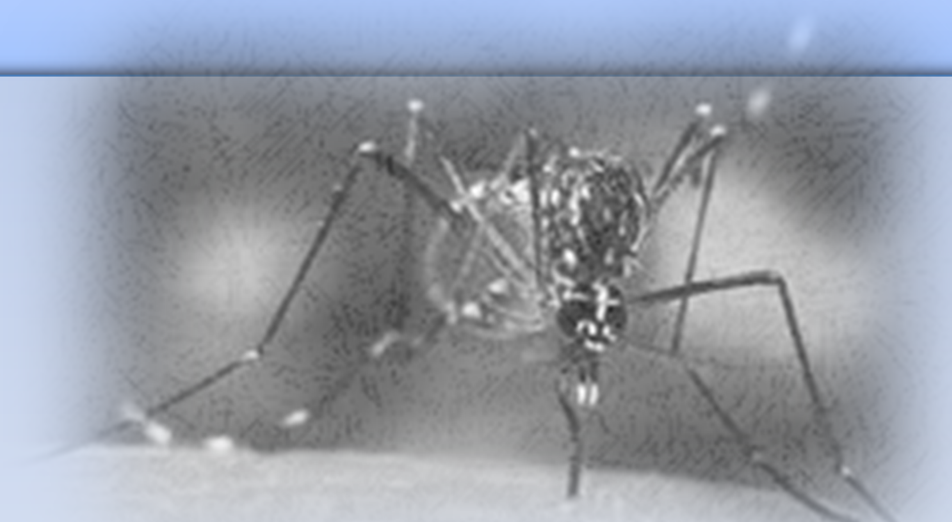
The Biology and Control of Mosquitoes in California



Vector Control Technician Certification Training Manual

Category B

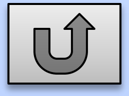
Instructions

This study guide is meant to replace the manual The Biology and Control of Mosquitoes in California.

- You can navigate through the guide at your own pace and in any order.

- Click on the purple home button to return to the main menu.

- Click on the gray return button to go to the chapter menu of the current slide.



- Click on the button if you want to access the glossary. Important terms are highlighted in red and appear in the glossary. The link to the glossary can be found at the beginning of each chapter.

Main Menu

California Code of Regulations §17-30056: Examination Content

The written examination for certification of vector control agency personnel shall consist of questions covering the following areas:

Label and labeling comprehension factors, including:

(A) The general format and terminology of pesticide labels and labeling;

(B) The understanding of instructions, warnings, terms, symbols, and other information commonly appearing on pesticide labels;

(C) Classification of the product, general or restricted; and

(D) Necessity for use consistent with the label.

Safety factors, including:

(A) Pesticide toxicity and hazard to man;

(B) Common exposure routes;

California Code of Regulations §17-30056: Examination Content

(C) Common types and causes of pesticide accidents;

(D) Precautions necessary to guard against injury to applicators and other individuals in or near treated areas, including medical supervision;

(E) Need for and use of protection clothing and equipment;

(F) Symptoms of pesticide poisoning;

(G) First aid and other procedures to be followed in case of a pesticide accident; and

(H) Safe and proper procedures for identification, storage, transport, handling, mixing of pesticides and disposal of pesticides and used pesticide containers, including precautions to prevent access by children.

Environment: The potential environmental consequences of the use and misuse of pesticides as may be influenced by such factors as climate and weather, non-target organisms, and drainage patterns.

California Code of Regulations §17-30056: Examination Content

The written examination for certification of vector control agency personnel shall consist of questions covering the following areas:

Vectors, including:

(A) A knowledge of relevant vectors and their distribution;

(B) Recognition of relevant vectors by distinguishing features of the vector organisms and/or characteristics of damage or other signs;

(C) Vector development and biology (life cycles) relevant to identification and control;

(D) Public health importance of relevant vectors, including a practical knowledge of vector-borne disease transmission, as it relates to and influences control programs; and

(E) Habitats where relevant vectors occur, including a practical knowledge of those environments.

California Code of Regulations §17-30056: Examination Content

Pesticides, including:

(A) Types of pesticides;

(B) Types of formulations;

(C) Characteristics of pesticides and formulations, including compatibility, synergism, persistence, and animal and plant toxicity;

(D) Hazards and residues associated with use, including applicable laws and regulations;

(E) Factors which influence effectiveness or lead to such problems as resistance to pesticides;

(F) Dilution procedures.

Pesticide application equipment and techniques including:

(A) Types of equipment and their uses, advantages, and limitations;

(B) Maintenance of equipment;

(C) Calibration of equipment;

(D) Operating procedures and techniques used to apply various formulations of pesticides;

(E) A knowledge of the most effective equipment and technique of application to use in a given situation;

(F) Relationship of discharge and placement of pesticides to proper use, unnecessary use, and misuse; and

(G) Prevention of drift and pesticide loss into the environment.

California Code of Regulations §17-30056: Examination Content

Non-chemical control methods: A practical knowledge of the importance and use of such methods as sanitation, waste management, drainage, exclusion, trapping, public education, and legal abatement.

Record Keeping: A familiarity with the principles and practices of biological and operational documentation.

Supervisory Requirements: A practical knowledge of State and Federal supervisory requirements, including labeling, regarding the application of restricted materials by a technician's aide.

Laws and Regulations: A basic knowledge of applicable State and Federal laws and regulations.

Introduction

- Arthropods are a huge group of invertebrate animals (*animals without backbones*) that include insects, arachnids (*ticks, mites, and spiders*), crustaceans (*crabs, lobsters, and shrimp*) and others.

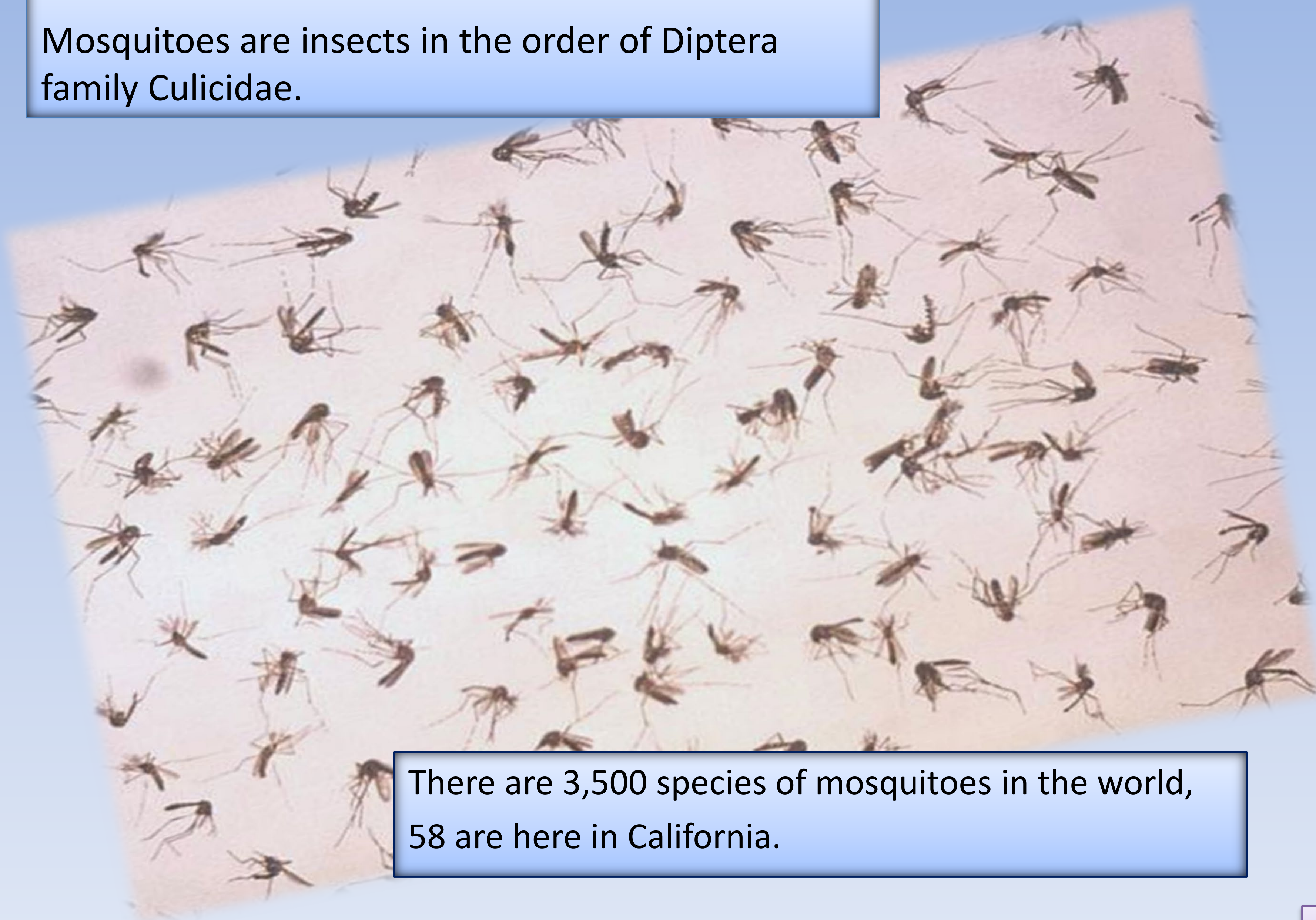
- There are millions of species of arthropods, all sharing characteristics of a hard exoskeleton and jointed legs.

- Many arthropods are pests of one kind or another, especially on agricultural crops and farm animals.

- Some arthropods are direct pests of people, their pets and wildlife.

- The most serious pests from the standpoint of public health are those that transmit pathogens that cause human diseases such as malaria, yellow fever, and West Nile virus.
- Pests that transmit pathogens in this way are called vectors. California Health and Safety Code § 116108 defines vectors as any animal capable of transmitting the causative agent of human disease or capable of producing human discomfort or injury, including, but not limited to, mosquitoes, flies, other insects, ticks, mites, and rats.
- Of all the arthropods, there is no group of more importance as a public health pest than mosquitoes.

Mosquitoes are insects in the order of Diptera family Culicidae.



There are 3,500 species of mosquitoes in the world, 58 are here in California.

- Mosquito pests that transmit organisms that result in infectious diseases in humans and other vertebrate animals are known as **vectors**.

- A vector is defined in the California Health and Safety code as:

  " any animal capable of transmitting the causative agent of human disease or capable of producing human discomfort or injury, including but not limited to, mosquitoes, flies, mites, ticks, other arthropods, and rodents and other vertebrates."

Organized control of mosquitoes began in California more than 100 years ago.
The first organized mosquito control efforts were in the salt marshes of San Rafael in 1904.

In 1910, Malaria in Penryn, Placer County, resulted in a community organization to control anopheline mosquitoes in an area from Newcastle to Loomis.

During the following years a number of tax supported mosquito abatement districts were formed. Many of them are in the Central Valley of California, where mosquitoes are a particularly serious problem.

In 1930, most of these districts joined together to form the California Mosquito Control Association. This association is now called the Mosquito and Vector Control Association of California, and presently (2021), there are 63 corporate members representing mosquito and vector control programs.

Certification to apply public health pesticides in California is based on successful testing in several areas.

Category A: Pesticide Application and Safety Training

plus at least one of the following:

Category B: Mosquito Biology and Control

Category C: Arthropods of Public Health Significance

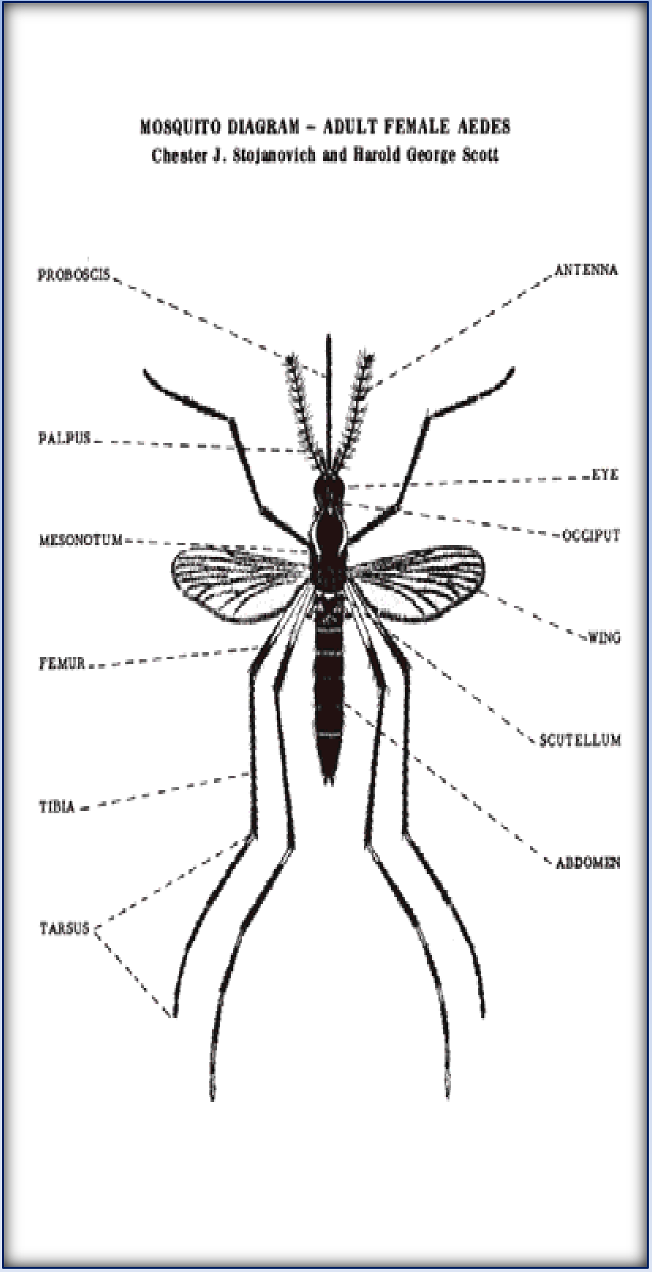
Category D: Vertebrates of Public Health Significance

Note: Technicians can only apply public health pesticides in the categories for which they have earned certification.

Individuals employed by public agencies must be certified by the California Department of Public Health to apply public health pesticides without the supervision of a certified applicator.

Biology of Mosquitoes

Chapter 1



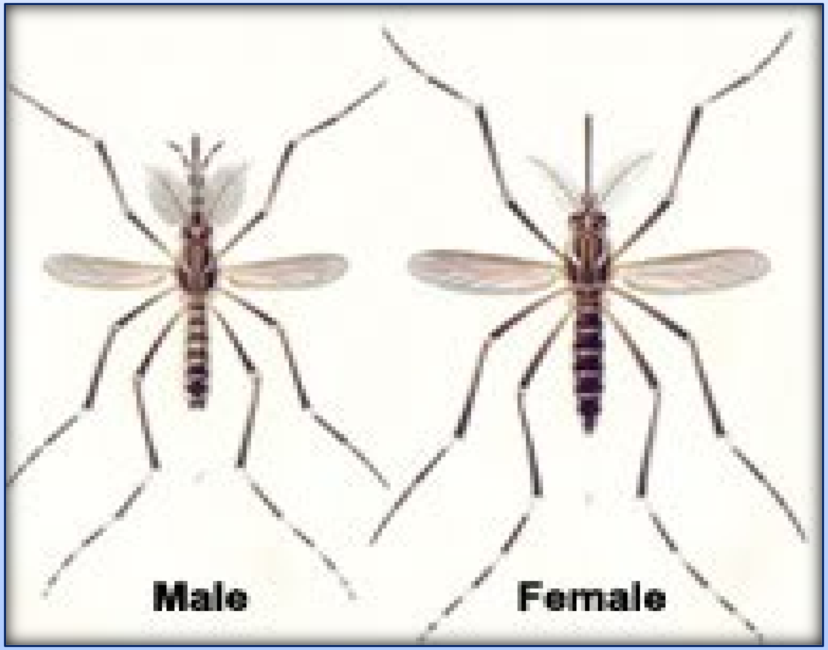
Morphology:

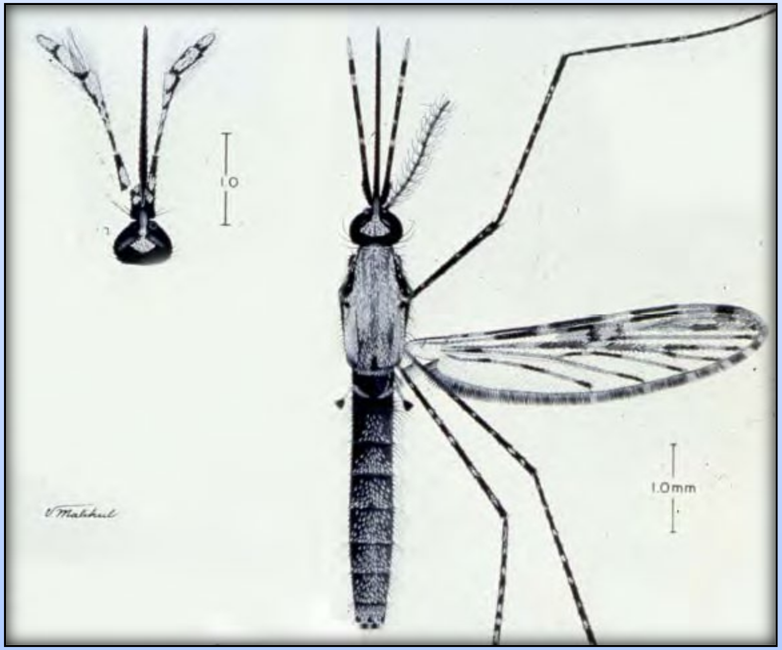
An understanding of morphology of mosquitoes is important to the identification of mosquitoes.

Some morphological characteristics are shared among all species of mosquitoes, while others form the base of groups of mosquitoes species, or individual species.

Adult mosquitoes have three distinct body regions: head, thorax, and abdomen.

Sexual dimorphism: is the term used to describe situations where characteristics differ between males and females. Male and female mosquitoes differ in many ways. These ways make it useful in seeing the differences between them.

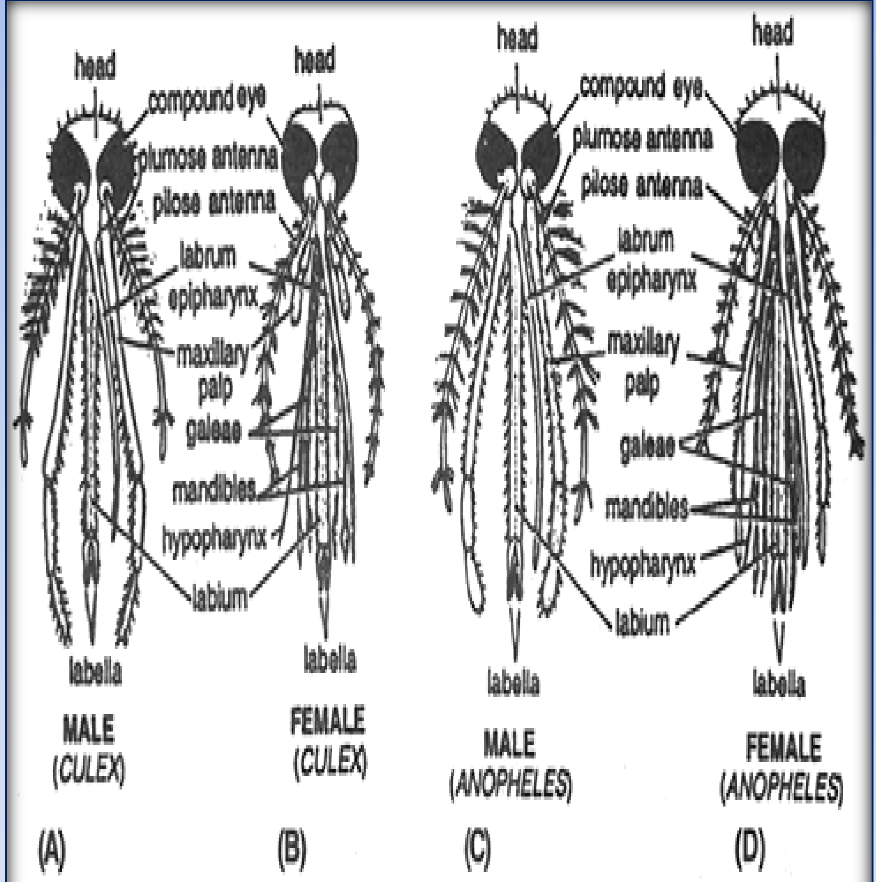




Drawing showing male (L)
and
female (R) heads.

Prominent features of the heads of mosquitoes are the palpi and proboscis.

- Females have short palpi and a long stiletto-like proboscis to penetrate the skin of vertebrate animals to obtain blood.
- Males have long hairy palpi and a long fleshy proboscis for taking nectar and fluids from flowers and fruit.



(A) Male *Culux* (B) Female *Culex* (C) Male *Anopheles* (D) Female *Anopheles*

- The proboscis of both the male and female mosquitoes are made up of a bundle of individual components.
- The female mosquito inserts only some of these structures when feeding, these structures together are called stylets.
- The active piercing parts are the movable toothed maxillary stylets.
- The female inserts these paired structures into the skin, with the teeth on one stylet anchoring itself to the flesh of the blood source while the other penetrates a vein.

The thorax

Supports a pair of wings and a pair of unusual organs called halteres.

- Halteres are adaptations of the second pair of wings. Most insect morphologists believe that the halteres are used for balance.
- The wings of mosquitoes vary greatly among species and are frequently used to identify species.

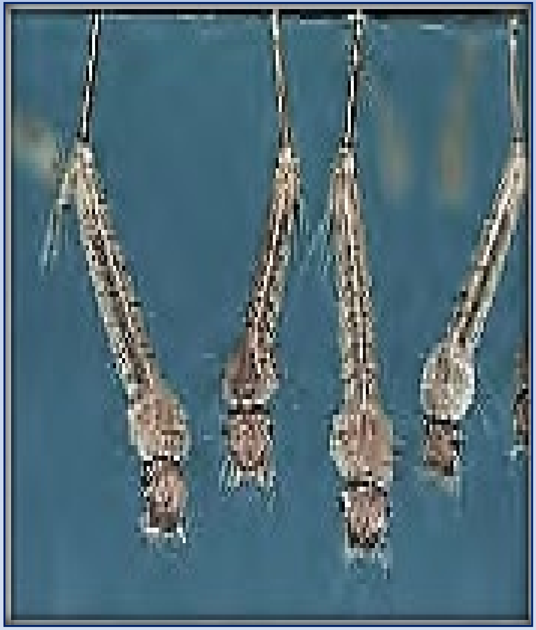
The abdomen

- Is long and tapering, carrying the reproductive organs.
- The male reproductive organs are complex and unique to individual mosquito species.
- In some instances of closely related species there is no other way to distinguish them.
- Closely related species that are very difficult to separate by conventional methods are called sibling species.

Larvae

Mosquito larvae vary a great deal in appearance and morphology from the adults.

Larvae are adapted for a aquatic life, and their feeding and breathing structures show this.



The head of mosquito larvae

- Is adapted for filtering particulate matter from water column for feeding.
- Because of this, the mouth parts are located dorsally (upward) in contrast to adult mosquitoes which have their mouthparts directed ventrally (downward).
- For eyes, larvae have simple light-sensitive structures.
- Another prominent feature of the head of the larvae are the brushes associated with the mouth. These brushes move continually while feeding to create a current to bring food into the mouth.

The thorax of mosquito larvae

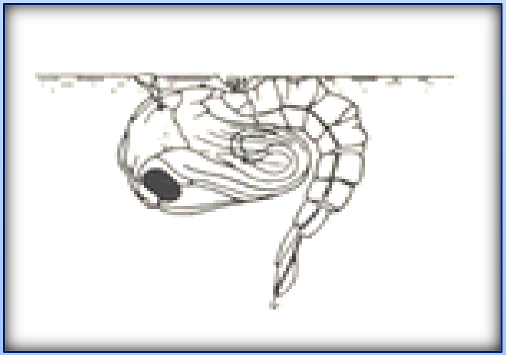
- Is a simple ovoid (egg-shaped) structure
- It is interesting to examine 4th-stage larvae under a microscope using light transmitted from below because the wings and other adult structures have begun to develop in this stage and can be readily seen.

The larval abdomen

- Consists of a number of segments, each bearing setae, some of which appear star-like or leaf-like. There is some disagreement as to the function of these structures.
- The most distinctive feature of culicine larvae (the major group of mosquitoes that includes species in the genera *Culex*, *Aedes*, and others) is the air tube.
- Culicine larvae hang from the surface of the water at an angle, and breathe through the air tube, the tip of which reaches to the water surface.
- Anopheline (mainly the genus *Anopheles*) larvae lack an air tube and hang parallel to the water surface.

Pupae

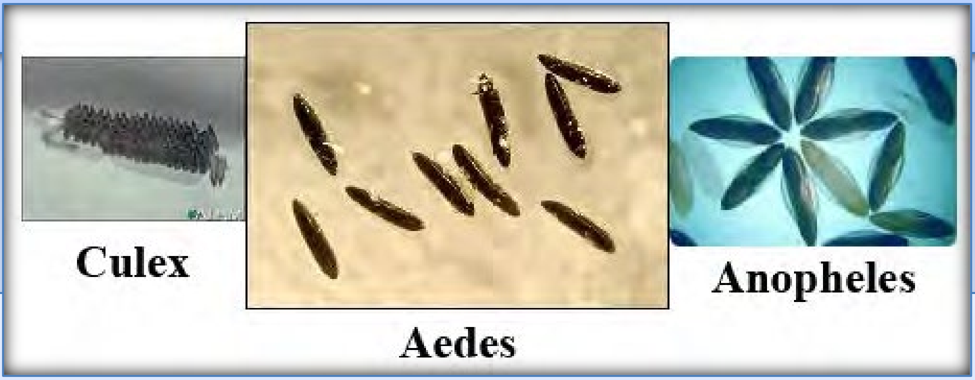
- Mosquito pupae (also called tumblers) do not offer many characters useful for identification.
- Pupae do not have a distinct head and thorax, rather a combination structure called the cephalothorax.
- The pupa has two respiratory trumpets projecting from the cephalothorax, and two large structures called paddles that project from the tip of the abdomen.



Anopheles pupa

Eggs

- Mosquito eggs vary significantly among the major groups of species, and in some cases among the individual species



- Eggs of species in the genera *Culex* and *Culiseta* are long tapered structures that are deposited on the surface of the water. These eggs are deposited a hundred or so at a time and held together by surface tension to form structures called rafts.

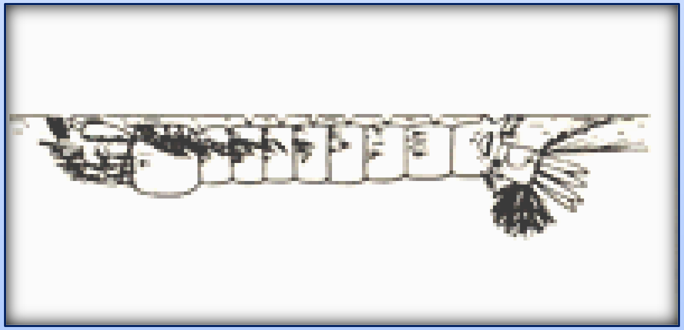
- Eggs of species in the genus *Aedes* and some other genera are deposited individually and appear to be very similar in shape and structure to the naked eye. However, microscopic examination shows very distinctive patters on the chorion (eggshell) that can be used for identification.

- Eggs of anopheline mosquitoes are also deposited individually, but on water surfaces. To keep them afloat, these eggs have structures on their sides called floats.

DIGESTION AND NUTRITION

- Mosquito larvae drink water and most species eat particulate food (diatoms, microcrustaceans, etc.) present in their aquatic habitats.
- These larvae have mandibles adapted for chewing and scraping, and they feed by creating a current of water with the movement of brush-like structures on the mouthparts.
- A few species of mosquitoes (e.g., *Toxorhynchites* spp.) are predaceous on other aquatic arthropods; these larvae have mandibles adapted for tearing and shredding.
- The amount of food available to larvae is one of the factors that determine the time needed to complete larval development.
- If food is limited, larval developmental time is extended.

- The digestive tract changes from that of a larva to an adult during the pupal stage, and so, the pupal does not feed.
- They do maintain water balance during the 1-2 days of the stage, probably by absorption through the pupal integument.



Anopheles larva

Digestion and Nutrition

ADULTS:

- Both male and female adult mosquitoes drink water and feed on sugar sources such as flowers or fruit.
- Most female mosquitoes require vertebrate blood to develop eggs for reproduction, and except under special situations, blood does not contribute to nutrition.
- Both males and females use the proboscis for feeding, but the females of most species have the proboscis further modified for piercing of vertebrate skin and penetration of blood vessels.
- Mosquitoes in the genus *Toxorhynchites* do not feed on vertebrate blood.
- As mentioned above, their larvae are predaceous, and sufficient protein is carried over to adult females for egg development.

  Autogeny is the term used to describe the development of eggs to maturity without a blood meal, and this trait appears in many species under various circumstances.

- Blood taken into the digestive tract goes to a different place than do sugars.
- Blood goes directly to the midgut, sugars go to a structure called the ventral (underside) diverticulum.
- This is accomplished by a series of receptors located at the entrance of the crop.
- These receptors act in the role of traffic officer and control a valve that sends the liquids to their proper destination.
- Some female mosquitoes store reserves to survive hibernation.
- These mosquitoes can convert proteins present in late-season blood meals to fat.
- Such females are very heavy (2-3 times normal body weight) at the beginning of winter, and very light when hibernation is broken in the spring.

EXCRETION AND WATER BALANCE

Mosquitoes face many problems in maintaining water balance.

- Adult mosquitoes drink water through their proboscis to maintain the proper amount of hydration just as other terrestrial animals do.
- However, this task is difficult for larvae. Larvae that live in freshwater habitats tend towards excess water uptake and loss of ions through osmosis.

Osmosis

is the biological mechanism by which water passes through semi-permeable membranes from the side of the membrane having a lower concentration of ions to the side of the membrane having the higher concentration of membranes.

The way to remember this is to realize that the water tends to dilute out areas of high ionic concentration. Freshwater mosquito larvae take in too much water because the ionic balance is greater within their bodies than it is in the water they are living in.

Freshwater larvae adapt to this situation by restricting water uptake, producing dilute urine, and taking up ions through large bladder-like organs called **anal papillae**. That is why anal papillae tend to be much larger in larvae in freshwater than in those in saline habitats.

Larvae in saline habitats have a very different problem. They tend to lose water, especially when salinity is so high that the ionic concentration of the water exceeds that of their bodies, and they tend to have too high an ionic concentration. To compensate for this, larvae in such habitats drink large amounts of water and by selective removal of ions by a set of organs called the **Malpighian tubules** and by the rectum.

The Nervous System

Mosquitoes in all stages have a well developed central nervous system.

- Larvae have a brain and a nerve mass called a **ganglion** in the head, connected to a ventral ladder-like paired and segmented nerve cord that reaches all the way to the end of the abdomen.
- There is a pair of ganglia in each abdominal segment.
- The central nervous system of adult mosquitoes is much the same as the larval system, and it is one of the systems that undergoes little change during the pupal stage.

Sensory Perception

- Adult mosquitoes have well developed compound eyes and apparently well-developed vision.
- They also have a variety of receptors on their antennae that can detect odors and water vapors.
- The antennae of female mosquitoes play an important role in location of hosts for blood meals.
- Adult females also have receptors on the tips of their abdomens that can detect the nature of potential sites for oviposition (egg laying).

Blood feeding

- The mechanism by which blood-seeking female mosquitoes locate potential hosts has been studied for many years, but much remains to be learned.
- One of the best mosquito repellents ever developed, DEET, has been used for more than 50 years, but exactly how it works is still not completely understood.

Blood feeding

The act of blood feeding in mosquitoes is facilitated by the salivary glands, a set of organs in the thorax of the adults. Salivary glands are also important in the transmission of disease pathogens because the pathogens can be injected into the blood stream at the time of feeding.

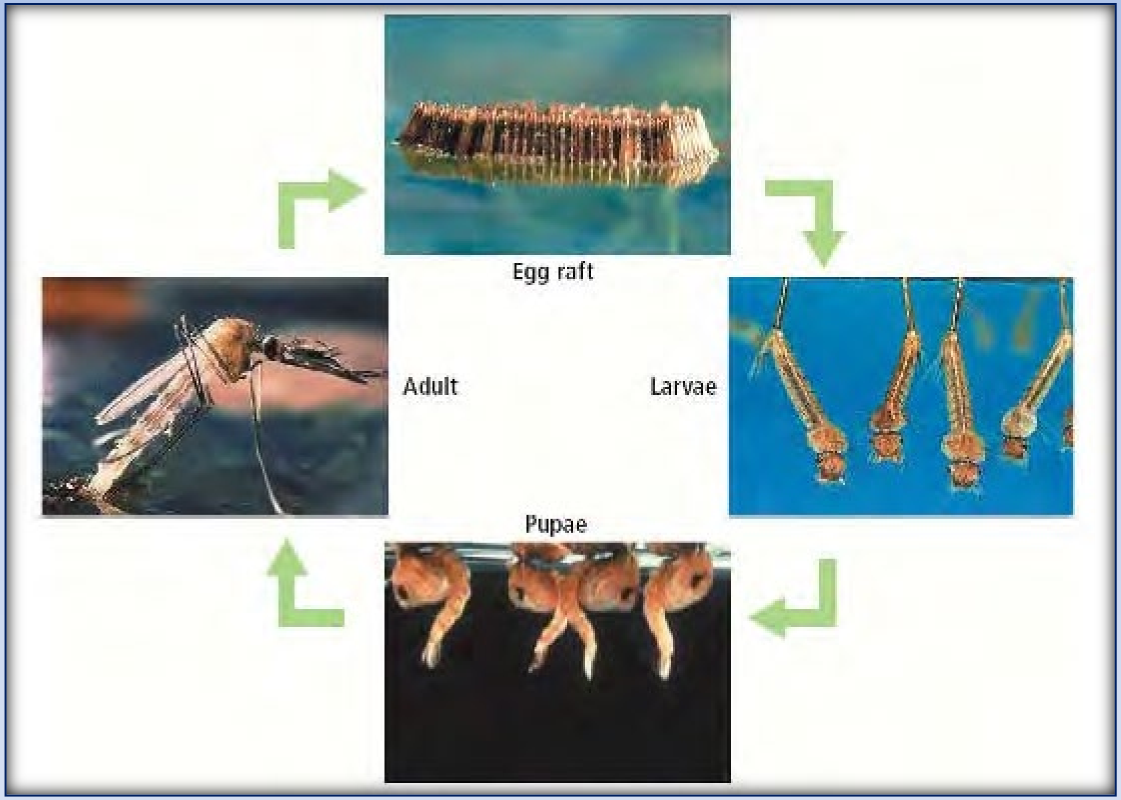
This type of transmission is called salivarian. It is the most common type of transmission and all arboviruses are transmitted in this way, as are malarial parasites.

Reproduction

Mosquitoes utilize sexual reproduction to produce new generations.

- Sperm from male mosquitoes is deposited in structures called spermathecae located at the tip of the abdomen of females.
- Fertilization of eggs takes place at the time of oviposition, not during mating.
- The number of spermathecae varies from 1 to 3. *Culex* females have 3, *Anopheles* have 1.
- A single female usually deposits from 100 to 150 eggs at one time. Over the course of her life she may deposit 3 to 4 batches of eggs.
- Mating between the two sexes nearly always takes place in midair swarms. Once a female is inseminated, her spermathecae will contain sperm for the remainder of her life.

LIFE CYCLE



Egg stage

The egg-laying habits of female mosquitoes vary widely between species.

- Some female mosquitoes lay eggs on water surfaces (e.g. *Anopheles*), others lay single eggs on moist soil (e.g. *Aedes*).
- Eggs laid on water surfaces usually hatch within a day or so, but eggs laid on soil surfaces do not hatch until the surfaces are flooded, which may occur months, or even years later.

Larval stage

- Small larvae are almost invisible to the eye when they hatch from the egg.
- Larvae molt 3 times to a 4th stage, which will molt to become a pupa. Each stage is called an instar (e.g. first instar, second instar, etc.).
- The time needed for this multistage process is dependent on environmental factors.
- Availability of food, water temperature, and even larval density play into this timeline.

Most mosquito species have larvae that are restricted to fresh water. However, larvae of a few species can develop under other conditions, e.g., brackish, salt water or water polluted with organic solids.

Adults

- Adult mosquitoes emerge 1-2 days after the appearance of pupae, with the males emerging first.
- The males need to come out first to allow time for their genitalia to harden and rotate into position for copulation.
- In summer, the entire life cycle, from egg to adult, may be completed in 10 days or less.

Adults

- Females feed on vertebrate blood for egg development.
- From the human standpoint, this female behavior is the single most important characteristic of mosquitoes.

Seasonal development

- Some species of mosquitoes have but a single generation per year (univoltine), there are others that have many (multivoltine), depending on the length of the season favoring the activity of the adult stage.
- To avoid seasons of the year not favorable to adult activity(usually winter), mosquitoes may have some kind of diapause mechanism.

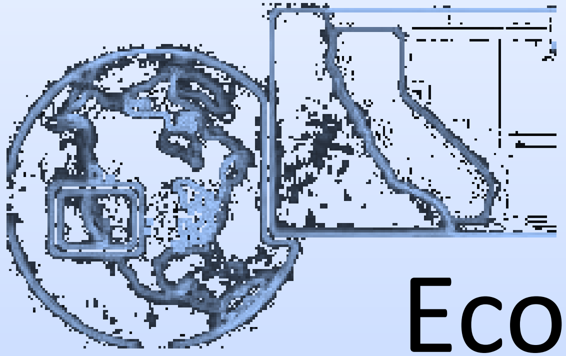
In *Aedes* and related genera, the diapause mechanism usually involves the egg stage. In temperate and subarctic regions *Aedes* populations may survive winters as desiccation-resistant eggs, sometimes under the surface of snow or along river flood plains. The larvae then hatch in the spring after the eggs are flooded from melted snow or after flooding of the riverbanks.

Culex and *Anopheles* females usually survive unfavorable periods while in diapause or as quiescent adults. Male mosquitoes usually do not survive unfavorable periods, so it is necessary for insemination to occur before the onset of diapause.

Some mosquito species larvae survive unfavorable periods in diapause (e.g., species of *Aedes, Anopheles, Culiseta*). Diapause can be variable in some species, depending upon the latitude at which they occur, with diapause occurring in the larval stage at warmer latitudes and in the egg stage at cooler ones.

As with other aspects of reproduction and development, diapause is controlled directly by **neurohormones**. This survival strategy can be induced in most species capable of diapause by exposure to juvenile hormone or one of its analogs.

Many tropical and subtropical species, such as *Aedes aegypti,* the yellow-fever mosquito, do not have a diapause mechanism.



Ecology of Mosquitoes

Chapter 2

Ecology of Mosquitoes

Bioregions

Weather & Climate

Relation to Vegetation

Seasonality (phenology)

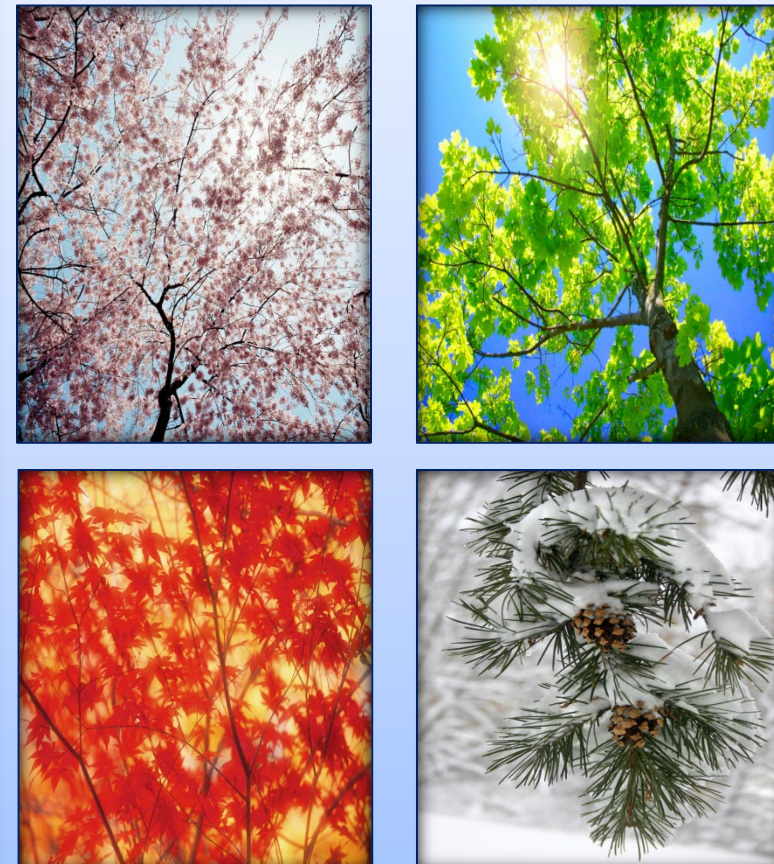
Competition

What is ecology?

- Ecology is a Greek word, literally it means the study of the household.
- The generally accepted definition of ecology as a science is the study of the distribution and abundance of life and the interactions between organisms and their environment.

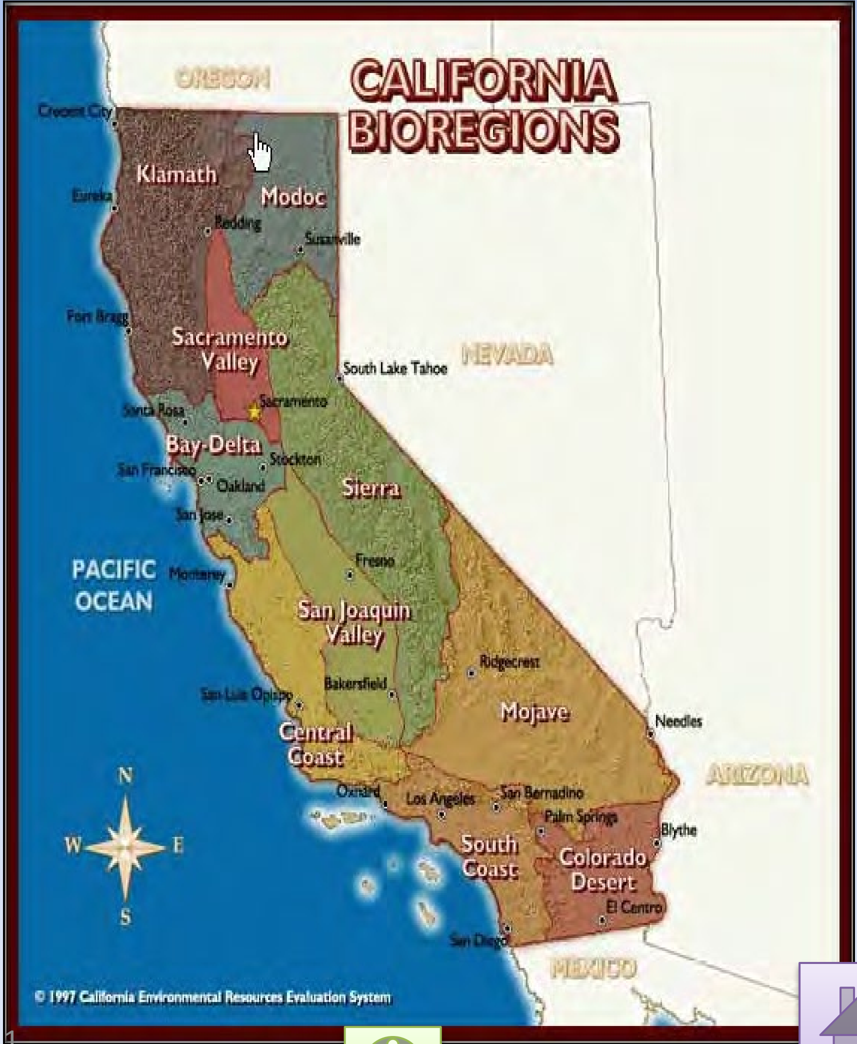
Ecology of Mosquitoes

- The ecology of mosquitoes involves the distribution and abundance of immature and adult mosquito populations of and how these are influenced by geographic distribution, elevation, weather and climate, vegetation and seasons.



Bioregions

- Many different classifications for biological regions of the world have been developed. Most have attempted to explain the flora (*the plant species that inhabit a given region*) based on climatic factors of temperature and precipitation.
- In California a system developed by the Inter-agency Natural Areas Coordinating Committee (INACC) recognizes 10 major zones. Klamath, Modoc, Sacramento Valley, Bay-Delta, Sierra, San Joaquin Valley, Central Coast, Mojave, South Coast, and Colorado Desert.
- Each of these bioregions has a characteristic mosquito fauna and the zones provide a convenient backdrop for studies on the factors that influence the geographic distribution of mosquito species and populations.



Weather & Climate

- It is difficult to distinguish between weather and climate.
- Generally, weather is used to describe short-term conditions that are present within a specified area, while climate is used to describe the long-term conditions of a specified area.

Relation to Vegetation

- Mosquitoes have particular relationships to vegetation within most of their life cycle stages.
- Larvae are hardly ever found in water that is lacking in vegetation in or around the water
- Some species of adult mosquitoes use vegetation in various forms for resting or oviposition sites.
- For example, *Aedes sierrensis*, the California treehole mosquito, lays eggs in the late summer and fall, when treeholes are dry. When winter rains flood the holes, the larvae emerge.

Relation to vegetation

Blossoms of a *Heliconia* plant, Darien Province, Panama

Collecting mosquito larvae from an aerial bromeliad, an example of phytotelmata.

- Water that is held by living plants is called phytotelmata. Treeholes are an example of this in California. In warmer parts of the world, especially in the wet tropics many species are associated with plants in this way.
- One such species is the *Aedes albopictus* that is now found in southern California.

Seasonality (phenology)

- Nearly all species of mosquitoes have patterns of seasonality. These patterns of vary somewhat depending upon geographic region.

- Some species produce only a single population in a year. These species are called **univoltine**. Some species, like *Aedes tahoenis*, have larvae that develop in the melted snow, so they have a life cycle that are not capable of additional generations. This phenological pattern is termed **obligatory univoltine**.

- Other species, especially those having very large geographic areas, may have many generations in warmer parts of their range (**multivoltine**), but have only a single generation in colder regions.

- However, if weather conditions are unseasonably warm, a second generation may result. This pattern would be called **facultative univoltine**.

- In southern California, many species are active almost all through the year, going into short periods of hibernation only during the coldest winter months.

Seasonality

Diapause is a term used to describe the suspension of particular physiological activities in mosquitoes in connection with hibernation (a period of inactivity during winter) or aestivation (inactivity during summer).

Aedes species often have eggs in a diapause state as a winter survival means. Some species also produce eggs that respond to day-lengths.

Many *Culex* and *Culiseta* mosquitoes diapause as inseminated females.

Hibernation exacts a heavy price on female mosquitoes, and many females that enter hibernation in the fall die from starvation or predation. Only a small proportion remains in the spring to begin a new year's generation of mosquitoes.

Competition

- When populations of two different mosquito species occupy the same habitat in the same area, one of the populations often dominates the other, sometimes to the total exclusion of the other. This is an example of competition between the two populations.

- One well known example of this kind of competition is that shown in Florida after the invasion of the USA by the Asian tiger mosquito, *Aedes albopictus*. In this case the tiger mosquito was in direct competition with the yellow fever mosquito, *Aedes aegypti*. As a result of this competition, over the next few years following the invasion of the Asian tiger mosquito, populations of the yellow fever mosquito disappeared from northern Florida.

- This particular situation is an example of **competitive displacement**. Competition between populations of different mosquito species is an important determinant of the geographic distribution of many mosquito species

Public Health Importance of Mosquitoes

Chapter 3

Non-infectious disease

Infectious diseases

Types of Transmission

Types of infections

Mosquito-borne

Diseases of California

Arboviruses

What is Disease?

The definition of a disease is any departure from good health. By this definition, a broken leg, a vitamin deficiency, an allergic reaction, and an infection are all diseases.

NON-INFECTIOUS DISEASES

Some people regard only the diseases caused by pathogenic microorganisms (infectious diseases) to be important when assessing the public health importance of mosquitoes, but this is a short-sighted viewpoint. There are other diseases caused by mosquitoes that are not infectious:

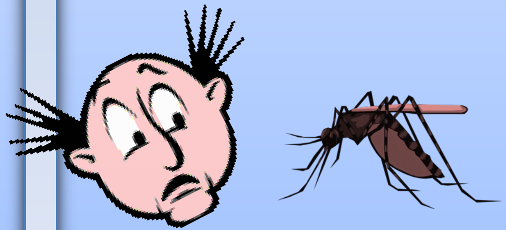
Non-infectious disease

1. Hypersensitivity. Some people and animals become hypersensitive to mosquito bites as a result of repeated exposure to their bites. This can also occur in people that work in mosquito control or mosquito research through constant dermal or respiratory contact with mosquitoes, or even with just their wing scales. Hypersensitive reactions are allergic reactions, and the consequences of these reactions vary from mild to extremely serious.

2. Secondary infections. Secondary infections occur when microbial organisms present on the skin of an individual enter the wound created by a mosquito bite. This often occurs as a result of scratching the bite. Although this is an example of an infectious disease, its connection with the mosquito is secondary.

3. Extreme discomfort. Some people react more strongly to mosquito bites than others. In these people, welts, swelling, and severe itching can result. This is probably a type of allergic reaction, but not necessarily a hyperallergic reaction.

4. Entomophobia. This is an emotional or psychological reaction and is manifested by extreme fear of insects. Attacks by mosquitoes can trigger this reaction in some people.



Infectious diseases

As discussed earlier, female mosquitoes of nearly all species require blood from vertebrate animals to develop their eggs, and many species bite people, their pets, and livestock for this purpose. The most important result of this behavior is the transmission of microorganisms that cause diseases such as malaria, filariasis, yellow fever, and dengue. These and other mosquito-borne diseases can have serious and sometimes fatal consequences for people.

Infectious diseases

There are many other mosquito-borne diseases, several of them caused by viruses. Some of these, such as Japanese encephalitis, La Crosse encephalitis, West Nile fever, Ross River disease, and Rift Valley fever, affect large numbers of people.

Types of Transmission

- The interactions between mosquito hosts and the pathogens they transmit are highly variable.

- Three basic types of transmission mechanisms are involved

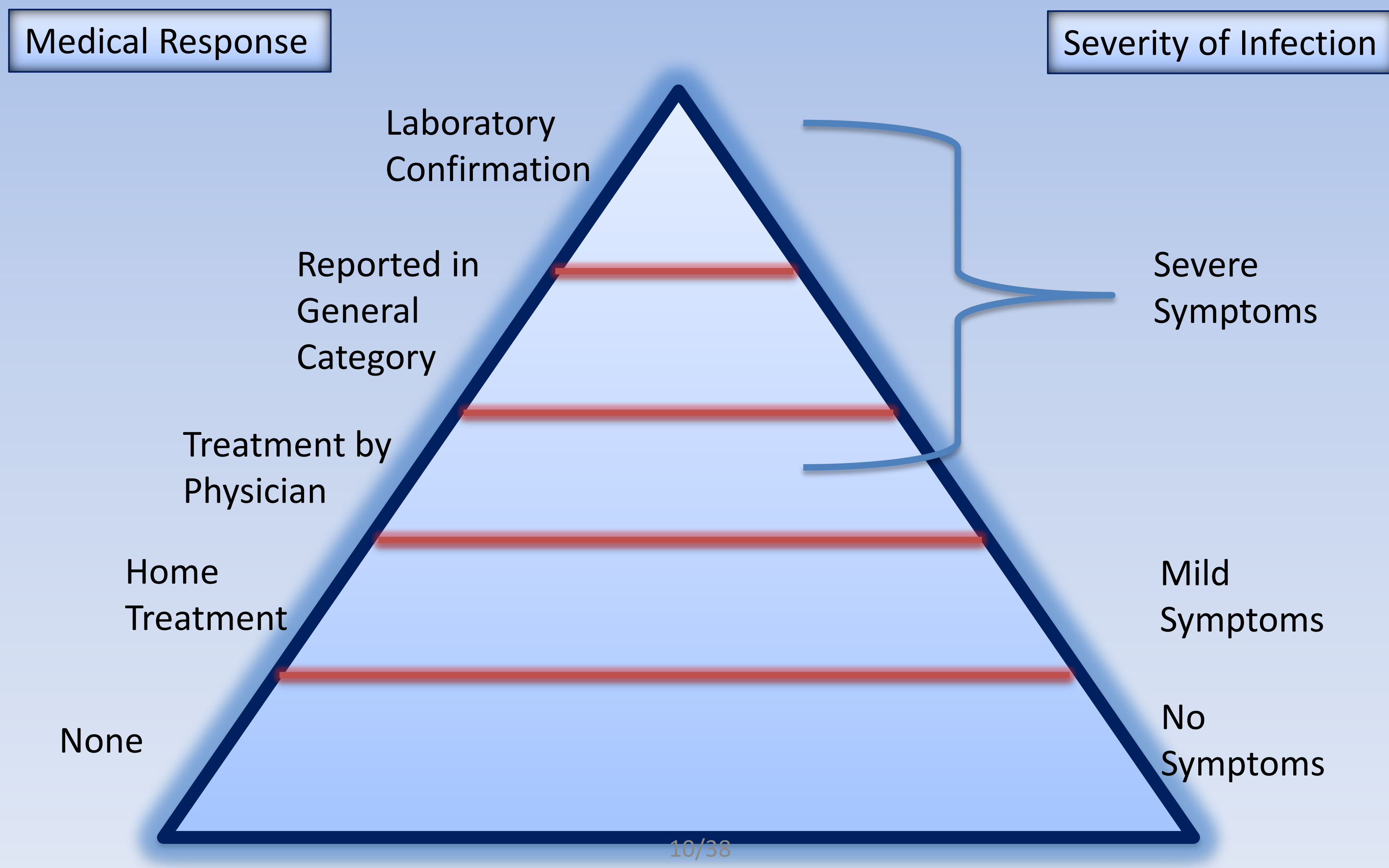
1. propagative transmission, in which the pathogen multiplies within the mosquito but does not undergo any changes in developmental form
2. developmental transmission, in which the pathogen undergoes developmental changes, but does not multiply
3. propagative - developmental transmission, in which the pathogen multiplies and undergoes changes in developmental forms

- Transmission of arboviruses is an example of propagative transmission. The virus is taken up by a female mosquito from a viremic host during blood feeding, multiplies many times, and eventually infects the salivary glands of the host. When the female mosquito takes another blood meal, she may infect a new host by the injection of saliva.

Types of Transmission

- Malarial parasites are transmitted by mosquitoes by propagative-developmental transmission. The life cycle of the malaria parasite is very complex.
- The only example of developmental transmission by insects is that of filarial worms. In California, the dog heartworm is transmitted in this way.
- Transovarial transmission occurs when a female mosquito transmits a pathogen to her eggs prior to oviposition.

Pyramid of Infection



Types of infections

- All diseases have a characteristic that is called the inapparent to apparent disease ratio.
- This characteristic is estimated by epidemiology studies, and is affected by things like the degree of immunity in a human population.
- Most arboviruses that result in human diseases have a very low ratio, usually from 1:100 to 1:1,000. This means that for every person infected with a pathogen only 1 in 100 or 1 in 1,000 developed disease symptoms, respectively.

Mosquito-borne Diseases of California

The most important mosquito-borne disease pathogens in California, the diseases that result from infections, and the primary vectors.

Pathogen	Disease	Vectors
California encephalitis virus	California encephalitis	*Aedes melanimon* (?)
St. Louis encephalitis virus	St. Louis encephalitis	*Culex tarsalis, Cx. quinquefasciatus*
Western equine encephalomyelitis virus	Western equine encephalomyelitis	*Culex tarsalis*
West Nile virus	West Nile fever, West Nile neuroinvasive disease	*Culex tarsalis, Cx. pipiens,* *Cx. quinquefasciatus*
Plasmodium vivax, *P. falciparum*	Malaria	*Anopheles freeborni, An. punctipennis*
Dirofilaria immitis	Dog heartworm	*Culex* spp., *Aedes* spp.

Arboviruses

- In California, the most important infectious diseases associated with mosquitoes are those resulting from infection by arboviruses.
- Arbovirus is the term applied to viruses that are associated with arthropods.
- Worldwide, the most important arbovirus vector is the mosquito.
- The tick is the second most important vector.

Arboviruses

- Dozens of arboviruses have been isolated from samples of mosquito adults and larvae. Although all the viruses detected in California have names (e.g., Jamestown Canyon virus, Northway virus, Buttonwillow virus, etc.), only a few are known to cause diseases in humans or other animals of economic value.

- The most frequently contracted diseases associated with mosquitoes in California are West Nile fever, St. Louis encephalitis, and western equine encephalomyelitis.

- Mosquito-borne arbovirus transmission cycles all follow a characteristic pattern.
- Mosquitoes become infected when they feed on infected vertebrates (usually birds in the case of California arboviruses). For this to happen, the vertebrates must be circulating the arbovirus in their blood streams. This is called a viremia, which may last for several days.

- In the case of West Nile virus, some birds develop a viremia, others do not.
- Some bird species develop a fatal infection, others do not.
- If the viremia is high enough at the time the female mosquito takes a blood meal, and if the mosquito is a competent vector, a generalized infection occurs, and virus eventually infects the salivary glands of the mosquito.

Vertebrates become infected when a blood-feeding mosquito injects viral particles from the salivary glands. Most arboviruses are neuroinvasive, which means that the viruses may infect the nervous system of the host, causing diseases such as encephalitis.

Two blood meals are usually required for a mosquito to successfully transmit an arbovirus: one to become infected, and a second to transmit the arbovirus to a susceptible vertebrate.

Some mosquitoes have been shown to take more than a single blood meal during a single gonotrophic cycle, but this is uncommon. Nevertheless, it is possible for certain species of mosquito to transmit certain viruses after only one blood meal. These mosquitoes can transmit their infections from infected females to their offspring, and the next generation of female mosquitoes is infected when they emerge. This is known as transovarial transmission (TOT).

- Most infections of arboviruses result from the bite of an infected arthropod, but there are other less common routes of infection.
- As with nearly all blood-borne infections, blood transfusions, organ transplants, and the transfer of pathogens from mother to fetus may result in infections.
- Arboviruses can’t be spread through casual contact such as touching or kissing a person with the virus, or by breathing in the virus.
- The incubation period of most human arbovirus diseases (the period between the time a person is bitten by an infected mosquito until that person develops disease symptoms) ranges from 3–14 days.

California Encephalitis

- There have been only four confirmed cases of California encephalitis in California. Three cases occurred in the Central Valley in the 1940’s with a fourth case diagnosed in a resident of Marin county in 1998.
- Although there have only been a few cases associated with this virus, it has been isolated from mosquitoes many times throughout the Central Valley, mainly from the *Aedes melanimon.*

Western Equine Encephalomyelitis

- Western equine encephalomyelitis occurs over much of the Western hemisphere. It was first recognized in the 1930s as a human and equine mosquito-borne disease.
- Mainly in the Central Valley of California, thousands of people and horses have died from severe infections due to WEE virus.
- As with many arbovirus infections, only a fraction of infected people will suffer from severe disease. Responses to the infection range from headache, to meningitis, to encephalitis.
- Recovery with life-long immunity is the usual course, but infections in young children can result in neurologic sequelae (long-lasting nervous system afflictions such as palsy after recovery.)
- In California, as in most of western North America, the primary vector of WEE is *Culex tarsalis*.

Western Equine Encephalomyelitis

- In spring, birds are the primary vertebrate hosts. Small mammals may be involved in some areas, with *Aedes melanimon* and *Aedes dorsalis* serving as vectors.
- In recent years, human cases of WEE have become relatively rare. Horse case numbers are also down from historic levels. This change is due to the efforts of abatement districts and the development of an effective vaccine for horses.

St. Louis Encephalitis

- Before the introduction of West Nile virus into California in 2003, St. Louis encephalitis virus (SLE) was the leading cause of arbovirus infections in the state. Since its discovery in the U.S. in 1933, SLE has been responsible for several large disease outbreaks.
- In 2019, there were six cases of SLE: Fresno Co. (2), Imperial Co. (2), Kern Co. (1), Stanislaus Co. (1).

St. Louis Encephalitis

- The virus that causes SLE can be found in horses, but it does not make them sick.
- The transmission cycle for SLE is similar to that of WEE, with birds as the main vertebrate host.
- *Culex tarsalis* is the primary mosquito vector, while *Culex quinquefaciatus* may be an important urban vector.

West Nile virus

- West Nile virus (WNV or WN) was first isolated in Uganda 1937.
- West Nile was first detected in North America in 1998. It is unknown how the virus was introduced.
- In humans, WNV infection usually produces either no discernable illness or mild to moderate flu-like disease with fever, sometimes with a rash. However it can cause severe and even fatal disease affecting the brain and spinal cord (West Nile neuroinvasive disease) in a small number of people.
- In the USA, 7% of all seriously ill patients have died, as have 10% with neuroinvasive disease.
- People who are infected with WNV and have flu-like symptoms are said to have West Nile Fever.

West Nile virus

- Unlike WNV within its original geographic range, mortality in a wide variety of bird species has been a hallmark of WNV activity in the U.S. Public health officials have been able to use bird mortality, particularly in the family Corvidae (crows, ravens, magpies, and jays) to track the movement of WNV.
- As of 2005, WNV has been shown to affect almost 300 species of birds, but most birds survive WNV infection.
- WNV is transmitted mainly by several species of *Culex*, the usual vectors of SLE. However, sixteen California species of mosquitoes have been shown to be infected with WNV in nature. Not all these species are important vectors.
- At least 27 species of mammals have been shown to be susceptible to WNV infection and disease has been reported in 20 of these.
- West Nile virus primarily infects birds. Humans and horses can also become infected with WNV by the bite of an infected mosquito.

West Nile virus

- Mosquitoes can become infected with WNV either through transovarial transmission or when they feed on birds previously infected with WNV.
- Circulating virus in the blood is called a viremia.
- Hosts, such as humans and horses, that do not develop a viremia cannot pass along the virus on to uninfected mosquitoes and are thus called dead-end hosts.
- Transmission during pregnancy from mother to baby or transmission to an infant via breastfeeding is extremely rare.

Yellow fever

- Yellow fever, a viral disease, has virtually disappeared from the USA because of the availability of an extremely effective vaccine. This vaccine may provide lifelong protection from just a single dose.
- Unfortunately, the availability of the vaccine is limited on a worldwide basis and many unvaccinated people live in areas where the mosquito vector, *Aedes aegypti,* is common.
- Yellow fever is an extremely serious disease. There is no treatment, and in humans, is commonly fatal.
- Periodic epidemics continue to occur in tropical and subtropical countries. *Aedes aegypti* is common in urban and suburban areas. The larvae of this species occur in many kinds of water-filled artificial containers such as shallow wells, water urns, discarded containers, and tires.

Treatment for mosquito-borne arboviruses in California

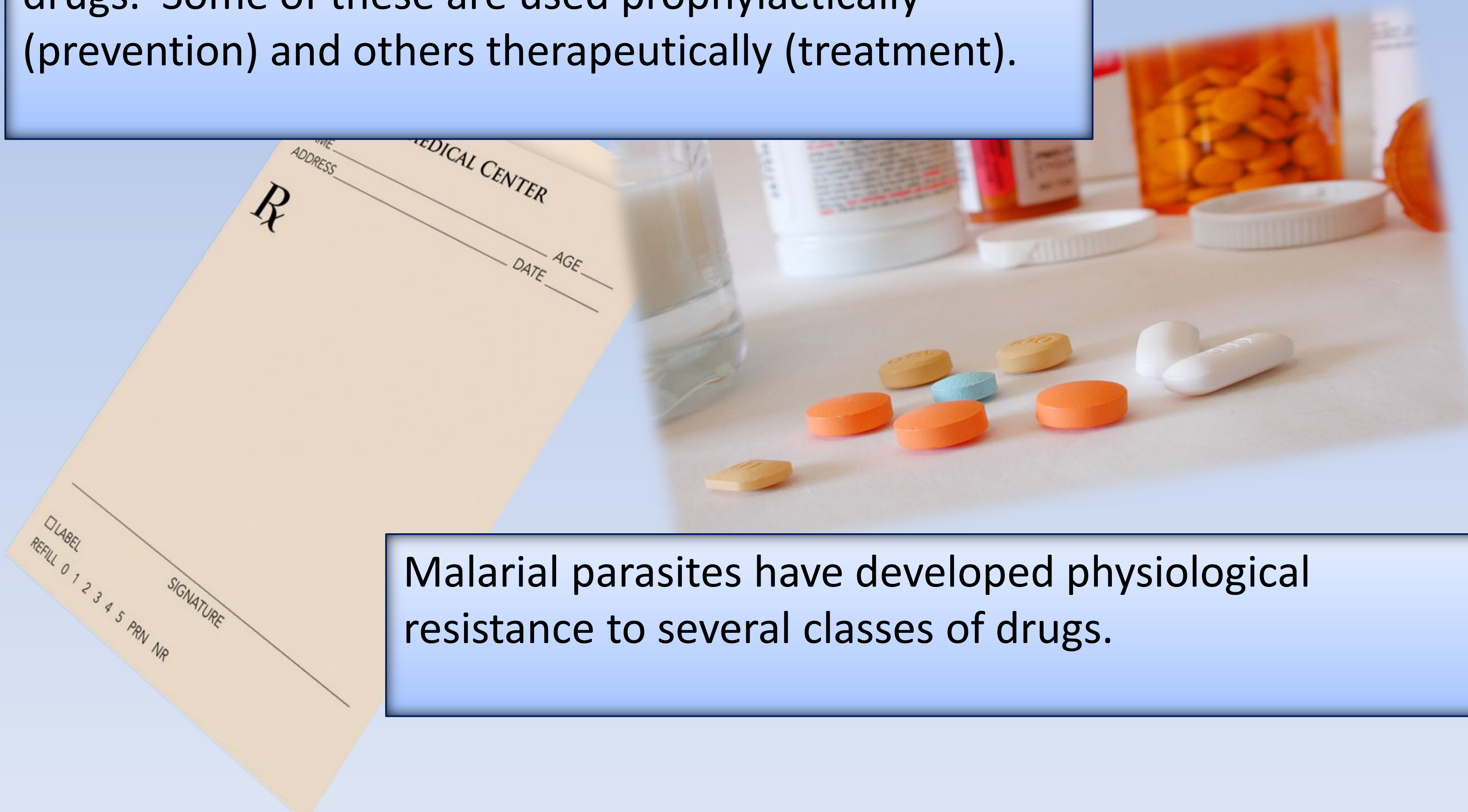
- Arboviruses: There are no specific treatment for human disease caused by an arbovirus infection. In severe cases, intensive supportive therapy is indicated, often involving hospitalization and intravenous fluids, airway management, respiratory support, prevention of secondary infections and good nursing care.
- Horses can be protected from infection by WEE and WNV by effective vaccines.

Malaria

- Globally, malaria is the most important mosquito-borne disease, affecting several hundred million people. In 2018, an estimated 405,000 people died of malaria, the majority were children in sub-Saharan Africa.
- *Anopheles* mosquitoes are the vectors of human malaria. Protozoa in the genus *Plasmodium* are the causative agents.
- The economic development of a number of tropical countries is hindered by malaria because of the burden of chronic infections in working-age men and women.
- Before World War II, malaria was an important disease in California. But because of a variety of factors including intense mosquito control efforts directed at the mosquito species that transmit the malarial parasite, locally-transmitted malaria is now rare in California.
- 103 malaria cases were reported in California in 2013, 100 of which were imported malaria (cases of malaria contracted outside of California from travelers that have come down with the disease after they returned). Exposure for three case patients could not be identified.

Malaria Treatment

Malaria can be treated with any of several effective drugs. Some of these are used prophylactically (prevention) and others therapeutically (treatment).

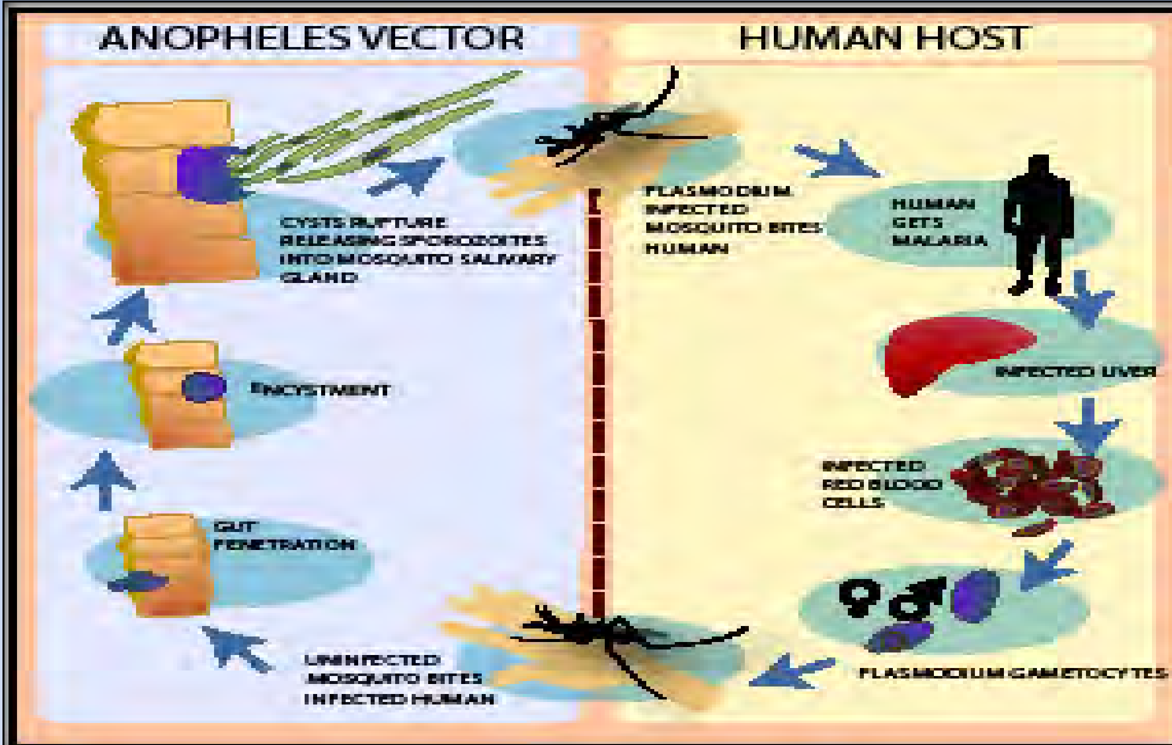


Malarial parasites have developed physiological resistance to several classes of drugs.

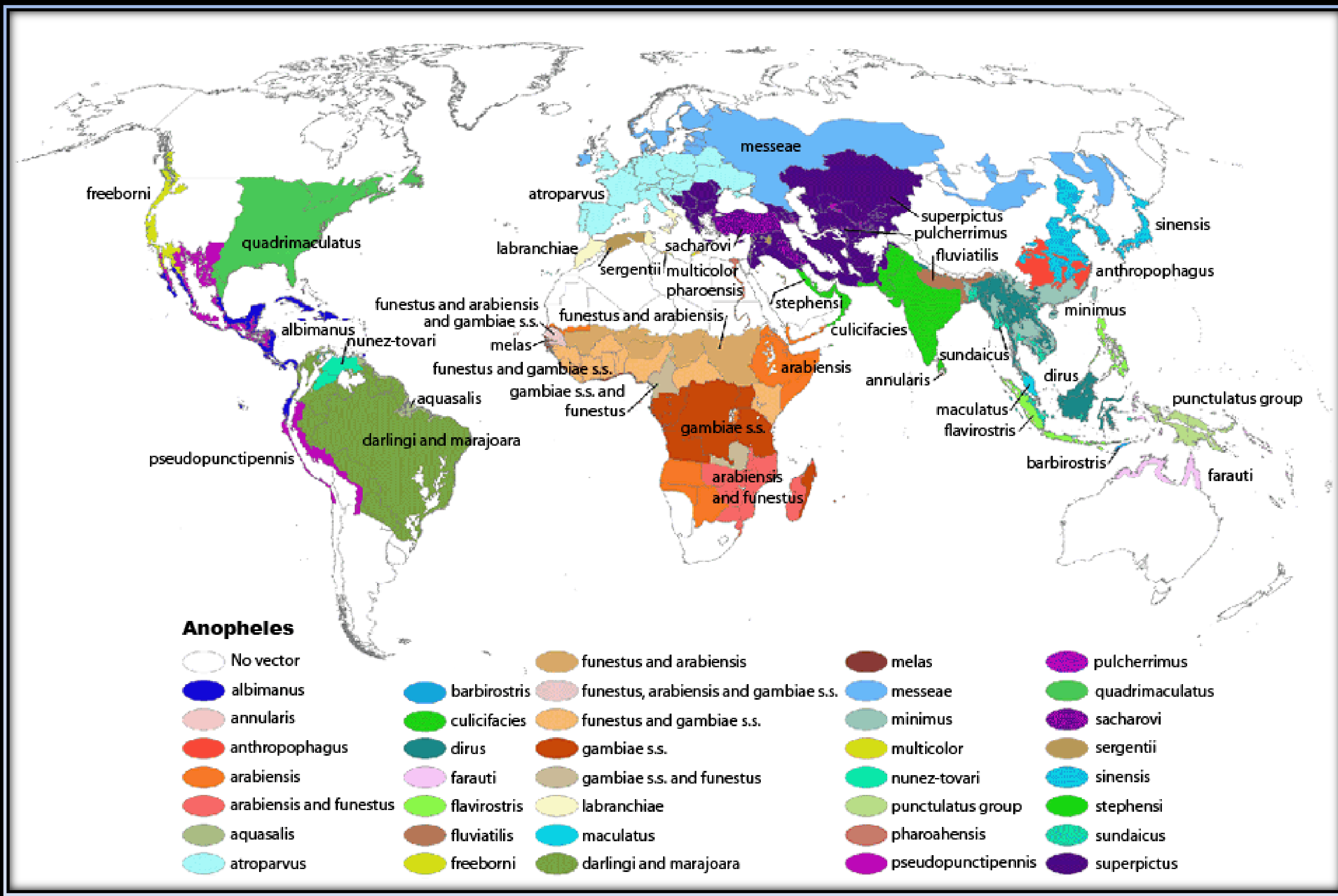
Malaria

Malaria parasites have a very complex life cycle, involving both multiplication of parasites and development of life-cycle stages. Anopheline mosquitoes are the vectors of human malaria, and because the sexual stages and fertilization occur within the mosquito, by definition they are the definitive hosts.

Parasite forms called microgametocytes (male sex cells) and macrogametocytes (female sex cells) occur in the peripheral blood of humans and are taken up by mosquitoes.



Fertilization of the female cells occurs within the gut of the vector mosquito. After several life cycle changes, and multiplication of forms within cysts on the gut wall, forms of the parasite called sporozoites enter the salivary glands of the mosquito and infect new hosts during blood feeding.



Global Distribution (Robinson Projection) of Dominant or Potentially Important Malaria Vectors

Dog heartworm

- Filariasis, is a general term applied to infection of vertebrate animals by many different species of parasitic worms belonging to the super family Filaroidea.
- A form of mosquito-borne filariasis is called lymphatic filariasis because infection can cause impairment of the lymphatic system.
- Lymphatic filariasis is a chronic disease that can lead to the well-known disfigurement of humans call elephantiasis.
- Heartworm (*Dirofilaria immitis*) occurs in dogs and other canids (e.g., wolves and coyotes) and felids (e.g., domestic cats).
- Heavy infection can result in large build up of worms in the cardiopulmonary system and can be fatal.

Dog heartworm

- Parasitic adult worms can live for many years in the pulmonary artery of vertebrate hosts. These infestations may result in serious disease for the host; infected dogs may die.
- Worms, called microfilariae, occur in the blood of infected vertebrate hosts and are taken up by female mosquitoes in a blood meal.
- Within the mosquito, the filariae molt several times until they eventually become infectious larvae. When the mosquito feeds, the filariae migrate from the mosquito's salivary glands to enter the host's body. Within the vertebrate host, these larvae may eventually develop into adult male and female worms that mate and produce microfilariae.
- *Aedes sierrensis* is the vector for *Dirofilaria immitis*.

Zika Virus

- First isolated in 1947 from the Zika Forest, Uganda.
- Vectored by *Aedes aegypti* and *Ae. albopictus*.
- Effects include microcephaly and other birth defects in infants, and Guillain–Barré syndrome in adults.
- There have been imported/travel-associated cases of Zika, but as of September 2021, there have been zero cases of local transmission in California.

Dengue fever

- Dengue, caused by five serotypes of the dengue virus, is a rapidly expanding world problem and now is considered second in importance only to malaria among mosquito-borne diseases.
- The increase in global human travel resulting from expanded air transportation has been paralleled by the increase in the number of viral strains causing dengue and the increase in the number of cases of a particularly serious form of the disease called dengue hemorrhagic fever.
- This form of the disease is most serious in children and is a significant cause of mortality.

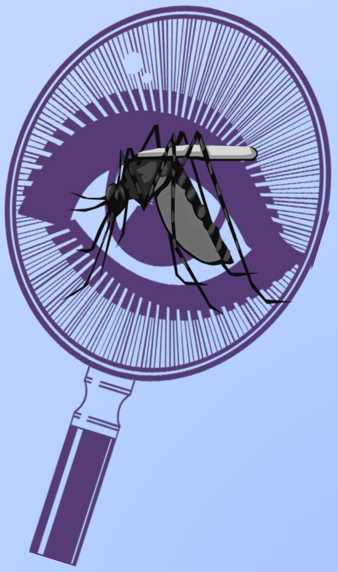
Dengue fever

- Infection by one serotype gives an individual life-long immunity to that serotype but only short immunity to other serotypes.
- Complications can include dengue hemorrhagic fever.
- Vectored by *Aedes aegypti* and *Ae. albopictus*.
- There have been imported/travel-associated cases of dengue fever, but as of September 2021, there have been zero cases of local transmission in California.

Chikungunya

- Infection caused by the Chikungunya virus.
- Symptoms may include headache, muscle pain, joint swelling, and a rash. Low mortality but joint pain can last for months.
- Vectored by *Aedes aegypti* and *Ae. albopictus*.
- In 2014, local transmission occurred in Florida. As of September 2021, there have been imported/travel-associated cases in California, but zero cases of local transmission.

Classification and Identification of Mosquitoes



Chapter 4

How animals and plants are classified

What are mosquitoes

Classification of mosquitoes

Important California species of mosquitoes

How animals and plants are classified

Animals and plants are classified using a system now called the Linnaean system of taxonomy. This system was devised by the Swedish botanist Carolus Linnaeus (aka Carl von Linne) and accepted generally by scientists from the date of Linnaeus's 10th edition of his book *Systema Naturae* published in 1758.

In this system, each recognizable form of living organism is named (or described, in taxonomic jargon) as a **species**. Closely related species are grouped into a **genus**, related genera into a **family**, families into an **order**, orders into a class, classes into a **phylum**, and finally phyla into **kingdoms.** For many years, only two kingdoms were recognized: Animalia, for animals, and Plantae, for plants. In recent years, more kingdoms have been created to accommodate things like **viruses** and fungi.

Using this system, human beings would be classified as follows:

- Kingdom: Animalia
- Phylum: Chordata
- Subphylum: Vertebrata
- Class: Mammalia
- Order: Primata
- Family: Hominidae
- Genus: *Homo*
- Species: *Homo sapiens*

Sharp-eyed readers will want to know why the species name uses the name of the genus in addition to the name of the species. This is because of another convention that goes back to the time of Linnaeus called the system of **binomial nomenclature**. This convention dictates that plants and animals are given a name consisting of two words: a genus and a species. This two-word name is known as the **scientific name** of the organism. Organisms often have common names, but only the scientific name has any formal standing in the taxonomy of animals and plants. For example, the most important **vector** of the yellow fever virus in the world is known by its common name, the yellow fever mosquito. Its scientific name is *Aedes aegypti*.

Scientific names of most organisms, including mosquitoes, have a long form and a short form. The long form of the yellow fever mosquito is *Aedes* (*Stegomyia*) *aegypti* (L.). The short form is just *Aedes aegypti*.

Scientific names are always in italics or underlined when they appear in print.

One final rule of bionomial nomenclature: genus names always begin with an upper case letter, species names do not.

What are mosquitoes?

- Mosquitoes are small flying insects and are related to other members of the order Diptera, the “two-winged flies.”
- They are further classified in the family Culicidae. The immature stages, called larvae and pupae, are aquatic and live in standing or nearly standing water sources in every biogeographic region of the world.
- Adult female mosquitoes of most species feed on blood of vertebrates, including humans, and this habit has resulted in great economic and public health significance for this group of insects.

- There are well over 3,000 species and subspecies of mosquitoes in the world.
- They occur in a variety of habitats, ranging from deserts at or below sea level to high mountain meadows at elevations of 10,000 feet or more.
- Adult mosquitoes are terrestrial flying insects; immature stages are aquatic. Larvae and pupae of the various species can be found in ponds, ditches, puddles, swamps, marshes, water filled rot holes of trees, rock pools, axils of plants, pools of melted snow, water in discarded tires, tin cans, and other artificial containers. Some species are most active and in the warmest part of the year, whereas others are adapted to cool temperatures.
- Many species of mosquitoes are rarely encountered and seldom pose a threat to the health or well-being of humans and domestic animals.
- However, other species are abundant, frequently encountered, and readily attack people, their pets, and their livestock. Some of these species transmit microbial organisms that cause malaria and encephalitis and other severe diseases of humans and other vertebrates.

Close relatives of the mosquito

- Other insects that resemble mosquitoes and may be mistaken for them include crane flies, gnats of various types, black flies, sewer flies, and midge.
- All of these small flies lack scales on their wings except for sewer flies. These flies frequently fly up through drains in shower rooms and public rest rooms. They can be recognized by their generally hairy bodies and leaf-shaped wings.

Crane flies are very common, and are larger than all but a few species of mosquitoes. Crane flies have very long wings and long fragile legs.

The flies that most closely resemble mosquito adults are the **non-biting midges**, or chironomids. They are roughly the same size as mosquitoes, but lack scaled wings. Also, they do not have an extended proboscis modified for sucking blood.

Biting midges, also called ceratopogonids, are also severe pests of people and other animals. The adults of these biting insects are so small that their presence is noticed only by the pain of their bite. For this reason they are also called “no-see-ums”. Biting midges usually have wings with pigmented spots (picture wings), but these are rarely visible with the naked eye.

Black flies, also called buffalo gnats, are smaller than most adult mosquito , and have a characteristic humped back (thorax). Female black flies have a short proboscis that is adapted for slashing and tearing rather than piercing. Female black flies are persistent biters of people and other animals. Black flies do not have scaled wings. Because the larvae are found only in moving streams, the adults are usually encountered near such habitats.

Classification of mosquitoes

Mosquitoes are classified into three subfamilies, each with different characteristics in all of their life cycle stages. The species of importance from the standpoint of public health are contained in the subfamilies Anophelinae (called anophelines) and Culicinae (called culicines). Females of species in a third subfamily, Toxorhynchitinae, lack mouthparts adapted for sucking blood from vertebrates.

Taxonomic note: The ending –nae (Culicinae) indicates subfamily while –dae (Culicidae) indicates family.

- Common genera of the subfamily Culicinae include *Culex*, *Aedes*, *Psorophora*, *Mansonia*, *Haemagogus*, *Sabethes*, *Coquilletidia* and *Culiseta*.

- Most species in the subfamily Anophelinae are contained in the genus *Anopheles*.

- The subfamily Toxorhynchitinae contains only the genus *Toxorhynchites*.

- The common mosquito genera can be identified by resting and feeding habits, reproductive strategies, or by the presence or absence of various features of the head, legs, abdomen, or wings. Mosquito larvae genera, for example, can be determined based on various morphological features, especially the patterns and numbers of hairs on the head, thorax, and abdomen.

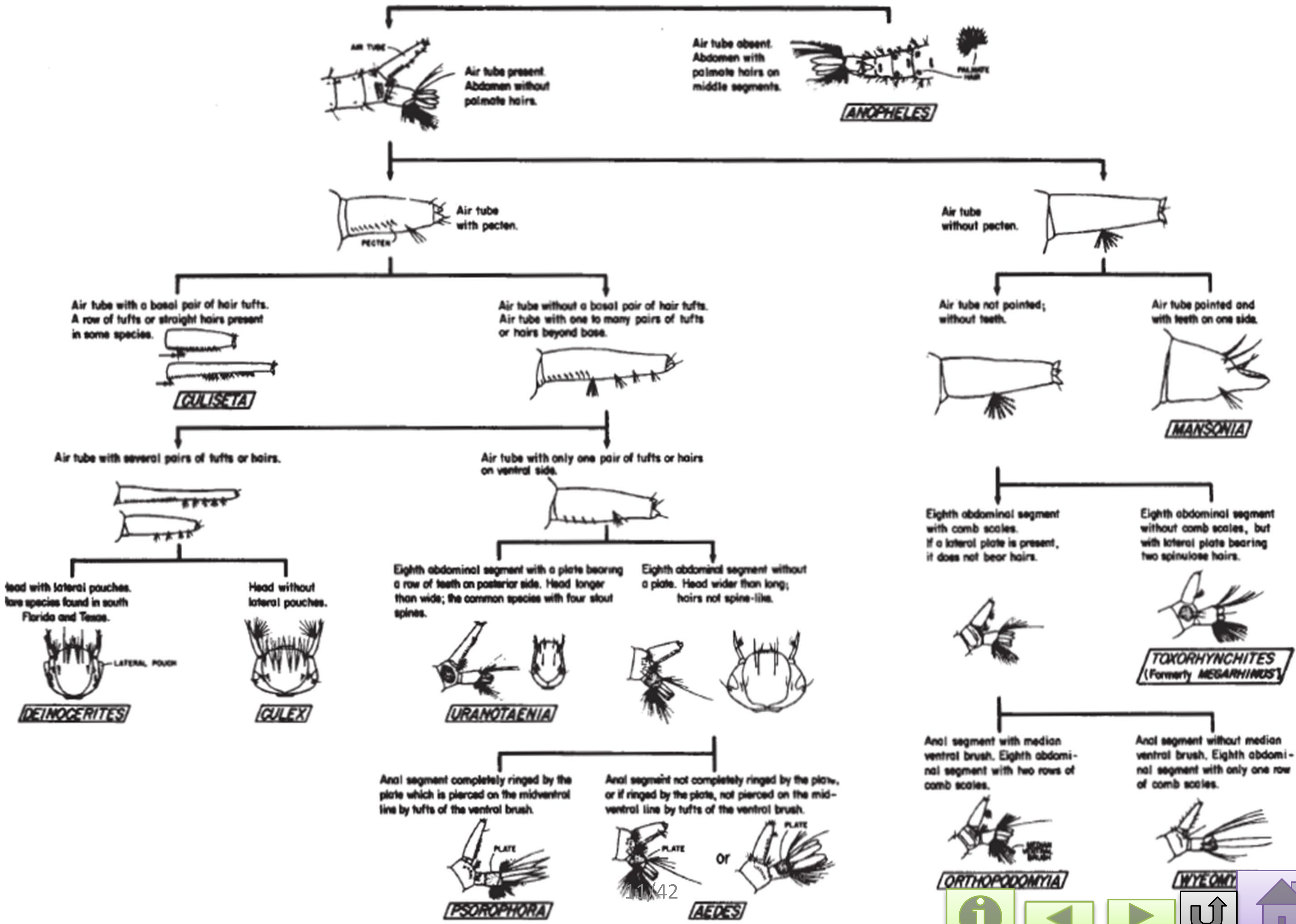
- Adult Culicine females blood feed with their bodies usually arranged somewhat parallel to the skin surface of their hosts. Culicine larvae have an air tube extending from the posterior section of their body and most species hang at rest from water surfaces at an angle of approximately 45°.

- Culicine females of the genera *Aedes* and *Psorophora* deposit single eggs, *Culex, Culiseta* deposit boat-shaped rafts of 100 or more eggs, while *Mansonia* and *Coquilletidia* deposit clusters of eggs attached to floating plants.

- Adult Anopheline females blood feed with their bodies usually arranged at an angle of 45°. Anopheline larvae lack an air tube extending from the posterior section of their body and rest with their body parallel to water surfaces. Anopheline eggs also are laid singly, but have elaborate floats extending from the sides of the eggs and can be found in clusters on water surfaces, forming interesting geometric patterns.

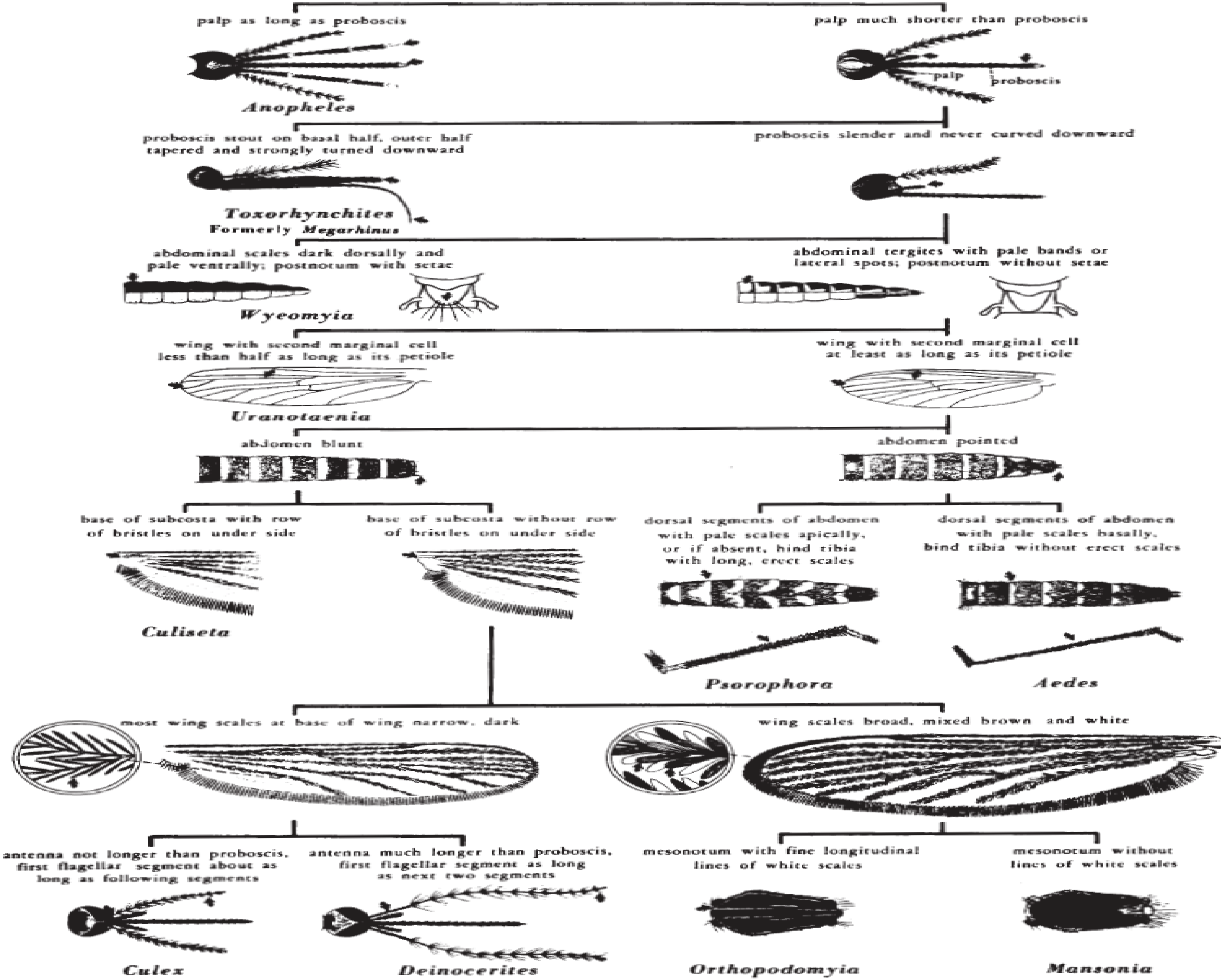
MOSQUITOES: PICTORIAL KEY TO U.S. GENERA OF LARVAE

Harry D. Pratt

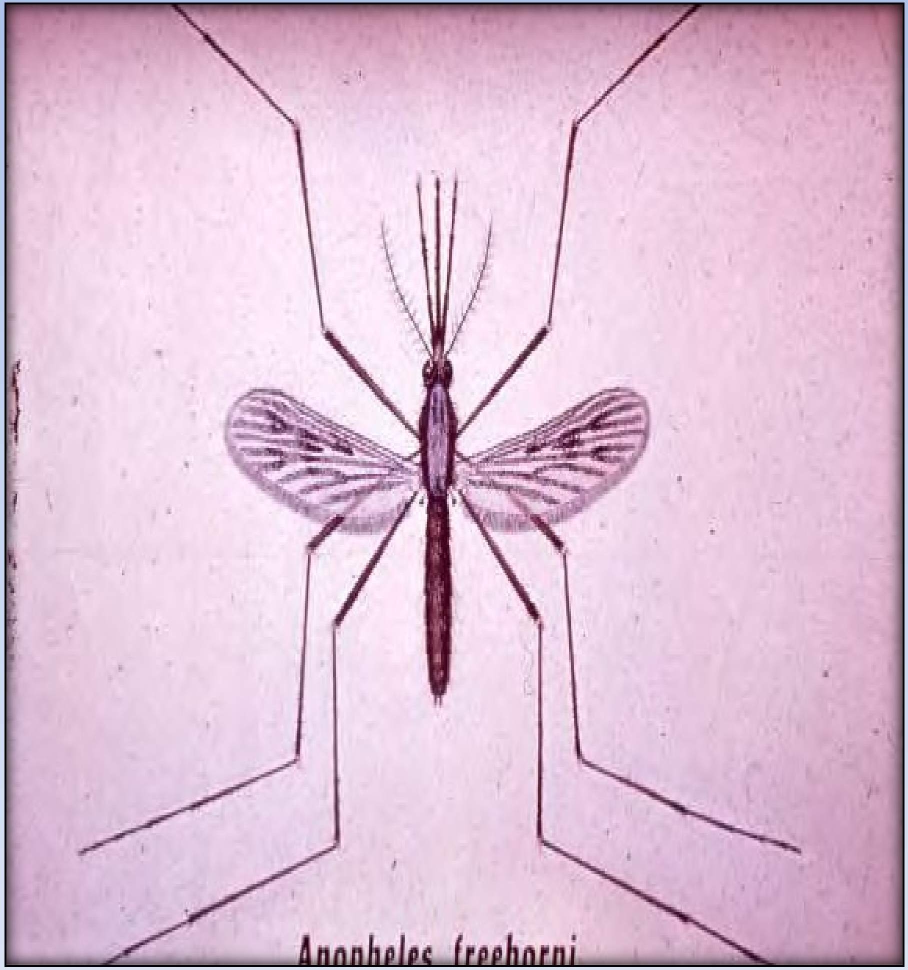


MOSQUITOES: PICTORIAL KEY TO UNITED STATES GENERA OF ADULTS (FEMALE)

Harry D. Pratt and Chester J. Stojanovich



Important California species of mosquitoes



- The following 24 species have been selected for discussion because they represent those most likely to be encountered by vector control technicians.
- Some of the species were chosen because they are important in transmitting mosquito-borne disease agents to humans and other vertebrates. Others are serious pests of humans and may be responsible for noninfectious diseases (e.g., hyper-allergic reactions).
- A few species are included because they have unusual and interesting life history and habitat associations.

Anopheles freeborni (Aitken)

- **Identification:** *Anopheles freeborni* (the western malaria mosquito) adults are medium-sized, slender, brown mosquitoes with palpi and tarsi without bands of pale scales. As members of the *Anopheles maculipennis* complex, they are easily separated from other California *Anopheles* by the presence of four dark scale patches on each wing and the fringe of the wing completely dark-scaled. *An. freeborni* larvae are typical *Anopheles* larvae in lacking air siphons and lying horizontally at the water surface when at rest. Distinguishing *An. freeborni* larvae from other California *Anopheles* larvae is difficult and relies primarily upon body hairs and the pattern of spots on the head.
- **Distribution:** *Anopheles freeborni* has been collected from below sea level near the Salton Sea to elevations above 6,000 feet in the Sierra Nevadas and Cascades. Although found throughout the state, the largest populations occur in rice-producing areas of the Sacramento Valley. Because of the uncertainty of the ranges of *An. freeborni* and the closely related *An. hermsi*, an accurate description of the geographical range of either is difficult.
- **Importance**: *Anopheles freeborni* is an efficient malaria vector and before World War II it was responsible for the transmission of this parasite throughout much of northern California and the Central Valley. Since that time, it has been responsible for several locally transmitted outbreaks in the northern part of the state. It readily enters homes and animal shelters to bite at dawn and dusk. This species is a significant pest during mid-summer and early fall in the rice producing areas of the Sacramento and Shasta Valleys.

Anopheles freeborni (Aitken)

- **Ecology:** Females of this species survive the winter in an inseminated, non-gravid, un-blood fed state. Diapausing females may move many miles to seek overwintering shelters in buildings, culverts, cellars or other protected places.

- On warm days in January or February, the females will leave their shelters to find blood meal sources. Blood meal sources are deer, sheep, horses, dogs and humans. Spring rain pools, river seepage areas, marshes, swamps, semi-permanent or permanent ponds in irrigated pastures, rice fields and drainage ditches are among the most common larval habitats.

- Eggs, as with all anophelines, have characteristic floats extending from the sides. They are laid separately on the water surface. The time required for the egg to hatch is affected by temperature, but usually occurs in 2-4 days. Larvae lie horizontally just below the surface of the water and feed by filtering suspended matter carried to the mouth by spiral currents created by the action of their oral brushes. The larval stage lasts about 15 days, depending upon the temperature and the quality of the larval nutrition. The pupal stage lasts about three days. The total developmental time from egg to adult is 20 or more days.

Anopheles hermsi Barr & Guptavanji

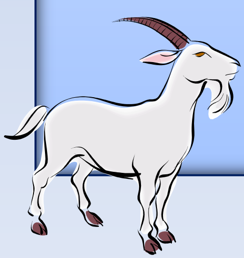
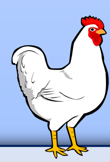
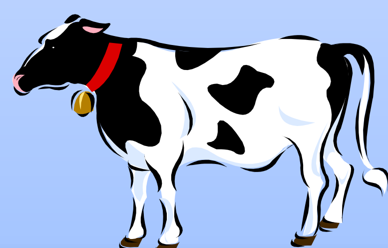
- **Identification**: *Anopheles hermsi* is a recently described species of the *Anopheles maculipennis* complex. Information on the bionomics of this southern California Species is limited and must be presumed to be similar to that of An. *freeborni*. The three members of this complex in California are *An. freeborni*, *An. occidentalis* and *An. hermsi*. All three of these three species are dark-legged, dark-palpi anophelines. Adults of *An. occidentalis* can be distinguished from the other two by having pale golden fringe on the tips of the wings. The other two species have dark scales on the fringe of the wings and are indistinguishable on the basis of morphology. Currently, separation of *An. freeborni* and *An. hermsi* is based on examination of stained microscope preparations of their sex chromosomes, and their geographic distribution.

- **Distribution:** In southern California, *An. hermsi* and *An. freeborni* appear to have separate and distinct distributions with *An. hermsi* occurring south and west of the Tehachapi Mountains and Coastal Ranges and *An. freeborni* occurring to the north and east of these ranges. In general, *Anopheles hermsi* appears limited to the coastal areas south of San Luis Obispo County. However, isolated populations of this species have been found in counties north of this point. This species has occasionally been called the “southern California malaria mosquito”.

Anopheles hermsi Barr & Guptavanji

- **Ecology:** *Anopheles hermsi* larvae have been collected in a variety of habitats including matted cattail stands, matted root systems of willow trees, river margins and the edges of canyon streams or pools. Larvae rarely are collected from habitats typically associated with *Anopheles* breeding (e.g., sunlit pools with heavy algal mats). In San Diego County, *An. hermsi* occurs in low numbers throughout the year with peak populations in June and July. Females bite in shaded situations beginning about ½ hour before sunset and continuing thereafter for 1-2 hours. A second peak of biting activity begins about one-half hour before sunrise and continues until shortly after sunrise. *Anopheles hermsi* is an aggressive, flighty biter and will attempt to feed on a number of different hosts in order to obtain a blood meal. Females have been known to feed on chickens, goats, cattle, dogs and humans.

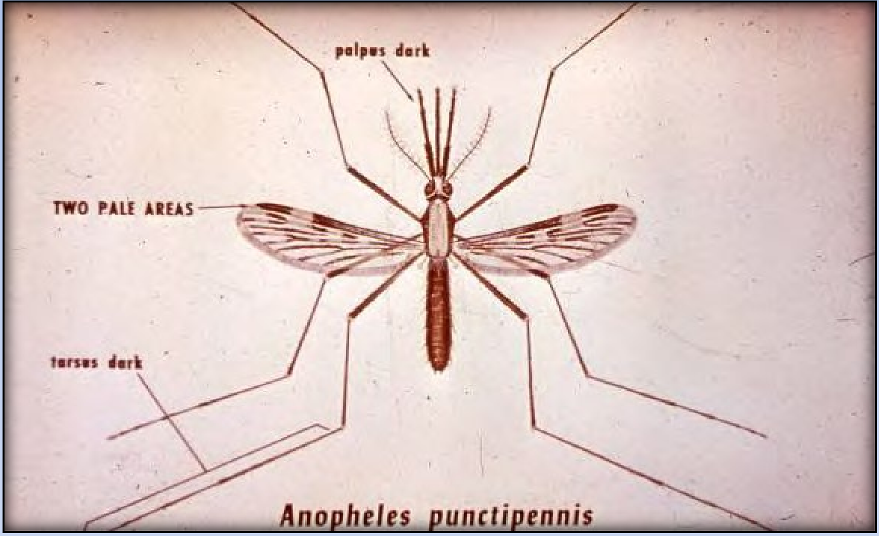
- **Importance:** In recent years, *An. hermsi* has been implicated as the vector in locally transmitted human malaria outbreaks in San Diego County.

Anopheles punctipennis (Say)

- **Identification:** *Anopheles punctipennis* (the woodland malaria mosquito) adults are medium-sized, brown mosquitoes with dark palpi, a wide grey longitudinal stripe on the mesonotum and two pale spots on the forward wing margin. Distinguishing *An. punctipennis* larvae from other California *Anopheles* larvae requires microscopic examination of the placement and branching of body hairs on the 4th and 5th abdominal segments. The pattern of dark bands on the head also is distinctive.

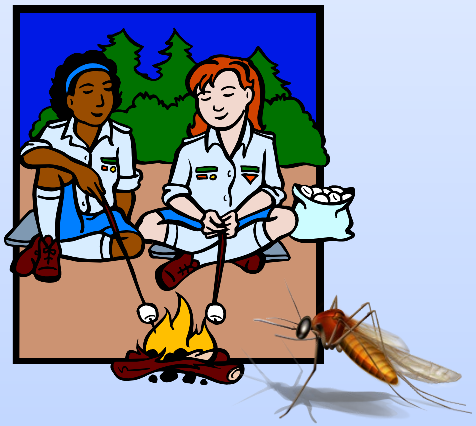
- **Distribution:** *Anopheles punctipennis* is the most abundant anopheline in the Sierra Nevada foothills and Coastal Ranges, where it is common and widespread. Isolated colonies sometimes are found on the floor of the Central Valley. It occurs abundantly below 4,000 feet and has been recorded as far south as Orange County along the coast and in the Tehachapi Mountains.



- **Ecology:** Larvae inhabit shaded grassy pools in cool wooded areas along intermittent creeks and permanent rivers. Adult females survive winters in diapause. Females are aggressive day and dusk feeders, but will seldom enter enclosed buildings to feed. Animals other than humans are the principal hosts but this mosquito bites humans frequently enough to be regarded as a porch biter and outdoor recreational pest.

Anopheles punctipennis (Say)

Importance: This species is susceptible to laboratory infection with human malaria parasites. In California, *An. punctipennis* was a significant cause of malaria in the early 1900s in Placer County. Problems with this species led to one of the first mosquito abatement programs in the state. It also was probably the vector responsible for the Lake Vera outbreak of malaria at a Girl Scout camp near Nevada City in the 1950s.



Aedes aegypti

aka

Yellow Fever mosquito

- **Identification:** The most notable characteristic of this species is scales on the scutum in the shape of a lyre. Fourth-stage larvae of this resemble those of *Aedes albopictus,* but the comb scales have strong spines whereas fringe of fine spicules, whereas *Ae. aegypti* comb scales have strong spines.

- **Distribution:** As of 2021**,** this species is widespread in southern California and the San Joaquin Valley.

- **Ecology:** Larvae of this species are found in a variety of artificial containers holding water such as tires, tin cans, tubs, bird baths, and flowerpot saucers.

- **Importance:** The females of this species are aggressive, cryptic, day biting mosquitoes, capable of vectoring yellow fever, dengue fever, chikungunya, Zika virus, and other human diseases.

Aedes albopictus (Skuse)

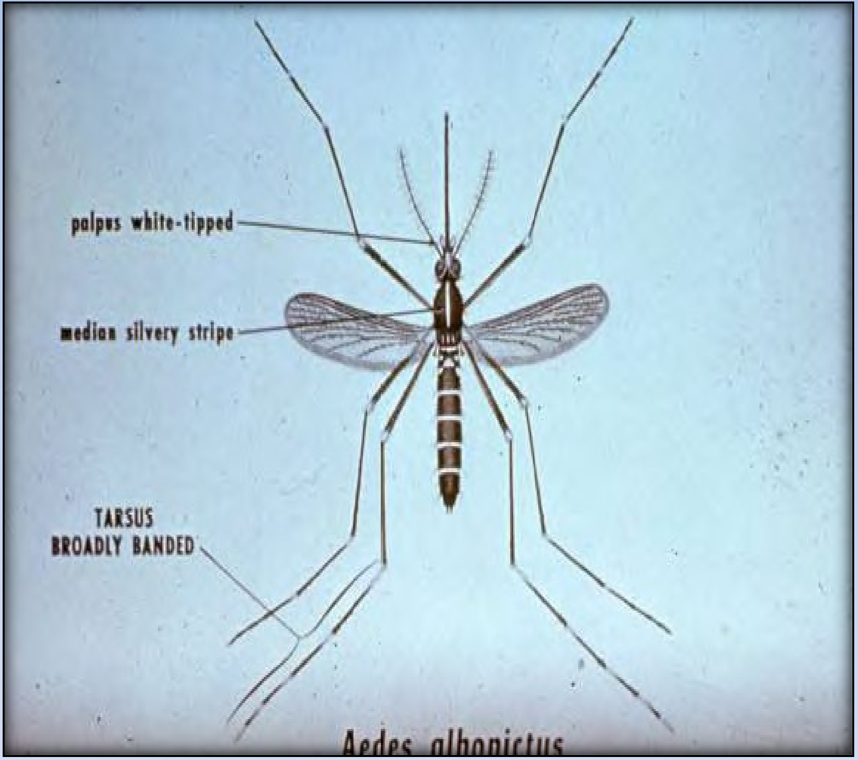
aka

Asian tiger mosquito

- **Identification:** The most notable characteristic of the species is a narrow stripe of white scales on the scutum, hence the name "tiger mosquito". Fourth-stage larvae of this resemble those of *Aedes aegypti,* but the comb scales have a fringe of fine spicules, whereas *Ae. aegypti* comb scales have strong spines.

- **Distribution:** The current infestation was detected in El Monte, CA, in 2011. As of 2021, *Ae. albopictus* has been detected in Los Angeles, Orange, San Bernardino, and San Diego, and Shasta counties.

- **Ecology:** Larvae of this species are found in a variety of artificial containers holding water such as tires, tin cans, tubs, and bird baths. Larvae can also develop in water held by living plants and plant parts. (phytotelmata).



- **Importance:** The females of this species are highly aggressive, day biting mosquitoes, capable of vectoring dengue, chikungunya, Zika virus, and other human diseases.

Aedes bicristatus Thurman & Walker

- **Identification:** Adults have unbanded tarsi, maxillary palpi have intermixed dark and pale scales, abdomen with complete basal bands of pale scales. Larvae have head hairs 5 and 6 two-branched, and an anal saddle incomplete.

- **Distribution:** This species is found in most localities in California with oak forests, primarily in the Coast Range and Sierra Nevada foothills. It may be found at elevations as high as 6,000 ft.

- **Ecology:** This species is one of the earliest *Aedes* to appear as an adult in California. The larvae can be found in shallow pools containing green algae, especially in vernal pools and roadside ditches. The substrate of these pools is almost always oak leaves.

- **Importance:** The females of this species are not aggressive human biters. The species is included here because of its unusual larval habitat and because of its relationship to a species of public health importance that occurs in the midwestern USA, *Aedes* (*Rusticoides) provocans*. This species is a probably vector of Jamestown Canyon virus to vertebrates in New York state. There are only nine species in the subgenus *Rusticoides* in the *bicristatus* is the only representative of this subgenus in California.

Aedes dorsalis (Meigen)

- **Identification:** *Aedes dorsalis* females are medium-sized, whitish to tawny-yellow mosquitoes, superficially resembling *Aedes melanimon.* However, these species are separable by the color of the scales on the anal wing vein; most of the anal wing vein scales are light in *Ae. dorsalis* and dark in *Ae. melanimon. Aedes dorsalis* larvae may occur with *Ae. melanimon* (inland) or *Ae. squamiger* (coastal) larvae throughout most of their range. Fourth-stage larvae of *Ae. dorsalis* can be distinguished from. *Ae. melanimon* by the much longer dorso-median hairs of the mesothorax (which are nearly as long as the antennae in *Ae. dorsalis*) and from *Ae. squamiger* by the shorter lateral hair of the anal segment (which is shorter than the saddle in *Ae. dorsalis*).

- **Distribution:** *Aedes dorsalis* generally is associated with tidal coastal marshes and with alkaline marshes or irrigated pastures inland. In California, it occurs abundantly along the coast, in the northeastern counties, on the eastern slope of the Sierra Nevada, in the Owens Valley and along the Colorado River. Small populations are located sporadically within the Coachella, Imperial and Central Valleys. There have been unsuccessful attempts to separate the coastal and inland populations into separate species based on differing body color, but apparently there is just a single, very adaptable species in California.

Importance: *Aedes dorsalis* is a major pest species both immediately surrounding its larval breeding source and, after periods of dispersal migrations, for quite some distances away. In addition, there is some evidence that *Ae. dorsalis* is involved as a secondary vector for WEE and CE in the Central Valley.

Aedes dorsalis (Meigen)

- **Ecology:** Adult *Ae. dorsalis* begin to appear on the tidal marshes in late spring, usually after the annual emergence of *Ae. squamiger.* Mating occurs during the first few days after emergence. Females often will disperse inland many miles from the tidal marshes to feed in pastures, woodlands or urban areas. However, they must return to the marshes to oviposit. Laid singly, eggs are deposited in batches of up to 130 eggs. Under ideal conditions, some *Ae. dorsalis* females may live as long as two months.

- Feeding primarily on large mammals such as horses and cattle, females readily take human blood when available and occasionally will feed on birds. Biting occurs most often during the daylight hours and at dusk with some blood feeding continuing into the night. Eggs of many diapausing *Aedes* species will not hatch until they have been exposed to very cold temperatures for periods as long as 6 months or more. This exposure is called **conditioning**. Once conditioned, eggs may hatch immediately when flooded, however, hatching may be blocked by low temperatures.

- Studies of coastal populations indicate that gradually decreasing temperatures cause the eggs to become dormant, whereas gradually increasing temperatures cause them to regain the ability to hatch when flooded. Thus, fall weather arrests hatching and causes the species to overwinter as diapausing eggs, which do not hatch until temperatures rise in the spring. *Aedes dorsalis* can pass from egg to biting adult in less than two weeks with the potential of producing 8-12 generations a year. *Aedes dorsalis* larvae are very tolerant of high salinity and the pupae can survive 48 hours after being stranded when a source is drained or dries prematurely.

Aedes hexodontus Dyar

Identification: This species is a typical dark-legged snow pool *Aedes*. All of these species are easily identified as larvae, but very difficult to identify as adults. Larvae are readily identified by the presence of (usually) six thorn-like comb scales. No other snow pool species in California has scales like these.

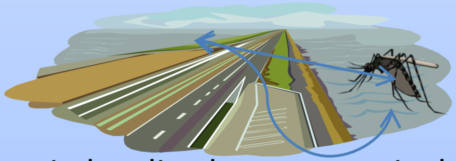
Importance: The Jamestown Canyon virus (JC) has been isolated from males and females reared from naturally-infected larvae many times, and this species is probably an important enzootic vector for this virus. In addition, this species is one of several that are the scourge of hunters, fishermen, forest rangers, campers, and other people exposed to them in the spring. About 30% of this group was found to have antibodies against JC in a serosurvey conducted several years ago.

Ecology: This species has a single generation per year (**univoltine**). Eggs are deposited in late spring and summer in moist depressions that will fill with snow the following winter. The eggs are conditioned to hatch by the winter temperatures beneath the snow. The eggs hatch later in the spring than those of *Aedes tahoensis*, a related dark-legged *Aedes* that occupy the same larval habitats. After emergence, the females mate and aggressively seek a blood meal from any available large mammal (including humans). After females have digested the blood meal and a batch of eggs has developed, the female returns and lays eggs at a location near the same snow pool from which they emerged.

Distribution: Occurs in mountainous areas in California, typically at elevations above 6,000 ft. They are especially common near mountain passes in the Sierra Nevada and Cascade Range, but also occur in the Trinity Alps and at the highest elevations of the Coast Range.

Aedes melanimon Dyar

- **Identification:** Female *Ae. melanimon* vary from brown to tan and have a predominantly dark-scaled abdomen with narrow basal bands of white scales across the top of each abdominal segment and a whitish stripe along the midline of each segment. Their dark tarsi have white bands overlapping the joints. *Aedes nigromaculis* is similarly marked, but its tarsal bands are restricted to the basal side of the joints. *Aedes dorsalis* markings are almost identical with those of *Ae. melanimon,* but the two species differ in general color (usually paler in *Ae. dorsalis* and darker in *Ae. melanimon*) and other subtle characters.
- **Distribution:** *Aedes melanimon* is primarily an inland mosquito occurring in most of the major inland valleys of California from Orange and Riverside Counties northward through the Central and Sacramento Valleys.
- **Ecology:** This species is often found in association with *Ae. nigromaculis* in irrigated pastures and alfalfa fields. It also occurs in many types of intermittently irrigated or flooded vegetated areas. Although *Ae. melanimon* larvae can tolerate slightly higher salinity levels than *Ae. nigromaculis,* both of these species are much less tolerant of salinity than *Ae. dorsalis. Aedes melanimon* also are common in duck hunting club ponds and wildlife areas flooded in late summer and early fall. Females are active biters at dusk with rabbits and cattle serving as the primary blood sources although they will readily feed on humans. They fly considerable distances and, when assisted by prevailing winds, can move ten or more miles from a breeding source.



- **Importance:** *Aedes melanimon* is not only a major pest in localized areas near its larval breeding sources, but it has been implicated as an enzootic vector of WEE and an endemic vector of CE in the Central Valley. The original isolation of CE was from *Aedes melanimon*, and almost all subsequent isolations of this virus have been from this same species.

Aedes notoscriptus (Skuse)

- **Identification:** Similar in appearance to *Aedes aegypti,* but has 3 longitudinal parallel stripes on the thorax instead of two, and has a white ring on the proboscis.

- **Distribution:** Native to Australia, New Guinea, Indonesia, and surrounding islands. Introduced and established in New Zealand (1918) and parts of southern California (2014). As of April 2021, has been detected in Los Angeles, Orange, and San Diego counties.

- **Behavior and Ecology:** Similar to *Ae. aegypti*
  - Daytime biting species
  - Closely associated with humans
  - Utilizes small containers for larval habitat, but will also use small natural sources like bromeliad leaf axils and tree holes
  - Feeds on humans, other mammals, and birds

- **Public Health Importance:**
  - Severe urban nuisance pest.
  - Primary vector of dog heartworm in Australia
  - Known vector of Ross River virus and Barmah Forest virus in Australia
  - Not known to vector dengue virus. Additional research needed to determine if this mosquito can vector Chikungunya or Zika virus.

Aedes nigromaculis (Ludlow)

- **Identification:** *Aedes nigromaculis* (the irrigated pasture mosquito) adults usually are medium-sized, but in the Central Valley rapid growth at high temperatures or larval crowding may result in the production of small individuals. Females have a line of yellowish-white scales extending down the center of the upper surface of the black-scaled abdomen. A white ring may be present on the proboscis and the basal portions of the tarsal segments are white-banded.
- **Distribution:** This widely distributed species has been reported from 49 of the 58 California counties. It has been collected from sea level to 6,000 feet in elevation.
- **Ecology:** *Aedes nigromaculis* larvae are associated with irrigated pastures and alfalfa fields. A brood is usually produced with each irrigation at intervals ranging from 10–16 days. In California, the irrigation season usually extends from March to November with peak *Ae. nigromaculis* populations occurring in July and August. During midsummer, larvae may grow rapidly and pupate in three days. The pupal stage lasts 1–2 days. Since the pupae can survive on damp, shaded substrates three days of standing water is sufficient to support adult emergence. The eggs are laid in damp areas subject to later inundation. Each *Ae. nigromaculis* female lays 100–150 eggs per batch with the first batch deposited 4–5 days after the female emerges. Due to the female's short life span (average 10–14 days and maximum 20 days), only 1–2 batches of eggs are deposited by each female before she dies. A majority, but not all of the eggs hatch with each irrigation. As temperatures drop in the fall, the eggs become dormant for the winter. In this state of dormancy (diapause) the eggs will not hatch until soil and water temperatures reach 64-70°F (18-21°C) in the spring.
- **Importance:** This mosquito is one of the most pestiferous *Aedes* in the Central Valley, second only to *Ae. melanimon.* Large populations may be produced, resulting in serious economic loss and considerable annoyance to domestic animals and humans.

Aedes sierrensis (Ludlow)

- **Identification:** *Aedes sierrensis* (the western tree hole mosquito) adults are brightly marked with white scales which contrast with the generally dark body. The tarsi have white bands overlapping the joints, the proboscis is unbanded and the tips of the palpi are white-scaled.

- **Distribution:** Although *Aedes sierrensis* is found widespread throughout California from near sea level to elevations above 9,000 feet, this species is most prevalent in the moist woodland coastal and Sierra Nevada foothill communities of northern California. Where it occurs in southern California, *Ae. sierrensis* is associated with coastal riparian and mountain environments.

- **Ecology:** Adults emerge and are most abundant in the early spring, but some emergence may occur in the summer and fall depending on the occurrence of rainfall, the amount of light reaching the tree holes and temperature. Adults have a limited flight range and generally are found close to breeding sites. Female *Ae. sierrensis* blood feed predominately on small and large mammals, including humans. Field studies repeatedly indicate small woodland mammals (rodents) as the primary sources of blood meals. *Ae. sierrensis* has a peak of feeding activity at dusk, but also bites during the day and night.

Aedes sierrensis (Ludlow)

- Females are not attracted to traps using light as an attractant, and specialized traps such as the Fay trap are required to sample adults.

- The immature stages are found mainly in the rot holes in trees. They have been found in more than 20 species of trees having cavities with external openings as small as ½ inch. They are infrequently taken in old tires, water barrels, tubs and other receptacles containing leaf litter.

- Eggs are laid scattered in batches of 50-150, usually in moist places inside a tree hole. They will not hatch for 12 days or more after being laid. Some eggs survive for long periods between floodings.

- The larval stage may last from 10 days to several months depending on environmental conditions. The pupal stage lasts four days or longer.

Importance: *Aedes sierrensis* can be a very annoying pest when humans invade its environment. It is most troublesome in wooded recreational and suburban areas. Although not presently considered a vector of human disease, *Ae. sierrensis* is the most important vector of dog heartworm in the coastal and foothill communities of northern California.

Aedes squamiger (Coquillett)

- **Identification:** Adult *Aedes squamiger* (the California salt marsh mosquito) are medium-sized, dark mosquitoes easily distinguished from other California *Aedes* by their characteristic broad wing scales.

- **Distribution:** This univoltine (one generation per year) species is closely associated with tidal and reclaimed marshes of the Pacific Coast from Baja California to Bodega Bay.

- **Ecology:** Adults appear on the marshes beginning in February or March. Before mating, both males and females move into wooded areas near the marshes for 4–7 days before the female is ready to blood feed. In favorable late spring weather, females disperse from salt marshes breeding sites over great distances in search of blood meals. After blood feeding, female *Ae. squamiger* return to the salt marshes to lay their eggs.

- **Importance:** On a localized and seasonal basis, *Ae. squamiger* is considered a major pest species with the females readily attacking humans during daylight hours and at dusk. Moro Bay virus has been isolated from this species, though this virus has not been associated with human disease.

Aedes taeniorhynchus (Wiedemann)

- **Identification:** *Aedes taeniorhynchus* (the black salt marsh mosquito) adults are medium-sized to small mosquitoes distinguished from other *Aedes* by a white median band on the proboscis, white tipped palpi and basal white bands on the hind tarsal segments that slightly overlap the joints.
- **Distribution:** *Aedes taeniorhynchus* occurs in California in coastal saline waters from Santa Barbara County to San Diego County and inland alkaline waters in the deserts of eastern Imperial and Riverside Counties along the Colorado River.
- **Ecology:** *Aedes taeniorhynchus* is a multivoltine species. In San Diego County, it breeds in high tide pools, primarily those supporting growth of pickleweed. Females mate when they are 30–40 hours old and avidly blood feed on cattle and occasionally humans.
- **Importance:** Although several arboviruses have been isolated from *Ae. taeniorhynchus,* including eastern equine encephalomyelitis (EEE) and Venezuelan equine encephalomyelitis (VEE), there is no evidence that this species transmits human disease pathogens in California.

Aedes tahoensis Dyar

- **Identification:** This species was previously known as *Aedes communis* (DeGeer). Population genetic studies of the *Ae communis* complex of species in North America showed that only *Ae. tahoensis*, previously considered a synonym of *Ae. communis,* occurs in California. This species is another dark legged snow pool *Aedes.* Identification of larvae is fairly easy; identification of adults is very difficult.

- **Distribution:** *Aedes tahoensis* is common along the crest of the Sierra Nevada at elevations above 4,500 feet from Inyo and Tulare Counties northward to Tehama and Lassen Counties.

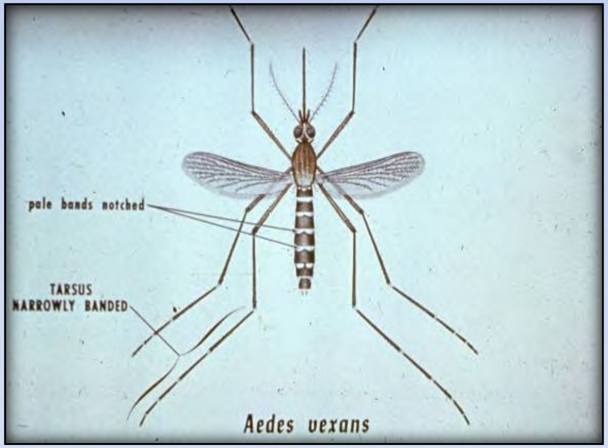
- **Ecology:** This univoltine spring species occurs in shaded, temporary snow-melt pools with clear margins and a bottom of pine needles. Larvae are found in the same habitats as *Ae. hexodontus*, but earlier in the year. *Ae. tahoensis* is often the earliest mosquito to emerge in the spring at high elevations.

- **Importance:** *Aedes tahoensis* often reaches numbers sufficient for it to be considered a localized pest species in mountain communities. Jamestown Canyon virus, a member of the California serogroup, has been isolated repeatedly from this species in California.

Aedes vexans (Meigen)

- **Identification:** *Aedes vexans* (the inland floodwater mosquito) adults are medium sized, brownish mosquitoes which are easily distinguished from other California *Aedes* by the indented (scalloped) transverse white basal abdominal bands, narrow white basal rings on the hind tarsi and dark wing scales

- **Distribution:** Widely distributed throughout the USA, *Ae. vexans* occurs in 33 of the 58 California counties. It does not occur in the coastal and high mountain counties.



- **Ecology:** *Aedes vexans* is a multivoltine species which typically breeds in woodland watercourses, but occasionally breeds in open pastures. Females lay 100– 180 eggs scattered in moist places left by receding or overflow pools. Shaded soil with a covering of leafy vegetation provides a particularly favorable oviposition site.

- **Importance:** Several arboviruses have been isolated from *Ae. vexans* in nature, including WEE and EEE. In California, this mosquito is not considered to be a vector of human disease.

Aedes washinoi Lanzaro & Eldridge

- **Identification:** A member of the *Aedes increpitus* complex, adult *Ae. washinoi* are morphologically inseparable from the other adult members of this complex, *Aedes increpitus* Dyar and *Aedes clivis* Lanzaro and Eldridge. Females of these species have tarsi with broad basal bands of white scales on most joints, dark-scaled wings with a few pale scales concentrated on the anterior veins and a dark-scaled abdomen with the top of each segment transversed by a complete basal band of pale scales.
- **Importance:** *Aedes washinoi* occasionally reaches numbers sufficient for it to be considered a localized pest species.

- **Distribution:** *Aedes washinoi* is common along coastal California at sea level, ranging eastward as far as the Sierra Nevada and Cascade Range foothills in some areas.

- **Ecology:** This species is generally a univoltine late winter and early spring species throughout most of its range, but possibly may be multivoltine at lower elevations. Larval sources include various types of freshwater ground pools, especially in riverine habitats. Females are active day biters, do not fly much more than ½ mile from larval sources and will readily attack humans.

Culex erythrothorax Dyar

- **Identification:** *Culex erythrothorax* (the tule mosquito) adults are medium-sized mosquitoes with a dark-scaled proboscis and palpi. The back and sides of the thorax are reddish-orange, wing scales are dark brown and legs are medium brown, giving it a bronze-like appearance. This mosquito may be confused with *Culex pipiens* and *Culex quinquefasciatus* but differs by the reddish thorax and yellowish abdominal bands (white bands in *Cx. pipiens* and *Cx. quinquefasciatus*).

- **Distribution:** This species occurs in 36 of 58 California counties, mainly in the foothill, coastal and southeastern desert areas.

- **Ecology:** Larvae have been collected year round in ponds, lakes, marshes and streams where there is shallow water that supports extensive tule or cattail growth. This is one of the few *Culex* species which overwinter as a 4th-stage larva. Females usually remain close to the wetland habitat and utilize a broad range of blood sources, including birds and humans. Peak landing and biting activity occurs one to two hours after sunset. This species is extremely difficult to sample using the standard 1-pint dipper.

- **Importance:** Despite isolations of several arboviruses (e.g., WEE and SLE) from *Cx. erythrothorax,* this species does not experimentally transmit these viruses by bite.

Culex pipiens Linnaeus

- **Identification:** This species is indistinguishable from *Culex quinquefasciatus* (Say) using morphological characters except those of the male genitalia. Larvae have head hairs 5 and 6 usually with five or more branches and a moderately long siphon tube bearing four tufts with the subapical tuft out of line.

- **Distribution:** *Culex pipiens* is widely distributed throughout the state north of the Tehachapi Range. Hybrids occur in central California (between approximately 5° to either side of 39°N latitude).

- **Ecology:** Diapausing *Cx. pipiens* overwinter as inseminated females. Males do not survive winter. Almost all females enter diapause because of exposure as mature larvae and pupae to shortened day-lengths. Diapausing females usually do not take blood meals, and the few that do will not develop eggs. Usually the breeding source is in or near the area from which complaints are received. Larval sources generally are in permanent or semi-permanent, foul, or polluted waters such as fish ponds, cesspools, septic tanks, catch basins, improperly maintained swimming pools, and dairy drains. Eggs are deposited on the surface of the water in rafts containing 120–200 eggs. Hatching usually occurs in 1–2 days with larval development requiring 4–6 days. Pupal development is quick, requiring only 1–2 days. Mating occurs 1–2 days after emergence with a blood meal usually necessary for eggs to be developed. Females feed mainly in the evening and at night, spending the daylight hours resting in cool, humid, dark places. Birds are the principal blood meal source for this species. However, they will attack humans and invade homes. Females feed mainly in the evening and at night, spending the daylight hours resting in cool, humid , dark places. *Cx. pipiens* is known to have autogenous populations.

- **Importance:** *Culex pipiens* has been found infected with encephalitis viruses (e.g., SLE, **WNV**, and WEE) in California, but its role in the natural transmission of these diseases is considered to be secondary to that of *Culex tarsalis*.

Culex quinquefasciatus Say

- **Identification:** This species is indistinguishable from *Culex pipiens* using morphological characters except those of the male genitalia (Fig. 4.10). Adults and larvae of the two species can be distinguished using various biochemical procedures. Adult *Culex quinquefasciatus* are medium sized brown mosquitoes with dark-scaled unbanded legs and an unhanded proboscis. Larvae have head hairs 5 and 6 usually with five or more branches and a moderately long siphon tube bearing four tufts with the subapical tuft out of line.

- **Distribution:** *Culex quinquefasciatus* is widely distributed throughout the state south of the Tehachapi Range. Hybrids occur in central California (between approximately 5° to either side of 39°N latitude). Populations of this complex to the south of this will be nearly all *Cx. quinquefasciatus*.

- **Ecology:** *Culex quinquefasciatus* do not survive winters as diapausing females, which may be one reason they do not occur in the cold climates occupied by *Cx. pipiens.* However, females do spend periods of cold weather in a short inactive state. Larval sources generally are in permanent or semi-permanent, foul, or polluted waters such as fish ponds, cesspools, septic tanks, catch basins, improperly maintained swimming pools, and dairy drains. Eggs are deposited on the surface of the water in rafts containing 120–200 eggs. Hatching usually occurs in 1–2 days with larval development requiring 4–6 days. Pupal development is quick, requiring only 1–2 days. Mating occurs 1–2 days after emergence with a blood meal usually necessary for eggs to be developed. Females feed mainly in the evening and at night, spending the daylight hours resting in cool, humid, dark places. Birds are the principal blood meal source for this species. However, they will attack humans and invade homes to annoy the occupants. Females feed mainly in the evening and at night, spending the daylight hours resting in cool, humid , dark places.

- **Importance:** *Culex quinquefasciatus* has been found infected with encephalitis viruses (e.g., SLE, WEE, and WNV in California, but its role in the natural transmission of these viruses is considered to be secondary to that of *Culex tarsalis* in rural situations. However, in urban environments, *Culex quinquefasciatus* may be the primary WNV vector. *Culex quinquefasciatus* is also a probable vector of dog heartworm.

Culex stigmatosoma Dyar

- **Identification:** *Culex stigmatosoma* is commonly called the banded foul water mosquito. Morphologically, this medium-sized mosquito is very similar to *Cx. tarsalis,* possessing pale bands that overlap the tarsal joints and a pale median band on the proboscis. Unlike *Cx. tarsalis*, the hind femur and tibia do not have a narrow line of white scales. Also, the black scales on the underside of the abdomen form oval or round spots instead of the pattern of V's exhibited by *Cx. tarsalis.*

- **Distribution:** *Culex stigmatosoma* is abundant throughout most of California, with the exception of the crest of the Sierra Nevada.

- **Ecology:** *Culex stigmatosoma* breeds in a variety of natural and man-made sources, particularly in highly polluted water sources such as dairy waste water lagoons, log milling ponds and sewage treatment ponds. Egg rafts consisting of 250 eggs are deposited directly on the water surface. In warmer parts of the state, adults and larvae can be collected throughout the year. In cooler areas, the adult females overwinter in protected locations such as animal burrows. Peak adult activity occurs in the summer months.

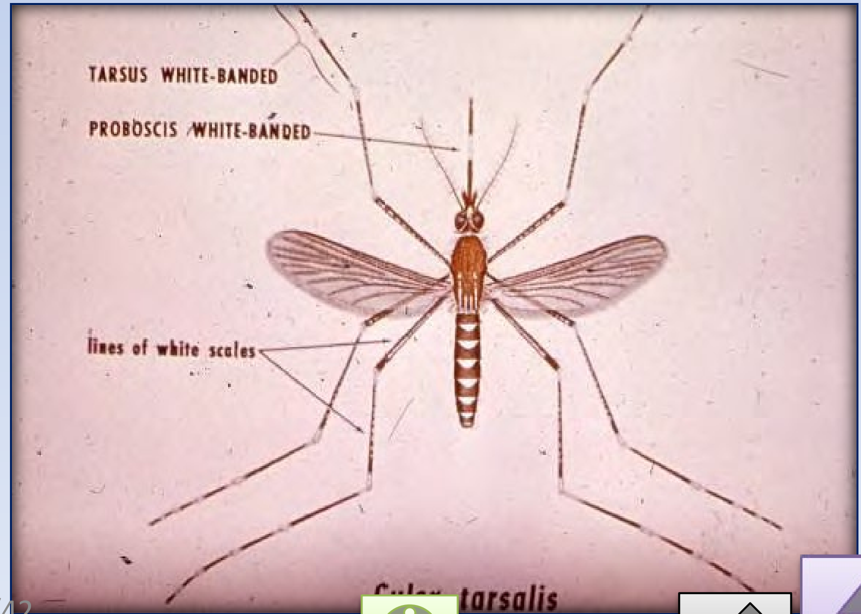
- **Importance:** Because *Cx. Stigmatosoma* feeds almost exclusively on birds and rarely bites humans, it probably is not involved in the transmission of human disease pathogens. However, this species may play a role in the secondary amplification and transmission of SLE in wild bird populations.

Culex tarsalis Coquillett

- **Identification:** *Culex tarsalis* (the western encephalitis mosquito) adults are medium sized, brownish mosquitoes with a median white band on the proboscis, white bands overlapping the tarsal joints and narrow lines or dotted rows of white scales on the outer surface of the hind femur and tibia. The underside of the female's abdomen is pale-scaled with an inverted V-shaped pattern of dark scales on each segment.

- **Ecology:** *Culex tarsalis* colonizes a wide variety of aquatic sources ranging from clean to highly polluted waters and is also able to tolerate fairly high salinity levels. It is associated with floodwater, rain pools, irrigation waters, ornamental ponds and dairy drains. Eggs rafts are laid on the water surface. However, throughout its range, *Cx. tarsalis* is most commonly associated with agricultural sources. *Cx. tarsalis* females show a preference toward birds, but also will take blood from cattle, horses and humans, often flying considerable distances (up to 16 miles with estimates indicating they can fly 20–25 miles if assisted by winds) to do so. This is important in the distribution and transmission of encephalitis viruses. *Culex tarsalis* are highly attracted to $C0_2$-baited traps and both males and females are attracted to light traps.

- **Importance:** In the fall, *Cx. tarsalis* occasionally becomes numerous enough to be considered a localized pest. However, its greatest importance is as a primary vector of SLE, WEE, and WNV.
- **Distribution:** This species occurs throughout California, having been recorded from all 58 counties over a wide range of elevations.



Culiseta incidens (Thomson)

- **Identification:** *Culiseta incidens* (the cool-weather mosquito) adults are large mosquitoes with narrow white bands on the tarsi and dark-scaled patches on the wings.
- **Distribution:** *Culiseta incidens* is found in every California county, most commonly along the coastal, foothill and mountain regions up to 9,500 feet. It occurs sporadically in the Central Valley and drier parts of southern California.

- **Ecology:** *Culiseta incidens* generally is associated with cool weather. Where summers are hot and winters cold, this species breeds mainly during the fall, winter and spring while aestivating during the summer. Immature stages are found in clean water with some degree of shading. Eggs are laid in rafts of 150-200 eggs on the surface of standing water.
- **Importance:** Female *Cs. incidens* are pests to humans in some areas, however, they feed mostly on large mammals such as livestock, and are not considered vectors of human diseases.

Culiseta inornata (Williston)

- **Identification:** *Culiseta inornata* (the large winter mosquito) females are easily recognized by their large size and generally light brown to rusty appearance. They have no conspicuous scale patches on their wings and the tarsi are un-banded.

- **Distribution:** *Culiseta inornata* is widely distributed in California and has been recorded from almost every county over a wide range of elevations.

- **Importance:** This species may feed on humans but the degree of nuisance varies geographically *Cs. inornata* is not considered a vector of human disease in California, although it has been found naturally infected with Jamestown Canyon virus.

- **Ecology:** *Culiseta inornata* is a cool weather mosquito. In the warmer southern part of its range it is most prevalent in the spring and fall and may occasionally appear in lesser numbers through the winter. It aestivates during the summer in protected areas such as animal burrows, road culverts and abandoned buildings. In the northern part of its range and in the Sierras of California this species breeds in the spring, summer and fall, and diapauses during the winter. The adults are strongly attracted to light and usually are the first species in the spring and the last in the fall to be sampled by light traps. The immature stages occur in sunlit sources, but may be found insources shaded from sunlight. Larvae are tolerant of moderate organic pollution and considerable levels of salinity and alkalinity. Eggs are laid on the water surface in rafts of 150-200 eggs. Females feed frequently on livestock at dusk and can cause economic losses through annoyance.

Psorophora columbiae (Dyar and Knab)

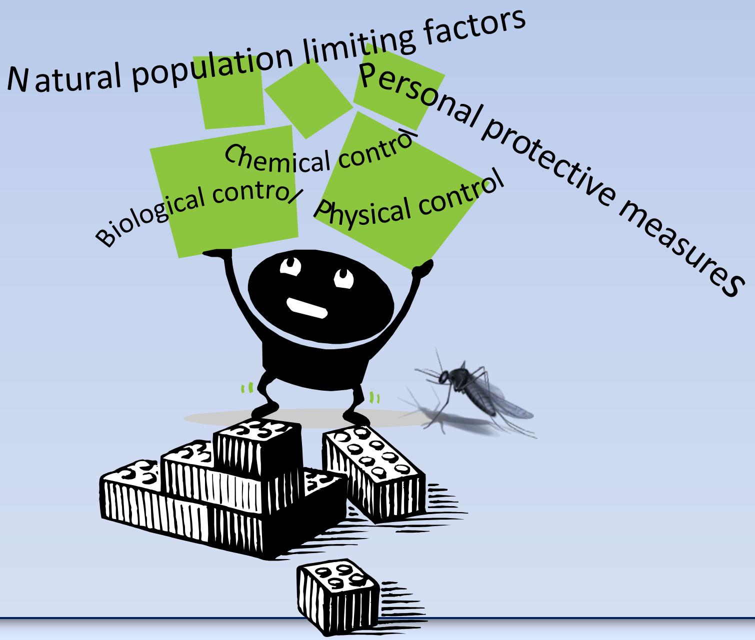
- **Identification:** Adult *Ps. columbiae* are medium-sized to large mosquitoes. Females have a pointed abdomen, a median white band on the first segment of the hind tarsi, and wings speckled with dark and light scales in no definite pattern. *Psorophora* and *Aedes* females appear similar.

- **Distribution:** This species is restricted to the arid regions of eastern San Bernardino, Riverside and Imperial Counties of southern California.

- **Ecology:** *Psorophora columbiae* breeds in irrigated fields, pastures, and date groves. Females lay about 100 eggs scattered on moist places on the soil, particularly where there is a growth of grass. Pre-flooding temperature is the primary factor controlling egg hatch.

- **Importance:** In California, this species is thought to have little vector potential for the transmission of human diseases. However, it is a major pest species in the southeastern desert agricultural areas where alfalfa and dates are grown.

Principles of Mosquito Control



Chapter 5

[*Mosquito Control*]
[*Integrated Pest Management in Mosquito Control*]
[*Types of Mosquito Control*]

Mosquito Control

- The main goal of mosquito control is the protection of people from the discomfort and diseases resulting from mosquito bites.
- The most serious of these are diseases caused by mosquito-borne human pathogens.
- Mosquito control is achieved by either direct or indirect human action, which can aid in the reduction or elimination of mosquito populations within a specific area.

- NATURAL POPULATION LIMITING FACTORS

Pathogens, Parasitism, Predation, Toxic plants, Competition,

Resource (food) availability

Physical limiting factors

Adults - Air temperature, Relative humidity, Protective shelter

Larvae - Water temperature, Dissolved salts/pollutants, and Currents

- CHEMICAL CONTROL METHODS

Adulticides: organophosphates, pyrethrum, synthetic pyrethroids

Larvicides: pyrethrum, microbials, biochemicals, petroleum oils

- PHYSICAL CONTROL METHODS

Aquatic habitats: water management, vegetation management, physical design

Terrestrial habitats: field grading, effective building codes, air conditioning

- BIOLOGICAL CONTROL METHODS

Releases of agents Pathogens, Parasites, Predators

Conservation of agents, proper water management, use of selective insecticides

- AREA PROTECTIVE MEASURES

Public relations Literature, public education, mosquito-proofing of public buildings

Area control Mosquito barrier treatments

- PERSONAL PROTECTIVE MEASURES

Personal measures Repellents, protective clothing, staying indoors Home control Draining of water, use of mosquito fish

Integrated Pest Management in Mosquito Control

- Mosquito populations in nature are regulated by natural factors that affect survival and mortality.

- Sometimes natural factors are not enough to reduce mosquito numbers below levels that prevent attacks against humans or the transmission of disease.

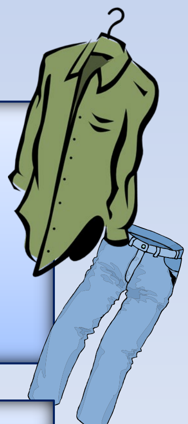
- When this happens action is required to reduce the numbers of mosquitoes.

- Effective and long lasting control can be attained by scientifically planned management and control strategies that are applied in a well-timed manner to reduce mosquito populations.

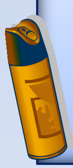
The strategies for mosquito control can be organized into different categories.

- Physical control is a method of reducing mosquito populations. Physical control means the modification and management of the environment of mosquitoes. Most of these methods involve water management, and are done cooperatively with other agencies charged with protection and management of lake, ponds, rivers, streams, marshes, and swamps. Some people use the term natural control for this approach to stress the value of maximizing the effects of natural regulatory mechanisms in controlling mosquitoes.

- Chemical control is the application of insecticides to adult or larval habitats of mosquitoes. Chemical control of larvae is usually preferred because the chemicals can be applied in a highly directed manner, with few effects to non-target organisms. Control of adults by chemicals either by ground or aerial-based means are usually only for emergency situations.



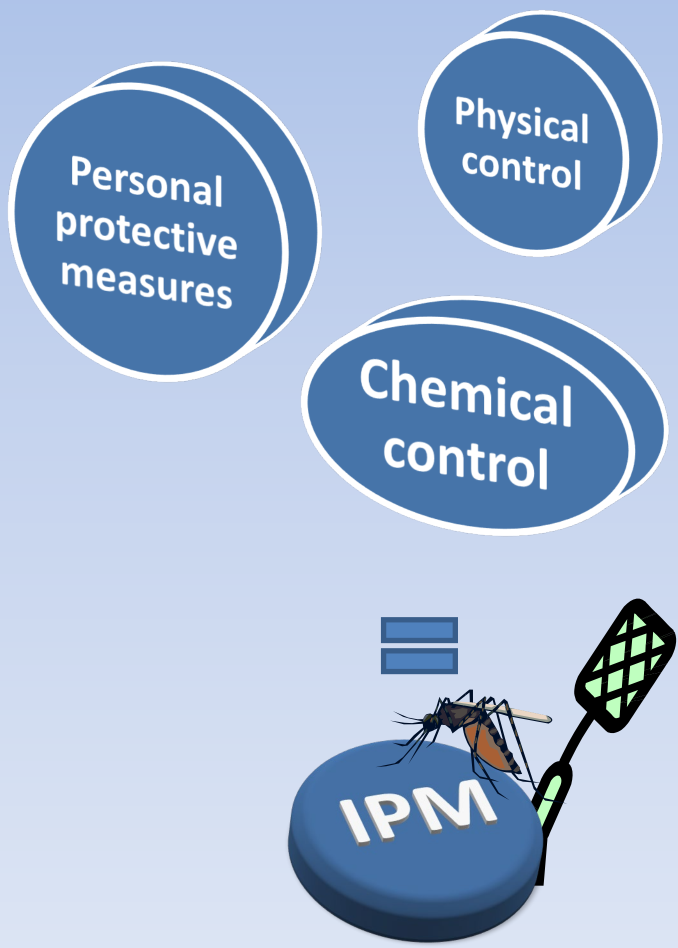
- Personal protective measures are the things individuals can do for themselves and their families to protect them from mosquito bites. The use of mosquito repellents, the wearing of clothing that minimizes the amount of skin exposed to mosquitoes, and avoidance of situations (e.g., being out-of-doors at dusk) are all examples of personal protective measures.



If similar methods are applied by a mosquito abatement agency (establishment of treated barriers, selective vegetation removal, etc.) then the term area protective measures is used.

- There is a philosophy that holds that all these methods should be used in concert for the most ecologically sound method of mosquito control. This philosophy is called integrated pest management (IPM). IPM was first developed as a comprehensive control strategy for agricultural pests, but is now meant to include vectors such as mosquitoes as well.

- Some people favor using the term integrated vector management (IVM) for the application of the comprehensive application of methods to mosquitoes and other vectors.



Natural Regulatory Mechanisms

- Limiting factors can be subdivided into two groups.
- Biological limiting factors: these are caused by the presence of other life forms such as pathogens, parasites, predators, or toxic plants which directly or indirectly impact mosquito survival or mortality.
- Non-biological limiting factors: include a variety of physical properties of the environment that directly or indirectly influence mosquito survival.

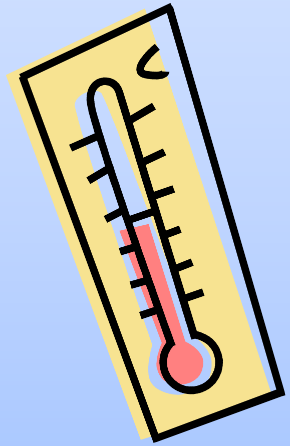
Biological Limiting Factor

- Biological factors important in the regulation of mosquito populations are those sources of mortality created by either competition from other organisms or the presence of pathogens, parasites, vegetation.

  -Both terrestrial and aquatic vegetation are important to mosquitoes, adult mosquitoes use terrestrial plants for resting and for protection from lethal high temperatures. Mosquito larvae use submergent and emergent plants to avoid predation. Adults use vegetation for oviposition sites. *Aedes sierrensis* use tree holes for this purpose.

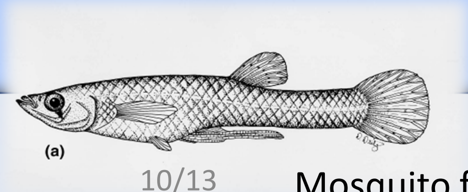
Physical Limiting Factors

- Physical factors include weather and climate, the presence or absence of snow pack, rock holes along stream banks, temperature, salinity, oxygen levels, pH, or water movement.



Types of Mosquito Control

- Chemical control, is the use of insecticides and herbicides to control mosquitoes.
- Physical control, is the alteration and management of large and small areas of the environment in the goal of lowering the mosquito population
- Biological control, is the use of natural enemies to manage mosquito populations.

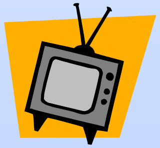


Mosquito fish

Area Protective Measures

- Area protective measures do just what they sound like. They protect large numbers of people in a given area. One way to think about the distinction between mosquito control and area protective measures is that the former is aimed at the direct reduction of mosquito populations, the latter at the protection of people from mosquitoes.

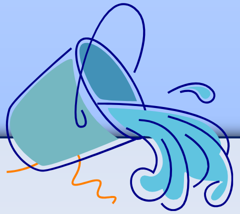
- The promotion of personal protective measures thorough mailings, websites, TV spots, and other media is an example of area protection.



Personal Protective Measures

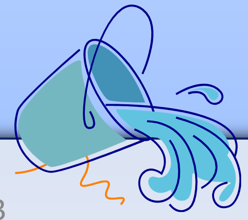
- The use of personal protective measures is the most effective way of protecting yourself from annoyance and diseases caused by mosquitoes.

- Know when the mosquitoes in your area are active seasonally and at what time of day they seek blood meals.
- When adult mosquitoes are present and active, avoid outdoor activity.
- If you must be outside during the time mosquitoes are biting, minimize the amount of skin you expose to mosquitoes. Wear long sleeved shirts or blouses, and trousers or slacks with legs that reach to the shoes.



Personal Protective Measures

- In the early spring, before adult mosquitoes are present, check and repair window and door screens. If doors or windows lack screens, install them.
- If mosquito biting is likely to be especially heavy, apply a mosquito repellent to exposed skin. Use an EPA registered repellent that contains DEET.
- If you are a camper, consider sleeping under a bed net during mosquito season, or use a tent with full netting. Repellents containing permethrin can be sprayed on your netting or clothes, but not directly upon the skin.
- Inspect your yard for sources of standing water. Do not permit water to remain for periods longer than a few days



Chemical Control Of Mosquitoes

Chapter 6

Principles of Insecticide Usage

- Insecticides must be used by trained personnel and after careful planning.
- Use insecticides as a last resort to complement biological, physical or natural controls.
- Apply insecticides in a manner that minimizes harm to non-target organisms. Use insecticides to treat specific sites where mosquitoes that are causing annoyance or creating a public health problem are being produced.
- Apply insecticides selectively to the proper life stage of the mosquito (e.g., egg, larva, pupa, or adult).
- Apply insecticides in a manner that will minimize personal hazard to the applicator and other persons in the vicinity.
- Apply insecticides in accordance with federal and state laws and regulations, and in compliance with the insecticide label.

Insecticides: Larvicides

- Larvicides are insecticides designed to be applied directly to the aquatic habitats of immature mosquitoes.
- Larvicides kill mosquitoes before they develop to the stage where female mosquitoes can suck the blood of humans and other animals, and thus transmit disease organisms.
- Larvicides are easy to apply in a way that makes direct contact with mosquito larvae.
- Generally, only three types of materials are available as larvicides in California: biorational insecticides, larviciding oils, and monomolecular films.

Insecticides: Adulticides

- When the abundance of adult female mosquitoes becomes so high that human discomfort becomes an issue in a large number of people, application of insecticides designed to kill adult mosquitoes often becomes the preferred alternative to larvicides. When outbreaks of human diseases caused by mosquito-borne pathogens occur, adulticides are the only choice.

Herbicides

- Mosquito control technicians frequently use herbicides to kill plants, or inhibit their growth when the plants either contribute to mosquito production, or prevent technicians from being able to control mosquitoes efficiently. Herbicides have been used in association with mosquito abatement operations for many years. In the early 1900s organic materials such as iron sulfate, copper nitrate, and sulfuric acid were used.

Insecticides: Repellents and Attractants

- Repellents are chemicals used to protect humans, livestock, or pets from bloodsucking mosquitoes. The most widely used chemical in repellent formulations is ***N,N*-Diethyl-*meta*toluamide**, or **DEET**.
- Substances that attract immature and adult mosquitoes have several purposes. Traps used for capture of adult female mosquitoes for testing for presence of virus usually contain an attractant.

Classes of Insecticides Used in Mosquito Control

- Organochlorines (chlorinated hydrocarbons)
  - Organochlorines are one of the first groups of insecticides synthesized, and include the well-known insecticide DDT.
  - Although DDT is still used for mosquito control in many tropical areas of the world, especially for malaria control, DDT's registration for nearly all uses was suspended by EPA many years ago, and consequently, it is no longer used for mosquito control in the United States.
- In the U.S., organochlorines are no longer registered for mosquito control.

Classes of Insecticides Used in Mosquito Control

- Organophosphates (OP)
  - Although a few OP formulations remain available for mosquito control, use has dramatically decreased because of resistance to OPs, the potential for non-target effects, and the development of replacement products. Members of this group contain phosphorous in their molecules.
  - Examples of OPs are malathion, naled, and chlorpyrifos.

Classes of Insecticides Used in Mosquito Control

- Pyrethrum
  - Insecticides in this group are natural organic products derived from plants in the genus *Chrysanthemum.* There are about 30 species in the genus, most of which use the generic name as their common name. The insecticide is produced by grinding of the flowers, thus releasing the active component of the insecticide, called **pyrethrin**. Sometimes you will see these insecticides referred to as pyrethrins. Insecticides containing pyrethrin are neurotoxic to nearly all insects. They are harmful to fish, but are far less toxic to mammals and birds. Plus, they do not last long once exposed to sunlight. Pyrethrin containing products are used widely in California for adult mosquito control.

Classes of Insecticides Used in Mosquito Control

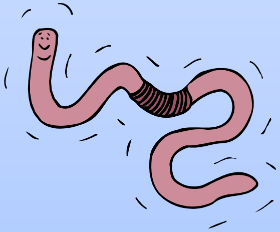
- Pyrethrum
  - Pyrethrin containing products are used widely in California for adult mosquito control. Pyrethrins are usually mixed with PBO (piperonyl butoxide), which acts as a synergist. Synergists are materials that are not necessarily pesticidal by themselves but have the effect of increasing the toxicity of insecticides with which they are mixed. Without PBO, treated insects would be knocked down, but would eventually recover.

Classes of Insecticides Used in Mosquito Control

- Pyrethroids
  - This is a large group of insecticides that have synthetically- produced active ingredients chemically similar to pyrethrin. Many insecticides containing pyrethroids are applied for adult mosquito control.

Classes of Insecticides Used in Mosquito Control

- Biorational Insecticides (Biorational or Bioinsecticides)
  - Biorational insecticides are pesticides that are considered relatively non-toxic to humans and also environmentally safe. The EPA defines biorationals as "certain types of insecticides derived from such natural materials as animals, plants, bacteria, and certain minerals."
  - Biorationals can be divided into two groups.



1. Biochemical – hormones, enzymes, pheromones and natural insect and plant regulators.

2. Microbials- Viruses, bacteria, fungi, protozoa, and nematodes.

Classes of Insecticides Used in Mosquito Control

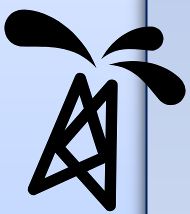
- The action of microbial insecticides is to kill mosquitoes either by toxins released by the microbial organisms or by infection by the organisms.

- Two common insecticides are a bacterial toxin produced by Bti (*Bacillus thuringiensis israelensis)*, and the live bacteria, *Bacillus sphaericus* (Bs).

Materials applied to water surfaces

- Petroleum oils

These products are refined from crude oil and in vector control are used both as carriers for insecticides, and more directly when mixed with a surfactant and applied to the water surface as a suffocating agent against mosquito larvae and pupae.



- Alcohols

This group of materials is for application to bodies of water for control of mosquito larvae (e.g., Agnique®). These materials are used in the form of a monomolecular film, and act by reducing surface tension of the water, eventually leading to the drowning of mosquito larvae and pupae.

Herbicides

- Herbicides are used in mosquito control to clear various types of mosquito aquatic habitats of weeds that provide favorable conditions for larval development.

- Mosquito control technicians should take special care in mixing and applying herbicides, and in learning the proper safety precautions needed for their use.

- Herbicide mixing, storage, and application can pose significant occupational health risks.

Herbicides

- Herbicides can be separated into **organic** or **inorganic** materials. Organic herbicides have a carbon based molecular structure and usually act by altering the normal growth pattern of the plant.

- Organic herbicides may be further divided into two major groups—the petroleum oils and the synthetic organic herbicides.

- Inorganic herbicides are often in the form of salt, or contain a metal that is toxic to plants, often preventing proper uptake of water or inhibiting movement of material across cell walls.

Formulations of Insecticides for Mosquito Control

- Insecticides are nearly always applied in formulations containing other materials.
- Unformulated insecticides are referred to as technical grade, and these are used only by toxicologist and other insecticide chemists or biologists conducting tests on resistance or the susceptibility of non-target organisms.
- All formulations sold in the USA must be labeled with complete instructions and restrictions for use.
- Formulations are nearly always the form in which insecticides are obtained by the mosquito control specialists, and it is the formulation that must be registered, have an EPA registration number, label, and a material safety data sheet.
- The formulation of any insecticide is identified by a letter or letter combination on the product label.

Emulsifiable Concentrates (EC)

- These chemicals consists of concentrated oil solutions of technical grade insecticides combined with an emulsifier, so it can be mixed with water later.
- Emulsifiers are like detergents that allow the suspension of vary small droplets in water to form an emulsion.
- Emulsifiable concentrates are used widely in mosquito control operations, with final water dilutions typically being made in spray tanks. Tank mixes are usually milky in appearance.

Wettable Powders (WP or W)

- These dispersible powders are finely ground, consisting of the active insecticide mixed with other ingredients to aid in the mixing and dispersion of the wettable powders when blended with a liquid, usually water for application by spray equipment. WP's are used most often as larvicides in mosquito abatement operations.

Soluble Powder (SP)

- These powders are similar to wettable powders, except that the active ingredient as well as the diluent and all formulating ingredients are completely soluble in water. SP's are used only as mosquito larvicides.

Granules (G)

- In a granulated formulation, the active ingredient is mixed with various inert clays to form particles of various sizes.
- Granular formulations are intended for direct application without further dilution.
- Granular applications of insecticides are especially useful in treating mosquito larvae in locations where heavy vegetation would prevent the insecticide from reaching the water.

Formulations of Insecticides for Mosquito Control

- Baits

  Baits are not extensively used in mosquito control.

- Aerosols (A)

  Aerosols or “bug bombs” are pressurized cans which contain a small amount of insecticide that is driven through a small nozzle under pressure from an inert gas.

- Flowables (F or L)

  A flowable liquid is usually mixed with water for use in a sprayer. It forms a suspension in water that requires continual agitation.

Formulations of Insecticides for Mosquito Control

- Water-soluble concentrate (WS)

These liquid formulations form true solutions in water and they do not require added agitation once mixed.

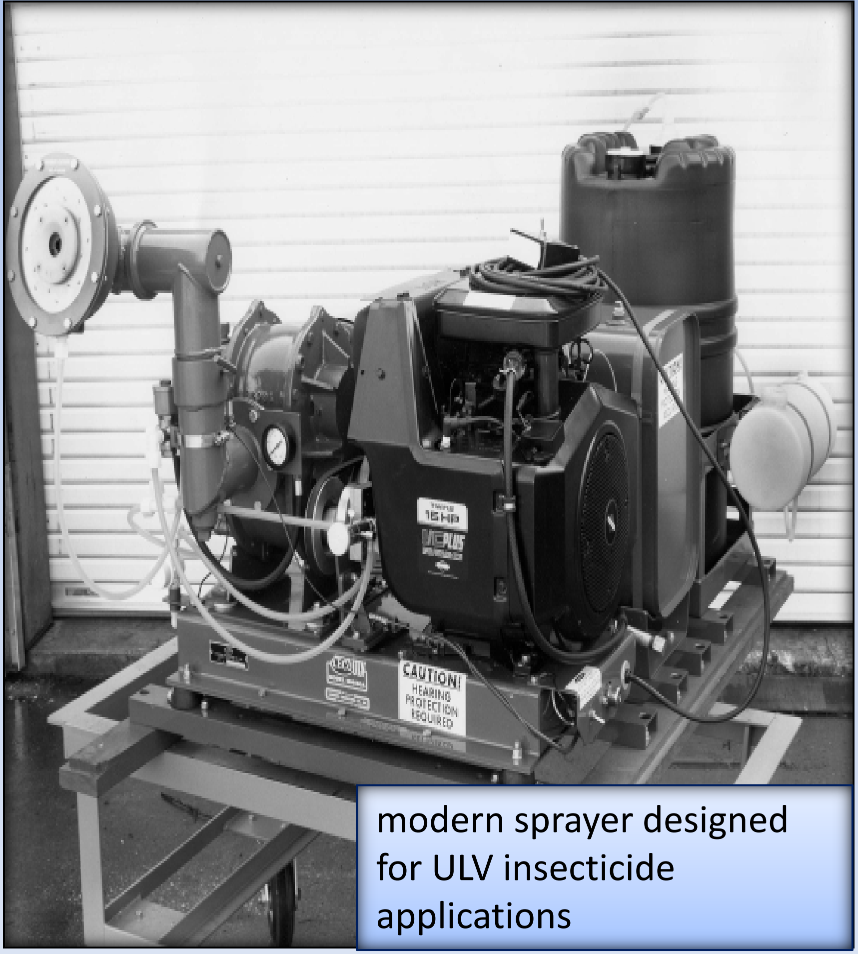
- Ultra-low volume concentrates (ULV)

These are sold as active ingredients in its original liquid form, or product dissolved in a small amount of solvent. The main use in public health is as a mosquito adulticide. ULV applications, when applied correctly are very effective and very safe to people and other non-target organisms. The preferred droplet size is between 10 – 30 microns.

Formulations of Insecticides for Mosquito Control

Fogging concentrates

- Fogging concentrates combine a insecticide with a solvent, with the type of solvent depending upon the type of fogging to be done.
- These formulations are sold only for public health use to control flies and mosquitoes.
- They are applied using special truck-mounted machines called foggers.



modern sprayer designed for ULV insecticide applications

Formulations of Insecticides for Mosquito Control

- Slow or Controlled Release

Some insecticides can be encased in an inert material for a controlled release, resulting in decreased hazard and increased likelihood of the active ingredient reaching the target organism. Sustained released mosquito larvicides are based on this principle.

- Other formulations

Others include formulations for impregnating clothing, bed nets, and curtains in tropical areas for malaria control. Bed nets treated with insecticides are known as ITNs – insecticide treated nets.

Equipment Used in Mosquito Control

- Unpowered Equipment

Generally suitable for relatively small insecticide applications, such as spot treatments of aquatic sites where mosquito larvae are present. Typical unpowered equipment for liquid pesticides includes some backpack and tank sprayers. Some are pressurized by hand while others have a continuously operated pump lever to maintain pressure in the pesticide tank. The typical size is between 1 – 5 gallons.

Insecticides in solid form (granules, slow release briquettes, powders, etc.) can be applied by hand, with small crank operated spreaders, dust cans, or similar devices.

Small, unpowered equipment is inexpensive, simple to use, and easy to clean and store. Small areas (less than an acre) can be treated by a single person in a relatively short amount of time. However, calibration of small unpowered devices can be difficult.

Equipment Used in Mosquito Control

- Ultra Low Volume Sprayers (ULV)

ULV sprayers are designed to apply extremely low volumes of highly concentrated insecticide is the form of very small (5-30 micron) droplets into the air. A micron is equal to 1/25,000 of an inch. ULV sprayers are used primarily against adult female mosquitoes, and require the use of insecticides formulated for this purpose. Most ULV sprayers utilize a small electric pump that can be very finely adjusted.

Effective ULV spraying requires careful attention to weather conditions. The very small droplets of concentrated insecticide tend to drift out of the target zone at high wind speeds. ULV applications generally are not effective at wind speeds over 10 MPH.

Temperature inversions are required for ULV applications. Inversions occur when ground temperatures are lower than those at higher altitudes. Under these conditions, the small particles generated by ULV sprayers remain suspended in the cool air at ground level.

Formulations of Insecticides for Mosquito Control

- Foggers are of two types: thermal foggers use flash heating of an oil solvent to produce a visible plume of vapor or smoke, and cold (ambient) foggers atomize a jet of liquid in a venturi tube under pressure from a high-velocity air stream.

Thermal fogger

- Cold foggers can use insecticides combined with oil, water, or emulsifying agents.

- Thermal foggers were used extensively in mosquito control operations at one time, but they have been largely supplanted with ULV sprayers.

- The design of most cold foggers have evolved into units specialized for use with ULV applications.

Calibration of Insecticide Equipment

- All insecticide labels contain information on allowable application rates. For an insecticide applicator to determine what dose is being applied, the application equipment must first be calibrated.
- There are many things that determine insecticide application rates. Some are related to the proper preparation of the tank mix, but many others are related to the operation, age, and condition of the application equipment.

Calibration of insecticide spray equipment is a legal requirement.
It is a violation of state and federal regulations to apply a insecticide in any manner other than as specified on the label.

Calibration of Insecticide Equipment

Calibration of equipment is important to the success or failure of a insecticide treatment. It is a waste of time and money to apply any insecticide in an inefficient or ineffective manner.

What is Calibration?

- Calibration is the preparation of insecticide spray equipment for spraying to insure that a insecticide is applied uniformly, in the desired area, and with the correct amount of active ingredient. Calibration is the only accurate way to determine that the rate of application is consistent with the label requirements. Careful preparation of tank mix and proper operation of equipment during actual applications are also important factors to an effective and legal treatment.

- Inaccurate insecticide application rates, spray patterns, and droplet size can all lead to ineffective and often illegal insecticide applications. These factors can lead not only to ineffective treatments, but also significant movement from insecticides away from the target area. Studies have shown that three factors stand out in insecticide applications that do not conform to label requirements: inaccurate preparation of tank mixes, worn spray nozzles, and improper calibration of spray equipment.

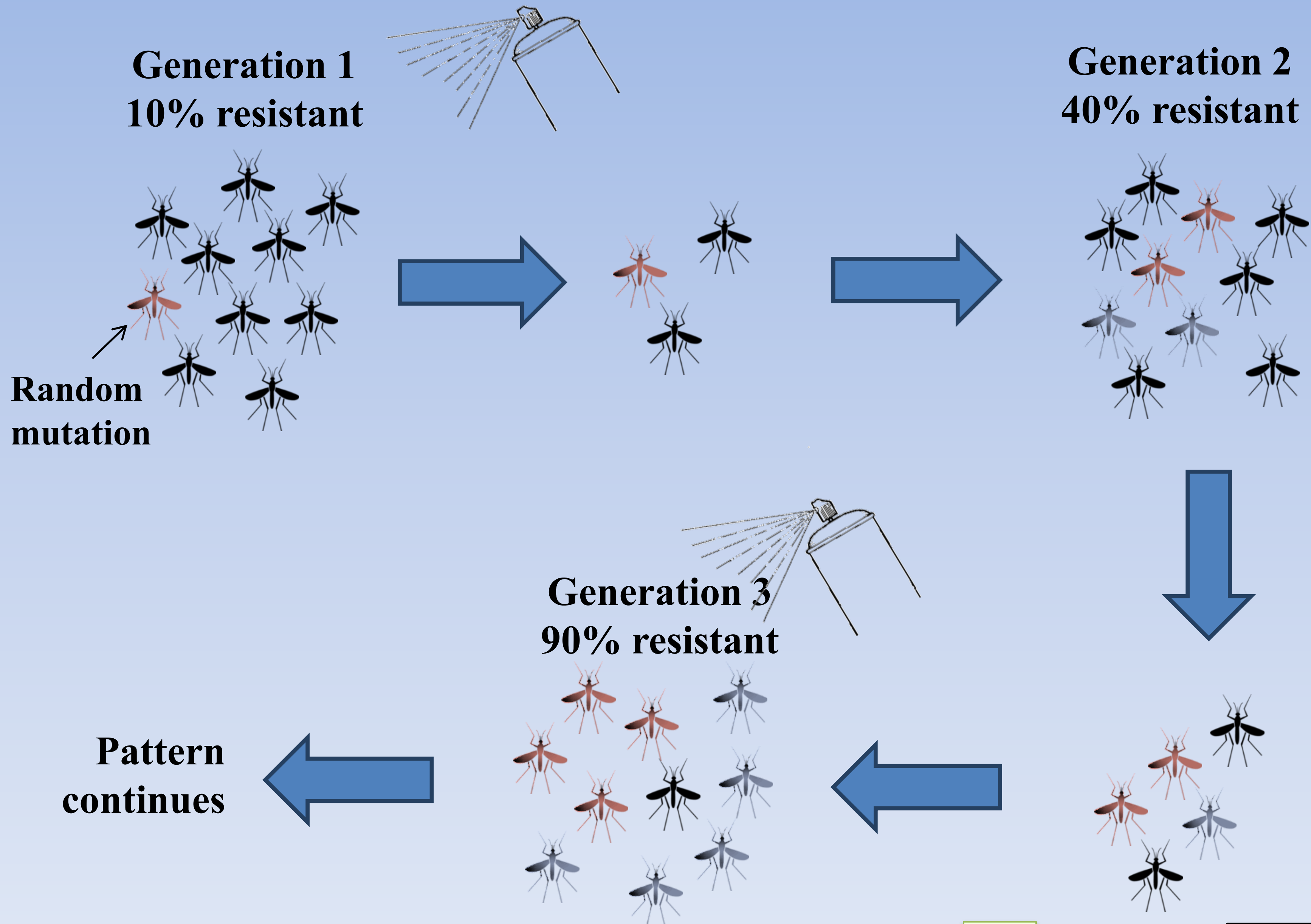
Resistance to Insecticides by Mosquitoes

- Insecticide resistance is the ability of pests to avoid the lethal effects of insecticides.
- Some mosquito populations use one or more different physiological defense methods to endure doses of insecticides that formerly were lethal.
- This can happen either by spontaneous mutations, or because a small number of the mosquitoes carry a gene for the insecticide resistance. Either or, resistance develops slowly to the point where the insecticide applications begin to fail after repeated exposure to the same material.

Resistance to Insecticides by Mosquitoes

- This happens because the mosquitoes that do not carry the gene are killed off and the ones that do carry the resistance gene live on and produce offspring that will also have the gene.
- The repeated exposure to treatment of the same insecticide by a population of mosquitoes that results in a change in the genetic makeup is called selection pressure.
- Knowing the process of the development of insecticide resistance is important to developing methods to avoid it.
- The basic principal is the preservation of susceptible genes in mosquito populations, and the aim to do this is called insecticide resistance management.
- Usually when a pest population becomes resistant to one insecticide it can be controlled by another, especially if it is from a different chemical family.
- Occasionally resistance to insecticides other than the responsible insecticide occurs and this is called cross resistance.

Pesticide as a Selection Pressure



Recognizing Resistance

- Not all mosquito control failures are because of resistance. Improper control practices maybe the reason.
- If the material was timed and applied properly at the recommended rate, and no other important factors have interfered with the insecticide application, resistance should be considered.
- Early signs of resistance can sometimes be seen in the field.
  - Increased difficulty in controlling mosquitoes in a given area.
  - Increased amount of mosquito-borne disease.
- Suspected resistance should be reported to your supervisor immediately so early action can be taken.

Resistance Management

Avoid under-dosing in insecticide applications. If this is done repeatedly it encourages survival of individual pests carrying genes for resistance, especially when the effects of the gene are not absolute (protects only partially).

Do not always treat a given population with the same insecticide. Switch to other products periodically. This is called insecticide rotation.

Test populations of vectors for evidence of resistance, and when it is detected switch to alternate insecticides.

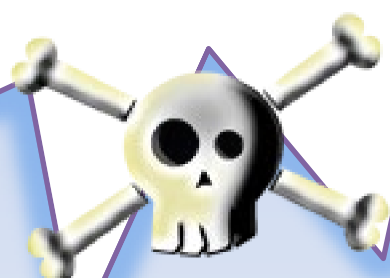
Avoid slow-release applications where pest populations are exposed for long periods of time to sub-lethal doses of one insecticide.

Combine insecticide applications with other forms of pest management such as biological control, habitat alteration, and use of biorational insecticides. The use of biorational insecticides is not a guarantee that resistance to these products will not occur, but resistance to biorational insecticides have been far less common than to conventional insecticides.

Toxicity of Mosquito Control Insecticides to Warm Blooded Animals

"All substances are poisons; there are none which is not a poison. The right dose differentiates a poison and a remedy."

-Paracelsus 1493-1541



Toxicity of Mosquito Control Insecticides to Warm Blooded Animals

- Insecticides are poisons, if they were not they could not be effective in controlling mosquitoes.
- Insecticides vary greatly in the toxicity hazard they represent to humans and domestic animals.
- Data from poison control centers in the USA show that deaths resulting from poisonings from insecticide exposure represent a relatively small proportion of total number of poison-related deaths.

Insecticide Toxicity and Hazards

- In terms of insecticide safety, there is an important difference between the words “**toxicity**” and “**hazard**”.
- Toxicity refers to natural poisonous potency of a material. Toxicity is evaluated in toxicology laboratories and is always expressed in quantitative terms such as LC_{50} (lethal concentration -50, the concentration at 50% of the reference organism).
- Hazard means the risk of poisoning when materials is used. Hazard depends not only on the toxicity of a material, but also on the risk of toxic exposure when used.
- Remember that toxicity is the capacity of a substance to produce illness or death, hazard is a function of toxicity and exposure.

Types of Toxicity

Toxicity may be divided into four types, based on the number of exposures to a poison and the time it takes for toxic symptoms to develop. The four types of toxicity based on exposure are:

- **Acute**, when a person suffers illness as the result of a single dose of a insecticide, it is referred to as an acute exposure.
- **Chronic**, when there is repeated or continuous exposure to a insecticide by a person, it is called chronic exposure.
- **Sub-chronic**, when there has been repeated or continuous exposure to a insecticide, but no measurable toxic affects have resulted, a person is said to have been subjected to sub-chronic exposure.
- **Delayed**, delayed toxicity may occur many years after exposure to a chemical and is most often only discovered in retrospective epidemiological studies (studies done after the fact.)

Route of Entry

- There are four common ways in which insecticides can enter the human body: through the skin, the mouth, the lungs, and the eyes.

Dermal. Absorption through the skin is the most common route by which insecticide applicators are poisoned by insecticides and other chemicals. This is called dermal exposure. Dermal absorption may occur as a result of a splash, spill, or drift when mixing, loading or disposing of insecticides.

Oral. If enough insecticide gets into the mouth, it may cause serious illness, severe injury, or even death. Insecticides may be consumed through carelessness or they may be consumed by individuals who are intent on personal harm.

Route of Entry

Respiratory. Insecticides are sometimes inhaled in sufficient amounts to cause serious damage to nose, throat, and lung tissues. The hazard of respiratory exposure is great because of the potentially rapid absorption of insecticides through this route. Vapors and extremely fine particles have the greatest potential for poisoning via respiratory exposure.

Ocular. Eyes are particularly absorbent, and therefore getting any insecticide in the eye presents an immediate threat of blindness, illness, or even death. Eye protection is always needed when measuring or mixing concentrated and highly toxic insecticides. Eye protection also should be used when there is a risk of exposure to dilute spray or dusts that may drift into the eyes.

Measurements of Toxicity

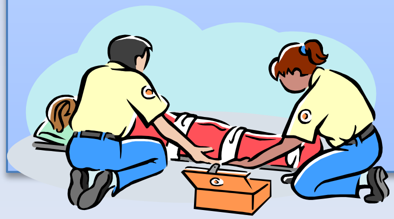
- The standard unit used to describe dosage in toxicity tests of insecticides are the LD_{50}, expressed as mg/kg of body weight.
- This figure refers to the number of mg of a chemical that will kill 50% of a group of test animals. It should be remembered that **the smaller the number, the more toxic the chemical tested**.
- The chemical with a small LD_{50} (such as 5 mg/kg) is very dangerous.
- The chemical with a large LD_{50} (1,000 to 5,000 mg/kg) is not very dangerous.

How Insecticides Affect Humans

- The exact way that insecticide poisoning can affect humans and the degree to which certain segments of the human population can be affected are not completely understood. However, the signs and symptoms of acute insecticide poisoning are well known.
- **Symptoms** are what a person feels and can express to others. Examples: pain, nausea.
- **Signs** are things one person can observe in another person, even if that person is unconscious. Examples: Redness of skin, swelling, hot and dry skin.

How Insecticides Affect Humans

Early recognition of the signs and symptoms of insecticide poisoning, and immediate and complete removal of the source of exposure may save a person's life. This is especially critical if the person is unconscious, or otherwise unable to communicate clearly.



Symptoms of Insecticide Poisoning

- Organophosphate, carbamate, and organochlorine insecticide use has dramatically declined or been eliminated in mosquito control operations in California. However, because some products with a high potential for human poisoning fall into these groups, the signs and symptoms associated with poisoning should be well known to insecticide applicators.

Organophosphate Insecticides

- Organophosphate poisons attach themselves to a chemical in the blood that is normally present and necessary for proper nerve functioning. This chemical is the enzyme cholinesterase.
- The organophosphate insecticide binds to the enzyme and makes it unavailable to make nerve connections. When this occurs the nerves in the body fail to send messages to the muscles properly. The muscles may receive continual or erratic stimulation, leading to twitching, tremors, or constant contractions. In cases of severe poisoning quick and proper medical treatment may reverse the effects of the poisoning, and the life of a person may be saved.

Blood Test for Operators

- California regulations require medical supervision of workers whose responsibilities expose them to insecticides known to have the potential to inhibit blood cholinesterase levels (e.g. organophosphates).
  (section 6728, health and safety code)
- The enforcement of this program is the responsibility of the California Department of Insecticide Regulation (DPR).

Organochlorine Insecticides

- Most compounds in this group are no longer registered for public health use in California. The organochlorines act on the central nervous system.

- Many of these compounds can be stored in the fatty tissues as a result of either large single doses or of repeated small doses.

Botanical Insecticides

- Insecticides derived from plants vary greatly in their chemical structure and also in their toxicity to humans. The toxicity of these pesticides ranges from pyrethrum, which is one of the least toxic of all insecticides to mammals, to strychnine, one of the most toxic.

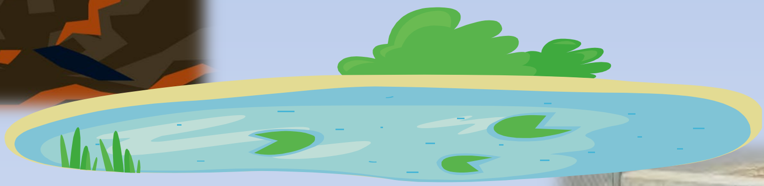
Toxicity of Selected Insecticides for Humans

Chemical Class	Insecticide	LD_{50} (mg/kg)
Organochlorines	Methoxychlor DDT	Oral/ Dermal 6,000/6,000 118/2,510
Organophosphates	temephos (Abate) malathion (Cythion) naled (Dibrom) fenthion (Baytex) chlorpyrifos (Dursban) dichlorvos (DDVP, Vapona) parathion, methyl parathion, ethyl	1,000/4,000 1,000/4,444 250/800 245/330 82/202 56/75 24/67 3.6/6.8
Botanicals	pyrethrum	>5,000 />2,000
Biochemicals	methoprene (Altosid) diflubenzuron (Dimilin)	34,600/>5,000 >4,640/> 1,860
Microbials	Bti (Teknar)	30,000/-
Pyrethroids	Resmethrin (Scourge)	2,700/ >2,000

Insecticide Toxicity Categories and Acute Toxicity Values

Category	Toxicity	Signal word required on label	LD_{50} (mg/kg) Oral and Dermal; µ/l, respiratory route		
			Oral	Dermal	Respiratory
I	High	Danger	0-50	0-200	0-2,000
II	Moderate	Warning	50-500	200-2,000	2,000-20,000
III	Low	Caution	> 500	> 2,000	> 20,000

Physical Control of Mosquitoes



Chapter 7

Physical Control of Mosquitoes

Physical Control of Mosquitoes in Natural Sources

Physical Control of Urban Residential Sources

Physical Control of Mosquitoes from Agricultural Sources

Physical Control of Mosquitoes in Large Water Storage and Conveyance Structures

Physical Control of Mosquitoes

- Some of the earliest forms of mosquito abatement were examples of physical control. For example, the methods used to control mosquitoes that transmitted yellow fever **virus** and malaria parasites in Central America during the building of the Panama Canal were physical control methods. Physical control of mosquitoes essentially is the modification of the environment in a way that reduces the number of mosquito breeding sites.

- Physical control often is integrated with chemical or biological control in successful IPM programs. In some instances, physical control by itself is sufficient to effectively reduce mosquito populations. Examples of physical control measures include draining of a pond, grading of an agricultural field to eliminate pools of standing water, or conversion of a swamp to farmland. California mosquito control agencies employing earth moving equipment to eliminate troublesome mosquito sources have demonstrated that well designed projects can benefit agriculture, the environment, and mosquito control mutually.

Physical Control of Mosquitoes

- Physical control may be as simple as shutting off the flow of irrigation water at the optimum time to prevent standing water. Conversely, it may be complex, requiring a detailed plan. Major projects usually involve other agencies and require activities such as aerial surveys, filling, grading, and ditching. Maintenance requirements of projects after completion can include ditch clearing, repairing water gates, or restoration of dikes.

Examples of Physical Control Measures

- Agricultural fields with low spots that hold irrigation water can be leveled more accurately with inexpensive modern, laser leveling systems. This prevents accumulation of irrigation pools where mosquito larvae may develop and enhances drainage of excess irrigation water.

- Marshes may be modified so that upland areas are periodically flushed with saline water, eliminating development of freshwater mosquito species.

- Artificial permanent or semi-permanent bodies of water may be kept mosquito free by modifying their banks to eliminate shallow regions with emergent vegetation where mosquito larvae can avoid predators.

- Engineered storm water structures for flood control and pollution mitigation can be designed and maintained to drain rapidly and completely to prevent mosquito production.

- Artificial structures for holding drainage water from highways may be designed in ways to avoid holding the water for periods long enough to permit completion of mosquito development. These structures are known as "Best Management Practices (BMPs)."

Constraints to Physical Mosquito Control Measures

- In the early 20th century, there were few objections to the physical methods used to eliminate mosquito breeding.

- Currently, a variety of public agencies have statutory regulatory responsibilities for water-related ecosystems these include streams, rivers, lakes, marshes, vernal pools, and neglected storm water storage and conveyance systems. Some of these agencies include the U.S. Army Corps of Engineers, U.S. Fish and Wildlife Service, the U.S. Environmental Protection Agency, and various state agencies.

- Mosquito control agencies now prepare plans in advance annually for any work planned involving mosquito control in waters under jurisdiction of the aforementioned resource agencies for their review and approval.

Physical Control of Urban Residential Sources

- Urban residential sources of mosquito breeding include ornamental ponds, neglected swimming pools and spas, runoff pools from over-irrigated landscape or leaking plumbing, clogged rain gutters, and faulty septic systems. Finding mosquito sources in residential areas requires intensive and frequent inspections. Swimming pools in unoccupied residences can be a problem for mosquito control programs during economic downturns.
- The species of mosquitoes that often emanate from these kinds of sources are also **vectors** of serious disease organisms such as WNV and SLE.
- The usual physical control methods that must be employed to solve urban residential mosquito problems involve maintenance, repair, and proper water management. The question of who will pay for these actions often leads to legal action.

Physical Control of Mosquitoes from Community, Commercial and Industrial Sources

- Large industrial facilities may have various types of holding ponds and other facilities for handling of liquid waste from manufacturing or processing activities.

- The usual involvement for mosquito abatement district personnel is to monitor and identify mosquito problems, and to advise the management on ways to eliminate the problem. Most commercial managers strive to be good public citizens, especially when their facilities are close to population centers.

- Publicly-owned facilities that may cause mosquito problems include gutters, catch basins, and culverts associated with public streets , community sewage disposal facilities, and public lakes and reservoirs.

Physical Control of Mosquitoes from Community, Commercial and Industrial Sources

- Some of the design features of drainage structures that tend to minimize mosquito breeding are:
  - Are free of small coves
  - Are large enough for wind to cause wave action
  - Are deep enough to discourage growth of emergent vegetation
  - Have steep inner levee faces to limit growth of shoreline vegetation
  - Are not loaded with organic wastes in the form of floating solids or vegetation
  - Are well maintained

Physical Control of Mosquitoes from Community, Commercial and Industrial Sources

- Mosquitoes associated with street and road structures for the capture and conveyance of storm-water and water from melted snow traditionally have been one of the biggest challenges for local agencies. Chemical control methods are expensive, tedious, and short-lived.
- Strategies have been adopted, including steep channels that cause flushing of immature mosquitoes.
- Since the early 2000's, all new construction (i.e., commercial and industrial buildings and residential housing tracts) must comply with federal and state clean water laws that mandate the proper management of storm-water and urban runoff.
- Mosquito control programs will need to become familiar with the structure and function of different storm-water systems and forge relationships with the local planning agency to obtain details of location.

Physical Control of Mosquitoes in Natural Sources

- Prior to the extensive water resource projects and land developments which now characterize California, mosquito problems mainly were related to natural sources such as swamps, marshes, river flood plains, and vernal pools.
- Fortunately, natural sources of water do not present as many mosquito problems as do artificial sources. This is because natural sources often contain fish and other mosquito predators, have free-flowing water not conducive to mosquito development, and often do not represent a rich source of food for mosquito larvae. However, there are notable exceptions this, such as river flood plains and flooded tree holes.
- Where significant problems with mosquitoes do occur in natural wetlands, solutions are usually complicated and arrived at only after considerable coordination with the various local and regional agencies having jurisdiction of some kind.

Salt Marshes

- Marshes are wetlands that are subject to frequent or continuous flooding. They are similar to swamps, but differ in that swamps are usually characterized by woody vegetation (e.g., mangrove swamps) whereas marshes typically feature grasses, rushes, reeds, typhas, sedges, and other herbaceous plants.

A coastal salt marsh with water flow restricted by trash.

- Salt marshes represent a special type of marsh that is found along coasts of oceans and bays in the intertidal zone between land and the sea. Salt marshes are usually associated with estuaries or bays, which in turn have shores consisting of mudflats and sandflats.

- Typical animals include mosquitoes such as *Aedes squamiger* and *Ae. dorsalis*. Because these species are aggressive human biters, salt marshes are of great concern to coastal mosquito abatement agencies. The challenge to mosquito abatement agencies is to address mosquito problems in ways that preserve the valuable characteristics of the marsh ecosystem while minimizing the production of biting mosquitoes.

Open Circulation Marshes

- It has been known for many years that ditching of salt marshes to increase tidal circulation helps reduce mosquito populations. Studies have shown that the increased tidal flushing increases fish diversity and density by improving fish access from tidal channels. This has a negative impact on mosquito populations through predation by fish, but a positive impact on other animals such as salt marsh song sparrows.

- Although ecologists often prefer to rely on natural marsh channels for tidal flushing, most recognize that well-planned ditching is preferable to application of insecticides for mosquito control.

Restricted Circulation Marshes

- When tidewater circulation is restricted due to a low **tidal prism** (=tidal volume) ditching may not be effective in reducing larval mosquito populations. Low tidal prisms may be due to artificial marsh obstructions such as roads, berms, inoperative tidal gates, or plugged culverts, or to natural deficiencies in water courses.

- In many cases, mosquito control may be achieved by removing restrictions: repairing tide gates, clearing existing or installing larger culverts, and installing new ditches to supplement natural water courses.

Impoundments

- Impoundments are areas in a salt marsh created by construction of earthen dikes that allow the areas to be artificially flooded during the mosquito breeding season. Most salt marsh mosquitoes will not lay their eggs upon standing water. Instead, they oviposit upon moist soil; and the eggs hatch when flooded by tides or rainfall. Thus impoundments may eliminate mosquito production from the area without having to use pesticides.

- Impoundments were once used extensively for mosquito control, but are seldom used today. The construction of dikes and the installation of maintenance structures are more expensive than managing marsh circulation, and marsh ecologists object to the significant changes in marsh flora and fauna that often accompany impounding.

Modern Marsh Management

- In the late 1800s and early 1900s, thousands of acres of salt marsh in California were converted to other types of land use though draining and filling. This was before the valuable role of salt marshes in the ecosystem was appreciated. Now, the emphasis is on comprehensive management of salt marshes in ways that meet multiple goals, including mosquito abatement.

- Federal, state and local legislation dictates that each proposed management activity meet standards for careful engineering and biological surveys and that the impact upon the environment be assessed before projects are undertaken.

Physical Control of Mosquitoes from Agricultural Sources

- The primary mosquito production problems of agricultural areas result during the application of irrigation water to crops and the drainage and storage of wastewater.

- Mosquito problems may arise with both large scale operations and small family farms. Generally, mosquito production in agricultural operations are most pronounced in areas where crops are irrigated. However, even in dry-farming areas, problems can be created in connection with stock ponds, wastewater ponds, and other water-holding activities.

Physical Control of Mosquitoes from Agricultural Sources

- The degree to which irrigation and drainage contribute to mosquito problems depends upon a number of factors. These factors include:

- Soil type and characteristics/Type of crop
- Water quality/Crop water requirements
- Ground slope/Management of intercrop periods
- Farm irrigation delivery and control systems/Water table
- Irrigation methods/Subsurface and surface drainage
- Soil intake rates (permeability)/Soil fertility
- Soil compaction/Soil sealing (bacterial, sedimentation)
- Presence of hardpan/Soil chemistry
- Cultivation practices/Soil temperature ranges

Physical Control of Mosquitoes from Agricultural Sources

- Proper drainage of excess surface water is essential to the prevention of mosquito problems. Even if draining practices are sound, it is necessary to maintain ditches and other structures for conveyance of drainage water in good order to prevent ponding sufficient to allow development of mosquitoes.

- Proper drainage of surface water depends on properly terraced and graded fields. This has become easier and more efficient with the advent of laser leveling systems

Flooded Agricultural Crops

- Rice fields and irrigated pastures are two crops that present enormous challenges to mosquito control agencies because both often involve flooding with irrigation water for long periods.

- Mosquitofish may come in with the irrigation water or may be added by mosquito control agencies, but they rarely distribute to all parts of the fields unless present in large numbers.

- The first irrigation of the season typically results in a generation of *Aedes* mosquitoes that develops rapidly in the absence of predators. Subsequently, *Culex* and *Anopheles* mosquitoes lay eggs and replace the emerged *Aedes*.

- Many physical methods have been used to reduce the numbers of mosquitoes produced in these crops. Timing of flooding is probably the most effective. Sometimes a delay in flooding of just a week or so can make a profound difference in mosquito development.

Intermittently Irrigated Crops

- Mosquito breeding in crops that are furrow or sprinkler irrigated can also produce mosquitoes. Alfalfa, cotton, corn, orchards, vineyards and date groves are among irrigated crops that frequently cause problems.
- Listed are some recommendations employed in applicable situations to improve irrigation water management and reduce mosquito production. These have been summarized from the recommendations of the Soil Conservation Service.

- Re-grade fields to proper slopes of 0.1-0.3 foot per 100 feet and eliminate irrigation grade reversals causing water to pond.
- Continue the slope to the end of the strip by eliminating the level section at the end of the irrigation run
- Reorganize irrigation systems allowing better control of water.
- Change method/direction of irrigation.
- Adjust delivery based on soil intake rate and length of run.
- Apply soil amendments
- Select the proper plants for the soil.
- Rotate grazing and eliminate cultivation or grazing of fields when they are wet.

Physical Control of Mosquitoes in Large Water Storage and Conveyance Structures

- As of 2014, California had over 1,400 dams and 1,300 named reservoirs with a maximum storage capacity of more than 38 million acre feet of water, of which 80% was used for irrigation.

- Reservoirs and their conveyance structures can be important sources of mosquitoes. However, large reservoirs and their associated concrete-lined ditches rarely present mosquito problems because standards of maintenance are usually very high, and the usual situations that promote mosquito breeding (clogged ditches, shorelines with emergent vegetation, etc.) usually are not present.

- Older dams and reservoirs can present problems with mosquitoes because of general aging and gradual deterioration of concrete surfaces.

- Reservoirs are filled each winter and spring as the runoff from higher land occurs and drawn upon later during summer and autumn. The area of drawdown around the margins of the reservoir between the surface elevations of maximum and minimum storage is called the zone of fluctuation. Where low areas in this zone retain water as the surface elevation is lowered, mosquitoes can breed unless cuts are made in the low ends of the depressions to make them self-draining.

Future Trends in Physical Control

- It is safe to say that there will never be a return to the days of wholesale destruction of wetlands in California or elsewhere. This is true of cases where the destruction was for the purpose of highway construction, creation of housing tracts, and other developments, and it is also true in the case of physical control for mosquito abatement. Federal and state laws now regulate changes that are permitted in wetlands, and even small projects require environmental impact assessments and review by a number of agencies and interested individual citizens.

- Another likely trend will be a continual reduction in the role of insecticides in mosquito control in wetlands. Accompanying this trend will be greater emphasis on wetlands management for mosquito abatement, which is simply modern physical control.

Biological Control of Mosquitoes

Chapter 8

Biological Control of Mosquitoes

Biological Control by Introduction of Natural Enemies

Microbial Organisms for Mosquito Control

Autocidal Control

Genetic Control

Biological Control of Mosquitoes

- Biological Control (BC) is the use of natural enemies to manage mosquito populations. There are several types of biological control including the direct introduction of parasites, pathogens, and predators to target mosquitoes.

Biological Control of Mosquitoes

- These introductions are of two types:
  - Inoculative, are single small introductions of natural enemies, followed by their semi-permanent establishment in the environment.
  - Inundative, are multiple releases of large numbers (often millions of individuals). In most field trials inundative releases have been more successful than inoculative ones.

Biological Control of Mosquitoes

- Microbial pathogens of mosquitoes include viruses, bacteria, fungi, protozoa, nematodes, and microsporidia.
- Biological mosquito control techniques has almost been totally directed at larvae.

Infecting *Cx. quinquefasciatus* with parasitic nematodes

- The management of habitats to conserve natural enemies of mosquitoes is important in mosquito control operations.
- With an expanded definition of BC to include toxins of microorganisms we can include the insecticide *Bacillus thuringiensis israelensis (Bti)* which can be both a BC and a biorational insecticide.

Biological Control by Introduction of Natural Enemies

- The most commonly-used species is *Gambusia affinis* (mosquitofish). This species is the most widely distributed fish worldwide for mosquito control. Carp and minnows have been effectively used as well.
- *Gambusia affinis* is not native to California, its natural geographic distribution is the south eastern USA. This species cannot survive the winter in many colder areas and must be re-introduced to mosquito habitats.
- *Gambusia affinis* has been used with great success against mosquitoes that breed in swimming pools, bird baths, and similar artificial water structures.
- Some mosquito abatement districts have developed large-scale rearing facilities for mosquitofish, but it needs to be remembered that they are not a native fish to California and their use is discouraged in some open water areas because they tend to attack young individuals of native fish species.

Microbial Organisms for Mosquito Control

- Microbial organisms *Bacillus thuringiensis israelensis* (Bti) and *Bacillus sphaericus* (Bs) contain characteristics of both microbial and BC agents

- Bti kills mosquito larvae when they ingest crystalline toxins produced by the bacteria. The toxin interferes with the larvae's digestion. Bs also produces toxins and larvae can suffer lethal effects from the infection.

Other Organisms Tested as BC Agents Against Mosquitoes

- Copepods, fungi (genus *Coelomomyces*), *Lagenidium* have been studied as BC agents against mosquitoes.
- Other organisms that are studied are mermithid nematodes (parasitic roundworms), *Planaria* (flatworms), and tadpole shrimp.
- Some California mosquito abatement districts with well established biological control programs do have successful operations for a few of these agents.

Autocidal Control

- Autocidal, means by which an organism kills or harms themselves.

- Related to pest control it means a way where sterile or genetically altered insects of a species is released to reduce the breeding success of a particular population.

- How autocidal control is carried out involves the rearing of large numbers of male insects, followed by their sterilization by means of either radiation or chemicals. Once sterilized these males are released to mate with the wild females resulting in a lack of fertile offspring.

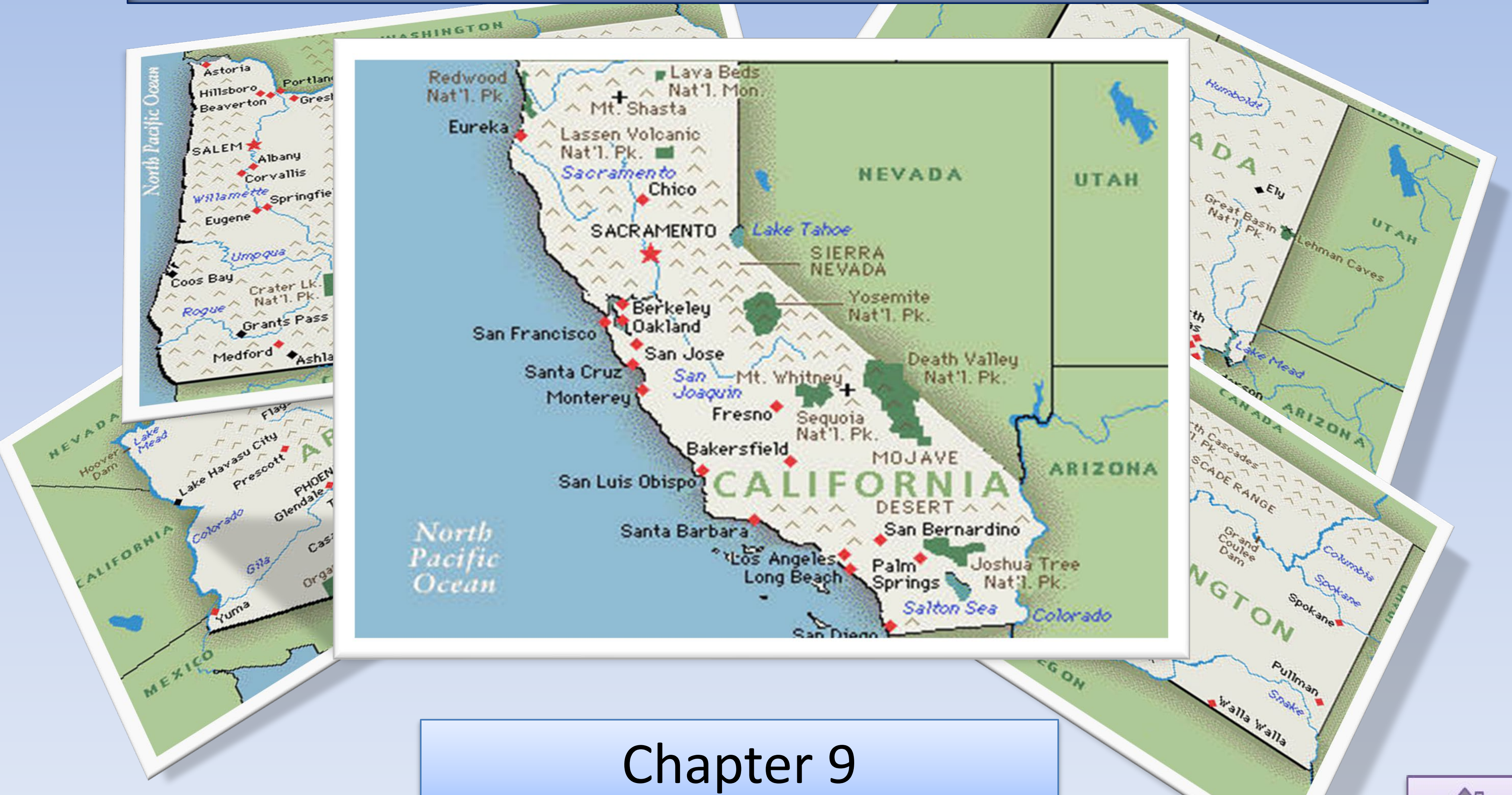
- Over time and repeated releases of the sterile males the natural (wild) population would decrease.

Genetic Control

- The autocidal design used to sterilize male pest insects are not considered genetic methods because there is not a change in the genes of the wild populations.

- In the area of genetics presently there is a active and exciting area of research for the future in not just mosquitoes but other arthropod vectors as well.

Mosquito Control in California



Chapter 9

Principal California Agencies Involved with Mosquitoes

Approaches to Mosquito Control in California

The Future of Mosquito Control in California

Principal California Agencies Involved with Mosquitoes

- Mosquito control in California is carried out by more than 70 local agencies, including mosquito and **vector** control districts, environmental health departments, and county health departments.
- As of April 2021, 63 of these agencies are members of the Mosquito and Vector Control Association of California (MVCAC).
- The objective of MVCAC is to promote cooperation among agencies and personnel involved in mosquito control and related subjects, to stimulate improved mosquito control methods, and to disseminate information about mosquito control.

Principal California Agencies Involved with Mosquitoes

- State organizations cooperate closely with local agencies conducting mosquito control. The California Department of Public Health (CDPH) provides many services to local agencies and to the public in connection with mosquito problems.

- Some of their activities include provision of technical support to agencies on mosquito control operations, testing and certification of public health pesticide applicators, coordination of a statewide mosquito-borne arbovirus disease surveillance program, performance of epidemiological investigations of human disease cases associated with mosquitoes, and coordination and participation in a regional emergency response in conjunction with the California Office of Emergency Services.

Principal California Agencies Involved with Mosquitoes

The Cooperative Agreement, is an agreement between CDPH and local agencies that agree to certain standards of operation whereby CDPH assumes responsibility for certain functions pertaining to the application of state laws and regulations pertaining to pesticide use for vector control by the districts.

Cooperating agencies agree to calibrate pesticide application equipment, maintain records of pesticide applications, submit pesticide applications and adverse pesticide application effects reports to the County Agricultural Commissioners, certify pesticide applicators, and submit to periodic inspections to insure agency activities are in compliance with state laws and regulations pertaining to pesticide use.

Principal California Agencies Involved with Mosquitoes

- The University of California (UC) also participates in mosquito-orientated activities. UC provides education in subjects related to medical entomology and vector biology, and many of these subjects have considerable content related to the biology and control of mosquitoes. UC also has the responsibility for research and development in mosquito biology and control. UC cooperates closely with CDPH and MVCAC in their research and development programs.

Approaches to Mosquito Control in California

- The basic approach to mosquito control in California is the control of mosquito larvae. This is accomplished through physical, biological, and chemical control methods.

- Mosquito control in California now is vastly safer and environmentally friendlier than it was just 50 to 60 years ago.

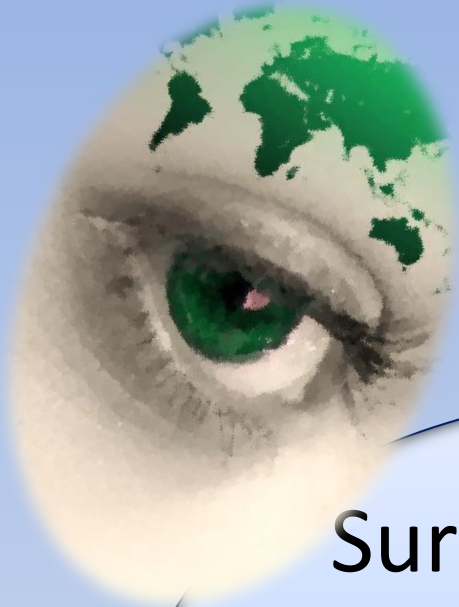
Approaches to Mosquito Control in California

The most important improvements to mosquito control in California are due to.....

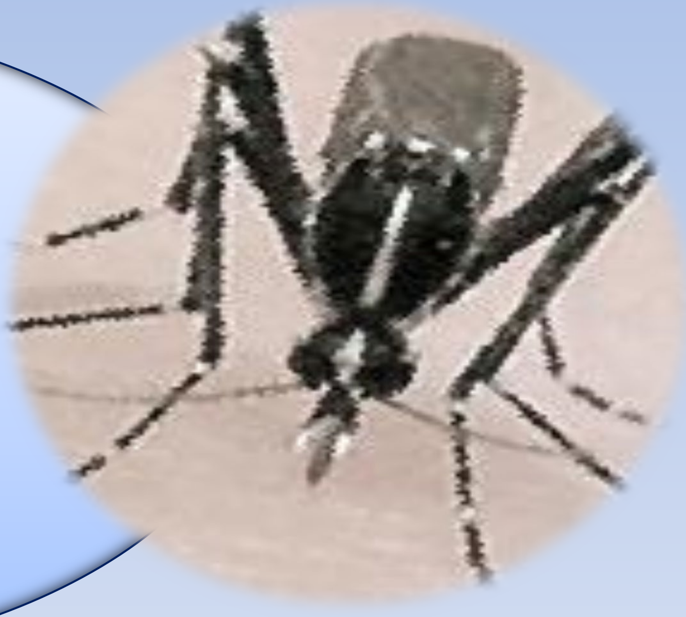
- The movement away from conventional persistent insecticides, such as organochlorines, organophosphates. The replacements for these comes from biorational insecticides.
- The development of improved pesticide dispersal equipment permitting sharply targeted applications and fine control over dosage.
- The creation of interagency cooperation to construct water conveyance structures in ways that minimize mosquito breeding.
- The adoption of comprehensive surveillance programs of both mosquito-borne disease and for the population of mosquitoes.

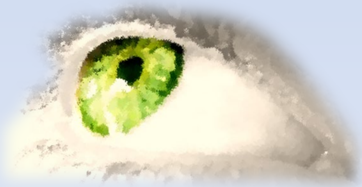
The Future of Mosquito Control in California

- Mosquitoes will continue to be a problem for the people of California.
- The emphasis on biorational insecticides to control mosquitoes will continue.
- Mosquito control technicians will continue to serve as educators of the public in mosquito control procedures and help the public understand the difference between conventional and biorational materials.
- The demand for training and certification of pesticide technicians will be continued and strengthened along with the advancements in mosquito control technology.



Surveillance for Mosquitoes and Mosquito-borne Diseases





Chapter 10

Surveillance for Mosquitoes and Mosquito-Borne Diseases

- Arboviruses
  - Surveillance for both human and equine diseases caused by infection with mosquito-borne arboviruses has been carried out in California for more than 80 years. Surveillance has been expanded to include arboviral infection in wild and sentinel vertebrates, and in wild caught mosquitoes.
  - CDPH, UC and the 60+ mosquito abatement agencies have a cooperative venture each managing a portion of surveillance activities.
    - CDPH manages the arbovirus program (reporting of results, and testing of surveillance samples)
    - UC conducts research on new surveillance testing and reporting methodology.
    - Mosquito abatement agencies, collect biological sampling for testing.

Surveillance for Mosquitoes and Mosquito-Borne Diseases

- Before 2000, the primary focus of the surveillance program was the two most important arboviruses in the state, WEE and SLE. The detection of WNV in New York in 1999 prompted a review and expansion of surveillance guidelines in California, and consequently, when WNV arrived in California in 2003, state agencies were well-prepared for its detection and monitoring.

Surveillance for Mosquitoes and Mosquito-Borne Diseases

The current surveillance plan is described completely in the "California Mosquito-borne Virus Surveillance and Response Plan" published by CDPH, UC and MVCAC.

An additional surveillance and response plan "Operational Plan for Emergency Response to Mosquito-borne Disease Outbreaks".

Analysis of Climate Variation

- Disease ecologists have observed that various weather factors tend to presage peaks of arboviral activity in North America.
- The work conducted by many individuals and agencies in California has advanced useful predictive models for arboviral activity based on climate forecasts.

Mosquito Abundance

- Mosquito abundance can be estimated by sampling larval and adult mosquitoes. This information helps abatement agencies with deciding what types of control activities should be taken.
- Mosquito larvae are sampled by use of a long-handled ladle called a “dipper.” Technicians sample small bodies of water and count the number of larvae appearing in the dipper as well as the number of dips. This is called larval density.
- Larval density is calculated by dividing the total number of larvae appearing in the dipper, divided by the total number of dips.
- High number of larvae do not always equal high numbers of adults because of mortality factors.

Mosquito Abundance

- Guidelines for adult mosquito surveillance are contained in the publication "Integrated Mosquito Surveillance Guidelines"
- Several methods are used to estimate adult abundance. The most common and oldest method is the New Jersey light trap. The trap needs a 110V power source, but little attention is needed after it is installed. For the estimation of Mosquito abundance is a nightly count of captured mosquitoes broken-down by species.

Example:
10 traps were operated for 5 night each, and the total number trapped was 73,234 and 23,678.
Cx. tarsalis: 73,234/10 X 5=
1,465 female per night.
Ae. melanimom: 23,678/10 X 5=
474 females per night

Mosquito Abundance

- Carbon-dioxide traps are used for both estimates of adult mosquito abundance and for collection of female mosquitoes for virus testing.
- Carbon-dioxide (dry ice) baited traps are small, light, battery powered, and portable.

Mosquito Abundance

- Gravid females of some species of mosquitos, such as *Culex* can be attracted to traps containing mixtures of oviposition stimulants like the extracts of rotten hay or grass. Female mosquitoes enter the trap and are forces into collection containers by a updraft fan.

Mosquito Abundance

- Another way to estimate female mosquito abundance is a "resting box". These are painted dark saturated colors like red, it is thought that the box looks like a dark hiding spot for the female mosquitoes with the color allowing technicians to be able to see the mosquitoes. Technicians remove the mosquitoes with a mouth aspirator.

Mosquito Abundance

- AGO Trap: Up to 8 weeks between inspections
- Doesn't support mosquito production
- Aids in control by removing gravid females
- Collects adults
  - Quick identification
- Estimate abundance
- No moving parts
- Large and visible to public
- Damage to specimens


CDC


CDC

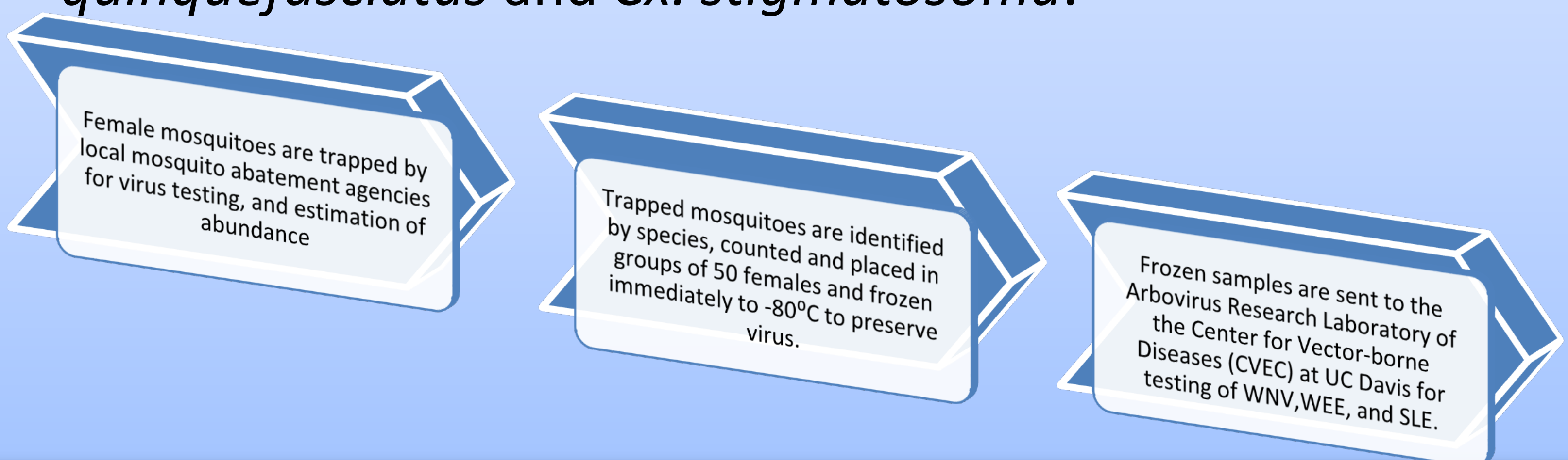
The sticky (capturing) surface faces the inside of the cylinder.
Make sure that the sticky board lays flat on the cylinder.

Mosquito Abundance

- **Biogents (BG)-Sentinel**
- **Specifically designed for *Aedes***
- **Mimics convection currents created by a human body**
- **Employs attractive visual cues**
- **BG-Lure as attractant**
- **Addition of CO_2**
- **Collapsible**
- **Captures males and females**
  - **Immediate ID**
- **Relative abundance**

Mosquito Infections

- Early virus activity can be detected by testing adult female mosquitoes for viral infection.
- Since *Culex tarsalis* is the vector for WEE, SLE, AND WNV, the arbovirus surveillance program focuses its testing on this species. Other important species are *Culex pipiens*, *Cx. quinquefasciatus* and *Cx. stigmatosoma*.



Avian Infections

- There are three ways avian populations can be tested for evidence of arboviral infections.
  - The use of chicken flocks maintained in cages as sentinels to detect arboviral antibodies.
  - The collection and bleeding of wild birds to detect arboviral antibodies.
  - The testing of dead birds for virus reported by the public in connection with the CDPH WNV Dead Bird Program.

Avian Infections
Sentinel Chickens

- In California, flocks of ten chickens are placed in locations where mosquitoes are known to be abundant, or where there is a history of arboviral activity.
- Technicians of local mosquitoes abatement agencies collect blood samples every two weeks by pricking the comb and allowing a drop of blood to flow onto a filter paper strip. The strip is dried and mailed for testing to the Richmond Lab of Vector-borne Disease Section of CDPH.
- Chickens infected by mosquitoes with arboviruses develop antibodies that are detected when testing. The term is seroconverted when the chickens are positive

- Mosquito-borne virus activity can be tracked by following patterns of seroconversion in sentinel chickens.

Avian Infections

- Live birds
  - Viral infections in wild bird populations can be monitored by capturing, bleeding, and releasing birds in traps or mist nets and testing their blood for signs of infection.

- Deadbirds
  - WNV, in North America frequently causes death in some species of birds, especially ones in the *Corvidae* family such as crows, magpies, and jays.

Avian Infections

- In 2000, the CDPH began a surveillance program for members of the public to report dead birds.
- The program is based on the reporting of dead birds by members of the public through a Dead Bird Hotline (1-877-WNV-BIRD) and via the West Nile website (http://westnile.ca.gov).
- Birds meeting certain criteria are collected by local agencies. Local agencies swab the bird’s oral cavity (following appropriate safety precautions), and press the sample onto an RNAse card. The cards are sent to the Arbovirus Research Laboratory of CVEC, where they are tested for WNV RNA (ribonucleic acid) using RT-PCR. Oral swabs from dead corvids are tested by some local agencies using rapid antigen tests; some agencies test dead birds “in-house” using RT-PCR.

Additional Infections

- In 2004, tree squirrels were added to the surveillance program, based on the fact they too are susceptible to fatal infections. However, squirrels were deleted from the surveillance program in 2014.
- Equine cases of WEE and WNV are no longer useful measures of virus activity because of the intentional or natural vaccination of horses, donkeys and mules. However, if WEE and WNV equine cases are confirmed, it is a sign that activity has amplified to levels where human cases are eminent.

Human Infections

- Local mosquito abatement agencies depend upon the rapid detection, confirmation, and reporting of human arbovirus cases to plan and implement emergency control activities to prevent further infections.
- Human cases are not a sensitive surveillance indicator of arboviral activity because most infected humans are asymptomatic.

Risk Assessment and Response Levels

- The California Mosquito-borne Virus Surveillance and Response Plan contains risk assessment guidelines based on values assigned to different levels of the surveillance components described above. These levels are evaluated annually by agencies cooperating in arbovirus surveillance. The entire plan can be downloaded in PDF format from the California West Nile virus website http://westnile.ca.gov.

WEE Surveillance Factor	Assessment Value	Benchmark
Adult *Culex tarsalis* abundance determined by trapping adults, identifying them to species, and comparing numbers to averages previously documented for an area for current time period.	1	*Cx. tarsalis* abundance well below average(≤50%)
	2	*Cx. tarsalis* abundance below average (51-90%)
	3	*Cx. tarsalis* abundance average (91-150%)
	4	*Cx. tarsalis* abundance above average (151-300%)
	5	*Cx. tarsalis* abundance well above average(>300%)

Mosquito-borne Virus Risk Assessment for WEE based on adult *Culex tarsalis* abundance

Risk Assessment and Response Levels

- Malaria
  - Before World War II, malaria was endemic in parts of California, especially the Central Valley. Malaria is no longer endemic in California, and very few human malaria cases occur as a result of being bitten by infected anopheline mosquitoes in the state. When this does happen, such cases are called "locally-transmitted malaria". However, several hundred cases of malaria are reported in California every year. Most of these are called "imported malaria", because the person is infected in a malarious area elsewhere in the world, and comes down with malaria after their return to California.
  - These cases are tracked carefully by the CDPH, and when evidence suggests that a rare instance of imported malaria has occurred, the cases are investigated thoroughly by epidemiologists. This type of surveillance is called passive surveillance.

- Filariasis
  - There is no systematic surveillance for canine filariasis (dog heartworm), although researchers have done surveys for infections in dogs and other susceptible vertebrates from time to time. Some studies have been done to incriminate various mosquito species as vectors, but such studies are not done routinely in California.

Surveillance for insecticide resistance by mosquitoes

- While researchers from the University of California, Davis and individual mosquito abatement agencies test populations of important species of mosquitoes for evidence of insecticide resistance, there is presently no comprehensive statewide surveillance program for this purpose.
- A surveillance program for insecticide resistance by mosquitoes will require standardization of testing methods, establishment of a central testing laboratory or training of local agency personnel for testing, a means of collecting and analyzing test results on a statewide basis, and means of periodic dissemination of test summaries mosquito abatement district personnel and other public health agencies.

Reporting and Dissemination of Surveillance Results

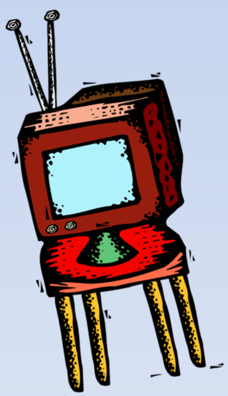
- **CalSurv**
  - CalSurv stands for California Vector-borne Disease Surveillance System, a cooperative program of the CDPH, MVCAC, and UC. It is a method for the collection of surveillance data and reporting of results for all vector-borne diseases, particularly for important diseases such as Lyme disease, Rocky Mountain spotted fever, and plague that heretofore have not had standardized surveillance systems comparable to the arbovirus disease surveillance system.
  - The CalSurv website is intended primarily for conveying vector-borne disease surveillance information to the general public. The website is based on a content management system, which is a system of software that allows for the assignment of content management to many specialists using access via the Internet. It is organized primarily along groups of vectors, but the menus are cross referenced by vectors, diseases, and pathogens, making access easier for the public to access specific information categories.

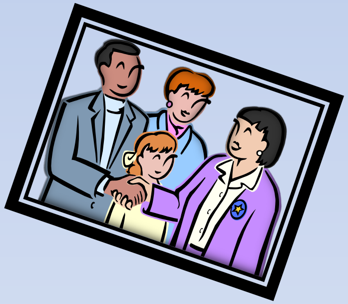
Reporting and Dissemination of Surveillance Results

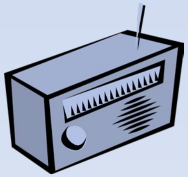
- **California Vector-borne Disease Surveillance Gateway**
  - The gateway provides a complete management system for surveillance activities by local agencies. As an example, a user may register and track sentinel chicken flocks, print specimen labels, and reports, and do all the other things concerning maintenance of chicken flock data management that previously had to be done by hand. It also provides for the reporting of mosquito abundance reports and shipping of mosquito pools for testing.
  - Using this system, individual agencies can maintain multi-year surveillance data that can be downloaded to agency computers in bulk. It also provides for data sharing among local agencies, state entities, and federal bodies. In addition, full mapping and analytical tools for analysis of multiyear data, including the calculation of risk response levels based on the scheme described above, are provided.
  - The services provided by this website are available only to registered users.

Public Relations in Mosquito Control

GOOD PUBLIC RELATIONS ARE AN ESSENTIAL PORTION OF ALL MOSQUITO CONTROL PROGRAMS.







Chapter 11

Public Relations in Mosquito Control

Types of Public Relations

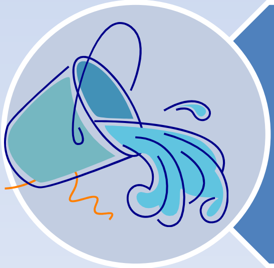
Public Relations Objectives

Public Relations Approaches

Public Relations in Mosquito Control

Mosquito control personnel must deal with people even more effectively than they deal with mosquitoes. If the public is to cooperate with and support our programs, they must understand what we are doing and why.

The more the public understands a mosquito control agency's efforts, the more cooperation and support the program will receive.



The best form of mosquito control is having the public know how not to raise mosquitoes and having them actively participating in monitoring their own properties for potential breeding sources.

Types of Public Relations

- Person-to-person
  - *Service requests*
  - *Telephone calls*
  - *Letters*
- Group contacts
  - *Presentations*
  - *Tours*
  - *Committee work*
  - *School visits*
- Public official contacts
  - *Local and state legislators made aware of your program*
- Mass media activities
  - *Television*
  - *Radio*
  - *Newspapers*
  - *Websites*
  - *Exhibits*

Public Relations Objectives

A successful public relations program consists of:

- *Having meaningful information to present*
- *Presenting it effectively*
- *Selecting the best delivery method for the information*
- *Insuring receptivity by the intended user of the information*

Public Relations Approaches

- Although the average field technician will not have the responsibilities or opportunities to engage in all types of public relations activity on a daily basis, the activities and behavior of the technician in the field are the most important part of any agency's public relation efforts.

- You represent your mosquito control program. Your level of knowledge and professionalism will leave a lasting impression with the public, for better or for worse.

Public Relations Approaches

- It will take time, energy, and effort to create a effective program. I can be accomplished whether a small one-person operation or a large fully-staffed organization.
- What needs to be addressed is by what means you will use and whether your media approaches will be controlled or uncontrolled.
- Uncontrolled media channels means of public service announcements, press releases, radio and the benefit of these are that they offer the opportunity to reach the largest audiences.
- Controlled media channels are those in which you as the information provider has some control over the content of messages you convey to your audience and what messages they receive.

Public Relations Approaches

Uncontrolled

- Public Service Announcements
- Press releases
- Newspapers
- Radio

Controlled

- Websites
- Bookmarks
- Brochures
- Information fact sheets
- Periodic newsletters
- Fair exhibits
- Presentations to students and civil groups

Appendix 1
Glossary

Many of the words defined here have additional meanings.

The definitions given here are related to pests, insecticides, and pest management.

Glossary

- A
  - **Active ingredient:** The component of insecticides formulation that kills or controls pests. The chemical that is responsible for the toxic effects in a formulation.
  - **Acre:** A land area of 43,560 square feet; equal to an area of 440 ft. long by 99ft. wide. Approximately equal to a sq. area 209 by 209 ft. Rectangle, 436 by 100ft. Metric equivalent is 0.405 hectares.
  - **Aestivation:** The survival of mosquitoes during hot summer periods.
  - **Anal papillae:** The soft fleshy lobes found on the anal segment of mosquito larvae. These lobes are associated with the physiological regulation of water balance in larvae. Species adapted to saline habitats have very small papillae to avoid excess loss of water; fresh water species have large papillae to avoid excess uptake of water.
  - **Antenna:** One of the paired sense organs in the heads on insects.
  - **Apical:** Refers to the apex or the position opposite to the base of an insect structure.
  - **Arbovirus:** Any virus that is associated with an arthropod. Most are transmitted to vertebrate animals by arthropods.
  - **Autogenous:** Mosquitoes that demonstrate the trait of Autogeny.
  - **Autogeny:** The production of viable eggs by mosquitoes and other blood-sucking insects without the necessity of a blood meal.

Glossary

- B
  - Bacteria: A group of single-celled microorganisms. Some are pathogens (disease causing),but most are providing necessary functions in the environment.
  - Basal: Refers to the base, or the position opposite to the apex of a insect structure.
  - Binomial nomenclature: The system for naming biological organisms where each type of organism is given a name consisting of a genus and species.
  - Biological control: The use of natural enemies to manage pest populations, including mosquitoes. It is also called biocontrol, for short.
  - Biopesticides: Are another term applied to biorational pesticide and insecticides.

- B
  - Biorational insecticides: Insecticides derived from natural materials such as animals, plants, bacteria, and some minerals. The EPA recognized three categories of biorational insecticides:
    1. Microbial insecticides
    2. Plant-incorporated protectants
    3. Biochemical insecticides.
  - Biorational pesticides: Are a group of pesticides that are considered to be relatively non-toxic to humans and environmentally safe.
  - Breeding place: A place where mosquito larvae develop.

Glossary

- C
  - **Calibration**: The testing and adjusting of insecticide application equipment to ensure a proper application rate.
  - **California encephalitis**: A disease of humans first reported in California caused by the California encephalitis virus.
  - **CE**: The abbreviation for the California encephalitis virus. CE is a member of the California serogroup of viruses so-named because CE was the first virus to be classified in the serogroup.
  - **Chemical control**: The control of pests including mosquitoes by the use of chemicals.
  - **Chemist**: One who works with chemicals
  - **Cholinesterase**: An enzyme present at the nerve junctions in animals and is necessary for proper functioning of nerve impulses.
  - **Classification**: The process of arranging a series of information into groups according to common characteristics. In vector control operations, insecticides target organisms, application equipment, laws, and regulations are just a few of the things that are frequently classified. For insecticide classifications the same material can often be classified into several different groups according to target species, chemical nature, manner or formulation, mode of action, and toxicity.
  - **Common name**: The well-known simple name of a insecticide accepted by the federal and state insecticide regulation agencies.
  - **Competitive displacement**: The replacement of one population of organisms by another in a given region, usually because of superior fitness for the particular environment.
  - **Conditioning**: A phenomenon in certain *Aedes* mosquitoes species whereby the eggs will not hatch until they have gone through several months exposed ti very cold temperatures.
  - **Cooperative agreement**: A formal agreement between the California Department of Public Health and mosquito control agencies with the CDPH overseeing the local control agency's activities.
  - **Complete metamorphosis**: The process of insect development which includes the egg, larva, pupa, and adult stages.
  - **Cross immunity**: The protection from infection by a pathogen resulting from vaccination or infection by a related pathogen.
  - **Cross resistance**: is a situation where physiological resistance to a insecticide by an insect population results in resistance to a second insecticide group of insecticides.
  - **Cuticle**: the outer covering (or skin) of a arthropod.

Glossary

- D
  - **Dead-end hosts**: In epidemiology, vertebrate hosts that become infected with a pathogen, but do not serve as a source of infection for any additional hosts. This is usually because the dead-end host does not circulate pathogens in the blood in sufficient concentrations to infect new vectors.
  - **DEET**: The common name for the insect repellent *N*,*N*-Diethyl-*meta*-toluamide
  - **Dermal**: Pertaining to the skin
  - **Developmental transmission**: A type of transmission of a pathogen by a mosquito or other vector arthropod in which the pathogen undergoes developmental changes, but does not multiply. Example: the transmission of filarial worms by mosquitoes.
  - **Diapause:** In insects, including mosquitoes, an altered physiological state in which certain activities such as bloodfeeding, ovarian development, or flying are suspended. Diapause is often triggered by shortened day-lengths or low temperatures, and terminated by lengthened day-lengths or warm temperatures.
  - **Disease**: Any departure from normal health in an organism. A vitamin deficiency is a disease. Infectious diseases are caused by infections with pathogenic microorganisms.
  - **Diurnal**: Refers to daytime.
  - **Dorsal**: Refers to the uppermost surface of an organism.

Glossary

- E
  - **Ecology**: The study of the relationship between a plant or animal and its surroundings.
  - **Ecosystem**: A type of biological organization made up of all the organisms in a given area.
  - **Emulsion**: A mixture of two unblendable substances. One substance (the dispersed phase) is dispersed in the other (the continuous phase). Examples of emulsions include butter and margarine, milk, and cream. Insecticide emulsions are created with an emulsifying agent.
  - **Encephalitis**: A disease characterized by inflammation of the brain.
  - **Encephalomyelitis**: A disease characterized by inflammation of the brain and the brain stem.
  - **Endemic**: Used to describe a human disease or an organism that occurs naturally in a given area.
  - **Enzootic**: Used to describe a non-human animal disease that occurs naturally in a given area
  - **Epidemic**: Used to describe a human disease outbreak resulting in an unusually large number of cases.
  - **Epizootic**: Used to describe a non-human animal disease outbreak resulting in an unusually large number of cases
  - **Exotic**: Refers to anything that is from some other place.

Glossary

- **Facultative:** Refers to phenomena such as diapause or autogeny where the phenomenon is variable depending upon various other factors (also see obligatory).
- **Family**: A taxonomic grouping of organisms containing one or more genera.
- **Fauna**: All the species of animals that are present in a given area, e.g., the fauna of Chile.
- **Flora:** All the species of plants that are present in a given area, e.g. the flora of California.

Glossary

- G
  - **Ganglion:** A nerve mass in insects: including mosquitoes. Part of the central nervous system.
  - **Genetic control:** A modern approach to mosquito control involving altering the genetic makeup of mosquitoes to make them infertile, reduce their ability to transmit human pathogens, or otherwise reduce their potential as pests and vectors. Usually, such genetically-altered mosquitoes are released into the environment in an attempt to "drive" the altered genes into wild populations of mosquitoes.
  - **Genus:** A taxonomic grouping of organisms containing one or more species (Plural: genera).

- **H**
  - **Hazard:** In toxicology, the risk of poisoning when a material is used. Hazard depends not only on the toxicity of a material, but also on the risk of toxic exposure when used.
  - **Herbicide:** A type of pesticide designed to kill weeds.
  - **Hibernation:** An altered state of some kind by which insects survive the winter.
  - **Hypersensitivity:** A condition in animals in which repeated exposure to foreign antigens (usually proteins) leads to a heightened and sometimes violent reactions to subsequent exposures to the same antigens.

Glossary

- I
  - **IGR**: Abbreviation for insect growth regulator.
  - **Imported malaria**: A case of human malaria acquired by being bitten by an infected mosquito in an area not in the same general location where symptoms occur and treatment is sought.
  - **Impoundment**: An artificial body of water created by damming or diking.
  - **Indigenous**: Refers to an organism native to an area. The opposite of exotic.
  - **In apparent to apparent disease ratio:** In epidemiology, the ratio of infections that do not produce clinical symptoms to those that do.
  - **Infectious diseases**: Diseases of animals or plants caused by infectious of pathogenic microorganisms.
  - **Inorganic:** Materials not containing carbon atoms.
  - **Insect growth regulator**: A type of biorational insecticide that kills insects by interfering with natural reproductive processes. These are usually synthetic versions of natural insect hormones, such as the juvenile hormone.
  - **Insecticide resistance**: The ability of an insect to withstand the lethal effects of an insecticide, usually by a physiological detoxification mechanism controlled by genetic mutations.
  - **Insecticide resistance management**: A combination of strategies used in insect control that tend to delay or prevent the development of resistance to certain insecticides.
  - **Integrated Pest Management (IPM):** A system of pest control in which various strategies are used in combination.
  - **Integrated Vector Management (IVM):** A system for control of vectors in which various strategies are used in combination. Many people understand IPM to encompass vector control and do not use the more specific expression of IVM.

Glossary

- J
  - **Juvenile hormone:** A naturally occurring biochemical occurring in insects that controls certain processes in metamorphosis. Synthetic versions of this biochemical are used as biorational insecticides.

- K
  - **Kingdom:** In science, one of three major categories into which natural objects are classified: Animal, Plant, and Mineral. In more recent years, additional kingdoms have been created in biology to accommodate things like viruses and fungi.

Glossary

- L
  - **Label:** Printed material attached to or printed on a pesticide container. The content and general format of labels is regulated by the US Environmental Protection Agency.
  - **Labeling:** All the technical information provided by the manufacturer of a pesticide, including the label.
  - **Larvae:** Immature forms of invertebrate organisms. In insects, the forms that appear after hatching from eggs and before becoming a pupae.
  - **Larvicide:** A insecticide used to kill larvae, usually of insects.
  - **LC_{50}:** A toxicological term used in pesticide testing that means the concentration required to kill 50% of a group of test subjects. The lower the number, the more toxic the pesticide.
  - **LD_{50}:** A toxicological term used in pesticide testing that means the dose required to kill 50% of a group of test subjects. The lower the number, the more toxic the pesticide.
  - **Limiting factor:** A factor, either biological or non-biological, that limits the size of a population of organisms. The most common biological factors are parasites and predators, the most common non-biological factors are weather and climate.
  - **Locally transmitted malaria:** A case of human malaria acquired by being bitten by an infected mosquito in the same general location where symptoms occur and treatment is sought.

Glossary

- M
  - Malaria**:** An anopheline mosquito-borne disease of humans caused by protozoan (single-celled animals) parasites in the genus *Plasmodium*. Malaria is probably the most important disease in the world. It has been called, with considerable justification, the world's number one killer.
  - Malpighian tubules: Organs in the abdomen of larval and adult mosquitoes associated with excretion.
  - Metamorphosis: Changes that an insect goes through during its life cycle. Insects with complete metamorphosis have eggs, larvae, pupae, and adults.
  - Multivoltine: Many generations per year. *Culex pipiens* is a mosquito that is multivoltine.

Glossary

- N
  - *N,N*-Diethyl-*meta*-toluamide**:** The chemical name for the insect repellent commonly known as DEET**.**
  - Neurohormones: Hormones in insects that are secreted by special glands that are associated with the insect nervous system. Ecdysone is a neurohormones.
  - Nocturnal**:** Active during night time. The opposite of diurnal.
  - Non-target organism: Any organism in an environment that is not the intended target of an insecticide application.

Glossary

- O
  - **Obligatory:** Refers to phenomena such as diapause or autogeny where the phenomenon is established regardless of any other factors (also see **facultative**)
  - **Oral:** Pertaining to the mouth, as in oral toxicity, the toxicity of a chemical when taken by mouth.
  - **Order**: A taxonomic group of organisms containing one or more families.
  - **Organic**: Chemical substances containing carbon.
  - **Organochlorines:** A class of insecticides contains chlorine groups; includes DDT, chlordane, lindane, and dieldrin. Also called chlorinated hydrocarbons.
  - **Organophosphates**: A class of insecticides that contains phosphate groups; includes malathion, and parathion
  - **Osmosis:** The movement of water across semi-permeable cell membranes from areas of lower concentrations of dissolved ions to areas of higher concentrations. To visualize this, remember that water always seeks to dilute out solutions of ions. A mosquito in pure fresh water will tend towards water uptake; a mosquito in saline water will tend towards water loss.
  - **Oviposition:** The laying of eggs by an insect, including mosquitoes.

Glossary

- P
  - Palpus: In mosquitoes, one of a pair of segmented sensory appendages that arise at the base of the proboscis.
  - **Parasite:** An organism that lives in or on another (called the host) and takes nourishment from the host. The parasite harms the host by depriving it of nutrients or If the host is a pest, the parasite is a biological control agent.
  - Parasitemia: The presence of circulating parasites in the blood of a host.
  - Pathogen**:** A disease-producing microorganism.
  - Permeability**:** The characteristic of membranes and other structures that permits the passage of fluids.
  - Personal protective measures: The things individuals can do for themselves and their families to protect them from mosquito bites.
  - Petroleum oils: Insecticides refined from crude oil for use as insecticides.
  - Phylum**:** A taxonomic group of organisms containing one or more orders.
  - Phytotelmata: Bodies of water held by plants. Mosquito larvae often develop in such bodies, especially in the tropics.

Glossary

- P cont.
  - Physical control: The management or alteration of physical features of the environment to control mosquitoes. An example is the management of salt marshes in ways that minimize mosquito breeding.
  - *Plasmodium*: The generic name for the protozoan parasite that causes human malaria.
  - Population: A large group of organisms of the same species living in a geographic area.
  - Population density: The number of organisms in a population expressed as a number per unit of area. Usually estimated by sampling.
  - Posterior: Situated behind. The opposite of anterior.
  - Predator: An organism that devours another organism for food. Predators are almost always larger then their prey; parasites are usually smaller.
  - Prism (tidal): The total volume of water flowing in and out of a tidal marsh by tidal action.
  - Proboscis: In mosquitoes, a bundle of individual structures called stylets that are bound together to form a snout. The proboscis is the structure involved in bloodfeeding.

Glossary

- P cont.
  - Propagative transmission: A type of pathogen transmission by mosquitoes and other arthropod vectors in which the pathogen multiplies within the vector but does not undergo any changes in developmental form. Example: the transmission of arboviruses by mosquitoes.
  - Propagative-developmental transmission: A type of pathogen transmission by mosquitoes and other arthropod vectors in which the pathogen multiplies within the vector and undergoes changes in developmental forms. Example: the transmission of malarial parasites by mosquitoes.
  - Propagative-developmental transmission: A by mosquitoes and other arthropod vectors in which the pathogen multiplies within the vector and undergoes changes in developmental forms. Example: the transmission of malarial parasites by mosquitoes.
  - Pyrethrin: The insecticidal-active chemical component of pyrethrum insecticides. Both the active ingredient and the insecticide are sometimes called pyrethrins. The correct usage would be to refer to the former as pyrethrin, the latter as pyrethrum.
  - Pyrethroids: Synthetic compounds produced for their chemical resemblance and insecticidal similarity to pyrethrin.

Glossary

- Q
  - Quinine: An anti-malarial drug prepared from the bark of the *Chinchona* tree. One of the oldest treatments for malaria known, it is still effective, especially against malarial strains resistant to other drugs.

- R
  - Reproductive potential: The maximum reproduction possible in a population in the absence of limiting factors. Reproductive potential is never reached in mosquito populations.
  - Riparian: Refers to rivers, as in riparian habitat.

Glossary

- S
  - **Saint Louis encephalitis** (SLE): The human disease caused by infection with St. Louis encephalitis virus.
  - **Salivarian transmission**: A type of transmission of disease pathogens by insects in which pathogens are introduced into vertebrate hosts by blood-feeding insects by the injection of infected salivary fluids.
  - **Salivary glands**: A set of glands located in the thorax of larval and adult mosquitoes. These glands contain substances that aid in feeding. In adult mosquitoes the transmission of various pathogens result from injection of infected salivary fluids.
  - **Selection pressure**: In population genetics any biological or non-biological factor that affects a segment of a population with a certain genetic makeup more than another segment with a different genetic makeup.
  - **Selective:** The characteristic of insecticides that are highly specific for certain organisms, and harmless to others.
  - **Sequelae:** A term used to describe a pathological situation where infections with a pathogen result in signs and symptoms occurring significantly later than the original infection**.**

Glossary

- S cont.
  - **Sexual dimorphism**: The situation in biological organisms such as mosquitoes where there are significant differences in form between males and females.
  - **Sibling species**: Species which satisfy the definition of separate species, but are virtually indistinguishable morphologically. *Culex pipiens* and *Culex quinquefasciatus* are sibling species.
  - **Sign**: Evidence of exposure to a dangerous pesticide or other disease process in a plant or animal that is observable by a person other than the plant or animal affected. In people, signs are observable by others even if the person affected is unconscious. In other animals and in plants, only signs are available as evidence of poisoning or illness.
  - **SLE:** The abbreviation for the St. Louis encephalitis virus.
  - **Species**: A group of populations of potentially interbreeding living organisms. Since passage of the endangered species act, the definition has been broadened to consider a population having some demonstrable stable difference from another population as a species in the legal sense, even if the populations are potentially interbreeding.
  - **Spermathecae:** Structures in the abdomens of female mosquitoes in which sperm is stored. Most culicines have 3 spermathecae, anophelines have one.
  - **Stadium**: The time between two successive molts in insects.

Glossary

- S cont.
  - Stage**:** Nearly synonymous with stadium.
  - Stagnant: In reference to water, non-flowing.
  - Surveillance: The monitoring or close watch over something. Mosquito abatement districts practice surveillance over mosquito-borne disease cases or mosquito population sizes.
  - Symptom**:** A feeling of unhealthiness that can be expressed by a person. It may represent a warning of pesticide poisoning. Plants cannot display symptoms, and most animals cannot display them in a readily recognizable form. Reasonable people will disagree on the question of whether non-humans can show symptoms at all, and the word symptom is often misused for "sign".
  - Synergist: Materials that are not necessarily a pesticide by themselves but have the effect of increasing the toxicity of insecticides with which they are mixed.

Glossary

- T
  - Target organism: The organism against which a control effort is directed. In this manual, a mosquito or a weed.
  - Tolerance: As applied to pesticides, the legal limit of the amount of pesticide that may remain in or on foods marketed in the USA. Tolerances are established by the EPA and are enforced and monitored by the FDA.
  - Toxicity: The inherent poisonous potency of a material. Toxicity is expressed in quantitative terms such as $LC_{50(lethal}$ concentration-50, the concentration at which a material will kill 50% of some reference organism.)
  - Trachea: In insects, one of the major tubes that conduct air throughout the body of an insect. Plural form is "tracheae".
  - Tracheole: In insects one of the fine tubules that branch off at the end of tracheae.
  - Transovarial transmission: The transmission of microorganisms from parent to offspring via infected eggs of an arthropod vector.

Glossary

- U
  - **ULV:** Ultra low volume. An application of a insecticide at a rate of less than ½ gallon per acre (5 liters per hectare). Because the volumes be sprayed are so small, extremely low doses of insecticide result, even when the insecticides are sprayed undiluted.
  - **Univoltine:** An insect that has only a single generation per year. *Aedes tahoensis* is a univoltine species.

- V
  - **Vector:** A vehicle for transporting a disease-producing organism (pathogen) from one host to another. In vector ecology, the most common vectors are insects and other arthropods. Vectors can transfer pathogens from one animal to another, and from one plant to another.
  - **Ventral:** The underside of something. The opposite of dorsal.
  - **Viremia:** The presence of circulating virus in the blood of a host.
  - **Virus:** A microorganism that can grow and reproduce only in living cells of other organisms. Often, viruses cause diseases in their hosts and are then pathogens.

Glossary

- W
  - WEE: The abbreviation for western equine encephalomyelitis virus, the virus that causes the disease western equine encephalomyelitis.
  - West Nile fever: One of the diseases caused by WNV.
  - West Nile neuroinvasive disease: One of the diseases caused by WNV.
  - Western equine encephalomyelitis: The disease cause by WEE.
  - WNV: The usual abbreviations for West Nile virus.

Glossary

- X
  - Xenobiotic: Any substance foreign or strange to life, like synthetic insecticides such as DDT.

- Y
  - Yolk: Substance within the eggs of mosquitoes providing nutritional material for development of embryos.

- Z
  - Zoogeography: The study of the geographic distribution of animals, including mosquitoes.

Appendix 2
Conversions of Units and Formulas Used with Insecticides

Length

1 mile (mi) = 1.609 kilometer (km)

1 km = 0.621 mi

1 meter (m) = 1.904 yards

1 centimeter (cm) = 0.394 inches (in)

1 in = 25.4 mm

1 micron (mµ) = 0.001 mm

1 mµ = 1/25,000 in

Liquids

1 fluid ounce (fl oz) = 0.0296 liters (l)

1 pint (pt) = 0.473 l

1 pt = 16 fl oz

1 gallon (gal) = 3.785 l

1 gal = 128 fl oz

1 pound (lb) = 0.454 kilogram (kg)

1 liter (l) = 33.81 fl oz

1 l = 2.113 pt

1 l = 0.264 gallons (gal)

Area

1 acre (ac) = 0.405 hectares (ha)

1 ha = 2.471 ac

1 ac = 43,560 ft2

Speeds

1 mile/hour (mph) = 1.609 kilometers/hour (km/h)

1 mph = 0.447 miles/second (mps)

1 km/hr = 0.621 mph

Weight

1 ounce (oz) = 0.0283 kg

1 kg = 2.205 lbs

Conversions of Units and Formulas Used with Insecticides

APPLICATION RATES

1 oz/ac = 0.070 kg/ha

1 meter/sec = 2.24 mph

1 l/ha = 13.69 fl oz/ac

1 l/ha = 0.855 pts/ac

1 kg/ha = 0.898 lb/ac

1 kg/ha = 14.27 oz/ac

FORMULAS

Gallons per acre = (5,940 x gallons per minute/nozzle)/(mph x nozzle spacing)

Gallons per minute per nozzle = (gallons per acre x mph x nozzle spacing)/5,940

Ounces per minute per nozzle = (gallons per acre x mph x nozzle spacing x 32)/1,485

Mph = distance traveled (ft)/(88 x minutes)

Mph = distance traveled (ft)/(0.47 x seconds)

Appendix 3
Additional Information

- Written materials

  - Bohart RM, Washino RK. 1978. Mosquitoes of California. Third Edition. University of California Press, Berkeley. 153 p.
  - Bohmont BL. 2007. The standard Insecticide user's guide. Pearson, Upper Saddle River NJ. 622 p.
  - California Department of Public Health, Mosquito & Vector Control Association of California, University of California. 2008. California mosquitoborne virus surveillance & response plan. Sacramento. 51 p.
  - California Department of Public Health. 2008. Operational plan for emergency response to mosquito-borne disease outbreaks (supplement to surveillance & response plan). Sacramento. 29 p.
  - Eldridge BF, Edman JD. 2003. Medical entomology. Revised edition. Kluwer Academic Publications, Dordrecht, The Netherlands. 657 p.
  - Meyer RP, Durso SL. 1998. Identification of the mosquitoes of California. Mosquito and Vector Control Association of California, Sacramento. 80 0.
  - Marer PJ. 2000. The safe and effective use of insecticides (Insecticide application compendium 1). 2nd Ed. University of California Division of Agriculture and Natural Resources, Oakland. 342 p.
  - Ware GW, Whitacre DM. 2004. The insecticide book, 6th Edition. MeisterPro Information Resources., Willoughby, OH. 488 p.

Additional Information

- Websites
  - California Department of Insecticide Regulation. http://www.cdpr.ca.gov/
  - California Department of Public Health, Vector-Borne Disease Section http://www.cdph.ca.gov/programs/vbds/
  - California Department of Toxic Substances Control Program (DTSP). A program of Cal/EPA http://www.dtsc.ca.gov/
  - California Environmental Protection Agency (CAL/EPA) http://www.calepa.ca.gov/
  - California Vectorborne Disease Surveillance Gateway http://gateway.calsurv.org/
  - CalSurv Website http://www.calsurv.org/
  - United States Environmental Protection Agency Insecticide Website: http://www.epa.gov/insecticides
  - West Nile Virus Website http://westnile.ca.gov/