITOES

TABLE I. COMPARISON OF MOSQUITO CHARACTERISTICS

CE-California Encephalitis DHW-Dog Heartworm WEE-Western Equine VE-Venezuelan Encephalitis
 SLE-St. Louis Encephalitis EEE-Eastern Equine Encephalitis VEE-Venezuelan Equine Encephalitis

| SCIENTIFIC NAME (Genus) | (Species) | DISEASE ASSOCIATION | FEEDING PREFERENCE | HABITAT | EGGS | BROODS/YEAR | OVERWINTER STAGE | EFFECTIVE FLIGHT RANGE |
|----------------------------|------------|------------------------|---|---|--|---|---------------------|---------------------------|
| Aedes | abserratus | | mammals | woodland pools | singly on low, damp ground | one | eggs | |
| | atropalpus | | mammals | rock pool | singly above water level | several | eggs | limited |
| | aurifer | | mammals | temporary pools, peat bogs | | one | eggs | 1/2 mile |
| | campestris | | mammals | temporary vernal pools | | one in north part of range; 2 or more in south | eggs | |
| | canadensis | DHW, CE, EEE | birds, mammals, amphibians, reptiles | temporary shaded woodland pools | singly on low, damp surface | one | eggs | 1/2 mile |
| | cinereus | DHW, CE, EEE | mammals | woodland pools, bogs, marshes | singly on low, damp surface | one | | limited |
| | communis | | mammals | woodland pools with high organic content | laid under leaves in dry beds of vernal woodland pools | one | eggs | |
| | decticus | | mammals | spaghnum bog pools | | | eggs | |
| | diantaeus | | mammals | woodland vernal pools | | one | eggs | |
| | dorsalis | SLE, WEE, CE, DHW | mammals & serious human pest | brackish & fresh water | laid above flood water & temporary pool levels subject to flooding | several | eggs | 10-20 miles or more |
| | dupreii | | | temporary woodland rain- water pools | | | eggs | |
| | euedes | | | large, open | | one | eggs | |
| | excrucians | CE, DHW | mammals | woodland & semi-permanent swamps & marshes | laid singly on damp earth | one | eggs | 1/2 mile |
| | fitchii | CE, DHW | mammals | mud at edge of pool | laid on damp earth | one | eggs | ± 1 mile |

CE-California Encephalitis
SLE-St. Louis Encephalitis

DHW-Dog Heartworm
EEE-Eastern Equine Encephalitis

WEE-Western Equine
VEE-Venezuelan Equine Encephalitis

VE-Venezuelan Encephalitis

| SCIENTIFIC NAME (Genus) (Species) | DISEASE ASSOCIATION | FEEDING PREFERENCE | HABITAT | EGGS | BROODS/YEAR | OVERWINTER STAGE | EFFECTIVE FLIGHT RANGE |
|--------------------------------------|------------------------|-----------------------|---|--|--------------------------------|---------------------|---------------------------|
| Aedes flavescens | | mammals | temporary & semi-permanent pools in meadows & marshes | | one | eggs | limited |
| grossbecki | | mammals | woodland pools in early spring | singly on damp, low surface | one | eggs | 1/2 mile |
| hendersoni | | mammals | tree holes, containers, prefer canopy of trees | laid above water level | several | eggs | ± 1 mile |
| impiger | | mammals | snow-melt pools | on soil or in soil cracks in dried pool beds | probably one | eggs | |
| implicatus | | mammals | temporary forest pools & floodplains | | one | eggs | |
| intrudens | | mammals | woodland pools, open bogs & marshes | | one | eggs | |
| mitchellae | | mammals | temporary rain pools | | | eggs | |
| provocans | | mammals | snow-melt pools & other semi-permanent marshes | | one | eggs | |
| punctor | CE | mammals | snow-melt pools | singly on low, damp depressions | one | eggs | |
| riparius | | mammals | spring pools | | one | eggs | |
| sollicitans | EEE, VE, CE, WEE, DHW | mammals, birds | salt & brackish marshes | singly on ground | several | eggs | 100 miles or more |
| spencerii | VEE | mammals | temporary rain & snow-melt pools | | 2 or 3 if weather is favorable | eggs | several miles |
| sticticus | CE, DHW | mammals | flood water pools in river floodplains | singly on low, damp surfaces | one, possibly more | eggs | 4 miles |
| stimulans | DHW, CE | mammals | temporary & vernal woodland pools | laid on damp soil | one | eggs | 2 miles |
| triseriatus | CE, DHW | mammals | treeholes (prefer basal part of tree), containers | laid singly above water level | several | eggs | 1/2 to 1 mile |
| trivittatus | CE, DHW | mammals | floodwater & woodland pools | singly on damp, low surface | several | eggs | 1/2 mile |
| vexans | EEE, WEE, CE, DHW | mammals | temporary pools | laid in or on soil in low lying areas | several | eggs | 5 to 10 miles |

CE-California Encephalitis DHW-Dog Heartworm WEE-Western Equine VE-Venezuelan Encephalitis
 SLE-St. Louis Encephalitis EEE-Eastern Equine Encephalitis VEE-Venezuelan Equine Encephalitis

| SCIENTIFIC NAME (Genus) (Species) | DISEASE ASSOCIATION | FEEDING PREFERENCE | HABITAT | EGGS | BROODS/YEAR | OVERWINTER STAGE | EFFECTIVE FLIGHT RANGE |
|--------------------------------------|------------------------|------------------------------------|---|--|---------------|-----------------------------------|---------------------------|
| Anopheles barberi | | mammals | treeholes & stump holes | singly on water surface | 2 or more | larvae | |
| crucians | | mammals | ponds, swamps, semi-permanent and permanent pools | singly on water surface | 2 or more | larvae | |
| earlei | | mammals | fresh water marshes partially shaded | singly on water surface | one | adult female | 1 to 2 miles |
| perplexens | | mammals | semi-permanent to permanent pools, lakes, & swamps | | | adults | |
| punctipennis | CE, DHW, Malaria | mammals | a wide variety of ground water accumulations which are cool & clean | laid singly on water surface | several | adult female | 1 to 2 miles |
| quadrimaculatus | DHW, Malaria | mammals | permanent fresh water with herbaceous surface growth | singly on water | several | adult female | 1 mile |
| walkeri | Malaria, DHW | mammals, wild & domestic animals | fresh water with emergent vegetation | singly on water surface | several | eggs | 1 to 2 miles |
| Coquillettidia perturbans | EEE | mammals, birds | permanent bogs, marshes with heavy aquatic vegetation | rafts on water | one irregular | as larvae attached to plant roots | 1 to 5 miles |
| Culex erraticus | | birds, mammals | grassy margins of ponds, marshes & lakes | rafts on water | several | adult female | |
| pipiens | CE, SLE, EEE, Malaria | birds, mammals | foul ground water & containers | rafts on water | several | adult female | 1 mile or more |
| peccator | | | stream pools & marshes | rafts on water | several | adult female | |
| restuans | EEE, SLE, DHW, WEE, CE | birds; rarely bite mammals | ditches, woodland pools, containers | rafts on water | several | adult female | 1 mile |
| salinarius | SLE, EEE | birds, mammals | fresh or foul pools, ditches | rafts on water | several | adult female | |
| tarsalis | EEE, SLE, WEE, CE | birds, mammals | clean or foul ground water, containers | rafts on water | several | adult female | 1 mile |
| territans | EEE | cold-blooded vetebrates esp. frogs | semi-permanent to permanent clean ground water pools | rafts on water | several | adult female | 1 mile |
| Culiseta impatiens | | mammals | semi-permanent ponds, & bog pools | rafts on water | one or more | adult female | |
| inornata | SLE, WEE, EEE | large mammals | ground pools, brackish & alkaline | in pasture pools, semi-permanent water | one or more | adult female | |

CE-California Encephalitis DHW-Dog Heartworm WEE-Western Equine VE-Venezuelan Encephalitis
 SLE-St. Louis Encephalitis EEE-Eastern Equine Encephalitis VEE-Venezuelan Equine Encephalitis

| SCIENTIFIC NAME (Genus) (Species) | DISEASE ASSOCIATION | FEEDING PREFERENCE | HABITAT | EGGS | BROODS/YEAR | OVERWINTER STAGE | EFFECTIVE FLIGHT RANGE |
|--------------------------------------|---------------------|--|---|---|--------------|------------------|------------------------|
| Culiseta melanura | EEE, CE | birds | small permanent bodies of water | laid on water surface | several | larvae | 100 to 1000 yds. |
| minnesotae | EEE, CE | birds, small mammals | | | one or more | adult female | |
| morsitans | | probably birds | temporary cold rain water pools, marshes | on damp earth or just above water level | one | larvae | |
| Orthopodomyia alba | | probably birds | tree holes, containers | singly on walls just above water line | probably one | larvae | |
| signifera | | birds | tree holes, containers | singly on walls just above water line | | larvae | |
| Psorophora ciliata | SLE | mammals (predaceous & cannibalistic as larvae) | unshaded temporary rain pools | damp earth or edge of container | several | eggs | |
| ferox | | mammals | temporary rain filled pools | damp earth in low areas subject to flooding | several | eggs | |
| Uranotaenia sapphirina | | rarely mammals | semi-permanent & permanent water with floating vegetation | rafts on surface water | several | adult females | up to 8 miles |
| Wyeomyia smithii | | rarely humans | water filled leaves of pitcher plant | leaves of pitcher plant | several | larvae | |

REVIEW QUESTIONS – CHAPTER 3: CHARACTERISTICS OF COMMON MICHIGAN MOSQUITOES

- Circle the genera of mosquitoes that are known to occur in Michigan:
 - Anopheles
 - Aedes
 - Coquillettidiae
 - Culex
 - Culiseta
 - Deinocerites
 - Haemogogus
 - Mansonia
 - Orthopodomyia
 - Psorophora
 - Uranotaenia
 - Wyeomyia
 - Toxorhynchites
- Effective flight ranges may be up to 100 miles or more for some mosquito species. True or False?
- Mosquitoes cannot overwinter as adults. True or False?

CHAPTER 4

MOSQUITO-BORNE DISEASES

ST. LOUIS ENCEPHALITIS (SLE)

This disease is caused by a virus that has a “natural” transmission cycle involving several species of wild birds and mosquitoes. The virus is present in the blood of infected birds, and when mosquitoes feed on infected birds, they ingest the virus with the bird’s blood. After one to two weeks at summer temperatures, the virus reproduces and spreads to the salivary glands of some mosquito species. Then it is inoculated into the next animal – bird, mammal or human – when the infected mosquito feeds. (See Figure 7.) At cooler temperatures, the virus development cycle in the mosquito is longer.

Once infected, the mosquito can transmit the virus each time it takes a blood meal. In the vertebrate host, usually a bird, the virus again reproduces and must reach a certain concentration in the blood to infect a suitable mosquito species that gets its blood meal from that animal. In most cases, this level is reached within less than a week after the infective bite occurs and lasts for only three to four days after which the virus in the blood is reduced below the level required to infect the mosquito. To become infected and later transmit the virus, a mosquito must feed on the infected vertebrate during this three to four day period.

In some species of birds, the virus level that develops is much higher than in other species. Those with the higher levels are the most important sources of infection for mosquitoes. Also, some mosquito species can become infected when feeding on blood with relatively low virus levels, and these species are the most important in transmitting the virus to the vertebrates because they pick up the infection easily. For some unknown reason, the SLE virus does not multiply in some mosquito species and so is not transmitted even though the mosquito has fed on an infected bird. Also, the virus does not develop to high enough levels in the blood of some vertebrates to infect even the most susceptible mosquitoes feeding on these animals. These vertebrates are called “dead end hosts” because the virus cannot be transmitted from them, through mosquitoes, to some other vertebrate. Humans, some other mammals and some bird species are “dead end hosts” for St. Louis encephalitis.

Vertebrates, birds, humans or other mammals infected with SLE virus do not always exhibit disease symptoms. Particularly birds, even those that develop high levels of virus in their blood, do not exhibit any symptoms. Mammals other than humans are thought to be dead end hosts and also do not exhibit symptoms when infected.

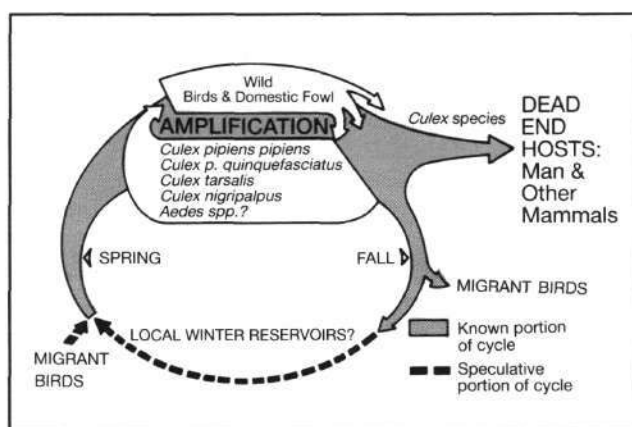


Figure 7. SLE Virus Cycle in the U.S.

The reactions of humans infected with SLE virus varies and depends upon their age, general health and other poorly understood characteristics. Human symptoms associated with SLE virus infections may range from subclinical (no apparent indications of infection) up to severe central nervous system symptoms that may produce temporary or permanent physical or mental disabilities, or even death. In general the fatality rate is higher and the symptoms more severe in people over age 50. In past epidemics, the fatality rates have ranged from 4 to 20 percent with most deaths occurring in the older age groups. Studies conducted on human populations in areas where epidemics have occurred indicate that for each person who developed symptoms of SLE virus infection (ranging from mild to severe) anywhere from 80 to 800 people had been infected with the virus but had not developed disease symptoms. The older age groups consistently exhibited the highest number and most severe symptoms of those infected during these epidemics.

In the Eastern United States, epidemics of SLE have occurred primarily in relatively densely-populated urban and suburban areas where suitable

bird and mosquito species live in close association with humans. These typically are lower socio-economic areas where there are many water-filled artificial containers that provide ideal breeding sites for mosquitoes, and populations of birds, such as sparrows and starlings, that live and nest in or near human residences. In Michigan, this disease has not been a major problem, except for 1975 when 93 human cases were reported with three deaths. Since then some human cases have been reported, but these have been scattered and did not occur in epidemic proportions.

Culex pipiens, the northern house mosquito, is thought to be the primary vector of SLE in most areas of the Central and Eastern United States where epidemics of this disease have been recorded, although other species also have proven to be important vectors in some past epidemics. *Culex pipiens* is one of the most common species of mosquitoes found in urban and suburban habitats and breeds prolifically in all types of artificial water containers that commonly are found in these locations. Examples of these containers are: cans, bottles, tires, water tanks, gutters, bird baths, flower urns and any other trash items capable of holding water with a high organic content. Other structures commonly associated with humans also can produce huge numbers of these mosquitoes during the warm months of the year — storm sewer catchbasins, cesspools, sewage lagoons, open septic tanks, polluted drainage ditches and water runoff impoundments, failed septic system drain fields and effluent from sewage disposal plants.

Culex pipiens are active in Michigan only during the warm months of the year, but adult females overwinter in locations that are protected from weather extremes such as outbuildings, attics and rodent burrows. All other stages are killed when exposed to freezing temperature. Eggs are laid in rafts of 40-500 on the surface of organically-polluted water. At summer temperatures, eggs hatch in one to two days and develop to adults in 8-10 days, but in the cooler temperatures of spring and fall this development might require two or more weeks. Breeding occurs throughout the warm months of the year, and populations in Michigan typically increase throughout the summer reaching their peak in late August. This species feeds primarily on birds, but there is some evidence in Michigan that it may change its feeding habits from mid-August to September and feed on other animals, including humans. This may explain, in part, why human outbreaks of SLE normally occur in late summer.

Other species of mosquitoes that are present in Michigan have been found naturally infected with SLE virus in other parts of the country. These include *Culex restuans*, *Culex salinarius*, *Culex territans*, *Culex erraticus*, *Aedes triseriatus* and *Anopheles crucians*. Whether or not these species play any significant role in transmitting SLE virus to humans is not known, but there is some evidence that *Culex restuans* and *Culex salinarius* may be involved in transmitting this virus from bird to bird.

It is not known how SLE virus is maintained in nature during the winter months when vector mosquitoes do not actively feed and animal infections are not detectable. There is some evidence that the virus can remain viable in overwintering *Culex pipiens* adults and, presumably, be transmitted when they feed on susceptible vertebrates in the spring. Whether or not this is the primary overwintering mechanism is not yet known.

EASTERN EQUINE ENCEPHALITIS (EEE)

EEE is a mosquito transmitted virus that causes a severe central nervous system disease in horses and humans. The EEE fatality rate in humans is 50 to 70 percent and in horses, 90 to 95 percent. Most humans and horses that survive this disease have severe, permanent neurological problems that may include mental retardation, behavioral changes, convulsions and paralysis. The disease is more severe in children than adults. Fortunately, human cases are rare, but the disease regularly occurs in horses each summer along the Gulf and Atlantic coasts as well as inland in such states as Florida, Massachusetts, New York, New Jersey, Maryland and Michigan. Although this virus produces a very serious disease when it infects humans and horses, the wild birds that serve as its usual "natural" vertebrate hosts show little or no symptoms when infected.

EEE, like St. Louis encephalitis, has a "natural" transmission cycle that involves wild birds and certain species of mosquitoes (Figure 8). The humans and horses that do become infected are "dead end" hosts that play no part in the further transmission of the virus to other vertebrates.

Other similarities between EEE and SLE are:

- 1) the infective levels of the virus in birds lasts for only a few days;
- 2) there are a limited number of bird and mosquito species that are capable of propagating and/or transmitting the virus; and

3) varying levels of virus are required to infect either the mosquito or vertebrate species if they are to function as vectors or sources of the virus.

As with the SLE virus, it is not known how EEE is maintained in the winter when the mosquito vectors are inactive. EEE differs from SLE in that it is primarily a rural disease centered in and near fresh water swamps. It also has a "natural" transmission cycle that involves wild bird populations that inhabit fresh water swamps and the mosquito species that breed in those swamps and feed on the birds. Also unlike SLE, the link between the "natural" transmission cycle and the horses and humans that become infected are mosquito species that readily feed upon birds, horses and humans. Another difference between the two viruses is that EEE may produce severe disease or fatalities in some bird species, for example pheasants, while SLE infections in birds are benign or produce minimal symptoms.

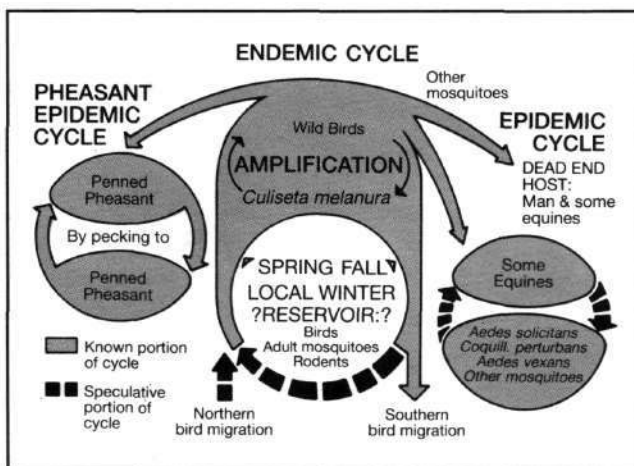


Figure 8. EEE Virus Cycle in U.S.

In all areas where EEE has been studied the primary mosquito vector in the fresh water swamp habitat (the location of the "natural" transmission cycle) has been *Culiseta melanura*, a fresh water swamp species that feeds almost exclusively on birds. There are a number of bird species that may be involved in this transmission cycle; for example blue jays, cardinals, and cat-birds. The link between this "natural" transmission cycle and the horses and humans that become infected are other mosquito species that feed readily on the infected birds, and then on horses and humans. Evidence indicates that along the Atlantic coast the major vector is *Aedes sollicitans*, the salt marsh mosquito. In Michigan, however, the link between the "natural" transmission cycle and humans and horses is thought to

be *Coquillettidia perturbans*, a species that abounds in permanent fresh water with marginal emergent vegetation, such as cattail.

In both the coastal and inland areas where EEE outbreaks have occurred, there are a number of other mosquito species from which EEE virus has been isolated and which may serve as important primary or secondary vectors in either the "normal" transmission cycle or the outbreaks involving humans or horses. These other mosquito species that are found in Michigan include: *Aedes triseriatus*, *Aedes canadensis*, *Aedes cinerius*, *Aedes vexans*, *Culex territans*, *Culex pipiens*, *Culiseta minnesotae*, and *Psorophora ciliata*. However, the significance of these species as vectors of EEE virus in nature is unknown.

WESTERN EQUINE ENCEPHALITIS (WEE)

Major, widespread outbreaks of WEE have occurred in the western parts of the United States and Canada. Although this disease has appeared in Michigan and adjacent states, it fortunately has never been a significant problem for either horses or humans in these localities. This disease is similar to EEE in that it occurs primarily in rural locations and has a "natural" transmission cycle that involves both mosquitoes and wild birds. (See Figure 9.)

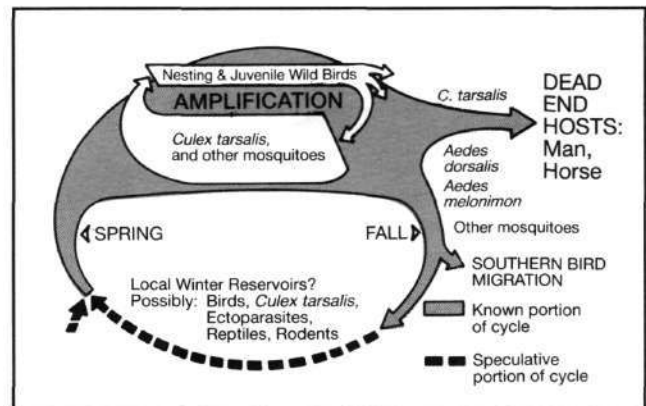


Figure 9. WEE Virus Cycle in U.S.

WEE can produce severe disease in both humans and horses, but both of these are "dead end" hosts and are not involved in further transmission of the virus. As with EEE, western equine encephalitis infections are more severe in children than in adults. Initial symptoms of WEE may include fever, headache, vomiting and a stiff neck, then may progress to confusion, disorientation, stupor, coma and other evidence of severe central nervous system infections.

Adults recover completely from this disease, although neurological problems may persist for some time. In children, however, about half of those infected suffer permanent neurological after-effects, including progressive mental retardation and varying degrees of physical and mental dysfunction. As with SLE, individuals infected with WEE exhibit a wide range of responses to the infection, ranging from minor, transient symptoms to severe central nervous system disease.

Infected wild birds infect the mosquitoes that feed on them, but as with both SLE and EEE, the WEE virus is present in the infected bird's blood for only 3-4 days in the amounts needed to infect the feeding mosquito. Birds infected with WEE normally do not show any symptoms.

Although several mosquito species are able to transmit this virus, *Culex tarsalis* has been the major vector in past outbreaks of this disease. This species usually breeds in both permanent and temporary ground water with high organic content, such as sewage effluent. In many areas of the west the species is most numerous where improper agriculture irrigation practices result in accumulated water. This mosquito feeds readily on both birds and mammals, so it serves as the major vector in the "natural" transmission cycle as well as transmitting WEE virus to humans and horses. As with SLE and EEE, it is not known how this virus is maintained in areas of the United States and Canada where adult mosquitoes are not active during the cold months of the year.

CALIFORNIA ENCEPHALITIS (CE)

The causative agent of the disease called CE may be one of several closely-related viruses. There also are a number of other related viruses, included in what is called the California virus group, that have been isolated from mosquitoes and vertebrates but are not known to cause any animal or human disease. Within the overall group there are seven "types" of virus that are known to exist in Michigan. Only two, LaCrosse and Jamestown Canyon viruses, are known to cause human disease. Of these, LaCrosse is by far the most commonly associated with reported human cases of CE. The symptoms can be highly variable, and it is believed that many, or even most, individuals infected with either LaCrosse or Jamestown Canyon virus do not become clinically ill. Those who do, may exhibit central nervous system disturbances ranging from fever and headaches, nausea and vomiting, up to and including paralysis and coma. Infections are rarely fatal and recovery is usually complete with no

permanent disabilities, although some individuals have shown post-infection behavioral changes such as irritability, speech changes and impaired scholastic ability. Disease symptoms are much more common in children than in adults.

Most individuals in the United States that have laboratory-confirmed cases of CE, with clinical symptoms, have been either residents of the North Central States or have recently visited these areas. The disease has been reported most frequently in Ohio, Indiana, Wisconsin, Illinois and Minnesota, but clinical cases also have been reported from Michigan and other states, although in smaller numbers.

California encephalitis is similar to SLE, EEE and WEE in that the viruses causing this disease also have a "natural" transmission cycles that do not include humans, which are "dead end hosts." (See Figure 10.)

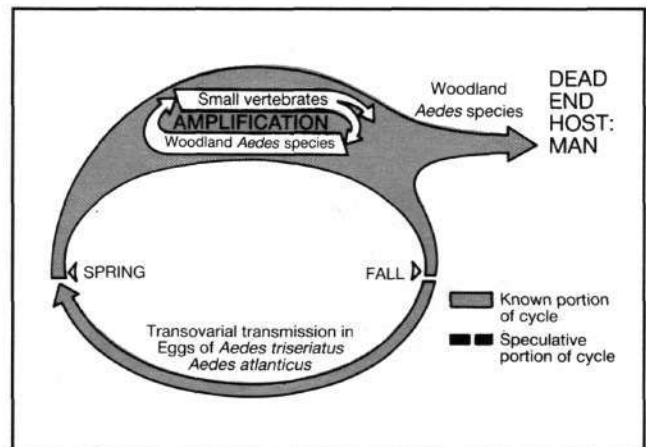


Figure 10. CE Group Virus Cycle in U.S.

The LaCrosse virus transmission cycle normally involves several species of small animals, such as squirrels, chipmunks, field mice, rabbits, and the mosquito, *Aedes triseriatus*, although other mosquito species also can transmit this virus. *Aedes triseriatus* is found in or near wooded habitats and their larvae develop in the rot holes in many kinds of deciduous trees as well as in a wide variety of containers in which rain water and organic debris have accumulated. For example, tires, tin cans, buckets and other water-holding trash in woodlots and forested areas are ideal breeding sites.

Aedes triseriatus feeds readily on small mammals as well as humans, so it is capable of maintaining the "natural" transmission cycle of the virus as well as infecting humans. Because this mosquito species has a very limited flight range and normally remains near its forest breeding

sites and small animal hosts, human cases usually are limited to individuals who live in or frequent such areas.

White-tail deer appear to be the usual vertebrate hosts for Jamestown Canyon virus in its "natural" transmission cycle. Several species of *Aedes* mosquitoes, which feed on humans as well as deer and other large mammals, are the usual vectors for both the "natural" transmission cycle and for transmitting this virus to humans. For the most part the *Aedes* species that are important vectors of Jamestown Canyon virus are present in wooded areas, but they have an extended flight range and often invade residential areas some distance from breeding sites, which usually are naturally occurring ground water accumulations in wooded or shaded areas.

All *Aedes* mosquitoes in Michigan overwinter in the egg stage. This is the mechanism by which both LaCrosse and Jamestown Canyon viruses survive from one year to the next. Eggs produced by adult female mosquitoes infected with either virus hatch during the summer or the following spring. The virus persists through the immature developmental stages and continues to infect the resulting adults, both males and females. When these infected females obtain a blood meal from a suitable host such as a white-tail deer or human, the virus is transmitted and infects the vertebrate on which the mosquito has fed. Male mosquitoes do not take blood meals and so cannot transmit the virus in this manner. However, males carry the viruses in their sperm and can transmit them to female mosquitoes during copulation. These females then become infected and can transmit the virus when they next feed upon a suitable vertebrate host. By these mechanisms the California group viruses can persist in nature for up to three or four years, even in the absence of infected vertebrate hosts.

DOG HEARTWORM

Dog heartworm is a relatively new problem in Michigan, but it is found in dogs in all parts of the Lower Peninsula and in most parts of the Upper Peninsula. It is a major threat to dogs throughout the state. Transmission of this parasite occurs only through the bite of an infected mosquito and involves a rather complicated development and transmission cycle. (See Figure 11.)

Adult heartworms normally attach to the right heart chamber or pulmonary artery of an infected animal. Once fertilized the female worm begins to release microscopic offspring, called micro-

filariae, into the animal host's blood. The microfilariae are ingested with the blood and develop in the mosquito. After two or more weeks, depending upon the temperature, the infective stage of the worm migrates to the mouthparts of the mosquito and is transmitted to the next vertebrate the mosquito feeds on. At this time the immature worms are still microscopic in size, but are able to move to the heart and pulmonary vessels of the animal, attach and develop to the adult stage. This takes approximately six months, and the cycle begins again. Successful growth to the adult and reproductive stage occurs only in dogs or closely-related animals, such as foxes and wolves. If an infected mosquito bites some other vertebrate, the transmitted immature worms are either absorbed by the animal's immune system or complete only partial development. These are "dead end" hosts for the parasite.

The severity of the disease these worms produce in dogs varies greatly, depending upon the number of worms in the dog, the age, breed and health of the animal and a variety of other factors. If the dog is not given appropriate drug treatment, the adult worms can live as long as five years in the dog. One individual worm is about the diameter of a toothpick and is 8 to 10 inches in length, but if the animal is not treated and is bitten repeatedly by infected mosquitoes, several hundred worms can accumulate in the heart and pulmonary vessels and form a mass that impedes the blood flow from the heart to the lungs. The symptoms associated with heartworm infections result from the mechanical obstruction to the blood flow as well as the physiological changes in the animal that are produced by reactions to the microfilariae and adult worms.

Approximately one quarter of the 60-plus species of mosquitoes that are known to occur in Michigan are capable of transmitting dog heartworms, and these include many of the species that also are major pests of humans. Although no one species is likely to act as a vector in all parts of the state, it is virtually certain that one or more potential vector species are present in every locality in the state from major urban areas to remote rural ones.

Mosquito-Borne Encephalitis Monitoring Program

As you have read, there are several types of viruses transmitted by mosquitoes in Michigan which are known to cause central nervous system disease in humans. Based on the known causes

these diseases, the following monitoring activities can be used to measure virus activity and to determine the potential for human involvement.

- 1) Bird/Mammal Blood Serology. Determines antibody levels to encephalitis virus or for virus isolation attempts.
- 2) Adult Mosquito Collections. Virus isolation studies can be conducted if live mosquitoes are collected and quickly frozen for storage until tests are conducted.

Both of these disease surveillance methods take time and require professional staff and established connections with specialized labs that can perform these tests properly.

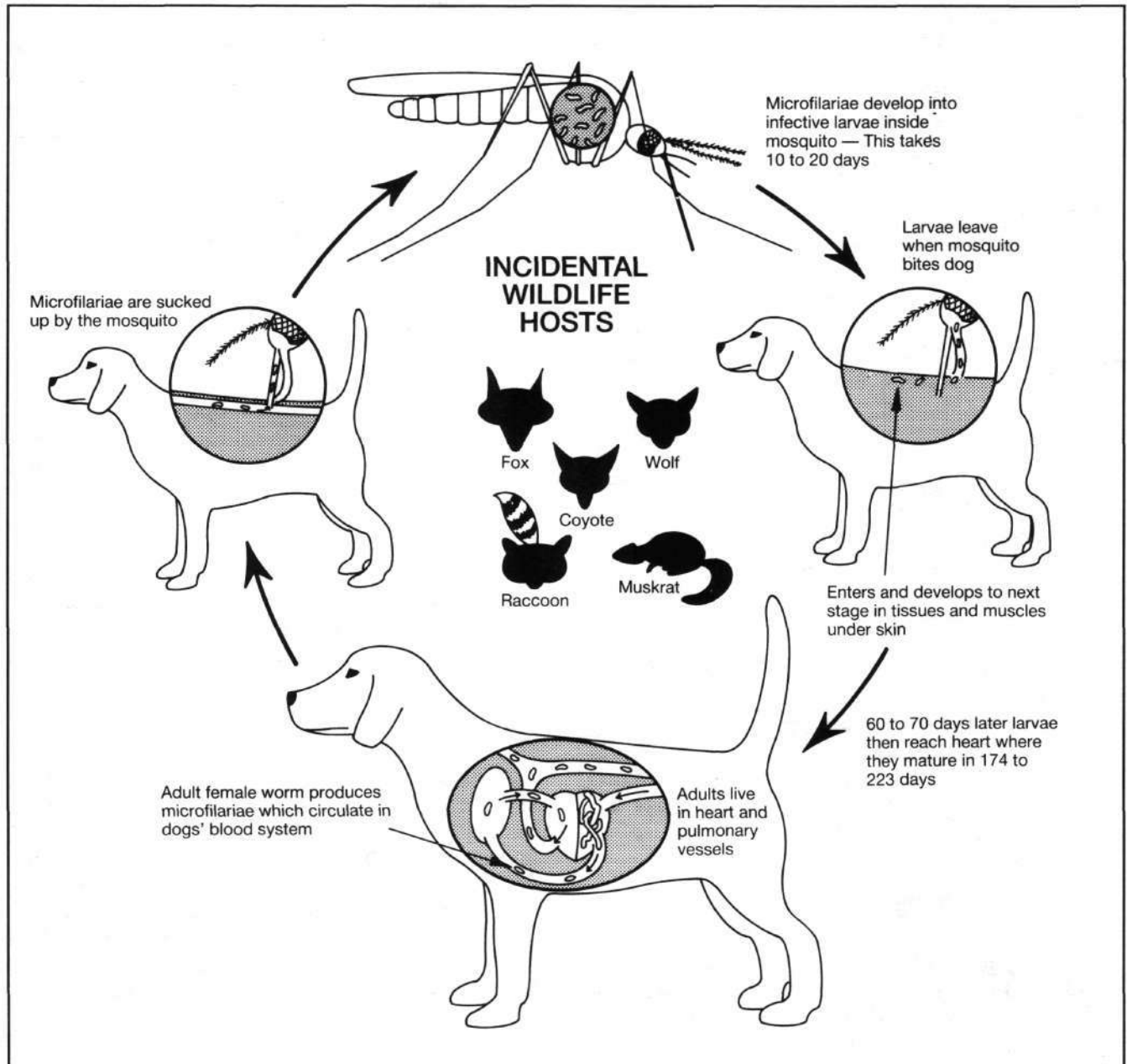


Figure 11. Dog Heartworm Life Cycle.

REVIEW QUESTIONS – CHAPTER 4: MOSQUITO-BORNE DISEASES

1. What words do the following acronyms represent: SLE, EEE, WEE, CE.
 2. The transfer of a virus back and forth between vectors is called the _____ cycle.
 3. A "dead end host" is one that:
 - a. is incapable of transmitting a particular virus.
 - b. dies after receiving a virus.
 - c. is outside of the "natural" transmission cycle of the virus.
 - d. both a and b
 - e. both a and c
 4. What vertebrate is involved in the "natural" transmission cycle of SLE?
 5. What dead end host is most severely affected by EEE?
 6. Birds infected with WEE normally do not show any symptoms. True or False?
 7. The human age group most likely to have severe symptoms from CE is:
 - a. children
 - b. teenagers
 - c. middle-aged adults
 - d. older adults
 8. The usual vertebrate host for the Jamestown Canyon virus of CE is:
 - a. humans
 - b. skunks
 - c. chipmunks
 - d. white tail deer
 9. Can your dog be infected with heartworm if there is no evidence of heartworm in the heart or pulmonary vessels area?
-

CHAPTER 5

INTEGRATED MOSQUITO MANAGEMENT

The most effective mosquito management and control strategy is an organized program under the direction of an entomologist or other qualified expert. These programs are based on sound biological, physical, and chemical data and the integration of the best and latest techniques and materials. The goal is to control mosquitoes while preventing any adverse effects on humans, wildlife, or the environment. Though this manual cannot address all of these areas in depth, some are described in this section.

SOURCE REDUCTION FOR MOSQUITO CONTROL

Environmental manipulation involving land, water, and physical characteristics such as draining, filling, ditching, and water management are the most effective and permanent methods to reduce mosquitoes. Initial costs for these projects are usually high, but the permanent effect of these measures reduces or eliminates the need for temporary annual, monthly, or weekly mosquito control activities, and is often the most cost-effective over an extended period.

Drainage for Mosquito Control

Drainage is used to eliminate standing water where mosquito larvae can live. This method may be applied to various sizes of standing water areas, from a few square feet to several hundred acres. In addition to mosquito control, draining often is valuable in reclaiming land for other uses such as agriculture, timber, housing, commercial uses, etc. Contour draining, for example, is an accepted practice in agriculture to prevent erosion and standing water from damaging crops and to allow better access for tillage. Many areas of standing water are made by earth-moving activities during construction, mining, quarrying, etc. Draining dries up these areas.

Drainage concepts are also used extensively to remove rain water from streets and highways throughout the country. When drainage is considered for swamps, marshes, and other larger bodies of water, the effects on wildlife and the natural environment must be studied.

In Michigan, drainage, as well as filling projects which can affect the natural environment, may be subject to the Goemaere-Anderson Wetland Protection Act for which the Department of Natural Resources has jurisdiction. Before attempting any draining, contact the Michigan Department of Natural Resources.

Ditching for Mosquito Control

Ditching of one type or another is usually involved in all drainage projects. There are many different types, sizes, construction methods and materials used in making ditches. Proper selection to match the objectives of the project is very important.

A properly constructed ditch should have the following characteristics:

- (1) Sufficient size and grade to carry peak loads of water yet maintain a flow at low water levels to avoid standing water;
- (2) Erosion-resistant shape and construction materials;
- (3) Minimal maintenance requirements;
- (4) Capable of delivering water to a suitable area.

Improperly constructed and poorly maintained ditches are common throughout Michigan. These ditches hold water and provide large mosquito breeding habitats. Much of the work of an organized mosquito control program is spent on these types of ditches in both ditch maintenance and other control procedures. Wide, deep ditches have been used in large marsh areas to collect and lower the water level. Fish, waterfowl and other wildlife can use the open water created by these ditches which then are less conducive to mosquito breeding.

Filling for Mosquito Control

Filling raises the level of soil up to grade to improve run-off of water and eliminate standing water that provides mosquito larval habitat. This is a useful technique for small depressions, vehicle ruts, depressions left by up-rooted trees, etc. Often this small job may require the use of heavy equipment. Filling and grading activities in conjunction with construction projects will prevent standing water.

Water Management for Mosquito Control

Although draining and filling may be considered water management, this section addresses management of water levels in manmade reservoirs. By raising and lowering water levels at times that will affect the biology and habitats of mosquitoes and the aquatic weeds that protect mosquito larvae from predators, mosquito populations can be reduced significantly.

During periods of heavy rainfall, dams hold back water to prevent flooding downstream. This increase in lake level often causes flooding of the eggs laid in the soil by floodwater *Aedes* species. Many of these eggs may hatch. However, dropping the water level before the larvae can mature, removes water from their breeding area and kills them. Or, if the larvae fall with the lowering water level, they are exposed to fish and other predators. *Anophele* species which may breed in the weedy backwaters can also be controlled by dropping the water level at various times. This may also control many of the aquatic weeds which protect developing larvae.

BIOLOGICAL MANAGEMENT AND CONTROL OF MOSQUITOES

Mosquito Pathogens. There are many bacterial, fungal, and viral pathogens which attack or kill mosquito larvae. Of these, the bacteria *Bacillus thuringiensis* variety *israeliensis* is widely available commercially and is used extensively in organized mosquito control programs. Since it is a biological product, it affects only mosquitoes and related insect species and is environmentally safe. It is sold under trade names such as "Teknar," "Bactimos," "Vectobac" and others. It is formulated as a wettable powder, emulsifiable concentrate or granular formulation. It is applied to larval breeding areas at recommended dosages using standard application equipment.

Mosquito Growth Regulators. In general, a mosquito growth regulator is a chemical that is similar to the juvenile hormone of the mosquito. When the material is applied to water breeding areas and taken up by the larval mosquito, it induces physiological changes which interfere with normal development. Simply stated, too much juvenile hormone does not allow the larvae to develop and emerge as adults. The larvae are not immediately killed but their development is stopped and malformed physiological changes eventually kill the immature form. The most widely available material is methoprene, commercially marketed under the trade name "Altosid." Since methoprene is biological in effect, it

is very specific for mosquitoes and related Diptera. This means it is non-toxic to vertebrate animals and is environmentally safe. The material is formulated as a suspension, impregnated on sand, or formed into brickettes. The suspension is applied by hand or vehicle-mounted sprayers; the sand by hand, vehicle or aircraft mounted spreaders, and the brickettes are applied by hand.

Mosquito Parasites. There are several parasites, including nematodes and protozoa, which attack mosquito larvae. Mermithid nematodes have worldwide distribution, and under ideal conditions, they may parasitize as high as 80 percent of natural mosquito populations. They have been reared and introduced into breeding areas and provide excellent control of mosquitoes. However, because nematodes must be reared in live mosquitoes, the cost of production has prevented commercial development of this and most other parasites. These parasites are very important in reducing the number of surviving mosquitoes.

Mosquito Predators. There are many predators of mosquitoes. Adult mosquitoes are eaten by spiders, mites, dragonflies, and other insects, birds, frogs, and bats. Mosquito larvae are eaten by other invertebrates such as water beetles, beetle larvae, dragonfly larvae, water spiders, other mosquito larvae, and by several species of fish. Only a few of these have been manipulated to provide greater control than would occur normally in nature. A popular but marginally successful example of predator-related control is the use of bird houses to attract purple martins to nest near our homes. These birds feed on mosquitoes as well as other flying insects, but their effectiveness in mosquito control is negligible.

In organized mosquito control programs, except for some very limited use of the predatory mosquito larvae of the genus *Toxorhynchites*, only top feeding minnows have been used extensively. Although the native guppy *Legister reliculatus* has been utilized, the South American minnow, *Gambusia affinis* is the most widely used. These minnows are available commercially and are introduced into ponds and certain other permanent bodies of water where they feed on mosquito larvae. Because they are top feeding, they may fall prey to other larger fish and therefore are not suitable for all waters. Although there are some cold resistant strains, these tropical fish usually will not survive in Michigan during years of severe prolonged cold winters and therefore, must be reintroduced each spring.

Sterilization. This technique involves rearing certain species of mosquitoes, sterilizing the male mosquitoes and releasing them in the wild population. The female mosquitoes usually mate only once and store sperm in a special organ (spermatheca). Eggs produced throughout the life of the female mosquito are then fertilized by this stored sperm. When the female mates with a sterile male, the female then lays infertile eggs. This technique effectively reduces populations of malaria mosquitoes in some isolated areas of Central America. However, due to several limitations, including cost effectiveness, this method is not widely used.

Genetics. Genetic manipulation has been researched extensively for several years. It has shown promise for some disease and population controls; however, none are in general use.

CHEMICALS FOR MOSQUITO CONTROL

Ecological and environmental concerns emphasize the need for integrated mosquito control programs. An integrated approach to mosquito control involves accurate and complete assessment of the problem and the employment of control measures that are best suited to the specific situation. The selected means of control may include any one or a combination of physical, biological, or chemical techniques.

In many situations, applying a chemical insecticide is necessary for acceptable control. Insecticides, as well as those responsible for applying the insecticides, are regulated by the U.S. Environmental Protection Agency (EPA) and the Michigan Department of Agriculture (MDA). All insecticides are classified as either general use or restricted use products by the EPA. The classifications are based upon the level of training necessary for someone to use the product safely, based upon environmental and health considerations. Only persons who are certified by the MDA may apply restricted use pesticides. Further, all pesticides sold in Michigan must be registered by the EPA and by the MDA. To gain EPA registration the product manufacturer must show that the product can be used according to its label directions for its intended purpose without presenting any undue health hazards or environmental damage.

Previously registered products are continually being reviewed by the EPA with consideration of use experiences and improving technology. If unacceptable hazards are identified, the product's registration is revoked on site and use directions are altered to eliminate the hazard.

Insecticides, like many other products such as household cleaners, drugs, medications, fire-arms, and automobiles, can cause accidents when used improperly or misused intentionally. Any insecticide used improperly can be a health hazard. When used responsibly, however, they can be of great benefit.

Irresponsibility cannot be legislated away. However, when mosquito control activities are undertaken by governing agencies (such as cities, townships, counties, or cooperating districts) professionally-trained, responsible individuals can manage the program and minimize accidents and prevent misuse of insecticides. The responsible manager seeks counsel with competent conservationists, environmentalists, fish and game specialists, biologists, and others before initiating control measures in areas where delicate ecosystems could be disrupted.

Larval Mosquito Control

Mosquito control should focus on the larval stage since treatment at this time is truly preventive. This stage in the life cycle is confined to water and is easier to treat than the adult stages. Mosquito larvae are generally more vulnerable to control measures than adults.

Larval breeding may be controlled by physical means such as draining, filling, or water level management. Biological methods may be effective using predatory fish, bacterial toxins, or growth regulators. If these methods are not feasible, chemical controls may be required.

Larvicidal control is of primary importance in areas where disease carrying mosquitoes abound, particularly where there is excessive flooding following natural disasters or prolonged rainy seasons. The degree of success in larval control, the chemical and formulation of larvicides and the methods and rate of application depends upon various environmental and physical conditions. These conditions include, but may not be limited to, the following:

1. The target mosquito species
2. Type of habitat, i.e., permanent or temporary marsh, pools, tires, catchbasins, sewage lagoons, ditches, ponds, intermittent streams, flood waters, artificial containers, polluted or clean waters, etc.
3. Size of area to be treated
4. Current and forecasted weather conditions
5. Water depth or movement of water
6. Organic content and pH of the water

7. Type and amount of emergent vegetation or vegetation cover
8. Non-target invertebrate population
9. Vertebrate populations
10. Potential for adverse environmental impact
11. Domestic use of water
12. Proximity to populated areas
13. Proximity to other sensitive areas
14. Applicable regulations and laws
15. Concerns for the public health, including imminent disease threats to the public
16. Level of control which is acceptable
17. Resources available, i.e., equipment, personnel, funds
18. Toxicity or hazards of larvicides
19. Use experiences with various materials and formulations
20. Anticipated number and frequency of treatments
21. An assessment of the probability of success of the method selected and its cost benefit ratio.

These and other conditions must be considered during planning as well as during operation of any control program. The scope of this manual does not allow a detailed listing of considerations involved for all conditions. Rather, it stresses having professionally qualified and experienced managers direct mosquito control programs.

The manufacturers of mosquito larvicides produce a variety of formulations designed to meet some of the demands imposed by the various biological, environmental, and physical conditions specific to effective larval control. These formulations and specifically-designed products include the following: emulsions, suspensions, wettable powders, solutions, surface films, capsules, brickettes, pellets, granulars, and other carriers such as sand and ground corn cobs. Carriers used in some of the bacterial toxins (B.t.i.) formulations which must be ingested by the mosquito to be toxic may actually provide nutrients to other aquatic organisms which are unaffected by the toxin. Formulations often include other materials to enhance mixing, sticking, emulsion, spreading, release rate, reducing water surface tension, etc.

The various formulations allow the manager to select a product to meet varying conditions and needs. These needs may include: mixing well with the water, not mixing with the water but forming a surface film; penetrating vegetation cover; short or long release or effectiveness times; and floating or sinking carriers.

The chemical larvicides which are registered and generally used in mosquito control are in Table 2. The listed insecticides are for information. The table is intended only as a guide. It may not include all registered chemicals nor does it imply that those listed are registered beyond the date of this publication. The use of proprietary or brand names are for example only and does not constitute product endorsement.

All insecticide products must be used according to label directions. Larval control must be based upon a complete and accurate assessment of the particular situation including frequent and recent larval study data.

Chemical Control of Adults

The purpose of adult mosquito control is to reduce the numbers of biting female mosquitoes to a level where they no longer present a nuisance or a disease threat. Such control improves the health and quality of life in the given area.

Using insecticidal aerosols for adult mosquito control is done only when mosquito surveys or disease monitoring indicate the need. To kill the adult mosquito, the aerosols must be applied so that they contact the mosquito.

Except for limited use of aerosols indoors and use of some residual sprays in and around the home, adult mosquito control is usually done on an area basis using ultra low volume (ULV) spray applications. There is an array of commercial equipment on the market designed for this type of application. Some are for hand carrying while others mount on wheel vehicles, boats, or aircraft.

With ground equipment, the direction of small particle movement is dependent largely upon existing air current (wind). The material must be released upwind from the area to be treated. It may be difficult to get adequate coverage with wheel-mounted equipment when road or street networks are limited. In these cases, all-terrain vehicles or hand-carried equipment may be used. Strong winds (above 8-12 m.p.h.) may dissipate and move the material through the area too rapidly to be effective or rising thermal currents may lift the material above the area.

ULV applications are most effective on flying mosquitoes. Therefore application should take place during times of changing light intensity such as dusk, early evening, and dawn. Some species of mosquitoes are active most of the night. Most species, however, become less active one to three hours after sunset.

When applying insecticides with ground equip-

TABLE 2. COMMONLY USED MOSQUITO CONTROL INSECTICIDES

| INSECTICIDE | STAGE | | | ORAL LD50 | DERMAL LD50 |
|---|--------|-------|-------|-----------|-------------|
| | LARVAE | PUPAE | ADULT | (mg/Kg) | (mg/Kg) |
| Malathion (Cythion R) | | | X | 1,000 | 4,100 |
| Chlorphyrifos (Dursban R) | X | | X | 96 | 2,000 |
| Fenthion (Baytex R) | X | | X | 255 | 1,680 |
| Temephos (Abate R) | X | | | 8,600 | 1,300 |
| Pyrethrum (Tossits R) | X | X | | 604 | 2,418 |
| Proprietary Petroleum (Golden Bear R) | X | X | | >10,000 | >3,000 |
| Monomolecular Surface Film (Arosurf R) | X | X | | >20,000 | >2,000 |
| Methoxychlor | | | X | 600 | 2,946 |
| Methoprene (Altosid R) | X | | | >34,600 | >3,000 |
| Bacillus thuringiensis var. israelensis (Teknar R, Bactimos R, Vectobac R) | X | | | >2,000 | >2,000 |
| Naled (Dibrom R) | | | X | 430 | 1,100 |
| Resmethrin (Scourge R) | | | X | 4,240 | 2,500 |
| Propoxur (Baygon R) | | | X | 95 | >500 |
| Carbaryl (Sevin R) | | | X | 500 | 1,497 |
| Dichlorvos (Vapona R) | | | X | 56 | >107 |
| Pyrethrins (Pyrocide R) | | | X | 1,500 | >1,800 |
| Bendiocarb (Ficam R) | | | X | 40 | >1,000 |

ment, the degree of control success, the chemical and equipment to be used, and the approach to application depends upon various environmental and physical conditions. These conditions include, but may not be limited to the following:

1. The major target mosquito species – its biology and habits
2. The timing of application to flight habits
3. Wind speed and direction
4. Temperature, i.e., rising thermal currents or temperature inversion
5. Size, location and character of the area to be treated, including the following –
 - a. urban, suburban, rural
 - b. street or road network vs. wind direction
 - c. obstructions and density of obstructions (buildings, trees, shrubs)
 - d. time required to cover area vs. equipment needed
 - e. identified locations which will not be sprayed
6. Current or forecasted weather conditions

7. Insecticide to use
8. Rate of application
9. Calibration of equipment for proper droplet size (Mass Median Diameter)
10. Frequency of retreatment
11. Environmental considerations
12. Pre and post treatment surveillance
13. Public information

These and other conditions must be considered during planning as well operation. Features such as the rate of application (0.5 to 5.0 ounces per acre), the small droplet sizes (5 to 27 microns with the average less than 17 microns), readily degradable chemicals, and time of day of application should be chosen to provide the most effective kill of adult mosquitoes with the least effect on the environment. The small droplets are designed to impinge on the fine hairs on the mosquito body. The size of the droplet and the amount of chemical in each is calculated to provide a minimum lethal dose to a mosquito. Flying insects larger than a mosquito which may encounter a droplet do not usually receive a lethal dose. Insects which are not flying at the time of

the application as well as other invertebrates and vertebrates, including wildlife and pets, are not affected. Most beneficial insects such as honey bees do not fly at night and are in some resting area not exposed to the spray. The chemicals used degrade rapidly and the small droplet size further enhances this degradation. Therefore, there is little, if any, residue remaining after a few hours.

During special circumstances such as potential outbreaks, actual disease epidemics, or following some natural phenomenon or disaster that re-

sults in large populations of mosquitoes, it may be necessary to treat large areas as quickly as possible. In these cases, aerial spraying may be warranted. Decisions about aerial spraying are made by the professional in charge after thorough investigation and consultation.

Products registered for ULV application in adult mosquito control are in Table 2. All insecticide products must be used in accordance with the label directions. Applying insecticides for adult mosquitoes must be based upon a complete and accurate assessment of the situation.

REVIEW QUESTIONS – CHAPTER 5: INTEGRATED MOSQUITO MANAGEMENT

1. The most effective and permanent method of mosquito control is _____.
2. Source reduction involves:
 - a. draining
 - b. filling
 - c. ditching
 - d. water management
 - e. all of the above
3. When using mosquito growth regulators, excess juvenile hormones do not allow _____ to develop and emerge as adults.
4. All insecticides are classed by EPA as either _____ use or _____ use products.
5. Mosquito control during the larval stage is truly preventive because:
 - a. the larvae are confined to water and therefore are easier to treat
 - b. larvae eat more than adults
 - c. larvae are generally more vulnerable to control measures than adults
 - d. a and b
 - e. a and c
6. What do the letters "ULV" represent in mosquito control?
7. Will an adult mosquito die after landing on a plant leaf which has been ULV adulticided the night before. Explain your answer.
8. All insecticide products must be used in accordance with _____ directions.
9. Noncertified applicators applying restricted use pesticides must be under the control and supervision of a certified applicator. True or False?

CHAPTER 6

EQUIPMENT FOR CHEMICAL APPLICATION

Effective mosquito control utilizes a wide variety of equipment to treat specific habitats and accommodate the various formulations of insecticides available. In general, all equipment can be divided into two categories: larviciding equipment and adulticide equipment.

LARVICIDING EQUIPMENT

Most larvicide formulations are either liquid or granular. Compressed Air Sprayers (Figure 12) are most commonly used when applying liquid larvicides. Select a sprayer that is an appropriate size for the job. Normally these are hand-carried and usually hold 1-5 gallons of formulation. It must operate adequately while being subjected to the abrasion of wettable powders and the deteriorating effect of some formulations on hoses, seals, tanks, etc. So, durability as well as convenience in filling, operating, and cleaning is required. Normally sprayers constructed of stainless steel and metal are much more durable than those made of plastic.

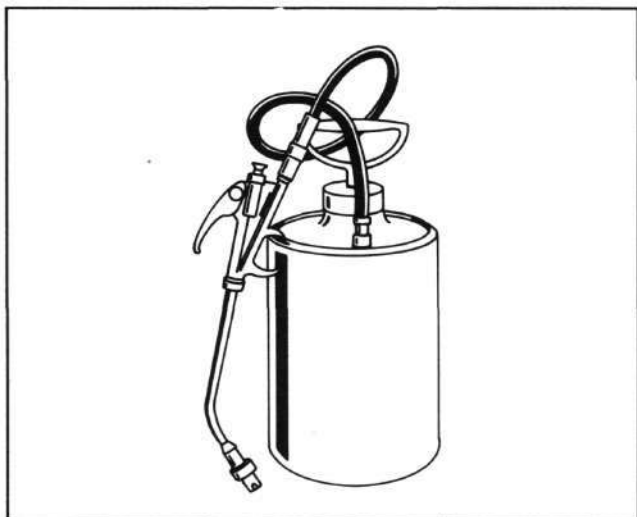


Figure 12. Compressed Air Sprayer.

Backpack sprayers (Figure 13) are carried on the back, leaving both the operator's hands free to direct the nozzle, change the spray pattern, etc. They may carry up to 5 gallons of formulation and can be purchased as either a gas-powered or manually-operated unit. These small sprayers

are ideal for larviciding mosquito habitat such as tires, catchbasins, treeholes, flooded lawns and other areas inaccessible by truck mounted units.



Figure 13. Backpack Sprayer.

Larger jobs such as roadside ditches and county drains can best be larvicided by using a truck-mounted sprayer (Figure 14) that has a large capacity tank (50-100 gallons) and a gas-operated motor and pump to deliver the liquid formulation. Many times a 100-200 foot hose is used on these units to provide greater range and versatility. These units are commonly used to larvicide roadside ditches, county drains and sewage lagoons.

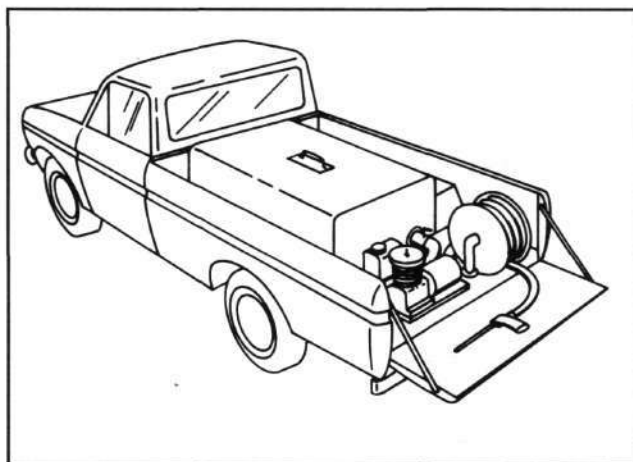


Figure 14. Trucked Mounted Sprayer.

Granular formulations can be applied with equipment as simple as a soup ladle for habitats such as tires and catchbasins or as complex as a truck-mounted compressed air applicator. The most commonly used hand-carried granular applicator is a crank-operated, spinning-disc type (Figure 15) for broadcast coverage over small areas inaccessible to vehicle-mounted units. Those which use a metal or solid plastic container to hold granular insecticide are preferred to the knapsack style holders. These are ideal for larviciding seasonally-flooded woodlots, flooded lawns and cross country ditches.

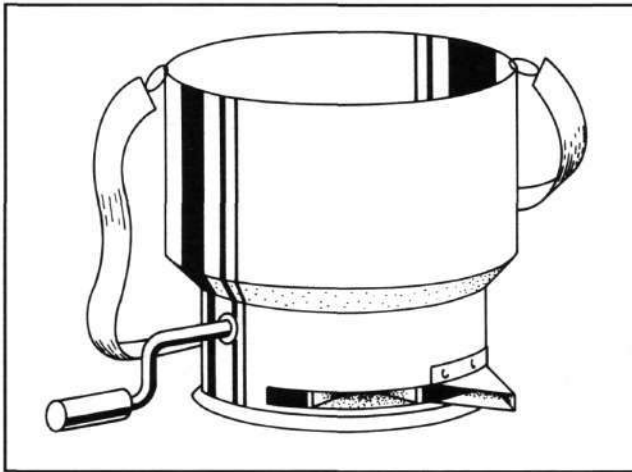


Figure 15. Granular Broadcast Applicator.

Controlling larvae in areas with extensive breeding in roadside ditches and county drains has led to the development of truck-mounted granular applicators (Figure 16) which work on the same principle as a sand blaster. Although these units vary in design, most use a gas motor to drive a compressor to create the pressure necessary to draw the granular formulation from the storage container and propel it out of the barrel and into the breeding area.

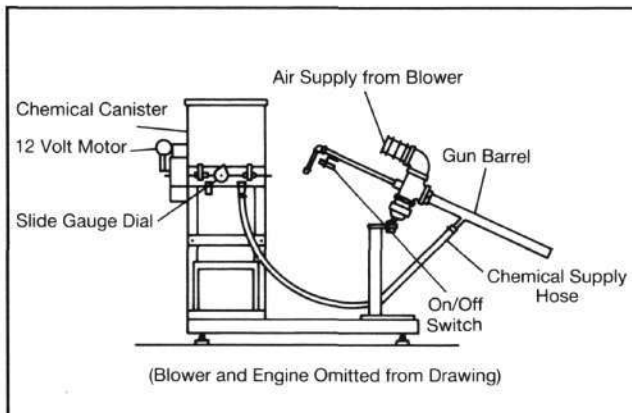


Figure 16. Truck Mounted Granular Applicator.

ADULTICIDING EQUIPMENT

Thermal fog machines, once the backbone of mosquito control adulticiding efforts are fast becoming obsolete. These units use a mixture of fuel oil and insecticide which is superheated to produce a cloud of fine droplets that linger near the ground and drift through areas inhabited by adult mosquitoes. Fogging is effective only as a contact application. The area to be fogged should be on the downwind side with the wind being no greater than three miles per hour. These machines usually have an output of 40 gallons per hour of the insecticide/fuel oil mixture.

Most adulticiding is performed with ultra low volume (ULV) equipment (Figure 17). These can either be purchased as hand-held units or truck-mounted units with a range of 1-4 spray heads. Since proper droplet size (12-18 microns) is very important in ULV applications those units with only 1 spray head are easier to maintain proper droplet size than multi-head units. This type of application only kills on contact so spraying should be done shortly after sunset when adult mosquitoes are most active. Treatment should take place on the downwind side of the area to be sprayed when the wind speed is no greater than five miles per hour.

ULV units normally provide control over a 300-foot swath when applied at the standard dose of 1 gallon per hour. This minimal use of insecticide combined with its effectiveness and cost savings is why most adulticide applications are now done using ULV equipment.

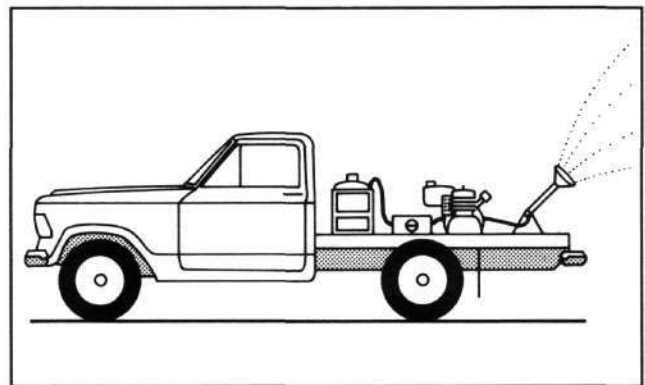


Figure 17. Truck Mounted ULV Unit.

Occasionally, areas difficult to spray in the evening, such as parks and golf courses are adulticided during the day using emulsifiable concentrate formulations. These insecticide/water mixtures are applied to foliage with various types of equipment, some already mentioned, and are capable of applying liquid formulations. These

applications provide direct kill of mosquitoes that are present and also give a short term residual kill for approximately 2-3 days.

Various types of equipment are also available for aerial larviciding and adulticiding, but are not included within the scope of this manual.

REVIEW QUESTIONS – CHAPTER 6: EQUIPMENT FOR CHEMICAL APPLICATION

1. List the two categories of chemical control equipment used to control mosquitoes.
 2. Liquid larvicides are usually applied with _____.
 3. _____ sprayers leave both hands free to direct the nozzle, change the spray pattern and other tasks.
 4. A _____ sprayer is used for large jobs such as larviciding roadside ditches, county drains, and sewage lagoons.
 5. Granular formulations of larvicide could be applied to small areas such as tires with a dipper. True or False?
 6. Thermal fog machines are preferred over ULV equipment for applying adulticide. True or False?
 7. Which of the following statements are true about fogging:
 - a. Fogging is only effective as a contact application.
 - b. Fogging should begin on the down-wind side of the area to be treated.
 - c. The wind speed should be no greater than 8 mph.
 - d. Fogging should be done shortly after sunset.
 8. What is the proper droplet size for ULV applications?
 9. Areas such as golf courses that are difficult to spray in the evening may be adulticided at night using _____ formulations.
 10. Aerial equipment is not available for larvicides and adulticides. True or False?
-

ADULT MOSQUITO SURVEYS

The adult survey evaluates the incidence of mosquitoes in a community where they might bite people, and shows the relative abundance of various species present at any time. Using this information and reference material on the breeding sites and habits of mosquito species, the vector control specialists can determine the need for a control program and conduct an effective search for larval breeding places.

The adult mosquito survey furnishes data for the use of ultra-low volume (ULV) spraying equipment at the best time and place and for reporting to supervisors and the public the extent of the problem and the results of control operations. Interpreting adult mosquito survey reports and translating this information into action will save time, materials and equipment, and help justify the entire operation.

Equipment

The required equipment is simple and inexpensive consisting of a collecting tube with aspirator, pill boxes, cages for live collections, field record forms or notebook, pencil, flashlight and map (Figure 19.)

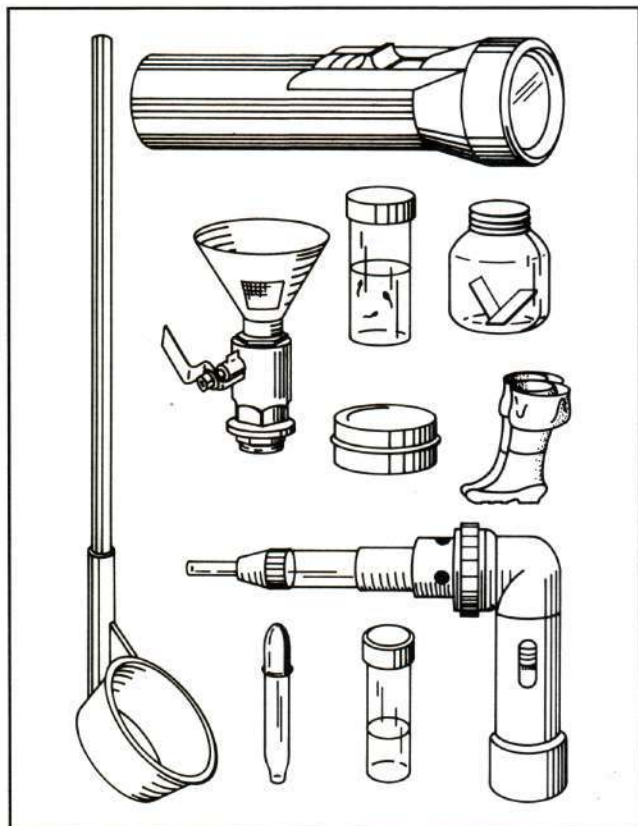


Figure 19. Collecting and Other Equipment for Mosquito Surveys.

The collecting tube can be made from a glass or plastic tube of any convenient size. Usually large test tubes about one inch in diameter and seven inches long are preferred. Fill the tube to a depth of about one inch with finely cut rubber bands, art gum, or other available rubber. Add just enough chloroform or ethyl acetate to cover the rubber. Place a disc of blotting paper over the rubber and then cover with a half-inch of cotton. Press two or three discs of blotting paper cut slightly larger than the tube down over the cotton. Close the tube with a cork; never a rubber stop. A simple collecting tube can also be made out of a 4 oz baby food jar and a small piece of Vapona (dichlorvos) strip.

Collecting tubes remain effective for several weeks and can be recharged when necessary by removing the discs and cotton and adding more chemical. Some workers wrap the base of the collecting tube with adhesive tape to lessen breakage, and others add an inverted paper cone inside the mouth of the tube to trap specimens more easily. The addition of crinkled tissue paper to the tubes helps keep specimens dry and prevents damage, making identification easier.

A simple mouth suction aspirator can be prepared from a section of plastic (or glass) tubing 12 inches long with an inside diameter of about 5/8 of an inch. Cover one end of the tube with a bobbinet or fine wire screening and then insert it into a piece of rubber tubing two to three feet long. Although a little more expensive, most districts now use battery operated mechanical aspirators.

Small pill boxes or salve boxes are convenient for holding dead mosquitoes until they can be identified. A wisp of crumpled soft tissue or lens paper will prevent damage to the specimens as they are carried about or shipped to a laboratory for identification.

Landing/Biting Collections

Collecting mosquitoes as they bite is a convenient method of sampling populations. In making biting collections or counts, the subject should expose part of his (or her) body by rolling up sleeves or trouser legs, or by removing his shirt. While the subject sits quietly for a designated period of time, usually 5 to 10 minutes, collect the mosquitoes with an aspirator and place them in a collection tube for later identification.

Most biting collections are made about sundown the most active time for most mosquitoes. If collecting at night, use a flashlight. Whether counts are made from human beings or animals, keep in mind that certain individuals are more at-

tractive to mosquitoes than others. Use the same person or animal throughout the survey. Make collections at regular intervals, at about the same time of day and for the same length of time, so that biting rates at different stations may be compared to show trends in mosquito populations.

With day-biting species, the index may be based on landing rate (the number of mosquitoes alighting on one's clothing in a given time) rather than those actually biting. This is more practical when populations are very high, and is useful for a rapid check of mosquito abundance before and after treatment. In areas where mosquito-borne disease occurs, use landing rates as opposed to biting rates.

Insect Net Collection

Insect nets are used for collecting mosquitoes from grass and other vegetation. This type of collection helps identify species which rest in these habitats during the daytime, such as *Aedes vexans* and *Ae. sollicitans*. There are also various homemade fabricated pieces of equipment such as battery powered aspirators which perform this same function.

Bait Traps

Horse-baited traps (stable traps) have been used successfully in other parts of the world especially where electrical power is not available. However, they are expensive to build, maintain, and transport, and have not been used extensively.

Dry ice attracts large numbers of some mosquito species. A portable mosquito bait trap using this principle is shown in (Figure 20). The trap is made from a 12-inch lard can. It has inwardly directed screen funnels and is baited with about three pounds of dry ice wrapped in newspaper. This style of carbon dioxide trap can be modified to permit the use of chicks or other birds as the bait.

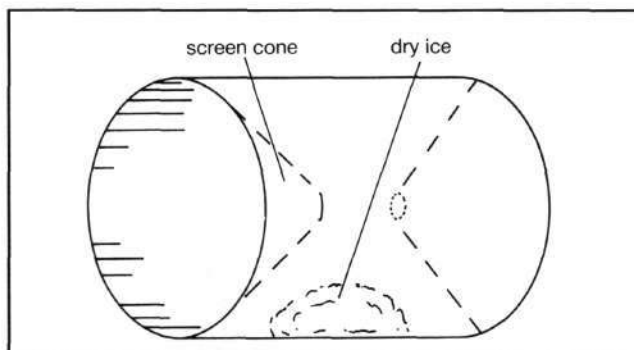


Figure 20. Carbon Dioxide Trap.

The culi-cone trap shown in Figure 21 was developed by the Michigan Department of Public Health in 1982. Constructed from used five-gallon plastic pails, it collects more mosquitoes than those made of metal. The trap has a key and slot construction which eliminates fasteners; may be completely dissembled for easy cleaning; has parts that are interchangeable between traps; and can be made for under \$5.00. This trap may be baited with young chickens, pheasants, house sparrows, or other birds. Dry ice may also be placed in the trap as the bait or may be used as a supplemental lure when using animals by hanging the ice in a paper padded book mailer near the trap.

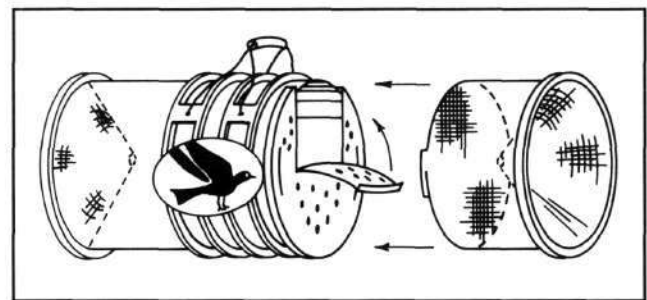


Figure 21. MDPH Culi-Cone Trap.

Daytime Resting Collection

Adults of most species are inactive during the day, resting quietly in dark, cool, humid places. Careful inspection of daytime shelters indicates the population density of these mosquitoes. This method is especially useful for Anopheline mosquitoes and is commonly used for *Anopheles quadrimaculatus*. It also helps in estimate populations of some Culicines such as *Culex pipiens*. An advantage of this method is its ability to fairly sample all mosquitoes with a more representative number of population age structure.

There are two types of mosquito resting stations: natural and artificial. Natural resting stations are present in areas such as houses, stables, chicken houses, privies, culverts, bridges, caves, hollow trees, and overhanging banks along streams. With experience you can evaluate the suitability of areas as resting stations by casual inspection. Dwellings, especially when unscreened, are often satisfactory resting stations. This is an especially important consideration when mosquito-borne diseases are being investigated. Under such conditions, using unscreened dwellings will indicate the number of mosquitoes which may bite humans and transmit encephalitis or other mosquito-borne diseases.

Only a few mosquitoes will use artificial resting

stations. There are a variety of artificial resting stations available. One of the more popular is the red box shelter, a 1-ft. cubed, wooden box with one side open, painted flat black on the outside and red on the inside. Such stations must be placed near the suspected breeding places in shaded, humid areas. Normally, the best placement is on the ground **not** facing easterly. Mosquitoes enter the shelters at dawn, probably in response to change in light intensity and humidity. They ordinarily do not leave until dusk.

Light Trap Collection

Many mosquito species are attracted to light, making it possible to use this response in sampling adult populations between dusk and dawn. The New Jersey mosquito light trap, developed in the 1930's, has been widely used in obtaining data on the density and species composition of mosquito populations.

The American model mosquito light trap (Figure 22) was developed as a modification of the New Jersey light trap. It was redesigned to reduce intake of moths and other nontarget insects.

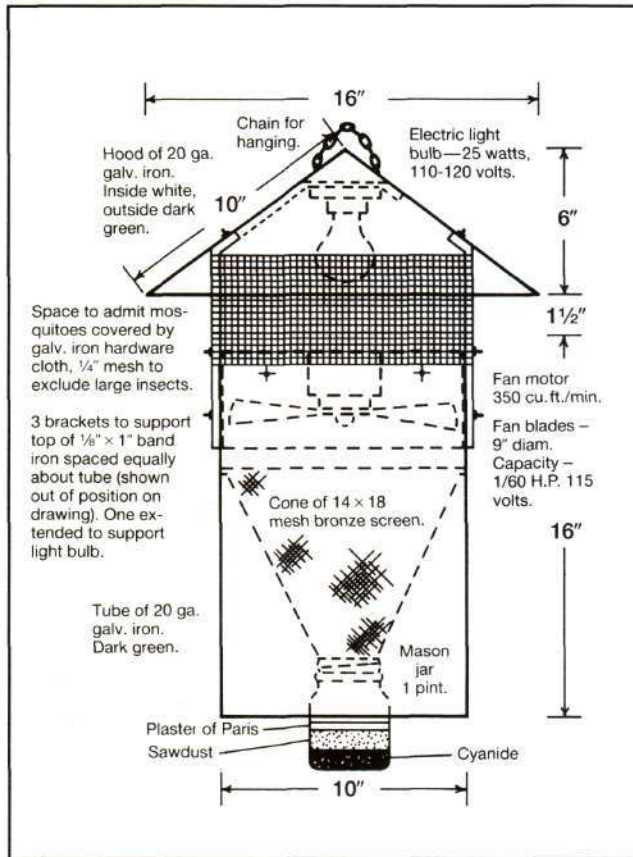


Figure 22. American Light Trap (Note: Piece of Vapona strip can be substituted in Mason jar to kill mosquitoes).

The Centers for Disease Control (CDC) Miniature Light Trap (Figure 23) was developed for greater portability in making live mosquito catches in remote areas where standard electric power is not available.

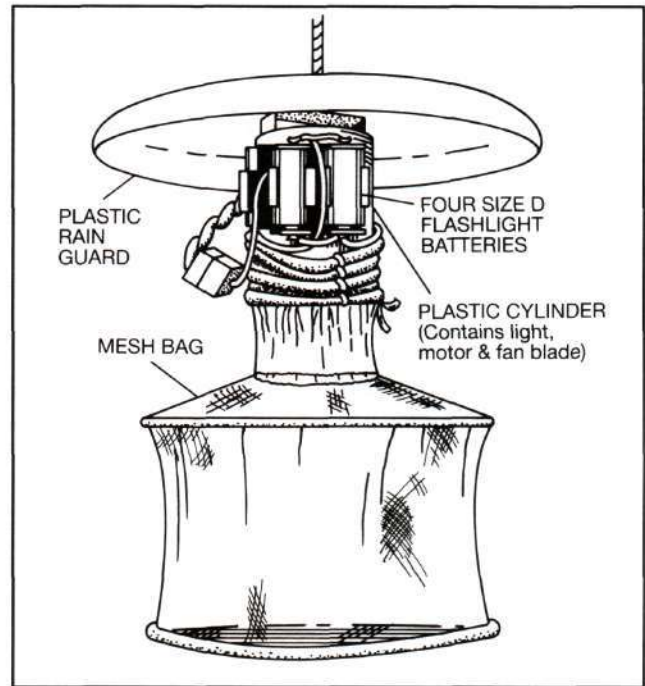


Figure 23. CDC Miniature Light Trap.

This small plastic trap has been field tested and works very well, especially in capturing spring *Aedes* (single generation) mosquitoes. In one instance, the miniature trap collected 25,000 *Psorophora confinnis* in a single night. It collects a high percentage of mosquitoes in proportion to other insects and many more females than male specimens, a desirable feature in collecting mosquitoes for virus studies.

Mosquito light traps attract adults from a considerably large area when they are placed in locations remote from competing light sources. To make the trap more attractive you can add a 2 lb block of dry ice wrapped in newspaper above the trap. As the mosquitoes respond to the attractants they are blown downward through a screen tunnel into a killing jar or a mesh bag suspended below the trap. The light and fan are normally powered from "D" cell batteries but a rechargeable 6 volt battery is preferred if the trap is to be used frequently.

The mosquito light trap is mounted on a post, or hung from a tree with the light 5½ to 6 feet above the ground. It should be located 30 or more feet from buildings in open areas near trees and shrubs. Do not place it near other lights, in areas open to strong winds, or near industrial

plants giving off smoke or gas. The traps are operated on a regular schedule from one to seven nights per week. They are turned on just before dark and turned off after daylight. The collection should be removed each morning and placed in a properly labelled box to be sorted and identified.

There are wide differences in the reactions of different species of mosquitoes to light. Therefore, use light trap collections in conjunction with other methods of sampling mosquito populations. These traps can be converted to monitor non light attracted mosquito densities by removing the light and only using CO₂ as the attractant. With light as an attractant they have proven very useful in measuring densities of some of the Culicine mosquitoes, such as *Aedes sollicitans*, *Aedes vexans*, and *Coquillettidae perturbans*. Some *Anophelines*, especially *Anopheles walkeri*, are also readily taken in light traps. The use of CO₂ only as a attractant collects large densities of *Ae. canadensis*, *Ae. fitichii*, *Ae. stimulans* and *Ae. intrudens*. The common malaria mosquito, *Anopheles quadrimaculatus*, however, is seldom taken in significant numbers. It has been reported that light trap collections of many species of mosquitoes show fluctuations on a four-week cycle correlated with the dark and bright phases of the moon, being greatest during the dark phases.

The Gravid Trap

Since transovarial transmission of SLE has not been proven in *Culex* mosquitoes, it is necessary to sample females that have already had a blood meal, and thus are possibly infected. A gravid trap (Figure 24) was developed by Dr. Paul Reiter of the Centers for Disease Control to capture those blood fed females. This trap is very effective in capturing large amounts of undamaged gravid *Culex* mosquitoes.

Gravid traps cannot be purchased from a manufacturer but can easily be built. The trap is light weight, portable and runs on one 6 volt gel cell rechargeable battery. One gallon of attractant placed in a black tray draws gravid females to the trap to oviposition. While flying above the attractant's surface, the mosquitoes are drawn into the collection chamber by an air current. The design of the trap and power from a 6 volt fan and motor create the air current. The mosquitoes are captured live and then can be used for virus isolation studies or species density information.

LARVAL MOSQUITO SURVEYS

Before beginning a larval survey, you must have information about the general breeding

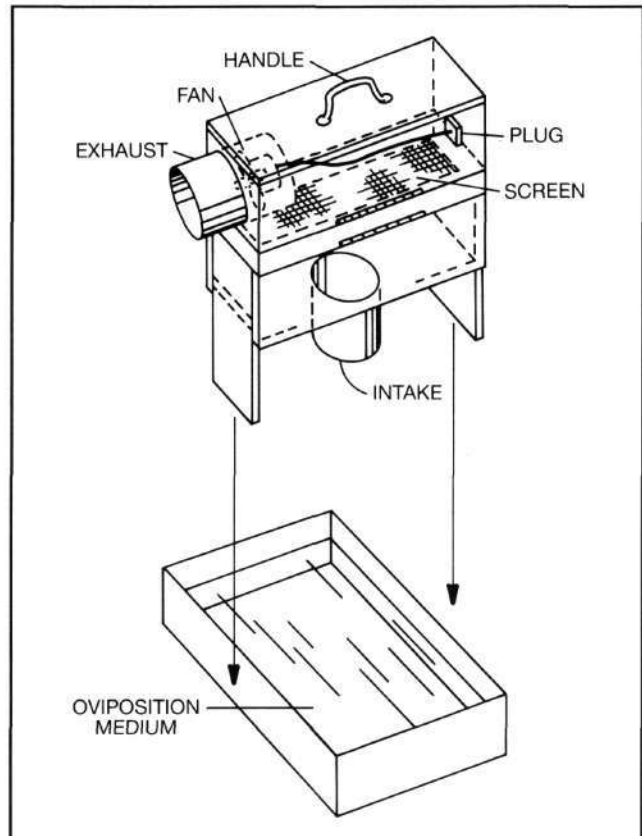


Figure 24. Gravid Trap (Attractant: 1-lb (0.5Kg) Hay, 1-oz. (5gm) Dried Brewers Yeast, 1-oz. (5gm) Lactalbumen, 30-gal (114 liter) water; Allow infusion to incubate 5 days)

habits of the species known or suspected to be in the area. It must be assumed that mosquitoes have adapted to almost every conceivable type of aquatic situation. An experienced person may be able to spot the probable mosquito-breeding places in a specific area using a rapid reconnaissance survey. Carefully number and mark these places on the map. More detailed inspection is then required to determine the specific breeding sites and to establish permanent larval sampling stations. Larval surveys show the exact areas in which mosquitoes breed and their relative abundance. For this reason, they are of special value in control operations.

Equipment

A white enameled or plastic dipper about four inches in diameter (350 ml capacity) is frequently used for collecting mosquito larvae (Figure 19). The handle of such a dipper may be extended to a convenient length by inserting a suitable piece of wood dowel or pvc pipe. Specially designed dippers can be created so that their capacity can be directly related to the water surface examined. Thus, the number of larvae per square foot or

meter can be computed with reasonable accuracy. White enameled or plastic pans are preferred over dippers by some inspectors. A convenient-sized pan is about 14" x 9" and 2" deep. The pan is used to sweep an area of water until the pan is half full. It may then be floated on the water surface while the larvae are removed.

Procedures

Mosquito larvae are usually found near surface vegetation or debris. Thus, in larger ponds or bodies of water, larvae are ordinarily confined to the marginal areas. Proceed slowly and carefully in searching for mosquito larvae. Disturbance of the water or casting shadows may cause the larvae to dive to the bottom. Anopheline larvae are collected by a skimming movement of the dipper with one side pressed just below the surface. The stroke is ended just before the dipper is full because larvae are lost if the dipper is filled to the point that it runs over.

Where clumps of erect vegetation are present, press the dipper into such clumps with one edge depressed so that the water flows from the vegetation into the dipper. Culicine larvae, such as *Aedes vexans* or *sollicitans* or species of *Psorophora*, require a quicker motion of the dipper as they are more likely to dive below the surface when disturbed.

Always record the number of dips made and the number of larvae found. Transfer the larvae to small vials by a wide-mouth pipette and preserve them in alcohol for later identification. It is possible to get a rough idea of the breeding by computing the average number of larvae of each species per dip. The number of dips required will depend on the size of the area, but for convenience make them in multiples of ten. Make inspections at intervals of one to two weeks during the mosquito breeding season, as areas which are entirely negative at one time may be heavily infested at another time due to the relationship between mosquito breeding and amounts of rainfall.

Variations in the procedure just described are required when inspecting for certain species. For example, *Coquillettidiae* larvae remain below the surface throughout their development. These larvae are found by pulling up aquatic plants (cattail, sedges, pickerelweed, etc.), washing them in a pan of water, and searching the bottom muck and debris.

Inspection for *Aedes triseriatus* involves searching for tree holes and artificial containers, such as tires, where this species breed. These containers are often too small for an ordinary dipper, but water may be siphoned into a dipper or pan where the larvae can be seen.

MOSQUITO EGG SURVEYS

Egg surveys are carried out primarily to determine the breeding places of mosquitoes. *Aedes* and *Psorophora* mosquitoes lay their eggs on damp soil in places subject to intermittent flooding. Two entirely different types of egg surveys may be carried out for these genera: sod sampling and egg separation.

Sod Sampling

Cut sod samples into 8 square inches of soil and vegetation. Trim to a thickness of about an inch, and store them for a week or more to allow the embryos time to develop within the eggs. The sod samples are then placed in glass jars and flooded with water. Identify the larvae after they hatch. In larval surveys, sod sampling delineates breeding areas, especially when sampling is done during times when breeding is not occurring.

Egg Separation Machines

Egg separation machines were developed as early as 1938 for separating eggs of *Aedes vexans*, and *Ae. dorsalis* from soil and debris. An entirely different technique (See Figure 25) was developed in 1956 using mechanical agitation, washing, screening out, or sedimentation of debris and

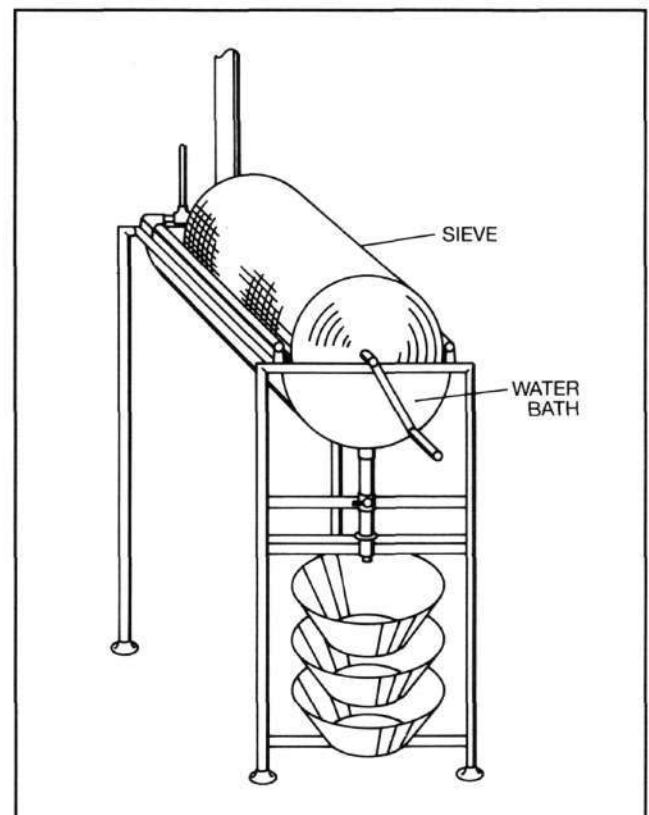


Figure 25. Egg Separating Machine.

flotation of the eggs in saturated salt solution. Sod or soil samples are cut in the field with a sharp trowel around a board 6 inches square (1/4 of a square foot), placed in plastic bags and stored (sometimes for months) in a cool room. The various species and densities of *Aedes* and *Psorophora* can be identified by microscopic examination of live or preserved eggs using standard methods.

OVIPOSITION TRAP

Collecting mosquito eggs in ovipositional traps helps detect and monitor container-breeding mosquitoes such as *Ae. triseriatus*. This mosquito is a vector of Jamestown Canyon and La-Cross Encephalitis and can transmit those disease transovarially.

The oviposition trap (See Figure 26) can easily be made out of No. 10 food cans (3 lb coffee cans) painted black inside and outside. The traps are placed in shaded areas on a tree at a height no greater than 1.2 meters and filled with water with a few dried leaves placed in the bottom of the can. An oviposition substrate made of a 6" x 6" muslin strip or balsa wood is then placed inside the can with the water covering about half of it. Gravid fe males will then use this substrate to lay eggs just above the water level in expectation of future water levels flooding eggs and causing them to hatch.

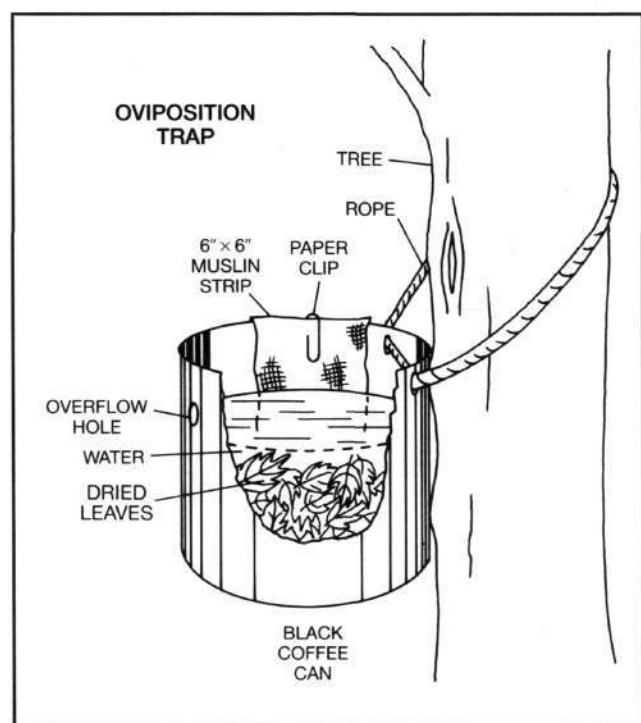


Figure 26. Oviposition Trap.

Check traps every 10-14 days to make sure they do not become a breeding source. If larvae are found in the trap, dump the water and reset the trap.

The ovipositional substrate is periodically collected and returned to the laboratory in ziplock bags. Keep these samples cool and moist during transportation, taking care to avoid too much moisture which could cause eggs to begin hatching. These eggs can be used for population density studies or reared to adults and used in virus isolation disease studies.

USING THE SURVEY DATA

Data from preliminary reconnaissance surveys are correlated with reported disease prevalence or complaints of pest mosquitoes. It is only after reviewing all of this information that the health office or mosquito control supervisor can make an intelligent decision as to the need for a control program and the type of control that will be most effective and economical.

Inspections must be continued routinely once a mosquito control project is under way. Information from inspections can be used to evaluate the progress of the control operations. The success or failure of a mosquito control project cannot be measured in terms of the number of feet of ditches constructed or the number of gallons of insecticides used. While these are useful statistics, it is the actual densities of mosquitoes that is significant. If the mosquito population is reduced to a satisfactory level, there should be accurate data showing this reduction to document the accomplishment. On the other hand, if mosquito populations remain high, these facts should be known so that efforts may be intensified to obtain control. It is always advisable to inspect some comparable breeding areas beyond the control zone at regular intervals to learn the normal fluctuation of various species throughout the season.

The correlation between mosquito annoyance and numbers captured in light traps have been established for some localities. In New Jersey, for example, it was determined that general annoyance did not ordinarily occur until the number of female mosquitoes of all species exceeded 24 per trap per night. Similar criteria can be worked out for other areas and also for various species. Standards for biting or landing rate collections as well as for other sampling methods for adult mosquitoes may also be readily established.

Counts of mosquito larvae are a bit more difficult to correlate with pest problems or disease

hazards. However, larval surveys reveal the specific sources of mosquito production. This information is invaluable to the control supervisor as it enables him or her to apply effective larvicides to the right places at the right times. Data over a period of time may also serve to justify the use of permanent control measures, such as Source

Reduction. More expensive operations, such as filling and draining, should be undertaken only when careful inspection of each area has shown its role in the production of the vector or pest species of mosquitoes which are important in the locality.

REVIEW QUESTIONS – CHAPTER 7: MOSQUITO SURVEILLANCE

1. The best time of day to make biting collections is:

- at dawn when the mosquitoes become active
- around sundown when mosquitoes reach their peak of activity
- early afternoon after the human subject has eaten
- any time it is convenient

2. With day-biting species, it is acceptable to record the number of mosquitoes that land on the subject rather than those that actually bite. True or False?

3. An insect net is best used:

- to catch mosquitoes flying near a trap
- when traps fail
- to collect species that rest in vegetation during the day
- near houses instead of traps

4. Light traps should be located away from buildings, trees and shrubs. True or False?

5. Since some mosquitoes are not attracted to

light, a light trap could be adapted for these species by:

- putting raw meat near the light
- removing the light and baiting the trap with dry ice.
- removing the light and baiting the trap with a sweet substance.
- none of the above. Use an insect net instead.

6. The term gravid describes:

- a mosquito with a short flight range
- a young adult mosquito
- a female mosquito about to lay eggs
- an adult female who has had a blood feeding.

7. A _____ is typically used to collect mosquito larvae.

8. The purpose of most egg surveys is to determine breeding areas. True or False?

9. Why is it important to know what is happening to mosquito populations outside of the control area?

CHAPTER 8

MOSQUITO MANAGEMENT BY HOMEOWNERS

Since most areas of the state do not have the advantages of an organized mosquito management/control program, the individual must take protective measures. There are many ways to reduce mosquito populations in and around the home to reduce the likelihood of mosquito bites. These activities are grouped into three primary management areas: personal protection; mosquito larvae control; and adult mosquito control.

PERSONAL PROTECTION

The aim of personal protection is to prevent mosquito bites despite large numbers of hungry mosquitoes. Personal protection is particularly important in areas where diseases, like encephalitis, are known or suspected to occur. During times of suspected mosquito-borne disease outbreaks, people in the affected area will be notified and encouraged to use personal protective measures.

Screening

Adequate window and door screens are still one of the best methods for personal protection from mosquitoes. Screens must be of proper mesh, fit tightly, and be kept in good repair. Slight tears or openings in screens, warped screens, or screens that do not fit or close properly require little time and expense to repair.

The ordinary window screen with 16×16 or 14×18 meshes to the inch will keep out most mosquitoes. Frequently, mosquitoes follow people into buildings or enter on the human or pet animal host. For this reason, screen doors should open outward and have automatic closing devices. Residual insecticide applications on and around screen doors give added protection.

Screening of camping tents and trailers is highly important to prevent mosquito biting. If tents or cabins are not fitted with adequate screening, use bed nets or mosquito bars when sleeping.

Avoiding Mosquitoes

Most mosquito species bite at night, especially during the twilight hours while some bite during

the daytime in wooded or other shaded areas. If possible, avoid exposure during these times and in these areas. Use protective clothing, insect repellent or go indoors. Children usually do not notice mosquito activity and bites while absorbed in play. Be especially watchful and see that they are protected, or call them indoors.

Protective Clothing

Clothing made of tightly woven materials that cover the arms and legs is good protection from mosquitoes. Button collars and keep trouser legs tucked into socks or boots. Studies show that some adult mosquitoes are more attracted to dark colored clothes than light colored. During very severe mosquito activity, if you must be outside, wear head and face nets, gloves, and knee-high boots.

Repellents

Chemical repellents will also help keep mosquitoes from biting. Two of the most common chemicals used in commercial repellents are N, N-diethyl-m-toluamide (DEET), and Ethyl Hexanediol (612). DEET is the most extensively used material and is sold under various trade names such as Off, Deet, Cutter, and others. It gives good protection against most mosquitoes and is available in liquid, foam, cream, stick, or spray. Studies show that Skin-So-Soft bath oil works as an effective repellent. Although not as active and persistent as products containing Deet, more frequent applications provide adequate protection with a less offensive scent.

A small amount of repellent prevents mosquito bites from two to four hours, depending on the circumstances, to the applied area. The amount of time the repellent is effective varies according to the individual, the amount of perspiration, wiping of the skin and the species and abundance of mosquitoes. As a rule, the product with the higher percentage of active ingredient works longest. Each individual must determine the length of time a repellent application is effective and repeat the treatment when necessary.

Repellents can also be applied to clothing. Clothing treated with repellent usually remains ef-

fective longer than treated skin. Some repellent formulations may soften or dissolve paints, varnishes, and plastics such as watch crystals, eyeglass frames, and rayon fabrics. Take care not to apply repellents to the eyes, lips, or other mucous membranes.

LARVAL MOSQUITO CONTROL

Individuals can do much to reduce the number of biting mosquitoes in and around their homes by eliminating or treating mosquito breeding areas. Some mosquitoes have limited flight ranges and may fly only a few hundred feet from their breeding areas. One such mosquito, *Culex pipiens*, a vector of St. Louis Encephalitis, breeds extensively in water and water containers around houses and is commonly known as the northern house mosquito. Take every effort to eliminate standing water which may support mosquito breeding. Some suggested precautions are:

- Eliminate all extraneous items from your yard such as tin cans, jars, bottles, old tires, oil drums, broken toys, old appliances, or any item which will catch and hold water.
- Repair any leaky pipes or outside faucets.
- Root or grow outdoor plants in sand or soil instead of only water.
- Empty and clean children's wading pools at least once a week and store so they will not collect rain water.
- Empty and refill pet watering containers daily.
- Cover garbage cans to prevent accumulation of rain water.
- Keep eaves troughs clean and free of leaves and other debris so water does not accumulate.
- Fill in tree rot holes and hollow stumps with sand or concrete.
- Stock ornamental garden ponds with mosquito-eating minnows and keep vegetation which protect mosquito larvae trimmed from the edge of the pond.
- Store boats covered or upside down so they will not collect and hold rain water.
- Examine flat roofs after rains to make sure no water remains for more than a week.
- When watering your lawn and garden, do not allow puddling in low areas.
- Maintain farm ponds according to good management practices.
- Drain or fill any low places in your yard where water collects and stands for more than five to seven days.

- Ensure that road ditches or other drainage ditches are kept free of vegetation or other debris which would cause them to hold water and prevent proper drainage. Pay particular attention to driveway culverts. See that water does not stand inside or near the ends of the culvert.

- Be sure that all permanent water containers such as wells, septic tanks, cisterns, water tanks, and cesspools are tightly covered and insect proof.

- Inspect septic drain fields. They must not fail and allow septic water to accumulate on the ground surface.

Marshes, swamps, and other standing water on individual properties should be considered for draining and filling when they are not significant wildlife habitats. If it is determined that these areas are beneficial wildlife habitats, use mosquito larvae control that is environmentally safe.

ADULT MOSQUITO CONTROL

Although elimination of mosquito larval breeding areas and larval control efforts around the house will eliminate a great number of mosquitoes, some mosquito species have flight ranges from one to several miles and may present a biting problem in and around your home. Since there may be a continuous resupply of adult mosquitoes from breeding areas some distance away, adult control (killing) activities are usually temporary and may require repeated application.

Most adult mosquitoes require and seek cool, damp, dark, shaded areas to rest during the day. Eliminating such areas on your property will cause adult mosquitoes to seek resting places elsewhere. Mosquito resting areas can be eliminated by:

- Keeping grass cut short at all times.
- Cutting and removing weeds and brush from yards and adjacent vacant lots.
- Trimming trees and shrubs to allow light and air underneath or between plants and structures.
- Screening or tightly closing outbuildings.
- Staking brush or garden vine vegetables, fruits or ornamentals.
- Storing firewood, lumber or other materials on racks 10 to 12 inches above the ground and at least 12 inches away from any structure.
- Screening or otherwise closing off mosquito accesses underneath or into the attics of all structures. Pay particular attention to basement,

cellar, or other underground areas.

- Eliminating hollow trees and fill tree rot holes and hollow stumps with sand or cement.
- Filling in animal burrows or holes in the ground and kill rats, moles, and gophers to prevent new burrows. Mosquitoes use such burrows as resting places.
- Be certain that wells, cisterns, septic tanks, cesspools, water tanks, etc., are tightly covered and insect proof.

Adult mosquitoes that get indoors can be killed quickly by aerosol sprays containing pyrethrin, resmethrin, or allethrin. Sprays are more effective if the treated area is kept closed for 15 minutes after spraying. In all cases, insecticides must be used in strict compliance with the label directions.

Under certain circumstances, such as planned outdoor parties or similar activities, insecticide spraying for adult biting mosquitoes may be advisable. There are several small hand held "patio" type foggers as well as canned aerosol foggers on the market which are suitable. Remember

these applications are **temporary** and usually kill only those mosquitoes that are flying in the area at the time. Therefore applications are most effective when applied at the time mosquitoes are most active, during twilight. Applications made earlier may kill some resting mosquitoes in the area. However, if the sprayed space is relatively small, infiltration of mosquitoes from outside the area may still present a significant biting problem.

Residual type insecticides applied to shrubs, trees, and brush near the home will remain effective for several days and will kill mosquitoes that rest there. Follow label directions.

Many people buy and use the electronic type bug killers hoping this will reduce the number of biting mosquitoes. Moths, flies, and other insects are attracted to the ultra violet light used in most of these units. However, mosquitoes much prefer the human body to this light attraction. Studies have concluded that these traps fail to reduce the adult mosquito biting rate even after 11 nights of continuous operation. In fact, one test on an individual 12 feet from a unit was bitten by mosquitoes more often than an individual 30 feet away.

REVIEW QUESTIONS – CHAPTER 8: MOSQUITO MANAGEMENT BY HOMEOWNERS

1. The most effective chemical in mosquito repellents is _____. It is found in products like "Off" and "Cutter."
2. It is useless to apply repellent to clothing because the chemicals must contact the skin to be effective. True or False?
3. List eight types of mosquito breeding habitat commonly found near homes.
4. Adult control (killing) activities are usually temporary and may require repeated applications. True or False.
5. List five ways to eliminate adult mosquito resting areas.
6. Which of the following control methods is NOT effective with mosquitoes?
 - a. screening all windows and doors
 - b. keeping house eaves troughs free of leaves and other debris
 - c. use of an electric "bug zapper."
 - d. use of pressurized can aerosols containing pyrethrin, resmethrin, or allethrin.

CHAPTER 9

METHODS FOR EVALUATING INSECTICIDE USE

The technology of mosquito control depends greatly on the use of insecticides to kill mosquitoes. Although there are many ways to prevent mosquito bites (for example, using repellents, eliminating larval habitats or adult harborages), it is the proper use of insecticides that ensures that mosquito control both works and is environmentally acceptable. One important facet of operational mosquito control is the **evaluation** of insecticides used to kill mosquitoes.

REASONS TO EVALUATE INSECTICIDE USE

There are at least five reasons to evaluate insecticides used for mosquito control:

1. To determine the effectiveness of on-going mosquito control operations;
2. To check treated sites or areas for possible re-treatment;
3. To test the effectiveness of new insecticides or new formulations of insecticides;
4. To determine the effects of insecticide application on non-target organisms;
5. To test for insecticide resistance in the mosquito populations.

The first two reasons mentioned above are probably the ones with which mosquito control personnel will be most concerned. These points address the question, "How effective are the mosquito control activities?" This question relates directly to evaluation through monitoring and surveillance practices. Reasons three and four relate more to experimental work than to monitoring, where mosquito control workers may wish to test new insecticides or formulations before including them into an operation. This requires posing specific questions, and collecting and analyzing data. In this case, the questions will probably be general such as, "Is insecticide A or formulation B effective in killing mosquitoes?" or "Does insecticide C harm non-target animals or plants in an unacceptable way?" Data must be collected in such a way as to answer these questions.

The fifth reason mentioned comes into play when operational workers are concerned that the mosquitoes they are attempting to control have become

resistant to insecticides. To address this concern, laboratory assay studies are usually required.

The two categories of insecticides used to kill mosquitoes are **adulticides** (insecticides that are applied into the air or onto surfaces to contact and kill adult mosquitoes); and **larvicides** (insecticides applied to water to kill mosquito larvae and pupae). The methods to evaluate adulticides differ because insecticides in these categories are applied to different parts of the environment (corresponding with the mosquito life cycle), and often have different modes of action and different toxic properties. Needless to say, any evaluation of an insecticide must take into account the ecology and behavior of the target insect. For example, it makes no sense to test a ULV formulation of malathion to control adult mosquitoes during mid-day because most mosquitoes have twilight biting activity periods.

EVALUATION PROCEDURES

Evaluating adulticides and larvicides usually requires **sampling** mosquito adults and larvae. "Sampling" differs from "collecting" in the systematic way in which the mosquitoes are acquired; sampling generally allows an estimate of the relative abundance of the mosquitoes, whereas collecting per se provides little more than presence or absence information. Chapter 7 deals with sampling and surveillance of mosquitoes, but some sampling methods appropriate for evaluation are repeated here.

Sampling adult mosquitoes can be accomplished with biting counts, dry-ice baited CDC light traps, New Jersey light traps, gasoline- or battery-powered aspirators to collect mosquitoes resting on vegetations, or other methods. Sampling larvae and pupae can usually be done with a standard 350 ml dipper attached to a wooden handle. Larvae and pupae of mosquitoes that have habitats difficult to sample with a dipper (for example, *Coquillettidia perturbans*, *Culiseta melanura*, *Aedes thibaulti*) can be sampled with a modified, hand-operated bilge pump. Mosquito larvae and pupae in container habitats such as tree holes or discarded tires can be sampled with a soup ladle, turkey baster, or siphon hose.

Evaluating adulticide applications requires sampling for purposes of surveillance and monitoring the target adult mosquito population. Monitoring is most efficient when a network of sampling stations is established for area-wide sampling. The relative abundance of mosquitoes in the samples should vary with the frequency of insecticide applications. When adulticides are applied, the treatment should be reflected by a reduction of the number of mosquitoes in biting counts and light trap collections. Generally, it is not possible to express in absolutely quantitative terms the actual reduction in adult mosquito population density after insecticide applications because of the relative nature of the sampling methods. However, if there is no observable reduction, then the effectiveness of the particular insecticide application should be questioned. Re-treatment, equipment calibration, or other procedures may be required.

Monitoring larvicide applications is usually easier than evaluating adulticides because larvae are generally easier to sample. To monitor counts of larvae and pupae, dip samples should be taken before and after larvicide application. A drastic reduction (usually to zero) in numbers of mosquitoes in dips taken after treatment indicates that the larviciding has been effective. For some larvicides, it is necessary to collect pupae, bring them into the laboratory and hold them to determine if adults will emerge. This is important when the larvicides are insect growth regulators (such as methoprene or fenoxycarb). Such larvicides do not immediately kill the larvae, but rather prevent the larvae and pupae from developing normally to adults.

Evaluating new insecticides or new formulations in the field requires a more elaborate experimental set-up than monitoring. For adulticides intended to kill flying mosquitoes (for example, ULV), an effective method for evaluation involves using sentinel, caged mosquitoes. Mosquitoes are either reared in the laboratory or are wild-caught, placed in known numbers in cages (mosquito-screen or 16-18 mesh works well), and are given a sugar source for nutrition. One hundred mosquitoes (same or closely-related species) per cage is adequate. Cages are strategically placed in areas which will and will not receive adulticide. The cages outside of the application zone are called "control" or "check" cages. Mortality in these cages after application cannot be attributed to insecticide, but is considered background mortality. There should be at least five cages in both the treated and check areas.

After the application is made, the number of

dead mosquitoes in each cage is counted, and the percent mortality per cage determined as:

$$(\text{number dead/total number in the cage}) \times 100 = \% \text{ mortality per cage}$$

Then, the mean percent mortality in treated or check cages can be calculated as the sum of percent mortality for all cages used. The efficacy of the adulticide, represented as **percent reduction** or **percent mortality**, can then be quantitatively estimated using **Abbot's formula**, as follows:

$$\frac{(\text{Mean \% mortality in test cages} - \text{Mean \% mortality in check cages}) \times 100}{(100 - \text{Mean \% mortality in check cages})}$$

Besides caged mosquitoes, it is also possible to assess the effect of aerial adulticiding with biting counts and light-trap catches. These efforts must be concentrated in treated and check areas and should be properly replicated to yield a good series of data. Take samples in both treated and check areas before and after application. Then, the percent reduction in number of adult mosquitoes in the treated area can be compared to the check area with the following formula derived from the work of Dr. Mir Mulla:

$$100 - \left[\left(\frac{C_1}{T_1} \times \frac{T_2}{C_2} \right) \times 100 \right]$$

where

- C₁ = mean number of adults (before application) in check area;
- T₁ = mean number of adults (before application) in treated area;
- C₂ = mean number of adults (after application) in check area;
- T₂ = mean number of adults (after application) in treated area.

Besides adulticides applied to kill flying mosquitoes, there are others applied to kill mosquitoes resting on surfaces. Often, these adulticides are applied to harborage areas (indoor or outdoor area where inactive adults rest and hide), and the adulticide may have some residual effects. Evaluating harborage adulticides requires sampling resting adult mosquitoes within harborage areas that either have been treated or serve as check zones. Sampling can be accomplished using aspirators that suck up the resting mosquitoes. Mosquitoes in designated treated and check areas should be sampled before and after treatment as with aerially-applied adulticides. Use Mulla's formula to calculate percent reduction.

Evaluating larvicides obviously requires a different sampling program than for adulticides, but the general theory is the same. Choose treated and check sites of similar size and appearance

for the tests. Sample larvae (at high replication with the dipper or other sampling devices) in check and treated sites both before and after application. If an insect growth regulator is being tested, then pupae should be brought into the laboratory and held until death or adults emerge. Percent reduction in treated sites compared with check sites can be calculated with Mulla's formula. Evaluating larvicides can also be conducted with caged, sentinel larvae where the abundance of naturally-occurring mosquitoes is low. However, this is usually not necessary.

Evaluating larvicides against *Coquillettidia perturbans* (cattail mosquito) larvae can be accomplished, but is generally difficult because of their specialized underwater habitat. Bilge pump sampling is a good alternative to dip sampling in certain habitats such as cattail stands in shallow water. When larval sampling is difficult or insect growth regulators are being tested, then adult emergence cages may be used in lieu of larval collections. These cages require special construction and regular attendance to be effective.

Sometimes, operational mosquito control personnel may find it necessary to evaluate the effects of the insecticides they use on non-target organisms. Non-target organisms are living things (such as fish, other insects, birds, other non-insect invertebrates) besides mosquitoes that may suffer morbidity or mortality from the insecticide application. Such evaluations may require extensive background work, special sampling programs, and carefully designed field studies. A very large, comprehensive evaluation is called an environmental impact study. Usually, experts in the biology of the non-target organisms must be consulted to carry out an evaluation. Further elaboration of this kind of insecticide evaluation is beyond the scope of this training manual, but be aware of non-target evaluations and procedures.

Mosquito resistance to insecticides is generally not a problem in Michigan, but the possibility of resistance should be considered when evaluations indicate low efficacy of an insecticide. The World Health Organization has established specific testing procedures for determining if resistance exists, and makes available resistance test

kits at a modest price. Several publications from the World Health Organization and the American Mosquito Control Association thoroughly review resistance testing procedures and should be consulted. Also, Cooperative Extension Service personnel and professional entomologists can provide advice on carrying out such tests.

The following publications review information on insecticide evaluations and testing procedures. Consult them to answer specific questions about sampling, field procedures, etc.

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REVIEW QUESTIONS – CHAPTER 9: METHODS OF EVALUATING INSECTICIDE USE

1. The best way to measure the effectiveness of mosquito control activities is through monitoring and surveillance practices. True or False?
 2. The two categories of insecticides used to kill mosquitoes are _____ and _____.
 3. Sampling adult mosquitoes can be accomplished with:
 - a. biting counts
 - b. dry-ice baited CDC light traps
 - c. New Jersey light traps
 - d. aspirators to collect mosquitoes resting on vegetation
 - e. all of the above
 4. Generally larvae and pupae are sampled with a _____.
 5. To monitor larvicides, dip samples must be taken:
 - a. before and after larvicide applications
 - b. twice a day
 - c. only at night
 - d. both a and b
 - e. both a and c
 6. What type of larvicide is monitored by collecting pupae and holding them in the lab to determine if adults will emerge?
-

CHAPTER 10

INCORPORATE PUBLIC RELATIONS INTO YOUR WORK

Public relations are the methods and activities of an individual, organization, corporation or government to promote a favorable relationship with the public. For persons involved with pesticide applications, good public relations are a necessity.

Problems arise when consumers have incomplete, misunderstood, or erroneous information. While the MDA certification process ensures that an applicator has an acceptable level of technical competence, the process does not stop there. In fact, it has just begun. To be a successful professional applicator, you must be able to communicate effectively with the public.

It is important to remember that issues surrounding pesticides are many and complex. Thus, it is unrealistic to expect to be able to resolve every issue or to have complete knowledge of such a complex field. However, developing a solid, well-thought-out public education plan pays dividends. There are "do's and don't's" in the art of public relations, which if understood, will result in more effective communication. The beneficial results of good public relations identifies the truly professional applicator.

To practice good public relations you must have:

- Technical competence;
- Professional appearance and attitude;
- The ability to identify and resolve problems before they magnify;
- Educational materials for distributing to customers.

Once you have those basic requirements, the following guidelines will also be helpful. You will want to adapt them so that you are comfortable using them. A commitment to practice quality public relations will pay off in increased professionalism and pride.

The Ten Commandments of Public Relations

1. Acquire technical competence.
2. Commit to excellence in all pesticide applications. See that technical decisions are

made competently, safely and with sensitivity to environmental quality.

3. Know your service community. Be honest about pesticide use, and the pluses and minuses connected with it.
4. Know and understand the rules and regulations governing your work.
5. Be prepared to educate and instruct your customers. Where possible, use handout brochures to reinforce what you say.
6. Use a focused and concise format to educate. Take time to listen. Avoid reacting emotionally.
7. Keep good documentation and good records. Investigate and attempt to resolve problems arising from control techniques or procedures immediately. Write a report as soon as you have the facts.
8. Be aware of changing techniques and technologies. Keep current with your professional field.
9. Collect a working reference library (books and reprints). Keep it current and technically correct. Become a member of an appropriate professional organization. These associations usually have journals and newsletters which provide information concerning technical breakthroughs as well as the latest in technology.
10. Practice good public relations regularly. Do not limit this practice to crisis situations. Strive to educate yourself and those you serve at every possible opportunity.

Developing a quality public relations program always includes an information and educational component. Various methods or styles of communication need to be recognized and included in the program. For example, a professional applicator communicating with an individual can use brochures, copies of scientific or technical reprints, video tapes or suggested reference books.

In communicating with groups of people or informing the general public over a wide geographical area, one must use other methods. Some of these techniques are better handled

using a specialized format. The examples* at the end of this chapter are furnished for your reference. Adapt them to meet your objectives.

Example 1 - Fact Sheet*

Example 2 - News Release*

Example 3 - Public Service Radio Announcements*

Example 4 - Public Service TV Announcements*

Example 5 - Interview Questions for Radio or Television*

Example 6 - Mailing list of local media - names, addresses, telephone numbers.*

*Michigan Dept. of Public Health Mosquito Manual - 1985 (These are examples only and are not necessarily all inclusive of facts and information).

EXAMPLE 1

FACT SHEET

EASTERN EQUINE ENCEPHALITIS (EEE)

It is hard to believe that a single bite from a mosquito carrying the EEE virus can kill a horse or a person but it can. Children and older people are most seriously affected by EEE and have less chance of surviving.

EEE is an inflammation of the brain which can cause permanent damage including mental retardation, behavioral changes, convulsive disorders and paralysis. The death rate among humans who contract the disease is 50 to 75 percent. Up to 95 percent of the horses that become ill with EEE will die.

DISEASE CARRIERS

Eastern Equine Encephalitis is one of the types of encephalitides that is carried by mosquitoes to people and horses. Mosquitoes carry the disease from birds harboring the virus.

Mosquitoes bite infected birds and carry the virus the rest of their lives. Birds are natural hosts for the virus and do not themselves become ill. The most common carriers of EEE virus in Michigan are robins, sparrows, blackbirds, cardinals, and wood thrushes.

The virus lives and grows in the mosquitoes' salivary glands. Therefore, every time the insect seeks food and bites, the bitten individual can become infected. That means horses, other birds and human beings. Incidentally, it is only the female mosquito that bites. She bites to get blood for her eggs.

HUMAN CASES OF EEE

In the past 20 years approximately 70 cases of EEE in humans have occurred in the United States. Michigan recorded its first human case in 1980 when a 13-year-old youth became critically ill and was left with serious permanent damage. The boy died 19 months later.

In 1981 there were 54 cases of EEE in Michigan horses. No human cases were found.

In 1982, eight horse cases were documented in Michigan with again no EEE illness in humans. Local and state health officials continue

monitoring each season.

A MYSTERY

It is not known how the EEE virus came into Michigan. Some experts think migratory birds bring it with them in the summer from the Gulf Coast states. Others think the virus may live through the winter months.

Because horses are more likely than humans to contract EEE, cases in horses usually always precede cases in humans in a given area. Then officials are alerted and intense investigation begins in an attempt to save lives.

HELP PREVENT EEE

Each of us can play an important part in protecting our families, ourselves and our neighbors. Remember, the EEE mosquitoes are found primarily in swampy areas. Therefore, for protection we suggest:

- Avoid areas, particularly swampy areas during evening hours, where mosquitoes are most active and biting.
- Wear protective clothing when mosquitoes are present.
- Use insect repellent on exposed skin.
- Keep window screens and door screens in good repair.

If necessary, local health officials will determine if ground or aerial spraying is needed. If so, safe, bio-degradable insecticides will be used under the direction of a qualified entomologist.

Spraying with insecticides will kill only those mosquitoes in the immediate vicinity. After the spray loses its effectiveness, the mosquitoes will return.

"Remember," _____ says, "the responsibility for helping to control mosquitoes is not solely the community's. Everyone can help by remembering that stagnant water is something to avoid. It doesn't matter where that stagnant water might be, in a public park or a child's wading pool at home. If it's there, get rid of it or properly treat it."

For more information, contact _____.

EXAMPLE 2

October 13, 1989

TO: ALL MEDIA

FOR: Immediate Press Release

CONTACT PERSON: John Doe
Mosquito Control

CITIES CAN HELP WITH MOSQUITOES

"The mosquito season will soon be at hand", said (Name), director of the (Health Department). "Not only are mosquitoes a pesky nuisance", he/she added, "but they are potential disease carriers as well. Note the problems Michigan has had in recent years with Eastern Equine Encephalitis, a mosquito-borne disease."

(Name) offered the following suggestions for area municipalities wanting to control mosquitoes. All actions are related to removing stagnant water as mosquitoes breed in this kind of environment. (Name) said every seven to ten days a new hatch of mosquitoes can be produced in an area of stagnant water.

Measures which can be taken follow:

- Eaves troughs, gutters, and flat roofs of buildings are areas which should be kept clean and drained to prevent mosquito breeding;
- Community cleanup campaigns should stress the removal of any type of containers where mosquito breeding can occur;
- Bodies of water such as roadside ditches, creeks, and rivers should be kept free-flowing with steep, smooth banks, little or no vegetation and no stagnant side pockets;
- Weeds should be trimmed along roadside ditches and creeks;
- Tree holes accumulating water are common mosquito breeding sites. Such holes should be filled with cement;
- Sewage lagoons at community sewage treatment plants should be checked for the presence of larvae from mid-June through September;
- Swimming and wading pools should be skimmed weekly;
- And storm sewer catch basins should be checked to determine if they hold pooled water. If catch basin hold water they should be sampled for mosquito larvae from mid-June through September. If larvae are present, then a larvicide should be applied. A larvicide should also be used for ornamental ponds and pools and woodland ponds.

(Name) reminded, too, that the responsibility for helping to control mosquitoes is not solely that of the community. Every individual can help by remembering that stagnant water is what all of us want to avoid. It doesn't matter where that stagnant water might be, in a public park or a child's wading pool at home.

EXAMPLE 3

PUBLIC SERVICE ANNOUNCEMENTS

RADIO

10 Seconds, 20 Seconds, 30 Seconds

ANNOUNCER: This is the mosquito season and mosquitoes breed in standing water. So check your yard and neighborhood and get rid of anything that holds water. Mosquitoes are not only a nuisance, they can carry disease: A reminder from the (H. Dept.)

ANNOUNCER: (County) may not have a mosquito control program, but your (Health Department) does have helpful information on what you can do to "Fight the Bite!" Contact the (Health Department) at (phone number) for information on what you can do to control mosquitoes in your yard and neighborhood.

ANNOUNCER: The mosquito season is here. Mosquitoes are not only a nuisance, they can transmit disease. Encephalitis and dog heartworm are a real concern to (County) health authorities. Remember, mosquitoes breed in standing water, so clean out eaves troughs, change the water in bird baths at least weekly, and cover or get rid of anything that can hold water.

Standing water can produce a new hatch of mosquitoes every seven to ten days. Do your part to "Fight the Bite!"

ANNOUNCER: When Eastern Equine Encephalitis is present in the horse population, there is always the danger that humans may get the disease from mosquito bites. So, as best you can, avoid being bitten by mosquitoes. The (health department) offers these suggestions: Use caution when out-of-doors, especially in the evening. Wear protective clothing and use a mosquito repellent. If your home has any defective screens, have them fixed.

Continue these precautions until after the first hard frost of Fall.

EXAMPLE 4

PUBLIC SERVICE ANNOUNCEMENT

TELEVISION

VIDEO

Fight the Bite Slide - super health department, name and phone number across bottom.

AUDIO

Mosquitoes are a nuisance . . . and a health menace! Get helpful information on how to control them. Call the (Health Department) and help "Fight the Bite!"

EXAMPLE 5

INTERVIEW QUESTIONS

RADIO OR TELEVISION

1. Can mosquito bites be dangerous to human health?
2. What kinds of disease can mosquitoes transmit to humans? To animals?
3. How does encephalitis affect adults and children?
4. Does encephalitis affect animals such as horses?
5. What does dog heartworm do to dogs?
6. What are the mosquito-borne diseases that we should be aware of in this area?
7. Were any of these infections found last year? This year?
8. Are we part of any mosquito control district?
9. How does a mosquito control district function and can it reduce the numbers of mosquitoes?
10. Would such a program have any adverse effect on the land, or on other insects and bird population?
11. Are there mosquito control programs in other parts of the country?
12. Have they effectively been able to eliminate or control mosquitoes?
13. What about controlling mosquitoes in wetlands and swamps? Would it be necessary to drain the swamps?
14. Any closing comments?

EXAMPLE 6

REFERENCE MAILING LIST OF LOCAL MEDIA

The Saginaw Press
P. O. Box 1776
Saginaw, MI 48602

The Township Times
2089 Wieneke
Saginaw, MI 48603

Tri-County Record Globe
P.O. Box S
Freeland, MI 48623

The Catholic Weekly
1520 Court Street
Saginaw, MI 48605

Bay Area Review Publishing
303 S. Hamilton
Saginaw, MI 48602

The Saginaw News
203 S. Washington
Saginaw, MI 48607

Frankenmuth News
231 Hubinger
Frankenmuth, MI 48734

WSAM (1400) & WKCQ-FM
410 Hancock Street
Saginaw, MI 48605

WGER-FM
6165 Bay Road
Saginaw, MI 48604

WJRT-TV
3121 Davenport
Saginaw, MI 48602

REVIEW QUESTIONS – CHAPTER 10: PUBLIC RELATIONS

1. Why should you include public relations as part of any mosquito control work?

- It is the law.
- It is an easy way to receive free advertising.
- It identifies you as a professional and builds customer support for your recommendations.
- It frees you from liability.

2. To explain how products work and accurately answer customers' questions, you need to know the pluses and minuses of the insecticides you use. True or False?

3. A public relations fact sheet is the same as a product label. True or False?

4. List five steps you can take to prepare yourself for good public relations.

GLOSSARY

Adulticide: Method of controlling adult stage of mosquito.

Aesthesia: Sensibility.

Ague: Malarial fever, or any other severe recurrent symptom of malarial origin.

Amplification of SLE Virus: Susceptible wild birds bitten by infected mosquitoes in turn become infected.

Amplifying Host: Infected birds/animals have a one to three day period of when a virus is present in their blood during which noninfected mosquitoes can obtain the virus from the bird or animal's blood.

Anorexia: Loss of appetite for food.

Anterior: At or toward the front.

Anteroventrally: In the front and underneath or on the lower side.

Antibody: Any substance formed in the blood which reacts with a specific antigen, or inactivates or destroys toxin.

Aphasia: Loss of power of expression by speech, writing, or signs, or of comprehending spoken or written language, due to injury or disease of the brain centers.

Apically: Pertaining to or located at the apex.

Arboviral: Pertaining to group of viruses including the causative agents of yellow fever, virus encephalitides, and certain febrile infections such as dengue, which are transmitted to humans by various arthropods including mosquitoes and ticks. Those transmitted by ticks are often considered in a separate category (tick-borne viruses).

Arthropod Vector: A member of the phylum Arthropoda which includes Crustacea, Myriopoda, Insecta, and Arachnoidea, which carries pathogenic organisms.

Aseptic Meningitis: Inflammation of the brain or spinal cord where pathogenic organisms are absent.

Cephalothorax: The body region formed by fusion of head and thorax in Arachnida and Crustacea.

Cerebrospinal Fluid: Fluid of the brain and spinal cord.

Dessication: The act of drying up.

Diapause: A period of biological dormancy. An interval in which development is arrested or greatly slowed.

Distal: Farthest from the center or the point of attachment or origin.

Edema: An accumulation of an excessive amount of fluid in cells, tissues, or serous cavities.

Encephalitis: Inflammation of the brain.

Encephalomyelitis: An acute inflammation of both brain and spinal cord.

Endemic: Present in a human community at all times, but occurring in only small numbers of cases.

Entomology: The study of insects.

Enzootic: Present in an animal community at all times, but occurring in only small numbers of cases.

Epidemiologic: Pertaining to the field of science dealing with the relationships of the various factors which determines the frequencies and distributions of an infectious process, a disease, or physiological state in a human community.

Epizootic: Pertaining to a disease that attacks many animals in any region at the same time.

Equine: Pertaining to horses.

Erythrocytes: Red corpuscle; a mature red blood cell.

Febrile: Relating to fever.

Gravid: An adult female mosquito which has had a blood feeding.

Harborage: Resting and hiding area of adult mosquitoes.

Instar: Any one of the larval stages of an insect between molts.

Larvicide: Method of controlling the larval stage of mosquito.

Malpighian tubules: Thread-like excretory tubes leading into posterior part of the gut of insects.

Meningoencephalitis: Inflammation of the brain and its membranes.

Miasma: A supposed noxious emanation from the soil or earth, alleged to cause disease endemic in certain areas such as malaria before the true cause became known.

Microfilariae: The embryo of Filariae.

Midgut: The mesenteron, or middle portion of the alimentary tract.

"Natural" Transmission Cycle: The transfer of a virus back and forth between vectors. Any organism that receives the virus but cannot transmit it to another organism, is considered to be outside of the "natural" transmission cycle and is a dead end host.

Necropsy: Autopsy, examination of the body after death.

Neurologic Sequelae: A pathologic condition resulting from a disease of the nervous system.

Nuchal: Pertaining to the nape or back of the neck.

Overwintering: Surviving through the winter.

Ovicide: Method of controlling the egg stage of mosquitoes.

Oviposition: The act of laying or depositing eggs.

Parenchyma: The distinguishing or specific cells of a gland or organ, contained in and supported by the connective tissue framework, or stroma.

Passiform: An order of bird which includes perching birds and songbirds such as jays, blackbirds, finches, warblers, and sparrows.

Pathogen: Any disease producing microorganism or material.

Predaceous: Living by seizing or taking prey; predatory.

Prodrome: A symptom indicating the onset of a disease.

Propagation: Reproduction; generation.

Proximal: Situated nearest the center of the body or nearest the point of attachment of a limb, etc.

Pupaecide: Method of controlling pupae stage of mosquito.

Residual: (Singular = residuum) residue or remainder.

Sequelae: (Singular = sequela) morbid condition following or as a consequence of a disease.

Serology: The branch of science dealing with serum, especially with specific immune or lytic serums.

Seropositive: Showing positive results on serological examination.

Sialorrhea: Salivation.

Source Reduction: Method of controlling mosquito breeding by eliminating their habitat.

Subclinical: Without clinical manifestations; said of the early stages, or a slight degree of a disease.

Transmission: The transfer, as of a disease.

Transovarian Transmission: The mechanism whereby virus is transferred directly from an infected female to her offspring through the egg.

Ultra Low Volume (ULV): An adulticiding method in which a premium grade insecticide is applied at an extremely low dosage using micron size droplets.

Vector: A carrier of pathogenic organisms.

Viremia: The presence of viruses in the blood.

Viremic: Having viruses in the blood.

Virus: One of a group of minute infectious agents, with certain exceptions not resolved in the light of microscope, and characterized by a lack of independent metabolism and by the ability to replicate only within living hosts.

Whirl: Anything in a circular or spiral growth pattern around a central body part.

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ANSWERS TO REVIEW QUESTIONS

Chapter 2 - Life Cycles

1. c
2. See page 6
3. T
4. T
5. F
6. e
7. Females. See pages 10-11
8. See page 11

Chapter 3 - Common Characteristics

1. a,b,c,d,e,i,j,k,l
2. T
3. F

Chapter 4 - Diseases

1. SLE - St. Louis Encephalitis, EEE - Eastern Equine Encephalitis, WEE - Western Equine Encephalitis, CE - California Encephalitis
2. "natural" transmission
3. e
4. birds
5. horses
6. T
7. a
8. d
9. no

Chapter 5 - Integrated Management

1. source reduction
2. e
3. larvae
4. general use or restricted use
5. e
6. Ultra Low Volume
7. no
8. label
9. T

Chapter 6 - Equipment

1. larviciding, adulticiding
2. compressed air sprayers
3. Backpack
4. truck-mounted
5. T
6. F
7. a,b,d
8. 12 - 18 microns
9. emulsifiable concentrate
10. F

Chapter 7 - Surveillance

1. b
2. T
3. c
4. T
5. b
6. d
7. dipper
8. T
9. See page 39

Chapter 8 - Management by Homeowners

1. DEET
2. F
3. See page 42
4. T
5. See page 42
6. c

Chapter 9 - Evaluating Insecticides

1. T
2. adulticides, larvicides
3. e
4. dipper
5. a
6. insect growth regulators

Chapter 10 - Public Relations

1. c
2. T
3. F
4. See page 48

NOTES

NOTES



PESTICIDE EMERGENCY INFORMATION

(Please post in an appropriate place)

For any type of emergency involving a pesticide, the following Emergency Information Centers should be contacted immediately for assistance.

Current as of August 1989



HUMAN PESTICIDE POISONING

Eastern Half of Michigan

within the Detroit city proper:

***(313) 745-5711**

within the 313 area code:

***1-800-462-6642**

Poison Control Center

Children's Hospital of Michigan
3901 Beaubien
Detroit, MI 48201

Western Half of Michigan

within the Grand Rapids city proper:

***(616) 774-7854**

Statewide

***1-800-632-2727**

Blodgett Regional Poison Center

Blodgett Memorial Medical Center
1840 Wealthy, S.E.
Grand Rapids, MI 49506

Upper Peninsula of Michigan

within the Marquette city proper:

***(906) 225-3497**

Upper Peninsula only:

***1-800-562-9781**

U.P. Poison Control Center

Marquette General Hospital
420 West Magnetic Street
Marquette, MI 48955



Michigan State University
Cooperative Extension Service
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PESTICIDE EMERGENCY INFORMATION:
Revised by Larry G. Olsen, Pesticide Education
Coordinator, Michigan State University.
Current as of August 1989—destroy previous
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SPECIAL PESTICIDE EMERGENCIES

Animal Poisoning

Your personal veterinarian:

and/or

Animal Health Diagnostic Laboratory, Michigan State
University:
(517) 353-1683

Pesticide Fire

Local fire department:

and

Fire Marshal Division, Michigan State Police:
(517) 322-1924

Traffic Accident

Local police department or sheriff's department:

and

Operations Division, Michigan State Police:
***(517) 337-6102**

Environmental Pollution

Pollution Emergency Alerting System (PEAS)
Michigan Department of Natural Resources:
***1-800-292-4706**
(Toll free for environmental emergencies)

For information on pesticide disposal and local pick-up days:

Michigan Department of Natural Resources
Waste Management Division:
(517) 373-2730

*** Telephone Number Operated 24 Hours**



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