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LOUISIANA MOSQUITO CONTROL
Association

MOSQUITO CONTROL TRAINING MANUAL

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COMMERCIAL PESTICIDE APPLICATOR CATEGORY 8A – MOSQUITO CONTROL

The 2020 edition of the Mosquito Control Training Manual is the fourth revision since the original 1978 edition by the Louisiana Mosquito Control Association. This manual is directed primarily to individuals who wish to become certified as commercial pesticide applicators in Category 8A Mosquito Control by passing a standard test administered by the Louisiana Department of Agriculture and Forestry (LDAF).

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LMCA MISSION STATEMENT

To carry on, to support, and to encourage research on the biology of mosquitoes and on the methods for their control, with special reference to those methods that are practicable under conditions existing in Louisiana, and, which are, so far as possible, conducive to the welfare, not only of man and his domestic animals and cultivated plants but also of the natural vegetation and animal life of the state. To encourage and to assist in the formation and development in Louisiana of local and parish mosquito control organizations. To carry on and to aid other organizations (local, parish, state, and national) in carrying on mosquito control programs. To procure funds and to aid other organizations in procuring funds, both private donations and by taxation, to support mosquito control research and control operations. To promote the training of personnel for mosquito control work. To disseminate knowledge of mosquitoes and of methods for their control to the general public and to workers in mosquito control programs, both within the state and elsewhere. To promote friendly, cooperative relations between different communities within the state and among Louisiana and neighboring states in the interest of effective, coordinated action in the attempt to solve their common problems of mosquito control.

To do each and every thing necessary or proper for the accomplishment of any of the purposes or the attainment of any one or more of the objectives herein enumerated or which shall at any time appear conducive to, or expedient for, the benefit of this corporation.

The LMCA has established several academic scholarships within the field of mosquito control and research. Scholarships are available to college students in Louisiana, Arkansas, Mississippi, Oklahoma, and Texas. For information, visit the LMCA website at www.lmca.us.

LOUISIANA MOSQUITO CONTROL Association

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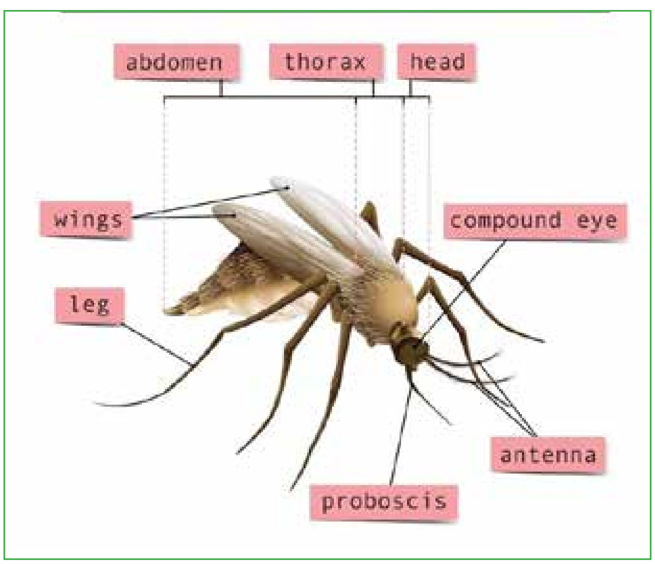
Chapter 1
BASIC INSECT BIOLOGY

Anatomy

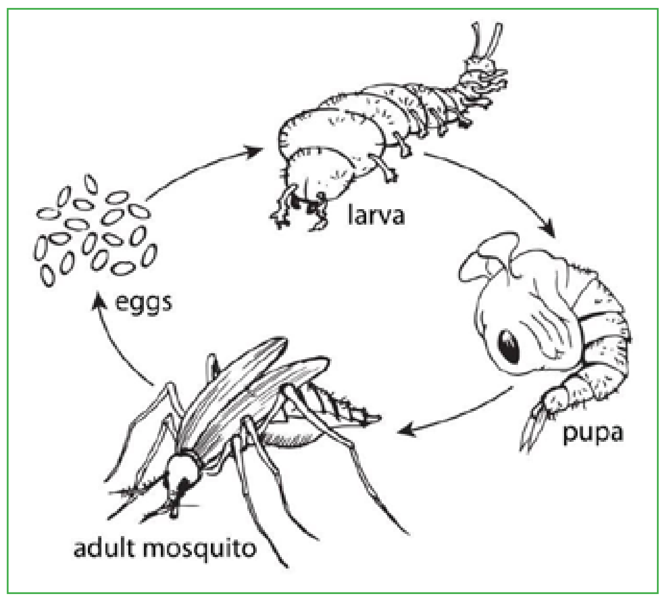
Because mosquitoes are insects, the best place to start is by learning about what makes something an insect. All insects have the same three things in common. (1) Three body regions, (2) six legs, and (3) a hard exoskeleton. The three body regions of insects consist of the head, thorax, and abdomen. The head consists of all the sensory and feeding structures. This includes the antennae and eyes (for smelling, hearing and seeing), the palps (for smelling and tasting), and the mouthparts for feeding. In mosquitoes, the mouthparts consist of a long strawlike structure called the **proboscis**. The proboscis is actually made up of several needlelike stylets that pierce into the skin to obtain blood. The thorax of an insect is what contains the wings, legs, and most of the muscles involved in locomotion. As mentioned earlier, all insects have six legs. When present, most insects have two pairs of wings. However, mosquitoes belong to the group of insects called flies and only have one pair of wings. Rather than having a second pair of wings, they have balancing organs called **halteres.** The abdomen in insects is what houses most of the organs for digestion, reproduction, and excretion. Unlike humans and mammals, insects do not have bones. Rather their skeletons, called exoskeletons, are on the outside of their bodies. The exoskeleton helps protect the insect.



Parts of a mosquito

Metamorphosis

All insects undergo metamorphosis, a change from one form to another. Easy ways to think about this are caterpillars morphing into butterflies or maggots morphing into house flies. While this is an oversimplification, it demonstrates that all insects change over time. There are actually two ways in which insects change, or metamorphosize. In incomplete, or gradual, metamorphosis, the insect gradually gets bigger and bigger over time until it eventually becomes a mature insect. In this type of metamorphosis, only the adult form will have fully functioning wings. Examples include various types of cockroaches, grasshoppers, and bedbugs. The other type of metamorphosis is called complete metamorphosis. In this type, insects will change completely from one form to another with a transitionary stage in the middle. This transitionary stage is called a pupa (or a cocoon). A pupa is a nonfeeding stage. Examples of insects with complete metamorphosis include beetles, butterflies, flies, moths, and bees.



Mosquito life cycle

Habitats

Insects exist in almost all parts of the world. They can be found in temperate, tropical, arctic, and even desert habitats. Typically, insects will have certain adaptations that allow them to live in these habitats. For example, insects that live in the arctic often have the ability to withstand freezing temperatures. Mosquitoes live in water as immatures. Because they do not have gills, they need special structures that allow them to breathe air at the surface. Mosquito larvae have a **siphon**, which functions a lot like a snorkel. They use the siphon to breathe air, even though they live in water.

Nutrition

Some insects, like beetles, have chewing mouthparts and will choose foods that require chewing. Other insects, such as butterflies, have siphons as mouthparts, which requires them to feed on liquids. As immatures, mosquitoes are filter feeders, chewing on small particles and organisms in the water. As adults, both male and female mosquitoes will feed on plant nectars. Females will also take a blood meal, in which she uses the protein for egg production.

Mosquito flower feeding

Chapter 1 - Practice Questions

1. What are halteres used for?

a. Sight
b. Smell
c. Reproduction
d. Balance

2. What type of metamorphosis does a mosquito go through?

a. Complete
b. Incomplete
c. Gradual
d. Both B and C

3. How many legs does a mosquito have?

a. 2
b. 4
c. 6
d. 8

4. What is the name of the structure that mosquito larvae use to breathe?

a. Horn
b. Snorkel
c. Gills
d. Siphon

5. What do adult male mosquitoes use for nutrition?

a. Blood
b. Nectar
c. Bacteria
d. They don't feed

Chapter 2

GENERAL STRUCTURE AND LIFE CYCLE OF MOSQUITOES

Mosquitoes belong to the order Diptera (true flies) and the family Culicidae. They are related to other Dipterans, including blow flies, gnats, house flies, and midges. Like all adult insects, mosquitoes have three main body parts: the head, thorax, and abdomen. There are four distinct stages in its life cycle: the egg, larva, pupa, and adult. While the adult is an active flying insect, the larval and pupal stages are aquatic.

Eggs

Mosquito eggs are white when first deposited, darkening within 12-24 hours. Single eggs are about 1/50th of an inch (0.5 mm) long and have a shape similar to a grain of rice when viewed with the naked eye. However, under magnification, eggs of different species vary in appearance, some examples of which include canoe-shaped, elongated, or elongated oval. Other notable examples include *Anopheles* eggs, which have lateral floats (entrapped air compartments) attached to each side, or *Toxorhynchites* eggs, which look similar in shape to ping pong balls. Some species lay eggs singly, while others are laid together to form rafts. The incubation period (elapsed time between oviposition and egg hatch) may vary considerably among different species.

Culex **egg rafts**

Desiccation resistant eggs

Some mosquito eggs can withstand drying for long periods (up to multiple years in some species). They are referred to as desiccation resistant because their hardened shell helps prevent the egg from drying out. Species that utilize this strategy (primarily *Aedes* and *Psorophora*) deposit their eggs on moist soil or another wet substrate that will eventually become flooded. This includes both habitats that receive frequent flooding, or those that only flood once a year. More detailed information on egg-laying habits of mosquitoes is found in the Bionomics chapter. Because these eggs can survive long periods prior to hatching, species using this strategy generally overwinter as eggs.

Non-desiccation resistant eggs

Other species lay eggs that must remain moist before hatching within a few days. As a result, species using this strategy (such as *Culex*, *Anopheles,* and *Culiseta*) generally lay their eggs directly on the water surface. Eggs that are deposited directly on the water surface (permanent-water breeders) may hatch in one to three days depending on temperature. Eggs of those species that are laid directly on the water surface have no means of preventing hatching. Therefore, these species survive adverse periods (overwinter) in the adult stage.

Larvae

The larvae (wigglers or wrigglers) of all mosquitoes live in water and have four developmental periods, or instars. Undergoing these changes can take four to 14 days depending on the water temperature (warmer water typically expedites development) and food. At the end of each instar, the larva sheds its skin by a process called molting. Mosquito larvae have three body regions – the head, thorax, and abdomen.

Head: The head bears the antennae, eyes, mouthparts, and hairs of varied sizes. Behind the antennae are the eyes, located near the hind margin of the head. The mouthparts are on the underside of the head near the front and include a series of brushes that vibrate rapidly, creating an eddy-like current that sweeps small organisms into the mouth upon which the larva feeds.

Thorax: The thorax is broader than the head or abdomen, and somewhat flattened from top to bottom. It has several groups of hairs, which are useful in identification of species. Neither wings nor legs are present in the larval stage.

Abdomen: The abdomen is long and generally cylindrical, consisting of nine distinct segments. The first seven segments are similar, but the eighth and ninth are considerably modified. The eighth segment bears a respiratory apparatus. This apparatus may vary in shape, but larvae of most species possess an elongate siphon or air tube. There are other mosquito larvae that have no air tube. The genus *Anopheles* has a cluster of small plates that serves the same purpose. The

Larvae

Anopheles larva also has several pairs of unique palmate hairs along its upper abdomen. These hairs assist the larva in maintaining its parallel position with the water surface while feeding. The ninth segment is commonly known as the anal segment and is modified for excretion of body wastes and regulation of body fluids and salt. Larvae belonging to the genus *Coquillettidia* and *Mansonia* remain underwater during their developmental stages and fasten themselves to the roots of water plants by means of an armed or toothed siphon tube.

Pupae

Unlike most insects, the mosquito pupa (tumbler) is very active, and, like the larva, lives in water. It differs greatly from the larva in shape and appearance. The pupa has a comma-shaped body divisible into two distinct regions. The front region consists of the head and thorax (cephalothorax) and is greatly enlarged. It bears a pair of respiratory trumpets on the upper surface. The second region is the abdomen, which has freely movable segments with a pair of paddle-like appendages at the tip. The pupal stage lasts only for a few days, during which feeding does not take place.

Pupae

Adults

The adult mosquito is an entirely airborne terrestrial stage. However, the transition from the pupal stage to the adult is the most vulnerable portion of the mosquito life cycle. The adult must slowly work its way out of the pupal casing using it as a float. Then the mosquito must stand on the water's surface for several minutes until its wings dry before it can become airborne. During this time, any kind of wave action could tip over the adult and cause it to drown. For this reason, mosquitoes breed in quiescent aquatic habitats and not in large bodies of water subject to waves. The adult male feeds strictly on nectar, whereas the female may need to feed on animal blood as well. The latter provides the protein necessary for egg production. It varies in length from approximately 1/16 to 1/2 inch (1.5-12.5 mm) and has three distinct body regions — the head, thorax, and abdomen. All parts of the body are covered to some degree with coarse hairs or scales, which contribute to various color patterns. These patterns are often useful for identification.

Adult mosquito

Head: The head of the mosquito is almost spherical and bears a pair of large compound eyes, a pair of antennae, a pair of palpi, and a large proboscis. The proboscis projects forward and slightly downward from the lower front margin of the head. Although it appears to be a single structure, it is composed of seven long, narrow mouthparts: two maxillae, two mandibles, a hypopharynx, a labrum, and a trough-like labium in which all the other mouthparts lie when not involved in the feeding process. Apart from the labium, the mouthparts collectively are called the fascicle, and this structure is inserted by the female mosquito into the host's skin to obtain a blood meal. In males, the mouthparts are modified from those of the female and are used only to suck nectar and plant secretions where no piercing is required.

Thorax: The middle section of the body is called the thorax and is composed of three segments. A pair of long, slender legs arise from the lower side of each of the segments. The first thoracic segment (prothorax) and the third segment (metathorax) are smaller in size when compared to the second segment (mesothorax). A pair of transparent wings are attached to the mesothorax. Each wing contains a network of veins that strengthen the wing for flight. Attached to the veins are numerous flattened scales that may form various color patterns useful in identification of mosquitoes. A pair of small knobbed structures, known as halteres, is found on the metathorax. These halteres vibrate rapidly when the mosquito is in flight, serving as organs for balance.

Abdomen: The abdomen is an elongate-cylindrical structure composed of 10 segments. The ninth and 10th segments are greatly modified for reproduction in both sexes. The modified terminal segments of the males are extremely useful in taxonomic work, but they are too complicated to be considered in this manual. The tip of the abdomen in females is either tapered or blunt and aids in the identification of different genera of mosquitoes. The color pattern of the abdomen may vary from one species to another, depending on the color and arrangement of scales and hairs, as well as the color of the underlying integument.

Males and Females

Understanding the difference between male and female mosquitoes is a crucial component of arboviral testing. Only females require a blood meal because they utilize the proteins in blood for egg development. As a result, males are not involved in disease transmission. Both males and females utilize sugars (from plant nectars) as a source of energy for flight. Adult females live longer than males, though males generally emerge first (protandry). Depending on species and conditions, females can live from a few weeks to months, with males typically living for about 10 days.

Visually, the males and females can be easily distinguished from one another. The main technique to determine a male from a female is to observe the antennae. Males have plumose (feathery) antennae, whereas females have only sporadic hairs. Males also have modified mouthparts, having longer maxillary palps than the proboscis. Females (except for the *Anopheles* genus) have shorter maxillary palps.

Chapter 2 - Practice Questions

1. True or False. Eggs of the Culex mosquito are laid singularly in damp soil.

a.True
b. False

2. What are the mouthparts of the adult female mosquito?

a. 1 mandible, 1 hypopharynx, 1 maxilla, 1 labrum, 1 labium
b. 2 mandibles, 1 hypopharynx, 2 maxillae, 1 labrum, 1 labium
c. 2 mandibles, 2 hypopharynxes, 2 maxillae, 1 labrum, 1 labium
d. 1 mandible, 2 hypopharynxes, 1 maxilla, 2 labra, 1 labium

3. What are the stages and order of a mosquito life cycle?

a. Egg, larva, pupa, adult
b. Egg, pupa, larva, adult
c. Egg, larva, adult
d. Egg, pupa, adult

4. The larvae of which genus lays parallel to the water surface?

a. *Aedes*
b. *Culex*
c. *Anopheles*
d. *Psorophora*

5. Which life cycle stages do not feed?

a. Egg and larvae
b. Egg and pupae
c. Larvae and pupae
d. Pupae and adult

Chapter 3

BIONOMICS AND RECOGNITION OF IMPORTANT MOSQUITO SPECIES

Before conducting mosquito control, it is important to know the biology of mosquitoes and to know specifically which mosquitoes are present. Therefore, mosquito identification is one of the crucial steps in identifying risks for both biting mosquitoes and mosquito-borne diseases in an area. Before conducting any mosquito control, you should learn more about the biology of the different mosquitoes you are trying to control.

Morphological traits of mosquitoes can often be very similar; however, appearance, as well as behavior, can vary greatly from species to species. Differences in appearance, especially in the larval and adult stages, allow accurate identification of the species. Behavioral differences permit various species to occupy numerous ecological niches with relatively little overlapping. Thus, knowledge of the source or breeding habitat of mosquitoes can provide a strong clue to their identification.

While many of the physical differences between species are minor and require specialists to fully comprehend, many others are readily apparent even to workers with limited training and experience. Fortunately, most of the important Louisiana species are easily identifiable, often by a single observed feature. Many of the breeding sites for these important species are also easily recognized. This section of the manual is designed to provide mosquito-control workers with basic information, including some shortcuts, which will equip them to deal with the important and most common Louisiana mosquitoes more effectively.

Following the discussion of the bionomics of each species is a list of the principal identifying features. Color illustrations of most species discussed are provided to enhance the discussions. Selected biological and ecological data on important species of mosquitoes are summarized in Tables below. A list of all relevant species found in the state of Louisiana with their relative prevalence and importance is also provided.

Floodwater Mosquitoes
(Lay eggs singly on non-aquatic surfaces outside of containers)

***Aedes sollicitans*. Photo by Nathan Burkett-Cadena**

Aedes sollicitans
(Tan Salt Marsh Mosquito)

Aedes sollicitans is a salt marsh-breeding species and one of the most important pest mosquitoes in Louisiana. It is a known vector of Venezuelan equine encephalitis (VEE) and a suspected vector of eastern equine encephalitis (EEE) in Louisiana and elsewhere.

Aedes sollicitans breeds along the Gulf coastal plains and inland areas where brackish water is available. The eggs of *Ae. sollicitans* are laid on moist soil in intermediate to fresh water marshes where they remain until flooded by high tides or rains. Breeding may occur in potholes, depressions, and "runs" (small, ditch-like depressions containing specific plant species) in otherwise level areas of the marshes which are subject to periodic, but not daily, flooding. The eggs require several days of drying (conditioning) in order to hatch when flooded. Development of the aquatic stages requires seven to 10 days depending on water temperature. Breeding takes place most of the year in the southern portion of Louisiana, being only briefly interrupted in cold weather, while, in the northern portions of the state, several generations are produced during the warm months.

The adults are strong fliers, often migrating in large swarms from the breeding areas in search of blood (host animals). They commonly fly 5-10 miles and may travel up to 40 miles when aided by favorable winds. Migration flights take place during early darkness and the adults are attracted to lights. During the day, the mosquitoes rest among the vegetation where they will readily attack any animal that disturbs them. They have made certain areas literally uninhabitable for humans and large animals.

Principal Identifying Characteristics:

1. Medium-sized, golden brown species.
2. Female abdomen is pointed.
3. Pale bands on bases of most tarsal segments
4. Pale band on the proboscis.
5. Basal dorsal bands on abdominal segments.
6. Median pale stripe running the length of the abdomen.

***Aedes taeniorhynchus*. Photo by Nathan Burkett-Cadena**

Aedes taeniorhynchus (Black Salt Marsh Mosquito)

Aedes taeniorhynchus is not as prevalent in Louisiana as *Ae. sollicitans.* Nevertheless, it is sufficiently abundant to constitute a serious problem at times in certain coastal areas and in some inland situations. The breeding habitats and its biology are like those of *Ae. sollicitans,* although it may breed in freshwater pools near salt marshes. The adults are strong fliers and bite freely at night or in shade.

Principal Identifying Characteristics:

1. Medium-sized to small golden-dark brown species.
2. Female abdomen is pointed.
3. Narrow pale bands on the bases of most segments of the tarsi and proboscis.
4. Basal dorsal bands on abdominal segments.

Aedes vexans (Inland Floodwater Mosquito)

Aedes vexans is a floodwater and temporary rain pool breeding mosquito of paramount importance throughout Louisiana. This species causes a painful bite and is a potential vector of West Nile virus (WNV), EEE, California encephalitis (CE), and canine heartworm.

***Aedes vexans*. Photo by Nathan Burkett-Cadena**

Ae. vexans are commonly found from March through October with several broods occurring during this period. They breed in rain pools, floodwaters, roadside puddles, and practically any temporary body of freshwater.

Winter typically is passed in the egg stage, although extended warm winter weather can lead to off-season broods with considerable pest nuisance. Not all eggs hatch with a single flooding and larvae appear periodically following alternate periods of flooding and drying during the season. Adults can migrate long distances from their breeding places, 10 or more miles being rather common.

Principal Identifying Characteristics

1. Medium-sized, brown species.
2. Female abdomen is pointed.
3. Proboscis is unbanded whereas tarsi possess very narrow pale basal bands.
4. Basal abdominal pale bands constricted at the middle to form an inverted "V."

Psorophora columbiae (Dark Rice Field Mosquito)

Psorophora columbiae is the most widespread and important species of *Psorophora* in the United States. It occurs throughout Louisiana and reaches considerable abundance in the riceland ecosystem. The females are fierce biters, attacking anytime during the day or night. In large numbers, they can kill livestock and make it practically unbearable for people to remain outdoors. For these reasons, this species would qualify as one of the most troublesome and economically important Louisiana

***Psorophora columbiae*. Photo by Nathan Burkett-Cadena**

mosquitoes. Its importance was heightened during the summer of 1971 when an epidemic VEE transmission occurred in the southern United States from Mexico.

Eggs of *Ps. columbiae* are deposited on moist soil that is subject to flooding. Situations with low, rank vegetation are ideal for egg deposition. Drained rice fields, fallow rice fields, and pastures are among the most favorable sites. Eggs must undergo a 4-5 day period of maturing before being able to hatch. Once matured, they can hatch within a few minutes of being flooded. Overwintering is in the egg stage. The larvae of *Ps. columbiae* are found in temporary rain pools, irrigation and floodwaters, and in seepage pools. The larval period is characteristically very short; during midsummer, it may be completed in as little as three and a half to four days. The pupal stage requires another one to two days. The number of generations per year varies from few to many, depending upon suitable hatching conditions and local temperatures. Areas which dry up and are then flooded a few days later may produce larvae with each flooding. Adults may live up to one to two months. They have a flight range of 10 miles or more.

Principal Identifying Characteristics:

1. Medium to large black species.
2. Female abdomen is pointed.
3. Apical pale marking on abdomen; markings triangular or divided into paired sub median patches.
4. Proboscis broadly banded with white.
5. Tarsi basally banded with white — the first hind tarsal segment with a broad median white ring as well.

Psorophora ferox
(Woodland Mosquito)

Psorophora ferox occurs in woodland areas of the Gulf Coast states. It is particularly annoying to homeowners who own homes on partially cleared woodland areas. Activity and blood feeding are most intense during daylight hours and feeding often seems to target the upper body and head of human hosts, sometimes referred to as the **headhunter mosquito.**

***Psorophora ferox*. Photo by Nathan Burkett-Cadena**

Principal Identifying Characteristics:

1. Body scales of adult are brilliant blue-purple.
2. Female abdomen pointed.
3. Last two segments of hind tarsi are totally white.
4. Larva has antennae longer than length of head.

Container-Breeding Mosquitoes
(Lay eggs singly on non-aquatic surfaces inside of containers)

Aedes aegypti
(Yellow Fever Mosquito)

Aedes aegypti is the urban vector of yellow fever, dengue fever, chikungunya, and Zika viruses throughout the tropical and subtropical regions of the world. It also has been implicated as a potential urban WNV vector. *Aedes aegypti* is permanently established in the southern portion of the United States, where frequently it becomes locally abundant and readily available to transmit reintroduced yellow fever or dengue viruses.

Aedes aegypti is a peri-domestic species of mosquito imported from Africa more than 300 years ago. In the U.S., larvae develop mainly in outdoor containers, such as tin cans, jars, bottles, dishes, and children's wading pools, near human habitations. They are often found in flower vases in

***Aedes aegypti*. Photo by Nathan Burkett-Cadena**

cemeteries, clogged roof gutters, discarded vehicle tires, and other types of human-generated artificial containers. Originally, *Ae. aegypti* bred in rot holes in trees and may occasionally still be found in such habitats. The adult female prefers human blood to that of other animals, typically seeking to feed during the daytime periods just after sunrise and just before sunset. It is a stealthy mosquito often succeeding in taking blood meals from the lower body and ankles. The larvae are likewise evasive, descending to the bottom of their breeding containers due to changes in light or upon being physically disturbed. They remain motionless, often for a sufficient period of time to be overlooked.

Principal Identifying Characteristics:

1. Small-to-medium-sized brownish-black species with silver accent markings.
2. Female abdomen is pointed.
3. Distinctive lyre-shaped pattern of white scales on the thorax.
4. Proboscis is unbanded, whereas tarsi possess pale basal bands.
5. Abdomen dark with narrow basal bands.

Aedes albopictus
(Asian Tiger or Forest Day Mosquito)

Aedes albopictus is a species native to Southeast Asia. In recent decades it has spread to Hawaii, North America, Central and South America, and Southern Europe. In the U.S., the species was first discovered in the area of Houston, Texas, in 1985, and has since spread throughout the country. Shiploads of natural rubber scrap tires from northern Japan have been identified as the source of Houston's initial population of *Ae. albopictus.* The interstate transportation of used and scrap tires is now the primary means of its dissemination. This species breeds abundantly in many of the same types of natural and artificial containers that *Ae. aegypti i*s known to use, particularly tires.

The Asian tiger mosquito can transmit several disease pathogens (e.g., dengue fever, yellow fever, and dog heartworm to a limited extent). In the U.S., it has also been implicated as a potential vector in transmission of WNV, EEE, California encephalitis CE)/LaCrosse (LAC), chikungunya, and possibly Zika viruses. However, most mosquito control personnel in the U.S. will agree that its aggressive biting behavior toward humans is the primary reason for most complaints. It seeks blood meals during the daytime at about the same time as *Ae. aegypti* (2-3 hours after sunrise and before sunset). The females are weak flyers, i.e., usually not dispersing more than several hundred feet from their larval developmental habitat. When they do fly, they generally stay close to the ground thereby avoiding strong or gusty winds.

There is substantial evidence that the Asian tiger mosquito, through competitive displacement, has replaced *Ae. aegypti* and *Ae. triseriatus* (Eastern Treehole Mosquito) in breeding sites in parts of their geographic range. Except in large subtropical urban areas, *Ae. albopictus* has replaced *Ae. aegypt*i in the U.S. For example, in Atlanta and areas north, *Ae. aegypti* is no longer found; however, in New Orleans, Houston, Miami, and areas south, *Ae. aegypti* is still present in significant numbers in some areas. Likewise, in more suburban areas where *Ae. triseriatus* formerly was abundant, *Ae. albopictus* is now the primary artificial and natural container colonizer.

Principal Identifying Characteristics:

1. Small-to-medium-sized black species with silver accent markings.
2. Female abdomen is pointed.
3. Similar in appearance to *Ae. aegypti*; but, in place of lyre-shaped pattern, there is a distinctive median narrow strip of white scales on the thorax.
4. Proboscis is unbanded whereas tarsi possess pale basal bands.
5. Abdomen dark with narrow basal bands.

***Aedes albopictus*. Photo by Nathan Burkett-Cadena**

***Aedes triseriatus*. Photo by Nathan Burkett-Cadena**

Aedes triseriatus
(Eastern Tree Hole Mosquito)

Although traditionally inhabiting woodland tree holes, *Ae. triseriatus* can also often be found quite often with *Ae. albopictus* in the same ecological niche around human habitations in small urban and suburban areas of Louisiana. The species is frequently collected from man-made containers, such as discarded tires, buckets, and even beer and soft-drink containers.

The bite is painful, and the species is frequently troublesome in both suburban and wooded areas. *Aedes triseriatus* is considered the primary vector of CE/LAC in the midwest and eastern U.S. It has also been implicated in WNV and dog heartworm transmission. Females tend to feed during the day, but prefer shaded areas to full sun. Larval development is slower than that of *Ae. aegypti* and *Ae. albopictus,* and those species may predominate in areas where distribution overlaps during the warmest season. *Aedes triseriatus,* however, is more cold-hardy and ordinarily is most abundant early and late in the season.

Principal Identifying Characteristics:

1. Medium-sized black species.
2. Female abdomen is pointed.
3. Tarsi and proboscis not ringed with light scales.
4. Sides of thorax covered with silvery-white scales separated by a broad central area of dark brown scales which broadens apically and contains a small median light-colored area.
5. Abdomen blue-black with basal patches of lateral white scales.

Permanent Water Mosquitoes
(Lay egg rafts on water surface)

Anopheles quadrimaculatus
(Malaria Mosquito)

Anopheles quadrimaculatus was historically — and remains the potentially principal vector of malaria — east of the Rocky Mountains. It has also been implicated in WNV and dog heartworm transmission. It occurs throughout the central and eastern U.S. and is very abundant in the southeastern states in rural and suburban areas. *Anopheles quadrimaculatus* is a freshwater mosquito found breeding in swamps, marshes, lake margins, rice fields, and slowly moving streams that are usually alkaline. The larvae prefer permanent or semi-permanent water containing floating debris or emergent vegetation, which provides protection from predators. During the summer the larval period is relatively short, about 12-14 days. The pupal period generally requires another two to three days. Anywhere from eight to 10 generations per year can be expected in Louisiana.

***Anopheles quadrimaulatus*. Photo by Nathan Burkett-Cadena**

In recent years, bionomic and genetic studies of this species have shown that it is actually a complex of five species, all of which occur in Louisiana. Based on the 1997 publication by Reinart et al., the species in the complex are now known as (in alphabetical order): *An. diluvialis* Reinert, (new species); *An. inundatus* Reinert, (new species); *An. maverlius* Reinert, (new species); *An. quadrimaculatus* Say; and *An. smaragdinus* Reinert, (new species). Unfortunately, the adult females of this species complex are very difficult to differentiate based on the characters typically used for identification in an operational context. There are differences described in all life stages, including eggs, larvae, pupae, males and females, but often special preparations or techniques are required to visualize those differences.

Based on laboratory infection studies, distribution, and feeding behavior, it is thought that the species that still retains the original name, *An. quadrimaculatus,* was the mosquito primarily responsible for malaria transmission in the eastern U.S. in the past. However, a more recent study by

Levine et al (2004) concludes that in areas where transmission was heavy, some of the other species in the complex probably contributed to local transmission.

In general, the newly described species differ in geographic distribution, feeding behavior, and habitat associations. Three of the five species can be found throughout Louisiana, with all five of them occurring in the southern half of the state. Those interested in knowing more are urged to consult the Reinert et al. (1997) and Levine et al. (2004) publications for specifics. The second publication contains updated distributions maps of the species.

Principal Identifying Characteristics:

1. Medium-to large-sized, to brown species. Palpi as long as the proboscis.
2. Female abdomen dark and blunt.
3. Each wing with four dark spots.
4. Pale knee spots on femora and tibiae.

***Anopheles crucians*. Photo by Nathan Burkett-Cadena**

Anopheles crucians

Anopheles crucians is susceptible to infection by malaria parasites in the laboratory; however, should the disease occur in the U.S., it is not regarded as a significant natural vector. It readily bites humans and if sufficiently abundant this species can become a significant pest throughout the southern part of Louisiana. *Anopheles crucians* breeds in acidic fresh water, such as that in cypress swamps, rice fields, and ponds. Larvae also occur in other habitats, such as lake margins and sluggish streams. Adults rest in shelters and are readily attracted to light traps. The flight range is about 1 mile.

Another Anopheles species, *An. bradleyi,* also occurs in brackish water habitats in Louisiana marshlands. The adult stage cannot be distinguished from *An. crucians* and their life cycles are similar.

Principal Identifying Characteristics:

1. Medium-sized dark brown species. Palpi as long as the proboscis.
2. Female abdomen dark brown and blunt.
3. Wings with alternating white and dark spots. Tip of wing white with three dark spots on anal vein, and front margin of wing dark-scaled.
4. Palpi have white bands.

Culex quinquefasciatus
(Southern House Mosquito)

Culex quinquefasciatus is abundant throughout Louisiana. This species is the major vector of WNV and St. Louis encephalitis (SLE) in Louisiana, and it has long been considered the primary vector of dog heartworm. However, a study by Lowrie (1991) using several Louisiana strains, showed *Cx. quinquefasciatus* was a poor vector of the parasite, but this may vary with strains found elsewhere. While its preferred hosts are birds, it will readily feed upon humans, dogs and other mammals. The abundance of the species and its feeding habits allow it to play a significant role in transmitting WNV and SLE from the bird reservoir to man. The species is most active at night and will readily enter houses to feed.

The southern house mosquito breeds prolifically in water that contains a high level of organic matter. It occurs in roadside ditches, catch basins, septic ditches, sewage oxidation ponds, storm water pump station reservoirs, septic tank and sewage treatment plant effluent, water contaminated with wastes from vegetables and meat-processing plants, and in man-made containers. Somewhat paradoxically, the greatest numbers are often encountered during dry spells when evaporation exceeds replenishment of water, resulting in the concentration of pollution in water bodies as they shrink.

***Culex quinquefasciatus*. Photo by Nathan Burkett-Cadena**

Principal Identifying Characteristics:

1. Medium-sized light brown species.
2. Female abdomen blunt.
3. No distinctive markings on legs, proboscis, or winds.
4. Pale "half-moon-shaped," basal bands on abdominal segments.

Culex salinarius

Culex salinarius is found statewide; however, it reaches its greatest abundance in coastal regions. It is a known vector of SLE and played a role in the transmission of the virus in the major epidemic of 1975 and in subsequent smaller outbreaks. More recently, it has been implicated as a likely bridge vector to bring WNV from birds to humans and other non-avian hosts. The species is most active during the spring and fall months when its populations attain their highest numbers. It is during the summer time that *Cx. salinarius* larvae and adults are difficult to locate. The larvae breed in fresh and brackish water in various habitats. Along the coast, breeding occurs mostly in the fresh, intermediate, and brackish marshes; elsewhere throughout the state, the larvae may occur principally in either fresh or foul water in ponds, pools, ditches, and, occasionally, in barrels or bilge water in boats. The females bite readily outdoors, usually during the early evening hours and occasionally enter dwellings.

***Culex salinarius*. Photo by Nathan Burkett-Cadena**

Principal Identifying Characteristics:

1. Medium-sized brownish species.
2. Female abdomen blunt.
3. No distinctive markings on legs, proboscis, or wings.
4. Abdomen mostly dark-brown scaled, often with narrow to moderately broad basal bands of dingy yellow scales.

Culiseta melanura

Culiseta melanura is an important vector in the bird-to-bird cycle of EEE transmission and is likely involved in a similar fashion in the WNV transmission cycle in Louisiana. In this sense, they act to maintain both of these viruses in the local environment. *Cs. melanura* feeds exclusively on birds, consequently other mosquito species (such as *Culex* or *Aedes* species) are responsible for human and horse infections because they will feed on birds in addition to humans and horses. Little is known of the habits of *Cs. melanura* adults except that they, like many other species, are attracted to lights. Females can be collected from resting boxes in the morning hours by use of suction aspirators.

Larvae of *Cs. melanura* often occur in small permanent to semi-permanent bodies of water, particularly around hardwood swamps, and in boggy palmetto filled areas. The larvae occur during late fall, winter, and early spring when water temperature is less than 60 degrees Fahrenheit.

***Culiseta melanura*. Photo by Nathan Burkett-Cadena**

Principal Identifying Characteristics:

1. Medium-sized dark brownish species.
2. Female abdomen blunt.
3. No distinctive markings on proboscis or wings. Abdomen usually appears unmarked when viewed from above.
4. Legs entirely dark scales except for pale posterior surface of femora.
5. Proboscis long.
6. Tuft of dark setae arising from the base of the subcostal vein on the underside of the wing.

Culiseta inornata
(Winter Mosquito)

Culiseta inornata is prevalent only during the colder part of the year in Louisiana. Because it is readily attracted to light, it can be collected in significant quantities in light traps. The females are seldom persistent biters, although they do occasionally attack humans. The species prefers to feed on large domestic animals and may become very troublesome to livestock. *Cs. inornata* has been implicated as a possible WNV vector, but because it tends to have low numbers during the summer months in Louisiana, it is not likely to be a major contributor to transmission in the state. However, its role in overwintering the virus is plausible but not proven.

***Culiseta inornata*. Photo by Nathan Burkett-Cadena**

The larvae occur in such situations as ground pools, salt marshes, and ditches, often with pollution. Large populations occur in cattle hoof prints during the late fall, winter, and early spring when pastures contain abundant surface water. They have also been collected from abandoned tires and other artificial containers, as well as from abandoned swimming pools in the New Orleans area following Hurricane Katrina in 2005.

Principal Identifying Characteristics:

1. Large species with speckled brown and white scales.
2. Broad wings.
3. Female abdomen blunt.
4. Abdomen with yellowish-white dorsal bands which widen laterally.
5. Tuft of yellowish setae arising from the base of the subcostal vein on the undersurface of the wing.

Coquillettidia perturbans
(Salt and Pepper Mosquito)

This is a troublesome species that bites in the early evening, and occasionally during the daylight hours in shade near its breeding area. The females readily enter houses and bite viciously. They are strong fliers. EEE and WNV have been recorded from wild-caught *Cq. perturbans*, but its role in the epidemiology of these viruses has not been determined.

Species of the genus *Coquillettidia* have a unique morphological adaptation. They have a sharpened structure on the siphon tube of the larva and on the trumpets of the pupa. They get their oxygen by osmosis and they stay under water by using the teeth on the siphon tube to attach to plant roots. The aquatic stages, for the most part, are passed entirely submerged. Detection of breeding sites is very difficult as the larvae quickly detach themselves from the host plants whenever they are disturbed. [This is also true for the species in the genus *Mansonia*.]

Breeding of *Cq. perturbans* takes place in marshes, ponds, and lakes that have a thick growth of aquatic vegetation. Larvae have been found associated with alligator weed, pickerel weed, cattail, water lettuce, arrowhead, aquatic sedges, and other aquatic plants. Larval development is slow, usually requiring several months. Larvae, which are produced in one season ordinarily, do not complete their development until the following spring. The adults emerge in late spring or early summer. Throughout most of its range, *Cq. perturbans* appears to have only one generation per year, though it is possible they may have more.

Principal Identifying Characteristics:

1. Moderately large speckled light and dark brown species.
2. Female abdomen blunt.
3. Wing scales very broad, mixed brown and white.
4. Proboscis and tarsi ringed with white — first tarsal segment of all legs with a single broad white ring in the middle.
5. Abdomen dark scaled with pale basolateral patches and occasionally with narrow basal segmental bands.

***Coquillettidia perturbans*. Photo by Nathan Burkett-Cadena**

Chapter 3 - Practice Questions

1. The primary overwintering stage for *Aedes albopictus* in Louisiana is:

a. Egg
b. Larvae
c. Pupae
d. Adult

2. Which species of adult mosquito in Louisiana has the shortest dispersal range?

a. *Culex salinarius*
b. *Aedes aegypti*
c. *Aedes vexans*
d. *Culiseta inornata*

3. What is a major identifying characteristic of the southern house mosquito?

a. Each wing has four dark spots
b. Median white stripe on thorax
c. Pale, half-moon shaped basal abdominal segments
d. Pale bands on legs

4. Where would you most likely find breeding *Anopheles crucians*?

a. Tire piles
b. Cypress swamps
c. Septic ditches
d. Tree holes

5. Which genus lays their eggs in rafts?

a. *Aedes*
b. *Psorophora*
c. *Anopheles*
d. *Culex*

6. The common name for *Culex quinquefasciatus* is?

a. Asian tiger mosquito
b. Southern house mosquito
c. Dark rice field mosquito
d. Floodwater mosquito

7. What is the scientific name for the salt and pepper mosquito?

a. *Coquillettidia perturbans*
b. *Culex salinarius*
c. *Culiseta inornata*
d. *Aedes albopictus*

8. Which is a common habitat for *Psorophora columbiae*?

a. Flower pots
b. Rice fields
c. Old tires
d. Ditches

9. *Anopheles quadrimaculatus* is the primary vector of what was disease?

a. Malaria
b. West Nile virus
c. Zika virus
d. Dengue

10. Which species was imported to the United States from Japan in ships of rubber scrap tires?

a. *Aedes vexans*
b. *Aedes aegypti*
c. *Aedes albopictus*
d. *Aedes triseriatus*

Chapter 4

MOSQUITO HABITAT RECOGNITION

Mosquito larvae develop in a variety of habitats. In fact, if there is a type of standing water that exists in Louisiana, there is probably a species of mosquito that exploits it. Below is a list of different types of mosquito habitats, with some general information on the types of mosquitoes you might expect to find in those habitats.

Artificial containers

Many species of mosquitoes in Louisiana lay eggs in artificial containers. Examples of artificial containers include tires, buckets, trash cans, toys, watering cans, and plant dishes. Species such as *Aedes albopictus* and *Aedes aegypti* commonly use these as habitats. However, in urban areas, *Culex quinquefasciatus* will also use these as a larval source.

Treeholes

Hollowed out holes in trees are a common larval habitat for a few mosquito species. Of important note, that this is a native habitat for our natural biological control organism, *Toxorhynchites*, which is the cannibal mosquito. Although cannibal mosquitoes frequently use this habitat, there are other species of mosquito that can be found in treeholes. This includes *Aedes triseriatus, Aedes albopictus*, *Aedes aegypti* and *Orthopodomyia signifera.*

Basic floodwater

In Louisiana, there is ample amounts of basic floodwater. This includes any type of open areas that become flooded after it rains. When these areas become flooded for a week or more, they create huge numbers of nuisance mosquitoes, such as *Aedes vexans*, and *Psorophora columbiae.* Many of these species can become nuisance problems in rice fields or in areas that are inundated by water after storms and hurricanes.

Abandoned swimming pools

To no surprise, abandoned swimming pools are an excellent mosquito habitat for many species, including our southern house mosquito, *Culex quinquefasciatus.* Abandoned swimming pools often have large amounts of dirty standing water and are void of very few predators. As a result, mosquito fish are often a great tool to control mosquitoes in these types of habitats.

Septic ditch. Photo by Jennifer Bushnell

Roadside ditches and septic ditches

Effluent from septic tanks are often discharged into ditches along the streets in residential areas. These highly organic standing water habitats offer prime larval habitats for *Culex quinquefasciatus.* While not all roadside ditches are septic, water in these habitats are typically highly organic in nature. Improving water movement and flow in these areas can help reduce numbers if water is not standing for a week or more.

Cattail marsh

Couquillettidia perturbans have a unique relationship with certain types of marsh plants, including those in cattail marshes. The larvae of this mosquito species pierces the plant tissue, while it is underwater, and breathes atmospheric oxygen from the plant. As a result, control of this mosquito species is often difficult, because they very rarely come to the water surface.

Saltmarsh

Since salt marsh habitats are incredibly saline, very few species have adapted to it as a larval habitat. However, those that do breed in salt marshes often come out in incredibly high numbers. Salt marshes are tidally influenced. Therefore, there are parts of the marsh that are frequently flooded, and those that are only flooded during the highest tides and rain events. Areas that are more frequently flooded through tides, often have predatory fish that can access those habitats, limiting mosquito larval numbers. However, in upper areas of the marsh that receive less flooding, but also have frequent rain, larvae can exist in large numbers. Species that lay eggs in saltmarshes include *Aedes sollicitans, Aedes taeniorhynchus,* and *Culex salinarius.*

Large wetlands

Louisiana is known for its dense wetland swamps, and slow-moving bayous. These areas have high diversity of plant and animal species, and are often away from residential areas. However, these locations also harbor some important nuisance and vector species, including *Anopheles quadrimaculatus.*

Small woodland pools

It is not unusual to find small woodland pools around parks and other residential areas. These woodland pools are excellent habitats for species, such as *Psorophora ferox.* Some of these pools can be seasonal in nature, or flood during heavy rain events. In some areas, they may remain dry for long periods of time, until intense rainfall events.

Chapter 4 - Practice Questions

1. Where would you most likely find breeding *Anopheles quadrimaculatus*?

a. Tire piles
b. Permanent swamps
c. Septic ditches
d. Tree holes

2. Which species would you be able to find in a tree hole?

a. *Culex territans*
b. *Culex salinarius*
c. *Anopheles crucians*
d. *Toxorhynchites rutilus*

Chapter 5

MOSQUITOES AND HUMAN DISEASES

Mosquitoes can transmit (**vector**) several important disease-causing pathogens that we will learn about in this chapter. In some diseases, mosquitoes serve as **amplification vectors**, in which they are involved in amplifying (or increasing) the virus in its natural hosts. They can also function as **bridge vectors**, in which they transfer the pathogen from one type of host (such as animal) to another (such as a human).

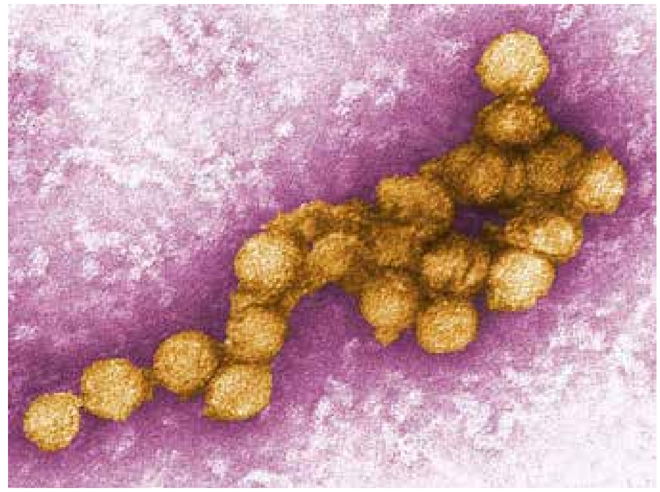
Malaria, dengue, and yellow fever were historically very important in Louisiana prior to organized mosquito control. In fact, hundreds of thousands of individuals lost their lives due to these diseases in the southern United States. While these diseases are rarely a concern in Louisiana in present times, the risk of arthropod-borne viruses (**arboviruses**) have become increasingly important in the state. In Louisiana, mosquitoes serve as vectors of many arboviruses, including West Nile virus, Eastern equine encephalitis virus, and St. Louis encephalitis virus. In addition to viruses, mosquitoes also serve as important vectors of other parasites and pathogens, such as those that cause malaria and canine heartworm.

The most common concern with many arboviruses in Louisiana is the risk of encephalitis in infected individuals. The word "encephalitis" means an inflammation of the brain and possibly the spinal cord (encephalomyelitis). While there are several causes for encephalitis, pathogens, such as West Nile virus can be one potential cause. Fortunately, not all individuals infected with arboviruses will exhibit neurological symptoms. Many are either asymptomatic or have flu-like symptoms.

Some arboviruses, such as dengue, Zika virus, and chikungunya, can all easily cycle between humans and competent mosquitoes. However, many of the significant arboviruses in Louisiana have an animal host that serves as a reservoir for the virus. **Reservoirs** are animals in which viruses replicate to high enough levels that mosquitoes can pick it up in nature. Arbovirus transmission cycles that have animal reservoirs are called **zoonoses**, meaning they occur naturally in cycles between mosquitoes and non-human vertebrates. While humans can get sick from West Nile virus, the levels are not high enough in our blood to infect another mosquito. Humans and animals that do not develop high enough viral loads for transmission are termed "**dead-end hosts**."

West Nile Virus

West Nile virus was introduced into in the United States in the New York area in 1999. Although originally misdiagnosed as St. Louis encephalitis (SLE), it was quickly recognized as responsible not only for human disease and several deaths, but also involved in heavy avian mortality, especially in the passerine family Corvidae (crows and jays). Like SLE, WNV is transmitted naturally between birds by certain species of mosquitoes. Humans, horses, dogs, cats and most other vertebrates are likely accidental or dead-end hosts, meaning they are not capable of passing the virus on to uninfected mosquitoes. For every 100 infected persons, only 20 will develop symptoms of fever or more severe disease, with most showing symptoms associated with a cold (headache, fever, fatigue and occasionally, rash, swollen lymph glands or eye pain). Only a few individuals (< 1%) develop severe disease, including high fever, headache, neck stiffness, stupor, disorientation, coma, tremors, convulsions, muscle weakness, vision loss, numbness and paralysis. These symptoms may last several weeks, and neurological effects may be permanent. About 10% of severe cases are fatal.



West Nile virus. Photo by the Centers for Disease Control and Prevention (CDC)

Following its initial introduction, WNV spread south and then west in the United States, probably transported during local and migratory movement of birds. WNV is known to kill more than 300 species of birds, and 60 mosquito species have been found infected, with many identified as potential vectors. Because of high viremia and resulting severe pathology in some birds infected with the virus, dead birds were once useful as an early indicator of WNV activity in a new area. Likewise, mosquito infections have tended to be a useful predictor of WNV activity. Sentinel chickens, while historically useful as indicators of SLE and Eastern equine encephalitis (EEE) circulation in the eastern

U.S., they have not been particularly useful in providing an adequate advance warning of WNV activity. In fact, in Louisiana, WNV positive sentinel chickens often occur at the same time as human cases in an area.

The virus was first found in Louisiana in 2001, with human cases continuing to occur annually. The more severe neuorinvasive cases reached 204 in 2002, and 77 in 2012. People over the age of 75 are at greatest risk for severe disease and death. Human cases usually begin to occur in late June or early July. Human cases have occurred in 75% of Louisiana parishes, with foci around most major urban areas.

Quick facts:

- Southern house mosquitoes, and other species of *Culex* are the most important amplification vectors of WNV.
- *Culex* mosquitoes also serve as bridge vectors of WNV.
- Birds are the reservoirs for WNV.
- Humans and other large mammals are dead end hosts of WNV.
- WNV is a virus in the family Flaviviridae.
- WNV occurs annually in Louisiana.
- People over the age of 75 are at greatest risk for severe disease and death.

St. Louis Encephalitis

St. Louis encephalitis (SLE) is another arboviral disease found in Louisiana, similar to WNV. It cycles between birds and primarily *Culex* mosquitoes. Infected humans may experience abrupt onset of fever, nausea, and vomiting with severe headaches. These symptoms develop within five to 15 days after a person is bitten by an infected mosquito. A person of any age may contract the disease; however, the symptoms are more severe in people 60 years of age or older. Case fatality rates may range from 3% to 30% with most occurring in the elderly.

Humans become infected with SLE only as a result of being bitten by an infected mosquito. There is no person-to-person transmission. The chances of contracting the disease are in direct proportion to the number of infected birds and the abundance of Culex mosquitoes in the vicinity. SLE outbreaks are most likely to occur from mid-summer to early fall and are often associated with extended drought earlier in the year. Drought conditions shrink the mosquito breeding habitats, reducing the available water for birds and increasing the likelihood of meeting one another. *Culex quinquefasciatus*, a foul water breeder, is the primary vector of SLE, and its numbers may increase in drought conditions. Although superficially like WNV in transmission cycle, and a member of the same virus family, SLE human cases tend to occur in urban areas where house sparrows, the primary vertebrate reservoir host, and *Culex quinquefasciatus* coincide. This may be due to a narrower mosquito host range for the SLE virus as compared to WNV.

SLE was first recognized as a disease in the early 1930s during outbreaks in St. Louis, Missouri, and Paris, Illinois. The most severe epidemic of SLE in recent decades swept through the Mississippi River Valley in 1975. In its path, a total of 1,941 confirmed and presumptive cases were recorded over 28 states and the District of Columbia, including 95 confirmed deaths. The states of Mississippi, Illinois, Indiana, and Ohio reported the most cases. There are approximately 128 human cases recorded annually in the U.S., but typically much smaller outbreaks occur.

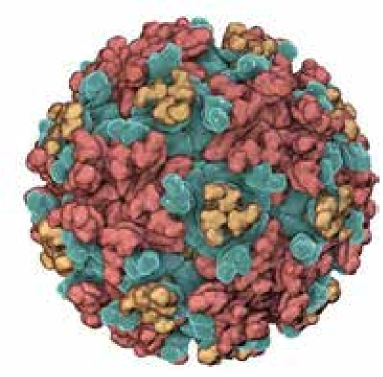
Louisiana did not record its first case of SLE until 1966 when seven human cases were reported (six cases from New Orleans and one from Monroe). Generally, in the 1960s and ’70s, the state only saw sporadic cases. In Orleans Parish there were two outbreaks occurring during 1980 (12 human cases) and 1994 (16). The next significant year for SLE was in 1998 when Jefferson Parish had 14 cases. The largest and most recent outbreak (2001) occurred in Ouachita Parish reporting 70 cases; since then there have only been sporadic cases annually.

Quick facts:

- Southern house mosquitoes, and other species of *Culex* are the most important amplification and bridge vectors of SLE.
- Birds are the reservoirs for SLE.
- Humans and other large mammals are dead end hosts of SLE.
- SLE is a virus in the family Flaviviridae.
- SLE still occurs but is far less common than WNV.
- Symptoms are more severe in people 60 years of age or older.

Eastern Equine Encephalitis

Eastern equine Encephalitis (EEE) is a viral infection maintained in nature by a bird-mosquito-bird cycle like SLE. It is distributed along the coastal states of the Gulf of Mexico and the Atlantic Ocean. In the U.S. there are approximately 5 human cases annually, with 220 human cases since 1964. EEE is the deadliest mosquito-borne virus to occur in the U.S., with a 30% fatality rate. Equines are involved as “dead end” hosts in the cycle along with man. EEE can infect persons of any age, but those younger than 15 and older than 50 are particularly vulnerable to severe disease. Onset of symptoms typically occurs three to 10 days after an infected mosquito bite. Half of those who



Eastern equine encephalitis virus

survive are afflicted with varying degrees of mental disability and paralysis.

A major outbreak of EEE is known to have occurred in Louisiana in 1947 when the virus produced disease in over 15,000 horses and 15 humans (7 fatalities). Since then, knowledge of the transmission cycle and availability of a vaccine for horses (but not for humans) has resulted in much reduced infection of horses and humans.

During the years 1964 to 1990 Louisiana only recorded two human cases, however since that time there have been one or more cases per year.

There are several mosquitoes, especially *Culiseta melanura,* that can maintain and transmit EEE in nature. Since *Cs. melanura* is uncommon and seldom bites man, other mosquitoes such as *Cs. inornata, Cx. quinquefasciatus* (southern house mosquito), *Aedes albopictus* (Asian tiger mosquito), *Ae. sollicitans* (tan salt marsh mosquito), *Ae. vexans, Ae. infirmatus, Ae. atlanticus,* and *Coquillettidia perturbans* are important in transmission from birds to man and/or equines. Factors favoring infection in man are the buildup of virus in wild bird populations and a high density of adult mosquito vectors. Human risk is highest in rural areas near bodies of water supporting development of competent mosquito vectors.

Quick facts:

- *Culiseta melanura* is the primary amplification vector of EEE.
- Numerous species of mosquitoes, such as *Ae. albopictus, Ae. sollicitans,* and *Cq. perturbans,* are important bridge vectors.
- Birds are the reservoirs for EEE.
- Humans and other large mammals are dead end hosts of EEE.
- EEE is a virus in the family Togaviridae.
- There is a 30% fatality rate, making it the deadliest mosquito-borne disease in the U.S.

Western Equine Encephalitis

Western equine encephalitis (WEE) is another arboviral disease in the United States and is found mainly in the states west of the Mississippi River. Louisiana has never recorded a human case of WEE. Although there have been 639 confirmed human cases since 1964, there have been fewer than one to two per year since 1996. Thirteen percent of infections (30% of infants) show disease with a 3% fatality rate. *Culex tarsalis* is the most important vector throughout the western United States, and, as with EEE, birds are the major host. East of the Mississippi River, *Cx. quinquefasciatus* is the suspected vector. Both man and equines are accidental or dead-end hosts. As with EEE, a vaccine for horses is available, but no vaccine is available for humans.

La Crosse (California group) Encephalitis

La Crosse encephalitis virus (LAC) is a member of the California group of encephalitis viruses (Family *Bunyaviridae*). The natural cycle of LAC differs from that of SLE, EEE, and WEE in that natural hosts are small and medium-sized animals such as rabbits, hares, and squirrels rather than birds. The vectors are mostly woodland mosquitoes (primarily *Aedes triseriatus*), and most of the human cases have occurred in people who lived or worked in or near wooded areas. Most cases of LAC have been reported from the states of Ohio, Wisconsin, West Virginia, and Minnesota. Advanced surveillance and detection of human disease from LAC in recent years has identified large foci in mid-Atlantic states such as West Virginia and in western North Carolina. There is an average of 70 cases per year, with most severe disease occurring in children younger than 16 years of age and resulting in a less than 1% fatality rate.

In Louisiana, only 25 cases have been reported since 1964 (although a 2001 OPH serosurvey showed 30% of Ouachita parish residents aged 60 and over had antibodies to the virus). The largest number of cases (nine) occurred in 1969, mostly from Lafourche Parish. Although from 1970 to 2000 there were only two cases reported, since 2001, one to three cases have been reported annually. These cases were probably identified due to increased awareness and testing for arboviral disease after the introduction of WNV. LAC has been isolated from several species of woodland mosquitoes, particularly *Ae. triseriatus* (the primary vector), *Ae. canadensis, Ae. trivittatus*, and Ae. *atlanticus,* all of which are found in Louisiana. It has also

Malaria parasite

been isolated from and can be transmitted in the laboratory by *Ae. albopictus,* a possible secondary vector in some areas.

Quick facts:

- *Aedes triseriatus* is the primary amplification and bridge vector of LAC.
- Small animals (rabbits, chipmunks, squirrels, and hares) are the reservoirs for LAC.
- LAC is a virus in the family Bunyaviridae.
- The most severe disease occurs in children less than 16 years of age and results in a less than 1% fatality rate.

Jamestown Canyon virus

Jamestown Canyon virus (JCV) is similar to LaCrosse virus, in that it is within the family Bunyaviridae. While there is still little known about this disease, it first appeared in Louisiana in 2017. There have been a variety of species that have been implicated as vectors, including *Culiseta inornata,* and early season *Aedes,* such as *Ae. canadensis.* Larger hoofed mammals, such as deer and cows, serve as the primary reservoir.

Quick facts:

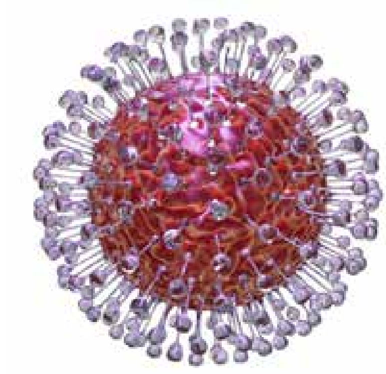
- Early season *Aedes* are the primary amplification and bridge vectors of JCV.
- Large hoofed animals (deer and cows) are the reservoirs for JCV.
- JCV is a virus in the family Bunyaviridae.
- Symptoms are similar to other California group encephalitis viruses.

Zika virus

Zika virus was first discovered in Africa (Uganda) in 1947. In May of 2015, it was detected in the Americas for the first time. While at the time, little was known about the virus, we have now begun to understand a great deal about negative impacts of this virus. Most individuals (about 80%) that become infected will not show symptoms. Of those that do, symptoms are generally mild, and includes fever, joint pain, conjunctivitis, and rash. Neurological complications or death are extremely rare. There is no specific treatment for Zika.

The current concern regarding Zika virus is the link between infection during pregnancy, and having a child born with microcephaly (reduced brain size). The virus has also been linked to Guillain-Barre syndrome, a condition in which the immune system attacks the peripheral nerves.

Container mosquitoes, such as *Aedes albopictus* (Asian tiger mosquito) and *Aedes aegypti* (yellow fever mosquito) are the two most important vectors of Zika virus that occur in our area. These mosquitoes lay eggs in backyard containers (buckets, trash cans, tires, bottles, etc).



Zika virus

Quick facts:

- *Aedes aegypti* is the primary amplification and bridge vector of Zika.
- Humans serve as reservoir hosts for Zika virus.
- Zika is a virus in the family Flaviviridae.
- The greatest concerns with Zika virus are the neurological complications that occur in a fetus, such as microcephaly.

Chikungunya virus

Chikungunya (CHK) gets its name from the Kimako language "that which bends up," referring to the arthritic pain caused by the illness. Chikungunya virus is an emerging arbovirus that has not yet been detected in the United States. Recent outbreaks of the disease have recently occurred in Europe and Asia, and the Caribbean. Illnesses are often mild and may go unnoticed. Serious illness or death rarely occurs. However, most cases deal with long-term health issues, such as severe joint pain. The virus is transmitted between humans and human biting mosquitoes. In Louisiana, we have two very important species (yellow fever mosquito and Asian tiger mosquitoes) which are potential vectors of this virus. These species are found in urban and suburban habitats, where they lay eggs in manmade containers.

Quick facts:

- *Aedes aegypti* is the primary amplification and bridge vector of CHK.
- Humans serve as reservoir hosts for CHK.
- CHK is a virus in the family Togaviridae.
- A large percentage of people that are infected are symptomatic, experiencing joint pain.

Dengue

Dengue is a viral disease commonly called "breakbone fever." Dengue is worldwide in its distribution, primarily in the tropics and subtropics, and infects 50 to 100 million people annually, with 200,000 severe disease cases. It is often characterized by severe headache, pain behind the eyes, high fever, backache, pain in the joints, and a rash, and may require several weeks to fully recover. These symptoms generally occur five to six days after an infected mosquito has bitten a susceptible person. In uncomplicated cases, death rarely occurs. There are four strains of dengue, and in some areas of the world, infection from several strains of the dengue virus may result in more severe and often fatal forms of dengue known as dengue hemorrhagic fever (DHF) and dengue shock syndrome.

Before 1980, the last major epidemic of dengue in the continental U.S. occurred in St. James Parish, Louisiana, in 1945. In that epidemic, the Louisiana Department of Health recorded 62 confirmed cases, but authorities estimated that there were probably several hundred inapparent and/or unreported cases. Previous U.S. epidemics of dengue occurred in 1934 in Hawaii, 1934 in Florida and Georgia, and 1922 in Florida and Texas. After the 1945 outbreak, single cases were recorded from Louisiana (1947) and Florida (1973).

Dengue is transmitted by the container breeders *Ae. aegypti* and *Ae. albopictus* in a mosquito-man-mosquito cycle. After biting an infected person, the female mosquito requires eight to 10 days for viral development before she is capable of virus transmission to man. Once infected, the mosquito remains infective for the remainder of her life. Although *Ae. aegypti* is the primary vector on a worldwide basis, *Ae. albopictus* is quite capable of serving as a vector, as evidenced in the 2015-2016 Hawaii outbreak.

Presently, there is no commercially available vaccine. Treatment for uncomplicated cases of dengue consists of providing the victim with as much relief from the disease symptoms as possible. The severe forms are normally treated with intravenous fluids or transfusions and other therapies.

Quick facts:

- *Aedes aegypti* is the primary amplification and bridge vector of dengue.
- Humans serve as reservoir hosts for dengue.
- Dengue is a virus in the family Flaviviridae.

Yellow Fever

Yellow fever is caused by a virus closely related to the dengue virus. In fact, yellow fever infections produce dengue-like symptoms in humans; however, the effects of yellow fever are normally much more severe. The fatality rate may reach 50% or more in epidemics. The virus is presently found in Africa, Central America, and South America. It is absent from the continental U.S. at present. The last epidemic of yellow fever in the continental U.S. occurred in New Orleans in 1905.

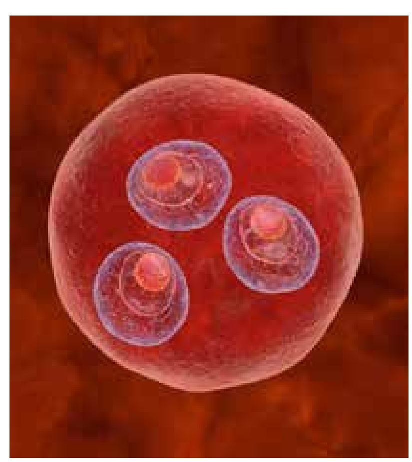
As with dengue, the yellow fever virus in transmitted in urban areas by *Ae. aegypti* and *Ae. albopictus.* Unlike dengue, however, the probability of virus reaching the U.S. is low. This may be due, in part, to the fact that yellow fever, along with cholera, smallpox, and plague are quarantinable diseases. This means that the Centers for Disease Control and Prevention in Atlanta, Georgia, are continually monitoring outbreaks of yellow fever in the western hemisphere. There is an extremely effective yellow fever vaccine called 17D. All persons who pass through yellow fever endemic areas must show evidence of proper vaccination prior to re-entry into this country. All arriving planes and ships are required to undergo insecticidal fumigation treatment to kill any mosquitoes that might otherwise be potential vectors.

Quick facts:

- *Aedes aegypti* is the primary amplification and bridge vector of yellow fever.
- Humans serve as reservoir hosts for yellow fever.
- Yellow fever is a virus in the family Flaviviridae.

Malaria

On a worldwide basis, malaria remains the most important human disease transmitted by mosquitoes. According to CDC information in 2018 there were 228 million human cases of malaria and 405,000 deaths. In the same year the U.S. had 2,000 cases related to travel from countries where malaria is transmitted. Most of the deaths (75%) are children under 10 years of age and pregnant women. In Africa, one in every 20 children dies from malaria. It is believed that malaria was introduced into the North American continent during colonization. Tens of thousands of cases



Bunyavirus (Lacrosse and Jamestown Canyon virus)

occurred in the U.S. before the 1930s, but there are no reliable statistics available for the period. However, in the 1930s, approximately 100,000 cases were reported annually; in the early 1940s, the number of cases was reduced dramatically due to the work of public health agencies using DDT during and after World War II and the Tennessee Valley Authority (TVA) source reduction program.

Since the late 1950s a few hundred to a few thousand new cases have been recorded annually, almost entirely attributable to military returnees from endemic regions. These cases were contracted outside the U.S., but symptoms appeared following re-entry into the country. Until recently, rarely has there been secondary infection contracted in the U.S. But since 41% of the world's population lives in malarious areas, the risk for importation is constant. Between 1957 and 2003, there have been 63 outbreaks of locally transmitted malaria in the U.S. In 2002 alone, there were 1,337 cases of malaria with eight deaths — five of the total cases were locally acquired.

Human malaria is caused by any of four *Plasmodium* species of protozoa and is characterized by fever, chills, sweating, and headache. If not treated, it may cause shock, renal failure, acute encephalitis, coma, and death. The disease is transmitted by *Anopheles* mosquitoes. In Louisiana, *An. quadrimaculatus* (formerly known as Species A in the five-member species complex, of which four species, Species A, B, C2, and D occur in Louisiana) is considered to be the primary historical and potential vector. Another species, *An. crucians,* may also be a competent vector. Both species are widespread in rural areas and are most abundant from April through September.

Quick facts:

- *Anopheles quadrimaculatus* is the primary amplification and bridge vector of the malaria parasites in Louisiana.
- Humans serve as reservoir hosts for malaria parasites.
- Malaria is caused by a protozoa, in the genus *Plasmodium.*

Canine Heartworm

Canine heartworm (*Dirofilaria immitis,* a filarial worm) is a serious disease for all breeds of dogs in Louisiana and other areas with subtropical or tropical climates. In the southern part of Louisiana, the infection rate is reported to be as high as 80% in dogs over 2 years and six months old, and almost 100% in dogs over 5 years old. Humans can also become infected, but the worms are unable to develop or mature.

The life cycle of canine heartworm involves two factors: mosquitoes and dogs. Mosquitoes ingest the immature worms or embryos called microfilariae that circulate in the blood of a dog while feeding. These immature worms migrate to the Malpighian tubules of the mosquito where they undergo development through several larval stages in nine to 14 days. The last stage called the third or infective stage larva then migrates to the mouthparts of the mosquito. When the female takes another blood meal, the larva falls out of the mouthparts and onto the skin of the dog. The dog becomes infected if the larva manages to find and enter the puncture wound, most fail to make this transition. The larvae grow and migrate through subcutaneous tissues and large blood vessels and eventually enter the right ventricle of the dog's heart – thus the name. The larvae grow into adult worms measuring about 11 inches for the females, and 6 inches for the male. The adult female worm lays no eggs but instead extrudes the microfilariae which circulate in the blood thus completing the life cycle.

Several genera of mosquitoes can transmit the parasite to dogs (e.g., *Aedes, Anopheles, Culex* and *Psorophora*). It is frequently reported in the literature that *Cx. quinquefasciatus* (southern house mosquito) is considered to be the most important vector of canine heartworm, but a study by Lowrie (1991) has shown that this is not the case, at least with several Louisiana strains he tested. A probable explanation for this lack of vector efficiency was first reported by Nayar and Sauerman (1975). They observed the formation of long, needle-like oxyhemoglobin crystals in the midgut of *Cx. quinquefasciatus* females shortly after ingesting *D. immitis* infected dog blood. These crystals blocked the migration of the microfilariae to their Malpighian tubule development site. Lowrie (1991) observed the same crystal formation and confirmed that they were oxyhemoglobin by SDS-PAGE gel electrophoresis. However, it is likely that the vector competency of *Cx. quinquefasciatus* strains may differ from one region to another. Other incriminated vectors of canine heartworms include *Ae. albopictus* and *Ae. vexans,* and *Ae. taeniorhynchus.*

If a dog in Louisiana is kept outdoors continuously without heartworm prophylactic medicine, there is nearly a 100% guarantee that the animal will eventually come down with a dog heartworm infection.

Quick facts:

- Several genera of mosquitoes serve as vectors of canine heartworm.
- Humans do not become infected, rather it is a parasite that infects canines.
- Canine heartworm is caused by a filarial worm.
- All heartworm is transmitted by mosquitoes.
- If left outdoors without preventatives, there is a 100% chance a dog will become infected with heartworm in Louisiana.

Chapter 5 - Practice Questions

1. What is the primary amplification vector of West Nile virus in Louisiana?

a. *Culiseta melanura*
b. *Culex quinquefasciatus*
c. *Aedes albopictus*
d. *Anopheles quadrimaculatus*

2. What is the primary vector of Malaria in Louisiana?

a. *Culiseta melanura*
b. *Culex quinquefasciatus*
c. *Aedes albopictus*
d. *Anopheles quadrimaculatus*

3. Which of the following pathogens has a bird as a reservoir?

a. Malaria
b. LaCrosse virus
c. West Nile virus
d. Dengue virus

4. Which of the following pathogens has a human as a reservoir?

a. St. Louis encephalitis
b. LaCrosse virus
c. West Nile virus
d. Dengue virus

5. Which of the following diseases is caused by a protozoa?

a. Malaria
b. LaCrosse
c. West Nile
d. Dengue

Chapter 6

ORGANIZATION AND PRINCIPLES OF MOSQUITO CONTROL

The Louisiana Mosquito Control Association advocates an Integrated Mosquito Management (IMM) approach, which utilizes methods or a combination of methods that give maximum control of mosquitoes with minimal impact on non-target organisms and the environment. The components of an IMM plan consist of mosquito sampling and surveillance, physical control (source reduction), chemical control, biological control, disease surveillance, public education, and mosquito susceptibility monitoring. The program can be in-house or contracted to a private company, but must consider cost-benefit ratios and be demonstrably sound from an economic standpoint.

Mosquito Control Methods

Effective mosquito control involves a three-step process — data collection, data analysis, and control. These three steps should be performed on a routine basis. It is important that before any control procedures are initiated, an assessment be made of the mosquito problem. The objective of the collection and analysis of data (mosquito sampling and surveillance phase of the IMM plan) is to provide information regarding the species, density, and stage of development of problem mosquitoes, as well as recognition of problem areas and developing strategies to initiate the plan of action for control.

Control methods can be classified under two categories — chemical/biological and physical mosquito control. Chemical/biological control, provides quick but short-term abatement of the mosquito problems. In most cases, it reduces only mosquitoes which are presently active. This type of control requires the application of adulticides and or larvicides. Physical control (source reduction) involves the elimination of breeding sites by sanitation, ditching, draining, or water-level management. Programs in Louisiana rely on sanitation and education for most source reduction. Public education programs should focus on reducing or eliminating breeding sites by emptying containers, discarding tires, or other sources. Breeding areas that do not cause persistent problems, or that can be economically controlled via larviciding, may not justify physical control.

The development of preventive mosquito control can be effective in areas where water management projects could create a variety of aquatic habitats favorable for mosquito production. Experience has shown that when proper consideration is given to potential mosquito problems during the initial stages of project planning, adequate provisions can be made for the prevention of mosquitoes or for minimizing the subsequent control measures required.

Inspecting a ditch for larva. Photo by Jennifer Bushnell

Finance and Budget Preparation

Community-wide mosquito control operations must be an ongoing program with a stable source of funds. Programs may be financed by several different methods that are dictated by local conditions. Sources of financing usually come from dedicated property taxes, fixed charges collected on a selected household utility, or local sales tax. Whatever the source, a budget is established each year based on projected needs.

The budget explains and justifies the costs for various operations. It should reflect the program's projected expenditures for personnel, chemicals, supplies and materials, contractual services, and equipment. It enables proper accounting and tracking of all expenses.

Personnel Training and Certification

Personnel selected to perform the various duties in mosquito control operations should be highly motivated and capable of being trained. The IMM approach is knowledge based and requires the applicator to know everything about the biology of the target. In chapter 13 (Laws) of this manual the Louisiana Department of Agriculture and Forestry (LDAF) requirements for certificate are laid out. Personnel are required by the Federal Insecticide, Fungicide, and Rodenticide Act (as amended) to be certified as commercial pesticide applicators, in order to permit the use of any pesticides in program operations. At least one of the supervisory personnel must be certified by the LDAF in category 8D, Supervisory Mosquito Control.

Facilities and Equipment

The specialized functions of a mosquito control program are most effectively performed using

facilities and equipment specifically designed or modified for dispersing insecticides. The loading areas, spray equipment, and spray vehicles should be highly maintained, constantly kept clean and free of any chemical contamination. All facilities should have proper labeling of chemical containers, mixing tanks and equipment. All spray systems should be calibrated once a year at a minimum or any time a modification is made to any component of the spray system. There should be facilities for maintenance and servicing of specialized equipment, laboratory facilities to support necessary biological and chemical studies and evaluations, and office facilities where the various activities can be coordinated.

Mosquito Control Program Planning

The planning for a mosquito control program requires the following:

1. Evaluation of the city or parish mosquito problem.
2. Securing a funding source and developing a budget.
3. Selection and training of personnel.
4. Surveillance activities.
5. Selection of control methods.
6. Selection of appropriate equipment.
7. Development of public information and education.

Mosquito Control Program Operation

A program of mosquito surveillance must be maintained in order to determine the magnitude of the problem and to assess the results of control activities. Control operations should include a well-planned, combined use of temporary control (insecticides and biological agents) and permanent control (source reduction). Details for these activities are provided elsewhere in this manual. Support provided by a mechanical service facility is a valuable addition to the operations of a mosquito control program because repairs, maintenance, and alterations to vehicles and equipment, most of which are specialized, may be required daily. This provides a means of returning equipment to service with minimum downtime. Other projects requiring the talents of trained personnel include field evaluation of specialized control techniques and new materials, insecticide resistance monitoring, public relations, and training activities.

Summary

To be successful, a comprehensive mosquito program should encompass all practical control techniques carefully tailored to the local situation. Every operation will have slightly different target species, equipment, and funding capabilities. Remember that the IMM approach to mosquito control is knowledge-based, surveillance-driven, and resource-limited.

Chapter 6 - Practice Questions

1. The combination of methods in a mosquito control program is called

- a. Integrated Mosquito Management
- b. Adulticiding
- c. Source reduction
- d. Cost-benefit analysis

2. Supervisory personnel in mosquito control must have which category license?

- a. 7A
- b. 7D
- c. 8C
- d. 8D

3. Which state agency in Louisiana provides certification in mosquito control?

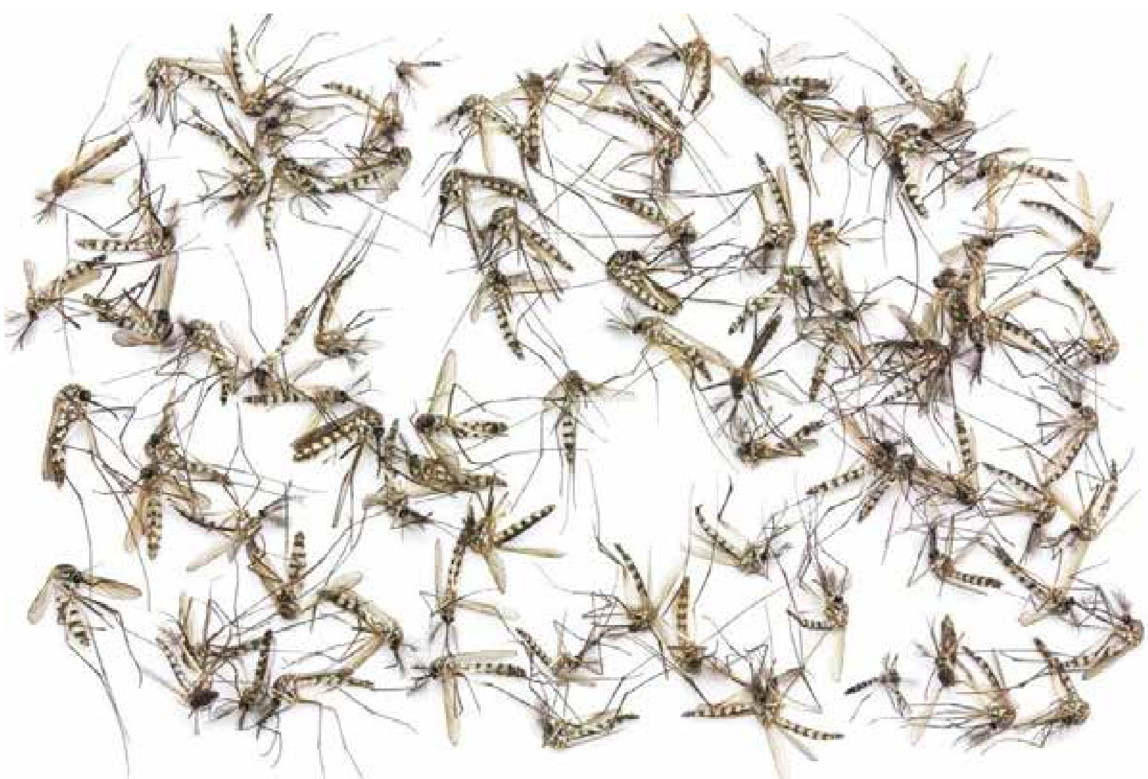
- a. Louisiana Office of Public Health
- b. Louisiana Department of Agriculture and Forestry
- c. Louisiana Department of Fish and Wildlife
- d. Louisiana Mosquito Control Association

4. Which of the following requires that all personnel applying pesticides be certified as pesticide applicators?

- a. NPDES Act
- b. Federal Certification Act
- c. Federal Insecticide, Fungicide, and Rodenticide Act
- d. Pesticide Regulation Act

5. What is the minimum number of times that spray equipment should be calibrated?

- a. Once a month
- b. Once a year
- c. Every other year
- d. When it stops working properly



Chapter 7

MOSQUITO SAMPLING AND SURVEILLANCE

The purpose behind mosquito inspections falls into one of two categories, "survey" or "surveillance." The term "survey" is usually applied to one-time gathering of inspection data to assess a situation. A survey may cover a small or large area and may be limited to one factor, such as breeding in artificial containers, or may include many aspects of the total mosquito problem. Surveillance, on the other hand, is a continuing process of inspection for the purpose of monitoring changes in mosquito populations. A good surveillance program indicates when control measures are needed as well as the effectiveness of the measures.

A basic inspection program for a mosquito control operation usually addresses the following: (1) adult mosquito population density and species composition, (2) rainfall and tide monitoring, and (3) breeding site locations. Many surveillance programs also include other types of inspection as well, such as (4) arbovirus surveillance in birds, (5) arbovirus surveillance in mosquitoes, (6) presence/absence surveillance for unique species, such as *Aedes aegypti* and *Ae. albopictus,* and (7) sampling of floodwater mosquito eggs to locate breeding sites.

Initial inspections or surveys are usually made to establish the need for control measures, and if a need is found, the results of the control measures will be assessed by subsequent inspections. In order to avoid comparing dissimilar parameters, it is necessary that inspections be consistent, both in method and location. For this reason, the keeping of clear, accurate records is as important as the data gathering itself. Records of inspections should be kept with the thought that subsequent inspections may be made by someone else less familiar with the area. Because record keeping is basic to all inspection procedures, it will be discussed before specific inspection methods.

Record Keeping

The record of any inspection should contain, in addition to the inspection data, the following basic information: inspector's name, date of inspection, and exact location. Location description, especially in rural areas, can sometimes be quite difficult. For this reason, a map with location keys can be very helpful. For routine surveillance work, numbered or named stations are usually established with their locations marked on a map. Then the location description becomes a simple matter of recording the station number or name.

In wide-ranging survey work narrative descriptions are sometimes needed to describe locations exactly. These should be simplified whenever possible. In cities, this is easy: "NW corner of lot, 15th Street and 9th Avenue" is a brief description, which leaves no doubt as to the location. There are some areas that are difficult to accurately locate (e.g., marshlands). However, maps can be subdivided into numbered or named areas for easy reference. Some common methods of subdividing maps involve the utilization of geographical features, artificial grids, or a combination of these to set boundaries on areas which are indexed for easy reference and filing. To avoid cluttering maps, the larger areas may be further subdivided using transparent overlays, again employing geographical features of a grid. Once the area of inspection is delineated by reference to index numbers, additional location data can be conveyed most clearly using cards that include a rough sketch of the area. In routine surveillance work, records of inspections are best kept on some type of standard inspection form. Data recording forms serve a dual purpose. They promote uniformity which makes records easier to read, interpret, and summarize. They also serve as a reminder to the inspector to record all pertinent information. Database management systems (computer programs designed to manage data) are the modern approach to record keeping. The use of tablets, laptops, and desktop computers allows users to access data from any location. The user can generate reports or make decisions based on the geospatial data presented. Geospatial data are datasets with location information tied to them such as GPS coordinates or address. An example would be to overlay a Google Earth image with an icon. Once the user clicks the icon information about that data point would be displayed, e.g., a mosquito service request, breeding source, or other important source.

Ovitrap. Photo by Jennifer Bushnell

Egg Survey

Ovitrap: The primary purpose of an ovitrap is to induce container-breeding species to lay their eggs in the trap, for subsequent identification. The most widely used ovitrap is the "little black jar" (LBJ). This consists of a glass or plastic jar, which is partially filled with water. A rough textured, fiberboard paddle, strip of seed germination paper, or strip of velour paper, long enough to extend above the water line, is placed in the jar. Container-breeding mosquitoes, such as *Ae. aegypti, Ae. albopictus*, and *Ae. triseriatus*, lay eggs (oviposit) on the paddle or paper in preference to the smooth-sided jar. The paddles are periodically removed and brought to the laboratory for microscopic examination. Other types of ovitraps have been developed for sampling other container/tree-hole breeding species. While they are not adult-sampling devices per se, ovitraps do furnish some index of adult mosquito density. Caution should be used, however, since the correlation between egg count and adult population density is not always consistent because the number of eggs laid (fecundity) may vary during the season or even over the lifetime of a single generation. Therefore, ovitraps are more commonly used to assess presence/absence in an area.

Egg Bucket: These are usually a plastic tub filled with hay infused and or fish emulsion fertilizer water. The primary purpose of these are to induce permanent water species such as *Culex quinquesfasciatus,* to lay eggs on the surface. The trap should be checked daily to collect and count the number of egg rafts present. The egg count numbers can help predict possible amplification of important disease species. Furthermore, the eggs collected can be hatched for larval and adult insecticide efficacy testing.

Mosquito dipper. Photo by Jennifer Bushnell

Collecting eggs. Photo by Jennifer Bushnell

Retrieving Eggs from Soil: During extended periods of drought, when larvae are difficult to locate, a search for eggs of floodwater species may be used to locate future breeding sites and to evaluate the magnitude of subsequent problems. It consists of shredding clumps of soil, washing the particles through a progressively finer series of sieves and, finally, isolating mosquito eggs by flotation in strong saltwater solutions. There are keys available to aid in the identification of eggs of floodwater mosquitoes. This surveillance method is not widely used by mosquito control districts.

Larval Surveillance

The best indication that a site produces mosquitoes is to find mosquito larvae in the water. In clear, shallow water over a light-colored bottom, visual inspection will reveal the larvae. In most other situations, vegetation, debris, turbidity, and the coloration of the larvae combine to make their detection difficult. In all cases, the larvae must be collected if they are to be positively identified, and the breeding potential of the habitat assessed.

Dipping into a habitat. Photo by Daniel McNamarra

Collecting mosquito larvae requires a minimum amount of supplies. The most common method of sampling is by dipping. A **common dipper**, made of plastic, is thrust into the water in a swift, but careful manner to capture larvae before they can dive beneath the surface. The number caught in a dipper of water is reported as "number per dip." While dipping, the person must be careful not to cast a shadow over the spot where the dip is to be taken. The shadow on the water surface alerts the larvae of possible danger, and they will descend to the bottom of the habitat. Pupae can descend particularly fast and will be even more difficult to dip.

Water may be removed with a large syringe or turkey baster in the case of tree holes or may simply be poured out from containers such as buckets and cans. A strainer or sieve may be used to capture the larvae or to separate them from dark-colored water and debris such as that found in discarded vehicle tires. During the warm months, there is a good chance of finding larvae of permanent water-breeding species at most times.

The presence of larval floodwater mosquitoes is dependent on tides, irrigation systems, and/or rainfall. Unless the site has undergone the proper flood-dry cycle just prior to inspection, larvae probably will not be present. To increase the probability of success, the inspection must be made soon after flooding occurs in order to locate larvae of floodwater mosquitoes as these species rapidly develop through the aquatic stages.

Sample site selection should be based on a thorough knowledge of vegetation associated with mosquito breeding habitat. This is particularly true in salt marshes where it is often difficult to determine if standing water is the result of daily tidal fluctuation or of recent intermittent flooding. Only the latter sites will produce mosquitoes.

With instruction and experience, the inspector learns to identify the plant species that are associated with daily (tidal), intermittently, or permanently flooded conditions, and also with fresh, intermediate, brackish, or saltwater situations. Such knowledge will enable a person to interpret the breeding potential of a relatively large area from a limited number of samples.

Landing rate. Photo by Jennifer Bushnell

Landing rate. Photo by Jennifer Bushnell

Landing rate. Photo by Jennifer Bushnell

Adult Surveillance

A collection of samples should be a true representation of the abundance and species composition of an adult mosquito population present at the time of collection. Unfortunately, not all mosquito species behave the same. Some are more strongly attracted to light than others, some are active at night (nocturnal), some are active during the daytime (diurnal), others are active during the twilight hours (crepuscular), some species prefer mammalian blood, and others prefer the blood of reptiles and birds. Add to this the fact that populations of the same species exhibit cyclical patterns of behavior (e.g., attraction to light and biting activity). It becomes evident that at any given time, it is unlikely that any sampling method will be completely unbiased. The data for an individual mosquito sampling must be evaluated carefully. It is only through experience and knowledge of mosquito biology that surveillance data can be accurately interpreted. The following is a brief description of the commonly used inspection techniques to assess adult mosquito populations.

Landing Rate Count: The simplest surveillance method is for the inspector to use themselves as bait. They stand and record the number and species of adult mosquitoes landing in a given period of time (usually one minute). They may also count the number of mosquitoes approaching, but not landing. Picking the proper station or site is important because adult mosquitoes tend to rest in shady, damp locations. The best counts will be made by starting early in the morning or late evening, this is especially important in the summer months. Also, it is important to be consistent when employing this method in so that inspectors always stand in the same location. However, sites change over time due to land development, so it may be necessary to move to a new location.

Aspirators: Handheld, backpack aspirators, and other devices are sometimes used to collect mosquitoes as mosquitoes come to land on inspectors and from inside discarded tires, vegetation, inside tree holes, or as they rest in other structures. These devices are generally used to collect a specific species of mosquito for virus testing. This method is used to collect *Ae. albopictus* which are often difficult to collect in large numbers.

Traps

A wide array of mechanical traps are available to collect adult mosquitoes. These traps utilize some form of power source (AC/DC), attractant, fan, and collection net or container. They can employ an up or down draft fan. The attractants or lure can be any combination of, but not limited to visible light, ultraviolet (black) light, carbon dioxide, fish emulsion, or hay-infused water. The location and set height can greatly affect the number of mosquitoes collected. As with landing rates being consistent with trap setup is important to gain meaningful data. It should be noted that manufacturers continue to produce new types of surveillance traps, the following are examples of the most common traps used by mosquito districts in Louisiana.

New Jersey Light Trap: The oldest standard for evaluating mosquito species dynamics, it was first produced in 1932. This trap employs a light to attract flying mosquitoes and a suction fan to draw them into a collection jar containing a kill agent. The New Jersey trap is generally affixed to a permanent collection site for the entire mosquito season. It should hang so that the top of the trap is 5 1/2 feet from the ground. The site selected must have little or no light competition to insure reliable data. It is powered from a household electrical outlet (110 volt). The trap is activated by a photo-electric switch or timer. The disadvantage of this type trap is the inability to collect a large variety of species. Some mosquito species aren't attracted to light or are active during the day. Typically, the mosquitoes associated with wide open spaces are more attracted to this type of trap, example (*Ps. columbiae, Cx. salinarius, Ae. vexans*).

Gravid Trap: The gravid trap, invented by Reiter (1983), makes use of the fact that female mosquitoes skip around the surface of the water tasting its composition with a spine (chemoreceptor) on the hind tarsal leg before ovipositing. By doing this, the female can tell whether the water is suitable for the survival of its larval progeny, e.g., is it saltwater or freshwater, polluted or not polluted, etc. This makes the gravid trap an excellent device for monitoring for WNV and SLE. Mosquitoes collected will be gravid, meaning that have they had at least one blood meal, and will have had an opportunity to contract a virus. *Cx. quinquefasciatus* mosquitoes infected with EEE virus have also been collected on a few occasions using gravid traps (unpublished data) in East Baton Rouge Parish.

The gravid trap is basically an inverted CDC miniature light trap without the light source. It is held in place over a pan of water with the fan blade creating an updraft into a collecting bag rather than the usual downdraft used by light traps. The water is made attractive for ovipositing females by mixing it with additives such as hay infusion, alfalfa pellets, or fish oil emulsion fertilizer. Operational users should create and maintain multiple batches of gravid water to ensure a constant supply during trapping season. This can be accomplished by utilizing totes or drums into which hay or alfalfa pellets can be mixed with water. The mixture when added to the trap gradually becomes less attractive, necessitating the replacement of the water each week. Most of the mosquitoes captured by the gravid trap are *Cx. quinquefasciatus* mosquitoes, but occasionally

Gravid trap. Photo by Daniel McNamarra

CDC light trap. Photo by Daniel McNamarra

smaller numbers of other species will be collected, so they too can be sent to a laboratory for arbovirus testing, for Louisiana this is the Louisiana Animal Disease Diagnostic Laboratory at LSU in Baton Rouge.

CDC and EVS (Encephalitis Vector Surveillance) Light Trap: These traps are usually hung on a tree or shrub branch, use battery power and are enhanced with carbon dioxide (CO_2). The CO_2 source may be a small block of dry ice or a cylinder of compressed gas. These baited light traps attract many species of mosquitoes not attracted to gravid or New Jersey traps. They enable the collections of day time biting mosquitoes. Unlike the gravid trap, they attract many mosquitoes seeking their first blood meal and, therefore, have not had an opportunity to blood feed and become infected with an arbovirus. However, the mosquitoes collected can still be used for disease surveillance.

Rotator (Hourly) Trap: This type of trap is used to identify the activity period of different mosquito species. As the mosquito season progresses adult mosquitoes will emerge at different times from their resting sites to begin blood feeding. The collection containers of this trap rotate at a set time. Once collected the highest activity period can be determined and spray mission times adjusted for peak performance.

Biogents sentinel trap. Photo by Daniel McNamarra

BG Sentinel Trap: A portable trap that rests on the ground, often used to collect *Ae. albopictus* and *Ae. aegypti* adult mosquitoes. It is baited with BG lure, a type of human scent and CO_2. This trap can be purchased with an automated counter that tallies the number of adult mosquitoes collected. It transmits the results via a cell signal to the web where users can login and view graphs with numbers collected. Like a rotator trap, the number of mosquitoes collected over time can help determine peak activity period of host seeking mosquitoes.

Resting Station: A resting station takes advantage of the fact that night-flying species frequently rest in dark, sheltered places during the day. A resting station may be a natural or man-made sheltered situation (e.g., rotted tree boxes). If manmade they are usually black wooden boxes (box trap) with red interiors, approximately one foot square with one end open. In either case, the resting mosquitoes may be counted with the aid of a flashlight or collected with a suction device (aspirator) or with a killing tube.

They are usually placed in areas where *Culiseta melanura* mosquitoes are known to occur. Inspectors visit the boxes on a regular schedule and aspirate any mosquitoes that are resting on the inside of the box. Collecting *Culiseta melanura* mosquitoes is very difficult, and this method has proven to be one of the better ways to collect infected specimens for EEE surveillance. It is labor intensive, and in general, only one or two mosquitoes are collected per box even in the most successful operations. Mosquitoes usually found in these include *Culiseta melanura* and *Anopheles spp.*

Truck Trap: The basic truck trap consists of a large funnel-shaped frame, usually rectangular in cross-section and covered with screen wire. This structure is mounted, with the large end forward, on the roof of a vehicle. The collection container is attached to the smaller end of the funnel. The trap operates like a seine as the vehicle moves along the road. This is the most nonselective of the traps; however, some selectivity occurs because of the time of day during which the traps are operated and the height of the trap above the ground. Also, only those mosquitoes that fly in open areas along roadways can be practically sampled.

Animal-Baited Trap: This screened enclosure usually contains a stanchion to restrain the bait animal and a means of capturing mosquitoes attracted to the bait. A variety of bait animals may be used in these traps (e.g., horses, cows, pigeons, mice). Most traps have solid walls with screen cones or baffles that allow the mosquitoes to enter through these openings but impede escape.

Sentinel Box Trap and FMEL (Florida Medical Entomology Laboratory) Trap: These are another example of baited traps that use live animals as an attractant. A sentinel chicken or other animal is placed inside the trap and the mosquitoes enter a small opening to feed on the animal. The mosquitoes collected from these traps are normally used to test for the presence of virus.

Summary

A good surveillance program takes time to develop. In addition it will probably change over the years due to changes in population demographics within the district as well as possible additions of new species and disease. However, there is simply no way to conduct an effective mosquito control program without an ongoing surveillance system based on sound science.

Chapter 7 - Practice Questions

1. The repeated collection and assessment of mosquito data over time is called

a. Survey
b. Surveillance
c. Mosquito arbovirus trapping
d. Ovitrapping

2. Which of the following tools is most commonly used to collect mosquito larvae?

a. Ovitrap
b. Light trap
c. Dipper
d. Box trap

3. Which trap is best for collecting *Culiseta melanura?*

a. Ovitrap
b. CDC light Trap
c. BG Sentinel Trap
d. Resting Box

4. The BG trap, was originally designed to collect which type of species?

a. Container *Aedes*
b. Gravid *Culex*
c. Bloodfed *Anopheles*
d. Cattail mosquitoes

5. Which of the following is the gold standard for collecting *Culex quinquefasciatus* for WNV surveillance?

a. Ovitrap
b. Gravid trap
c. BG Sentinel Trap
d. Resting Box

Chapter 8

MOSQUITO-BORNE VIRUS SURVEILLANCE

In Louisiana, mosquito abatement districts (MADs) must weigh control decisions based on both nuisance levels of mosquitoes, as well as virus activity within a region. Arboviruses, such as West Nile virus, play a major role in targeted control efforts by MADs. Therefore, it is essential to be able to accurately assess the level of virus within the communities you serve.

Surveillance (collecting and evaluating data) is the first step in controlling arbovirus outbreaks. Currently the surveillance methods used in Louisiana are both passive (data comes to you) and active (you actively collect samples). Passive surveillance relies on information being provided from other sources, such as notification of human or animal cases. Officially reported human and animal cases are often provided to mosquito control districts from the Office of Public Health. In addition, active surveillance methods are conducted by actively going out and sampling either mosquitoes or birds. Information on how to sample mosquitoes, wild birds, and chickens for virus can be found later in this chapter.

Once samples are collected, materials are sent to the Louisiana Animal Disease Diagnostic Laboratory (LADDL) for testing. LADDL, in cooperation with the Department of Health and Hospitals (LDHH), employs the latest techniques to test birds and mosquitoes for SLE, EEE, WNV, and other relevant arboviruses, including chikungunya and Zika. All testing results by LADDL are then reported to the CDC's national database called ArboNET.

Arbovirus Surveillance Standards

Surveillance activities in Louisiana are updated annually and are consistent with the latest published CDC guidelines, epidemic/epizootic West Nile Virus in the United States. These standards provide detailed information on costs, how to prepare samples, numbers of samples to submit, viruses to test for, and when samples should be submitted. The Louisiana Arboviral Sampling Standards are updated and approved annually and are recognized as the standards for arboviral surveillance in the state of Louisiana. Updated surveillance standards can be found on the Louisiana Mosquito Control Association website.

Preparing Mosquitoes for Testing

Once mosquitoes are collected and identified, they are sorted into a unit called "**pools**". Pools are a group of mosquitoes of the same species, which were collected at the same date and time. The pool size is often between five and 100 mosquitoes,

Pile of dead mosquitoes. Photo by Daniel McNamarra

depending on the size of the species. Pools of mosquitoes are then placed in plastic vials for testing. LADDL should be contacted to order these plastic vials at no cost (except shipping) to a district. MADs should consult the arbovirus surveillance standards to determine when they can submit pools for testing. All pools are submitted to LADDL, along with a spread sheet containing the information on species, collection date, and trapping location. At their facility, mosquitoes can be tested for one or several arboviruses, including WNV, EEE, SLE, Chikungunya, and Zika. Specific testing of viruses is determined by which species are submitted, and if there is a specific risk for a particular virus in a region.

Ideally, MADs should consider maintaining a cold chain from the time mosquitoes are collected in traps until they are processed at LADDL. A **cold chain** is a means of keeping samples **cold** to ensure that the virus does not degrade in a sample. Examples of cold chains include placing trap nets in a cooler with dry ice, sorting and identifying samples on a chill table, and then transporting samples to LADDL in a cooler. While the cold chain is useful with some virus detection techniques, such as cell culture, the lack of cold chain does not seem to reduce the ability to detect arboviruses with reverse transcription polymerase chain reaction (RT-PCR).

Mosquito Virus Testing

Currently, LADDL uses a molecular test called RT-PCR (reverse transcription polymerase chain reaction). The RT-PCR method is a common tool to detect relatively low levels of virus within a sample. It has advantages over other techniques in that it can detect viral RNA at low levels in a relatively short amount of time. LADDL tests samples weekly, usually providing summaries of testing results each Friday.

Reverse transcription polymerase chain reaction

While most of the testing for viruses is conducted at LADDL, some MADs test mosquitoes for viruses in their own facilities (in-house). An advantage to using in-house testing is that results can be provided quickly, allowing for timelier control decisions. However, only LADDL results can be submitted to the Centers for Disease Control national database, ArboNET. Therefore, in-house testing should not be reported to the CDC and serves only to help improve MAD control decisions. As a result, many MADs will combine in-house testing with specimen testing at LADDL, while many just rely on LADDL for all testing.

The two commercially available testing products include the **VectorTest** and **RAMP**. The advantage of both tests is that mosquitoes can be collected in the morning and tested the same day. Both tests are designed to detect viral antigens (foreign substances produced by the viruses that cause an immune response). This is slightly different from the RT-PCR method used by LADDL, which is designed to detect the actual RNA from the virus. However, these tests are much less sensitive than RT-PCR, resulting in more false negatives.

Test	Detects	Detection Level (PFU/ML)	Assay Time
VectorTest	Viral antigens	100,000	15 min.
RAMP	Viral antigen	10,000	24 hours
Virus cell culture	Infectious viruses	100	3 days
TaqMan RT-PCR	Viral RNA	0.1	4 hours

Infection Rates and Indices

Once mosquitoes have been collected and tested, it is important to assess the degree of virus activity in a region. Current simple measures include the **minimum infection rate (MIR)**, the **vector index (VI)**, and the **maximum likelihood estimation (MLE)**. Each of these measures allows mosquito control programs to make decisions on when and where to focus mosquito control efforts.

The **MIR** is one of the most common measures used by mosquito control. The MIR is a number that represents the minimum number of infected mosquitoes per 1,000 tested. It can be useful to make comparisons of MIRs in different regions to assess potential risk to humans and animals.

$$MIR = \text{The number of (positive pools/Total number of mosquitoes tested)} \times 1000$$

Culex quinqs	Total collected in August	Number of positive pools	MIR
Region 1	12,500	3	0.24
Region 2	8200	15	1.83
Region 3	22,000	3	0.14
Region 4	33,500	0	0

Looking at the examples in the above table, you can see that the highest infection rates are in Region 2, and there has been no virus detected in Region 4.

When infection rates are low, and when pool sizes are the same size, MIR and MLE will provide similar infection rates. However, the **MLE** provides a more accurate measurement when infection rates are high, and when pool sizes are variable. MLE infection rates are calculated with an Excel spreadsheet add-in. This add-in can be found at (http://www.cdc.gov/ncidod/dvbid/westnile/software.htm). This add-in will calculate both the MLE and MIR in a simple to use program.

The **vector index (VI)** has recently become popular as it factors in both infection rates and the vector population size. The population size (N) can be determined by the number of mosquitoes per trap night for a species. Infection rate (P) is simply the proportion of the mosquito population that is WNV positive.

$$VI = \sum (N*P)$$

Culex quinqs	MIR	Average per trap night	VI
Region 1	0.24	32	7.68
Region 2	1.83	6	10.98
Region 3	0.14	250	35
Region 4	0	120	0

In the above table, you can see that Region 3 has become more relevant than in the previous table, since vector populations are high, and there is still relevant virus activity in the area. Therefore, MADs might make control decisions on both virus activity and vector abundance.

In addition to the above-mentioned techniques, MADs can assess risk by looking at population abundance of important vector species (e.g., *Culex* *quinquefasciatus* averages), the total numbers of positive pools, or the percentage of pools testing positive. Whichever method a mosquito control program uses, it should be consistent over an entire season to evaluate risk over time. Additional tools (GIS, Excel, etc.) can help programs assess risk over time and space.

Surveillance Reporting

There are two primary arbovirus reporting databases that MADs should become familiar with, including the national CDC reporting website called **ArboNET** and the Louisiana local database called **LASTS**.

ArboNET is the national arbovirus surveillance system, which tracks arbovirus activity annually around the country. It is maintained through the CDC (Centers for Disease Control and Prevention), and functions to monitor relevant arboviruses in humans, animals, sentinels, and vectors. Much of the arbovirus surveillance and testing conducted by MADs in Louisiana is submitted to ArboNET through the Louisiana Office of Public Health.

LASTS (The Louisiana Arbovirus Surveillance Tracking System) is an LMCA-funded website designed to help monitor arbovirus activity in the state. This web-based database is used by MADs and other state agencies for tracking arbovirus activity in Louisiana. Data include field and laboratory results for mosquitoes and lab results for chicken and wild bird surveillance. Currently, the LASTS system monitors relevant arboviruses, including West Nile virus (WNV), St. Louis encephalitis (SLE), Eastern equine encephalitis (EEE), Chikungunya (CHIKV), and Zika virus (ZIKA).

To use this service, you must first obtain a username and password by emailing the LMCA office. Once this step is complete, data for a specific district can be entered and stored for record-keeping. Additional information can be viewed on the LMCA website and also by visiting (www.laarbo.net).

Reporting is a fundamental component to conducting mosquito and arbovirus surveillance. The LMCA, LDHH, LADDL, MADs, and other agencies share mosquito-borne disease surveillance data regularly. This is done so control decisions can be made on a timely basis to prevent disease transmission. Sharing information on a timely basis also ensures the public can be appropriately informed to take preventative and protective measures.

Arbovirus Surveillance in Birds

While mosquitoes are vectors for arboviruses, the hosts in which they feed on can also be an important source for virus surveillance. Birds serve as a reservoir (long-term host that carries a pathogen) for several important arboviruses (WNV, SLE, EEE) in Louisiana. As a result, many mosquito control programs monitor live bird populations to detect these mosquito-borne viruses. Usually this involves bleeding sentinel chickens or wild birds to detect antibodies for mosquito-borne pathogens. Both methods are expensive and labor intensive, but can give results that cannot be obtained by other means. In addition, these mosquito-borne pathogens may sometime be detected in chickens or wild birds long before they cause infections in humans or horses. MADs should consider the costs and benefits of implementing this type of surveillance in their programs.

Sentinel chicken flocks: Chicken flocks (and sometimes quail, pheasant, or other birds) are often retained in cages placed in strategic sampling areas and bled periodically to monitor arbovirus activity. These birds are commonly called **sentinels** and may provide valuable information about arbovirus activity in a specific area because they do not travel outside of the confines of the cage. The sentinel birds should be raised in a mosquito-free environment and tested before they are placed in the sampling area. If, having tested negative on the initial bleeding, the sentinel bird tests positive after being placed at the sampling site, it is an indication of arbovirus activity in that area.

Once the bird tests positive, it should be removed and replaced with a bird that has not been exposed to arbovirus. A supply of unexposed birds should be readily available to replace those infected with the virus at the sampling sites. There should be a minimum of two chickens at each sampling site and a minimum of one chicken from each sampling site should be bled and the blood tested each week. Many sentinel flocks are needed to sample large areas adequately, so this method can be costly.

Sentinel chicken flocks are tested for **IgM** antibodies (antibodies that are produced due to **new** infections). When a bird tests positive for specific IgM antibodies, it means that a recent exposure to a specific virus has occurred. This is an indicator that there are mosquitoes in the geographic area that are capable of transmitting virus to humans.

Wild birds: Bird populations can be sampled on a regular basis to detect mosquito-borne encephalitis activity in an area. Mosquito control workers trap and bleed wild birds on a regular basis. Samples of blood for each bird are sent to LADDL for testing. If the bird is infected (viremic) the test will return positive. However, a positive result does not indicate the time of exposure or the location where the bird was exposed to the virus. The test detects virus, so the bird probably has been infected recently. Usually a bird remains viremic (virus within the blood) seven to 10 days. The number of birds testing positive in an area, is informative and may constitute a call for increased surveillance and/or mosquito control in the area.

There are a variety of methods available for collecting wild birds, with the most common capture method being mist nets and baited traps. One must obtain the appropriate state and federal permits before collecting birds with any of these methods. Furthermore, banding permits are required if one wishes to band birds before they are released.

Those attempting to collect wild birds for arbovirus studies should note established flyways and areas already frequented by birds, since it is very difficult to lure birds into new areas or away from areas where they are already feeding. It is also important to note the time of day that birds are active at the site. Pre-baiting the area with grain or other foods that are attractive to the species of birds that you hope to trap can be very helpful in increasing the collection success. Some workers also use recorded birdcalls and/or decoys to lure wild birds into their nets. Mechanical birdcalls and decoys may also be useful during the mating season or for trapping species that are very territorial. Gregarious species may respond to other kinds of birdcalls or larger numbers of decoys.

Mist nets: These nets are perhaps the most common means of collecting wild birds in Louisiana. The most popular nets are about 40 feet long and 7 feet high. They are commonly attached at either end to metal poles and are suspended 4 to 5 feet above the ground. These nets are made of materials that are difficult for birds to see so they fly into the nets and become entangled in the fibers. Mosquito control workers remove the birds from the net, draw a blood sample and release the birds at the collection site. Mosquito control workers may also band the birds prior to release. This is helpful in the event the bird is collected again at a later date. If the bird tests negative on the first bleeding and then tests positive when it is collected a second time the worker knows that virus was active in the bird population during that sampling window.

The amount of blood required and handling procedures change from time to time as laboratory test methods change and/or improve. If you are interested in establishing a wild bird surveillance program, contact a mosquito abatement district that does this routinely for procedures and instructions. LADDL can also give information on protocol and procedures to follow in submitting blood samples for arbovirus testing.

Baited traps: These traps are usually made of wire and designed to trap birds from a specific study area. A variety of traps have been designed to do this and they may be placed on the ground or on stands. The bait (grains, seed, insects, or some combination) is scattered around and inside the trap to attract the birds. Additional bait is usually placed at the site for several days prior to the expected collection date to condition the birds to the traps and to lure them inside. The birds enter the trap through a small hole to get the bait and cannot find their way out or they may trigger a mechanism that closes the cage, depending on trap design. Bait traps are usually equipped with large hinged openings so that the birds can be easily removed. Elevated bait traps may be more attractive to some species of birds and they can be used if cats or other predators pose a threat to the trapped birds. Bait traps may be especially useful in trapping sparrows, grackles, doves, quail, and pigeons.

Chapter 8 - Practice Questions

1. Which agency is responsible for testing mosquitoes, birds, and other animals for arboviruses in Louisiana?

a. LMCA
b. LDHH
c. CDC
d. LADDL

2. What is the name of the surveillance system database used in Louisiana?

a. LADDL
b. LASTS
c. ArboNET
d. VirusWeb

3. If you submit six pools of mosquitoes (each with 50 mosquitoes per pool), and one comes back positive, what is the minimum infection rate?

a. 3.33 per 1000
b. 20 per 1000
c. 120 per 1000
d. None of the above are correct

4. You determine that the infection rate in 2012 was 5 per 1,000. In that same year, the average trap catch was 10 mosquitoes per night. What is the vector index?

a. 0.5
b. 5
c. 50
d. 5000

5. Which of the following is not a form of surveillance?

a. Collecting and testing mosquitoes
b. Public health informing you of a human case
c. Testing sentinel chickens for arboviruses
d. Informing the public that you will be spraying

6. An animal strategically placed in order to sample for virus activity in a region is called a:

a. Vector
b. Sentinel
c. Pool
d. Detector

Chapter 9

PHYSICAL CONTROL OF MOSQUITOES (SOURCE REDUCTION)

All mosquito larvae require **stagnant** (non-moving) water until they emerge as adults. This includes ditches, marshes, swamps, pools, basins, depressions, and small natural and manmade containers, such as tires buckets, and trashcans. While many of these types of habitats can be controlled with larvicides or biological control, there are several physical control options available to help provide more sustained control efforts.

Source reduction refers to any method of physically altering or removing a mosquito-breeding site to render it unsatisfactory for the completion of the mosquito life cycle. Source reduction takes many forms, including tire removal, filling depressions, and improving drainage. It also includes the flooding of areas to flush out larvae and to increase the number of natural predators, such as fish, reaching these areas. Below are some source reduction options for specific types of habitats you may encounter in your region.

Source Reduction in Specific Habitats

Artificial Containers: Anything capable of holding standing water for five continuous days or more has the potential to produce mosquitoes. Some of the more common artificial habitats include cans, buckets, abandoned tires, clogged rain gutters, trashcans, cemetery vases, children's toys, abandoned swimming pools, and plastic tarps. These are excellent habitats for many of our domestic species, including *Aedes aegypti, Aedes albopictus, Aedes triseriatus,* and *Culex.* Source reduction in these types of habitats rely on **sanitation and education**. For disposable items, work with homeowners and communities to frequently remove unwanted items. Encourage tire pickups and recycling in areas with numerous tire issues. For trashcans, make sure they are covered with tight lids. If lids are not available, have homeowners drill holes in the bottom. For homeowners wishing to use rain barrels, make sure that all openings are covered (including the often-overlooked overflow hole). For common items, such as buckets and watering cans, make sure that they are turned over to prevent collection of water. For other permanent containers, such as bird baths and plant dishes, make sure homeowners flush out the habitat weekly with fresh water. For many of these permanent structures, you can consider using source reduction combined with other control options (larvicides or biological control).

Natural Containers: Natural containers, include any natural structure that can hold water for five or more continuous days. Examples include tree holes

Emptying bucket. Photo by Lauren Bishop, CDC image library

(*Aedes triseriatus*) and rock pools (*Aedes japonicus*). If tree holes become a problem, they can be filled with sand or other materials to prevent water collection. In Louisiana, we also have a mosquito that is a natural predator, *Toxorhynchites rutilus*, that lives in tree holes and feeds on other mosquito larvae using that habitat.

Swamps and Marshes: Swamps (flooded woodlands) and marshes are common mosquito larval sites for many species, including *Aedes taeniorhynchus* and *Aedes sollicitans* (Saltmarsh mosquitoes), *Anopheles quadrimaculatus* (permanent water swamps), and many species of *Culex* and *Culiseta*. Permanent water mosquitoes often prefer deeper water containing emerging vegetation, which provides larvae protection from predatory fish and insects. In the shallower parts of the swamp and upper marshes, where water levels fluctuate with rains and high tides, floodwater mosquitoes may breed in great abundance during periods of inundation. In the 1930s and 40s, salt marsh grid ditching was used to drain marshes of standing water. Today, these methods are no longer preferred as the grid ditch system can become clogged and attract mosquitoes. Current source reduction efforts on these types of habitats include water management, including the concept of **open marsh water management** (OMWM). With OMWM, the goal is to help allow predators (fish) access to areas on the marsh that are producing mosquitoes. Districts wanting to conduct OMWM projects often consult with other national and local agencies within their jurisdiction to develop water management plans. All water management projects must be approved prior to implementing.

Floodwaters: Many low depression areas can create floodwater habitats for species such as *Aedes vexans* and *Psorophora columbiae.* Floodwater habitats include any area that temporarily floods for at least five days or more after heavy rains. This would include lawn depressions, pastures, erosion areas, tire ruts, depressions made by animals or human activity, and silt deposits. While many of these areas do not remain flooded in between rains, they can produce very large numbers of mosquitoes. Because these types of floodwater sites are temporary, improving habitat for predators (fish) is usually not an option. Therefore, **filling** in low lying areas might provide a more long-term solution. Mosquito control programs should consider monitoring these sites closely after heavy rains.

Rice fields and oil fields: Many of our important economic pests, such as *Psorophora columbiae* (the dark rice field mosquito), thrive in irrigated cropland areas, such as rice fields. While rice fields are often flooded (they alternate rice and crawfish in many of these fields), the greatest mosquito problems occur on the edges, and when water dries up to create smaller pools void of predators. Mosquito control programs should work with farmers to identify any specific areas of concern.

Oil field drilling locations can also create mosquito problem areas. When a drilling location is prepared in a marsh, a canal is usually dug from the nearest waterway to the drilling site. The spoil is generally deposited as a continuous bank without regard to natural drainage conditions, which can create impounded situations conducive to heavy mosquito breeding. Abandoned waste pits are also frequently ideal for mosquito production. Holes left from dynamite blasting by seismographic survey crews have been observed to breed mosquitoes, but this is a lesser problem. Mosquito control programs should identify specific areas of concern.

Retention and detention basins: After heavy rains, retention and detention basins are designed to collect and move water away from roads and buildings. **Detention basins** are designed to temporarily detain water for a short period of time (less than five days). These types of habitats often become mosquito problems when they become clogged and water is not flowing. Source reduction efforts include improving drainage and unclogging basins. **Retention basins** are different from detention basins in that they are designed to retain water for a longer period of time (more than five days). Because water is typically deep in these habitats, mosquito larvae will often limit themselves to the more shallow edges with vegetation. Source reduction efforts include ensuring that grass is mowed around the edges and that emergent vegetation does not grow in these habitats. Sites should be monitored for mosquito larvae, and additional control options (larvicides and biological control) should also be considered.

Ditches: Drainage and septic ditches are a specific type of man-made structure that is used to help collect and move rainwater away from roads and buildings. These types of habitats are ideal for species of *Culex* that prefer more organic water, such as *Culex quinquefasciatus.* In areas of Louisiana homeowners have individual septic tanks that drain and provide a constant supply of water to said ditches. Occasionally, property owners may build their own ditches to help move water away from septic tanks. Improperly made and unnecessary ditches created by homeowners should be discouraged and filled whenever possible. Source reduction of ditches can be problematic, but if water movement can be improved, it could provide a more long-term solution. These types of habitats should be monitored and controlled frequently, as *Culex quinquefasciatus* is the most important vector species of West Nile virus in the state.

Mangrove swamps: Mangrove swamps are less abundant in Louisiana but can be found in some coastal areas of the state. Because it is saltwater, very few important species, such as *Aedes taeniorhynchus,* can exist in this habitat. While Louisiana has large tidal flow in the coastal areas, small collections of water can occur in these habitats, which can produce mosquitoes. If these sites become a problem, mosquito control programs can assess where larval habitats occur, and consider water management options if necessary.

Other habitats: Highways and railroads are almost always built on an embankment, creating a type of dam that often blocks natural drainage. Culverts are designed to allow for artificial drainage, but improper design or installation can result in undrained areas where mosquitoes can breed. Also, borrow pits, from which roadbed fill is taken, make good larval habitats if not properly engineered.

Specific Control Measures

Control measures for source reduction fall into six broad categories: drainage, flushing, water management, filling, sanitation, and education.

Drainage: Often mosquito habitats exist because areas are not properly draining. Improving drainage in areas can help ensure that water is moving as it should (mosquitoes do not like moving water) and not collecting in low-lying areas. Unclogging ditches and basins can help improve water flow. Where the land is high enough for gravity drainage, simple ditching to promote rapid runoff of rainwater can be an efficient means of preventing mosquitoes.

Flushing: Tidal flushing is a means of increasing coastal tidewaters into mosquito larval areas, to increase movement of natural predators into the environment. This can be accomplished by digging level ditches with the bottoms at least at mean sea level and preferably below low tide level. This permits the area to be flushed by daily tides and keeps water in the ditches, which serves as a reservoir for larvae-eating minnows and other predators. Along the edge of a ridge, a combination of drainage and flushing is often employed. Drainage ditches from swales along the ridge feed into level ditches in the marsh. This prevents mosquitoes from utilizing this habitat following rains and abnormally high tides.

Water Management Strategies: Proper water management can minimize the wet/dry cycle conducive to floodwater mosquito breeding. This may include techniques such as water-level management and open marsh water management. The Louisiana Wildlife and Fisheries Commission and several large land corporations do most water management in Louisiana. Water-level management in the marsh is usually accomplished by installing low-level dams (weirs) across the tidal streams about 6 inches below the marsh floor. This permits daily tidal action in the area and helps stabilize water bottoms, reducing turbidity. It also prevents complete drainage of the area during excessively low tides.

Trappers, duck hunters, and crawfish producers maintain impoundments to promote production of food plants. In such situations, it is usual practice to drain the water during summer months to allow establishment of vegetative growth. This often creates mosquito breeding in residual pockets of water. A system of ditches inside the impoundment to promote drainage during the period of dewatering can correct this situation. When the impoundment is eventually flooded, these ditches permit easy access to the area by boat, making this type of control compatible with the landowners' interests.

While open marsh water management (OMWM) is typically conducted in Atlantic states, it can provide a good alternative to marsh management strategies by improving the overall ecology of the salt marsh. The goal of OMWM is to locate mosquito breeding areas and modify them in a way to create a refuge for natural predators.

A major part of source reduction work is done in areas that support valuable wildlife and fisheries resources. It is therefore in the interest of mosquito control to create as little disturbance to the natural environment as possible. In many cases, source reduction can serve to restore a habitat to its original condition or to enhance wildlife production. There are some situations where source reduction is not possible without destroying some wildlife or fisheries habitat. In these instances good judgment must rule. This emphasizes the need for professional direction of mosquito control programs and cooperation among all agencies involved. Permits from the U.S. Army Corps of Engineers must be obtained before source reduction efforts can begin on many wetland areas.

Filling: Often times, small lawn depressions and low-lying areas can be filled to prevent the collection of water. Soil, road debris, or canal dredging may be used to fill and eliminate areas where mosquito larvae occur.

Sanitation: Artificial container reduction can be extremely important, especially in urban areas. It is important to identify the problem areas within a community to help correct the situation. Proper tire disposal became important with the introduction of *Aedes albopictus*, as this species readily lays eggs in tires. Laws were enacted to eliminate and cleanup tire dumps. Mosquito control programs can work with their local jurisdiction to find ways to improve tire pickup and disposal. Improperly maintained areas can result in artificial water holding containers. Gutters and downspouts should be monitored and flushed out regularly. Trashcans can produce mosquitoes if not properly covered. If towns do not use covered trashcans, programs can work with the sanitation department to help find covers or to drill holes in the bottom. In areas with high amounts of artificial containers, you can work with your community to plan cleanup days. Local laws may help justify enforcement of clean up if necessary.

Education: Education of homeowners to employ sanitation in yards can play an important role in reducing mosquito production in residential areas. The list of things that can be done by homeowners is almost endless. Filling plant trays with sand, not leaving children's toys out, removal of trash, washing birdbaths and pet water dishes, and stocking ornamental ponds with fish are just some of the important components of reducing breeding sources. In addition, many mosquito control programs will leave door hangers with check lists or other educational material to help homeowners identify problem areas. For a detailed outline of educational options available, please refer to chapter 14.

Photo by Jill Hightower.

Chapter 9 - Practice Questions

1. Which type of source reduction method would be most appropriate for controlling *Aedes albopictus*?

a. Drainage
b. Flushing
c. Sanitation
d. Water management

2. Which of the following habitats would you consider filling in order to control *Aedes vexans*?

a. Roadside ditch
b. Lawn depression
c. Tree hole
d. Salt marsh

3. For which habitat would you consider using open marsh water management (OMWM)?

a. Roadside ditch
b. Lawn depression
c. Tree hole
d. Salt marsh

4. Improving water movement in septic ditches, could improve reducing which species

a. *Aedes albopictus*
b. *Culex quinquefasciatus*
c. *Coquelletidia perturbans*
d. *Culiseta melanura*

5. Which of the following is a potential way to increase the movement of predators into a mosquito habitat?

a. Drainage
b. Flushing
c. Sanitation
d. Filling

Chapter 10

BIOLOGICAL CONTROL OF MOSQUITOES

Toxorhynchites

Biological control is the use of natural enemies to control a target pest. While mosquitoes have many natural enemies (birds, bats, spiders, beetles, and ants), very few are commonly employed in controlling mosquitoes. Natural enemies used in biological control include parasites, predators, and pathogens. Parasites are organisms that live inside a host and feed on tissues and fluids. Nematode worms are an example of a mosquito parasite that could be explored as a biological control option. Predators are animals that immediately kill and feed on a prey organism. While there are many predators that eat mosquitoes, the most common biological control agents are fish and copepods that feed on the larvae. Pathogens are any type of microorganism (virus, bacteria, fungus, protozoa) that cause disease or death in a target organism. Bacterial derived products, such as *Bacillus thuringiensis israelensis* (*B.t.i*) were once classified as biological control agents. However, they are now grouped into a special category called biorational control products. Also known as biopesticides, these slightly differ from biological control methods, since these are pesticides that are derived from natural materials, such as animals, plants, bacteria, and certain minerals. This chapter will focus on the use of predators because they are the most commonly used biological control agents in mosquito control.

Predators of Mosquito Larvae

Numerous predators of mosquito larvae (and pupae) have been investigated for mosquito control, including: fish, turtles, tadpoles, cyclopoid copepods, tadpole shrimp (*Triops*), aquatic bugs (notonectids and belostomatids), aquatic beetles (*dytiscids*), dragonfly and mayfly nymphs, planarians, and hydra. Only fish and cyclopoid copepods are used operationally because they have two essential properties for control operations (1) sustainability, and (2) **s**uitable supply sources. Fish and copepods can be collected from large natural populations or mass-produced at a reasonable cost. Therefore, there is typically a constant and suitable supply source for both. Second, when introduced to breeding sites, these predators multiply to numbers that are large enough to kill virtually all mosquito larvae, and they maintain their numbers for extended periods of time. While other natural predators can be employed, their regular use in operational programs might be challenged by cost, sustainability, and whether there is a suitable supply source.

Fish

Fish have been in widespread use for more than 70 years. Fish are effective since they meet both criteria in that they can sustain themselves in field, and there are multiple supply sources. Fish feed on a variety of food sources in the absence of available mosquito larvae. Having a broad diet allows these fish to maintain themselves in numbers sufficient to eat almost any number of mosquito larvae that might periodically appear. Many kinds of fish are effective for mosquito control, but topminnows (Poeciliidae) and killifish (Cyprinodontidae) are used most frequently because they are small and abundant, making them convenient to capture and transport, and they usually thrive in large numbers when introduced to mosquito-breeding habitats.

The mosquito fish, *Gambusia affinis* (a species of top minnow), has been so effective for mosquito control that it has been used more than all other species of fish combined. *Gambusia* is particularly useful because it thrives in a broad array of aquatic habitats including freshwater, brackish water, clean water, or polluted water; and it tolerates a wide range of temperatures (1-38 degrees Celsius).

The recommended stocking rate for *Gambusia* is 0.5-1.5 pounds per acre (pound = ca. 500 fish). Control is usually rapid, though maximum control may be achieved only after the fish have had a month or two to build up their numbers. For example, *Gambusia* usually builds up to about 5,000

Gambusia affinis

fish/acre in rice fields. Smaller stocking numbers are acceptable (e.g., 0.2 of a pound/acre) if it is possible to wait an extra few weeks for the population to grow.

Guppies *(Poecilia reticulata)* are a topminnow used for mosquito control in some of the conditions where *Gambusia* is not suitable, such as excessively polluted water. Guppies have a major limitation. They can survive only in water above 10 degrees Celsius and thus need to be reintroduced into control areas at least once a year.

Least killifish *(Heterandria formaosa)* are common topminnows in Louisiana marshes. They can provide effective mosquito control at sites where the water is sometimes so shallow that it barely covers the soil.

Collecting and raising fish

Fish are only practical if there is an economical source of supply. Many mosquito-control districts collect their fish from a site where they are naturally abundant. Sites without fish, but that have appropriate conditions can be stocked and maintained to create a new and abundant source.

Mosquito-eating fish are commonly trapped and collected from their natural habitat and either reared in a facility or directly transported to their intended control sites. Fish can be transported on trucks safely in concentrations of 0.5-1.5 pounds of fish per gallon of water if aeration is provided. Aeration can be achieved by bubbling air (oxygen) through the water, or by means of a rotating paddle that is enclosed by a screen guard to prevent injury to the fish.

Some limitations to using fish

It is common for fish to eliminate almost all mosquito larvae, but there are situations where fish are not so effective. For example, in aquatic vegetation, larvae can hide from fish. Some vegetation (e.g., *Spartina* grass in marshes) can be so thick that the fish have no access at all. Fish may also be temporarily ineffective when aquatic animals other than larvae become so abundant that the fish prey on those animals instead of the mosquito larvae. Fish cannot survive for long in an aquatic habitat that is very small (e.g., a discarded tire), nor can they survive when a site dries up. Therefore, other organisms, such as copepods, can be ideal in small habitats.

Copepods

Copepods satisfy both criteria for operational use, in that they are sustainable, and there are adequate supply sources. Copepods are convenient and inexpensive to produce and transport in large numbers and are particularly suitable for some mosquito habitats where fish will not work.

Copepods are tiny crustaceans, 1 millimeter in length, and are abundant in nature almost everywhere there is water. They are voracious predators, and the largest species (***Mesocyclops***, ***Macrocyclops***, and ***Megacyclops***) prey on first-instar mosquito larvae. Smaller species of copepods generally are not large enough to be effective predators of mosquito larvae.

Copepod

Because copepods are so small, they thrive in habitats that are too small for fish. They can also move easily through the middle of thick aquatic vegetation that fish cannot penetrate. Copepods can survive when a site dries up, provided the soil retains some moisture, and reemerge when a site floods, just in time to consume hatching mosquito larvae.

Application of copepods in tires

The most established use of copepods is for control in discarded tires. They can survive in tires as long as the tires retain moisture, which can be periods of months or years. Tires in wooded or otherwise shaded areas are particularly suitable. The best species for tires is *Mesocyclops longisetus*, and the best season during which to introduce it to tires in Louisiana is spring. Copepods can be introduced into tires with a backpack sprayer.

A single fertilized adult female introduced into a tire will produce enough offspring in two months to control any hatching of mosquito larvae. Placing as few as 50 to 100 adults per tire will provide immediate control of all new Aedes larvae that hatch within the tire, and they will continue to kill all larvae as long as they survive in the tire. If a tire is newly discarded (and therefore

Tire pile

completely clean inside), it may be necessary to put a small amount of food (e.g., a few grains of rice) in the tire to sustain the copepod population. If there are mosquito larvae in the tire at the time of introduction and immediate control of late instar larvae is desired, it is best to apply microbial larvicides simultaneously in order to kill any larvae too large for the copepods to kill. Only one application of larvicide should be required, as the copepods will deal with any subsequent hatching of mosquito larvae.

Application of copepods in larger habitats

Among groundwater sites, copepods are most effective in discrete pools (e.g., flooded vacant lots, swales, or woodland pools) that have water for at least a few months. For sites that have water during the fall, winter, and spring, it is best to use *Macrocyclops albidus*, a species that is tolerant of winter temperatures; *Macrocyclops* should be introduced as soon as the site has water in the fall. After introduction, copepods usually increase their numbers by about one hundredfold with each generation (two to three weeks) until they reach the limit of the food supply at the site. They will usually survive at a site until it dries out completely.

Once *Mesocyclops*, *Macrocyclops*, or *Megacyclops* have developed large populations in ground pools, the pools will usually have a small number of mosquito larvae, if any. However, control is not always complete, because copepods are not very effective predators of some species of *Culex*, particularly *Cx. salinarius.* In addition, control of any mosquito species can be incomplete in large, ecologically heterogeneous habitats (e.g., marshes, rice fields, or residential ditches) because copepod abundance in these habitats can be spatially patchy and change with the seasons.

Cannibal Mosquitoes

Toxorhynchites mosquitoes are large, non-biting mosquitoes that lay eggs in containers. Their larvae prey on other mosquito larvae, while adults do not blood feed. Some species of *Toxorhynchites* can be mass-produced in the laboratory for introduction into containers. They can be introduced as eggs or larvae, but the most effective way is to release gravid females so that they can deposit their eggs in containers. The great strength of *Toxorhynchites* is the ability of females to find inconspicuous containers, including ones that are inaccessible to mosquito-control operators. A single treatment with *Toxorhynchites* will last for about three weeks, which is the time it takes *Toxorhynchites* larvae to pupate.

Toxorhynchites should be used in conjunction with conventional source reduction to control hidden and inaccessible containers that are not eliminated through other means (e.g., plugged rain gutters that collect rainwater or tree holes in woodlots near residential areas).

Larvae of ***Toxorhynchites rutilus***, a native species of Louisiana, are common during the summer months in tree holes, tires, and other containers, where they make a significant natural contribution to mosquito control. Because naturally occurring numbers of *Tx. rutilus* are not sufficient to eliminate mosquito larvae from all containers, mass release of *Tx. rutilus* at critical times of the year (e.g., the beginning of the mosquito season) might augment natural control. Unfortunately, mass production of the Louisiana variety (*Tx. rutilus septentrionalis*) has not yet been possible, though mass production of the Florida variety (*Tx. rutilus rutilus*) has been achieved.

Toxorhynchites amboinensis is an exotic species that has been mass produced successfully and released with encouraging results. During a seven-week study in New Orleans, *Ae. aegypti* populations were reduced 95% when adult female *Tx. amboinensis* were released in conjunction with ground ULV treatments. Comparable *Ae. aegypti* populations were reduced by only 30% when malathion was used without *Tx. amboinensis.*

The major limitation of *Tx. amboinensis* is that it cannot reproduce to maintain a long-term field population under Louisiana conditions. It is therefore necessary to release large numbers of *Tx. amboinensis* every few weeks to maintain control. The release rate should be about 50 adult female *Toxorhynchites* per acre.

Improving Habitat for Biological Control Agents and Natural Enemies

Mosquito control programs can help strengthen both natural enemy and biological control populations by monitoring habitats. Since most biological control is focused on larval stages, aquatic habitats can be modified to improve survival and sustainability of predators.

Keeping wet areas wet and dry areas dry

In the source reduction chapter, we discussed how some mosquito habitats can either be drained or modified to become a permanent water habitat. If water cannot be drained from a site, it may be best to manage the site in such a way that water is

Salt marsh. Photo by Scott Harrington.

present continuously. Permanent water can greatly improve habitat for natural predators. However, there are some options if habitats must alternate between wet and dry conditions. Holding ponds and access ditches can also serve as reservoirs for predators, which can disperse into the surrounding areas when flooded.

Controlling pollution

Water pollution can play a major role in mosquito production. Some mosquito species depend upon pollution to protect them from predators. For example, *Cx. quinquefasciatus* breeds in residential ditches that are polluted by the effluent from septic tanks. *Cx. quinquefasciatus* can survive in the polluted water, but most of its predators cannot. Furthermore, *Cx. quinquefasciatus* proliferates due to the nutrient materials found in polluted waters. Controlling and reducing water pollution can then help reduce *Cx. quinquefasciatus* populations by reducing the preferred habitat and encouraging natural predator populations.

Application of insecticides

Several broad-spectrum pesticides can potentially kill predators of mosquito larvae. Therefore, habitats being treated with biological control agents, such as backyard swimming pools, should be evaluated in areas recently treated with adulticides. Many larviciding products, such as *Bacillus thuringiensis var. israelensis (B.t.i.)*, are specific to mosquito larvae. Therefore, product selection can also impact biological control success.

Chapter 10 - Practice Questions

Which of the following is a type of biological control?

a. Copepods
b. Monomolecular films
c. Lethal ovitraps
d. All of the above

Which of the following is called the cannibal mosquito?

a. *Culex quinquefasciatus*
b. *Toxorhynchites rutilus*
c. *Mesocyclops*
d. *Gambusia affinis*

The two most important properties in using biological control in applied mosquito control programs include:

a. Cost and longevity
b. Supply source and sustainability
c. Voracious appetite and specificity
d. Cost and specificity

***Bacillus thuringiensis israelensis (B.t.i)* is considered**

a. A chemical insecticide
b. A predatory biological control agent
c. A biorational control product
d. A parasite

What type of organism is *Mesocyclops longisetus*?

a. Fish
b. Predatory mosquito
c. Parasite
d. Copepod

Chapter 11

LARVAL MOSQUITO CONTROL

Control of Immature Mosquitoes

Larval control is a two-step process that begins with identifying the species of mosquito, stage of development and associated habitat. Once you are aware of the species and habitat, then you can ultimately make the appropriate control decisions (physical, chemical, biological, mechanical, or no action required).

As you approach a larval habitat, you are probably already aware of the potential species that may exist in that habitat. If not, you should review the chapters on habitats and bionomics of important species. Mosquito larvae are collected from most habitats using a standard mosquito larval dipper. In smaller or hard-to-reach sites, such as tires, catch basins, and tree holes, a siphon, turkey baster, bilge pump or other alternative sampling equipment can be used. Once larvae are collected, they should be reared to fourth instar larvae or adults and identified to species using a taxonomic key, such as the one in the back of this manual. The habitat that the larvae were found in will also provide clues to the species identification.

Once you identify the species and habitat type, you can select the most appropriate control method. For example, *Aedes albopictus* and *Ae. aegypti* are two mosquito species that can be controlled in part by emptying and disposing of man-made containers (see source reduction chapter). Species such as *Culex quinquefasciatus*, which can be found in permanent water, may require chemical control with bacterial larvicides, insect growth regulators, or surface oils. Some mosquito species that cause no concern to human or animal health, such as *Wyeomyia smithii,* may not warrant any control. There is no catch-all solution when it comes to controlling mosquito larvae. Therefore, keeping track and recording what is most effective in your program is extremely important.

The focus of this chapter will be on the use of larvicides (products targeting immature mosquito life stages). The majority of larvicides used in mosquito control are considered biorational, meaning they are derived from natural sources (such as from bacteria), and most often have fewer impacts to non-target organisms.

Types of Larvicides

Those derived from bacteria: The most widely used larvicide products in Louisiana are derived from bacteria. Bacterial larvicides may incorporate several different strains of bacterium, and are effective, economical, and environmentally friendly. Examples of bacterial derived larvicides include *Bacillus thuringiensis* subspecies *israelensis (B.t.i)*, *Bacillus sphaericus (B.s.)*, and *Saccharopolyspora spinosa* (Spinosad).

Bacillus thuringiensis subspecies israelensis (B.t.i) was the first bacterium to be widely used in mosquito control. *B.t.i.* was discovered in Israel in 1976 and became commercially available in 1983. The larvicidal activity of *B.t.i.* is due to the presence of toxic crystals found in the bacterium that disrupts the mosquito gut after ingestion. Commercial formulations of *B.t.i.* actually utilize these toxic particles, rather than using the live bacteria. Because B.t.i. doesn't use living organisms, it is not biological control in the conventional sense, rather it is considered biorational control.

In order for *B.t.i.* to be effective, it requires an alkaline gut to help make the crystals effective. Therefore, a major advantage of *B.t.i.* is that it is unlikely to have non-target effects to most organisms because of differences in gut pH. While there are other subspecies (or serovarieties) of *Bacillus thuringiensis*, *B.t.i.* kills only larvae of mosquitoes and closely related flies. It has no damaging effects on plants or other organisms.

Perhaps the most serious limitation of *B.t.i.* is that a single application kills mosquito larvae only for a few days. The *B.t.i.* toxins retain their effectiveness for a long time, but within a few days, the *B.t.i.* particles settle to the bottom of the water, where mosquito larvae cannot ingest them in sufficient quantity to be killed. It is therefore necessary to reapply *B.t.i.* every seven to 10 days to maintain control. *B.t.i.* briquets or dunks are special formulations that are able to kill larvae for several weeks by continuously releasing *B.t.i.* particles over time.

Bacillus sphaericus (B.s.) was first isolated in California in 1964 and became commercially available in 1991. Similar to *B.t.i.*, *B.s.* toxins cause damage to the stomach lining of larval mosquitoes when ingested. Unlike *B.t.i.*, *B.s.* is composed of live bacterial spores that continue to live and propagate in aquatic habitats for up to 30 days. Because of this, *B.s.* works well in organically polluted water, continuing to kill mosquito larvae for many weeks if conditions are right. However, the effectiveness and long-lasting qualities of *B.s.* can be hindered if water temperatures drop.

Saccharopolyspora spinosa (Spinosad) is the newest bacterial larvicide on the market. The spinosad bacteria was first discovered in soil collected at an abandoned sugar mill in the Virgin Islands in 1985. Spinosad is a mixture of two chemicals, spinosyn A and spinosyn D. Spinosad

Ditch spraying. Photo by Daniel McNamarra

has been used to control agricultural pests for decades, but only became commercially available for mosquito control in 2007. Unlike *B.t.i* and *B.s.*, spinosad kills by attacking the nervous system, effectively paralyzing a treated insect.

Spinosad can be used in a variety of aquatic habitats, including permanent water and floodwater habitats. Many formulations of spinosad exist, including tablets, granules, and liquid, each having different residual qualities. Since spinosad works differently from all other mosquito larvicides, it can be a great tool for dealing with resistant mosquitoes.

Combination products: As a result of the diversity of bacterial larvicides available, vendors have started to offer larvicides as duplex mixtures. For example, *B.t.i.* and *B.s.* have been mixed together to give control with quick knock down *(B.t.i.)* and longevity *(B.s.)*. In general, the effectiveness of bacterial larvicides can be reduced if (1) there is thick vegetation that prevents particles from dispersing to all of the larvae, (2) the water is organically polluted, or (3) the water contains a large quantity of particulate matter that the larvae consume in favor of the larvicide. Under these conditions, it is necessary to apply the product at its maximum label rate to achieve appreciable results.

Insect growth regulators (IGR): IGRs may be referred to as juvenile hormone mimics, and kill by interfering with insect growth and development. These chemicals stimulate cuticular inhibitors within the mosquito body that in turn disrupts the normal life cycle progression. The result is that the exoskeleton of the larva or pupa fails to form properly, thereby preventing complete emergence in the larva-pupa molt or pupa-adult molt. The most common IGR used for controlling mosquitoes is s-methoprene.

S-methoprene can be used in a variety of aquatic habitats including catch basins, roadside ditches, artificial containers, flooded areas, etc. One benefit of s-methoprene is that it can provide control even after the treated site has gone through a wet-dry-wet cycle. However, when sampling after treatment with s-methoprene, technicians will still encounter larvae, as mosquitoes treated with the IGR do not immediately die, unlike other larvicides. IGRs are target specific and come in several forms: briquet, pellet, water-soluble pouches, granules, and liquid. Each formulation provides residual control, with some products lasting up to 150 days.

Pyroproxifen is not yet registered for use in Louisiana, but it has been evaluated for use around the world in autodissemination traps. Pyroproxifen is a juvenile hormone mimic that is toxic to mosquito larvae at extremely small doses. As a result, several trapping technologies are being developed employing its use. One strategy, called **autodissemination**, occurs when the adult female mosquito picks up the pyroproxifen, and then disseminates the product to its future larval habitats.

Surface oils and films: These chemicals include monomolecular films (alcohol) or petroleum distillates (mineral oil) that kill mosquito larvae and pupae when applied as a surface film to breeding habitats. These products work by reducing the surface tension of the water, making it more difficult for larvae and pupae to stay at the water surface and breathe through their air tube. This, in turn, kills the larva or pupa by suffocation and drowning. Some advantages of these surface control agents are that they quickly kill all aquatic stages, including pupae, and have little or no residual effect. Some disadvantages of monomolecular films are that dried vegetation and floating debris tends to absorb the product, and sustained winds can prevent the proper spread of monomolecular films across the water surface.

Larvicide Resistance

Considering larvicides are often applied at the maximum label rate, the development of resistance to these products can be a concern. The best method for testing larvicide resistance is to use concentration mortality data. In these experiments, larvae are exposed to a series of different concentrations of larvicide, and mortality is scored 24 to 48 hours later. The concentrations that killed 50% (LC50) and 95% (LC95) of the mosquitoes are calculated using statistical analyses. Comparisons can be made between the LC values of a susceptible lab colony and mosquitoes sampled from the wild. LC values from the wild can be divided by susceptible LC values, resulting in a resistance ratio, which tells you how resistant the wild population is. Ratios greater than fivefold tend to be an indicator that some degree of resistance has developed.

Larvicide Formulations

Formulations are discussed in detail in the EPA guide *National Pesticide Applicator Certification Core Manual,* which is distributed by the Louisiana Cooperative Extension Service. Therefore, only a brief description of formulations commonly used for mosquito control is given in this chapter.

Dry or Solid Formulations

Granules – Granular particles are much larger than those of dusts and wettable powders and are formulated on porous carrier materials like clay or ground corncobs. The carrier material may have the pesticide coated on its outer surface, or the pesticide may be absorbed into the material itself. Sometimes granules are encapsulated, or coated with a slowly dissolving material. As the coating dissolves, the pesticide is slowly released, ensuring the presence of the toxin in the larval habitat for an extended period. This formulation is generally used when excessive plant growth is present in the larval habitat.

Bti granules

Sand – Sand can be used to create on-site granular formulation by combining liquid larvicide products with sand. Sand formulations were originally developed to control larvae in tree canopied swamps and coastal salt marshes in Florida.

Briquets – Briquets are similar to granules but much larger and they come in a variety of sizes and shapes. Briquets slowly dissolve and release a sustained amount of larvicide over time. Briquets are normally applied to shallow depressions in no-flow or low-flow water conditions (e.g., woodland pools, catch basins, etc.).

Pellets – Pellets, like briquets, slowly release a larvicide and offer control for up to 30 days. Pellets can be applied by hand, truck, or airplane and can treat a wide variety of habitats (e.g., containers, woodland pools, flood plains, etc.).

Liquid Formulations

Emulsifiable Concentrates: An emulsifiable concentrate formulation usually contains a liquid active ingredient, one or more petroleum-based solvents, which give EC formulations their strong odor, and an agent that allows the formulation to be mixed with water to form an emulsion.

Liquid Larvicides and Aqueous Suspension products mix easily with water. These can be injected or mixed with water to obtain the proper application rate. These products require agitation after sitting for prolonged time.

Surface Oils – These are petroleum-based products that kill larvae by suffocation.

Selection of Proper Equipment

Hand Sprayers: The compressed air sprayer is the mainstay of most hand-applied pesticide operations. Usually the sprayer is a small (1 to 5 gallon) cylindrical tank furnished with an air pump, hose, spray gun, and other components necessary for applying larvicide.

Granular Applicators: A wide variety of applicator equipment is available, including handheld, truck mounted, and aerial. Handheld equipment may be a simple spreader, or it may be a backpack-powered sprayer. These are generally used for small areas. Truck mounted equipment consists of a granular hopper and a blower and is used primarily to treat roadside ditches. The treatment of large areas (e.g., marshland, rice fields, and pastures) can be accomplished by using aerial application.

Power Sprayers: There are many types and sizes of power equipment available for large-scale mosquito control operations. A power sprayer usually consists of a power source (i.e., gasoline engine, electrical), pump, chemical storage tank, and one or more hoses for delivery of material. These units can be mounted on skids or permanently mounted to spray vehicles. The versatility of a skid-mounted sprayer allows it to be removed whenever the vehicle is needed for other purposes. Power sprayers are used to apply many different pesticide formulations. They are used for residual spraying to control resting adult mosquitoes, and they are used to apply larvicides in roadside ditches and woodland pools.

Mist Sprayer / Duster: These are truck-mounted sprayers used for area wide larviciding. These apply liquid B.t.i. to neighborhoods from public roads, enabling control of container breeding species mosquitoes on a large scale. An example of this is the Buffalo Turbine spray system.

Aerial Equipment: Application equipment is custom mounted upon or within an aircraft. In principle, a tank contains larvicide that is distributed under pressure to nozzles that regulate the spray. The size and configuration of nozzles, system pressure, altitude, and air speed greatly influence the distribution and quantity of larvicides. Chemicals registered for aerial application have specific instructions that pertain to their proper use. These label directions, as with any pesticide label, should be strictly followed.

Guidance Equipment: Global positioning satellite (GPS) systems are deployed in aerial and ground larviciding systems. These systems are integrated with computer software to improve application accuracy. Spray missions are recorded and can be displayed later on a desktop computer. Multiple parameters are recorded, including spray path, date, time, temperature, wind speed, and wind direction. The display of moving maps in real time allows for spray adjustments, ensuring proper application of insecticide to target areas. This equipment can be expensive, but its cost is usually compensated for through increased mosquito control efficiency.

Methods of Application

Larviciding: The term "larviciding" is used to describe the procedure of applying insecticides to kill immature mosquitoes (larvae and pupae) in the water. In order to help preserve the susceptibility of mosquito species to insecticides, the same class of material should not be used both as a larvicide and an adulticide, especially against the same species.

Hand Application – Larviciding by hand is usually restricted to breeding areas that are too small for aerial treatment and inaccessible to vehicles. Ground larviciding is normally performed with petroleum oils, monomolecular films, insect growth regulators, and/or other formulations using biological agents (e.g., *B.t.i.*).

Truck-based Applications - Ground larviciding by truck was normally restricted to roadside ditches and other breeding areas. Also, larvicide equipment may be mounted on four-wheelers or other all-terrain vehicles for control in remote locations. Currently, new technologies have been implemented where larvicides have been applied to neighborhoods using specialized mist blowers.

Aerial Application – Determination of the need for aerial spraying involves knowledge of the target species (including life history and behavior) and delineation of the infested areas. Aerial larviciding is utilized for larger and more remote breeding areas. Liquid and solid (i.e., granular, sand) formulations are the materials of choice. Most aerial larviciding can be conducted during the daytime.

Care and Maintenance of Equipment

Selection of the proper type and size of equipment is important for any application of mosquito larvicide. However, the effectiveness of applications largely depends on equipment that is subjected to a regularly scheduled maintenance program and frequently calibrated to a standard specified on the product label. General directions for proper maintenance include the following points.

1. Operation of equipment according to manufacturers' specifications.
2. Immediately report any failure if it cannot be quickly repaired in the field.
3. Keep equipment clean. Empty and clean the chemical storage and delivery system periodically; also clean strainers and nozzles so the equipment will be ready for the next use. Do not allow larvicide to stand in an idle machine. Always observe regulations regarding the safe disposal of the rinse or waste.
4. Keep machines properly lubricated.
5. Use preventative maintenance on equipment that will be out of service for long periods of time. Cover and store equipment to avoid accumulations of dirt, debris and moisture.

All spray equipment should be calibrated annually or anytime a modification is made to the system. Modifications include any equipment related to the spray system, i.e. changing chemical product, pumps, chemical lines, spray head, etc. This ensures you are always applying the chemical according to label requirements.

Chapter 11 - Practice Questions

1. Which of the following is a liquid formulation of a larvicide?

a. Sand
b. Emulsifiable concentrate
c. Granule
d. Briquet

2. Which of the following is not a bacteria-derived larvicide?

a. Bacillus thuringiensis isrealiensis
b. Spinosad
c. Bacillus sphearicus
d. Methoprene

3. The word "biorational" refers to

a. Any pesticide that breaks down quickly
b. Any product that is derived from natural sources
c. Any pesticide that has zero non-target effects
d. Any product with high toxicity

4. Which of the following products will ultimately kill adults trying to emerge, but most often does not immediately kill larvae in the habitat?

a. Spinosad
b. Monomolecular films
c. Bacillus sphearicus
d. Methoprene

5. Which of the following products functions by breaking the surface tension of the water in the habitat, which results in larvae and pupae unable to breathe?

a. Spinosad
b. Monomolecular films
c. Bacillus sphearicus
d. Methoprene

Chapter 12

ADULT MOSQUITO CONTROL

Ground ULV spray truck

Adult mosquito control (adulticiding) focuses on killing the adult stage of the mosquito. As a result, mosquitoes are targeted while in flight or at rest, rather than as immatures within an aquatic environment. Adulticiding is incredibly important when (1) the levels of nuisance biting mosquitoes is high, (2) there is increased risk for virus transmission, and/or (3) when adult mosquitoes pose other increased risks to humans or animals.

Surveillance is incredibly important to justify where and when adulticiding applications will occur. The first step in the control of adult mosquitoes is to identify the pest species. This can be accomplished using a variety of methods as discussed in chapter 7 of this manual. It is important to continuously monitor mosquito populations to recognize when chemical control of adult populations is needed. There will be times when adult populations are low enough or weather conditions prevent the need for spray applications.

Historically, the use of pesticides to control pests increased following development of DDT in 1944. Dramatic results encouraged the dependence on chemicals in all pest control operations, including organized mosquito control programs. During the last 15 to 20 years, questions have been raised about the heavy dependence on pesticides and their effects on the environment. Pesticide laws have been passed restricting the use of certain pesticides and requiring more emphasis on integrated control. The establishment of pest annoyance thresholds for man and domestic animals enables mosquito control programs to provide effective control without overkill, thus reducing the amount of chemical usage in the environment.

Proper Insecticide Usage

Pesticides are toxic to living organisms. They must be used with care and in accordance with label instructions. Following the label allows for control of target pests without causing significant damage to non-target organisms or the environment. Accordingly, pesticide users must carefully follow instructions for proper usage, disposal, and cleanup, as stated on the label.

Selection of Pesticides and Equipment:

Pesticides must be labeled for the intended use. Material should be readily available and reasonable in cost. Pesticides should be easily formulated. Appropriate equipment for pesticide application must be readily available and in good working order.

Application of Pesticides:

Use pesticides to supplement physical, cultural, or natural methods of control. Apply pesticides in a manner that offers minimal hazards to non-target organisms, man, and the environment. Use pesticides to treat only those specific sites where mosquitoes are present. Apply pesticides selectively to the proper life stage of the mosquito (some adulticides may be most effective against the early stages of larval development, while others are more effective against later stages of development). Apply pesticides in accordance with federal and state laws and regulations and in compliance with specific instruction on the label – READ THE LABEL.

Principal Advantages of Adulticiding	Principal Limitations of Adulticiding
Rapid and dramatic reduction of adults.	Results are often temporary.
Can potentially reduce the risk of increased arbovirus transmission.	Risk of non-target effects.
Can be used in combination with other control methods for increased population reduction.	Some pesticides may cause unsightly stains or damage automobile finishes and other surfaces.
Economic benefits derived from adulticides applications often offset the costs.	Insecticide resistance may develop within mosquito populations after prolonged usage.
Can quickly reduce the burden of biting mosquitoes on humans and animals.	Pesticides are expensive and costs continue to rise.

Types of Adulticides

Pyrethrins: Pyrethrins are naturally occurring plant secondary metabolites with insecticidal properties that are found in members of the genus *Chrysanthemum.* They function by binding to sodium channels on the nerves, causing paralysis and death. **Pyrethrum** is one product that has been used in mosquito control. While it is often considered one of the more environmentally acceptable adulticides, it breaks down rapidly when exposed to light.

Pyrethroids: Pyrethroids are synthetic compounds whose structures mimic pyrethrins. These products were modified in order to have increased stability, allowing them to persist in the environment longer. Like pyrethrins, pyrethroids also disrupt the sodium channels on the nerves, resulting in paralysis and death. Examples of pyrethroids used in mosquito control include **permethrin**, **resmethrin**, **deltamethrin**, **prallethrin**, **etofenprox**, and **phenothrin (also known as Sumethrin)**. Additionally, **bifenthrin**, permethrin, **lambda-cyhalothrin**, and deltamethrin are also commonly used as barrier treatments for mosquito control. Pyrethroids are extremely toxic to fish and should be applied carefully and according to the product label.

Organophosphates: Naled, **Malathion**, and **Chlorpyrifos** are organophosphate adulticides that are used in mosquito control programs. They are variable in toxicity and persistence, but most often breakdown quite rapidly. Organophosphates work by inhibiting an enyzyme (cholinesterase) that breaks down acetylcholine (an important neurotransmitter) on the surface of nerve cells. Since the enzyme gets inhibited, nerves continue firing, causing paralysis and death. This cellular process is highly conserved in animals, meaning that humans can be negatively impacted. It is recommended that employees working extensively with organophosphates be tested for acetylcholinesterase annually, before and after the spray season.

Piperonyl butoxide (PBO): Many formulated adulticides have PBO added to increase their efficacy. PBO has little to no toxic properties, but functions as a **synergist** (a compound or pesticide that enhances the toxicity of another pesticide) by inhibiting detoxification processes in arthropods. As a result, insecticides can be more effective, even with less of an active ingredient.

Insecticide Formulations

Usually, insecticides must be mixed with one or more other substances to make them safe and easy to apply. This mixture of the active and inert ingredients is called a pesticide formulation. Formulations are discussed in detail in the EPA guide *National Pesticide Applicator Certification Core Manual*, which is distributed by the LSU AgCenter. Therefore, only a brief description of formulations commonly used for mosquito control is given in this chapter.

Dry or Solid Formulations:

Insecticidal Dusts – These consist of an inert carrier, such as talc or pyrophyllite, and an insecticide (active ingredient) that is usually in the range of 1% to 10% of the total weight. Although dusts are usually low in cost, easy to apply, non-staining, and nontoxic to vegetation, they are rarely used in mosquito control. Poisons in dust form are generally not absorbed through the skin but may be dangerous if inhaled. Dusts do not adhere well to vertical surfaces such as walls and are easily removed by winds and rain. They are unsightly in the home and have been replaced, for the most part, by sprays and aerosols.

Wettable Powders (Suspensions) – Wettable powders, prior to being mixed with water for application, look like dusts. Unlike dusts, they contain wetting agent in additions to the insecticide and inert ingredient. Wettable powders are not commonly used in mosquito control. They are not suitable for ultra-low volume (ULV) applications and leave a residue. Some larvicides are available as wettable powders. One drawback is that they must be agitated while applied.

Liquid Formulations:

High Concentrates (Solutions) – These are special formulations consisting of pesticides diluted with an oil to contain not less than 1.5 pounds of active ingredient (A. I.) per gallon. In mosquito control, they are often used in ULV application for control of adult mosquitoes. This formulation allows the pesticide to stick to objects and target organisms.

Emulsifiable Concentrates (EC) – These formulations contain an insecticide, a petroleum carrier, and an emulsifying agent that permits the formulation to mix well with water. When diluted, emulsions need little agitation and can be used as a residual spray both outdoors and indoors. They can also be used as aerosol sprays for adult mosquito control. Caution should be used during applications, as ECs can damage some plants and stain certain surfaces.

Aerosols – An insecticidal aerosol is a fine spray with droplets ranging from 0.1 to 50 micrometers in diameter. The finer aerosols remain suspended in the air for an extended period, killing insects by contact. Droplets of 5 to 15 micrometers in diameter appear to give the best control in outdoor applications on mosquitoes.

Selection of Proper Equipment

The selection and use of proper equipment for mosquito control will ensure that adulticides are dispensed to the target accurately, efficiently, and safely, with minimal contamination to the environment or adverse effects upon man. When considering purchasing equipment you should select based on (1) the appropriate size for the job, (2) durability, (3) efficient design (4) safety features to user and the environment, and (5) cost-to-benefit to the program. In addition, equipment should always be properly inspected and calibrated before each use.

Hand Sprayers: The compressed air sprayer is the mainstay of most hand-applied pesticide operations. Usually the sprayer is a small (1 to 5 gallon) cylindrical tank with an air pump, hose, and spray gun. Hand sprayers are most often used for larvicidal treatments of areas less than an acre in size or for use in applying residual applications of insecticides around a home or business.

Backpack Mister and Hand Foggers: These contain a chemical tank and a small gas or electric engine with a blower for the atomizing of the chemical. Commonly used around homes and public spaces, they offer an economical way of treating adult mosquitoes in small areas. Both are used to control mosquitoes and for barrier treatments. The technician should follow the chemical label and user guide prior to any application.

Thermal Fog Applicators: Through the early 1980s large thermal fog machines were used much the same as aerosol dispensers in the home. The machines were generally mounted on trucks and produced a thick foglike cloud dispensed downwind. This method, although still applicable in some states, is considered obsolete in Louisiana due to the high cost of petroleum diluents, the traffic hazard imposed by the "smoke screen," and the safety of children who tend to follow along behind the truck in the thick fog. Small portable thermal fog generators still have a limited use in urban areas for treating storm drain systems during disease outbreaks.

ULV Ground Sprayer: ULV spraying is the application of small amounts of highly concentrated adulticide. The ground sprayer usually holds 5 to 20 gallons of concentrate or formulation. It is often mounted on the bed of a half-ton truck. In contrast, the thermal fogger was much larger and heavier, and its adulticide tank contained 25 to 200 gallons or more. The unit was usually mounted on a much larger vehicle, such as a 1- to 3-ton truck.

Most ULV ground sprayers use a blower that delivers high-speed air to break up and transport the spray droplets to a point just outside the nozzle orifice. The prevailing winds (<10 mph) act to move the adulticide droplets across the treatment area. No wind (<1 mph) often results in poor dispersal of the adulticide and this results in poor control of mosquito populations in the vicinity. ULV applications use less adulticide per acre than did thermal foggers. The result is less environmental contamination, saving in adulticide costs, reduction of diluents, and reduced time for loading or transporting adulticides. Another advantage of ULV aerosols is avoidance of dense fogs such as those produced by thermal fog generators. ULV ground equipment should produce a carefully regulated and monitored flow rate and spectrum of droplet sizes. Usually the nozzle should be directed upward at an angle of 45 degrees to ensure maximum dispersal of insecticide. Vehicle speed should not exceed that designated on the insecticide label. The spray should always be shut off when the vehicle is stopped, even momentarily.

Aerial ULV Equipment: ULV application equipment is custom mounted upon or within an aircraft. In principle, the tank contains the adulticide that is distributed under pressure to nozzles that regulate the spray. The size and configuration of nozzles, system pressure, altitude, and air speed greatly influence the distribution and quantity of adulticides. Chemicals registered for aerial ULV application have specific instructions that pertain to their proper use. These label directions, as with any pesticide label, should be strictly followed.

Guidance Equipment: Global positioning satellite (GPS) systems are deployed in aerial and ground spray systems. These systems are integrated with computer software to improve application accuracy. Spray missions are recorded and can be displayed later on a desktop computer. Multiple parameters are recorded, such as spray path, date, time, temperature, wind speed, and wind direction. The display of moving maps (real time) allows for spray adjustments, ensuring proper application of insecticide to target areas. This equipment can be expensive but is usually compensated for through increased mosquito control efficiency.

In truck with computer equipment. Photo by Jennifer Bushnell

Care and Maintenance of Equipment

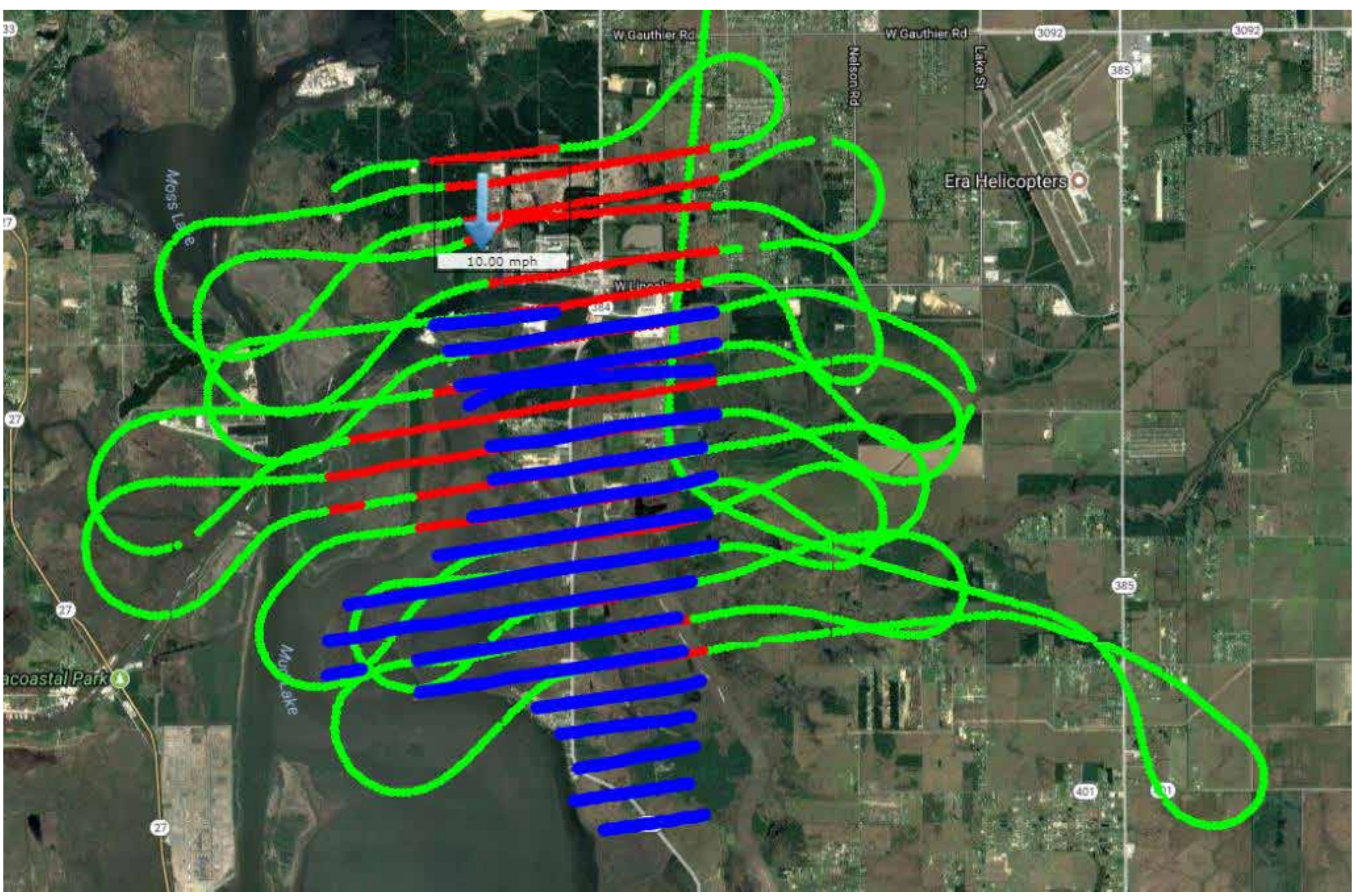
Selection of the proper type and size of equipment is important for any application of a mosquito adulticide. However, the effectiveness of applications largely depends on equipment that is subjected to a regularly scheduled maintenance program and frequently calibrated to a standard specified on the product label.

All spray equipment should be calibrated annually or anytime a modification is made to the system. The modification includes any equipment related to the spray system, e.g., changing chemical product, pumps, chemical lines, spray head, etc. This ensures you're always applying the chemical according to labeling requirements.

There are many options available for calibrating equipment, and mosquito control programs can work with their vendors and other programs for guidance on how to calibrate.

Equipment can be expensive, so proper care and maintenance will also ensure that equipment will be available to use for a long time. Ensuring that all equipment is properly cared for will also help improve safety overall. Guidelines on how to maintain equipment can be found in the chart below.

General directions for proper maintenance
Operate equipment according to manufacturers' specifications.
Immediately report any failure if it cannot be quickly repaired in the field.
Keep equipment clean. Empty and clean the chemical storage and delivery system periodically, also clean strainers and nozzles so the equipment will be ready for the next use.
Do not allow insecticides to stand in an idle machine because some are corrosive and may form a sludge that is difficult to remove.
Always observe regulations regarding the safe disposal of the rinse.
Keep machines properly lubricated.
Use preventative maintenance on equipment that will be out of service for long periods of time.
Cover and store equipment to avoid accumulations of dirt, debris, and moisture.



Aerial spray application showing spray swith on lines (red) and drift to target (blue).

Methods

Adulticiding: The term "adulticiding" is used to describe the procedure of applying adulticides to kill flying adult mosquitoes or those adults resting in vegetation, buildings, or similar harborage. Ground and aerial application of adulticides normally take place in the evening and night; they are targeting the flying adult populations to attain the greatest control effects. This time period helps avoid flight activity of non-target insects. Applicators should remember that this is the most visible form of control. Adulticiding is not a long-range substitute for such permanent measures as drainage, land filling, water management, and good sanitary practices.

Ground Application – Controlling adult mosquitoes by means of ground application involves a wide range of equipment types such as portable hand-held sprayers and sophisticated ULV cold-fog generators. The types of equipment used in an abatement program should be based on the nature of the operation and the environmental character of the treatment area. Presently, mosquito control districts in urban areas rely on truck-mounted ULV sprayers as the primary method to control flying adult mosquitoes. Trained personnel are essential to maintain and operate these machines to ensure proper droplet size and flow rate.

Aerial Application – Application of adulticides from aircraft is employed to treat large and/or inaccessible areas quickly and thoroughly. Aerial spray operations must be controlled at all times because effective application is dependent upon the care and precision with which it is carried out. Aerial spraying results primarily in control of adult mosquitoes in flight at the time of application.

To obtain uniform coverage of an area, careful observance of planned flight patterns, altitudes, air speeds, and air temperatures is essential. Aerial applications for mosquito control are usually conducted at altitudes below 300 feet. Operations at excessive altitudes or in high winds can cause misapplication of adulticides, resulting in insufficient chemical reaching the target area. Altering air speed, nozzle diameter, or pressure will change the rate of application, spray pattern, and swath width.

Weather (high winds, thermals, low ceiling, and low visibility) may limit the use of aerial spraying. Early morning (dawn) and, particularly, late evening (dusk) hours are the most effective times to utilize aerial spraying. Wind speeds are usually lower at these times. Air temperature inversions are greater in the morning and facilitate droplet placement. Also, the late evening and early nighttime hours are periods of greatest mosquito flight activity. Because aerial application is expensive, costs of modifying, equipping, and operating aircraft should be weighed carefully against the cost and efficiency of ground control before a spraying program is undertaken.

Barrier Treatment: A chemical alternative to adulticiding is barrier treatment. Using chemicals with a residual effect to prevent or kill resting mosquitoes. The technician sprays vegetation or buildings with an approved chemical, an example is pyrethroid-based products mixed with water. Backpack misters and hand foggers can be used for this. In larger areas side-by-sides or ATVs with power sprayers may be utilized. There is a drying time with these products before people and pets can safely use the area. Remember to read and follow the label.

Resistance to Insecticides

With the availability of different insecticides for mosquito control, there exists a responsibility to use them wisely in order to prevent the mosquitoes from developing resistance. Resistance is a change in response to an insecticide by becoming less vulnerable to its toxic effects. These changes in response can be due to (1) metabolic resistance, (2) target site resistance, (3) penetration resistance, or (4) behavioral resistance.

Metabolic Resistance: When chemicals enter the body, detoxifying enzymes help break it down (metabolize), allowing it to be easily removed from the body. In metabolic resistance, the insects may have improved or increased levels of these enzymes, allowing them to be able to more efficiently remove the insecticide from the body.

Target Site Resistance: Certain genetic mutations can occur that can prevent the insecticide from properly binding or acting on a target site. One example of this is **kdr** (knockdown resistance), which can result in resistance to pyrethroids. Kdr is due to specific genetic mutations on the voltage-gated sodium channel.

Penetration and Behavioral Resistance: Mosquitoes can also become resistant to insecticides through other mechanisms. For example, they may form a thicker outer cuticle, resulting in reduced penetration of the insecticide. Additionally, insects may exhibit behavioral changes (e.g., rest in more protective areas).

Preventing Resistance

There are several things that can lead to the development of resistance. However, there are methods that can be employed to help minimize the risk of resistance.

1. **Rotate multiple classes of Insecticide:** Using a single class of insecticide each year throughout an entire season can increase the risk of insecticide resistance. If possible, programs should rotate products with different modes of action (e.g., Organophosphates that target cholinesterase and pyrethroids that target sodium channels).
2. **Use products with less residual action:** Insecticides that are constantly in the environment, especially at lower

than optimal rates, can quickly select for resistance. While products are applied at label rates, they can slowly degrade over time, reducing mosquitoes to rates that are no longer lethal. As mosquitoes are exposed to these low rates, they can develop resistance to those products. If residual products are used, bioassays should be conducted to assess the efficacy of these products in the field.

3. **Monitor habitats where slow-release formulations are used:** Over time these formulations have less active ingredient to release and can create a situation where a sub-lethal dose is acting on the mosquito population. As in the above, frequent sampling, and bioassays should be conducted to assess the efficacy of these products in the field.
4. **Apply products with different modes of action to different life stages:** In order to prevent resistance, you should never use the same mode of action on larvae that you will also use on adults. An example of this would be applying Temephos (an organophosphate) to control larvae, and then using Malathion (also an organophosphate) to control adults. Rather, mosquito control programs should select larval and adult control products with different modes of action.
5. **Treat only when needed:** Using insecticides routinely instead of when there is a problem exposes all generations to the toxicant. This does not allow for susceptible genes to thrive in the population. Treating every habitat regardless of if it is producing large numbers of mosquitoes also selects all generations and exposes all life stages to the insecticide. Because we know we will never eliminate mosquitoes, it is important to keep refuge areas where insecticide susceptible mosquitoes can develop.
6. **Routinely monitor for insecticide resistance.** A routine resistance-monitoring program would include routine testing of populations. The number and time of populations tested in a given area will vary depending on the species. For example, weak fliers such as *Cx. quinquefasciatus* should be tested from many areas within a district while strong fliers such as *Ae. taeniorhynchus* or *Cx. salinarius* can be sampled from fewer locations. Ideally, populations should be sampled before the season, mid-season, and at the end of the season in order to assess resistance in the population.

Testing for Resistance

The simplest insecticide resistance test for adulticides is the CDC bottle bioassay. The bottle bioassay detects the presence/absence of resistance through a timed assay. Mosquitoes are placed into a bottle coated with a known concentration of insecticide. Every 15 minutes the number of dead mosquitoes are counted. The "wild" collected mosquitoes are then compared to results in susceptible mosquitoes (usually with 100% mortality around 60 minutes for most products and species). The advantage of the bottle bioassay over other tests, is that results can be obtained within a couple of hours. The methodology can be obtained on the LMCA website.

Chapter 12 - Practice Questions

1. Which of the following is NOT a type of insecticide resistance?

a. Behavioral resistance
b. Rotation resistance
c. Metabolic resistance
d. Target site resistance

2. Which of the following classes of insecticides does Naled belong?

a. Pyrethrin
b. Pyrethroid
c. Organophosphate
d. PBO

3. Which of the following methods of adulticiding would you use for residual control in a backyard neighborhood?

a. Ground ULV
b. Aerial ULV
c. Barrier treatment
d. Global positioning system

4. Which of the following is the application of small amounts of highly concentrated adulticide?

a. ULV sprayer
b. Thermal fogger
c. Hand sprayer
d. Guidance equipment

5. PBO improves the effectiveness of a product by:

a. Inhibiting detoxification of the active ingredient.
b. Reducing the time before knock-down.
c. Adding an additional mode-of-action.
d. Increasing the persistence of the product.

Chapter 13

LAWS AFFECTING PESTICIDES IN LOUISIANA

In Louisiana pesticides are important in the production of food and fiber, as well as in the protection of humans and their surroundings. Louisiana has had laws and regulations affecting pesticides for many years. These laws are based on the needs of the people, and concern for the protection of them and their environment.

Louisiana laws have been tailored to comply with all requirements of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) as amended. Congress passed laws in 1972, 1975, and in succeeding years that amended the basic law.

Federal Insecticide, Fungicide, and Rodenticide Act

When Congress amended FIFRA in 1972, the Environmental Protection Agency (EPA) was designated to carry out the provisions of the act. Some of the provisions include the following:

1. Use of any pesticide inconsistent with the label is prohibited.
2. Deliberate violations can result in heavy fines and/or imprisonment.
3. All pesticides are to be classified into general use or restricted categories.
4. Anyone applying restricted-use pesticides must be certified by the state in which he or she lives.
5. Pesticide manufacturing plants must be registered and inspected by the EPA.
6. States may register pesticides on a limited basis when intended for special local needs.
7. All pesticides must be registered with the EPA, whether shipped in interstate or intrastate commerce.
8. For a product to be registered, the manufacturer is required to provide scientific evidence that the product, when used as directed, will not cause unreasonable adverse effects on man or the environment.

Congress also authorized the EPA to grant state primacy to the individual states who wished to regulate pesticides within their borders if the state pesticide laws were at least as stringent as FIFRA. Louisiana received state primacy, and the Louisiana Department of Agriculture and Forestry was designated as the State Lead Agency (SLA).

Clean Water Act — National Pollutant Discharge Elimination System Permit (NPDES)

In 1972 Congress passed the Clean Water Act (CWA) to restore and maintain the integrity of our nations water. Section 301 of the CWA prohibits any point source discharge of pollutant to waters of the United States. To legally discharge a pollutant without violating section 301 one must obtain authorization from EPA under section 402, NPDES. The state of Louisiana has the Louisiana Pollutant Discharge Elimination System (LPDES) Pesticide General Permit (PGP) LAG8700 to cover mosquito control applicators. The permit is required to make spray applications over any water in our state. A copy of the permit, along with frequently asked questions can be found on the Louisiana Department of Environmental Quality's website: http://www.deq.louisiana.gov.

Louisiana Laws and Regulations

In Louisiana pesticides are basically regulated by two laws - the Louisiana Pesticide Law and the Louisiana Structural Pest Control Act. Each of these laws covers some aspect of pesticides as required by federal law, and all are designed to meet the needs of the people in Louisiana.

Louisiana Pesticide Law

This law establishes the procedure for registering pesticides in Louisiana, as well as procedures for sampling pesticides for purity and proper labeling. The recommendation, sale, application, and use of pesticides are also important parts of this act. These points are addressed in provisions for Licensing and Certification of Agricultural Consultants, Pesticide Dealers, and Pesticide Applicators.

Licenses are required of all businesses that are in the business of making recommendations as to the use of pesticides (agricultural consultants), selling restricted-use pesticides (pesticide dealers), and applying pesticides (owner-operators). Certification is recognition by the state of Louisiana that a person has satisfactorily proven that he/she knows the safe and correct way to carry out his job in relation to recommendation, handling, or use of pesticides. Agricultural consultants, pesticide salespersons, commercial applicators, and private applicators (farmers) must be certified.

Other provisions of this act set up procedures for filing complaints regarding pesticides, collecting and analyzing pesticide samples, enforcement action against persons violating sections of the Act, and disposal of waste pesticides and containers.

Louisiana Structural Pest Control Act

This law regulates persons in the business of applying pesticides in the category of Institutional, Structural, and Health-Related Pest Control. These persons are involved almost exclusively with control of household pests. Details on the two Louisiana laws are available from the Louisiana Department of Agriculture and Forestry (LDAF) or at the website: http://www.ldaf.state.la.us/ldaf-programs/pesticide-environmental-programs/.

Registration and Classification

The manufacturer must register every pesticide. Pesticides with the same active ingredients, but with a different formulation or different uses, must have different labels. Always check the label carefully. Each must be classified "general" or "restricted-use pesticide" (RUP). General- (unclassified) use pesticides should damage the environment very little, or not at all, when used according to label directions and may be applied by anyone. Restricted-use pesticides may damage the environment or be harmful to man even when used according to label directions. Individuals applying a RUP must show that they are competent to do so. They show their competency by passing the certification examinations and so become a certified applicator.

Certification

To apply restricted-use pesticides, an applicator must prove that he/she knows the safe and correct way to apply pesticides. Federal regulations set forth standards for certification, including the naming of a lead agency in each state. In Louisiana, it is the LDAF that carries out the certification program. The LSU AgCenter conducts the educational program for pesticide applicators. The federal standards include the following:

1. The private applicator should possess a practical knowledge of the pest problems and pest control practices associated with his/her operations including the proper storage, use, handling, and disposal of pesticides and containers and his/her related legal responsibility.
2. The commercial applicator must meet some general standards that are divided into eight core areas of knowledge and specific standards for each of the 10 categories of applicators designated in federal regulations.

Category 8. Public Health Pest Control

This category is for commercial applicators and state federal and other government employees using or supervising the use of pesticides in public health programs for the management and control of pests having medical and public health importance. This category has been subdivided into six categories, two of which are applicable to mosquito control.

8A. Mosquito Control Applicator: This category is for commercial applicators and government employees who are applicators in mosquito control programs

8B. Rodent Control: This subcategory is for commercial applicators and government employees who are applicators in rodent control programs.

8D. Mosquito Control Program Supervisor: This category is for commercial applicators and government employees who are supervisors in organized mosquito control programs. This subcategory has prerequisites the applicator must satisfy before testing. The applicator should contact the Pesticide Safety Education Director at the LSU AgCenter or the Certification and Training Program Manager at the LDAF for the details.

Category 10. Demonstration and Research Pest Control

Category 10 includes individuals who demonstrate to the public the proper use and techniques of application of pesticides with restricted uses, or supervise such demonstrations and persons conducting field research with pesticides, and, in doing so, use or supervise the use of pesticides with restricted uses.

Violation and Penalties

Everyone involved with pesticides should be aware of acts that are violations of FIFRA and the penalties for these violations. Violations include such items as:

1. Detaching, altering, defacing, or destroying any labeling.
2. Failing to keep records.
3. Using or making available for use any registered pesticide classified for restricted use for some or all purposes other than as provided for in FIFRA or regulations there under.
4. Using any registered pesticide in a manner inconsistent with its labeling.
5. Disposing of any pesticide or its container except as the labeling directs and according to state laws and regulations.

Enforcement

The LDAF is responsible for the enforcement of Louisiana pesticide laws and the FIFRA within Louisiana.

Information

Further information on the pesticide laws and certification procedures may be obtained from LDAF or the Pesticide Safety Education Director at the LSU AgCenter, the Louisiana Cooperative Extension Service.

Chapter 13 - Practice Questions

1. Which of the following prohibits any point source discharge of pollutant to waters of the United States?
a. Louisiana Structural Pest Control Act
b. FIFRA
c. Pesticide Reduction Act
d. Clean Water Act

2. Which agency enforces pesticide laws within Louisiana?
a. Louisiana Department of Agriculture and Forestry
b. Environmental Protection Agency
c. Louisiana Department of Fish and Wildlife
d. Louisiana Department of Health

3. What is the certification category in Louisiana for Mosquito Control Applicator?
a. 8A
b. 8B
c. 8C
d. 8D

4. What does NPDES stand for?
a. National Pesticide Discharge Elimination System
b. National Pollutant Discharge Elimination System
c. National Pesticide Discharge Environmental System
d. National Pollutant Discharge Environmental System

5. Failing to keep records is considered a?
a. Penalty
b. Violation
c. Enforcement
d. Certification

Chapter 14
PUBLIC EDUCATION

Educating the public about mosquitoes and their control is essential to successful operations. Mosquito outbreaks and disease threats often pique public interest in mosquito control activities, giving applicators the chance to share what we do to reduce mosquitoes. Personnel are often invited to make presentations to the media, schools, civic associations, homeowner associations, and other groups. Most mosquito control programs take advantage of these opportunities to distribute information and educate the public on basic mosquito control. When citizens understand basic mosquito biology and act to reduce mosquito breeding sites around their homes, it results in fewer mosquitoes and less dependence on insecticides. It may also reduce the incidence of mosquito-borne disease.

Mosquito control personnel often initiate contact with these, and other, groups to open lines of communication. Contact groups may include the following: television stations, radio stations, newspapers, subdivision newsletter editors, civic associations (Lions Clubs, Rotary Clubs, Kiwanis Clubs), 4-H clubs, Boy and Girl Scout troop leaders, YMCA branches, local libraries, computer clubs, schools, universities, and day care centers. By initiating contact with these groups before, it usually opens lines of communication that can be very helpful in ensuring that you are able to disseminate information. Some examples of the public education programs by mosquito abatement programs in Louisiana include the following:

Television/Radio Commercials: Some mosquito abatement districts produce "spots" for television and radio and pay for airtime for the "spots" during times of greatest disease potential or following large or extended rain events. The information is intended to call citizens to action to reduce mosquito-breeding sites around their homes and to encourage them to take precautions against disease bearing mosquitoes. And some mosquito abatement districts make use of public access television channels on local cable television. The television specials are productions for local cable television and can be very effective in giving information to the public about mosquitoes, mosquito-borne diseases and control methods.

The paid "spots" or commercials are generally aired during times when you want to get specific information to the public quickly. Generally, local cable television presentations cannot be used to disseminate special information quickly. But these programs frequently run several times throughout the course of the year and provide a good medium for disseminating information on mosquitoes, mosquito biology, mosquito-borne diseases, and control techniques that citizens can implement around their homes.

Press Releases: Many mosquito abatement districts issue press releases to local media when they wish to convey information and motivate the public to action quickly. Press releases should be brief. Always give your name, address, and phone number so media personnel can contact you for follow-up information. Press releases often result in other contacts from media personnel and frequently result in expanded coverage of the information you are attempting to disseminate. The press releases should be sent to all newspaper, television, and radio stations in your area at the same time.

Schools: Most mosquito abatement districts cultivate relationships with public and private schools in their area and make presentations whenever possible. And some mosquito abatement districts disseminate mosquito kits and teaching plans for teachers to use to teach special projects. A mosquito kit consists of a clear plastic container that holds water in the bottom so the students can observe mosquito larvae. It is screened on top to help keep adult mosquitoes from escaping. Often, specific instructions on how to use the kit, mosquito eggs, larvae food, and appropriate teaching plans accompany the mosquito kit to aid the classroom instructor. Some mosquito control agencies have worked with classroom teachers to develop grade-specific teaching plans for grades K-12. One of the great values of mosquito kits is that the teaching aid stays in the classroom throughout the entire developmental period of the mosquito (from egg to larvae to pupae to adult). This helps to reinforce messages and to imprint in the student's mind that

mosquitoes develop slowly and that the student should make routine inspections around the home to locate breeding mosquitoes.

Day Care Centers: Some mosquito abatement districts spend time during the summer making presentations to children at day care centers about mosquitoes and mosquito control. Day care personnel are always looking for ways to keep children occupied and entertained during the summer. So some mosquito abatement districts send their personnel to the day care centers to make presentations or invite the children to their facility for presentations and tours. Instructors hand out mosquito inspector badges, coloring books, crossword puzzles, or other items to reinforce the mosquito abatement message. Frequently, the instructor will give day care children a checklist to take home so they can have their parents help them inspect around their homes to locate and remove mosquito breeding habitats. The youngsters receive a "mosquito inspector badge" when they complete the assignment. Information about these programs is available from many of the larger mosquito abatement districts in Louisiana.

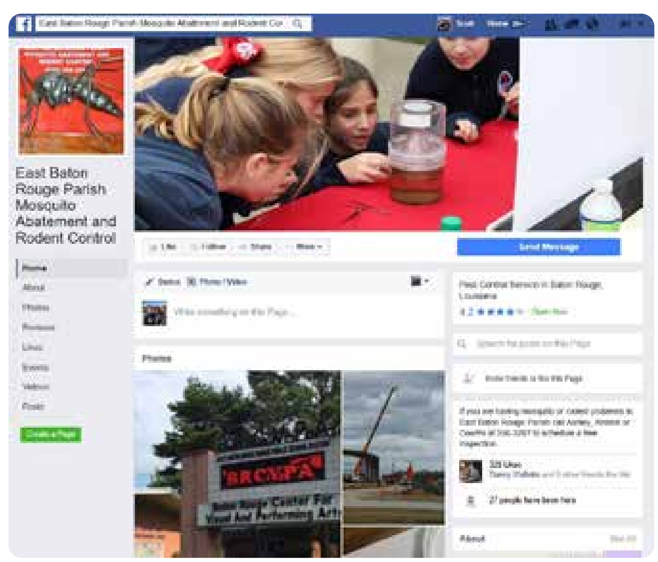
Video Presentations: In addition to producing "spots" for television, some mosquito abatement districts also produce educational materials in house. These productions may cover biology, disease, prevention, control methods, or other items of special interest. They are made available to schools, video stores, and local television stations to promote good mosquito control in the area. These presentations may be produced and directed by mosquito control personnel, or the mosquito abatement district may hire a professional firm to produce a specific product.

Educational Booklets and Other Materials: Materials such as booklets, coloring books, bookmarks, pencils, book covers and other educational materials can be dissemenated in the community. These materials are distributed through the schools, day care centers, libraries, and civic associations or at public events where the district sets up displays. One of the great advantages of using materials like this is that it frequently stays around the home, in the classroom, or with the student throughout the course of the year. The constant presence of the educational tools reinforce the mosquito control message and is more likely to result in the person taking action on a regular basis to control mosquitoes.

Displays: Mosquito abatement districts set up displays at festivals, fairs, Earth Day events, home, garden shows, public shopping centers, or at other community gatherings in their area. These events often attract people who would not be present at schools, day care centers, or civic association meetings. Mosquito control personnel can reach the community with mosquito control messages and communicate information to citizens in unusual and very productive ways by having displays that are very interactive.

Websites: Most mosquito abatement districts have developed websites that include educational materials, contact information, and other items that will assist the citizen and motivate people to work with the local mosquito control program to help reduce mosquito populations in the area. Often these websites contain links to other informational websites. The links may include the Louisiana Mosquito Control Association, American Mosquito Control Association, Centers for Disease Control (CDC), Environmental Protection Agency (EPA), LSU AgCenter, Louisiana Department of Health and Hospitals (LDHH), or other organizations that have helpful information on mosquitoes, mosquito control, mosquito-borne diseases, pesticides, pesticide safety information, insect repellents, and other matters of interest.

Social Media: In recent years mosquito abatement districts have employed social media such as Twitter, Instagram, and Facebook to get information out. The advantage of social media is that it allows for the interaction with people by sharing and receiving information. This interaction allows the upload of photos and videos, which can be viewed by all. Also, with comment sections we can share our thoughts. Social media is an up-to-date way of sharing real time information.



LMCA Educational Efforts

The LMCA promotes public education in a variety of ways, some of which are the LMCA website, Annual Mosquito Awareness Week, Education Day, and science fairs.

Mosquito Awareness Week: In conjunction with the AMCA, the LMCA promotes Mosquito Control Awareness Week. This usually happens at the end of June and is a national promotion of mosquito control. Mosquito awareness week encourages the public to drain containers, dress appropriately when outdoors, and wear approved repellents. It is directed to the homeowner, letting them know what they can do to prevent mosquitoes.

LMCA Education Day: The LMCA education day committee visits a school in the host city of that year's annual meeting site. Multiple mosquito abatement districts get involved in planning and organizing this event. They give hands-on demonstrations, show touch stations, display mosquito equipment (traps, spray equipment, trucks, etc.), and give presentations on mosquito biology to students.

Educating the Homeowner

Educating homeowners on how to control mosquitoes and avoid being bitten by mosquitoes is important to our control efforts. Most people still think that spraying alone will solve their problem, not understanding what all goes into mosquito abatement. It's our job to communicate the what, when, where, why, and how of mosquito control. The use of brochures, websites, social media, and television enables us to get the message out by communicating the facts and dispelling myths.

Mosquito districts should make home inspections after receiving any complaint of mosquito activity. During these visits a technician must try to identify the nuisance species and breeding habitat associated with it. Once the species is identified, a control method can be utilized. In some instances, the control method might be as simple as emptying water-holding containers and handing out brochures on container breeding mosquitoes. Others may require larvicide treatments, scheduling spray trucks or aerial flights. After a property inspection is conducted the technician should follow up with the homeowner to give feedback. All inspections and treatments must be documented for administrative purposes.

Information about what the homeowner can do to prevent mosquitoes should be conveyed during the visit. Brochures and door hangers with basic information about mosquitoes can be handed out or hung on doors. They should at the least include information about mosquito breeding sites (artificial containers, tires, ditches, etc.) and the use of approved mosquito repellants. Just by informing others with what they themselves can do is the biggest return for our effort.

Chapter 15

COOPERATIVE MOSQUITO CONTROL

Mosquito control professionals should execute strategies designed to acquaint other agencies with the activities and goals of mosquito control programs. At the same time, mosquito control professionals should have a working knowledge of the operations of other agencies that could impact mosquito control efforts. Examples of some of these agencies include: the U.S. Army Corp of Engineers, U.S. Fish and Wildlife Service, and Federal Emergency Management Agency. When agencies better understand each other's operations, conflicts are minimized and cooperation maximized. This chapter will look at various agencies whose operations may impact mosquito control activities.

U.S. Army Corp of Engineers

This branch of the U.S. Army has various missions that will impact mosquito control operations. One of its primary missions is planning and directing the construction of navigation and flood control projects for the federal government. Many of these projects will cause changes in the ecology of an area, affecting the production of mosquitoes.

One example of this is the creation of dredged spoil or fill collection areas along navigable waterways. Due to silting, many waterways must be dredged every three to four years to maintain proper depth for safe navigation. The dredged material is pumped onto diked land areas adjacent to the waterway. On most spoil banks, the silt dries between dredging and cracks are formed across the surface. These cracks then provide favorable conditions for floodwater mosquito production upon subsequent rainfall. Although some spoils do not crack, they often settle unevenly, holding rainwater or flooding temporarily. Also, improperly placed spoil banks may impede natural drainage, resulting in additional problems outside these spoils.

Parishes with large navigable waterways need to recognize the potential problems posed by such areas. Prior to the start of these projects, personnel of both agencies should evaluate the situation and have a working plan. Cooperative agreements can be achieved, as evidenced by ongoing arrangements by parishes in Louisiana and other areas of the U.S.

Other responsibilities of the Corps are with the permitting process for wetland related projects. Any alteration of wetland habitat will require a permit from the Corps. This process can be somewhat cumbersome but will be necessary before the start of any drainage project.

Wildlife and Fisheries

It is almost a given that all mosquito control agencies in Louisiana will interact with either the U.S. or Louisiana wildlife and fisheries agencies. Because there are no simple rules to cover all situations, a good working relationship should be maintained.

More and more natural wetland habitat is being protected. This is to safeguard the necessary habitat for the vast diversity of birds, mammals, and aquatic life that exist in our state. Unfortunately, many of these natural areas (wildlife refuges/management areas) are in close proximity to large populated centers. Therefore, mosquitoes produced on these areas impact greatly the health and well-being, as well as stymieing the economic growth of these communities. By working together, both agencies promote one another, assuring acceptance by the citizenry.

Marsh management is a good example of how some of these conflicts arise. Wildlife agencies manage the marsh for the production of food for wildlife. The intent is to remove water during the spring and summer, allowing grass seeds to germinate. However, during this period, heavy rains may inundate these areas for one to two weeks, allowing alternate flooding and drying and maximizing the production of certain floodwater species. Cooperative efforts could provide that impoundments be constructed to receive the needed rainwater for germination, but to eliminate the surface water in a period of three to four days. This would thereby achieve the goals of both agencies.

If this type of cooperative water management were not possible, then steps should be put in place to allow for various mosquito control activities. These should include the use of larvicides and/or adulticides at such a time to ensure effective mosquito control with the least environmental impact. A response plan could be formulated annually and thoroughly evaluated before implementation.

Mosquito control agencies involved with encephalitis surveillance activities will also interact with wildlife and fisheries. This is especially true if wild birds and animals are to be part of the surveillance program. Scientific collecting permits will be needed from both Louisiana Department of Wildlife and Fisheries and the U.S. Fish and Wildlife Service. The U.S. Fish and Wildlife Service will also require a banding permit should a surveillance program desire to band wild birds.

The above scenarios are just a few examples of how mosquito control and fish and wildlife agencies interact. The U. S. Fish and Wildlife Service is working on an official handbook to address mosquito control practices on federal wildlife lands. This publication could enhance the ability of mosquito control agencies to work on federally protected lands to ensure public health and at the same time ensure the protection of habitat for wildlife.

Agriculture

There are several agricultura-related governmental entities with which mosquito controllers will interact. Probably the most important of these is the Louisiana Department of Agriculture and Forestry (LDAF). This agency is the regulatory body that formulated laws, rules, and regulations by which mosquito controllers must operate. These regulate certification, licensing, record keeping, product registration, product handling and storage, and product application. LDAF personnel will periodically inspect operators for compliance and investigate complaints for possible violations. If violations are evident, due process, with imposition of penalties will follow. Mosquito control agencies should work with LDAF to understand these provisions and assure compliance.

In addition to regulatory responsibility, LDAF works to maintain the health and well-being of agricultural livestock. When disease threatens state livestock, the LDAF state veterinarian will be involved to track the disease and coordinate their response. Through their contacts statewide, a network can quickly be established to obtain case history and look for evidence of new cases. They can also be of assistance with timely and expert media advisories. Any time mosquito-borne illnesses, such as EEE, are a threat, this office should be notified and efforts coordinated.

The United States Department of Agriculture (USDA) also has a veterinary branch similar to that of the state. When WNV was introduced into the U.S., USDA became an active player. That was because this disease was considered an import and they were charged with tracking its progress. Once foreign disease looks to be endemic, their role is diminished.

One other activity of USDA is mosquito research. Their lab in Gainesville, Florida, (formerly housed in Lake Charles) has and continues to be a valuable asset to the mosquito control industry. Research from this facility has led to several biological control agents, improved traps for surveillance, improved rearing techniques and improved repellents. From time to time, mosquito controllers may be asked to help cooperate in one of these endeavors.

One other agricultural agency in Louisiana is the LSU AgCenter. Part of the Louisiana State University system, the LSU AgCenter has extension agents (county agents) working with all 64 parishes. Their mission is one of education that uses research-based knowledge focused on issues and needs. By working with the local extension service office, mosquito controllers can expand their educational program opportunities and reach out to a larger audience. There is also a wealth of expertise available that can be tapped for a variety of needs.

Public Health

Louisiana Department of Health (LDH) is the lead agency for tracking diseases of public health importance. Mosquito-borne diseases fall into this category. Because of this, mosquito control agencies can expect to work cooperatively with LDHH on a regular basis. The extent to which the agencies will work together may range from strictly receiving advisories, to working hand in hand to stop an ongoing outbreak. Recent outbreaks in 1999 and 2001 serve as examples of the extent of these interactions.

In 1999, Louisiana experienced one of the worst outbreaks of Eastern equine encephalitis (EEE) on record. The outbreak began in the south-central region of the state and then slowly spread throughout. Close to 100 horse cases and three human cases were reported. LDH personnel tracked the outbreak and maintained close contact with mosquito control agencies and the news media. But because the outbreak was widespread and random

in nature, a focal working point for investigative work was difficult. Toward the latter stage of the outbreak, federal Centers for Disease Control (CDC) personnel were requested for looking into the outbreak. Unfortunately, little valuable information was obtained.

The St. Louis encephalitis (SLE) outbreak in northeast Louisiana in 2001 was quite different. Over 70 human cases were reported in a relatively small region over approximately a four-month period. At the beginning, LDH personnel were once again involved in tracking the disease and advising the general public. However, once it was determined that the outbreak was progressing and not subsiding as expected, LDH personnel became more involved and the CDC was contacted. This resulted in LDH and CDC personnel working directly with the mosquito control efforts in all aspects of inspection and control, as well as sampling for viral activity. Valuable information was gathered and may be helpful in preventing future outbreaks.

Public health will always be an important issue for mosquito control agencies. All efforts should be made to ensure ongoing communications and relations with LDH.

Hazardous Materials

There are many products in the day-to-day operations of mosquito control that are regulated for their storage and disposal, including pesticides, oils, fuels, and cleaning solvents. These products must be properly stored and, when considered a waste, properly disposed. Two agencies that will interact with operators on these issues are the Louisiana Department of Environmental Quality (LDEQ) and the Louisiana State Police.

Mosquito control operators should generate little, if any hazardous waste products. In fact, most waste that will be generated is either non-hazardous or recyclable. Unfortunately, there are instances when hazardous wastes are generated, requiring proper storage and disposal. Because of this, many mosquito control operations maintain a LDEQ waste generation number, allowing them to properly store and dispose of any waste they may generate. Most will be classified as small quantity generators, due the small amount of waste accumulated throughout the year. It is important to size-up your operation and determine whether it is necessary to obtain this type of a permit.

Storage of the various materials listed above, also requires mosquito control operators to submit Tier II forms to the Louisiana State Police. The Tier II form is part of the Right to Know Law, which establishes a database of stored hazardous materials throughout communities. Copies of the Tier II forms also go to local fire departments and Governors Office of Homeland Security Emergency Preparedness (GOSHEP). This information is required to be updated annually for further use by emergency response personnel and by parishes for planning purposes. Visit that website: www.gohsep.la.gov.

Local Government

There are many departments within local government with which mosquito control managers should become familiar. Public works, gravity drainage, planning, and sewage are just a few entities whose daily operations often effect the potential for an area to produce mosquitoes. Mosquito control managers should confer with these entities to better plan the prevention or subsequent elimination of mosquito breeding sites. Examples of some relevant projects include roadside ditch construction and maintenance, catch basin design, sewage effluent management, and new housing development. Through regular consultation and input, mosquito control managers can play a major role in minimizing the impact these projects have on mosquito production.

Emergency Management

When a disaster strikes or an extraordinary event occurs, the affected area may be declared a disaster area. That's when the Federal Emergency Management Agency (FEMA) guidelines become important to mosquito control agencies. FEMA documentation may vary depending on the disaster or event as to how agencies can be reimbursed for services rendered during the disaster. In our state, we coordinate and communicate with FEMA through the Louisiana Office of Emergency Preparedness (LOEP) Disaster Recovery Division. They are responsible for ensuring reporting systems are in place as set by FEMA with local districts providing services if a disaster occurs. The LOEP has command and control authority to task state and local agencies during emergency situations. Mosquito control personnel must therefore communicate their role to the LOEP so that when a disaster strikes a smooth, coordinated transition for services will be made. Contact the LOEP at www.LOEP.state.la.us.

Industry

Sometimes we can forge a unique mix that benefits all parties involved. Such is the case when mosquito professionals interact with industry representatives to conduct practical field tests. This collaborative effort can assist in ensuring the effectiveness of a product currently being used in the control of mosquitoes. Furthermore, as new products are developed collaborative efforts of this type give manufacturers real-time, real-world tests of their products.

Field tests have been conducted by mosquito control agencies to augment the work previously done by industry. Cooperatively, previous tests were done on insecticide efficacy, environmental impact, and technology for application equipment. Many districts have been instrumental over the years in providing assistance to industry for these types of field tests.

Chapter 16

TECHNOLOGY

The use of technology in the surveillance and control of mosquito populations continues to develop and evolve. Computers, tablets, and smart phones are being used to input and access a variety of data. This information can be shared or displayed geographically, in spreadsheets, and in reports. The development of database management systems has led to real-time data collections and communications.

Database Management Systems

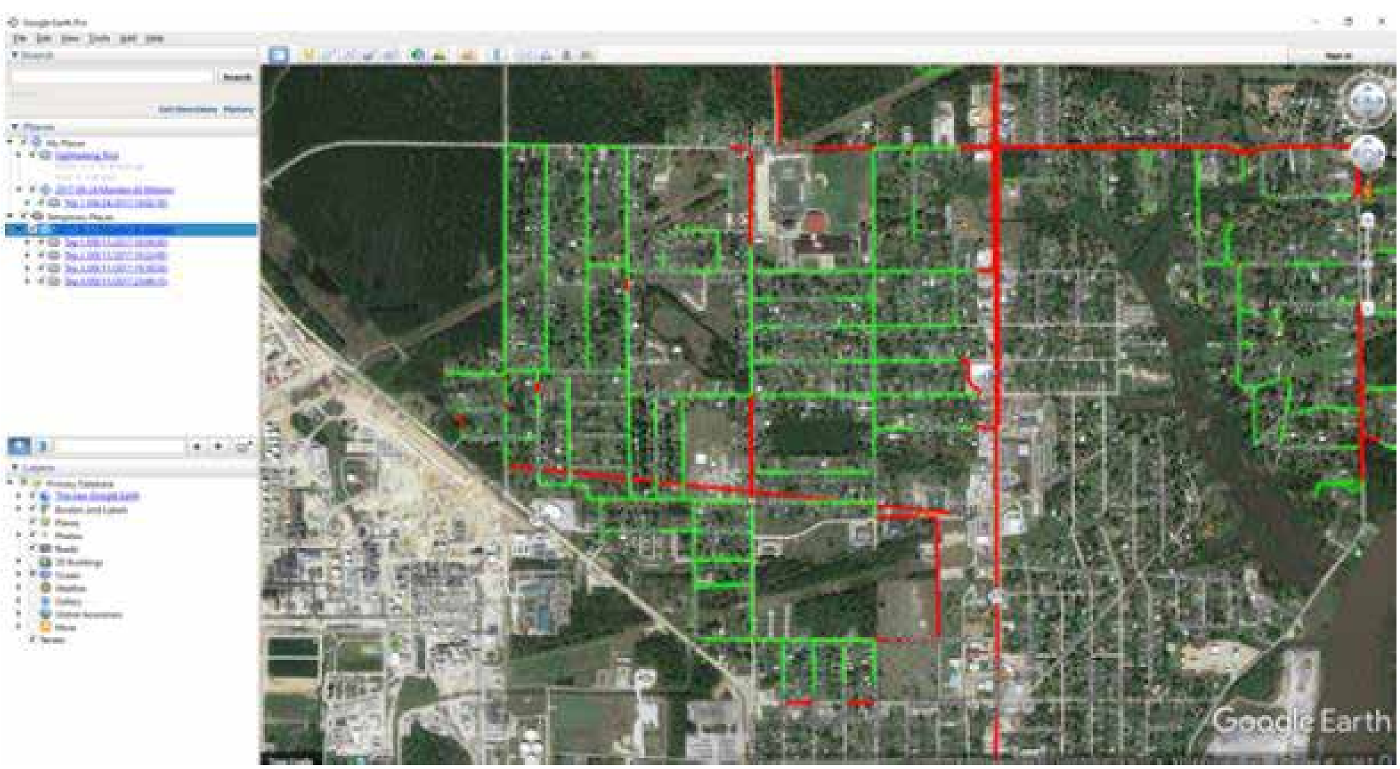
A database management system is software designed to manage data in a database. These systems can be developed in house or purchased from a vendor. In mosquito control these systems are specifically developed with mosquito control activities in mind. Data, such as landing rate counts, breeding sites, and homeowner complaints, can be compiled and geographically displayed on a map. Most databases are centralized and can be viewed by multiple users. The records kept by the district provides current and historical data. They help the districts develop strategies on which areas may need control activities.

Ground Application Equipment

The use of ground application systems to track spray applications is a valuable tool. Most organized mosquito districts have some form of tracking to ensure drivers are making efficient and proper spray applications. These systems record all aspects of the spray mission (speed, application rate, switch on/off, and control the spray). Once the driver returns from the night's spray mission, data is uploaded either physically or electronically. The information from the mission can then be used to generate reports. Remember that all spray applications are reportable to the Louisiana Department of Agriculture.

Aerial Application Equipment

Similar to ground equipment, aerial spray application technology has become the standard. The use of aerial spray system, weather probe, and drift technology has enhanced the ability of aerial applicators to hit their targeted area. Unlike crop dusting, mosquito spray is released at a height that requires proper offset. While in the air the computer determines the wind direction and speed to establish the proper offset to spray. The pilot

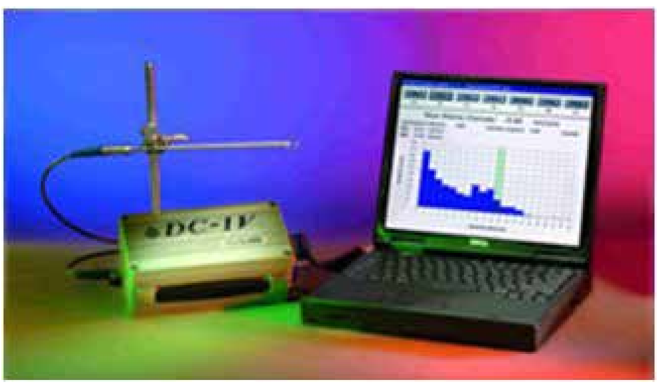


then can spray the block knowing the spray will drift into the targeted spray block. These systems usually have some way of displaying obstructions, such as radio towers, providing an additional level of safety.

Typically, after deciding where an application is to occur, office personnel draw spray blocks utilizing specific software. These spray blocks are then uploaded into the aircraft computer for the night's spray mission. The application rate and acres treated determine the amount of spray chemical needed. Once back on the ground the spray mission data can be downloaded. Reports and maps of the application can be saved electronically or printed.

Calibration Equipment

Districts may employ droplet measurement technology in their equipment calibrations. The label on all ground and aerial adulticides require a specific droplet size range. Spray equipment must be adjusted to make sure it complies with the label requirements. Technology exists to aid in the quick assessment of a spray cloud.



UAV (Unmanned Aerial Vehicle)

Unmanned aircraft system, or drone, technology has been rapidly evolving for the last few years, both in the commercial and recreational arenas. Companies have designed many uses for UAVs that include: mapping, surveying, inspection, agriculture, rescue, healthcare, sales (real estate property asset aerial photography), autonomous transportation, and delivery of goods. The drone industry has grown rapidly, and companies that setup, train, and repair drones as the primary business have become more common. Infrared and other types of photography technology are also in use.

There are many possible applications for drone use in the future of mosquito control. Direct uses in this industry are just beginning to be seen. Methods include liquid and pellet larvicide application to areas that are difficult or impossible to reach by vehicle or boat and high definition camera surveillance for identifying locations where larvae may exist, prior to pesticide application.

The FAA now requires all commercial drone pilots to be licensed. There are three ways to fly a UAS for work, business, or non-recreational reasons:

- Following the requirements in the Small UAS rule (Part 107).
- Following the rules in your Section 333 grant of exemption.
- Obtain an airworthiness certificate for the aircraft.

Drone

Social Media / Internet

Districts, vendors, and contractors are using the internet to share and inform everyone about mosquitoes and their control efforts. The use of websites by districts provide citizens with a range of information and what they can do to help. Vendor websites provide information on labels, safety data sheets, spray equipment, products, and contacts.

Social media, which includes Facebook, Twitter, YouTube, and other sites, continues to grow, with more people staying connected. It's a good idea to appoint or hire personnel in the district or office to be responsible for periodically providing updated information.

ANSWERS TO CHAPTER QUESTIONS

Chapter	Answers
1 – Basic Insect Biology	**d, a, c, d, b**
2 – General Structure and Life Cycle of Mosquitoes	**d, b, a, c, b**
3 – Bionomics and Recognition of Important Species	**a, b, c, b, d, b, a, b, a, c**
4 – Mosquito Habitat Recognition	**b, d**
5 – Mosquitoes and Human Disease	**b, d, c, d, a**
6 – Organization and Principals of Mosquito Control	**a, d, b, c, b**
7 – Mosquito Sampling and Surveillance	**b, c, d, a, b**
8 – Mosquito-borne Virus Surveillance	**d, b, a, c, d, b**
9 – Physical Control of Mosquitoes	**c, b, d, b, b**
10 – Biological Control of Mosquitoes	**a, b, b, c, d**
11 – Larval Mosquito Control	**b, d, b, d, b**
12 – Adult Mosquito Control	**b, c, c, a, a**
13 – Laws Affecting Pesticides in Louisiana	**d, a, a, b, b**

A

- **Abiotic:** Not biological; characterized by the absence of life.
- **Adult**: The mature stage of a mosquito's life.
- **Adulticide:** An insecticide that targets control of the adult life stage of an insect.
- **Aerobic:** Requires oxygen to live, living or active only in the presence of oxygen; usually in reference to bacteria.
- **Aggregation:** A collection; group.
- **Agrichemicals:** Chemicals used for agricultural use; e.g., herbicides, pesticides, fertilizers.
- **Amplify:** To increase or intensify.
- **Amplifying hosts:** In mosquito-borne disease ecology, the vertebrate hosts which are fed on by infected mosquitoes, become infected and serve as a source of the disease agent for other mosquitoes; generally, these hosts are not affected by the infection.
- **Arbovirus:** A combination of the words arthropod and borne; any of a group of RNA viruses, including those that cause Yellow fever, dengue, Eastern equine encephalitis, St. Louis encephalitis and West Nile virus, which are transmitted to animals and man by mosquitoes, biting flies and ticks.
- **Arthropod:** As used by mosquito control to denote insects of public health or nuisance importance, including all mosquitoes, midges, sand flies, dog flies, yellow flies, and house flies.
- **Atomization:** The process of producing minute or very small droplets.
- **Avirulent:** The form of a pathogenic organism (e.g., virus, bacteria) that is not highly infectious or does not cause disease; no longer virulent.

B

- **Berm:** A wall or mound of earth; a ledge or shoulder, as along the edge of a road.
- **Biocontrol:** Suppression of undesirable animals or plants by the introduction of or manipulated enhancement of a pests' natural enemies.
- **Bionomics:** Of or relating to ecology or biology of an organism.
- **Biorational products:** Products derived from nature.
- **BGS trap:** A surveillance tool that is commonly used for collecting container Aedes species.
- **Botanical:** Of or related to plants.
- **Brackish:** Somewhat salty, containing a mixture of seawater and fresh water.
- **Bromeliad:** A member of the pineapple family of plants, usually having stiff, leathery leaves and spikes of bright flowers, often grown under shade trees; "tank" bromeliads such as tillandsia, billbergia and neoregelia hold water and can produce mosquitoes.
- **Brood:** A large group of mosquitoes that hatch or emerge at the same time; sometimes referred to as a generation of mosquitoes.
- **Bs – (*Bacillus sphaericus*):** A naturally occurring soil bacterium that infects and kills mosquito larvae, microbial insecticide that is commercially available.
- **Bti – (*Bacillus thuringienis israelensis*):** A naturally occurring soil bacterium that controls mosquito larvae; microbial insecticide that is commercially available, which is highly selective, controlling the larval stage of mosquitoes and black flies.

C

- **Canopy:** The portion of a tree above the trunk, usually the leafy area, that forms a cover above open space between the ground and tree branches.
- **Cattail:** Tall, slender leaved emergent plant from the genus Typha, often found clogging ditches and retention areas; often associated with *Coquillettidia perturbans* mosquito larvae.
- **CDC Light Trap:** A surveillance tool that was developed by the U.S. Centers for Disease Control to provide a reliable and portable sampling device for the collection of mosquitoes and sand flies used in arbovirus studies, taxonomic studies and population density surveys; mosquitoes are attracted to a light and carbon dioxide bait then held in a collection net or jar.
- **Chikungunya:** An arbovirus that can be transmitted by *Aedes aegypti.*
- **Coagulation:** Process of becoming solid, as in the clotting of blood.
- **Copepod:** A minute aquatic invertebrate abundant in both fresh and saltwater that preys upon mosquito larvae.

- **Culvert:** A conduit, especially a drain, as a pipeline construction of stone, concrete or metal that passes under a road or through an embankment or dike.

D

- **Dead-end host:** In the ecology of disease organisms, those infected hosts from which the organism cannot be transmitted to another host in the normal manner; e.g., the mosquito cannot pick up the virus from the blood: a human may become infected with EEE but becomes a dead-end host as a mosquito cannot pick up the virus from a human and transmit it to another organism.
- **Deer fly:** A biting fly of the family Tabanidae, genus Chrysops that is triangular in shape and about one-half inch long; related to but smaller than horse flies.
- **DEET (N,N-diethyl-m-toluamide):** A commonly used type of insect repellent.
- **Dengue:** Also known as "breakbone fever"; an acute viral infection characterized by headache, severe joint pain and a rash.
- **Detritus:** Any accumulation of disintegrated material or debris; in biology, the breakdown of organic materials.
- **Diapauses:** A period of spontaneous dormancy between periods of activity; typically caused by environmental conditions.
- **Diptera:** The order of insects that includes flies, gnats, and mosquitoes.
- **District:** Any mosquito control program for the purpose of controlling arthropods within boundaries of said district.
- **DNA:** Abbreviation for deoxyribonucleic acid, a protein associated with the transmission of double stranded genetic information found in cell nuclei and especially in the genes.
- **Dog heartworm:** A very common, parasitic worm (*Dirofilaria immitis*); disease of canines and to a lesser extent cats that can be debilitating, even fatal; transmitted by a large number of mosquito species.
- **Dormant:** Having biological activity suspended; as being in a state of suspended animation; similar to diapauses.

E

- **Eastern encephalitis:** Also known as Eastern equine encephalitis or EEE. A viral disease of humans and horses associated with *Culiseta melanura* and transmitted to mammals by Aedes, Coquillettidia, and other mosquitoes.
- **Efficacy:** Effectiveness.
- **Emergent plants:** Aquatic plants that are rooted in the soil with the leaves extending above the water surface; examples: arrowhead, water lily, American lotus, smartweed, cattail.
- **Encephalitic:** Of or near the brain.
- **Encephalitis:** Inflammation of the brain or brain stem.
- **Encephalomyelitis:** Inflammation of the brain and spinal cord.
- **Endemic:** A disease constantly present in a particular region; native to a particular country, nation, or region, said of plants, animals and customs.
- **Entomology:** The scientific study of insects.
- **Epidemic:** An outbreak of disease affecting many individuals at once; a sudden rapid spread, growth or development of an insect population; according to the U.S. Department of Health definition, an outbreak of disease affecting one individual above the norm.
- **Epidemiology:** The study of the causes and control of disease, all the elements contributing to the occurrence or non-occurrence of a disease in a population; ecology of disease.
- **Epizootic:** A disease prevalent and spreading rapidly among many individuals of animals in a community at the same time.
- **Estuarine:** Related to an estuary.
- **Estuary:** An inlet or arm of the sea; especially the lower portion or wide mouth of a river where the salty tide meets the freshwater current; the part of the wide lower course of a river where its current is met by the tides.
- **Exotic:** Not native to the place where found, see endemic.
- **Exponential:** Increasing in extraordinary proportions because of greatly increased population.

F

- **Fauna:** The animals occurring, developed or adapted or living in a specified environment, as distinguished from flora.
- **Febrile:** Of or characterized by a fever; feverish.
- **Flora:** Plant life characteristic to a particular area, as distinguished from fauna.
- **Flushing:** Rinsing.
- **Focus or foci:** Any center of activity, such as a disease or mosquito breeding.

G

- **Gambusia:** A genus of fish in family Poeciliidae (order Cyprinodontiformes); principally found in freshwater habitats, though some species may also be found in brackish or saltwater habitats; also known as mosquitofish, which refers more specifically to one species, G. affinis.
- **Hammock:** A fertile area in the southern United States that often is somewhat higher than its surroundings and is characterized by hardwood vegetation.
- **Hay infusion:** The highly odorous protein-rich water that results from soaking hay or grass in water for several days or weeks; on a large scale, in wet yards or fields this is very attractive for egg laying and mosquito development.

H

- **High marsh:** Salt marsh which is not inundated by daily tides and hence can serve as a mosquito breeding site, as distinguished from low marsh.

I

- **Imported malaria:** Malaria acquired outside of the United States; airport malaria is malaria acquired near an airport due to infected travelers or infected mosquitoes that comes from a malarial area.
- **Impoundment:** Method of controlling salt marsh mosquitoes by creating a berm around a high salt marsh and flooding it during mosquito breeding season, achieving control by depriving salt marsh mosquitoes of suitable egg-laying habitat.
- **Induced malaria:** Malaria acquired through artificial means, such as a blood transfusion or common syringes.
- **Infection rate:** The percent of a group of organisms including humans that become infected with a microorganism when exposed to a specific concentration of the microorganism; often dose related.
- **Instar:** The four phases of a mosquito larva.
- **Integrated pest management:** Also known as IPM, a pest control strategy that uses an array of complementary methods: mechanical devices, physical devices, genetic, biological, legal, cultural management, and chemical management; the opposite of set calendar spraying.
- **Intermediate host:** In parasitology, a host in which a parasite develops to some extent but not to sexual maturity.
- **Invertebrate**: An organism that does not have a spinal column.
- **Irrigation:** The artificial watering of land by canals, ditches, pipes, or flooding to supply moisture for plant growth.

L

- **La Crosse virus:** A mosquito-transmitted arbovirus that belongs in a group of mosquito-borne viruses called the California group; that causes encephalitis in humans and is transmitted primarily by the tree hole breeding mosquito *Aedes triseriatus,* common in the midwestern United States.
- **Landing rate count:** A surveillance method for determining the density of a local mosquito population; an individual record of the number of mosquitoes that land on the observer over a designated period of time.
- **Larva(e):** For mosquitoes, the feeding aquatic state of the mosquito, commonly referred to as a wiggler or wriggler due to the lashing movement of the body sideways in the water.
- **Larvicide:** Is an insecticide that is specifically targeted against the larval life stage of an insect or a chemical or biological product targeting the control of the aquatic life stage of an insect.
- **Latent:** Dormant but capable of normal development under correct conditions; present but invisible or inactive; lying hidden and undeveloped with a person or thing.
- **Levee:** An embankment, often of soil, built alongside a river or field to prevent flooding or to contain water.
- **Low marsh:** Salt marsh that is inundated by daily tides, as distinguished from high marsh.
- **Lunar tides:** Tides associated with the movement of the moon.

M

- **Maintenance host:** Those host species essential for keeping a microorganism present in an area especially when the organism is at low levels; can also include hosts that harbor the organism during non-transmission phases, such as winter.
- **Malaise:** A vague feeling of physical discomfort or uneasiness; as early in an illness.
- **Malaria:** An infectious disease, generally intermittent and recurrent, cause by any of

four protozoan of the genus Plasmodium that are parasitic in the red blood corpuscles and are transmitted to humans by Anopheles mosquitoes and to birds and other mammals by a variety of mosquito genera.

- **Malathion:** An adulticide material.
- **Metabolic:** Relating to the chemical changes in living cells by which energy is provided for vital life processes.
- **Metamorphosis:** The transition between the four stages of a mosquito's life; consisting of egg, larva, pupa, and adult.
- **Methoprene:** A larvicide material.
- **Micron:** A unit of length equal to one thousandth of a millimeter.
- **Microweather:** Weather that occurs on a very local basis, such as a neighborhood or block.
- **Midge:** Also known as "blind" mosquitoes because they look like mosquitoes but do not bite; non-biting midge flies or chironomids commonly occur in inland and coastal natural and manmade bodies of water.
- **Molt:** The shedding of the exoskeleton when a mosquito larva goes through the four phases of the larval stage of a mosquito's life cycle.
- **Monomolecular film:** A larvicide material.
- **Morbidity:** The rate of sickness in a specific community or group.
- **Morphological:** Structural, relating to a body part.
- **Mosquito fish:** Commonly used for fish of the genus Gambusia but not limited entirely to them; more rarely, any fish that eats mosquito larvae.
- **Mortality rate:** The proportion of deaths in a specific population.
- **Mosquito:** Two-winged flies that belong to the family Culicidae in the order Diptera; there are over 3,500 species of mosquitoes.
- **Myalgia:** A pain in one or more muscles.

N

- **Naled:** An adulticide material; also known by trade name Dibrom.
- **Neap tides:** During the quarter moons, the sun partially cancels lunar pull, producing smaller tidal ranges.
- **Nematode:** Microscopic worms which often are parasites of man, animals, plants, and insects.
- **Niche:** Microhabitat; site supplying the necessary physical and biological conditions necessary for the life of an organism.

O

- **Octenol:** 1-octen-3-ol, a volatile compound that has been isolated from ox breath and is synthesized for use as an attractant in traps for tsetse flies and mosquitoes.
- **Oil of lemon eucalyptus (p-menthane 3,8-diol (PMD):** Insect repellent, an essential oil.

P

- **Picaridin:** (KBR 3023) Insect repellent; sometimes known as "Bayrepel" outside the U.S.
- **Parasites:** Organisms that obtain nutritional requirements from another host organism but usually does not kill the host organism.
- **Passerine:** Largest order of birds, consisting chiefly of perching songbirds, including fly catchers, larks, swallows, crows, jays, chickadees, nuthatches, wrens, mockingbirds, thrashers, thrushes, gnatcatchers, waxwings, shrikes, starlings, vireos, tanagers, warblers, blackbirds, orioles, finches and sparrows.
- **Pathogen:** A specific cause of a disease including bacteria, protozoa, the fungi or virus.
- **Permethrin:** An adulticide material and can be used as a repellent.
- **Pest:** Living organisms that are found where they are not wanted or that cause damage to crops or humans or other plants and animals.
- **Pesticide:** Any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest.
- **pH:** A measure used to express the acidity and alkalinity on a scale of 0 to 14 with 7 representing neutrality, values below 7 indicating acidity and values over 7 expressing alkalinity.
- **Pneumatophores:** A submerged or exposed root that functions as a respiratory organ of a swamp or marsh plant like the black mangrove; erect roots that are some form of upward appendage or extension of the underground root system.
- **Predaceous:** Preying on other animals.
- **Proboscis:** The mouthpart of the mosquito.
- **Prop-roots:** The exposed, upright roots of the red mangrove, which appear to prop up the plant.
- **Protozoa:** A general term referring to all single-cell organisms, excluding bacteria, rickettsia, and viruses, some of which are

parasites on mosquitoes and other serious parasites of man.

- **Pupa(e):** The non-feeding aquatic stage of mosquitoes shaped like a comma; the stage in mosquito metamorphosis between larva and adult.
- **Pyrethrum:** A plant product derived from some chrysanthemums and used as an insecticide.

R

- **Raft:** A floating, cohesive mass of mosquito eggs.
- **Rafting:** The tendency of larvae to congregate in very thick masses; also known as balling.
- **Repellent:** A substance used to repel insects.
- **Reservoir host:** The animal species in which a pathogen is maintained during periods when transmission is low or absent.
- **RNA:** Abbreviation for ribonucleic acid; similar in design to DNA but is a single strand; central to the synthesis of proteins associated with the control of cellular chemical activities and is important in the genetic makeup of many viruses.

S

- **Saline:** Consisting of or containing salt.
- **Salt marsh:** Flat land subject to flooding by saltwater.
- **Sentinel:** Something that keeps watch, as in sentinel chickens used to monitor for the presence of St. Louis encephalitis, EEE, and or West Nile virus.
- **St. Louis encephalitis (SLE):** A disease caused by the mosquito-borne virus affecting humans, transmitted by Culex mosquitoes in North America and amplified in wild birds .
- **Source reduction:** Elimination of mosquito-producing sites, physical land, or water management of arthropod breeding areas to reduce the area's suitability for mosquito breeding.
- **Spring tides:** During the new and full moons, the sun and moon combine to produce extra high tidal ranges.
- **Systemic:** Absorbed into and effective throughout the body of an organism.

T

- **Temephos:** A larvicide material; also known as trade name Abate.
- **Temperature inversion:** When the temperature increases rather than decreases with increasing height, which can greatly affect adulticiding applications or operations.
- **Tidal creek:** A creek in a salt marsh or mangrove forest formed and maintained by the natural drainage of tidal waters during ebb tide.
- **Tides:** Cyclic rising and falling of Earth's ocean surface caused by the tidal forces of the moon and the sun acting on the oceans.
- **Topography:** Physical and natural features of an area, especially elevation.
- **Transmission rate:** The rate at which a pathogen is transmitted from an infected host to an uninfected host.
- **Transovarial transmission:** Passed from mother to offspring through the ovary.
- **Truck trap:** A mosquito surveillance device; vehicle mounted funneling device that collects flying insects into a collection bag and used to determine mosquito densities; a truck with a conical trap which, when driven slowly on trapping route, collects adult mosquitoes to aid in identifying mosquito species, densities and locations. One of the many surveillance tools used to identify pest mosquito population.
- **Turbidity:** Muddiness, cloudiness, or haziness of a fluid caused by individual particles, such as suspended solids that are invisible to the naked eye.

U

- **ULV:** Abbreviation for ultra-low-volume cold aerosol technique, an insecticide application technique in which a sprayer produces a cloud of minute, micron range particles through a shearing action at the sprayer nozzle.
- **UV:** Abbreviation for ultraviolet, a solar radiation having a wavelength shorter than that of visible and longer than that of X-rays.

V

- **Vector:** An organism capable of transmitting a pathogen from one host to another either mechanically or biologically.

- **Vector potential:** A qualitative measurement of the likelihood that a particular organism can transmit a particular pathogen.
- **Vertebrate:** An organism which has a spinal column.
- **Viremia:** Presence of virus in the blood.
- **Viremic:** Having a virus in the blood.
- **Virulent:** A highly infectious microorganism able to overcome the natural defenses of the host; marked by a rapid, severe, and destructive course.

W

- **Water hyacinth:** *Eichhornia crassipes*, a widespread, invasive, exotic floating plant that grows in large mats; associated with Mansonia mosquito larvae.
- **Water lettuce:** Pistia stratiotes, a floating plant that resembles a floating open head of lettuce, it grows in large mats; associated with Mansonia mosquito larvae.
- **Western equine encephalitis:** Also known as WEE, a mosquito-borne viral disease of humans and horses; typically found west of the Mississippi River; transmitted by mosquitoes of the genus Culex and Culiseta.
- **West Nile virus:** Also known as WNV, a mosquito-borne disease that is caused by a virus transmitted by Culex mosquitoes; encephalitis in humans and horses, as well as mortality in certain domestic and wild birds and animals.

Z

- **Zika virus:** A mosquito-borne arbovirus transmitted by *Aedes aegypti.*

TABLE 1. Common conversions used in pesticide applications

Multiply	By	To get
Acres	43,560	Square feet
Acres	4,840	Square yards
Acres	0.405	Hectares
Bushels	64	Pints
Bushels	32	Quarts
Cubic feet	1,728	Cubic inches
Cubic feet	0.037	Cubic yards
Cubic feet	7,481	Gallons
Cubic feet	59.84	Pints (liquid)
Cubic feet	29.92	Quarts (liq)
Cups	8	Ounces (liq)
Cups	16	Tablespoons
Feet	30.48	Centimeters
Feet	12	Inches
Feet	0.305	Meters
Feet	0.333 or 1/3	Yards
Gallons	3.785	Liters
Meters	100	Centimeters
Meters	3.281	feet
Meters	39.37	Inches
Meters	0.001	Kilometers
Meters	1,000	Millimeters
Meters	1.094	Yards
Miles	5,280	Feet
Miles	1,760	Yards
Miles per hour	88	Feet per min
Miles per hour	1,467	Feet per sec
Miles per minute	88	Feet per sec
Miles per minute	60	Miles per hr
Ounces (dry)	28.35	grams
Ounces (dry)	0.063	pounds
Ounces (liquid)	0.063	Pints (liq)
(‘C) + 17.98	1.8	Temperature (F)
Ounces (liquid)	0.031	Quarts (liq)
Parts per million	0.001	Grams/liter
(‘F) -32	0.555	Temperature (‘C)
Pecks	16	Pints (dry)
Pecks	8	Quarts (dry)
Pints	0.125	Gallons
Pints	0.473	Liters
Pints	2	cups
Pints (liquid)	16	Ounces (liq)

Multiply	By	To get
Gallons	128	Ounces (liq)
Gallons	8	Pints (liq)
Gallons	4	Quarts (liq)
Gallons, H2O	8.345	Pounds of h20
Grams	0.001	kilograms
Grams	1,000	milligrams
Grams	0.035	ounces
Grams per liter	1,000	Parts per million
Hectares	247	acres
Inches	2.54	centimeters
Kilograms	1,000	grams
Kilograms	2.205	pounds
Kilometers	3,281	feet
Kilometers	0.621	miles
Liters	.264	gallons
Liters	2.113	Pints (liq)
Liters	1.057	Quarts (liq)
Pints (liquid)	.5	Quarts (liq)
Pounds	453.592	grams
Pounds	16	ounces
Pounds	0.0005	tons
Quarts	2	pints
Quarts	0.25	gallons
Quarts	0.946	liters
Quarts (liquid)	32	Ounces (liq)
Quarts (liquid)	2	Pints (liq)
Rods	16.5	feet
Square miles	640	acres
Square yards	9	Square feet
Square yards	1,296	Square inches
Tablespoons	3	teaspoons
Temperature (‘C) + 17.98	1.8	Temperature (F)
Temperature (‘F) -32	0.555	Temperature (‘C)
Tons	907.185	Kilograms
Tons	2,000	Pounds
Yards	3	Feet
Yards	36	Inches
Yards	0.914	Meters

Table 2. Mosquito species known from Louisiana, their distribution, importance, and breeding habitat. Distribution: U = Urban, S = Suburban, R = Rural

Taxonomic Group	Distribution in Louisiana	Medical Importance	Pest Importance	Larval Habitat
Genus *Anopheles*				
An. atropos	Common in southern parishes, but not in swarms	WNV	Will bite, but is not typically abundant	Salt/Brackish water
An. barberi	Found across whole state, uncommon	WNV	None	Tree holes/artificial containers
An. bradleyi	Common in southern parishes	WNV	Moderate	Coastal salt/brackish water
An. crucians	Across entire state (R)	WNV	Pest in cloudy, dark or crepuscular conditions	Clean, shaded fresh water, ideally with vegetation
An. georgianus	Very rare; in southern parishes	None	None	Clean water seeping from hillsides
An. perplexens	Extremely rare	None	None	Springs and streams
An. pseudopunctipennis	Extremely rare	Major malaria vector in more tropical regions	None	Clear sunlit pools and margins of slow-moving streams
An. punctipennis	Across entire state (R, S)	May vector dog heartworm	Moderate	Clean, fresh water, also in large containers
An. quadrimaculatus	Across entire state (R, S)	Historically important malaria vector, WNV	Major biting pest, at dusk and early evening	Clean water with aquatic vegetation, can adapt to artificial containers or polluted water
An. walkeri	Commonest in southern parishes just above the freshwater line	None	Too rare	Freshwater marshes and pools with emergent vegetation
Genus *Aedes*				
Ae. cinereus	Rare, known from southern parishes	None	Too rare	Pools and ditches in wooded areas
Ae. vexans	Across entire state	Dog heartworm, WNV	Severe biting pest when populations are large	Temporary and semi-permanent pools in wooded or open areas
Ae. japonicus	Newly introduced to U.S., not yet known from Louisiana	WNV	Competent vector of WNV, JE	Natural and artificial containers in shaded areas. Prefer water rich in organic matter.
Ae. aegypti	Found in some urban areas (U)	Dengue, Yellow Fever, WNV	Bites at lower extremities when populations are large	Shaded artificial containers
Ae. albopictus	Abundant in urban areas (U)	EEE, SLE, LAC, dengue, WNV	Major biting pest	Artificial containers, old tires
Ae. atlanticus	Across entire state (S, R)	WNV	Can be a pest to homes near wooded areas	Fresh, semipermanent pools in wooded areas, also overgrown ditches in towns
Ae. canadensis canadensis	Widespread (S, R)	WNV, dog heartworm	Can be a pest to homes near wooded areas	Shallow freshwater puddles, temporary pools in wooded areas
Ae. canadensis mathesoni	Widespread (S, R)	WNV	Can be a pest to homes near wooded areas	Shallow freshwater puddles, temporary pools in wooded areas

Taxonomic Group	Distribution in Louisiana	Medical Importance	Pest Importance	Larval Habitat
Ae. dorsalis	Rare	WNV	Too rare	Both salt and freshwater habitats in other states
Ae. dupreei	Across entire state (S, R)	WNV	Too rare	Semi-permanent pools in wooded areas
Ae. epactius	Extremely rare	none	Too rare	Containers, rock holes and tree holes
Ae. fulvus pallens	Widespread, known from most parishes (S, R)	WNV	Vicious biter, but not abundant	Fresh, semipermanent pools in wooded areas
Ae. grossbeck	Widespread (S, R)	WNV	Vicious biter, but not abundant	Fresh, semipermanent pools in wooded areas
Ae. infirmatus	Across entire state (S, R)	WNV	Can be a pest to homes near wooded areas	Fresh, semipermanent pools in wooded areas
Genus *Aedes*				
Ae. mitchellae	Widespread, known from many parishes	None	Mild, not abundant	Fresh, shallow pools in open areas
Ae. nigromaculis	Extremely rare	WNV	Too rare	Open freshwater areas in other states
Ae. sollicitans	Widespread, known from most parishes	WNV	Major pest in coastal parishes	Saltwater marshes, rarely in freshwater pools
Ae. sticticus	Widespread, known from many parishes (S, R)	WNV	Severe biting pest in wooded areas	Rainwater flooded ditches and pools in wooded areas
Ae. taeniorhynchus	Known from parishes adjacent to salt marsh *(S, R)*	WNV	Vicious biting pest, particularly in shaded areas. Readily flies long distances.	Salt marshes flooded by tide or rain
Ae. thibaulti	Across entire state (R)	None	Too rare	Water pooled in hollow trees and stumps
Ae. tormentor	Southeastern parishes above L. Pontchartrain, and Southwestern parishes (S, R)	None	Vicious biting pest in wooded areas	Rainwater flooded ditches and pools in wooded areas
Ae. trivittatus	Rare, known from a few scattered parishes (R)	WNV	Too rare	Semi-permanent freshwater pools and ditches in wooded areas, swamps, and fields
Ae. hendersoni	Extremely rare, known from a single parish (R)	None	Too rare	Tree holes in wooded areas
Ae. triseriatus	Across entire state (S, R)	LAC	Biting pest in its breeding areas	Tree holes and artificial containers
Ae. zoosophus	Extremely rare	None	Too rare	Tree holes in adjacent states
Genus *Culex*				
Cx. coronator	New record in state	WNV	Too rare	Temporary rain-filled pools and artificial containers in Texas
Cx. declarator	New record in state		Too rare	Rock pools, swamps, tree holes in the tropics
Cx. nigripalpus	Uncommon, found in southern and central parishes (R)	WNV, SLE	Too rare	Semi-permanent freshwater pools, usually in wooded areas
Cx. quinquefasciatus	Across entire state (U, S, R)	WNV, SLE	Moderate	Highly polluted water, such as sewers and ditches
Cx. restuans	Across entire state (S, R)	WNV, SLE	Seasonally abundant, not a major biter	Freshwater pools, ponds and ditches

Taxonomic Group	Distribution in Louisiana	Medical Importance	Pest Importance	Larval Habitat
Cx. salinarius	Across entire state (S, R)	WNV, SLE, EEE	Severe biting pest	Saline, brackish and freshwater pools. Will use artificial containers if other water is absent.
Cx. tarsalis	Across entire state (R)	WNV, SLE, WEE	Too rare	Freshwater semi-permanent pools, ponds and ditches
Cx. erraticus	Across entire state (R)	WNV	Will bite, usually not abundant near human residences	Freshwater swamps, ponds and permanent pools with vegetation
Cx. peccator	Widespread, known from most parishes (R)	None	None	May breed in semi-permanent to permanent freshwater pools. Most common in hollow bases of trees in wooded swamps
Cx. pilosus	Uncommon, known from a few southeastern parishes (R)	None	None	Freshwater ponds, pools and ditches
Cx. territans	Across entire state (S, R)	WNV	Abundant, but doesn't feed on humans	Freshwater semi-permanent to permanent pools in wooded areas. Also found in open and wooded swamps and artificial containers.
Genus *Culiseta*				
Cs. inornata	Across entire state (U, S, R)	WNV, EEE	Biting pest when populations are large	Will utilize almost any breeding habitat, but prefers salt marshes, and wooded freshwater ponds and pools
Cs. melanura (Coquillett)	Known from several scattered parishes, probably exists in many others (S, R)	WNV, EEE	Too rare	Bases of trees and hollow stumps away from sunlight
Genus *Coquillettidia*				
Cq. perturbans	Widespread, known from many parishes (S, R)	EEE	Vicious biter at dusk, only near breeding areas	Attached to roots of aquatic plants in continuously flooded fresh water.
Genus *Deinocerites*				
De. cancer	Coastal salt marsh (S, R)	WNV	Rare	Breeds in crabholes in mangrove or grassy saltwater marshes
Genus *Mansonia*				
Ma. dyari Belkin, Heinemann, and Page	(S, R)	None	Vicious biter, pest when abundant	Attached to roots of aquatic plants -- often associated with water hyacinth *(Eichornia crassipes)* or water lettuce *(Pistia)*
Ma. titillans	(S, R)	WNV, VEE, dog heartworm	Vicious biter, pest when abundant	Attached to roots of aquatic plants -- often associated with water hyacinth (Eichornia crassipes) or water lettuce (Pistia)
Genus *Orthopodomyia*				
Or. alba	Very rare, known from only a few parishes (R)	None	Rare, doesn't bite humans	Tree holes. Also artificial containers in other states.
Or. signifera	Across entire state (S, R)	WNV	Rarely bites humans	Tree holes and artificial containers

Taxonomic Group	Distribution in Louisiana	Medical Importance	Pest Importance	Larval Habitat
Genus *Psorophora*				
Ps. columbiae	Across entire state (S, R)	WNV	Major pest: vicious biter, can be extremely numerous	Open freshwater temporary pools, ponds and ditches. Also abundant in inactive rice fields.
Ps. discolor	Found across entire state, but rarely abundant (S, R)	None	Bites, but isn't usually abundant	Freshwater temporary pools, ponds and ditches
Ps. cyanescens	Across entire state (R)	None	Very painful bite, only abundant in very localized areas	Open freshwater temporary pools, ponds and ditches
Ps. ferox	Across entire state (S, R)	WNV	Serious biting pest to homes near wooded areas	Wooded freshwater temporary pools, ponds and ditches
Ps. horrida	Northern and southwestern parishes (S, R)	None	Vicious biter, usually outnumbered by other biting species	Wooded freshwater temporary pools, ponds and ditches
Ps. johnstonii		None		
Ps. longipalpus	Extremely rare, known from 1 parish (R)	None	Too rare	Probably flooded woodland habitats
Ps. mathesoni	Widespread, known from most parishes (S, R)	None	Vicious biter, can be local nuisance	Temporary freshwater depressions, adjacent to streams, bayous in low wooded areas
Ps. ciliata	Across entire state (S, R)	Larvae predaceous. WNV, SLE	Large, vicious biter, but seldom reaches great abundance	Temporary water pools, ponds and ditches. Also open areas adjacent to salt marshes.
Ps. howardii	Across entire state (S, R)	Larvae predaceous. WNV, SLE	Large, vicious biter, but seldom reaches great abundance	Temporary pools and depressions flooded by rain.
Genus *Toxorhynchites*				
Tx. rutilus septentrionalis (Dyar and Knab)	Across entire state	Larvae predaceous.	None	Tree holes and artificial containers
Genus *Uranotaenia*				
Ur. lowii (Theobald)	Across entire state (R)	None	None	Densely vegetated edges of semi-permanent or permanent freshwater pools, ponds and swamps. Usually in open areas, occasionally in partially wooded areas.
Ur. sapphirina (Osten Sacken)	Across entire state (R)	WNV	None	Densely vegetated edges of semi-permanent or permanent freshwater pools, ponds and swamps in open areas
Genus *Wyeomyia*				
Wy. smithii	Rare	None	None	In leaf bases of pitcher plant

Table 3. Glossary of technical terms used in keys to the mosquitoes of Louisiana

aculeate	Covered with minute, needlelike spines.
acus	A small hardened plate attached posterolaterally to the base of the siphon.
anal papilla-saddle index	Number equaling the length of the anal papillae divided by the saddle length.
anterior	Toward the front of the body.
anterior angle	A distinct angle in the anterior margin of the mesokatepisternum.
apex	Point of a body segment farthest from midpoint of the body, the most apical point.
apical	Distant from the midline of the body. Opposite of “basal.”
apicolateral	The points farthest from the midline of the body, toward the sides of the given segment. Combination of apical and lateral.
appressed	Flattened down.
attenuated	Long and slender, gradually narrowing toward the tip.
barbed	With minute, short points projecting at an angle from the surface.
basal	Near to the midline of the body. Opposite of “apical.”
basal tubercle	Cuplike socket from which a seta arises.
detached	Separated by a distinct distance from the rest of the group to which it belongs.
dichotomously branched	Having branches which repeatedly divide into two sub-branches.
distalmost	Farthest from the point of attachment of the given segment.
dorsal	On the back, or upper surface of the body. Opposite of “ventral.”
emarginated	Having the margin interrupted by a notch or shallow indentation.
hypostigmal scales	Scales immediately ventral to (below) the spiracle.
inflated	Broader in the middle region, narrower at the base and apex.
integument	The membrane covering the surface of a body part.
labella	The two terminal lobes visible at the tip of the proboscis.
lateral	At the left and/or right sides of the body.
longitudinal	Along the long axis of the given anatomical part. Opposite of “transverse.”
margin	Border or edge.
median	On the midline, or at the midpoint.
midventral line	Imaginary line extending along the center of the ventral surface.
ocular line	The line between the posterior margin of the eyes and the anterior margin of the occiput.
palmate	With flattened, usually horizontal branches radiating from a common point on a short stem.
pectinate	With long or short branches arising at regular intervals along one side.
pleuron	The lateral surface of a given body segment. (pl. ‘pleura’)
posterior	Toward the rear of the body.
precratal setae	Tufts of the anal segment which arise before the grid.
rudimentary	Greatly reduced and simplified.
sclerotized	Hardened and thick, usually opaque.
scutal fossae	Anterolateral depressions in the surface of the scutum.
siphonal index	Number which equals the length of the siphon divided by its basal width.
spiniforms	Thick, spinelike projections, usually uniform in width along their entire length.
spinose	Having large, sturdy projection, with sharp or narrowly rounded tips.
spinules	Minute, stiff spines.
subapical	Near to, but not at, the apex.
subequal	Nearly equal.
tracheae	Internal tubes, dark and visible through the surface membrane.
transverse	Perpendicular to the long axis of the given anatomical part. Opposite of “longitudinal.”
ventral	The lower surface of the body. Opposite of “dorsal.”
ventroposterolateral	On a body segment, the lower surface, toward the back, at the left and right sides. Combination of ventral + posterior + lateral.

ILLUSTRATED KEY TO COMMON MOSQUITOES OF LOUISIANA

By Mark Fox

Introduction

This key is designed for operational mosquito control personnel, students in entomology, or any person interested in acquiring introductory knowledge of mosquitoes commonly found in Louisiana.

For detailed ecological information on the mosquitoes of the region, the reader is referred to: (1) King, Bradley, and McNeel 1944 (The Mosquitoes of the Southeastern United States); (2) Carpenter et al. 1946 (Mosquitoes of the Southern United States) and (3) Carpenter and LaCasse 1955 (Mosquitoes of North America).

Acknowledgements

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GENERA AND SPECIES INCLUDED IN KEY

Genus ANOPHELES Meigen

Anopheles atropos Dyar and Knab
Anopheles Bradleyi King
Anopheles crucians Weidemann
Anopheles punctipennis (Say)
Anopheles quadrimaculatus Say2
Anopheles pseudopunctipennis Theobald

Genus AEDES Meigen

Aedes aegypti (Linnaeus)
Aedes atlanticus Dyan and Knab
Aedes canadensis (Theobald)
Aedes cinereus Meigen
Aedes dupreei (Coquillett)
Aedes fulvus pallens Ross
Aedes infirmatus Dyar and Knab
Aedes mitchellae (Dyar)
Aedes sollicitans (Walker)
Aedes sticticus (Meigen)
Aedes taeniorhynchus (Weidemann)
Aedes tormentor Dyar and Knab
Aedes triseriatus (Say)
Aedes trivittatus (Coquillett)
Aedes vexans (Meigen)
Aedes japonicus (Theobald)
Aedes hendersoni (Cockerell)
Aedes thibaulti (Dyar and Knab)

Genus COQUILLETTIDIA Dyar

Coquillettidia perturbans (Walker)

Genus CULEX Linnaeus

Culex erraticus (Dyar and Knab)
Culex nigripalpus Theobald
Culex pilosus (Dyar and Knab)
Culex pipiens Linnaeus
Culex quinquefasciatus (Say)
Culex restuans Theobald
Culex salinarius Coquillett
Culex tarsalis Coquillett
Culex territans Walker
Culex coronator Dyar and Knab
Culex peccator Dyar and Knab

Genus TOXORHYNCHITES Theobald

Toxorhynchites rutilus (Coquillett)

Genus DIENOCERITES Theobald

Dienocerites cancer Theobald

Genus CULISETA Felt

Culiseta inornata (Williston)
Culiseta menlanura (Coquillett)

Genus MANSONIA Blanchard

Mansonia dyari Belkin, Heinemann and Page
Mansonia titillans (Walker)

Genus PSOROPHORA Robineau-Desvoidy

Psorophora ciliate (Fabricius)
Psorophora columbiae (Dyar and Knab)
Psorophora cyanescens (Coquillett)
Psorophora discolor (Coquillett)
Psorophora ferox (Humboldt)
Psorophora horrida (Dyar and Knab)
Psorophora howardii Coquillett
Psorophora longipalpus Randolph & O'Neill
Psorophora mathesoni Belkin and Heinemann
Psorophora johnstonii (Grabham)

Genus URANOTAENIA Lynch-Arribalzaga

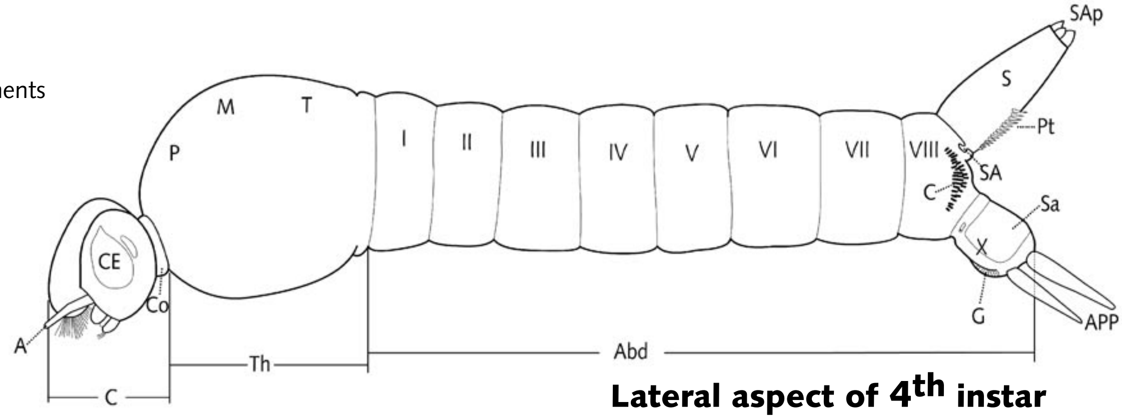
Uranotaenia lowii Theobald
Uranotaenia sapphrina (Osten Sacken)

Genus WYEOMYIA Theobald

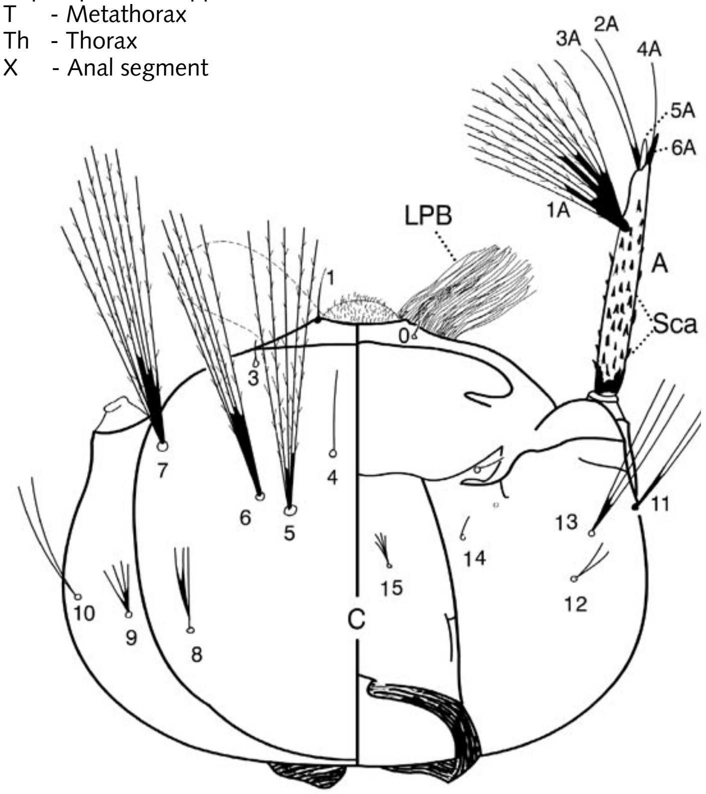
Genus ORTHOPODOMYAI Theobald

Orthopodomyai alba Baker
Orthopodomyai signifera (Coquillett)

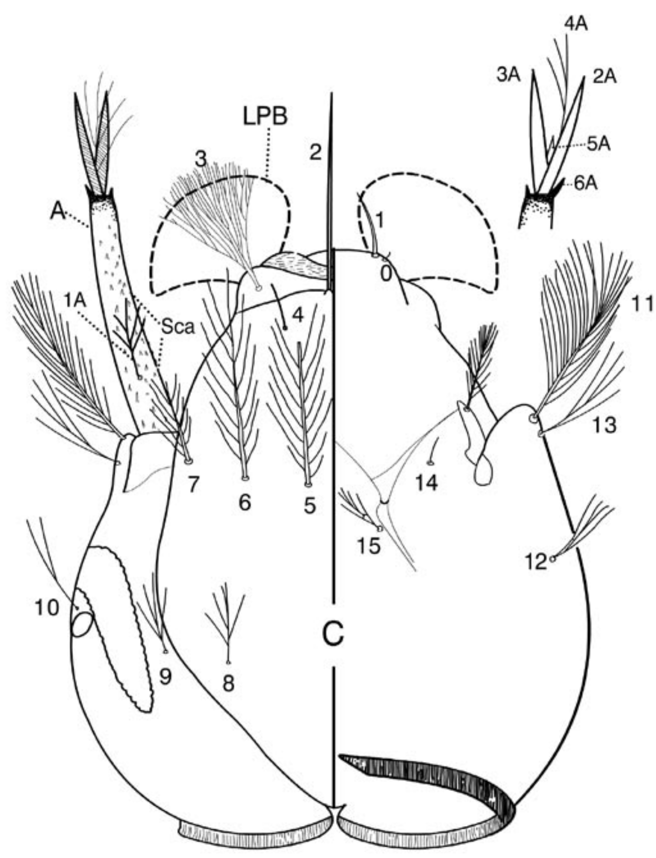
A - Antenna
Abd - Abdomen
I-VIII - abdominal segments
APP - Anal Papillae
c - comb plate
C - Head
CE - Compound Eye
Co - Collar
G - Grid
M - Mesothorax
P - Prothorax
Pt - Pecten
S - Siphon
Sa - Saddle
SA - Acus of Siphon
SAp - Spiracular Apparatus
T - Metathorax
Th - Thorax
X - Anal segment



Lateral aspect of 4th instar culicine larva



Culicine



Anopheline

C - Head
0-C - outer preclypeal hair
1-C - inner preclypeal hair
2-C - inner clypeal hair
3-C - outer clypeal hair
4-C - postclypeal hair
5-C - upper head hair
6-C - lower head hair
7-C - preantennal hair
8-C - sutural hair
9-C - transsutural hair
10-C - supraorbital hair
11-C - basal hair
12-C - infraorbital hair
13-C - subbasal hair
14-C - postmaxillary hair
15-C - submental hair

Anatomy of 4th instar larval head

A - Antenna
1-A - antennal tuft
2-A - dorsal sabre
3-A - ventral sabre
4-A - terminal antenna hair
5-A - papilla
6-A - fingerlike process

LPB - Lateral Palatal Brush
Sca - Scape (shaft) of antenna

Note: in drawings with a split view, the left half represents the dorsal aspect, and the right half represents the ventral aspect.

Anatomy of 4th instar larval thorax

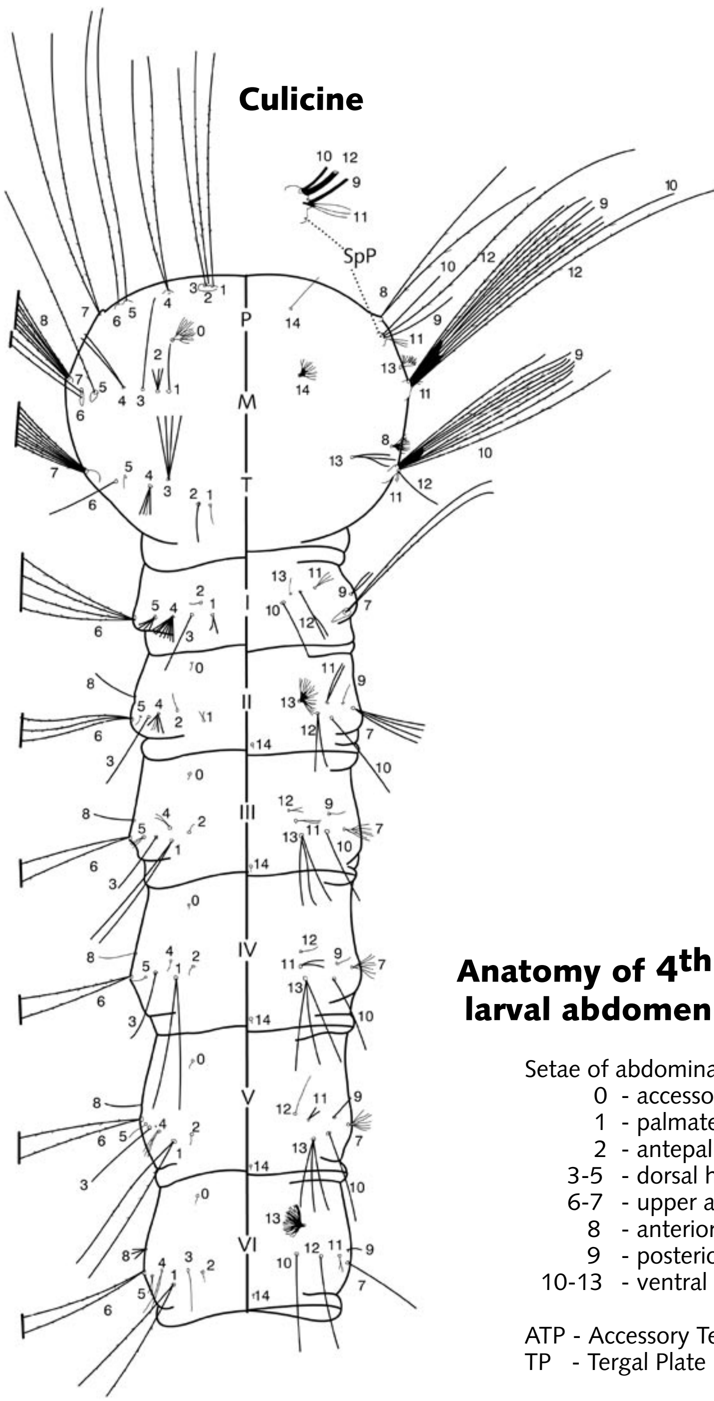
P - Prothorax
- 0-P - accessory dorsal hair
- 1- to 3-P - shoulder hairs
- 4- to 7-P - dorsal hairs
- 8-P - dorsolateral hair
- 9- to 12-P - prothoracic pleural hairs
- 13-P - ventrolateral hair
- 14-P - median ventral hair

M - Mesothorax
- 1- to 7-M - dorsal hairs
- 8-M - dorsolateral hair
- 9- to 12-M - mesothoracic pleural hairs
- 13-M - ventrolateral hair
- 14-M - median ventral hair

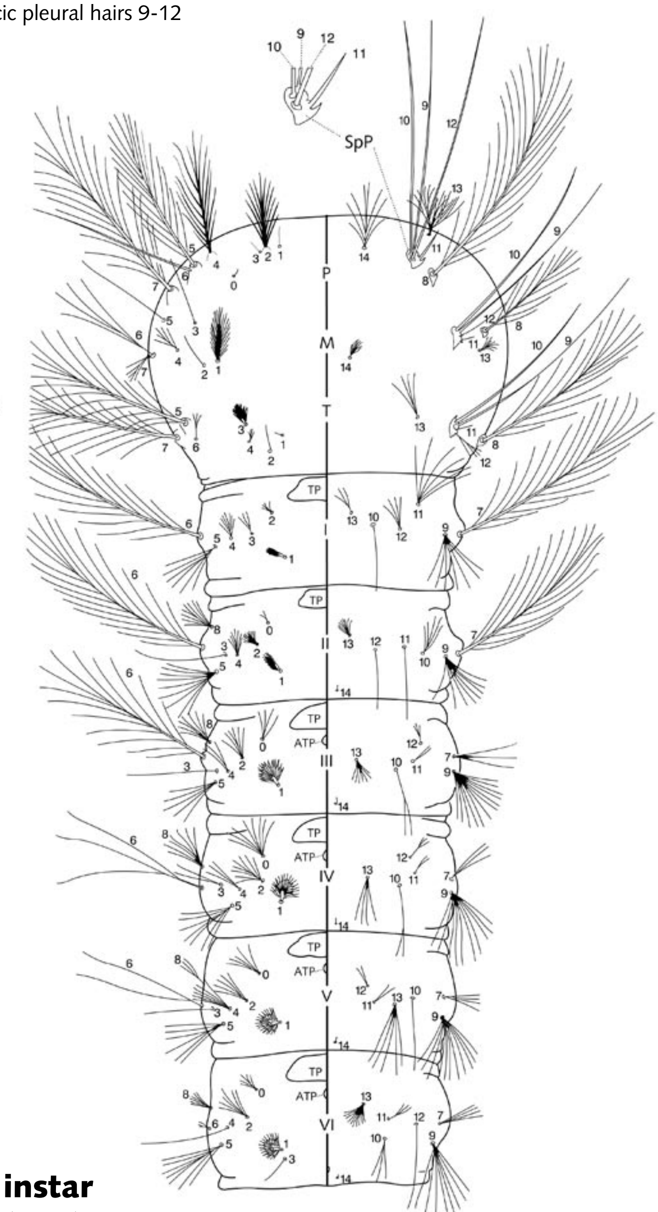
T - Metathorax
- 1- to 7-T - dorsal hairs
- 8-T - dorsolateral hair
- 9- to 12-T - metathoracic pleural hairs
- 13-T - ventrolateral hair
- 14-T - median ventral hair

SpP - Setal Support Plate of thoracic pleural hairs 9-12

Culicine



Anopheline

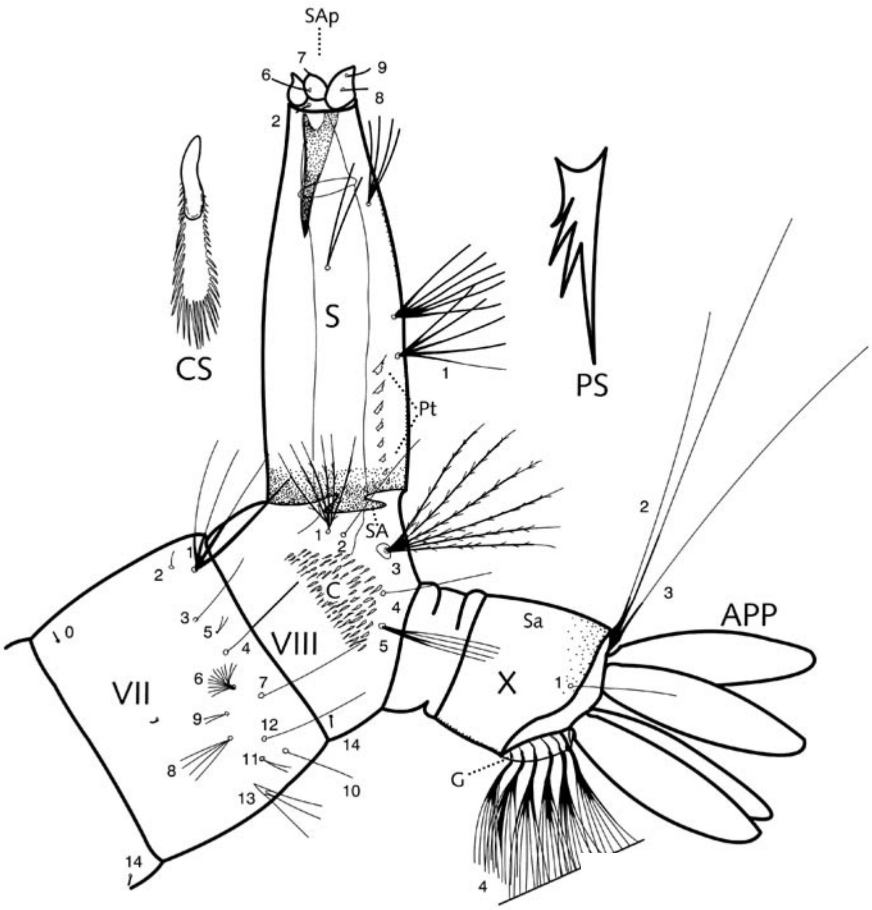


Anatomy of 4th instar larval abdomen (I-VI)

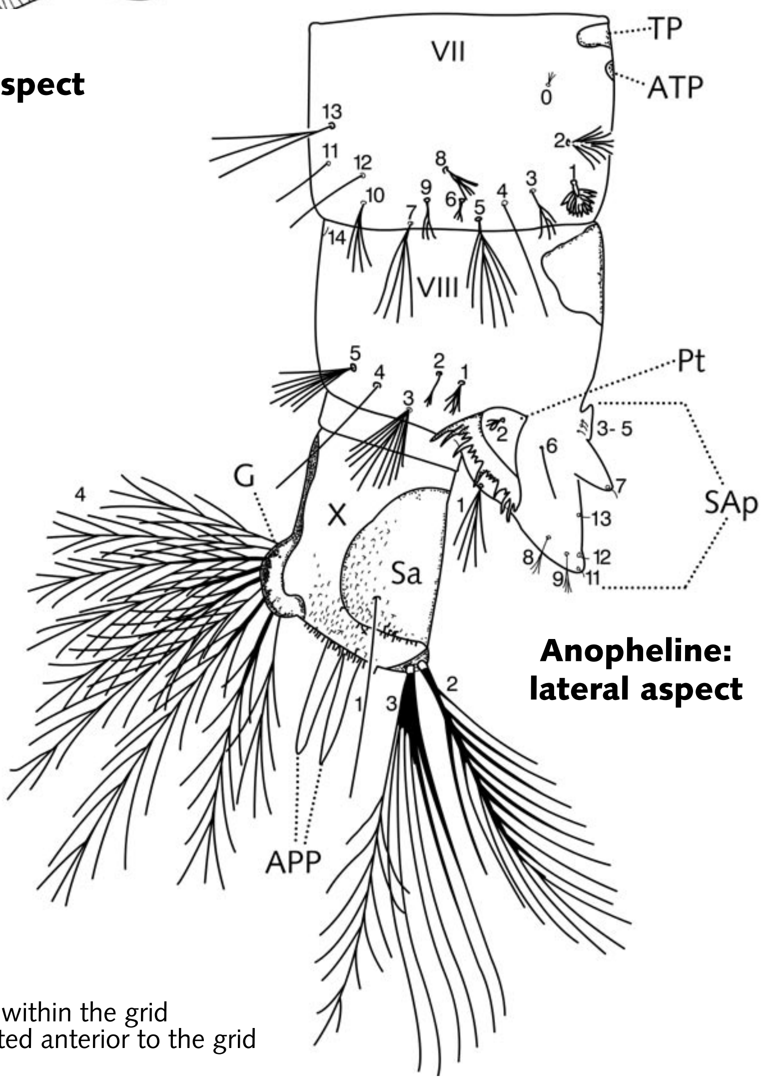
Setae of abdominal segments I-VII
- 0 - accessory dorsal hair (absent on segment I)
- 1 - palmate hair
- 2 - antepalmate hair
- 3-5 - dorsal hairs
- 6-7 - upper and lower lateral hairs
- 8 - anterior dorsolateral hair
- 9 - posterior ventrolateral hair
- 10-13 - ventral hairs

ATP - Accessory Tergal Plate
TP - Tergal Plate

Anatomy of 4th instar larval abdomen (VII-X)



Culicine: lateral aspect



Anopheline: lateral aspect

APP - Anal Papillae
ATP - Accessory Tergal Plate
C - Comb
CS - Comb Scale
G - Grid
PS - Pecten Spine
Pt - Pecten
S - Siphon
SA - Acus of Siphon
Sa - Saddle
SAp - Spiracular Apparatus
TP - Tergal Plate
X - Anal segment

Setae of segment VIII
- 1 - first pentad
- 2 - second pentad
- 3 - third pentad
- 4 - fourth pentad
- 5 - fifth pentad

Setae of segment S (SAp for *Anopheles*)
- 1-S - postspiracular hair
- 2-S - dorsolateral hair
- 6-S - proximal dorsal valve hair
- 7-S - distal dorsal valve hair
- 8-S - proximal ventral valve hair
- 9-S - distal ventral valve hair

Setae of segment X
- 1-X - saddle hair
- 2-X - upper caudal hair of dorsal brush
- 3-X - lower caudal hair of dorsal brush
- 4-X - ventral brush
  - cratal setae - individual elements of 4-X inserted within the grid
  - precratal setae - individual elements of 4-X inserted anterior to the grid

Larval Genera

1. Respiratory siphon absent; at least some abdominal terga with seta 1 palmate (Fig. 1a)..***Anopheles***

1'. Respiratory siphon present; seta 1 on abdominal terga never palmate (Fig. 1b)..2

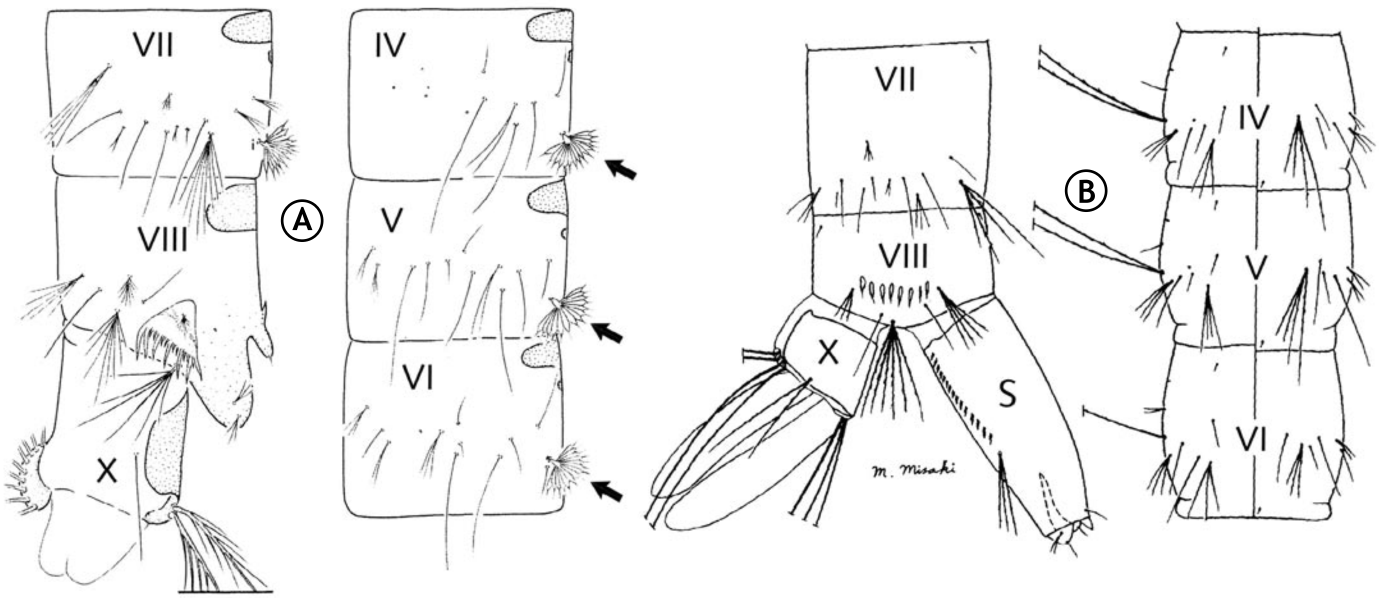


Figure 1.
A. Lateral view of abdominal segments IV-X - *An. quadrimaculatus*
B. Lateral view of abdominal segments IV-X - *Ae. albopictus*

2(1'). Siphon attenuated apically, with dorsal saw, adapted for piercing plant tissue (Fig. 2a)..3

2'. Siphon not attenuated apically, not adapted for piercing plant tissue (Fig. 2b)..4

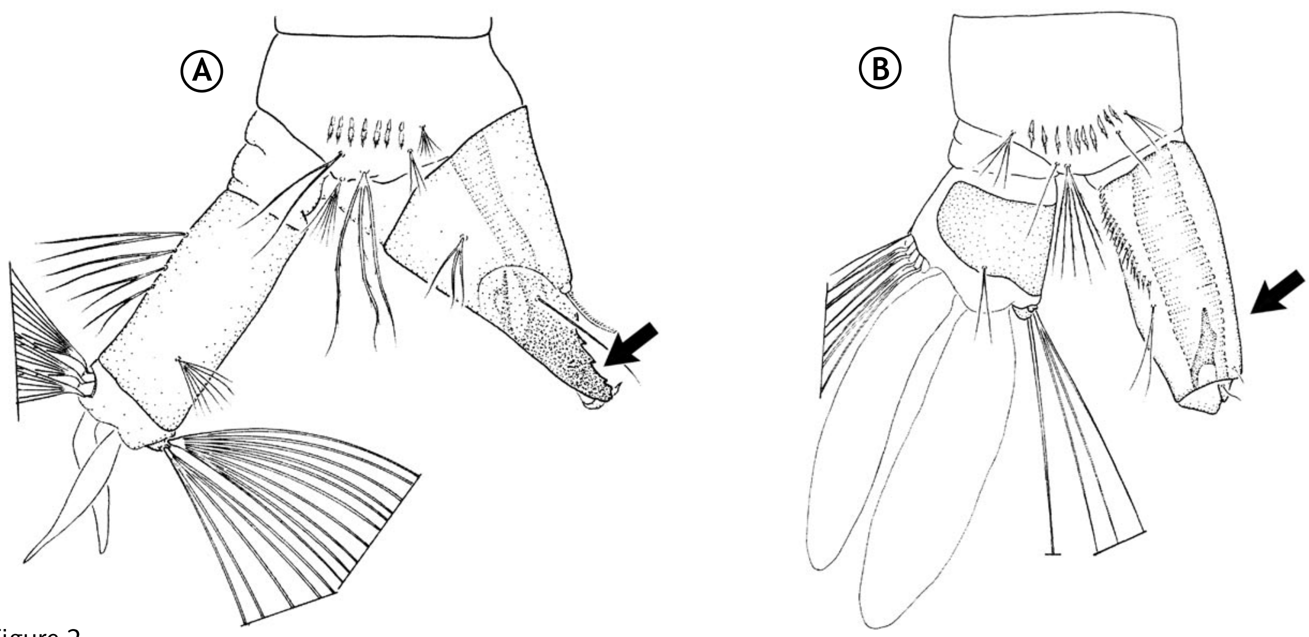


Figure 2.
A. Lateral view of abdominal segments VIII-X - *Ma. dyari*
B. Lateral view of abdominal segments VIII-X - *Ae. aegypti*

3(2). Setae 2, 3-A as long as antennal agellum, or longer (Fig. 3a); saddle bears three or four robust, precratal setae (Fig. 3b)..***Mansonia***

3'. Setae 2, 3-A much shorter than antennal agellum (Fig. 3c); saddle without precratal setae, or if present, no more than two thin setae posteriorly (Fig. 3d)..***Coquillettidia perturbans***

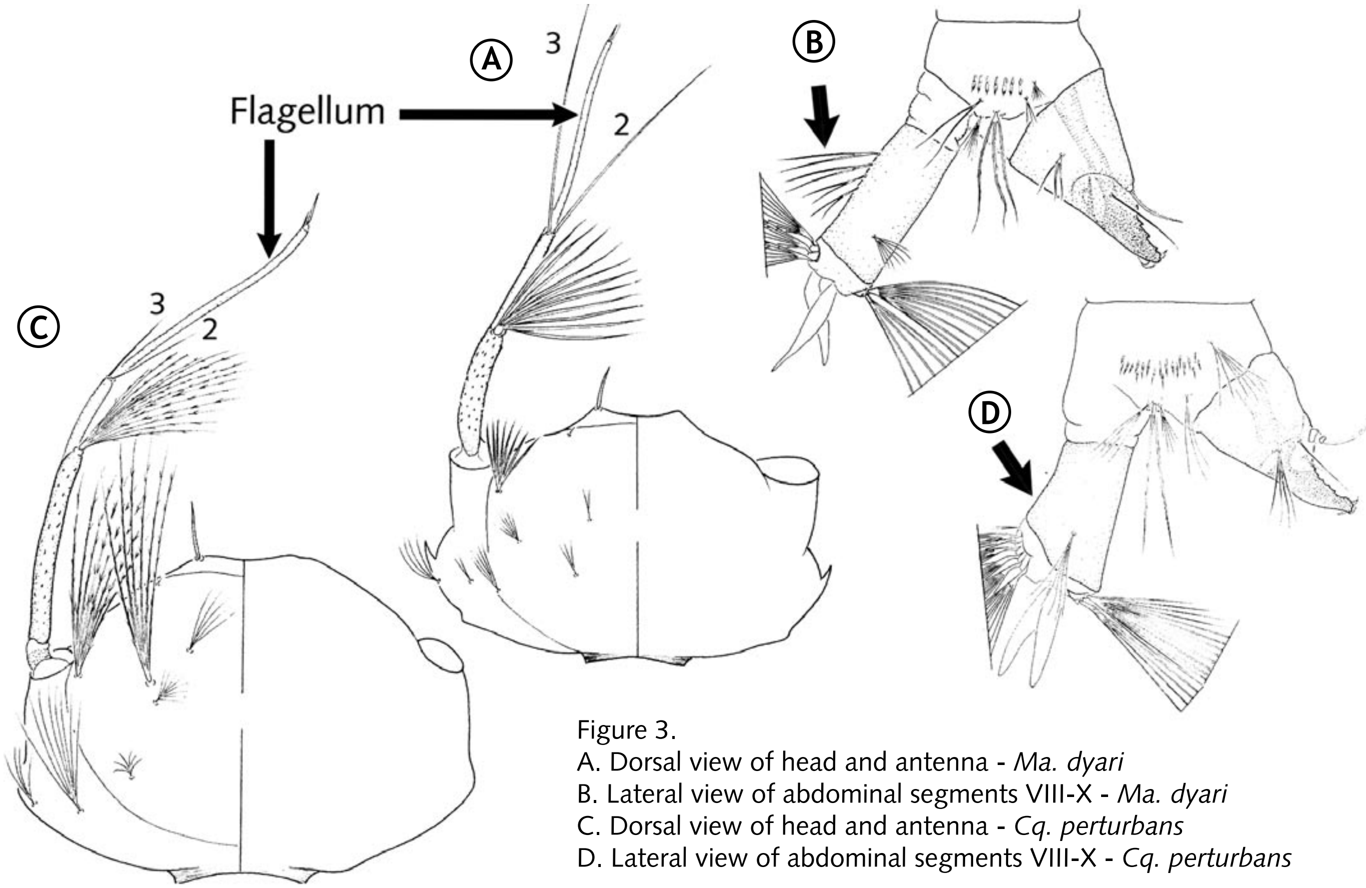


Figure 3.
A. Dorsal view of head and antenna - *Ma. dyari*
B. Lateral view of abdominal segments VIII-X - *Ma. dyari*
C. Dorsal view of head and antenna - *Cq. perturbans*
D. Lateral view of abdominal segments VIII-X - *Cq. perturbans*

4(2'). Siphon without pecten spines (Fig. 4a)..5

4'. Siphon with pecten spines (Fig. 4b)..7

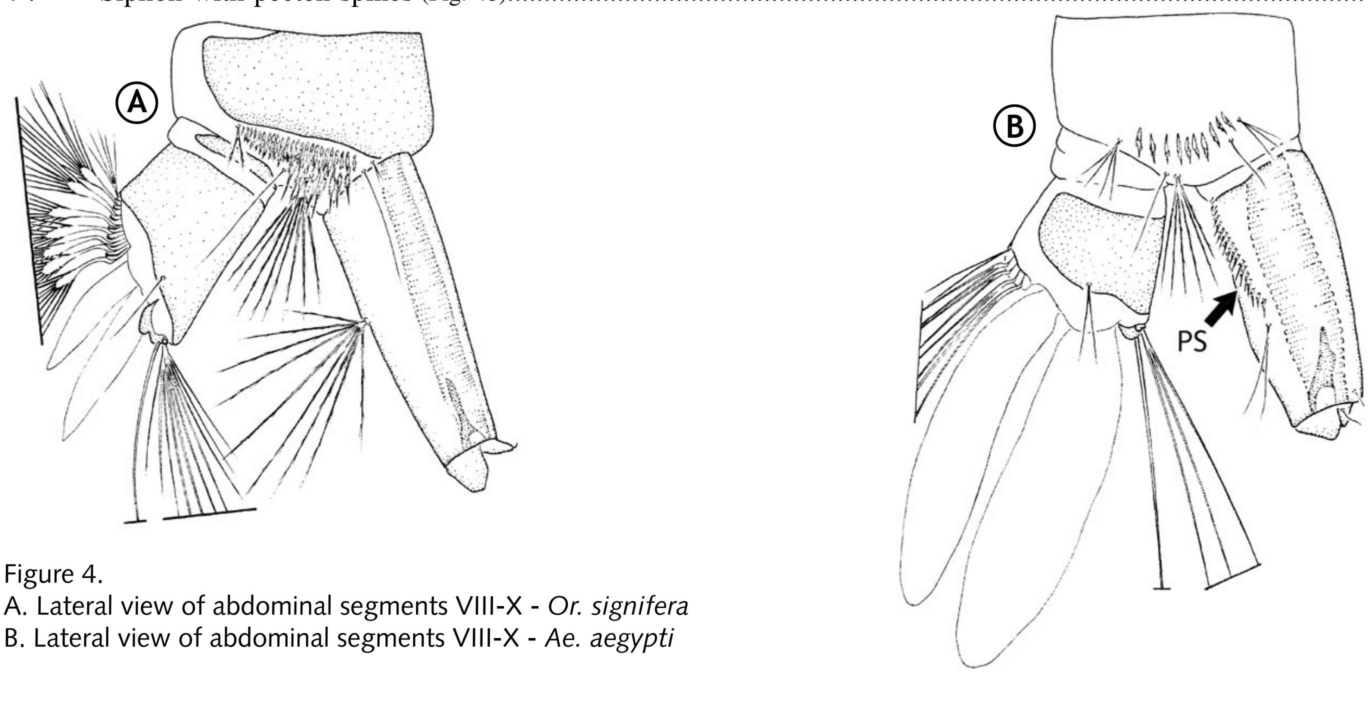


Figure 4.
A. Lateral view of abdominal segments VIII-X - *Or. signifera*
B. Lateral view of abdominal segments VIII-X - *Ae. aegypti*

5(4). Lateral palatal brush composed of few, stout, curved rods (Fig. 5a); comb scales absent; large, dark larva (Fig. 5b)..***Toxorhynchites rutilus***

5'. Lateral palatal brush composed of many thin, sometimes pectinate, filaments (Fig. 5c); with comb scales (Fig. 5d)..6

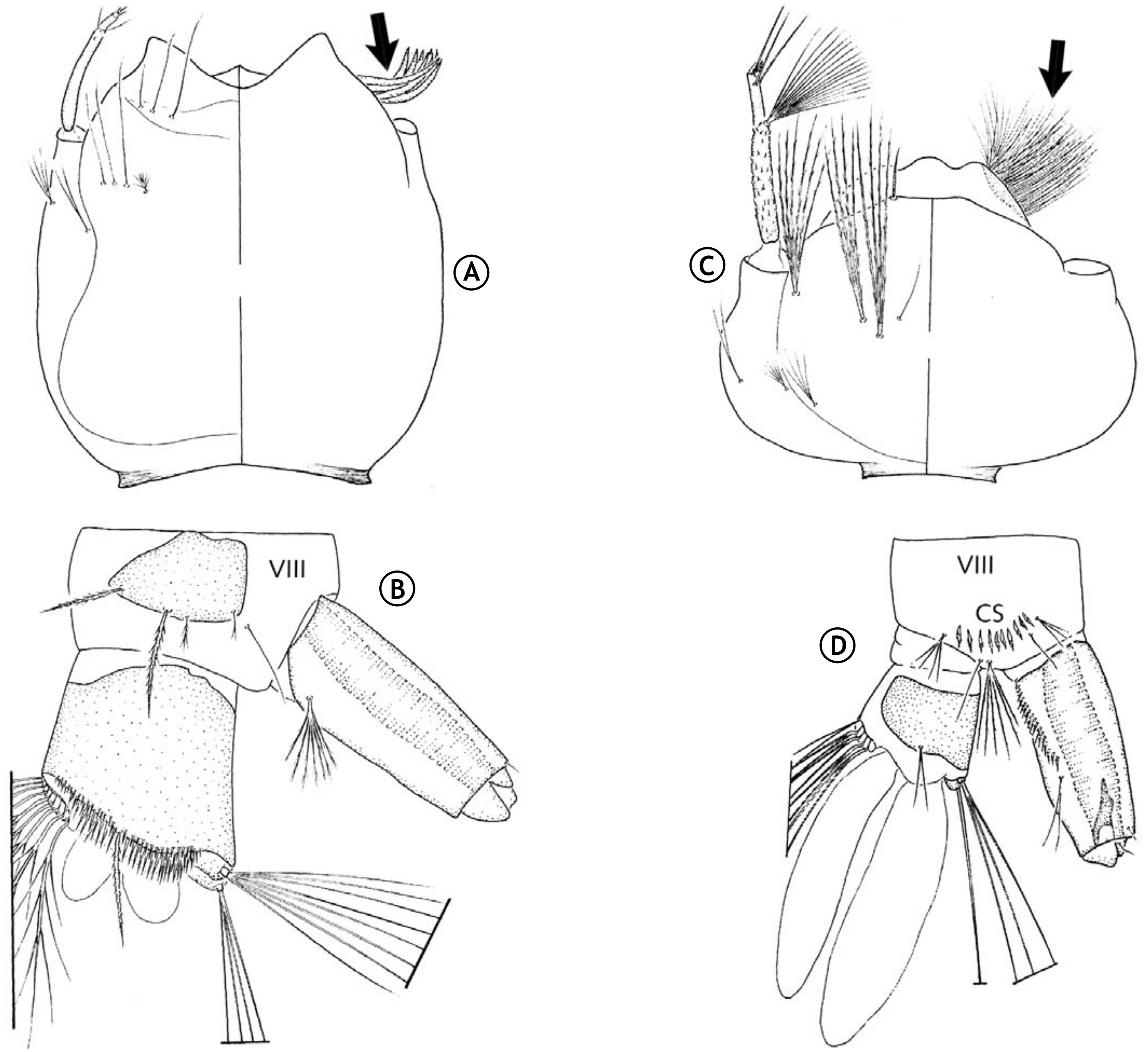


Figure 5.
A. Dorsal view of head - *Tx. rutilus*
B. Lateral view of abdominal segments VIII-X - *Tx. rutilus*
C. Dorsal view of head - *Cx. quinquefasciatus*
D. Lateral view of abdominal segments VIII-X - *Ae. aegypti*

6(5’). Segment X without median ventral brush, seta 4-X a pair of ventroposterolateral setae; comb scales in single row (Fig. 6a)..***Wyeomyia smithii***

6’. Seta 4-X forms a well developed median, ventral brush; comb scales in two rows (Fig. 6b)..***Orthopodomyia***

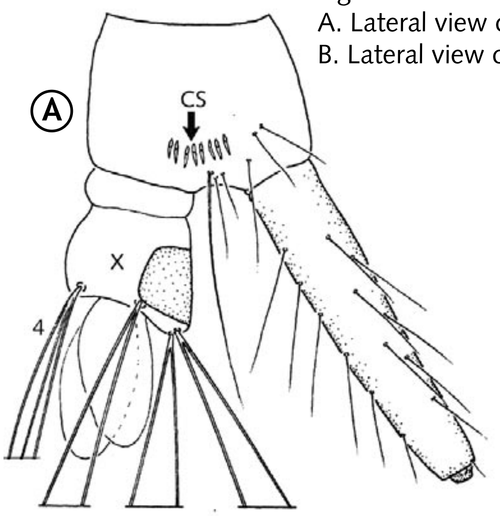
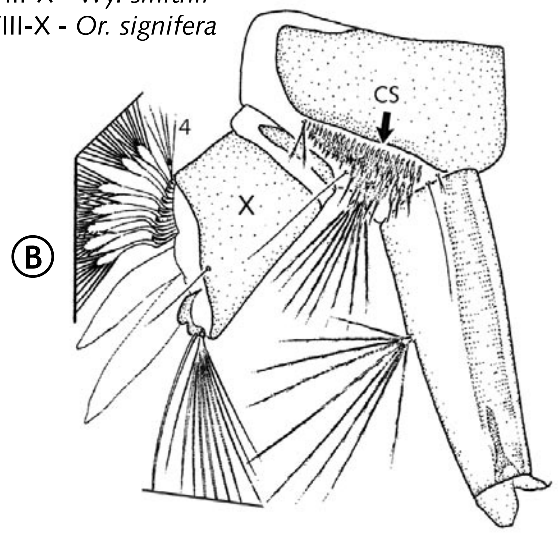


Figure 6.
A. Lateral view of abdominal segments VIII-X - *Wy. smithii*
B. Lateral view of abdominal segments VIII-X - *Or. signifera*



7(4’). Segment VIII with large, lateral comb plate bearing comb scales (Fig. 7a); head longer than wide; upper and lower frontal head hairs 5-6 stout and spinose (Fig. 7b)..***Uranotaenia***

7’. Segment VIII without comb plate (if present, small) (Fig. 7c); head wider than long; head hairs 5-6 not spinose (Fig. 7d)..8

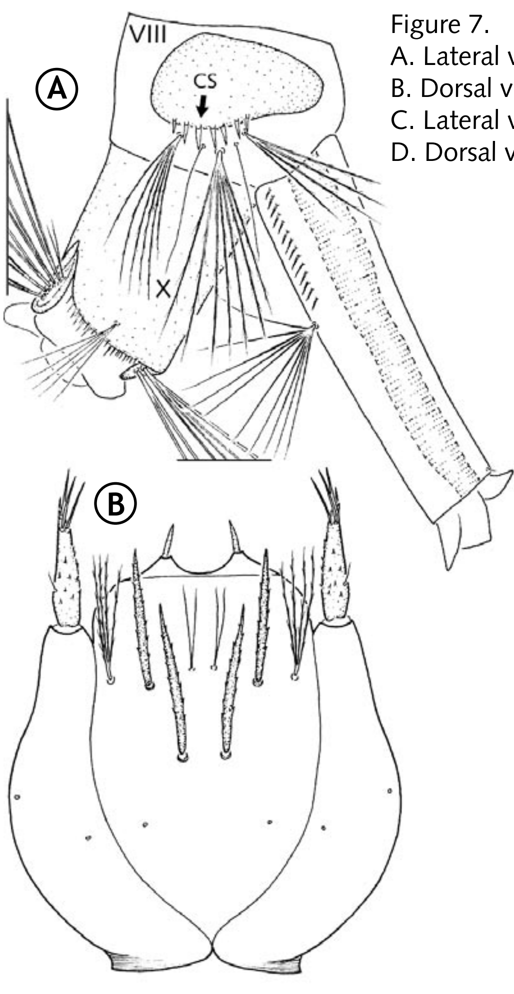
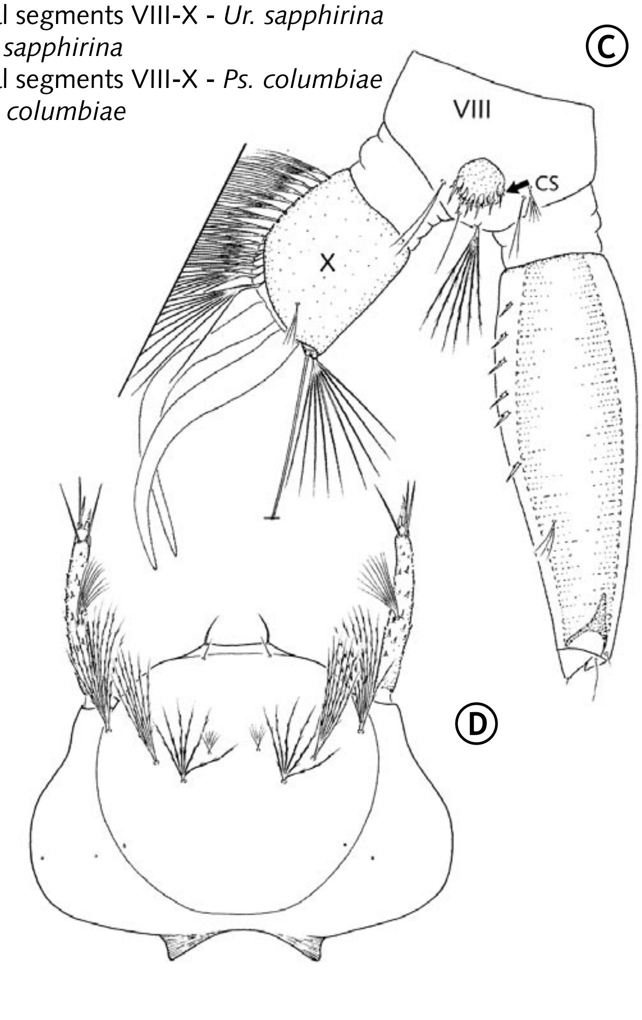


Figure 7.
A. Lateral view of abdominal segments VIII-X - *Ur. sapphirina*
B. Dorsal view of head - *Ur. sapphirina*
C. Lateral view of abdominal segments VIII-X - *Ps. columbiae*
D. Dorsal view of head - *Ps. columbiae*



8(7'). Head capsule widest near level of bases of antennae (Fig. 8a); segment X with dorsal and ventral sclerotized plates (Fig. 8b)..***Deinocerites cancer***

8'. Head capsule widest in posterior 0.5 (Fig. 8c); segment X with single sclerotized saddle (Fig. 8d)...9

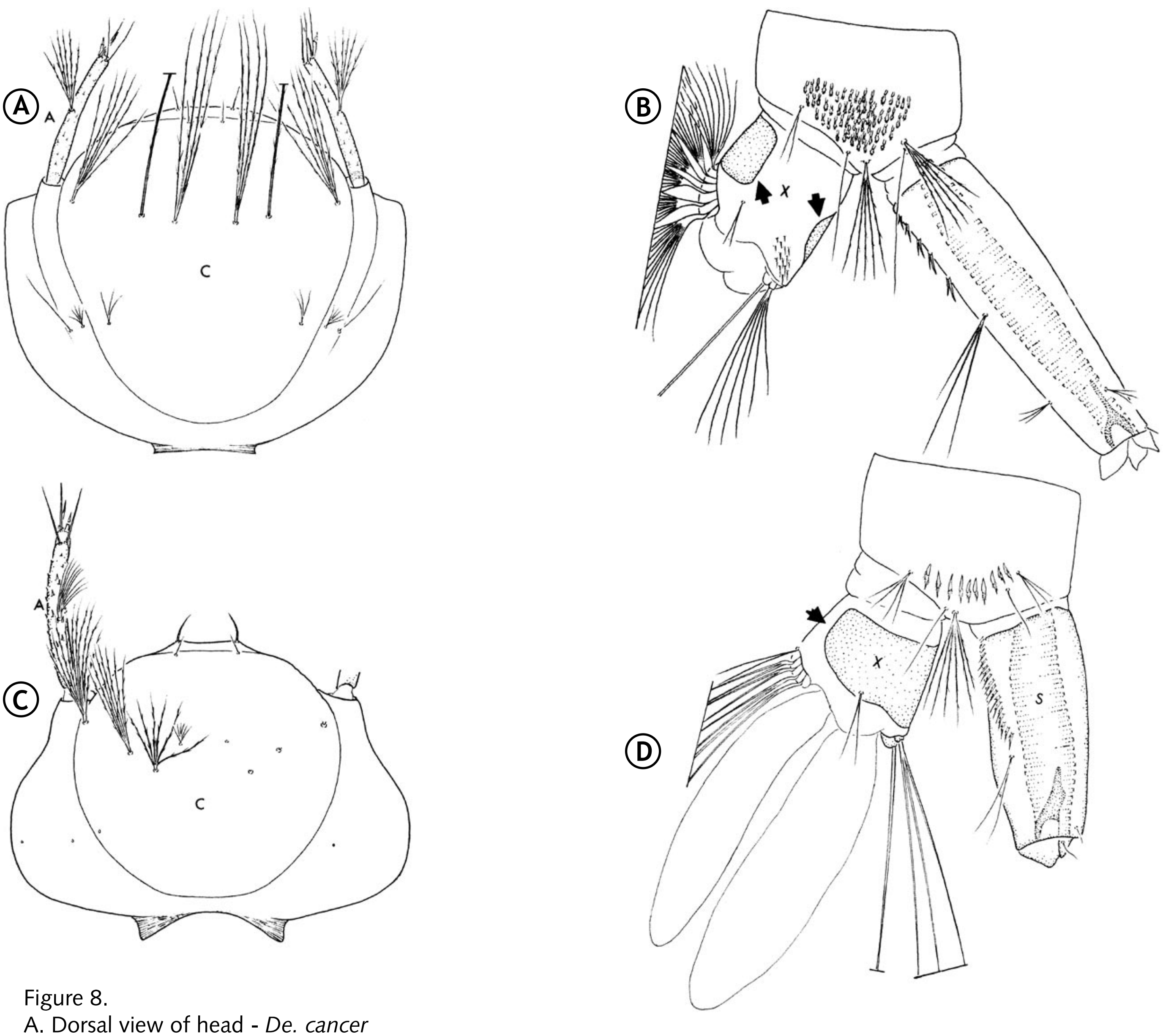
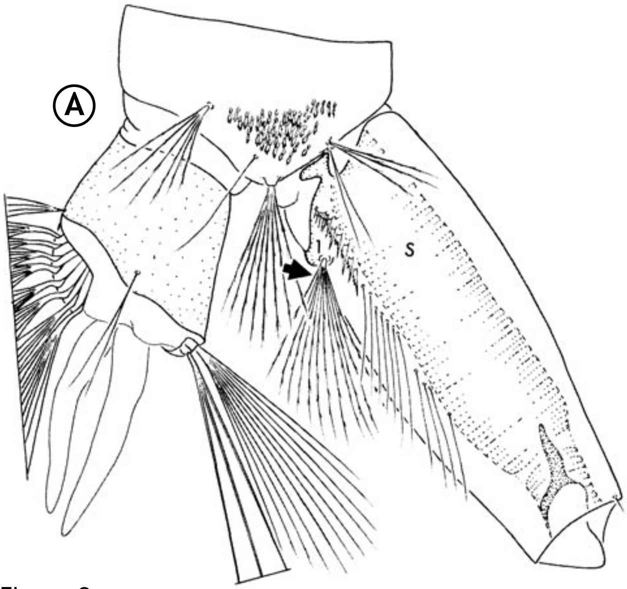


Figure 8.
A. Dorsal view of head - *De. cancer*
B. Lateral view of abdominal segments VIII-X - *De. cancer*
C. Dorsal view of head - *Ps. columbiae*
D. Lateral view of abdominal segments VIII-X - *Ae. aegypti*

9(8').	Siphon with at least a basal pair of ventral setae (Fig. 9a)..***Culiseta***
9'.	Siphon with setae elsewhere, not ventrally near base (Fig. 9b)...10



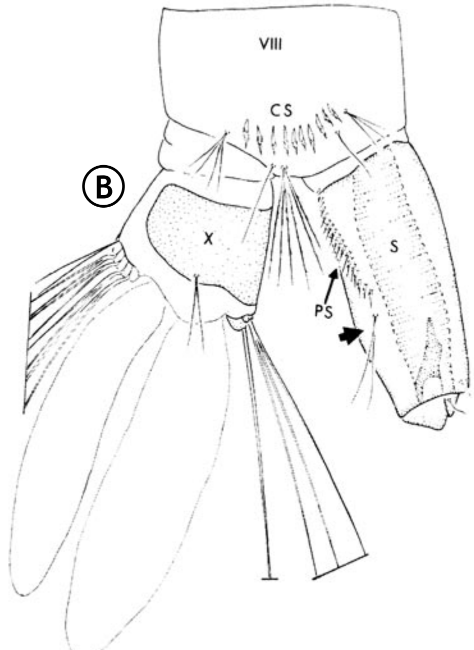
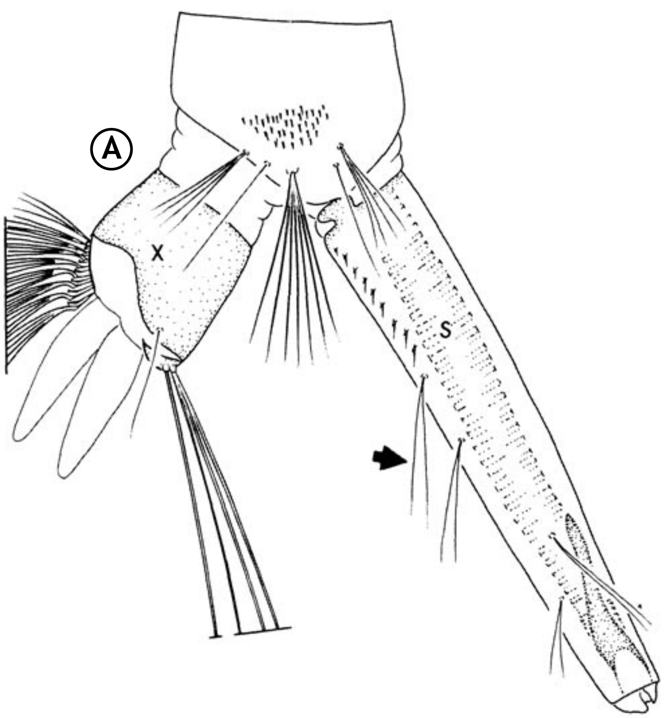


Figure 9.
A. Lateral view of abdominal segments VIII-X - *Cs. inornata*
B. Lateral view of abdominal segments VIII-X - *Ae. aegypti*

10(9').	Siphon with three or more pairs of setae (Fig. 10a)..***Culex***
10'.	Siphon with but one pair of setae (Fig. 10b)..11



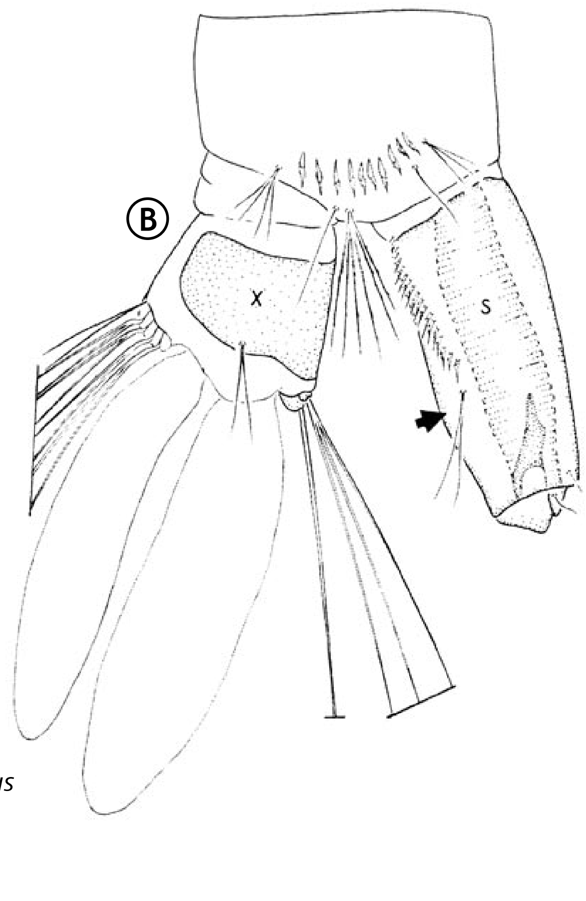


Figure 10.
A. Lateral view of abdominal segments VIII-X - *Cx. quinquefasciatus*
B. Lateral view of abdominal segments VIII-X - *Ae. aegypti*

11(10’). Saddle completely encircling segment X, pierced along midventral line by row of precratal setal tufts (Fig. 11a)..*Psorophora*

11’. Saddle usually not encircling segment X (Fig. 11b); if so, tufts of ventral brush are confined posterior to it (Fig. 11c)..***Aedes*** (s.l.)

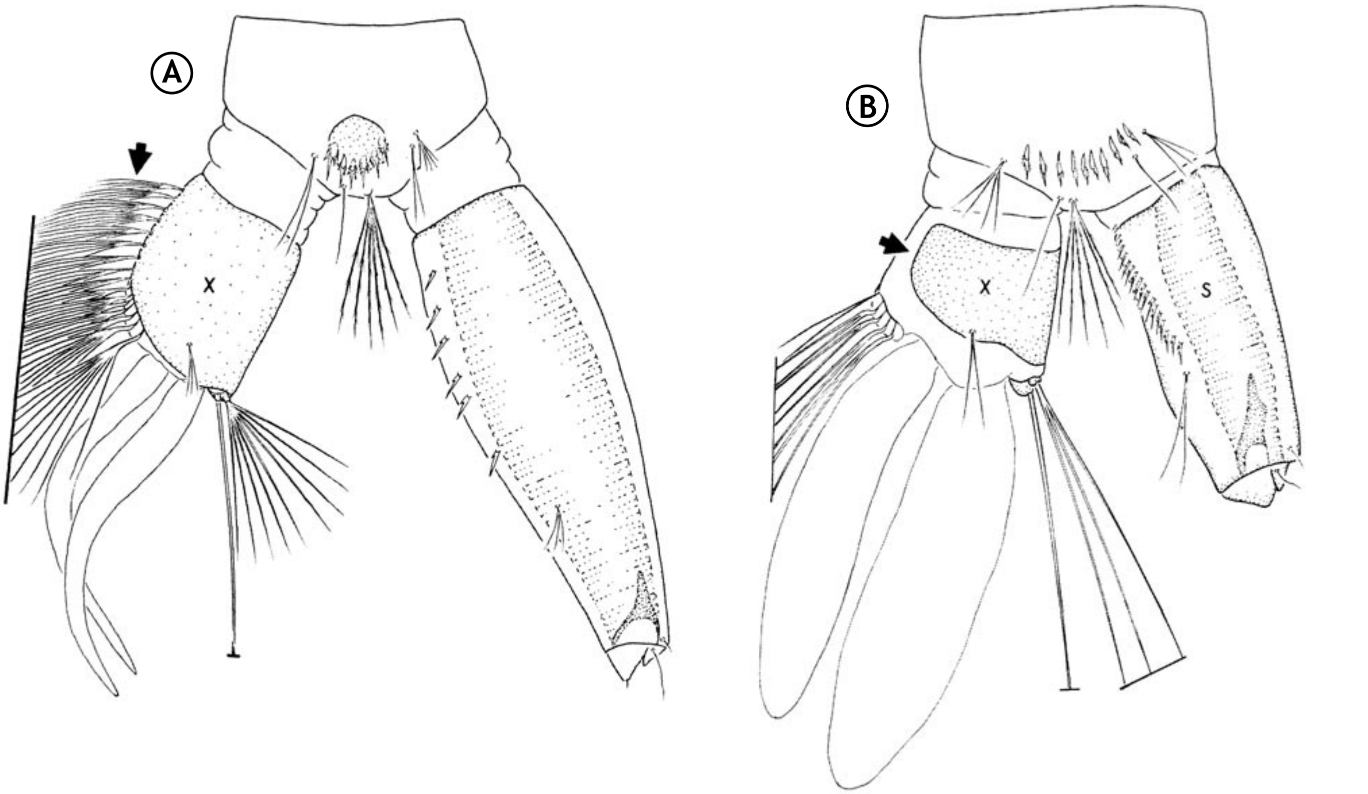
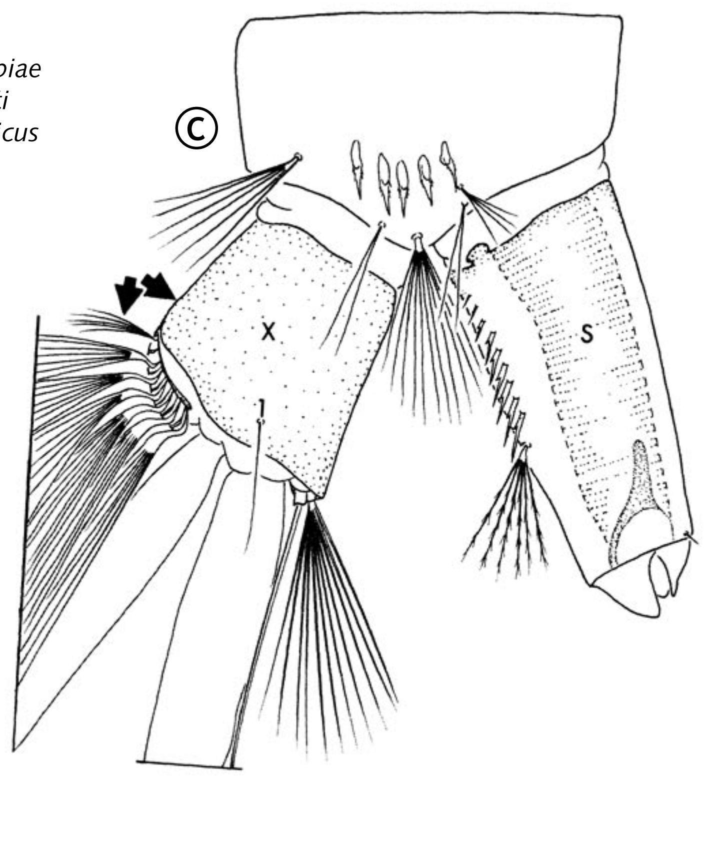


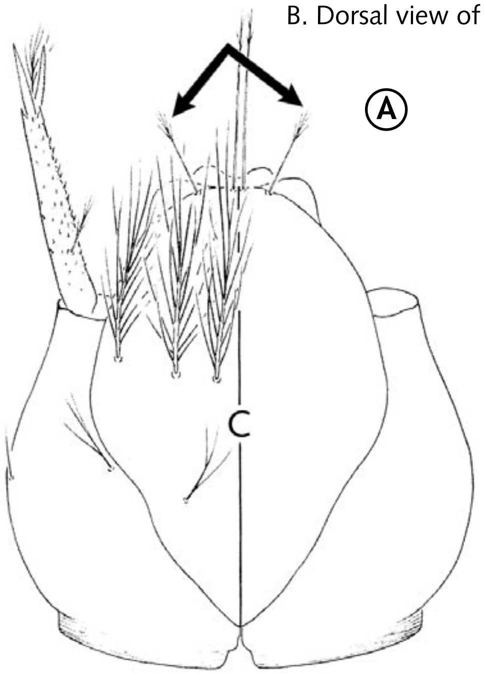
Figure 11.
A. Lateral view of abdominal segments VIII-X - *Ps. columbiae*
B. Lateral view of abdominal segments VIII-X - *Ae. aegypti*
C. Lateral view of abdominal segments VIII-X - *Ae. atlanticus*

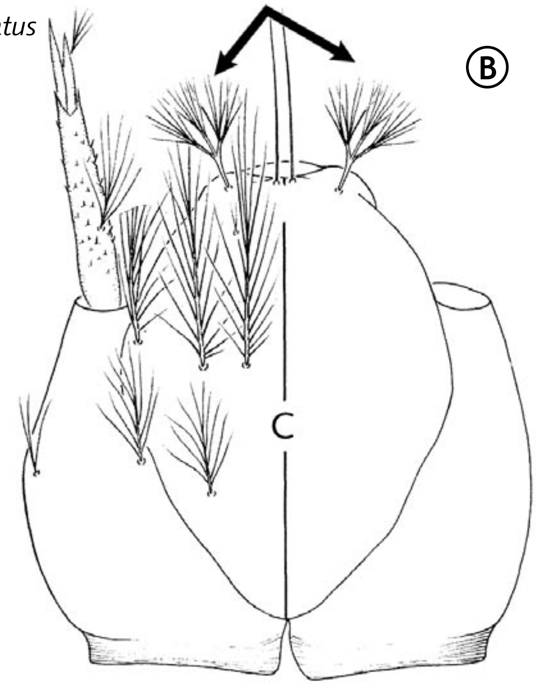


Anopheles Larvae

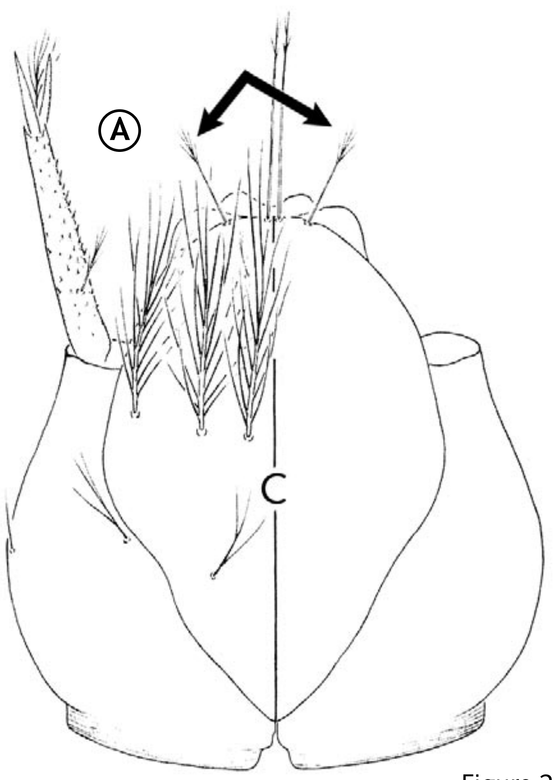
1. Outer clypeal hairs with ten or fewer branches (Fig. 1a)..2
1'. Outer clypeal hairs with 25 or more branches (Fig. 1b)..3

Figure 1.
A. Dorsal view of head - *An. atropos*
B. Dorsal view of head - *An. quadrimaculatus*





2(1). Outer clypeal hairs with five to ten branches (Fig. 2a)...***An. atropos***
2'. Outer clypeal hairs simple (Fig. 2b)..***An. pseudopunctipennis***



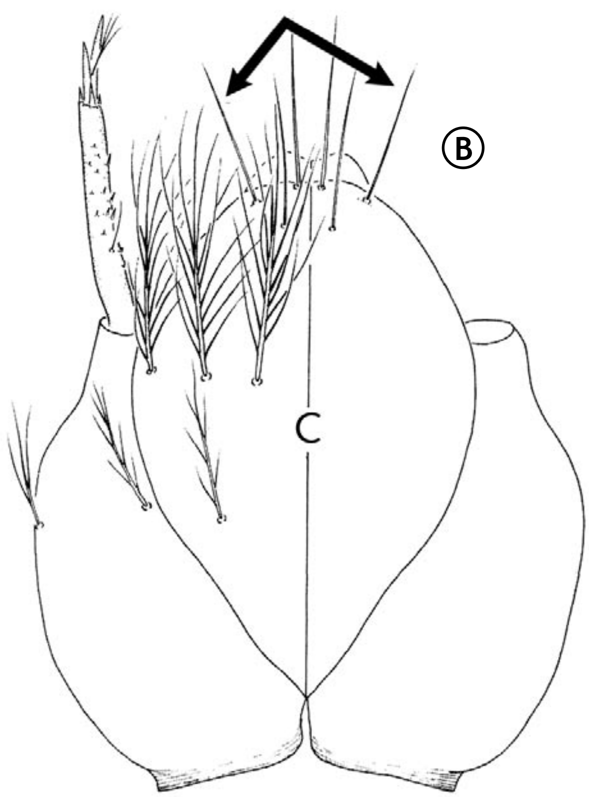
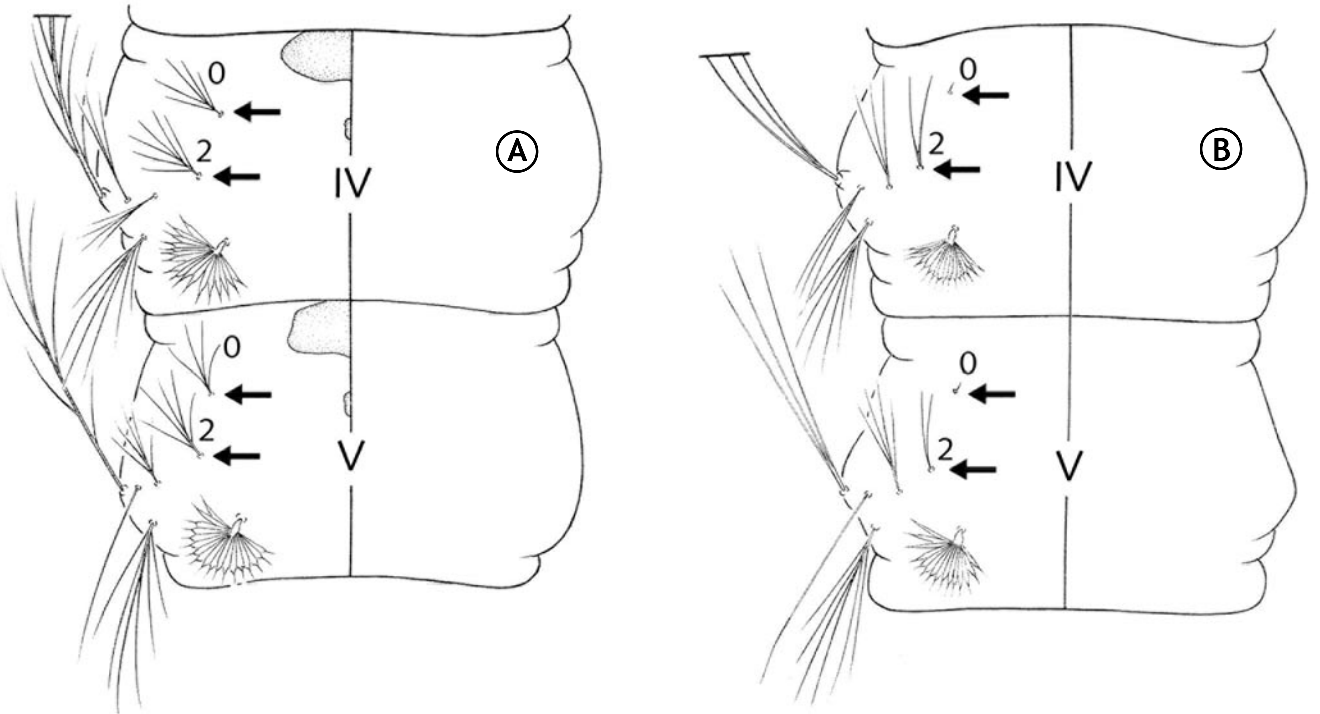


Figure 2.
A. Dorsal view of head - *An. atropos*
B. Dorsal view of head - *An. pseudopunctipennis*

3(1'). Hairs 0 and 2 multiple on abdominal segments IV-V (Fig. 3a)..***An. crucians***

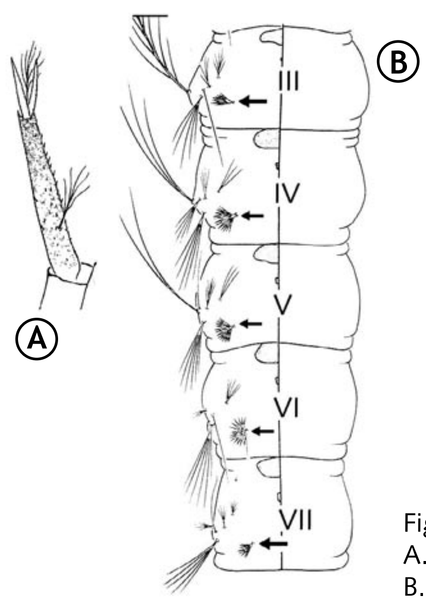
3'. Hair 0 on abdominal segments IV and V rudimentary or apparently absent; hair 2 single or double (Fig. 3b)..4

Figure 3.
A. Dorsal view of abdominal segments IV-V - *An. crucians*
B. Dorsal view of abdominal segments IV-V - *An. punctipennis*



4(2'). Antenna largely brownish (Fig. 4a); palmate hairs on abdominal segments III and VII definitely smaller than those on segments IV, V and VI (Fig. 4b)..***An. bradleyi***

4'. Antenna pale, darker at apex (Fig. 4c); palmate hairs on abdominal segments III-VII uniform in size (Fig. 4d)...5



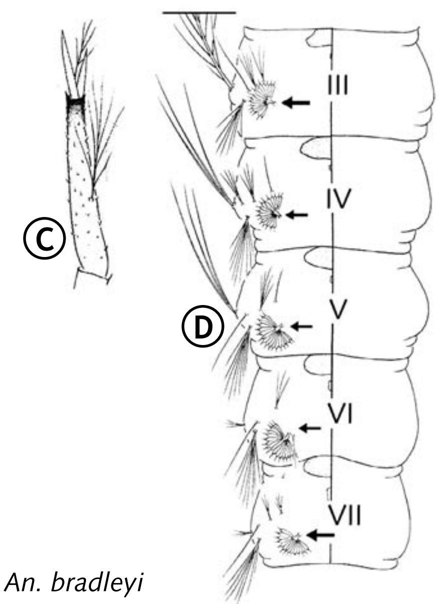


Figure 4.
A. Dorsal view of antenna - *An. bradleyi*
B. Dorsal view of abdominal segments III-VII - *An. bradleyi*
C. Dorsal view of antenna - *An. quadrimaculatus*
D. Dorsal view of abdominal segments III-VII - *An. quadrimaculatus*

5(4'). Inner clypeal hairs separated by less than the width of a basal tubercle (Fig. 5a); hair 2 on abdominal segments IV and V usually double (Fig. 5b)..***An. punctipennis***

5'. Inner clypeal hairs separated by at least the width of a basal tubercle (Fig. 5c); hair 2 on abdominal segments IV and V single (Fig. 5d)..***An. quadrimaculatus*** complex*

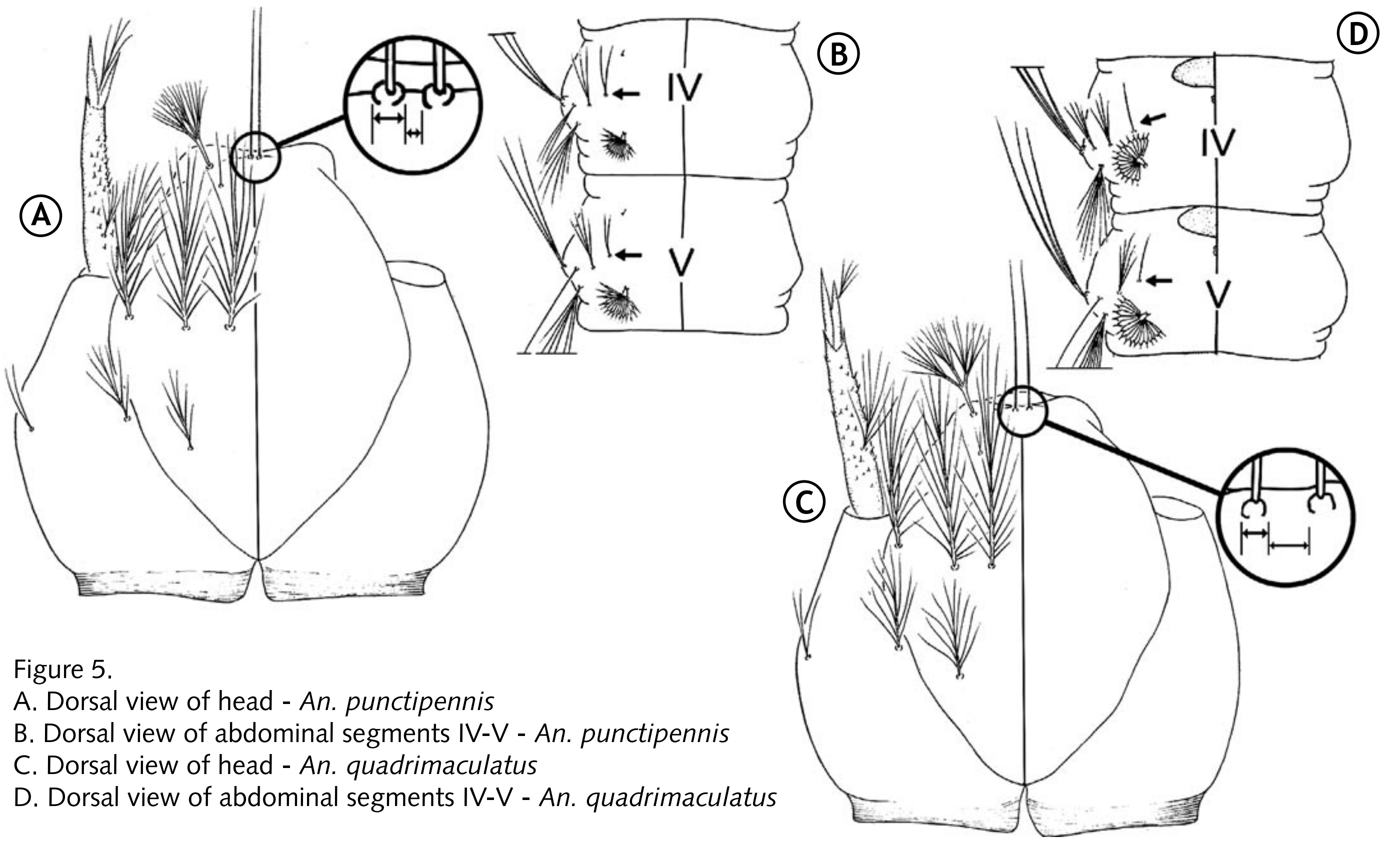


Figure 5.
A. Dorsal view of head - *An. punctipennis*
B. Dorsal view of abdominal segments IV-V - *An. punctipennis*
C. Dorsal view of head - *An. quadrimaculatus*
D. Dorsal view of abdominal segments IV-V - *An. quadrimaculatus*

* Species A, B, C2 and D of the *Anopheles quadrimaculatus* complex are found within Louisiana (Rutlidge and Meek, 1998). Reinert et al (1999) described the morphological distinctions between the members of this species complex for all life stages.

Aedes Larvae

1. Saddle completely encircling segment X (Fig. 1a)..2
1'. Saddle not completely encircling segment X (Fig. 1b)..10

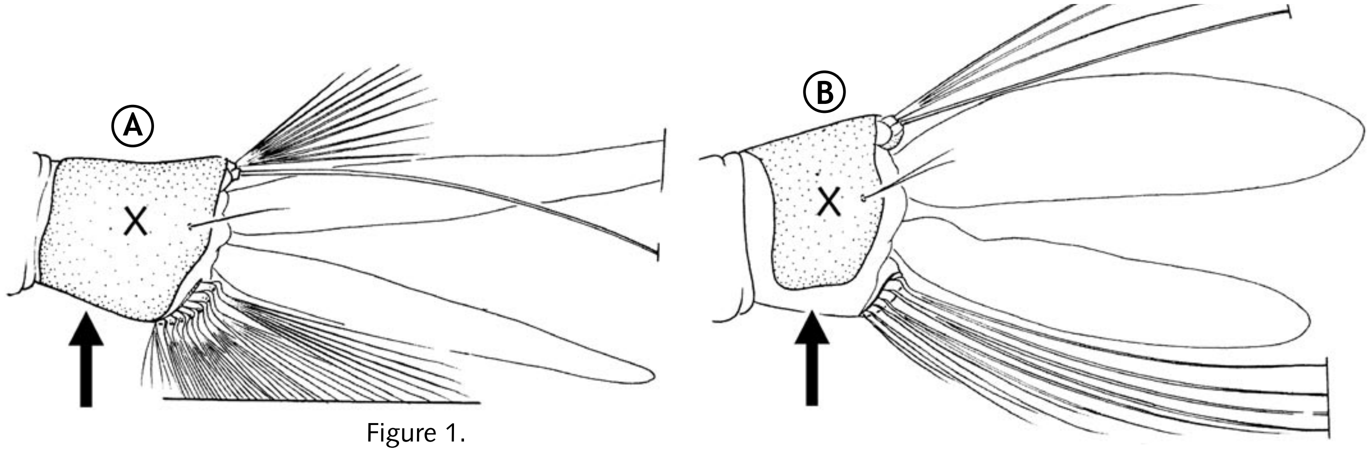


Figure 1.
A. Lateral view of abdominal segment X - *Ae. atlanticus*
B. Lateral view of abdominal segment X - *Ae. aegypti*

2(1). Pecten on siphon with one or more distal spines
detached apically (Fig. 2a)..***Ae. fulvus pallens***
2'. Pecten with spines more or less evenly spaced (Fig. 2b)..3

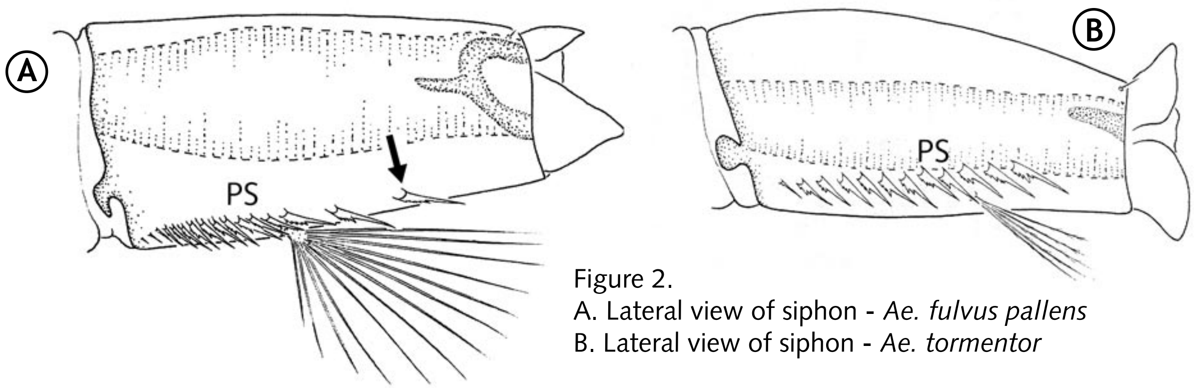


Figure 2.
A. Lateral view of siphon - *Ae. fulvus pallens*
B. Lateral view of siphon - *Ae. tormentor*

3(2'). Siphonal tuft 1-S attached within pecten (Fig. 3a)..................................***Ae. tormentor***
3'. Siphonal tuft l-S attached distal to pecten (Fig. 3b)..4

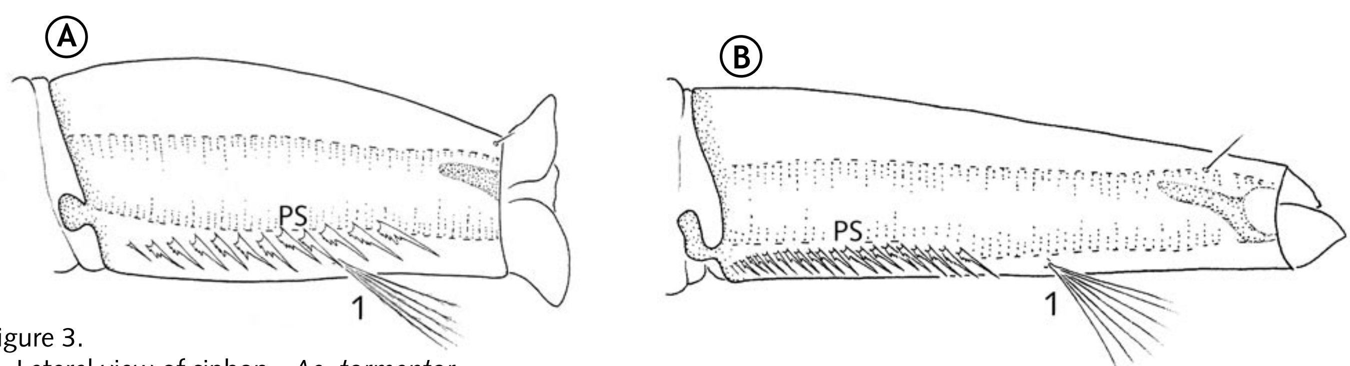


Figure 3.
A. Lateral view of siphon - *Ae. tormentor*
B. Lateral view of siphon - *Ae. mitchellae*

4(3'). Comb scale with apical spine at least four times the length of subapical spinules (Fig. 4a); thoracic integument smooth (Fig. 4b)........5

4'. Comb scale with apical spine not more than three times length of subapical spinules or fringed with subequal spinules (Fig. 4c); thoracic integument usually aculeate (Fig. 4d)........8

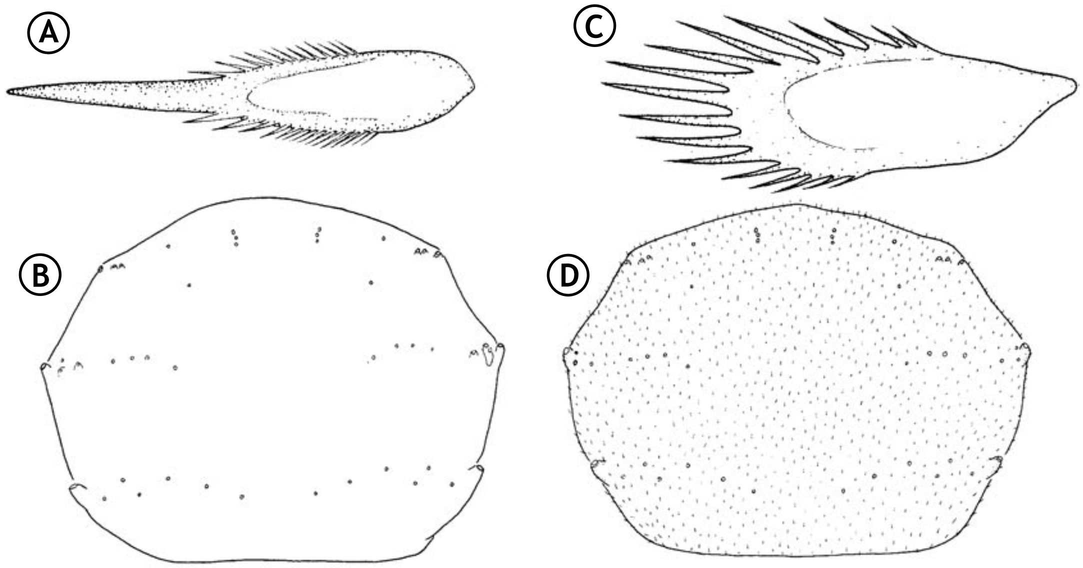


Figure 4.
A. Comb scale - *Ae. atlanticus*
B. Dorsal view of thorax - *Ae. sollicitans*
C. Comb scale - *Ae. taeniorhynchus*
D. Dorsal view of thorax - *Ae. taeniorhynchus*

5(4). Anal papilla-saddle index at least 8.0; papilla with darkly pigmented tracheae; seta 2-X with two or three branches (Fig. 5a)........***Ae. dupreei***

5'. Anal papilla-saddle index 5.0 at most, usually much less, papilla lacking dark tracheae; seta 2-X with four or more branches (Fig. 4b)........6

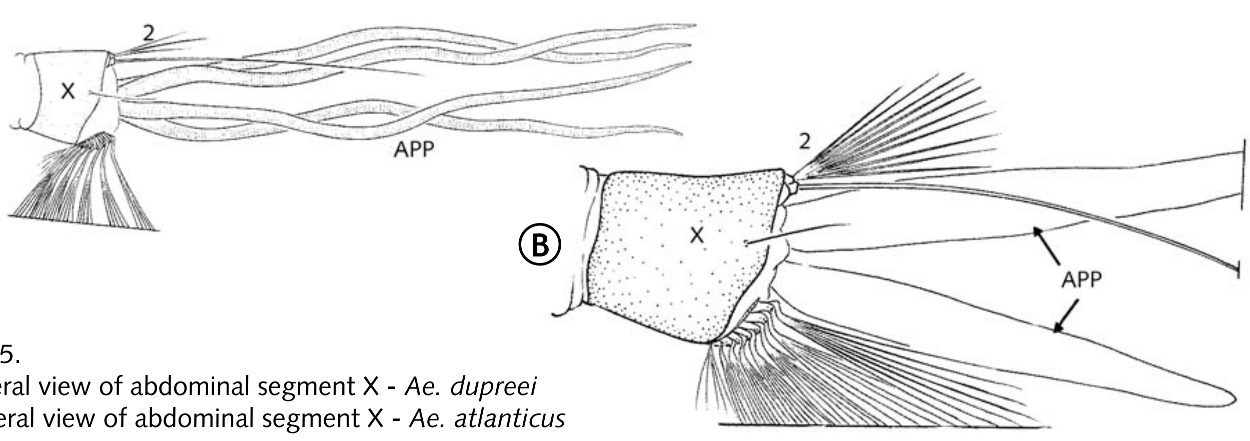
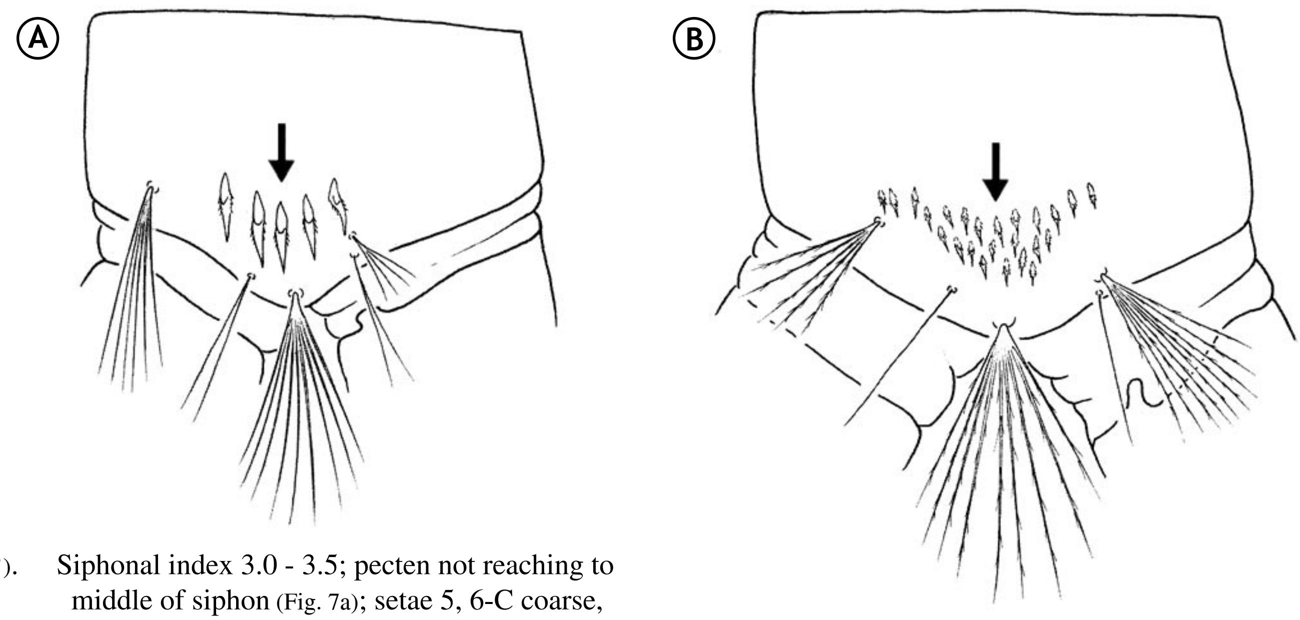


Figure 5.
A. Lateral view of abdominal segment X - *Ae. dupreei*
B. Lateral view of abdominal segment X - *Ae. atlanticus*

6(5'). Four to nine large comb scales on abdominal segment VIII (Fig. 6a)..***Ae. atlanticus***

6'. Comb scales on segment VIII small, usually number 10-30 (Fig. 6b)..7

Figure 6.
A. Lateral view of abdominal segment VIII - *Ae. atlanticus*
B. Lateral view of abdominal segment VIII - *Ae. sollicitans*



7(6'). Siphonal index 3.0 - 3.5; pecten not reaching to middle of siphon (Fig. 7a); setae 5, 6-C coarse, uniform in diameter (Fig. 7b)..***Ae. mitchellae***

7'. Siphonal index 2.0 - 2.5; pecten extending beyond midpoint of siphon (Fig. 7c); setae 5, 6-C fine, becoming more slender toward tip (Fig. 7d)..***Ae. sollicitans***

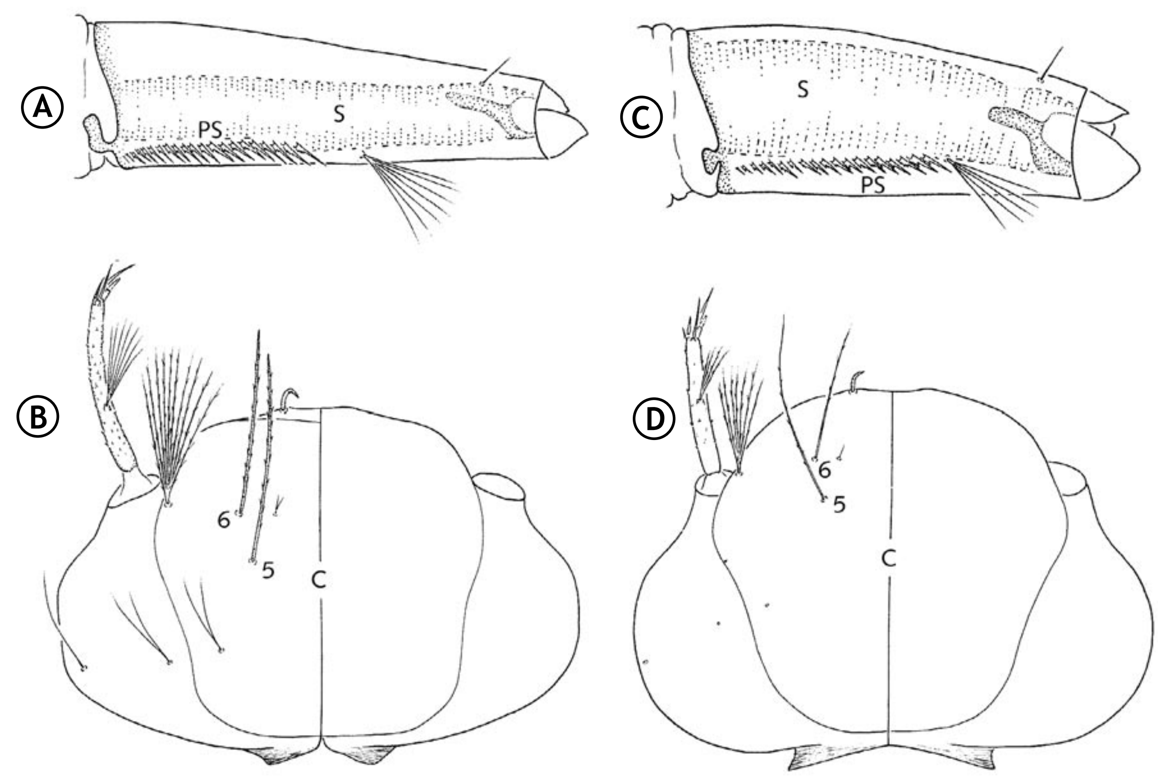


Figure 7.
A. Lateral view of siphon - *Ae. mitchellae*
B. Dorsal view of head - *Ae. mitchellae*
C. Lateral view of siphon - *Ae. sollicitans*
D. Dorsal view of head - *Ae. sollicitans*

8(4'). Comb scale with apical spine slightly smaller than subapical spinules, or only slightly stouter and longer (Fig. 8a)..***Ae. taeniorhynchus***

8'. Comb scale with apical spine one to three times the length of subapical spinules (Fig. 8b)..9

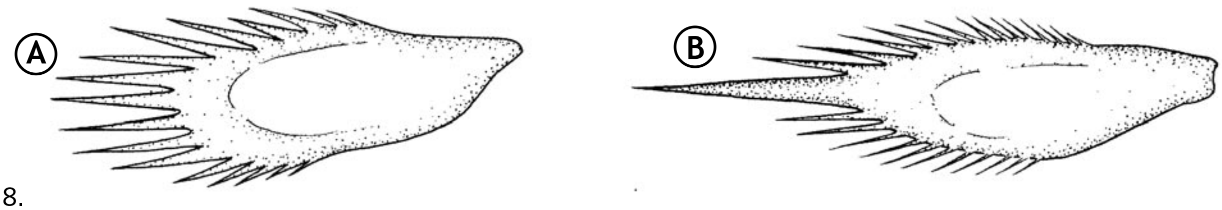


Figure 8.
A. Comb scale - *Ae. taeniorhynchus*
B. Comb scale - *Ae. infirmatus*

9(8'). Comb scale with median spine three to four times the width and at least twice the length of subapical spinules (Fig. 9a); head hair 7 extends past point of insertion of antennal tuft (Fig. 9b)..***Ae. infirmatus***

9'. Comb scale with median spine about twice as wide and 1.3 times as long as the subapical spinules (Fig. 9c); head hair 7 does not extend past base of antennal tuft (Fig. 9d)..***Ae. trivittatus***

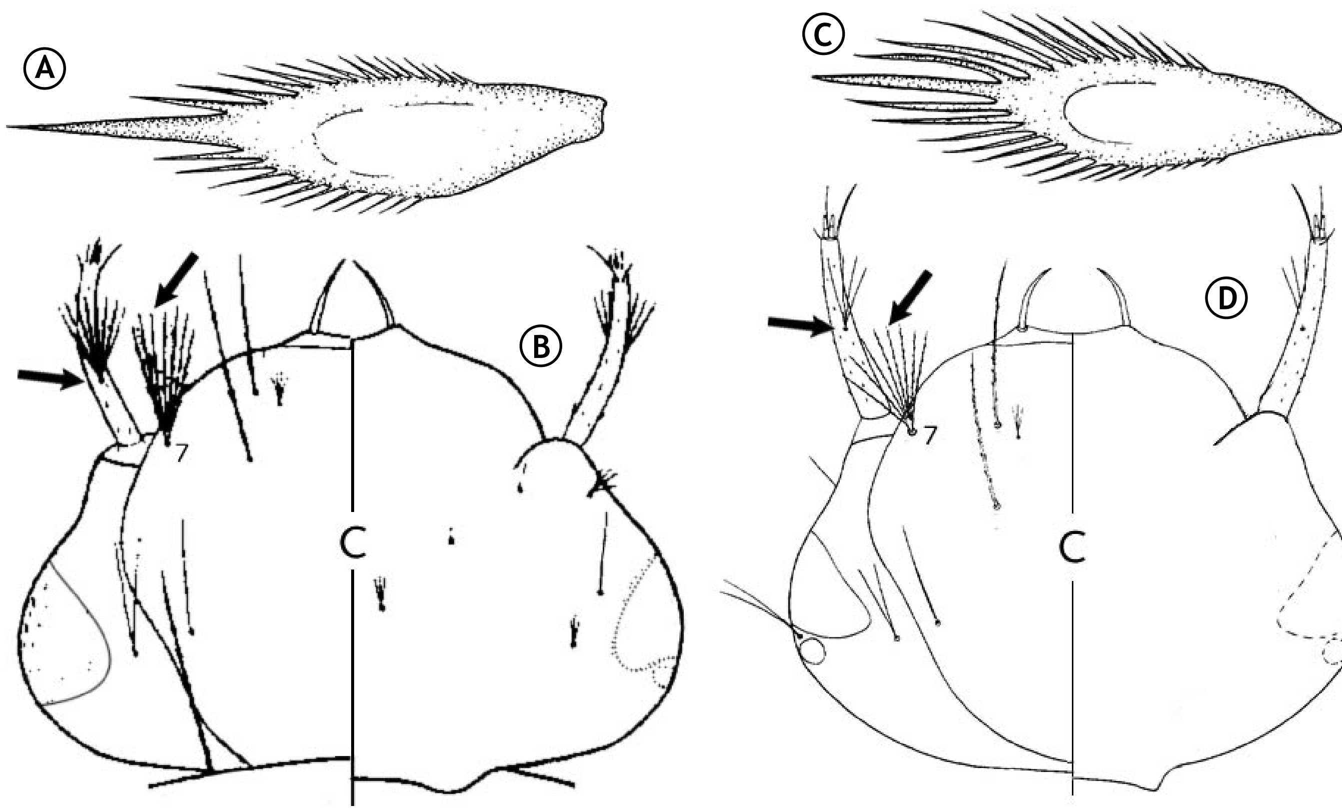
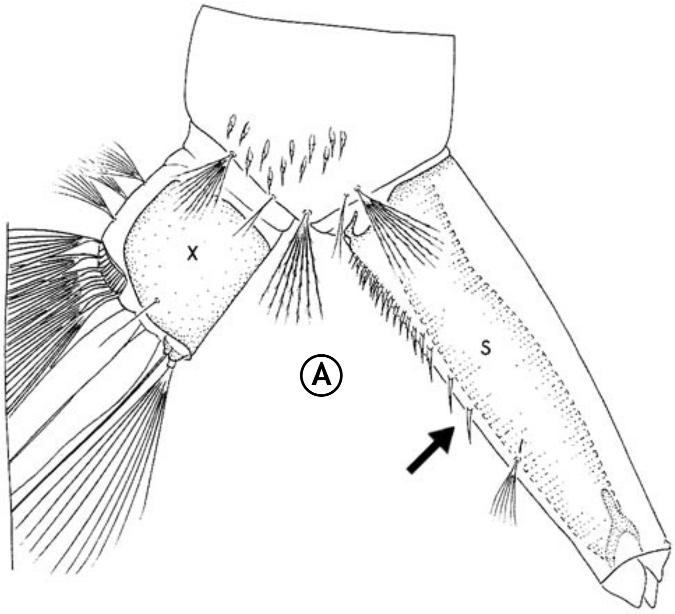


Figure 9.
A. Comb scale - *Ae. infirmatus*
B. Dorsal/ventral view of head - *Ae. infirmatus*
C. Comb scale - *Ae. trivittatus*
D. Dorsal/ventral view of head - *Ae. trivittatus*

10(1'). Pecten on siphon with one or more spines detached distally (Fig. 10a)........11

10'. Pecten with spines more or less evenly spaced (Fig. 10b)........13



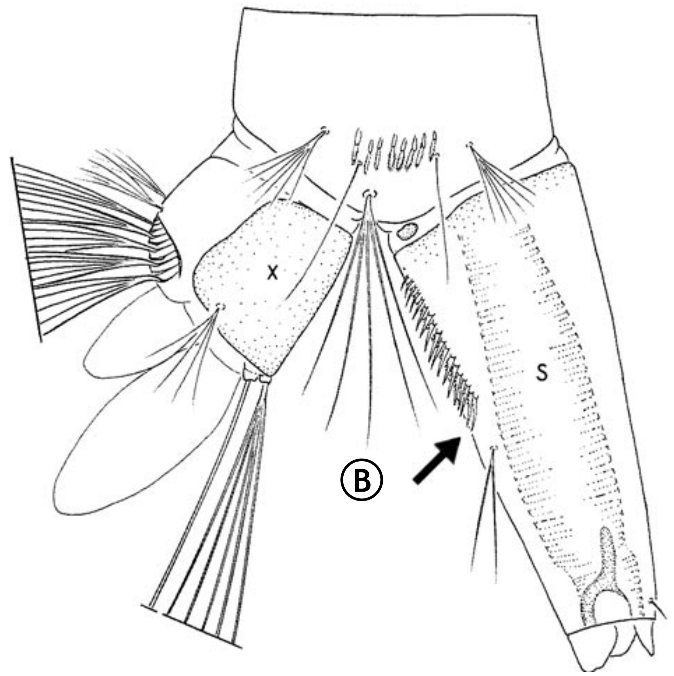
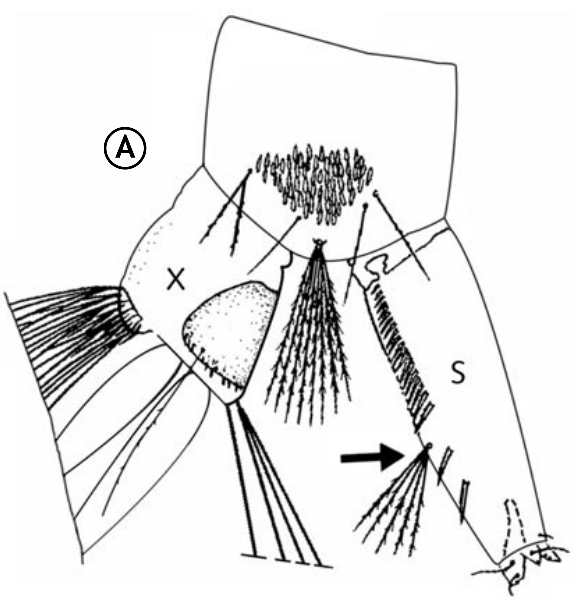


Figure 10.
A. Lateral view of abdominal segments VIII-X - *Ae. vexans*
B. Lateral view of abdominal segments VIII-X - *Ae. triseriatus*

11(10). Siphonal tuft 1-S inserted within pecten row (Fig. 11a)........***Ae. japonicus***

11'. Siphonal tuft 1-S inserted distal to pecten row (Fig. 11b)........12



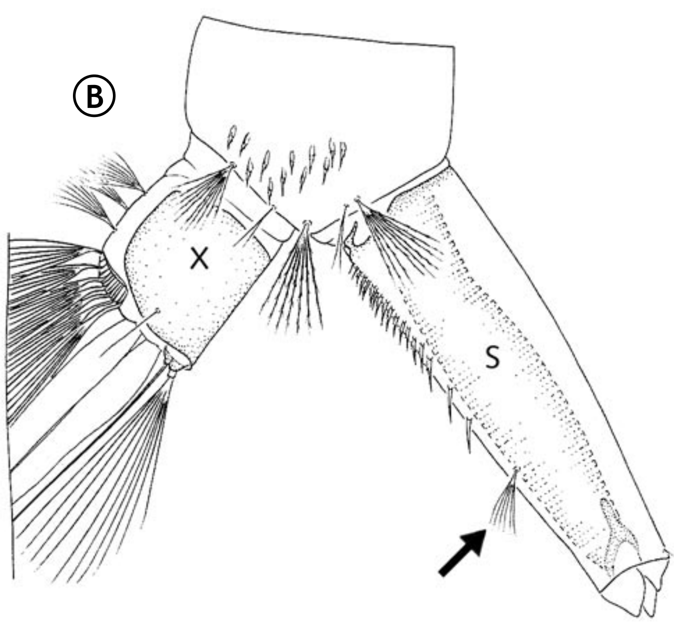
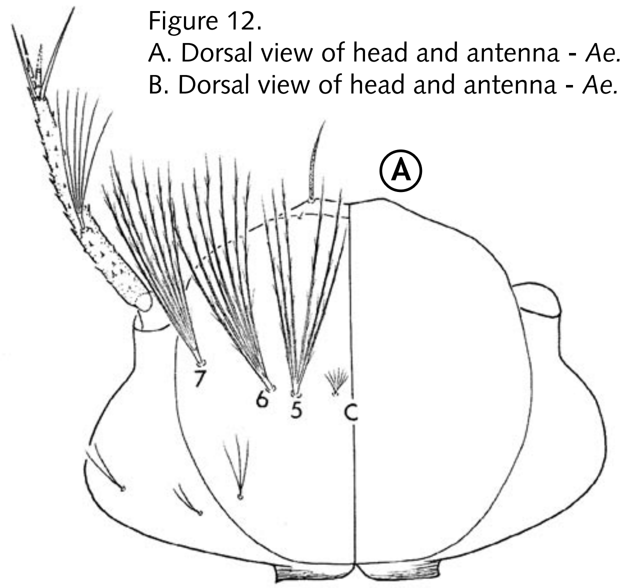


Figure 11.
A. Lateral view of abdominal segments VIII-X - *Ae. japonicus*
B. Lateral view of abdominal segments VIII-X - *Ae. vexans*

12(11’). Lower frontal head hair 6-C with four to eight branches; head hairs 5, 6, and 7 inserted in a straight line (Fig. 12a)..*Ae. cinereus*

12’. Lower frontal head hair 6-C double or triple; hairs 5, 6, and 7 not inserted in a straight line (Fig. 12b)..*Ae. vexans*



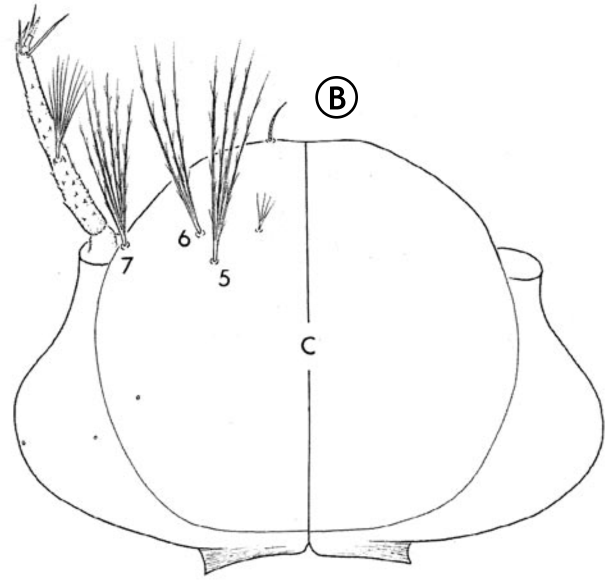
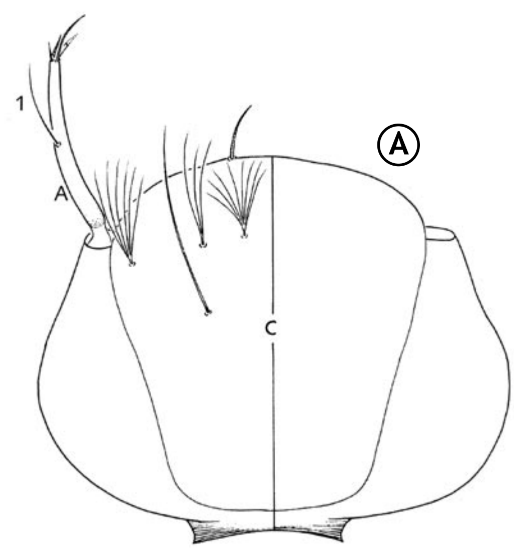


Figure 12.
A. Dorsal view of head and antenna - *Ae. cinereus*
B. Dorsal view of head and antenna - *Ae. vexans*

13(10’). Antenna usually smooth, or with tiny spinules; antennal tuft 1-A single or double (Fig. 13a)..14

13’. Antenna with prominent, coarse spinules; antennal tuft 1-A with more than three branches (Fig. 13b)...17



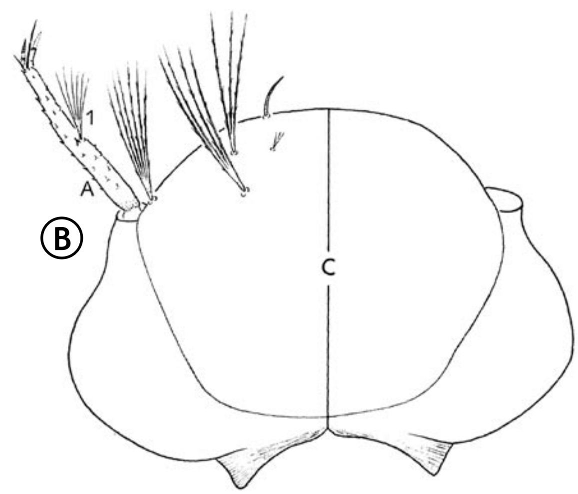


Figure 13.
A. Dorsal view of head and antenna - *Ae. triseriatus*
B. Dorsal view of head and antenna - *Ae. sticticus*

14(13). Comb scale with pointed, unfringed, median spine with shorter spinules (Fig. 14a)..15

14’. Comb scale rather blunt apically, evenly fringed (Fig. 14b)..16

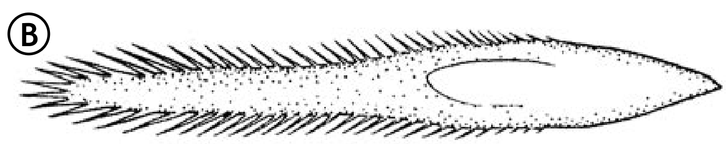


Figure 14.
A. Comb scale - *Ae. aegypti*
B. Comb scale - *Ae. triseriatus*

15(14). Comb scales with strong subapical spines (Fig. 15a); setal support plate of meso- and metathoracic setae 9-12 with prominent spine (Fig. 15b); seta 7-C single (Fig. 15c)..***Ae. aegypti***

15'. Comb scales with basolateral fringe of fine spinules (Fig. 15d); setal support plate of meso- and metathoracic setae 9-12 with short thin spine (Fig. 15e); seta 7-C double (Fig. 15f)..***Ae. albopictus***

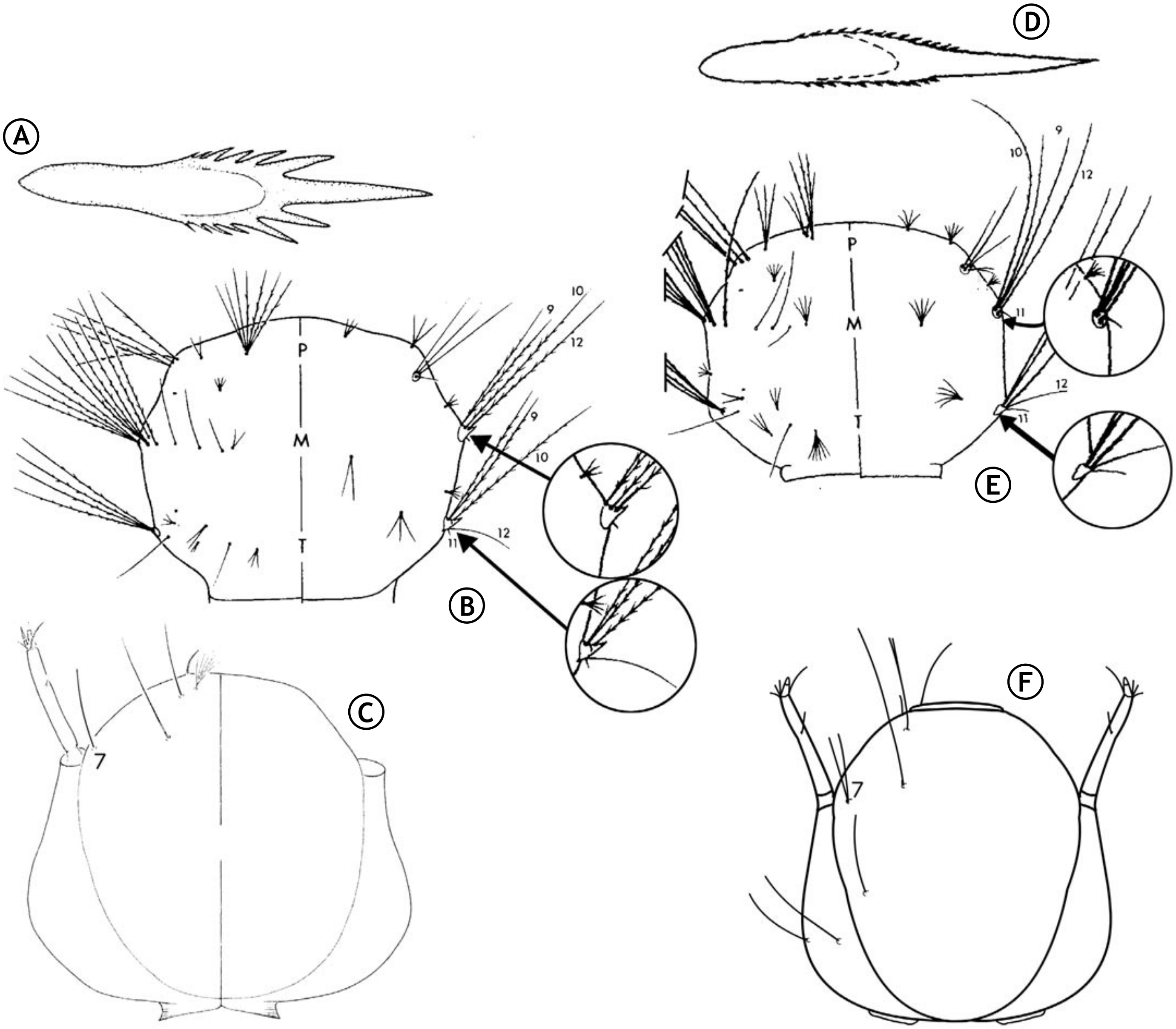


Figure 15.
A. Comb scale - *Ae. aegypti*
B. Dorsal/ventral view of thorax - *Ae. aegypti*
C. Dorsal/ventral view of head - *Ae. aegypti*
D. Comb scale - *Ae. albopictus*
E. Dorsal/ventral view of thorax - *Ae. albopictus*
F. Dorsal/ventral view of head - *Ae. albopictus*

16(14'). Seta 4-X with six pairs of fanlike setae; anal papillae not bulbous, dorsal pair longer than ventral pair (Fig. 16a); acus usually attached to siphon, if detached, situated close to its base (Fig. 16b)..***Ae. triseriatus***

16'. Seta 4-X with five pairs of fanlike setae; both pairs of anal papillae about same length, bulbous (Fig. 16c); acus detached and removed from base of siphon (Fig. 16d)..***Ae. hendersoni***

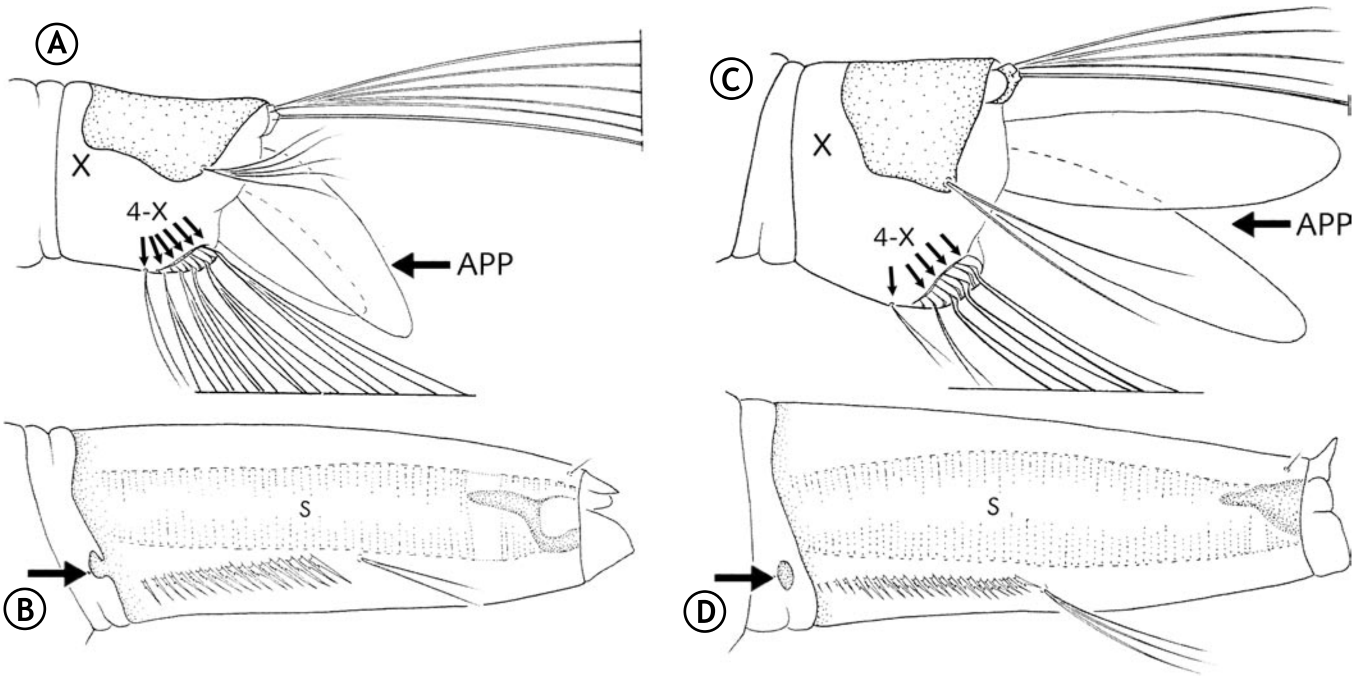


Figure 16.
A. Lateral view of abdominal segment X - *Ae. triseriatus*
B. Lateral view of siphon - *Ae. triseriatus*
C. Lateral view of abdominal segment X - *Ae. hendersoni*
D. Lateral view of siphon - *Ae. hendersoni*

17(13'). Comb scale with median spine at least 1.5 times the length of subapical spinules (Fig. 17a)...***Ae. sticticus***

17'. Comb scale fringed with subequal spinules or with short median spine less than 1.5 times the length of subapical spinules (Fig. 17b)...18

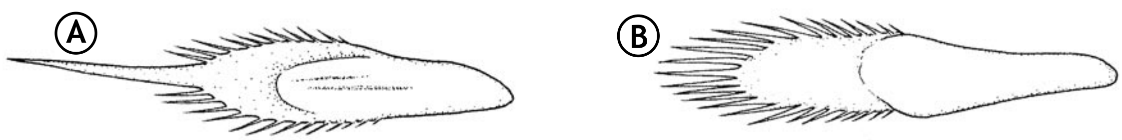


Figure 17.
A. Comb scale - *Ae. sticticus*
B. Comb scale - *Ae. c. canadensis*

18(17'). Comb scale fringed with subequal spinules (Fig. 18a);
seta 6 on abdominal terga I and II double (Fig. 18b)..***Ae. canadensis***

18'. Comb scale with apical and subapical spines much stouter
than lateral spinules (Fig. 18c); seta 6 on abdominal terga
I and II three- or four-branched (Fig. 18d)..***Ae. thibaulti***

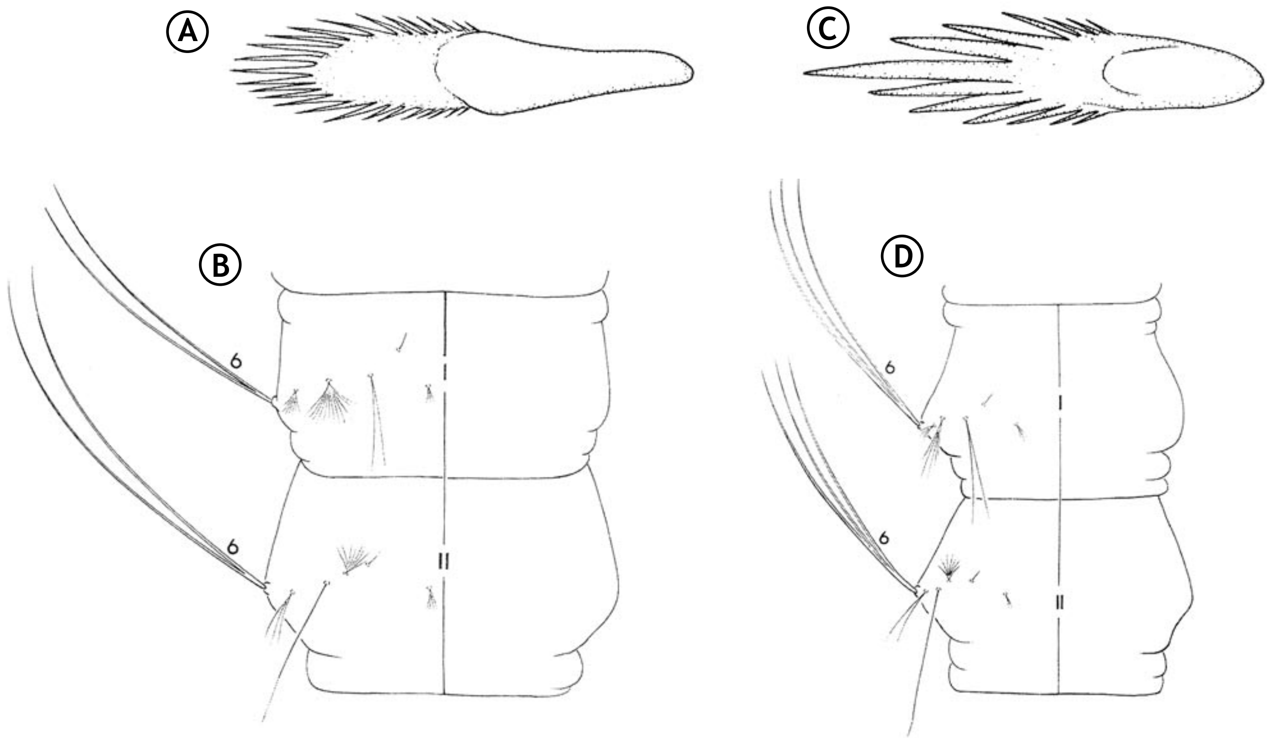


Figure 18.
A. Comb scale - *Ae. canadensis*
B. Dorsal view of abdominal segments I and II - *Ae. canadensis*
C. Comb scale - *Ae. thibaulti*
D. Dorsal view of abdominal segments I and II - *Ae. thibaulti*

Culex Larvae

1. Seta 6-C with three or more branches (Fig. 1a)........2
1'. Seta 6-C single or double (Fig. 1b)........7

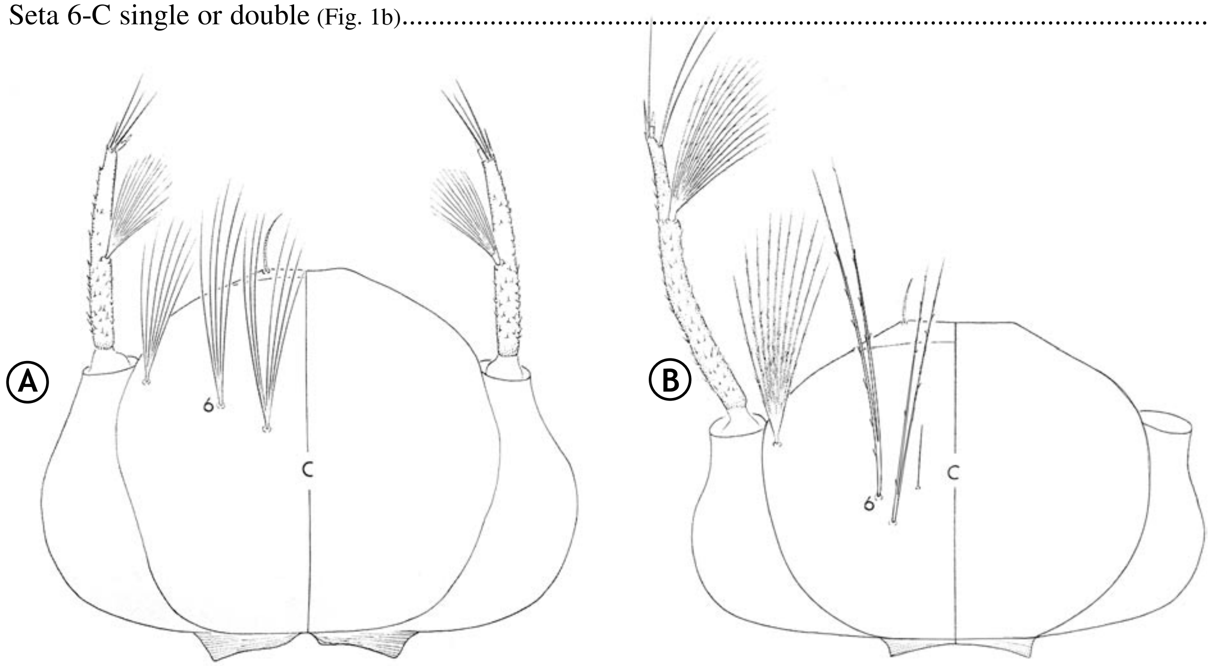


Figure 1.
A. Dorsal view of head - *Cx. restuans*
B. Dorsal view of head - *Cx. territans*

2(1). Siphonal setae long, irregularly placed, mostly single (Fig. 2a)........***Cx. restuans***
2'. Siphonal setae placed linearly, sometimes with one or two pairs dorsally out of line, mostly branched (Fig. 2b)........3

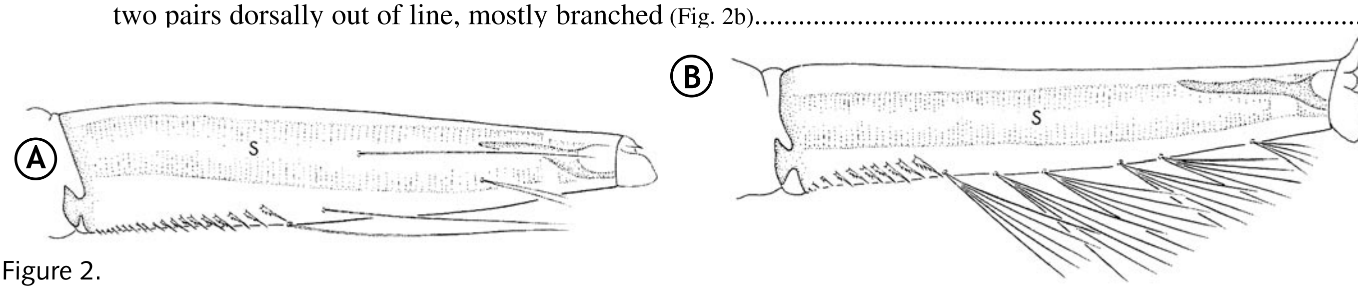


Figure 2.
A. Lateral view of siphon - *Cx. restuans*
B. Lateral view of siphon - *Cx. tarsalis*

3(2'). Siphon with setae in straight line, usually with five to nine pairs (Fig. 3a)........***Cx. tarsalis***
3'. Siphon with three to five pairs of setae not all in straight line, one or two pairs dorsally out of line (Fig. 3b)........4

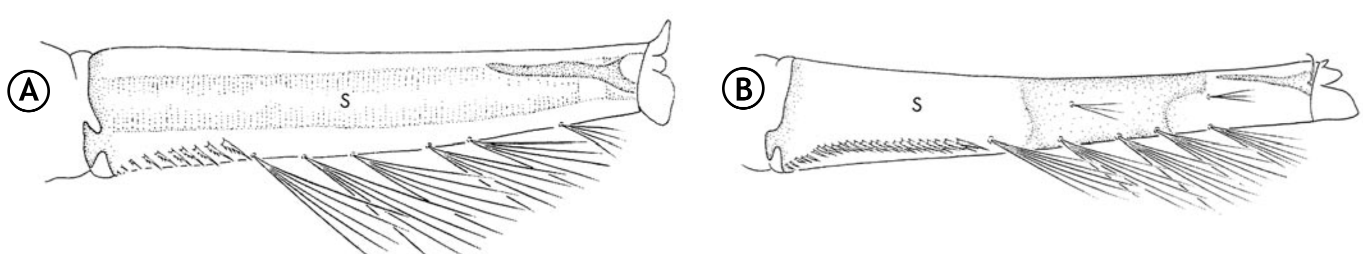
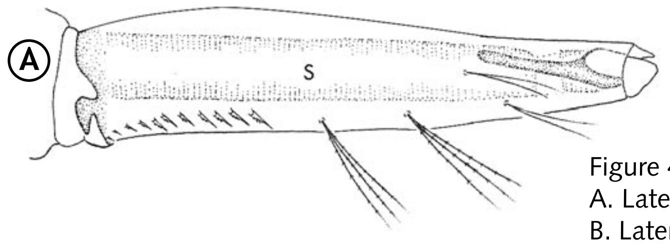


Figure 3.
A. Lateral view of siphon - *Cx. tarsalis*
B. Lateral view of siphon - *Cx. peccator*

4(3’). Siphonal index 4.0 - 5.0 (Fig. 4a)..*Cx. quinquefasciatus*
4’. Siphonal index 6.0 - 10.0 (Fig. 4b)..5



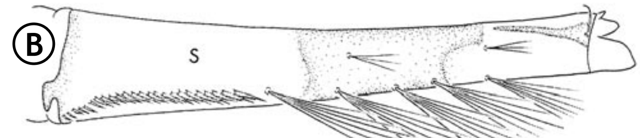


Figure 4.
A. Lateral view of siphon - *Cx. quinquefasciatus*
B. Lateral view of siphon - *Cx. peccator*

5(4’). Thoracic integument with fine aculeae; seta 1-M sub-
equal to 2-M (Fig. 5a); seta 1-X single (Fig. 5b)..*Cx. nigripalpus*
5’. Thoracic integument smooth; seta 1-M much longer
than 2-M (Fig. 5c); seta 1-X usually double (Fig. 5d)..6

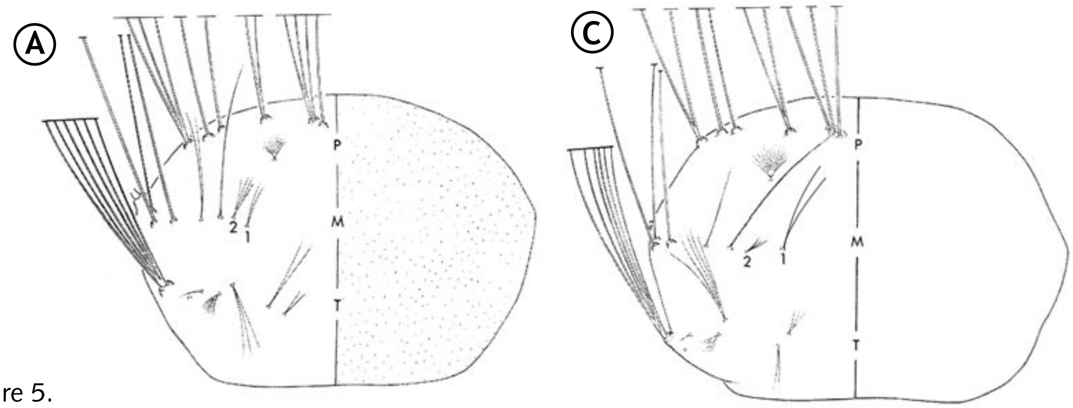
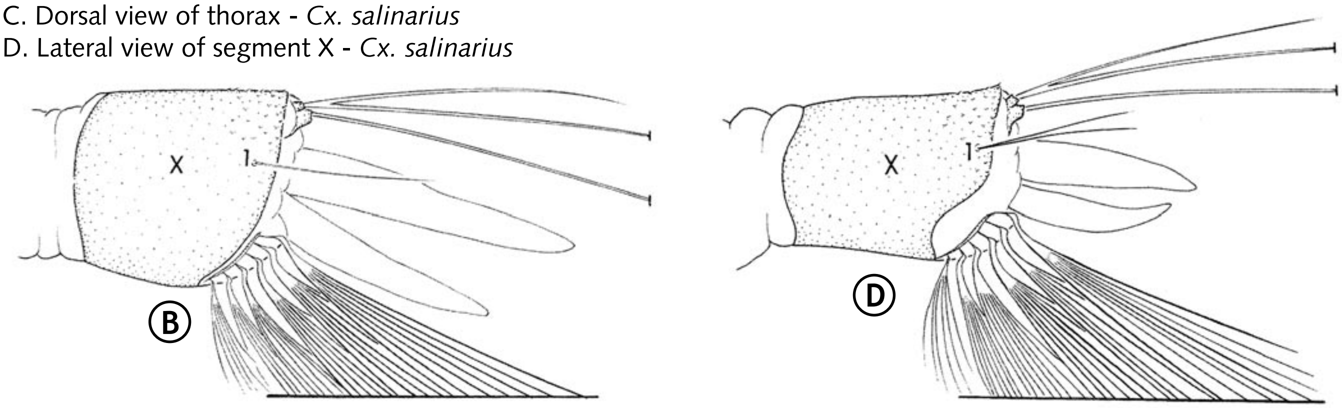
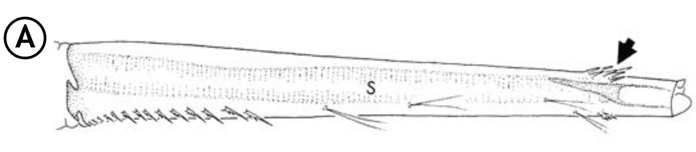


Figure 5.
A. Dorsal view of thorax - *Cx. nigripalpus*
B. Lateral view of segment X - *Cx. nigripalpus*
C. Dorsal view of thorax - *Cx. salinarius*
D. Lateral view of segment X - *Cx. salinarius*



6(5’). Siphon with strong subapical spines (Fig. 6a)..*Cx. coronator*
6’. Siphon lacking strong subapical spines (Fig. 6b)...*Cx. salinarius*



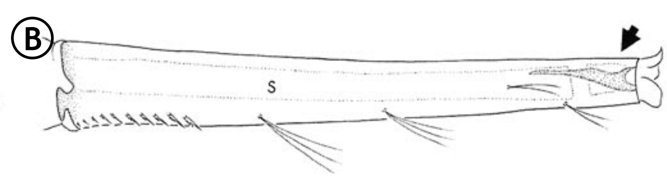


Figure 6.
A. Lateral view of siphon - *Cx. coronator*
B. Lateral view of siphon - *Cx. salinarius*

7(1’). Siphon distinctly curved; siphonal index 4.5 or less; distalmost seta very near apex (Fig. 7a)..***Cx. pilosus***

7’. Siphon only slightly curved, if at all; siphonal index 6.0 or more; distalmost seta not near apex (Fig. 7b)..8

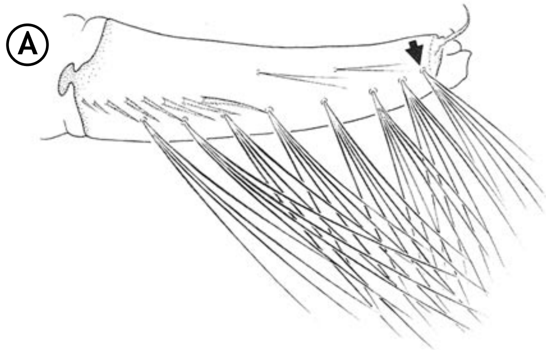
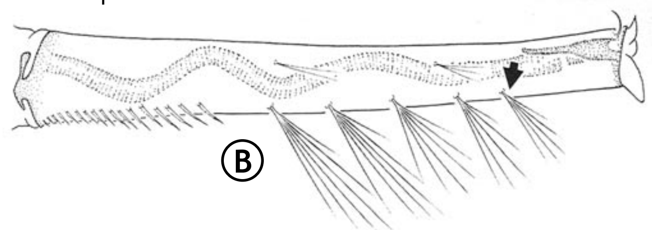


Figure 7.
A. Lateral view of siphon - *Cx. pilosus*
B. Lateral view of siphon - *Cx. erraticus*



8(7’). Comb scales with large median spine, fringed by short spinules (Fig. 8a)..***Cx. erraticus***

8’. Comb scales evenly fringed with short spinules (Fig. 8b)..9

Figure 8.
A. Comb scale - *Cx. erraticus*
B. Comb scale - *Cx. peccator*

9(8’). Siphon with dark band just beyond midpoint, siphonal seta 2-S sharply curved (Fig. 9a)..***Cx. peccator***

9’. Siphon without dark band, siphonal seta 2-S not sharply curved (Fig. 9b)..***Cx. territans***

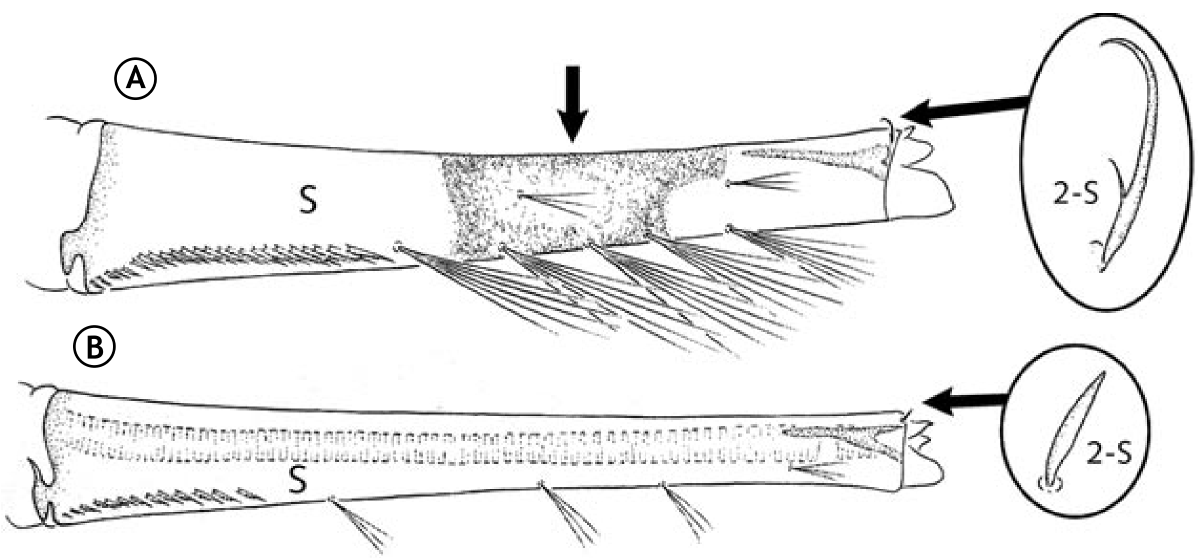


Figure 9.
A. Lateral view of siphon - *Cx. peccator*
B. Lateral view of siphon - *Cx. territans*

Psorophora Larvae

1. Pecten teeth numerous (12 or more), each terminating in a hairlike filament; siphonal tuft 1-S represented by a single long hair (Fig. 1a)........2

1'. Pecten teeth fewer than ten, not prolonged into hairlike filaments; siphonal tuft 1-S multiple, large, small, or apparently absent (Fig. 1b)........3

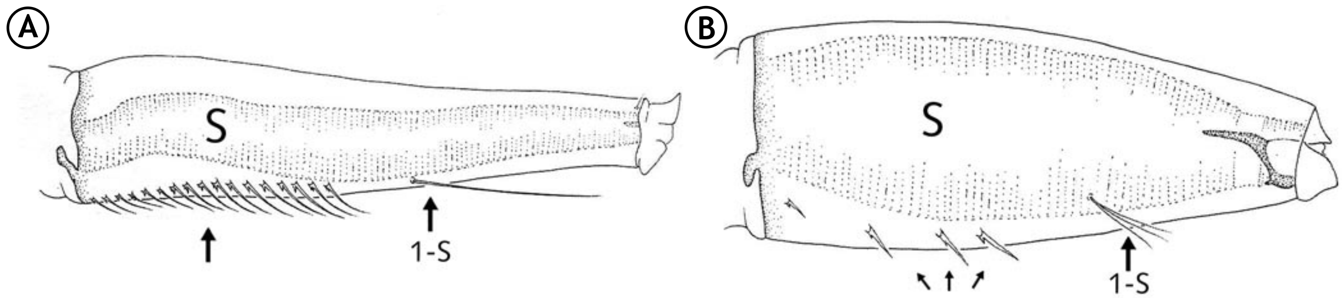


Figure 1.
A. Lateral view of siphon - *Ps. howardii*
B. Lateral view of siphon - *Ps. columbiae*

2(1). Seta 1-X divides near the base into three or four branches (Fig. 2a)........***Ps. ciliata***

2'. Seta 1-X single or forked beyond middle (Fig. 2b)........***Ps. howardii***

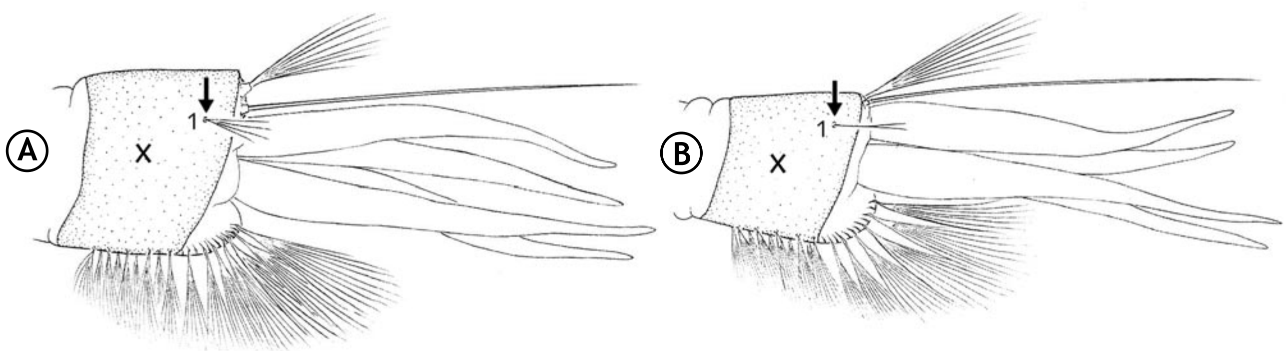


Figure 2.
A. Lateral view of abdominal segment X - *Ps. ciliata*
B. Lateral view of abdominal segment X - *Ps. howardii*

3(1'). Siphonal tuft 1-S large, as long as the siphon; siphon small, not in ated (Fig. 3a); antennae in ated (Fig. 3b)..***Ps. discolor***

3'. Siphonal tuft 1-S small or apparently absent; siphon large, more or less in ated medially (Fig. 3c); antennae not in ated (Fig. 3d)..4

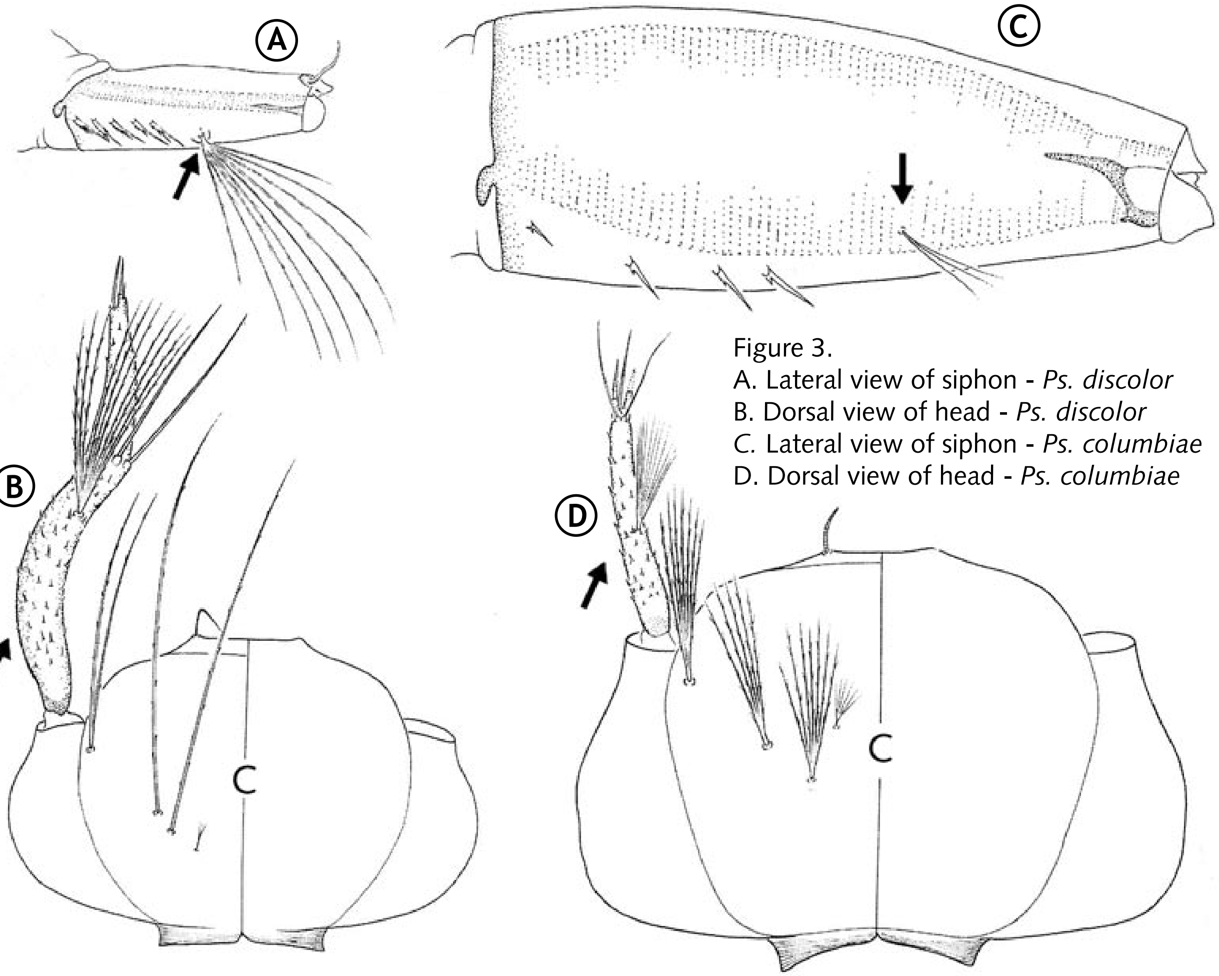


Figure 3.
A. Lateral view of siphon - *Ps. discolor*
B. Dorsal view of head - *Ps. discolor*
C. Lateral view of siphon - *Ps. columbiae*
D. Dorsal view of head - *Ps. columbiae*

4(3'). Upper and lower frontal head hairs 5 and 6 multiple (Fig. 4a)..***Ps. columbiae***

4'. Upper frontal head hair 5 single or double (rarely triple); lower frontal head hair 6 single, double or triple (Fig. 4b)..5

Figure 4.
A. Dorsal view of head - *Ps. columbiae*
B. Dorsal view of head - *Ps. cyanescens*

5(4'). Upper frontal head hair 5 and lower frontal hair 6 long and single (Fig. 5a)..*Ps. cyanescens*

5'. Upper frontal head hair 5 double, lower frontal hair 6 double or triple (Fig. 5b)..6

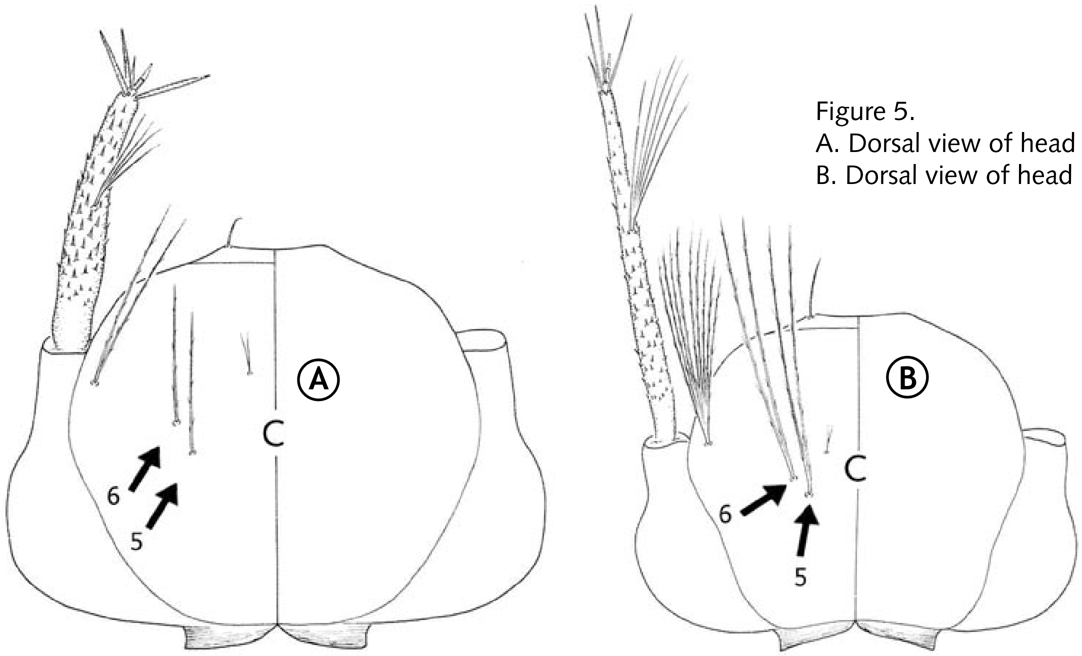


Figure 5.
A. Dorsal view of head - *Ps. cyanescens*
B. Dorsal view of head - *Ps. ferox*

6(5'). Antennae distinctly longer than the median length of the head (Fig. 6a)..7

6'. Antennae about as long or slightly longer than the median length of the head (Fig. 6b)..8

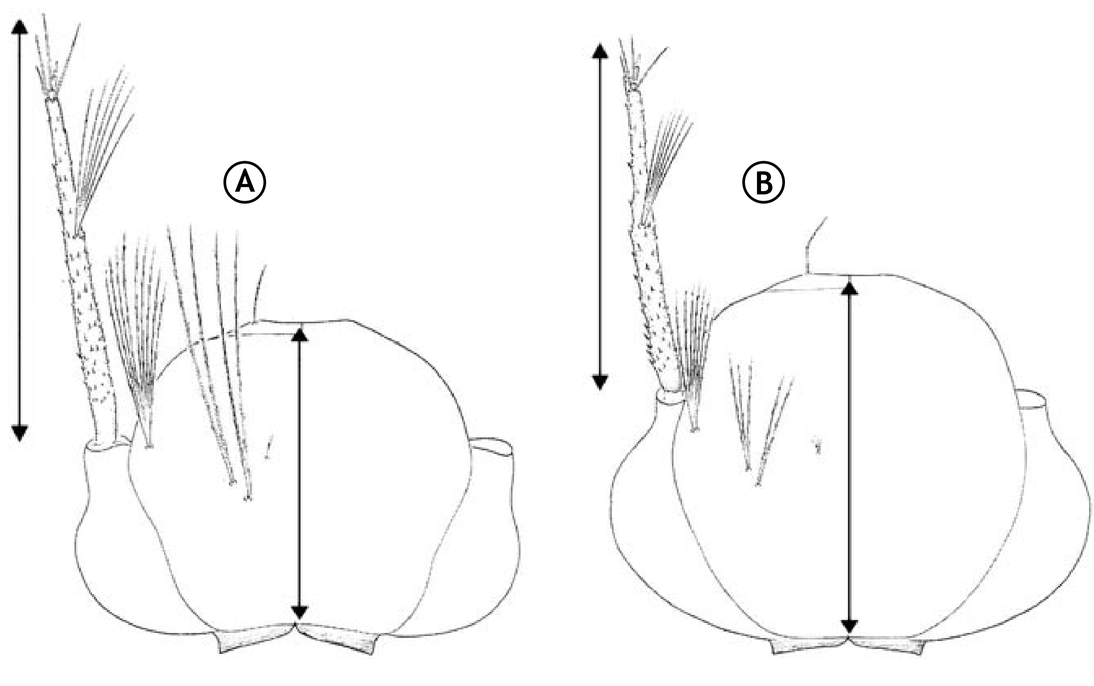


Figure 6.
A. Dorsal view of head - *Ps. ferox*
B. Dorsal view of head - *Ps. horrida*

7(6). Lateral abdominal hair 6 single or double on segments IV-VI (Fig. 7a); branches of upper frontal head hair 5 and lower frontal 6 nearly equal (Fig. 7b)..*Ps. ferox*

7'. Lateral abdominal hair 6 multiple on segments IV-VI (Fig. 7c); branches of upper frontal head hair 5 and lower frontal 6 not equal, one branch being shorter and weaker (Fig. 7d)..*Ps. longipalpus*

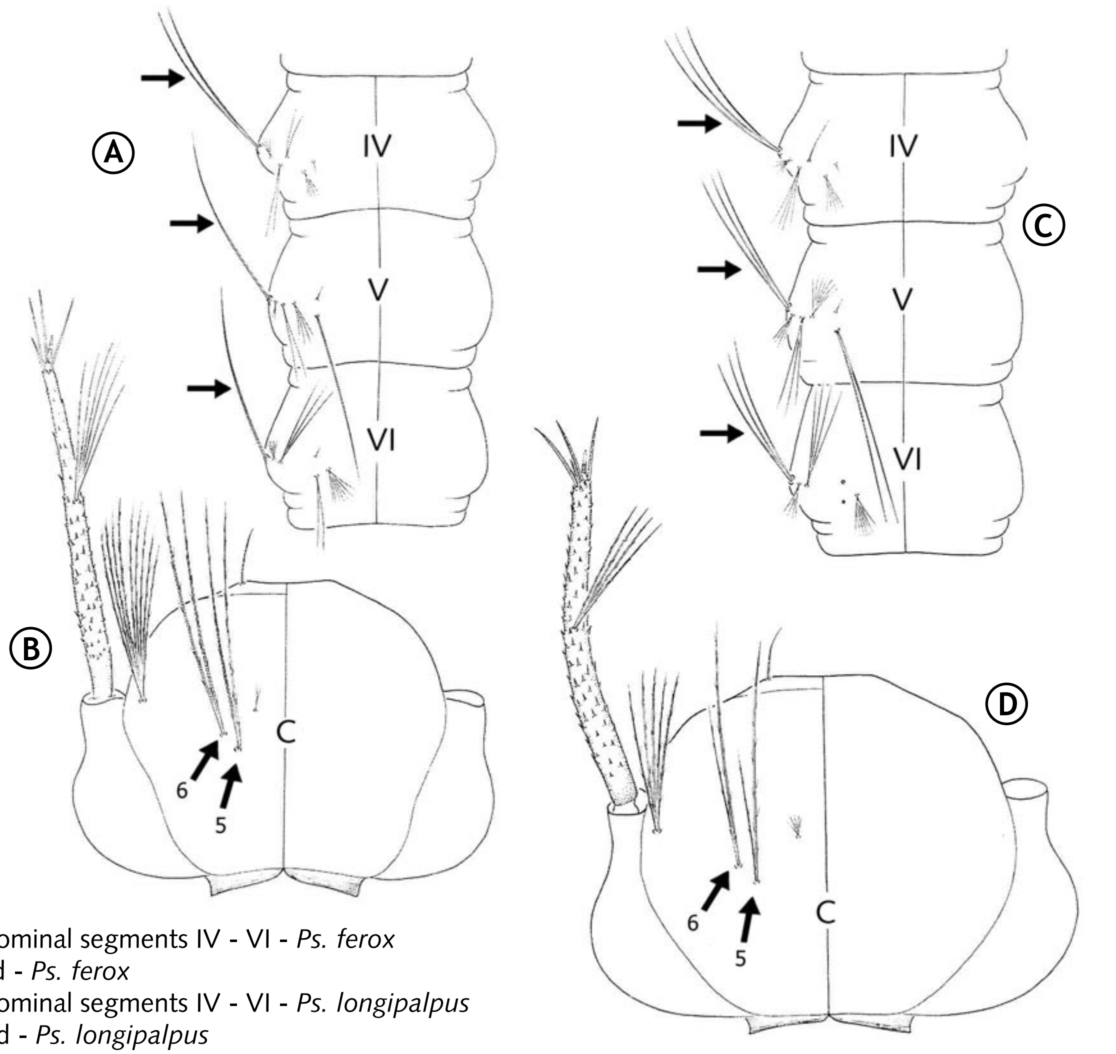


Figure 7.
A. Dorsal view of abdominal segments IV - VI - *Ps. ferox*
B. Dorsal view of head - *Ps. ferox*
C. Dorsal view of abdominal segments IV - VI - *Ps. longipalpus*
D. Dorsal view of head - *Ps. longipalpus*

8(6'). Siphon only slightly in ated (Fig. 8a)..*Ps. mathesoni*

8'. Siphon strongly in ated (Fig. 8b)..9

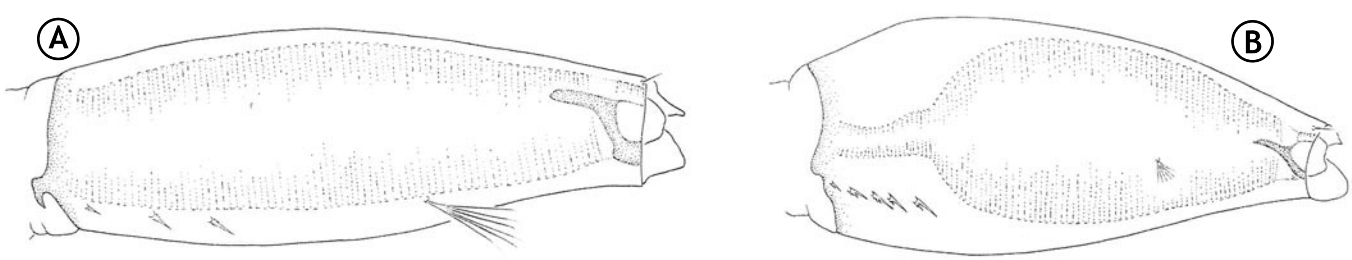


Figure 8.
A. Lateral view of siphon - *Ps. mathesoni*
B. Lateral view of siphon - *Ps. horrida*

9(8'). Siphonal index 3.5 or more, siphon with distinct subapical, narrowed part (Fig. 9a); abdominal segment X with seven or more fan-like setae attached on the anal saddle (Fig. 9b)..***Ps. horrida***

9'. Siphonal index 2.5 to 3.0, siphon without subapical, narrowed part (Fig. 9c); abdominal segment X with four to six fan-like setae attached on the anal saddle (Fig. 9d)..***Ps. johnstonii***

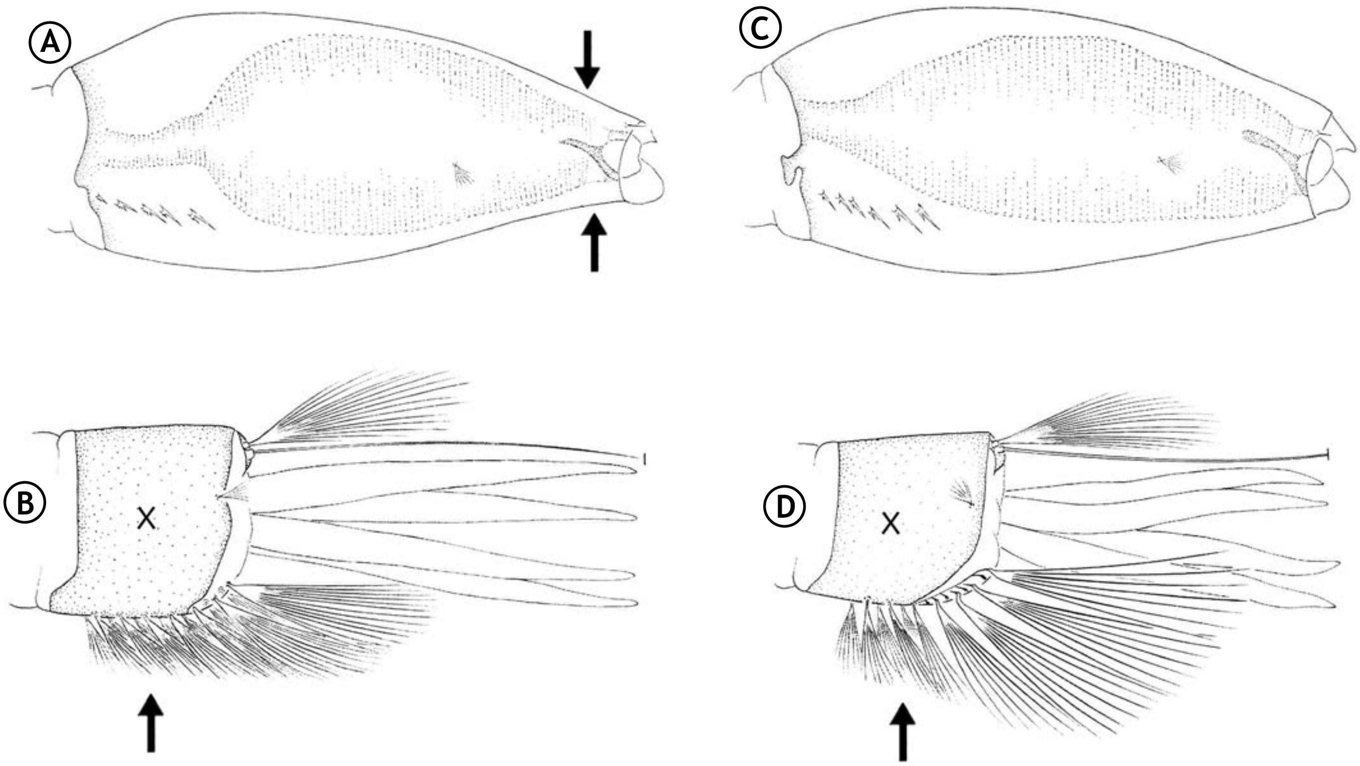
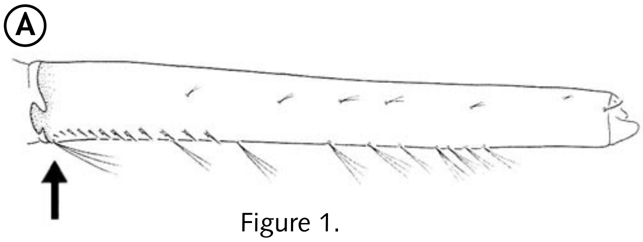


Figure 9.
A. Lateral view of siphon - *Ps. horrida*
B. Lateral view of abdominal segment X - *Ps. horrida*
C. Lateral view of siphon - *Ps. johnstonii*
D. Lateral view of abdominal segment X - *Ps. johnstonii*

Culiseta Larvae

1. Small two- to three-branched tuft inserted at base of siphon (Fig. 1a)....................................... ***Culiseta melanura***

1'. Siphonal tuft large, multiple, barbed, inserted within pecten (Fig. 1b)....................................... ***Culiseta inornata***



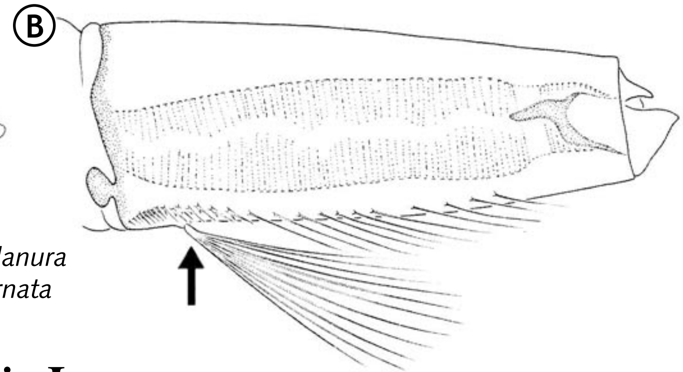
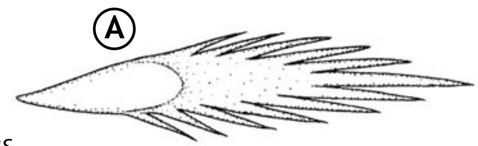


Figure 1.
A. Lateral view of siphon - *Cs. melanura*
B. Lateral view of siphon - *Cs. inornata*

Mansonia Larvae

1. Comb scale broad with several stout sub-equal spinules (Fig. 1a).. ***Mansonia dyari***

1'. Comb scale slender with single spine (Fig. 1b)... ***Mansonia titillans***



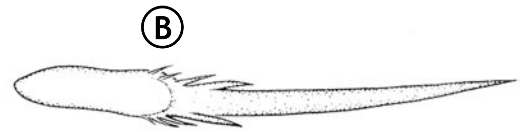
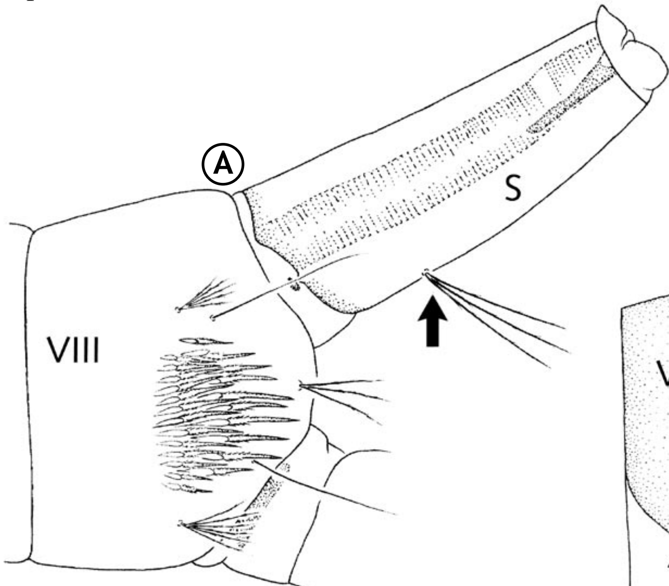


Figure 1.
A. Comb scale - *Ma. dyari*
B. Comb scale - *Ma. titillans*

Orthopodomyia Larvae

1. Siphonal tuft two- to four-branched and less than 0.75 as long as that part of the siphon beyond the tuft; abdominal segment VIII without a large dorsal sclerotized plate (Fig. 1a)... ***Orthopodomyia alba***

1'. Siphonal tuft with more than four branches and more than 0.75 as long as that part of the siphon beyond the tuft; abdominal segment VIII with large dorsal sclerotized plate (Fig. 1b)... ***Orthopodomyia signifera***



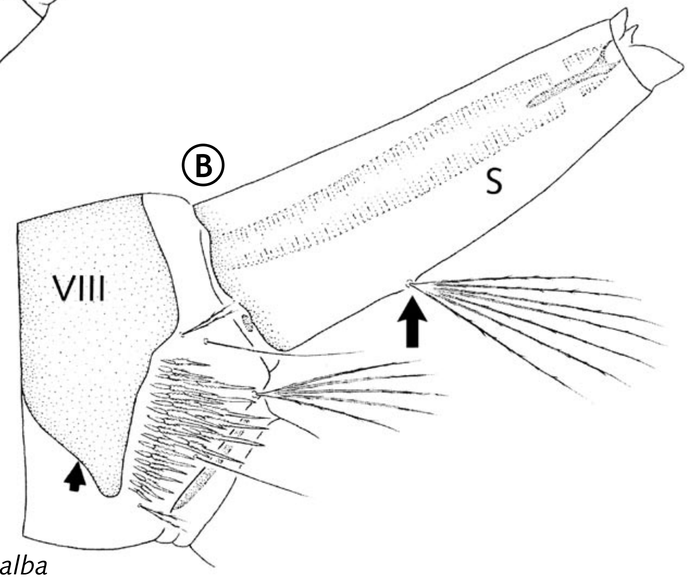


Figure 1.
A. Lateral view of siphon and abdominal segment VIII - *Or. alba*
B. Lateral view of siphon and abdominal segment VIII - *Or. signifera*

Uranotaenia Larvae

1. Seta 3-P four- to eight-branched, more than half as long as 1-P (Fig. 1a); seta 6 double on abdominal segments I and II (Fig. 1b)..***Uranotaenia lowii***

1’. Seta 3-P eight- to ten-branched, much less than half as long as 1-P (Fig. 1c); seta 6 triple on abdominal segments I and II (Fig. 1d)..***Uranotaenia sapphirina***

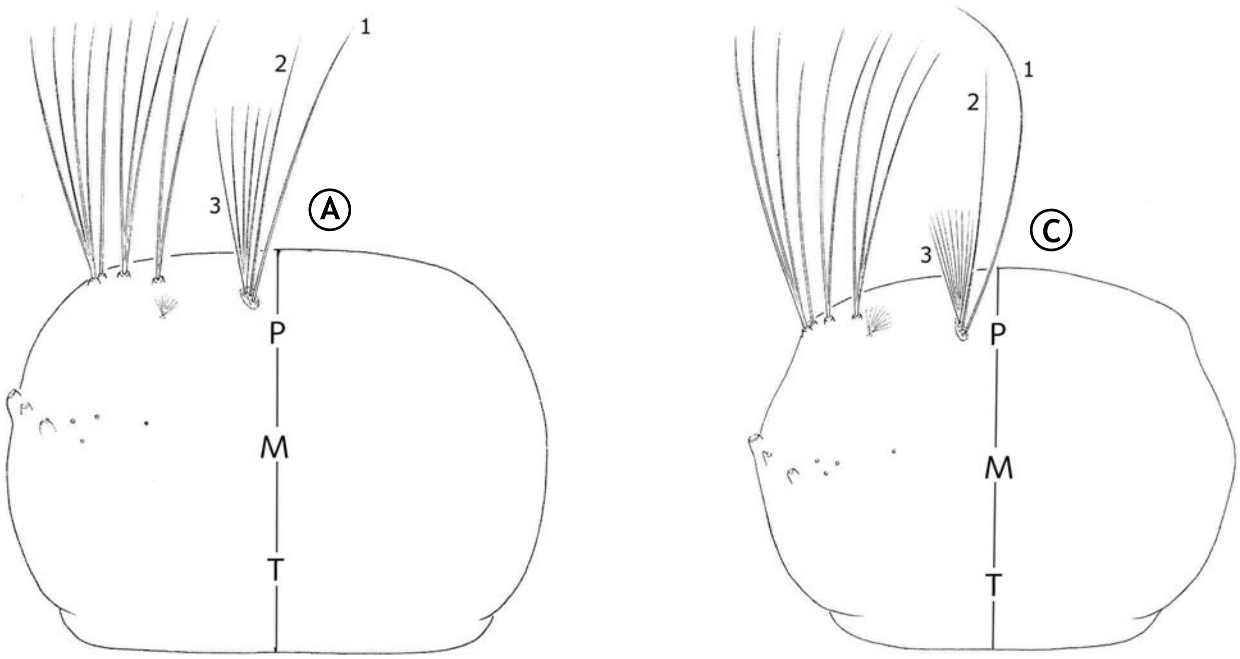
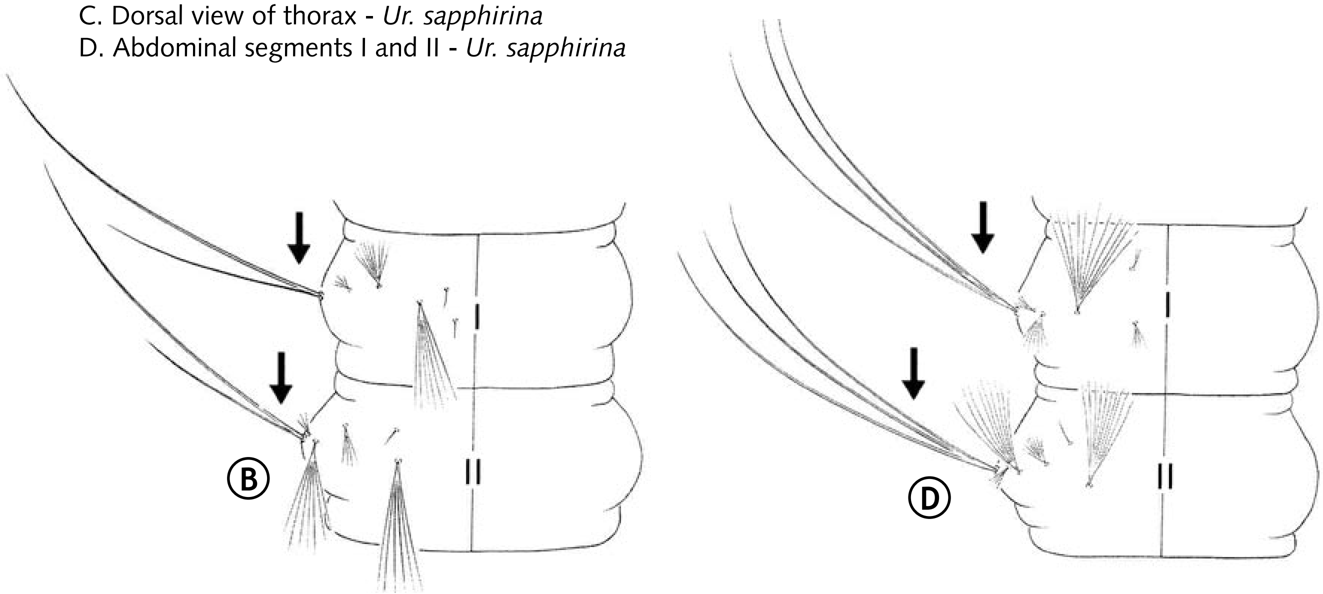
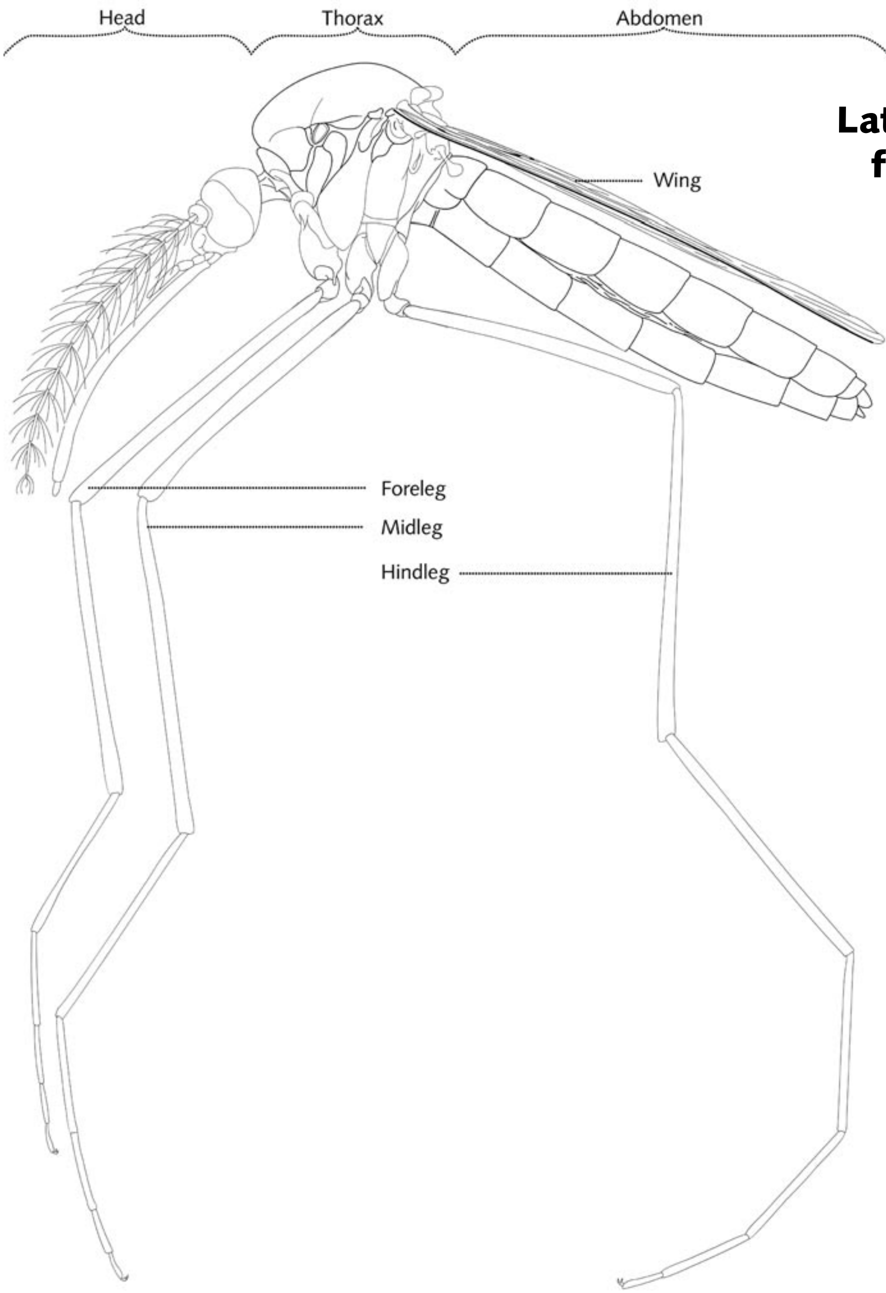
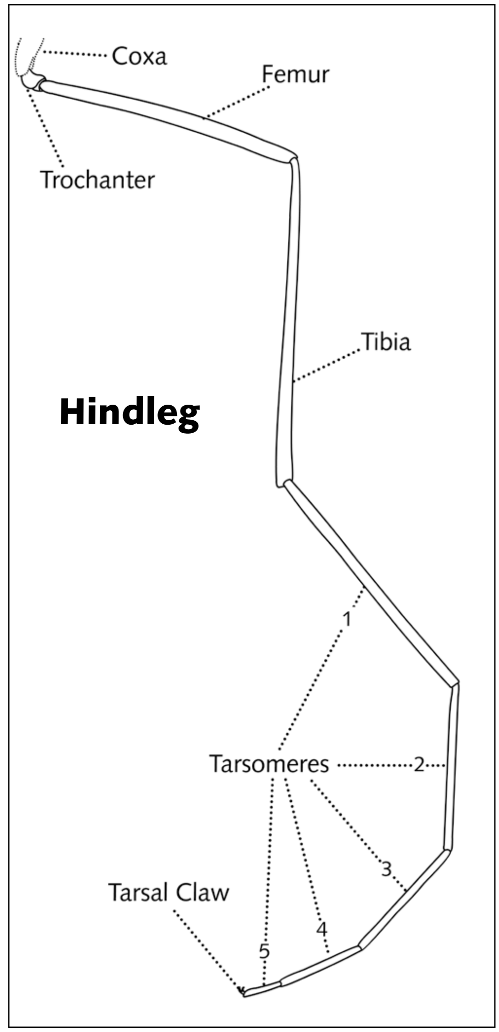


Figure 1.
A. Dorsal view of thorax - *Ur. lowii*
B. Abdominal segments I and II - *Ur. lowii*
C. Dorsal view of thorax - *Ur. sapphirina*
D. Abdominal segments I and II - *Ur. sapphirina*

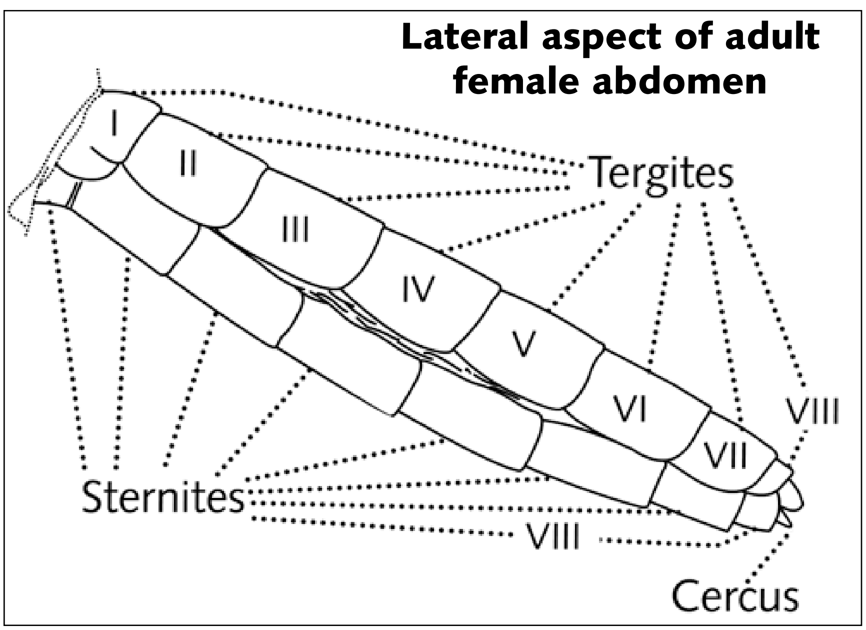


Lateral view of adult female mosquito



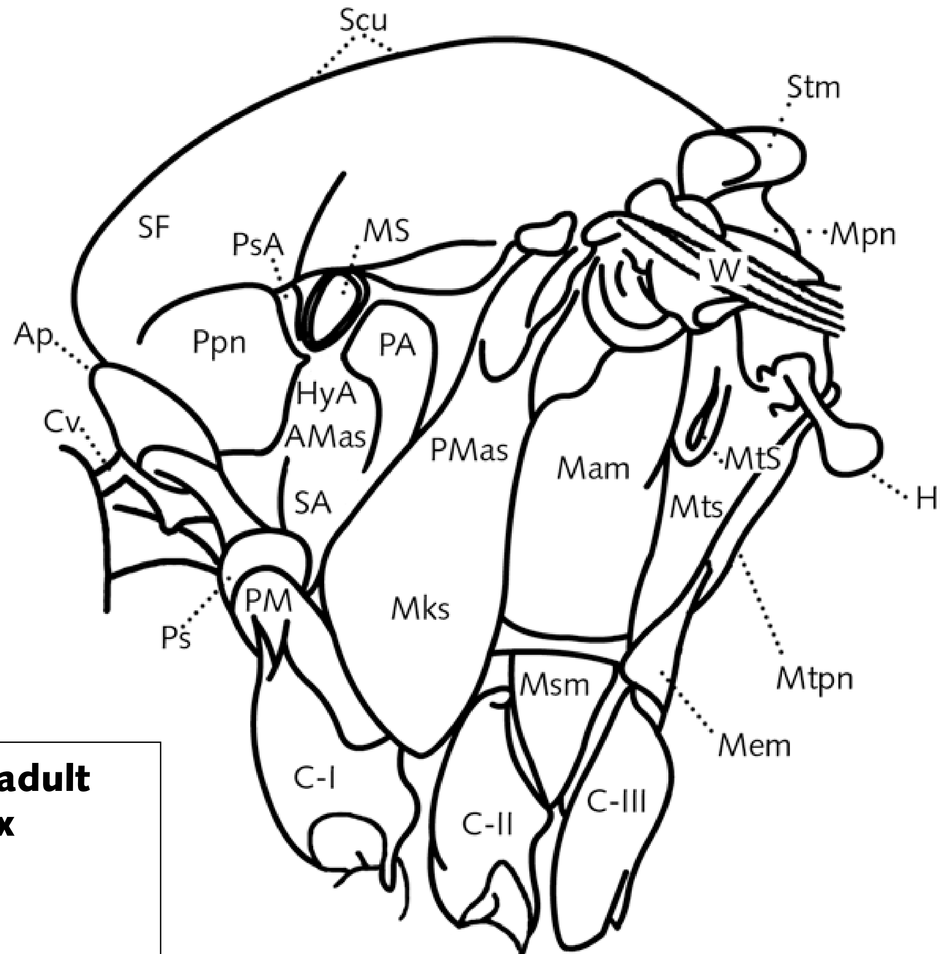


Hindleg

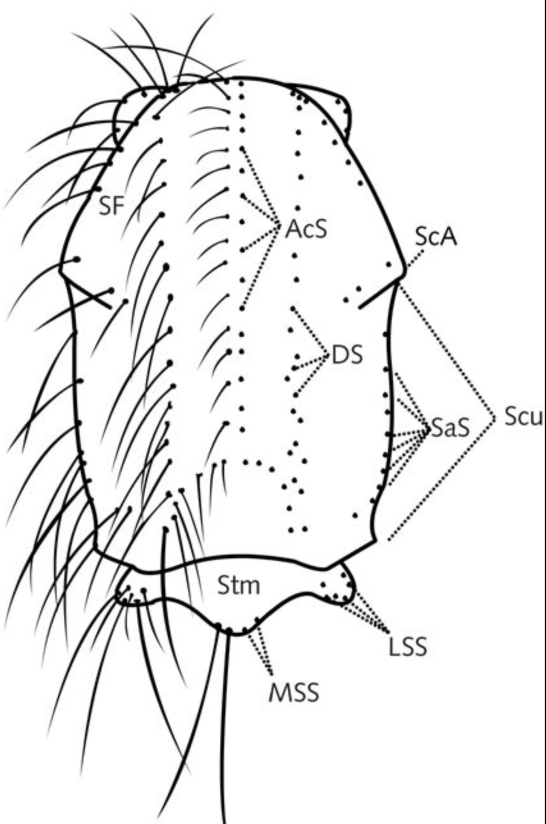


Lateral aspect of adult female abdomen

Lateral aspect of adult female thorax



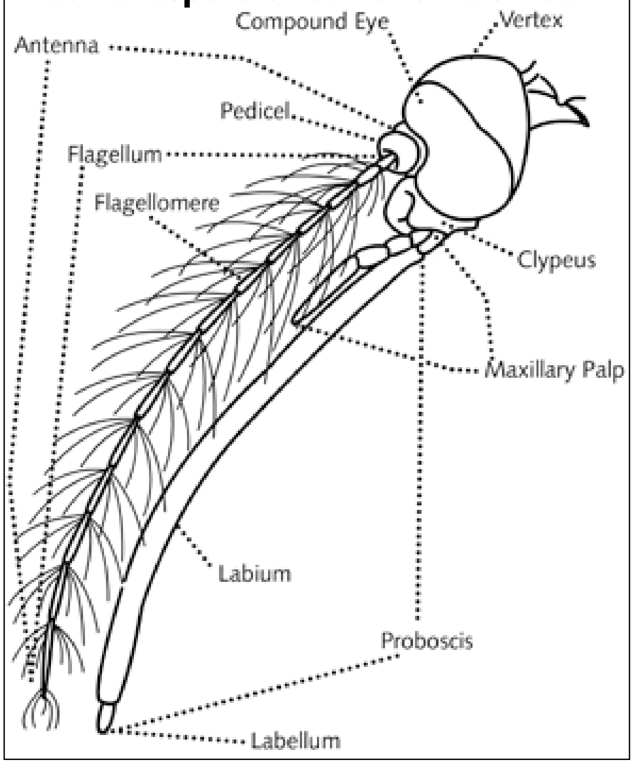
Dorsal aspect of adult female thorax

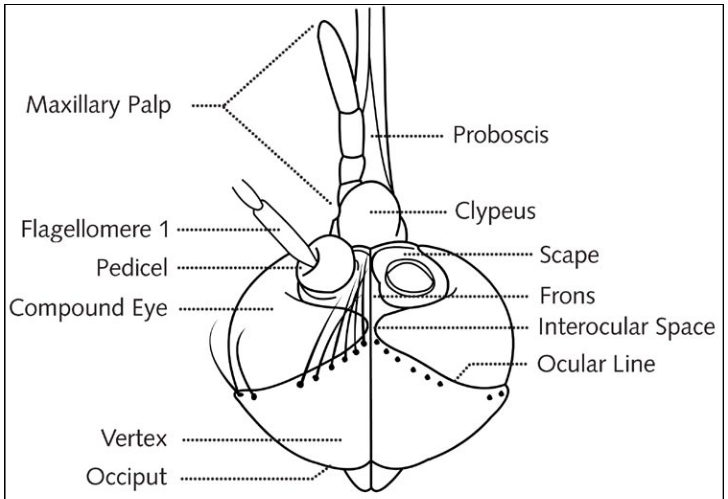


Anatomical abbreviations for adult thorax

AcS - Achrostichal Setae
AMas - Anterior Mesanepisternum
Ap - Antepronotum
C-I - Forecoxa
C-II - Midcoxa
C-III - Hindcoxa
Ce - Cercus
Cv - Cervix
DS - Dorsocentral Setae
Hl - Halter
HyA - Hypostigmal Area
LSS - Lateral Scutellar Setae
MSS - Median Scutellar Setae
Mam - Mesanepimeron
Mem - Metameron
Mks - Mesokatepisternum
Mpn - Mesopostnotum
MS - Mesothoracic Spiracle
Msm - Mesomeron
Mtpn - Metapostnotum
Mts - Metepisternum
MtS - Metathoracic Spiracle
PA - Postspiracular Area
PM - Postprocoxal Membrane
PMas - Posterior Mesanepisternum
Ppn - Postpronotum
Ps - Proepisternum
PsA - Prespiracular Area
SA - Subspiracular Area
SaS - Supraalar Setae
Scu - Scutum
SF - Scutal Fossa
ScA - Scutal Angle
Stm - Scutellum
W - Wing

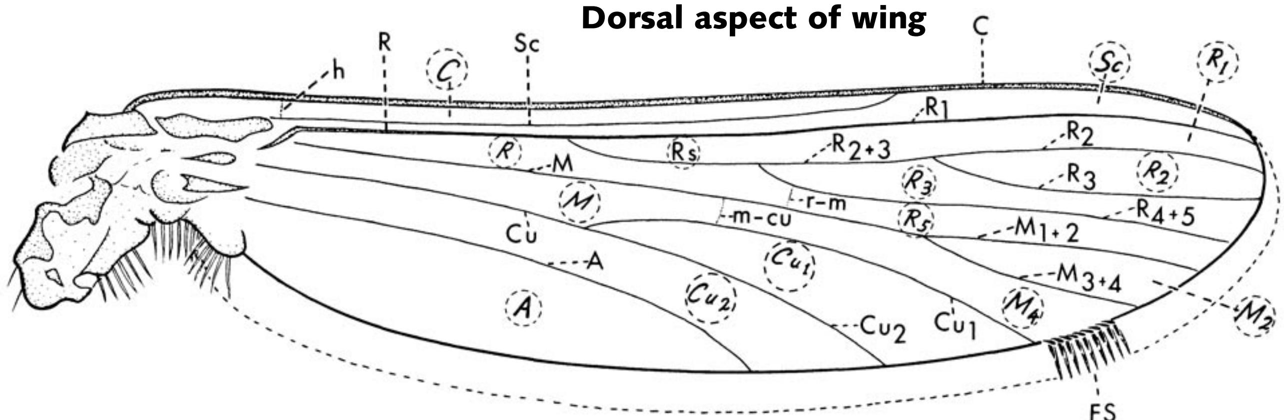
Lateral aspect of adult female head





Dorsal aspect of adult female head

Dorsal aspect of wing



Wing vein abbreviations

- A - Anal vein
- C - Costal vein
- Cu - Cubital vein
- Cu_1 - Anterior branch of cubital vein
- Cu_2 - Posterior branch of cubital vein
- h - humeral crossvein
- M - Medial vein
- M_{1+2} - Anterior branch of medial vein
- M_{3+4} - Posterior branch of medial vein
- m-cu - medio-cubital crossvein
- R - Radial vein
- R_1 - Anteriormost branch of radial vein
- Rs - Radial sector vein
- R_2 - Anterior branch of radial sector vein
- R_{2+3} - Connector vein of radial sector vein
- R_3 - Median branch of radial sector vein
- R_{4+5} - Posterior branch of radial sector vein
- r-m - radio-medial crossvein
- Sc - Subcostal vein

Wing cell abbreviations

(cell abbreviations are circled in the image above)

- C - Costal cell
- Cu_1 - $Cubital_1$ cell
- Cu_2 - $Cubital_2$ cell
- M - Medial cell
- M_2 - $Medial_2$ cell
- M_4 - $Medial_4$ cell
- R - Radial cell
- R_1 - $Radial_1$ cell
- R_2 - $Radial_2$ cell
- R_3 - $Radial_3$ cell
- R_5 - $Radial_5$ cell
- Sc - Subcostal cell

Adult Female Genera

1. Palpi about as long as proboscis (Fig. 1a)..*Anopheles*
1'. Palpi shorter than proboscis (Fig. 1b)...2

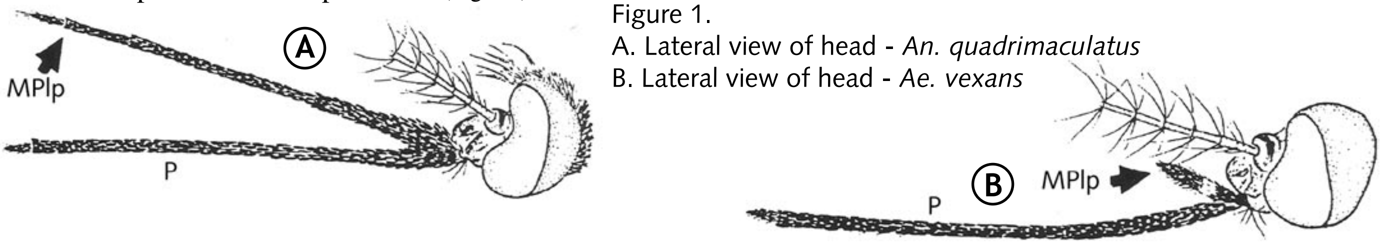


Figure 1.
A. Lateral view of head - *An. quadrimaculatus*
B. Lateral view of head - *Ae. vexans*

2(1). Proboscis stout basally, outer half tapered and curved downward (Fig. 2a); posterior edge of wing strongly emarginated at apex of vein Cu_2 (Fig. 2b)..*Toxorhynchites rutilus*
2'. Proboscis slender and not curved downward (Fig. 2c); wing edge evenly rounded or only slightly emarginated at apex of vein Cu_2 (Fig. 2d)..3

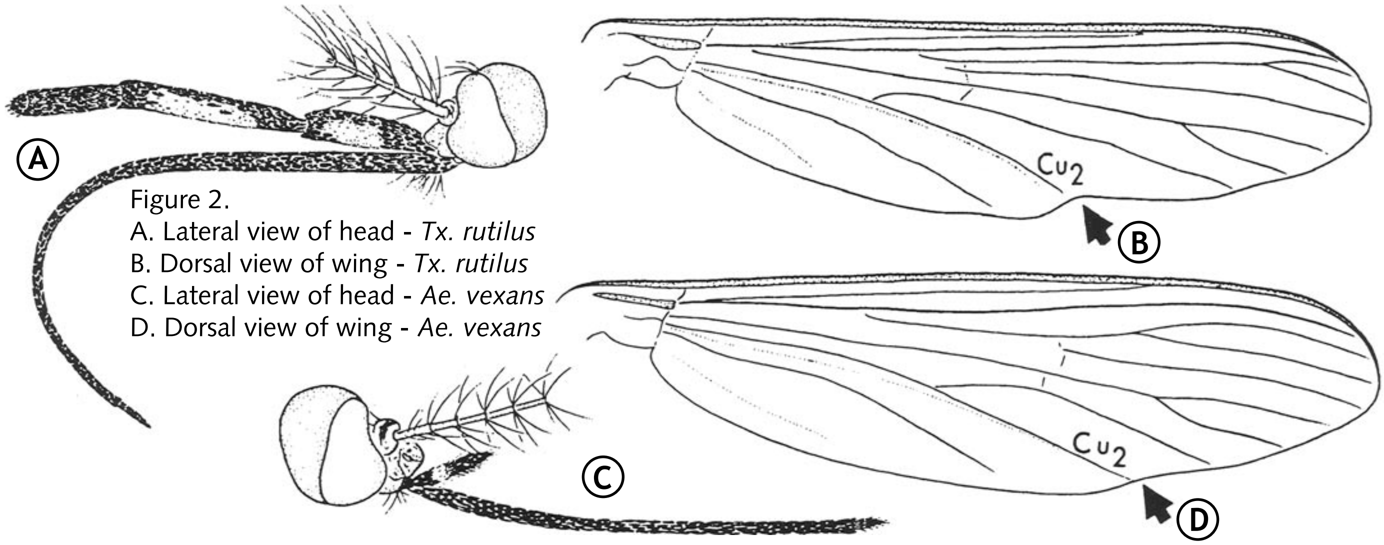


Figure 2.
A. Lateral view of head - *Tx. rutilus*
B. Dorsal view of wing - *Tx. rutilus*
C. Lateral view of head - *Ae. vexans*
D. Dorsal view of wing - *Ae. vexans*

3(2). Abdomen with dark scales dorsally and pale scales ventrally, the two colors meeting laterally in a straight line (Fig. 3a); mesopostnotum with setae (Fig. 3b)...*Wyeomyia smithii*
3'. Abdominal tergites banded or with lateral spots (Fig. 3c); mesopostnotum without setae (Fig. 3d)..4

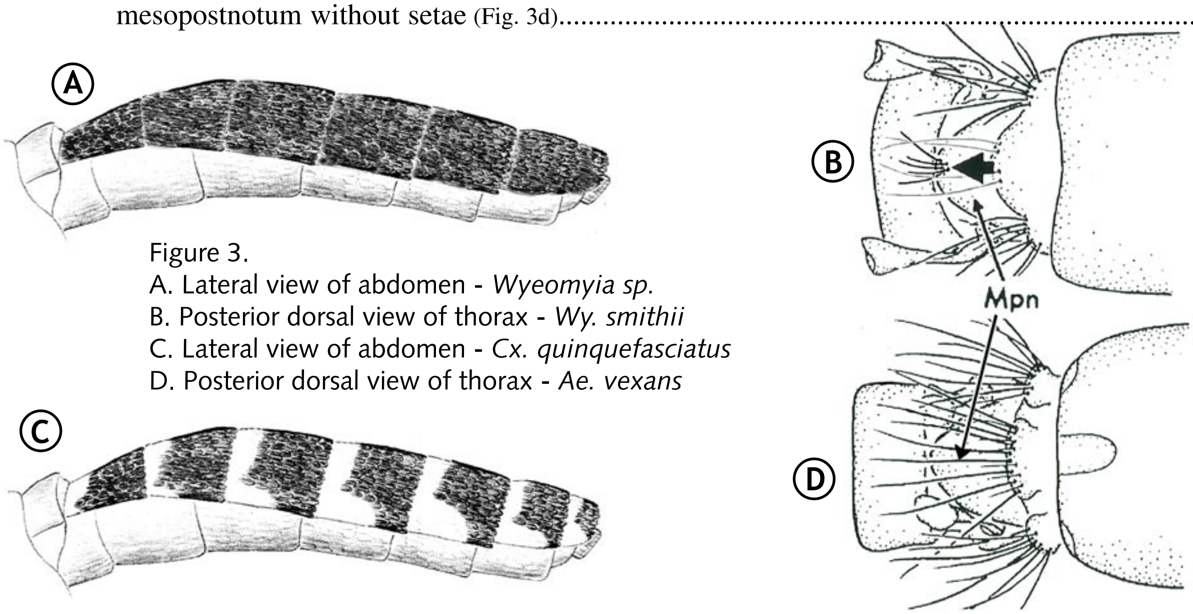


Figure 3.
A. Lateral view of abdomen - *Wyeomyia sp.*
B. Posterior dorsal view of thorax - *Wy. smithii*
C. Lateral view of abdomen - *Cx. quinquefasciatus*
D. Posterior dorsal view of thorax - *Ae. vexans*

4(3). Radial cell of wing less than half as long as vein R_{2+3} (Fig. 4a); thorax usually with patches of irridescent blue or white scales (Fig. 4b)..***Uranotaenia***

4'. Radial cell of wing at least as long vein R_{2+3} (Fig. 4c); blue scales absent on thorax (Fig. 4d)..5

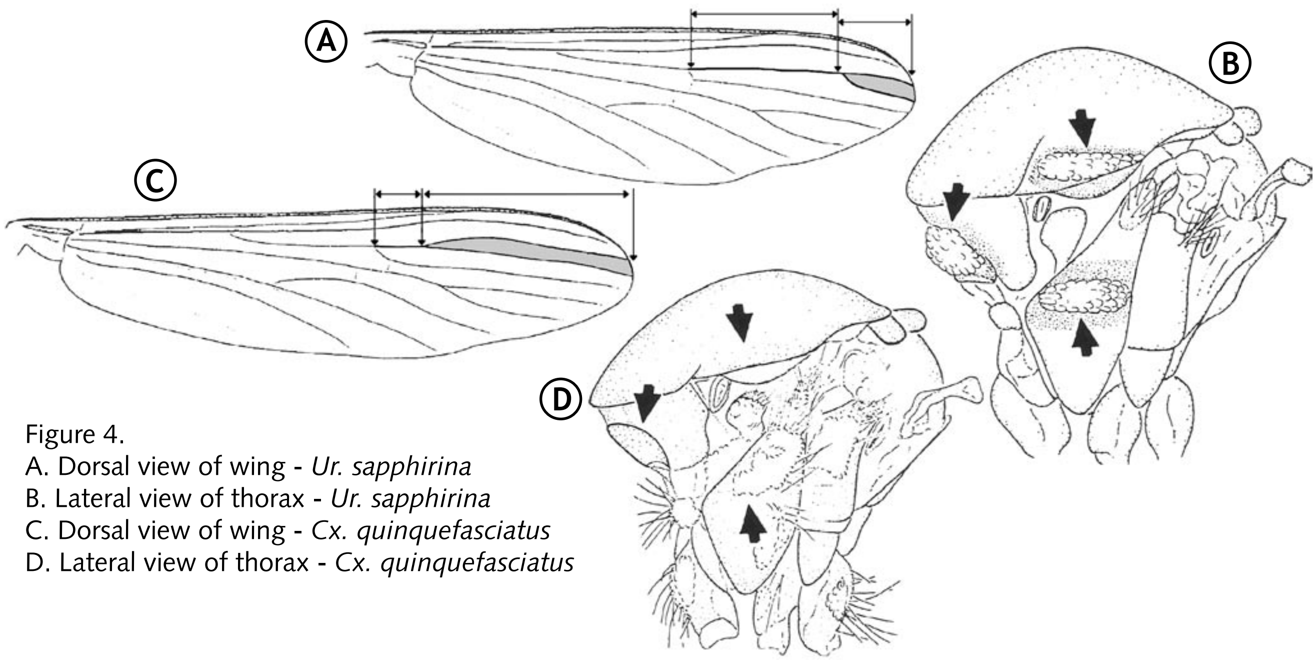


Figure 4.
A. Dorsal view of wing - *Ur. sapphirina*
B. Lateral view of thorax - *Ur. sapphirina*
C. Dorsal view of wing - *Cx. quinquefasciatus*
D. Lateral view of thorax - *Cx. quinquefasciatus*

5(4). Abdomen pointed at tip (Fig. 5a)..6

5'. Abdomen blunt at tip (Fig. 5b)..7

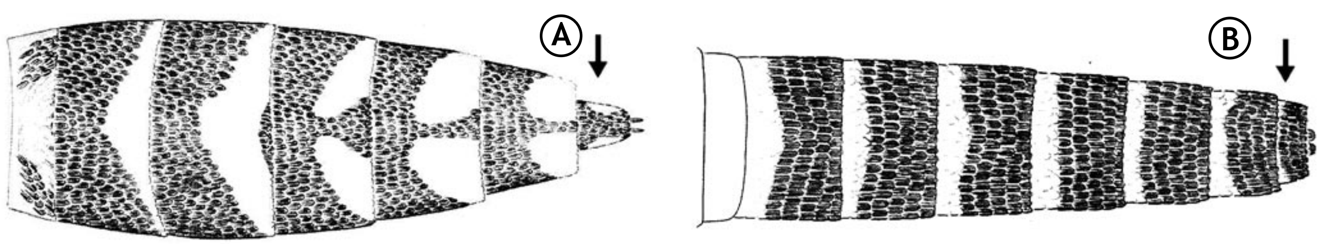


Figure 5.
A. Dorsal view of abdomen - *Ps. ferox*
B. Dorsal view of abdomen - *Cx. restuans*

6(5). Dorsal segments of abdomen with light scales apically (Fig. 6a), or if absent, hindtibia with conspicuous, long, erect scales (Fig. 6b); prespiracular setae present (Fig. 6c)..*Psorophora*

6'. Dorsal segments of abdomen with light scales basally (Fig. 6d); hindtibia never with long, erect scales (Fig. 6e); prespiracular setae absent (Fig. 6f)..*Aedes*

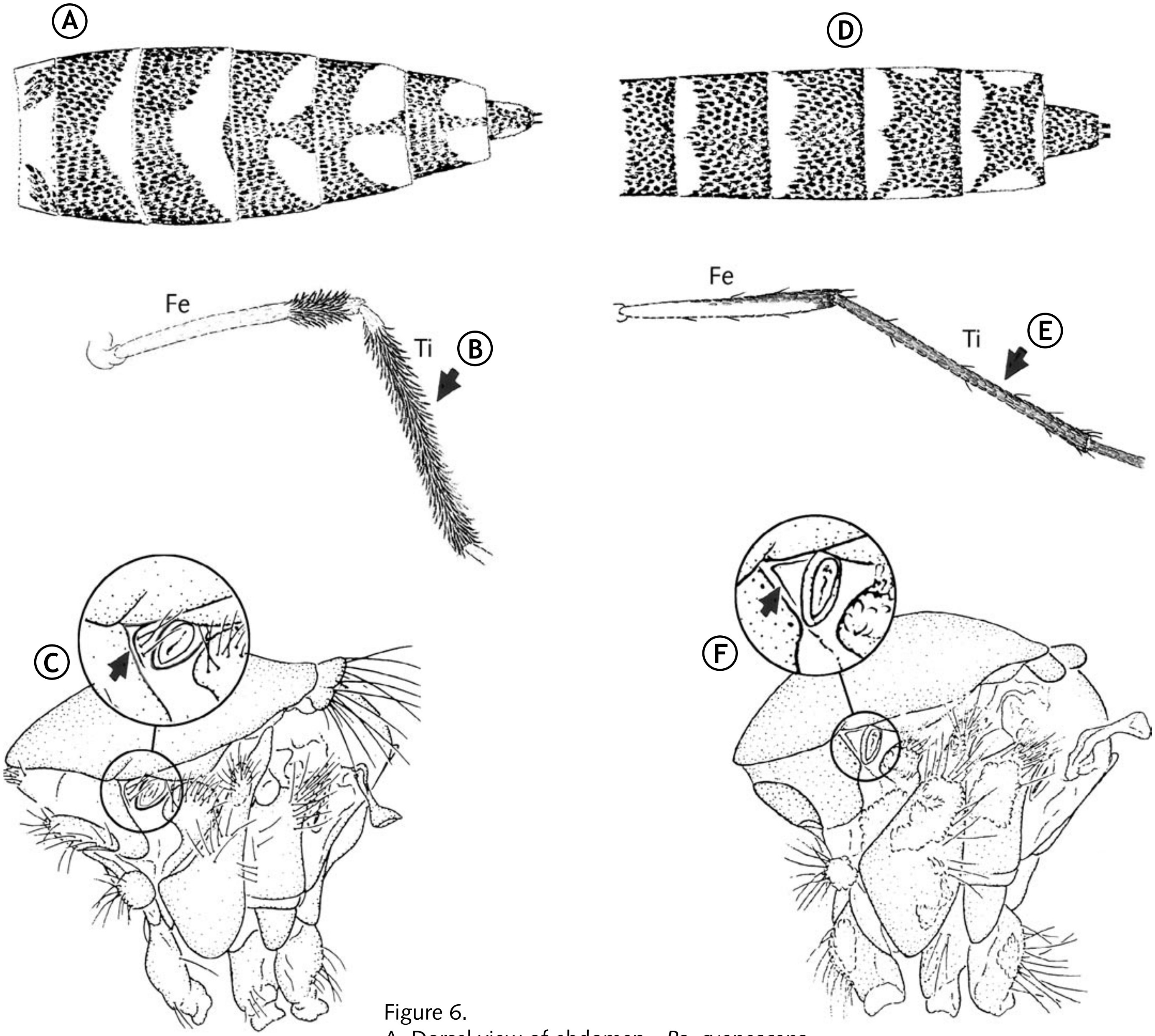
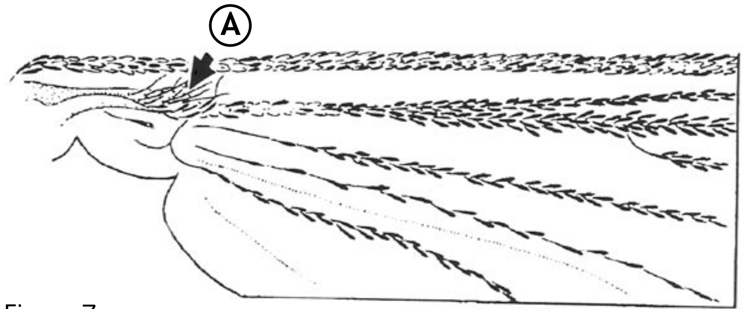


Figure 6.
A. Dorsal view of abdomen - *Ps. cyanescens*
B. Lateral view of hindtibia - *Ps. ciliata*
C. Lateral view of thorax - *Ps. ciliata*
D. Dorsal view of abdomen - *Ae. vexans*
E. Lateral view of hindtibia - *Ae. infirmatus*
F. Lateral view of thorax - *Ae. vexans*

7(5’). Base of subcosta on underside of wing with a tuft of setae (Fig. 7a); prespiracular setae present (Fig. 7b)..***Culiseta***

7’. Base of subcosta without a tuft of setae (Fig. 7c); prespiracular setae absent (Fig. 7d)..8



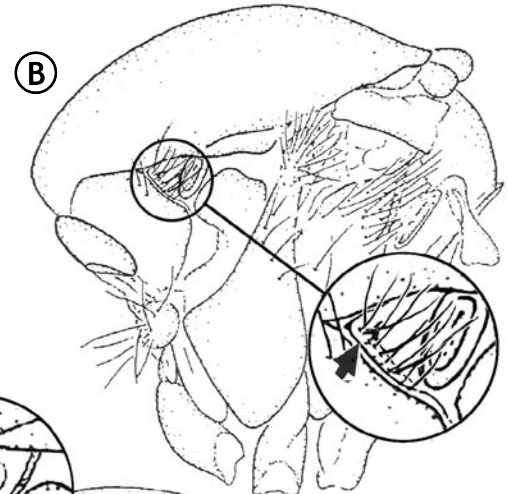
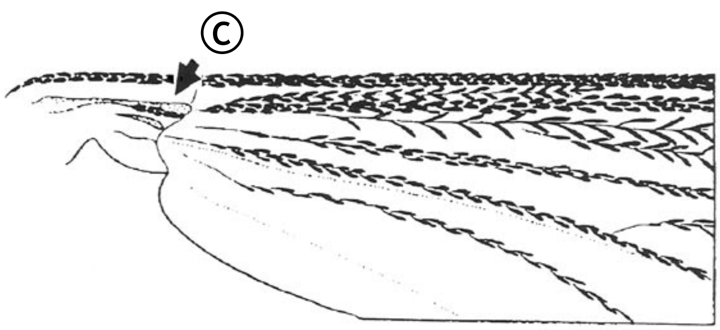
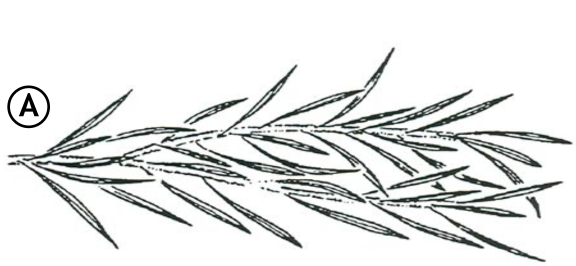


Figure 7.
A. Ventral view of basal half of wing - *Cs. inornata*
B. Lateral view of thorax - *Cs. inornata*
C. Ventral view of basal half of wing - *Cx. quinquefasciatus*
D. Lateral view of thorax - *Cx. quinquefasciatus*



8(7). Wing scales narrow (Fig. 8a)..9

8’. Wing scales broad, mixed brown and white (Fig. 8b)..10



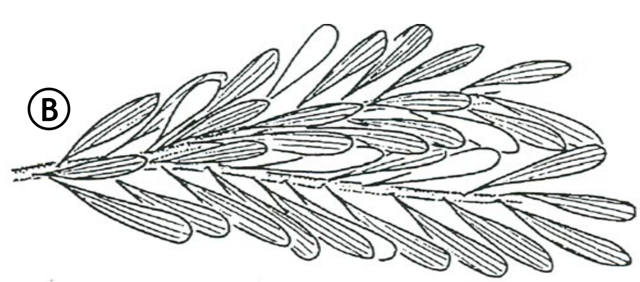
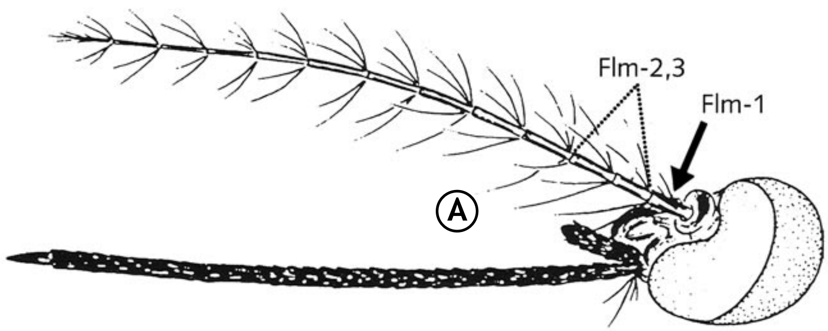


Figure 8.
A. Dorsal view of wing veins - *Cx. quinquefasciatus*
B. Dorsal view of wing veins - *Cq. perturbans*

9(8). Antenna not longer than proboscis, first agellomere about as long as following segments (Fig. 9a)..***Culex***

9’. Antenna longer than proboscis, first agellomere as long as next two segments together (Fig. 9b)..***Deinocerites cancer***



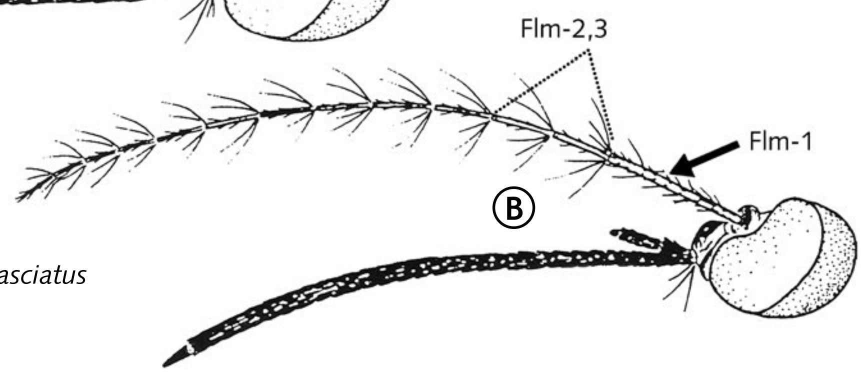


Figure 9.
A. Lateral view of head - *Cx. quinquefasciatus*
B. Lateral view of head - *De. cancer*

10(8’). Mesonotum with fine longitudinal lines of white scales (Fig. 10a)...***Orthopodomyia***

10’. Mesonotum without white lines of scales (Fig. 10b)...11

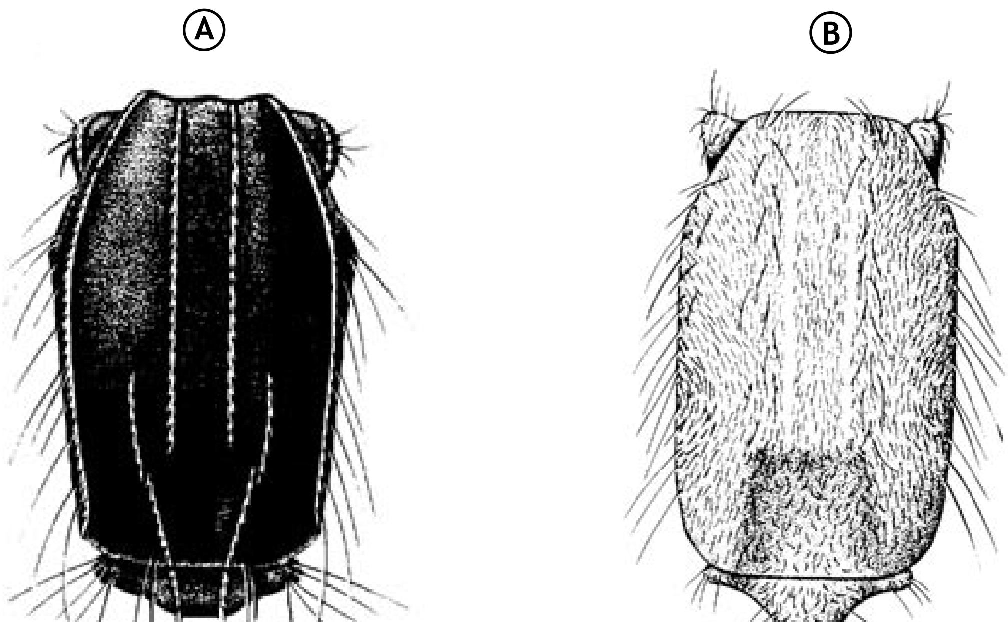


Figure 10.
A. Dorsal view of thorax - *Or. alba*
B. Dorsal view of thorax - *Cq. perturbans*

11(10). Wide pale band near distal end of hindtibia (Fig. 11a); postspiracular bristles absent (Fig. 11b).. ***Coquillettidia perturbans***

11'. Hindtibia without pale band (Fig. 11c); postspiracular bristles present (Fig. 11d)... ***Mansonia***

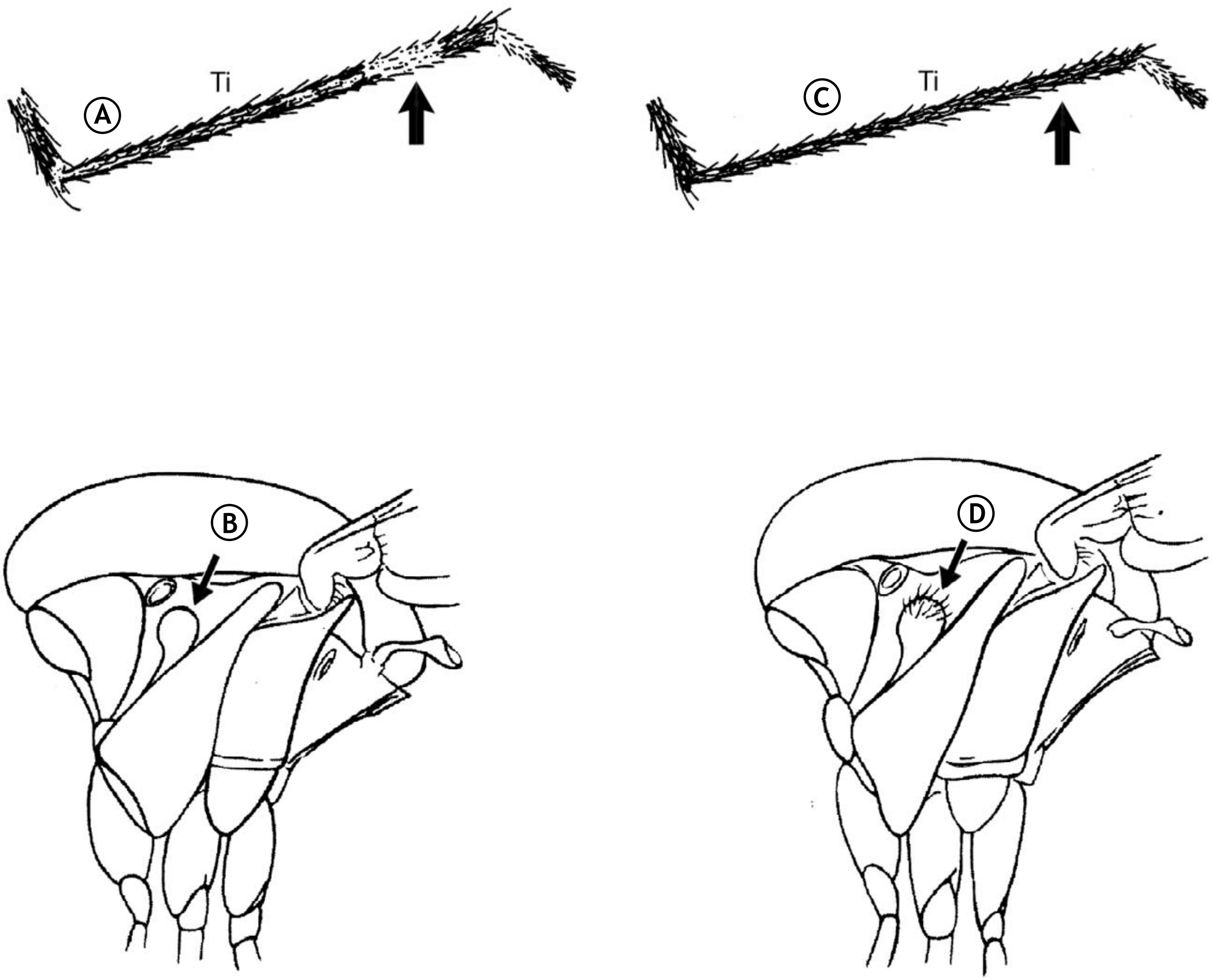


Figure 11.
A. Hindtibia - *Cq. perturbans*
B. Lateral view of thorax - *Cq. perturbans*
C. Hindtibia - *Ma. titillans*
D. Lateral view of thorax - *Ma. titillans*

Anopheles Adults

1. Wings with areas of white or yellow scales (Fig. 1a)..2
1'. Wings entirely dark-scaled (Fig. 1b)..5

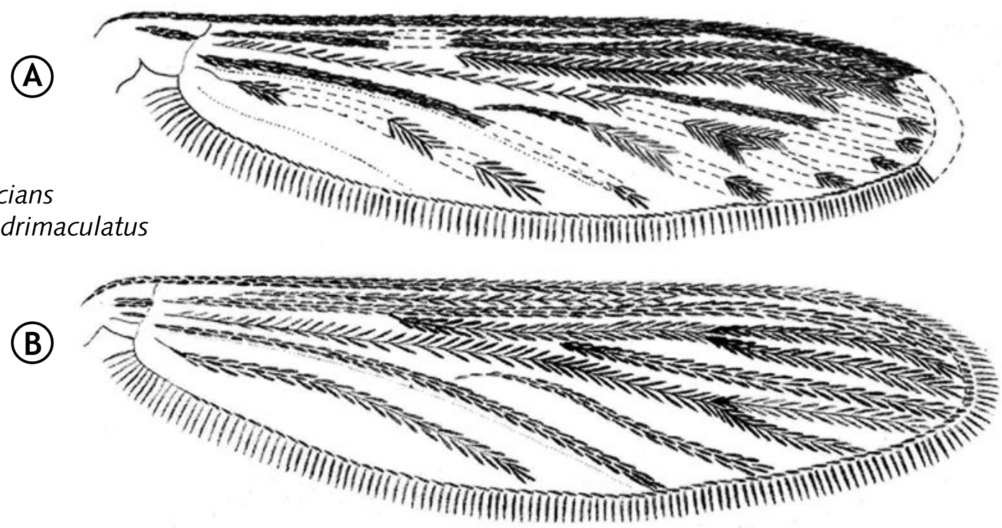


Figure 1.
A. Dorsal view of wing - *An. crucians*
B. Dorsal view of wing - *An. quadrimaculatus*

2(1). Palpi unbanded (Fig. 2a)..***An. punctipennis***
2'. Palpi banded (Fig. 2b)..3

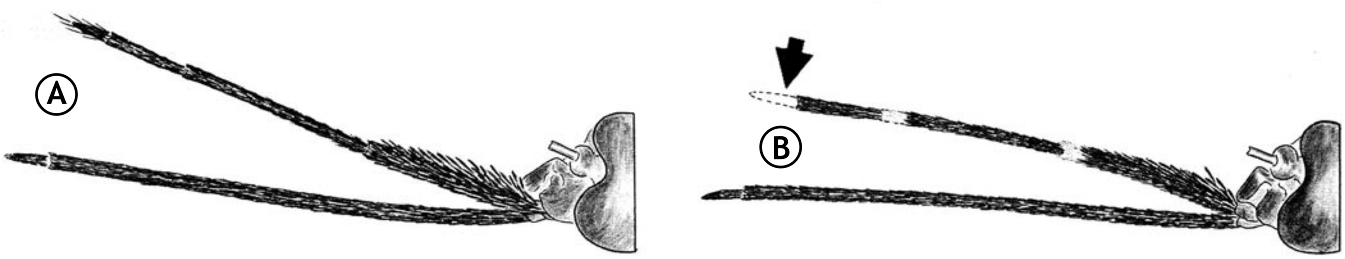


Figure 2.
A. Lateral view of head - *An. punctipennis*
B. Lateral view of head - *An. pseudopunctipennis*

3(2'). Front margin of wing with two pale areas, one at wingtip, and one at junction of costal and subcostal veins (Fig. 3a)..***An. pseudopunctipennis***
3'. Front margin of wing with one pale area at wingtip (Fig. 3b)..4

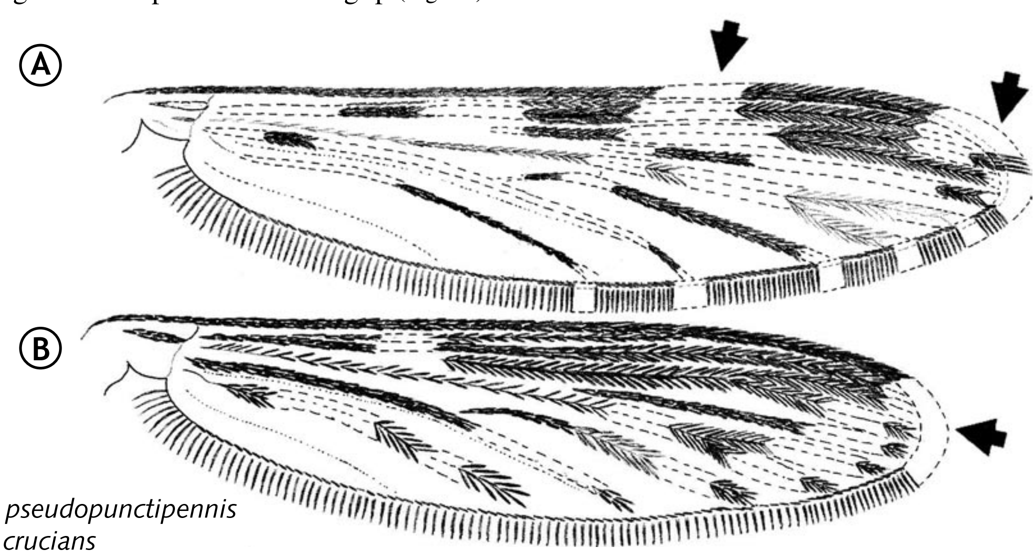


Figure 3.
A. Dorsal view of wing - *An. pseudopunctipennis*
B. Dorsal view of wing - *An. crucians*

4(3). Wing vein Cu partly or entirely dark-scaled (Fig. 4a)..***An. crucians***
4'. Wing vein Cu often entirely white-scaled (Fig. 4b)..***An. bradleyi***

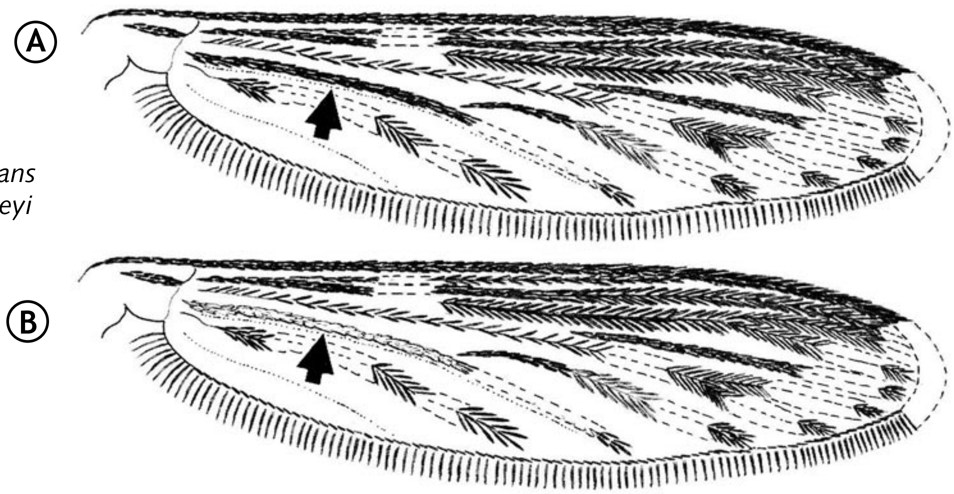


Figure 4.
A. Dorsal view of wing - *An. crucians*
B. Dorsal view of wing - *An. bradleyi*

5(1). Wings unspotted (Fig. 5a); distal end of hindfemur without light kneespot (Fig. 5b)..***An. atropos***
5'. Wings spotted by clumping of dark scales (Fig. 5c); distal end of hindfemur with light kneespot (Fig. 5d)..***An. quadrimaculatus*** complex*

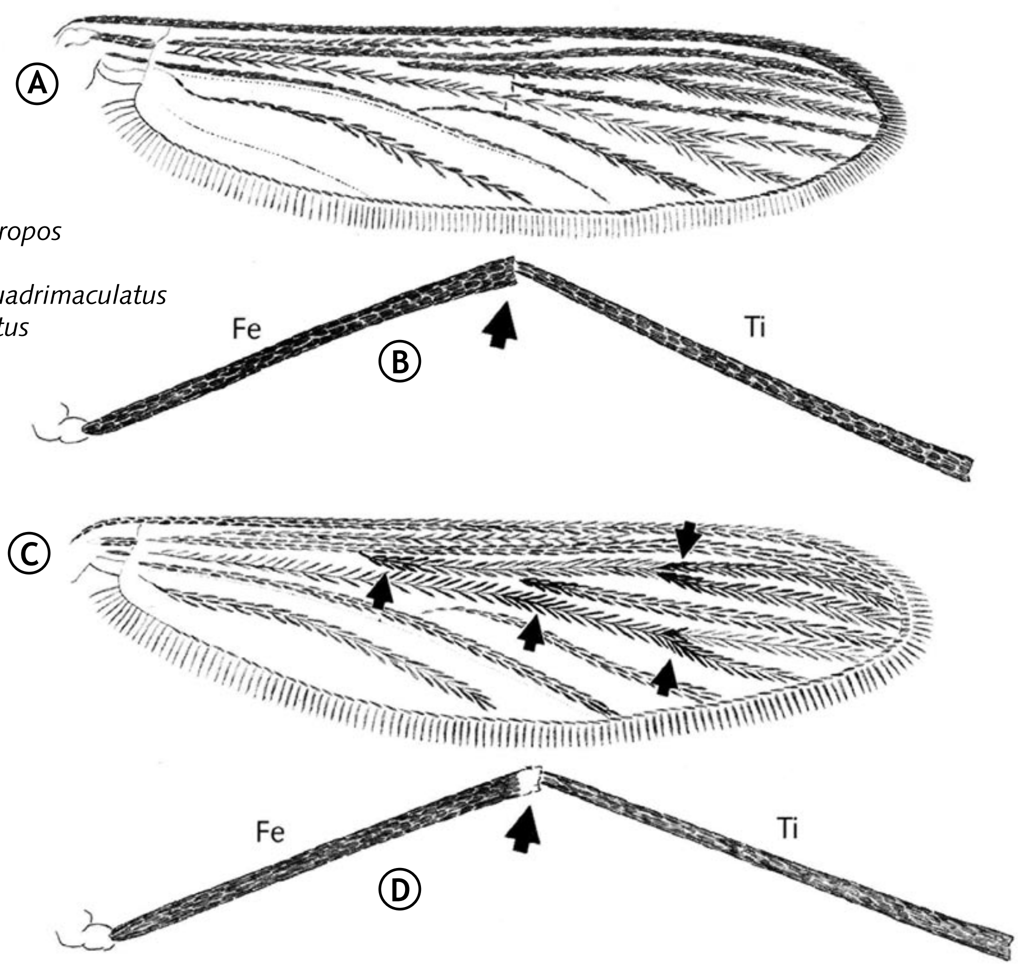


Figure 5.
A. Dorsal view of wing - *An. atropos*
B. Hindleg - *An. atropos*
C. Dorsal view of wing - *An. quadrimaculatus*
D. Hindleg - *An. quadrimaculatus*

* Species A, B, C2 and D of the *Anopheles quadrimaculatus* complex are found within Louisiana (Rutlidge and Meek, 1998). Reinert et al (1999) described the morphological distinctions between the members of this species complex for all life stages.

Aedes Adults

1. Hindtarsomeres with pale bands (Fig. 1a)..2
1'. Hindtarsomeres without pale bands (Fig. 1b)...10

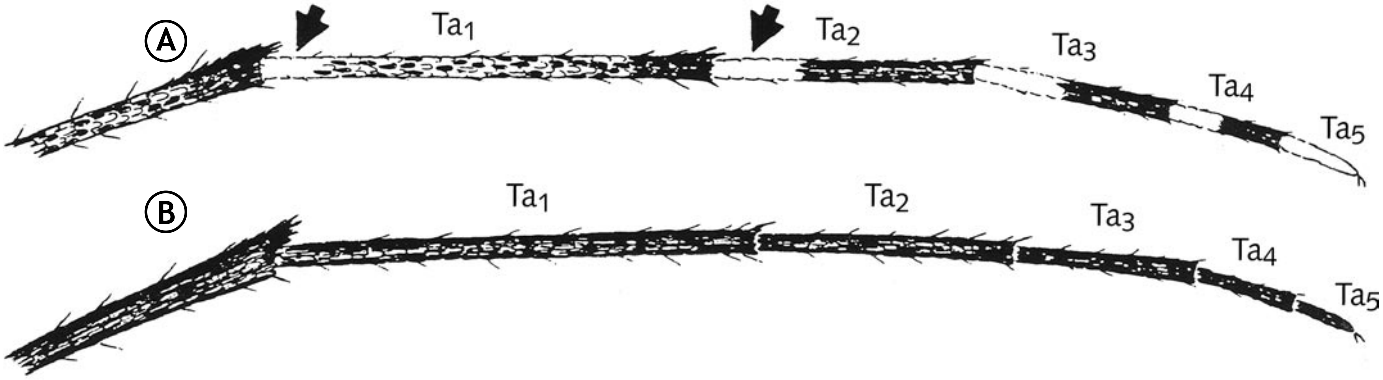


Figure 1.
A. Hindleg - *Ae. mitchellae*
B. Hindleg - *Ae. triseriatus*

2(1). Hindtarsomeres pale-banded on basal part of segment only (Fig. 2a)..3
2'. Hindtarsomeres pale-banded both basally and apically, at least on some segments (Fig. 2b)..9

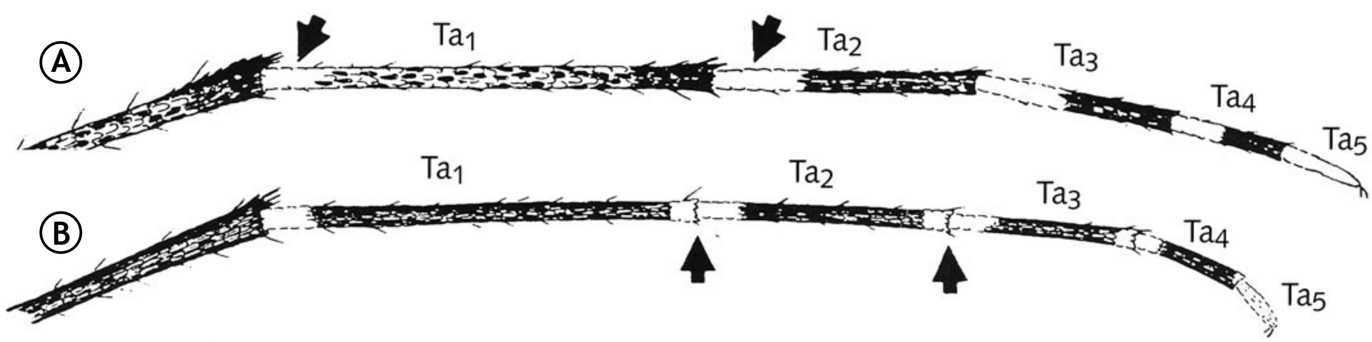


Figure 2.
A. Hindleg - *Ae. mitchellae*
B. Hindleg - *Ae. c. canadensis*

3(2). Proboscis with definite pale-scaled band near middle (Fig. 3a)..4
3'. Proboscis lacking definite pale-scaled band near middle (Fig. 3b)..6

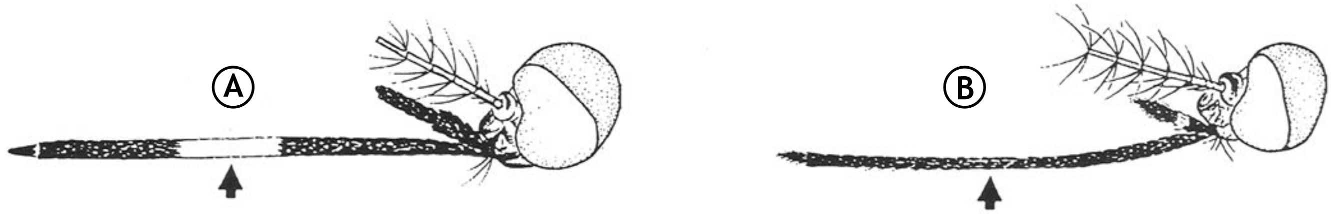
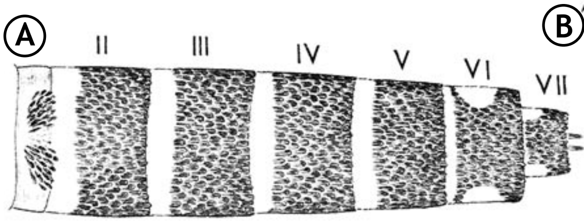
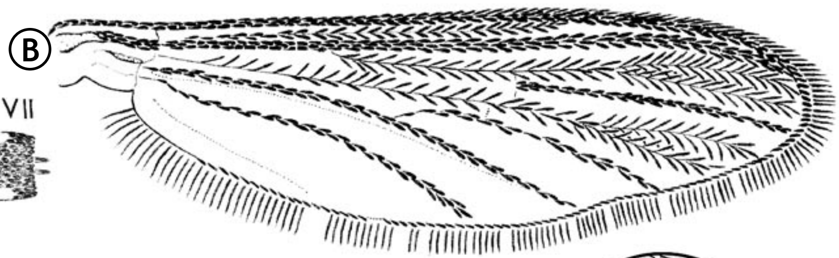


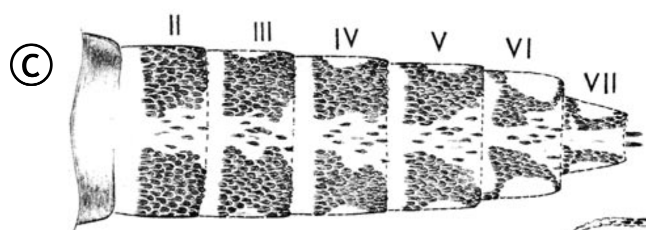
Figure 3.
A. Lateral view of head - *Ae. sollicitans*
B. Lateral view of head - *Ae. vexans*

4(3). Abdominal terga with transverse, basal, pale bands, but lacking median, longitudinal stripe (Fig. 4a); wing dark-scaled (Fig. 4b)..***Ae. taeniorhynchus***

4'. Abdominal terga with pale-scaled, transverse bands, and longitudinal stripe or rows of disconnected spots medially (Fig. 4c); wing scales either all dark or intermixed dark and pale (Fig. 4d)..5







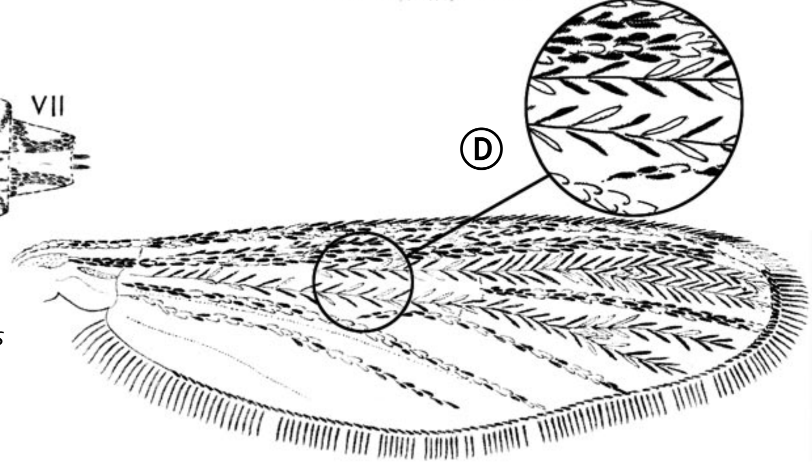
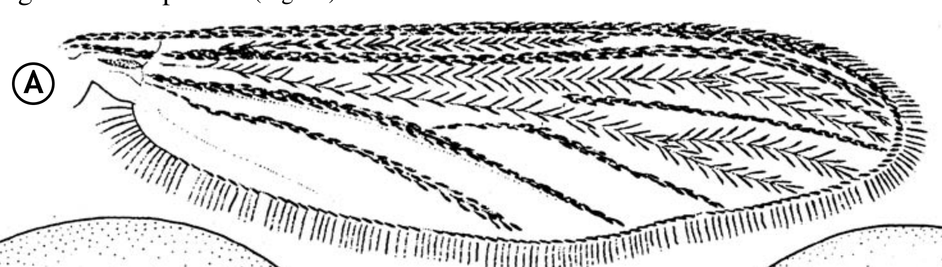
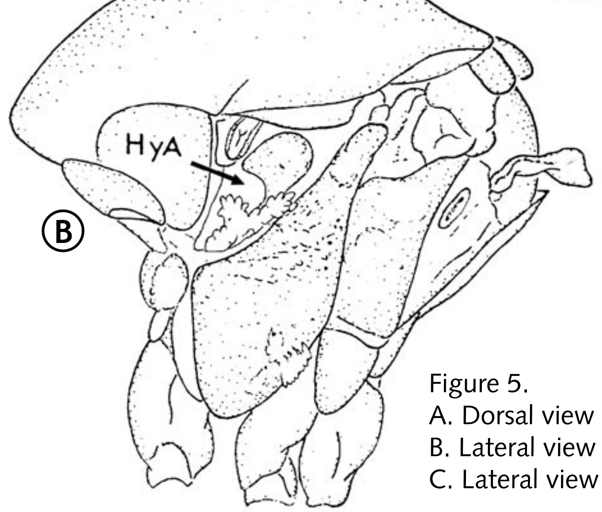


Figure 4.
A. Dorsal view of abdomen - *Ae. taeniorhynchus*
B. Dorsal view of wing - *Ae. taeniorhynchus*
C. Dorsal view of abdomen - *Ae. sollicitans*
D. Dorsal view of wing - *Ae. sollicitans*

5(4'). Wing with scales all dark (Fig. 5a); hypostigmal scales absent (Fig. 5b)..***Ae. mitchellae***

5'. Wing with dark and pale scales intermixed (Fig. 4d above); hypostigmal scales present (Fig. 5c)..***Ae. sollicitans***





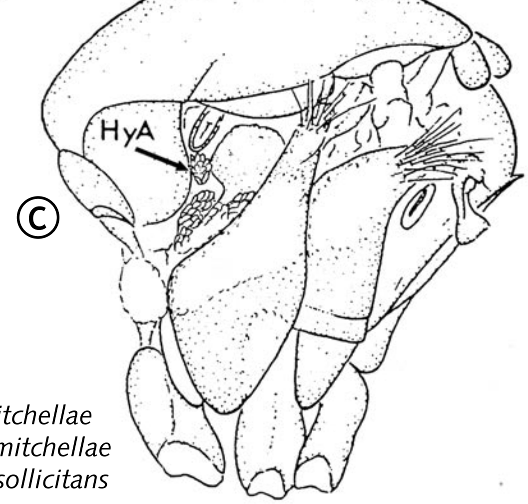


Figure 5.
A. Dorsal view of wing - *Ae. mitchellae*
B. Lateral view of thorax - *Ae. mitchellae*
C. Lateral view of thorax - *Ae. sollicitans*

6(3’). Scutum with conspicuous lyre- or modified lyre-shaped markings of silvery or yellow scales on background of dark scales (Fig. 6a)........7

6’. Scutum without such markings (Fig. 6b)........8

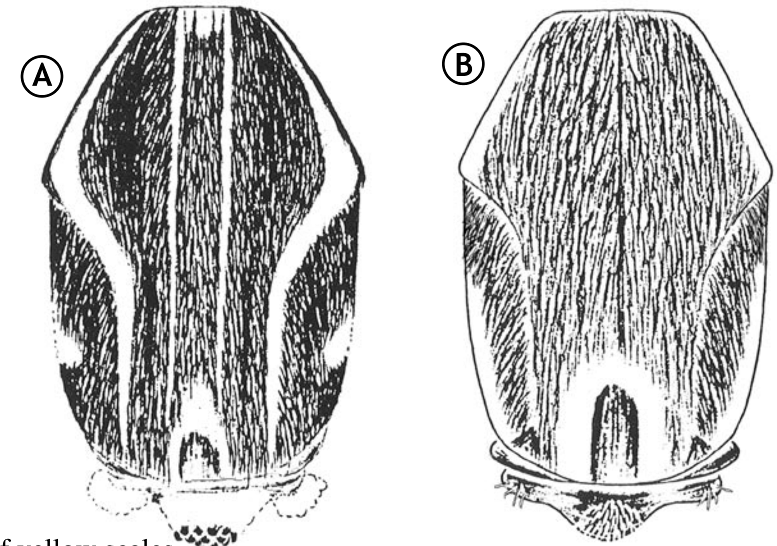


Figure 6.
A. Dorsal view of thorax - *Ae. aegypti*
B. Dorsal view of thorax - *Ae. c. canadensis*

7(6). Scutum with median, longitudinal stripe of yellow scales (Fig. 7a); abdominal terga III-VII without dorsal pale bands (Fig. 7b); hindtarsomere 5 dark-scaled (Fig. 7c)........***Ae. japonicus***

7’. Scutum without median, longitudinal stripe (Fig. 7d); abdominal terga III-VII with basal, transverse, pale bands (Fig. 7e); hindtarsomere 5 pale-scaled (Fig. 7f)........***Ae. aegypti***

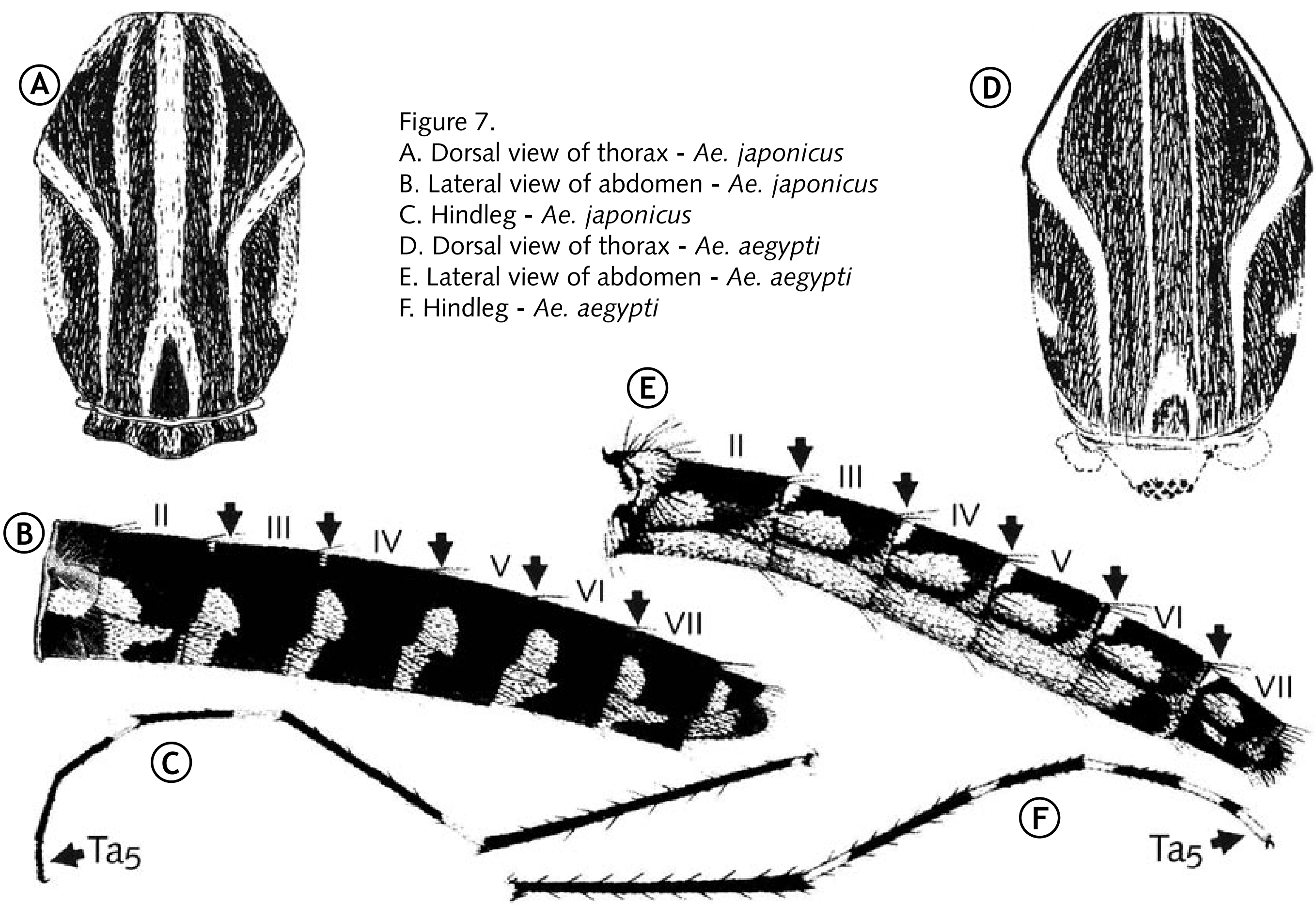


Figure 7.
A. Dorsal view of thorax - *Ae. japonicus*
B. Lateral view of abdomen - *Ae. japonicus*
C. Hindleg - *Ae. japonicus*
D. Dorsal view of thorax - *Ae. aegypti*
E. Lateral view of abdomen - *Ae. aegypti*
F. Hindleg - *Ae. aegypti*

8(6'). Scutum with single narrow stripe of white scales (Fig. 8a); basal pale bands on abdomen without posterior notch but aring laterally (Fig. 8b); basal pale bands of hindtarsomeres broad, that on tarsomere 2 covering more than 0.3 of segment (Fig. 8c)..***Ae. albopictus***

8'. Scutum without single narrow white stripe of scales (Fig. 8d); basal pale bands on abdomen with posterior notch (Fig. 8e); basal pale bands of hindtarsomeres narrow, that on tarsomere 2 covering 0.2 or less of segment (Fig. 8f)...***Ae. vexans***

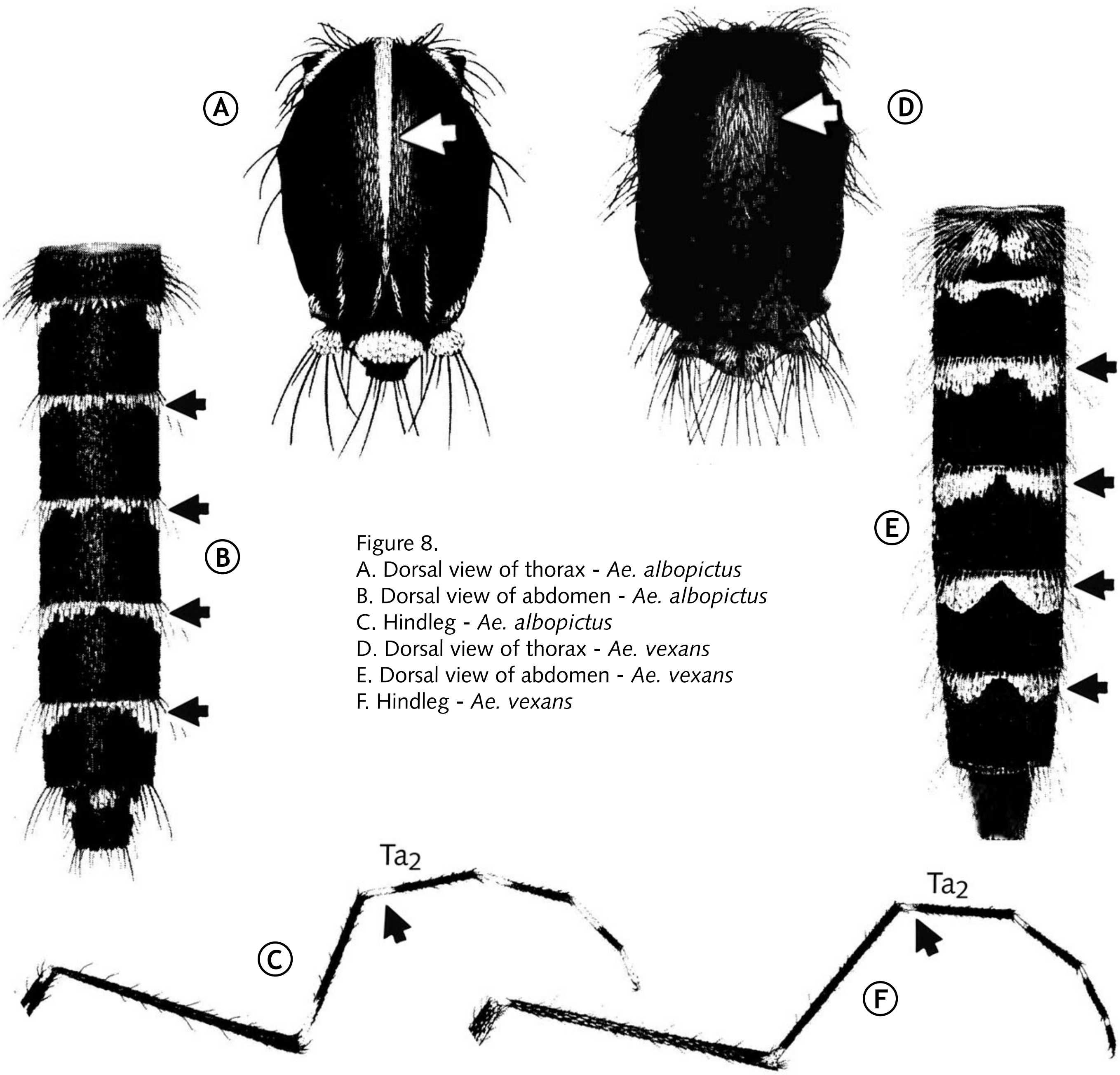
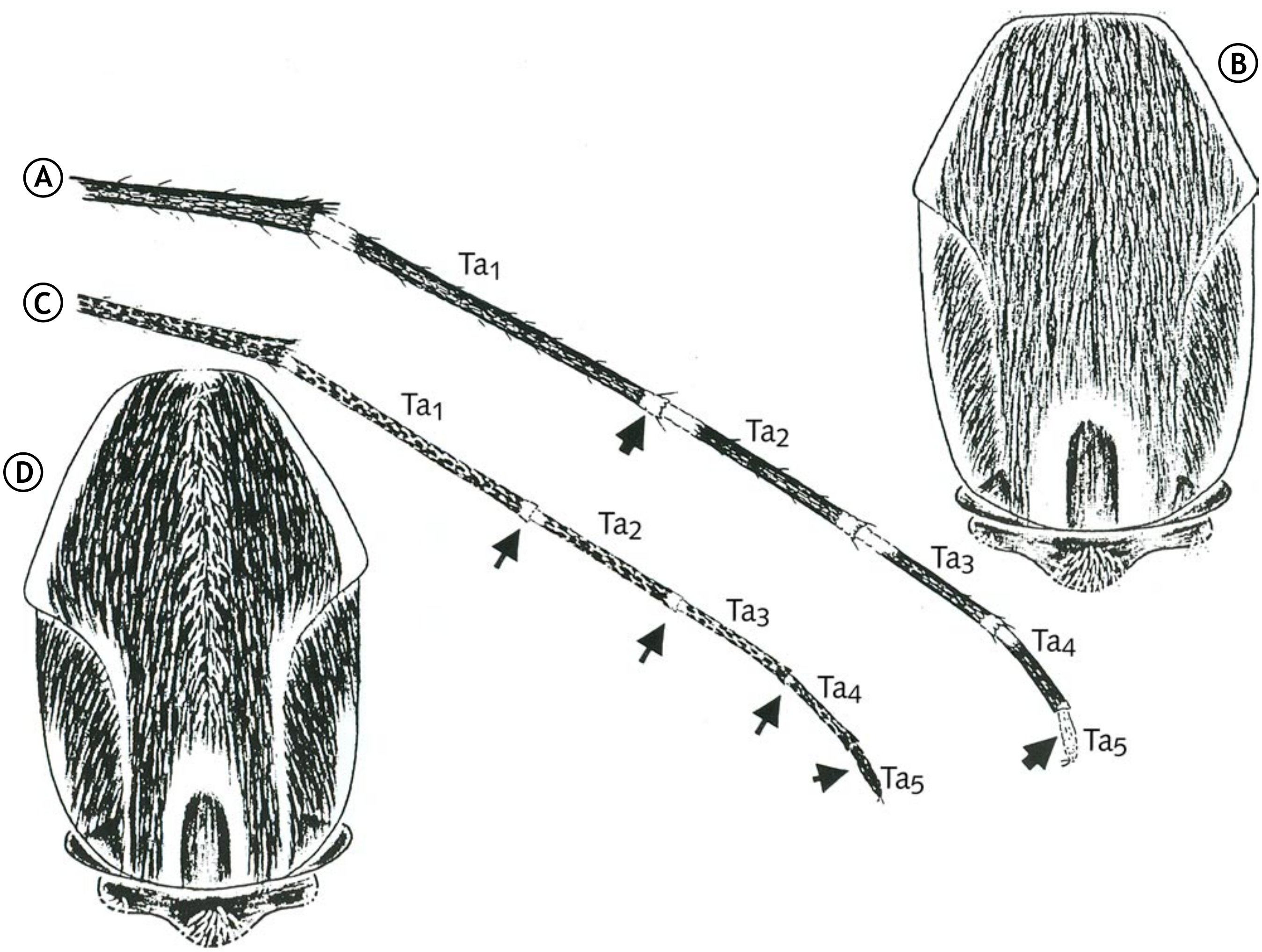


Figure 8.
A. Dorsal view of thorax - *Ae. albopictus*
B. Dorsal view of abdomen - *Ae. albopictus*
C. Hindleg - *Ae. albopictus*
D. Dorsal view of thorax - *Ae. vexans*
E. Dorsal view of abdomen - *Ae. vexans*
F. Hindleg - *Ae. vexans*

9(2'). Hindtarsomeres 1-4 with broad, pale, basal and apical bands, hindtarsomere 5 entirely pale-scaled (Fig. 9a); scutum with golden-brown scales (Fig. 9b)..***Ae. canadensis***

9'. Hindtarsomeres 1-2 with narrow, pale, basal and apical bands, hindtarsomeres 3-4 with only basal pale bands, hindtarsomere 5 dark-scaled (Fig. 9c); scutum with scales mostly dark brown, with indefinite median stripe of paler scales (Fig. 9d)..***Ae. c. mathesoni***

Figure 9.
A. Hindleg - *Ae. canadensis*
B. Dorsal view of thorax - *Ae. canadensis*
C. Hindleg - *Ae. c. mathesoni*
D. Dorsal view of thorax - *Ae. c. mathesoni*



10(1'). Scutal integument with pair of dark, posterolateral
spots (Fig. 10a); mesonotum gold-colored..***Ae. fulvus pallens***
10'. Scutal integument lacking dark, posterolateral spots (Fig. 10b)...11

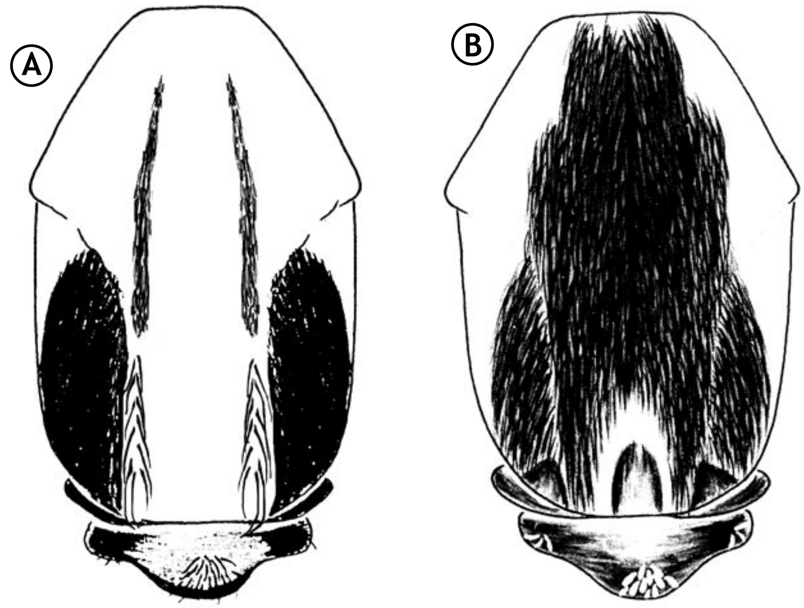


Figure 10.
A. Dorsal view of thorax - *Ae. fulvus pallens*
B. Dorsal view of thorax - *Ae. triseriatus*

11(10'). Scutum with patch or median stripe of silvery white,
pale white or pale yellow scales (Fig. 11a), or with
silvery white scales laterally (Fig. 11b)...12
11'. Scutum without silvery white scales medially or laterally,
nor pale white or pale yellow scales medially (Fig. 11c)..17

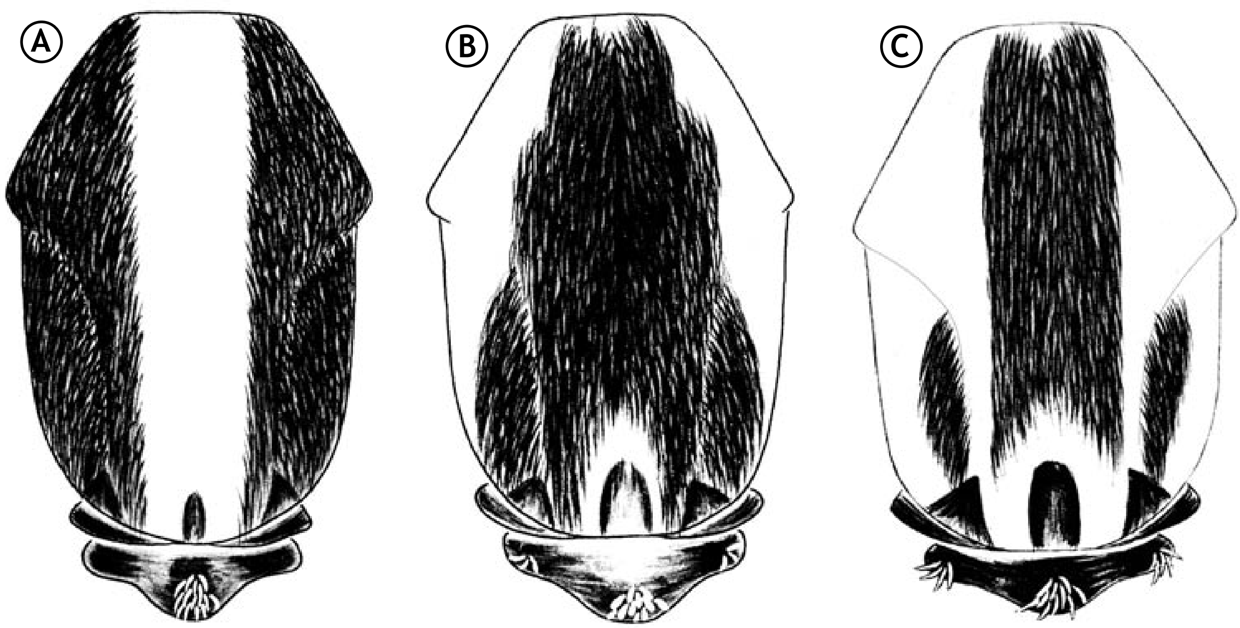


Figure 11.
A. Dorsal view of thorax - *Ae. atlanticus*
B. Dorsal view of thorax - *Ae. triseriatus*
C. Dorsal view of thorax - *Ae. sticticus*

12(11). Scutum with median, longitudinal stripe of dark brown scales and silvery-white scales laterally (Fig. 12a)..13

12'. Scutum with one or two broad patches or stripes of silvery-white, pale white or pale yellow scales medially (Fig. 12b)..14

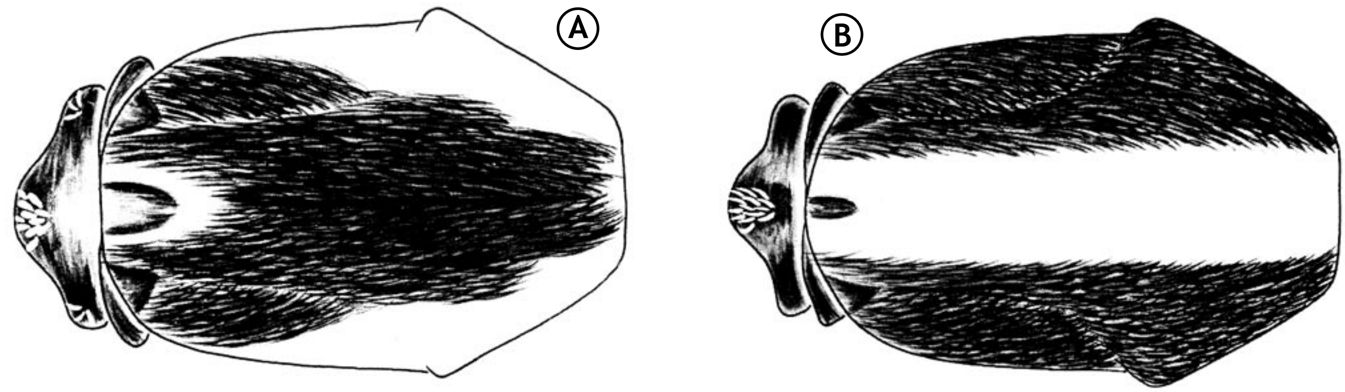


Figure 12.
A. Dorsal view of thorax - *Ae. triseriatus*
B. Dorsal view of thorax - *Ae. atlanticus*

13(12). Setae of anterior portion of scutum relatively few and weak, silver scaling of scutal fossa usually restricted to lateral and posterior portions (Fig. 13a); claws of fore- and midlegs evenly curved, tooth less than 0.3 length of claw (Fig. 13b)..***Ae. triseriatus***

13'. Setae of anterior portion of scutum numerous and well-developed, silver scaling usually covering entire scutal fossa (Fig. 13c); claws of fore- and midlegs abruptly curving, tooth 0.2 to 0.3 length of claw (Fig. 13d)..***Ae. hendersoni***

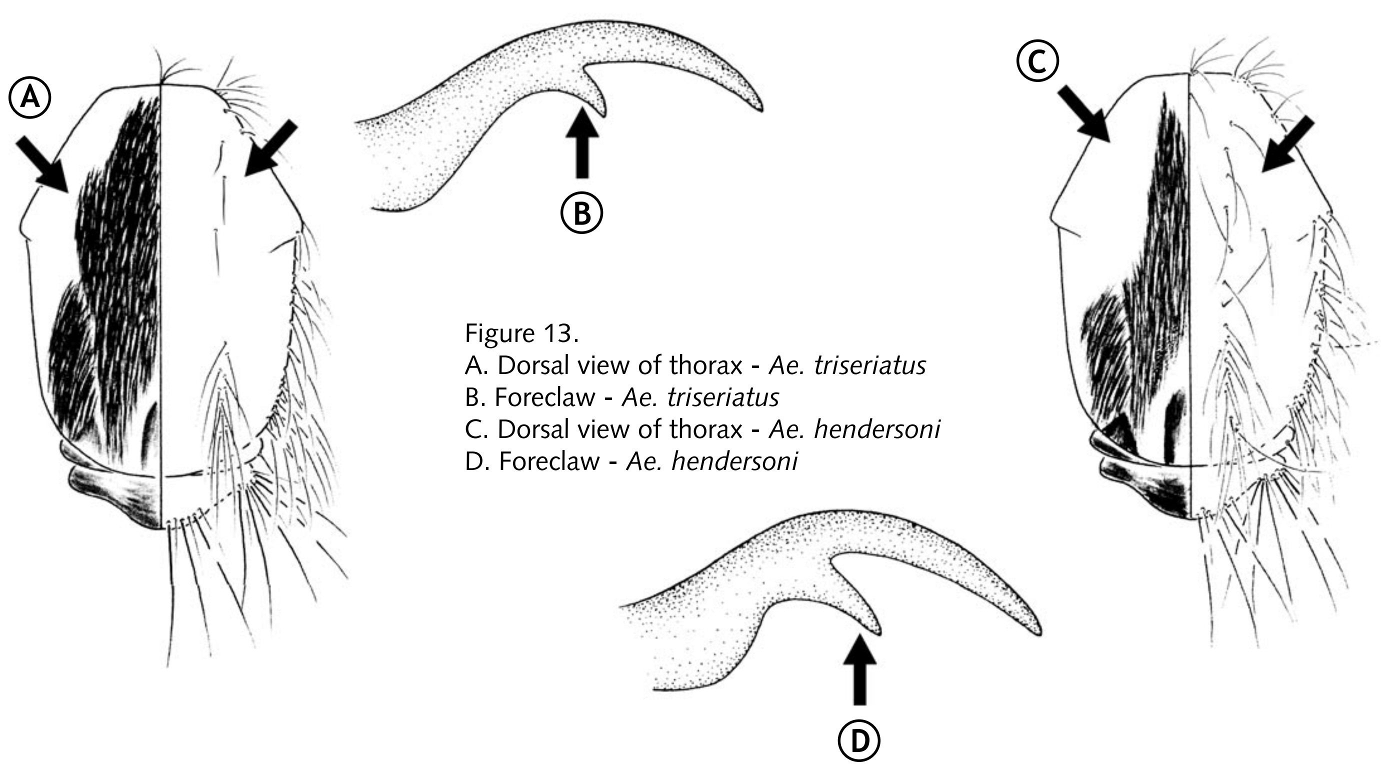


Figure 13.
A. Dorsal view of thorax - *Ae. triseriatus*
B. Foreclaw - *Ae. triseriatus*
C. Dorsal view of thorax - *Ae. hendersoni*
D. Foreclaw - *Ae. hendersoni*

14(12'). Scutum with two broad white stripes, separated by a bronzy-brown median strip (Fig. 14a)..***Ae. trivittatus***

14'. Scutum with a single white stripe (Fig. 14b)...15

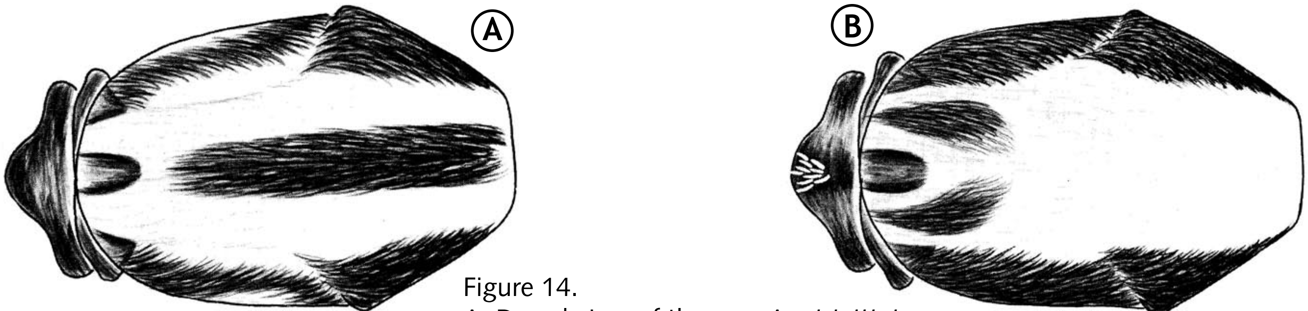


Figure 14.
A. Dorsal view of thorax - *Ae. trivittatus*
B. Dorsal view of thorax - *Ae. infirmatus*

15(14'). Scutum with anteromedian patch of silvery-white or pale yellow scales that extends to midpoint of thorax or a little beyond, and is much broader than lateral, dark-scaled areas (Fig. 15a)..***Ae. infirmatus***

15'. Scutum with median, longitudinal stripe of silvery scales, extending full length of thorax, usually narrower than lateral dark-scaled areas (Fig. 15b)...16

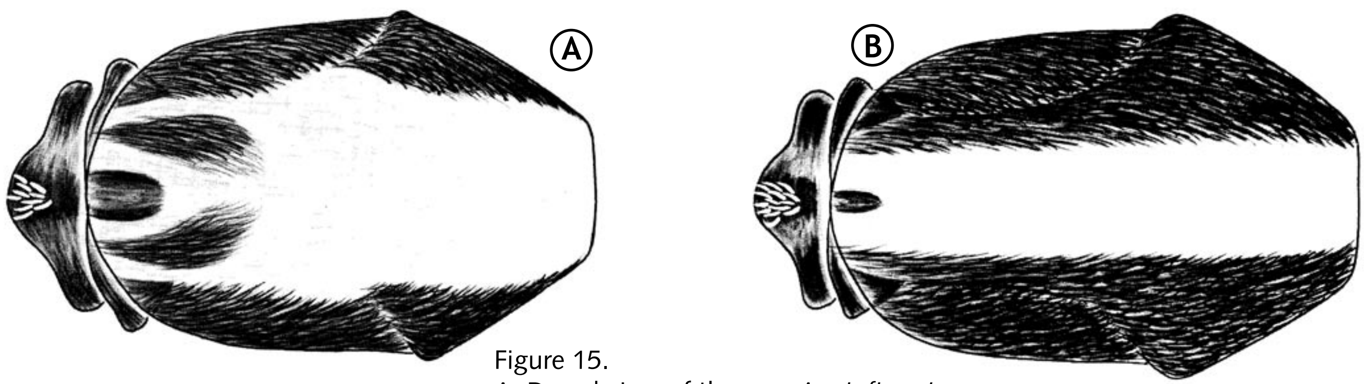


Figure 15.
A. Dorsal view of thorax - *Ae. infirmatus*
B. Dorsal view of thorax - *Ae. atlanticus*

16(15'). Occiput with few or no dark scales laterally (Fig. 16a); small species, wing length about 2.5mm..***Ae. dupreei***

16'. Occiput with prominent spots of dark appressed scales laterally (Fig. 16b); medium-sized species, wing length 3.0 - 4.0mm..***Ae. atlanticus, Ae. tormentor***

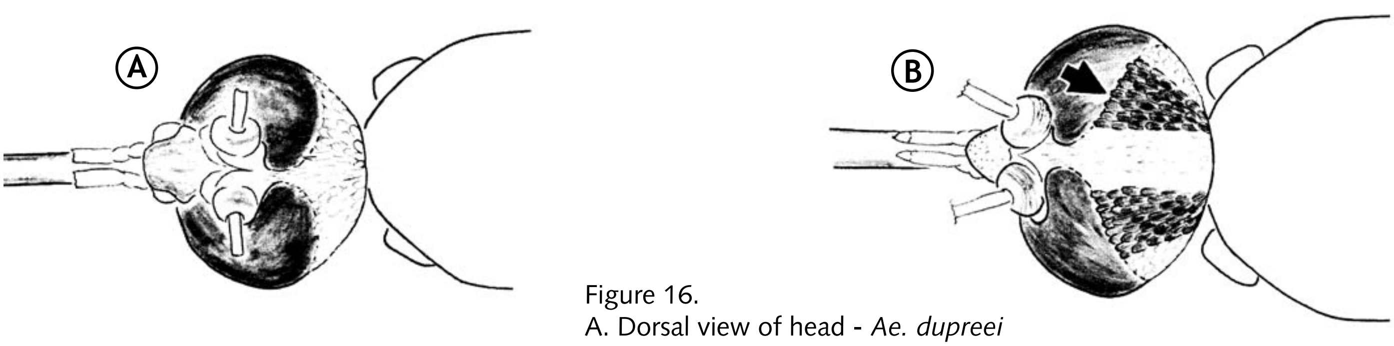


Figure 16.
A. Dorsal view of head - *Ae. dupreei*
B. Dorsal view of thorax - *Ae. atlanticus*

17(11’). Abdominal terga without basal, pale bands, or, if present, banded on fewer than half of terga (Fig. 17a)..***Ae. thibaulti***

17’. Abdominal terga always with pale, basal bands on more than half of abdominal terga, usually banded on segments I-VII (Fig. 17b)...18

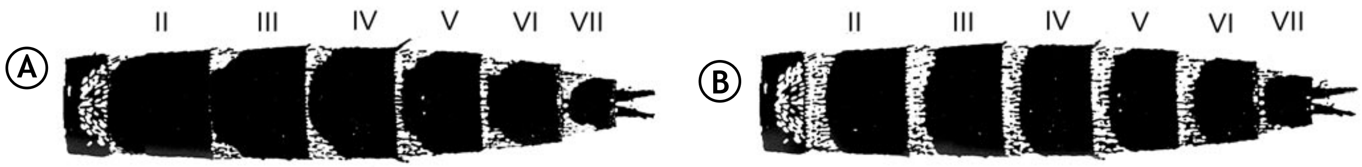


Figure 17.
A. Dorsal view of abdomen - *Ae. thibaulti*
B. Dorsal view of abdomen - *Ae. sticticus*

18(17’). Scutum with dark, median, longitudinal stripe (Fig. 18a); mesokatepisternum with scales extending to near anterior angle (Fig. 18b)..***Ae. sticticus***

18’. Scutum with uniformly colored scales (Fig. 18c); mesokatepisternum with scales usually not extending to anterior angle (Fig. 18d)..***Ae. cinereus***

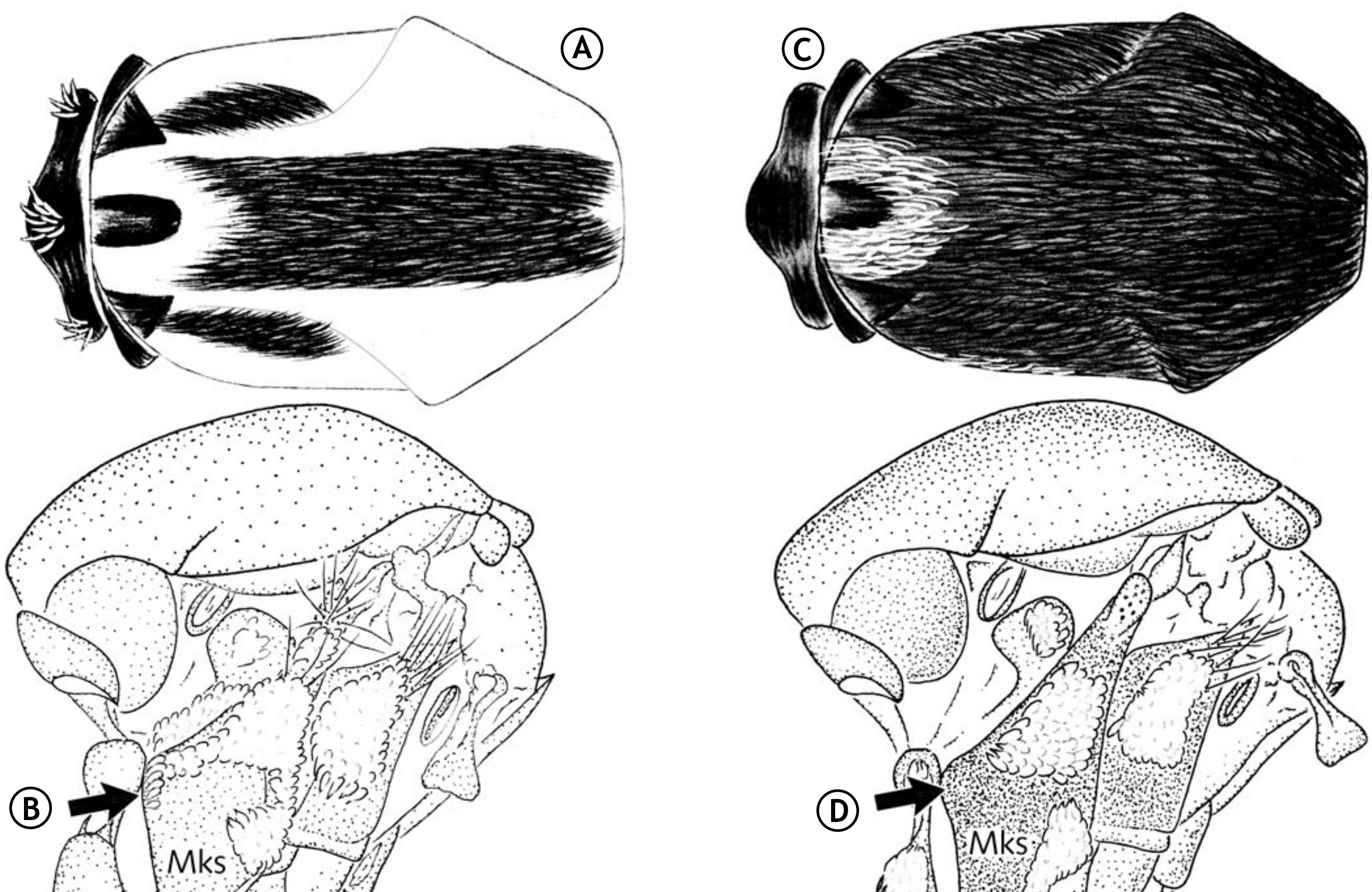


Figure 18.
A. Dorsal view of thorax - *Ae. sticticus*
B. Lateral view of thorax - *Ae. sticticus*
C. Dorsal view of thorax - *Ae. cinereus*
D. Lateral view of thorax - *Ae. cinereus*

Culex Adults

1. Scutum with middorsal, acrostichal setae (Fig. 1a);
occiput with narrow scales dorsally (Fig. 1b)....................2

1'. Scutum without middorsal acrostichal setae (Fig. 1c);
occiput with broad, appressed scales dorsally, sometimes limited to ocular line (Fig. 1d)....................8

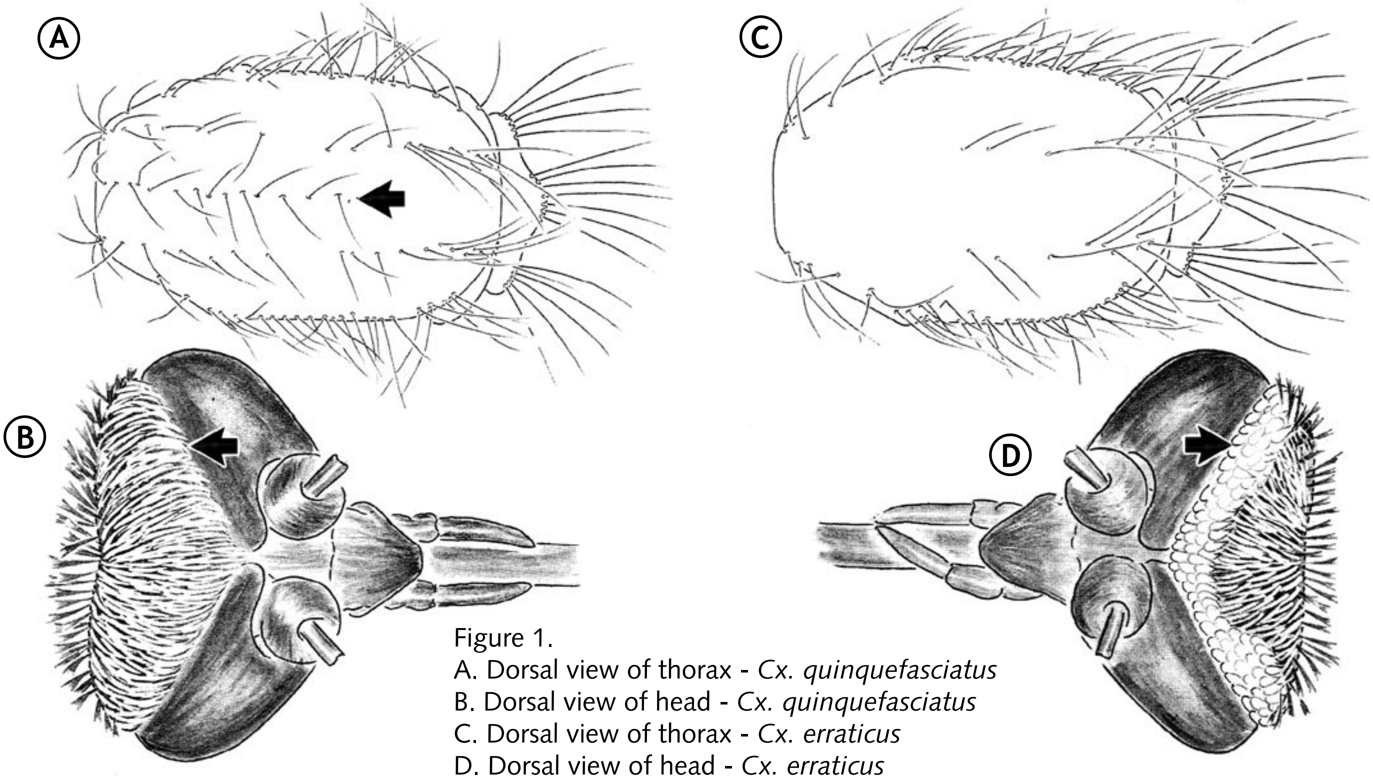


Figure 1.
A. Dorsal view of thorax - *Cx. quinquefasciatus*
B. Dorsal view of head - *Cx. quinquefasciatus*
C. Dorsal view of thorax - *Cx. erraticus*
D. Dorsal view of head - *Cx. erraticus*

2(1). Abdominal terga with bands or lateral patches of pale
scales along apical border (Fig. 2a)....................***Cx. territans***

2'. Abdominal terga with bands or lateral patches of pale
scales along basal border (Fig. 2b)....................3

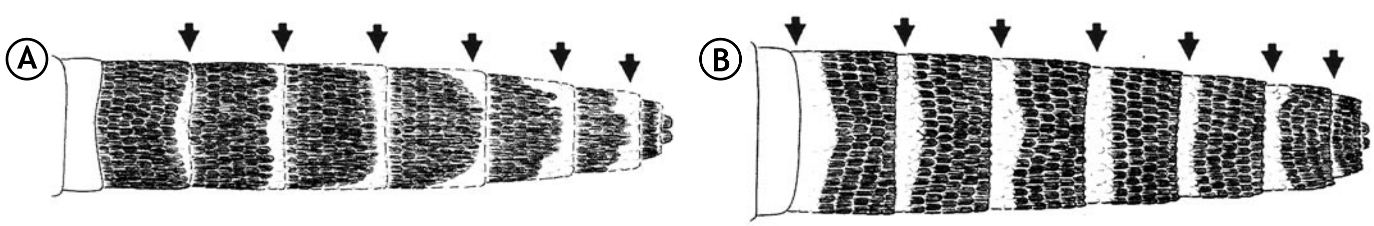


Figure 2.
A. Dorsal view of abdomen - *Cx. territans*
B. Dorsal view of abdomen - *Cx. restuans*

3(2'). Hindtarsomeres with basal and apical pale bands (Fig. 3a)....................4
3'. Hindtarsomeres entirely dark-scaled (Fig. 3b)....................5

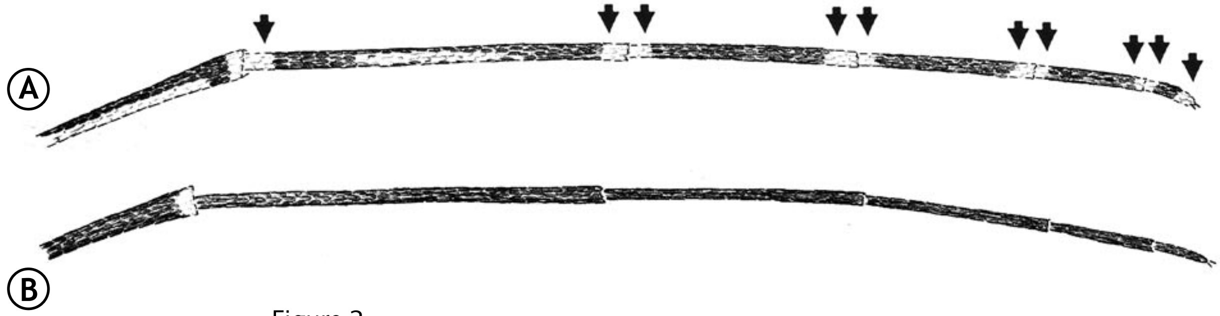


Figure 3.
A. Hindleg - *Cx. tarsalis*
B. Hindleg - *Cx. restuans*

4(3). Palpi tipped with white, proboscis ringed with white scales (Fig. 4a)....................***Cx. tarsalis***
4'. Palpi entirely dark, proboscis with white scales ventrally
near the middle (Fig. 4b)....................***Cx. coronator***

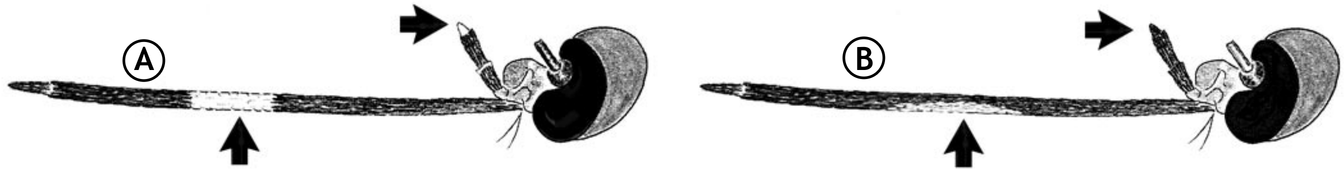


Figure 4.
A. Lateral view of head and proboscis - *Cx. tarsalis*
B. Lateral view of head and proboscis - *Cx. coronator*

5(3'). Abdominal terga not banded, or with narrow, basal,
pale bands (Fig. 5a)....................6
5'. Abdominal terga with conspicuous, basal bands of
pale scales (Fig. 5b)....................7

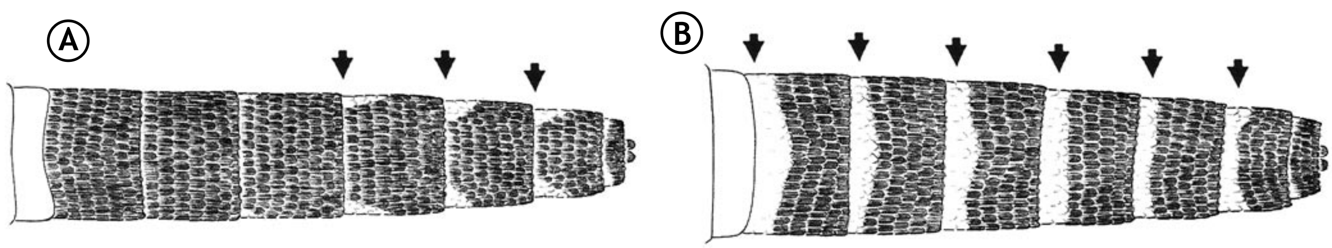


Figure 5.
A. Dorsal view of abdomen - *Cx. nigripalpus*
B. Dorsal view of abdomen - *Cx. restuans*

6(5). Scale patches on thoracic pleura absent, or if present, in groups of fewer than six scales (Fig. 6a); abdominal terga usually without basal bands of pale scales, tergum VII mostly dark-scaled (Fig. 6b)..***Cx. nigripalpus***

6'. Thoracic pleura with several patches of pale scales each with six or more scales (Fig. 6c); abdominal terga usually with narrow, basal bands of dingy yellow scales, tergum VII mostly yellow-scaled (Fig. 6d)..***Cx. salinarius***

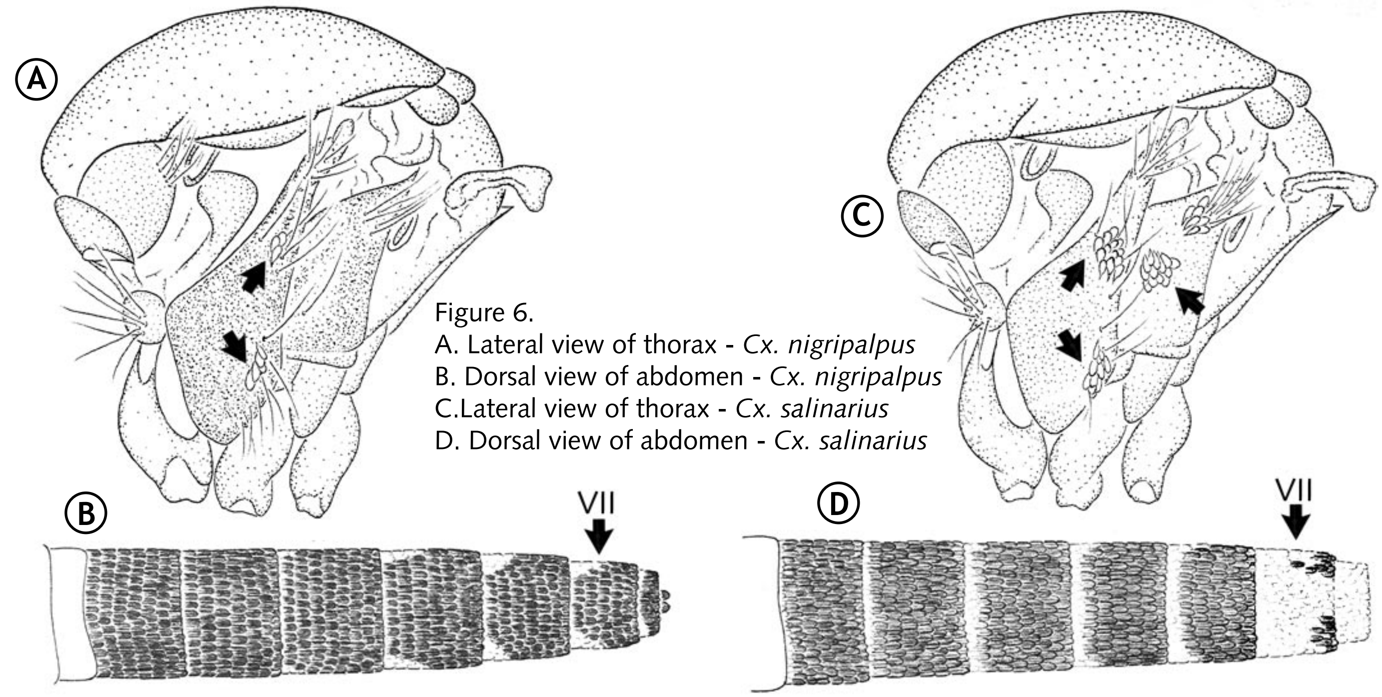


Figure 6.
A. Lateral view of thorax - *Cx. nigripalpus*
B. Dorsal view of abdomen - *Cx. nigripalpus*
C.Lateral view of thorax - *Cx. salinarius*
D. Dorsal view of abdomen - *Cx. salinarius*

7(5'). Basal pale bands of abdominal terga rounded posteriorly, with marked sublateral constrictions, narrowly joined to large lateral pale patches (Fig. 7a); scutum always lacking pale-scaled spots (Fig. 7b)...***Cx. quinquefasciatus***

7'. Basal pale bands of abdominal terga not rounded posteriorly, broadly joined to large lateral pale patches with only slight sublateral constrictions (Fig. 7c); scutum with (Fig. 7d) or without pale-scaled spots..***Cx. restuans***

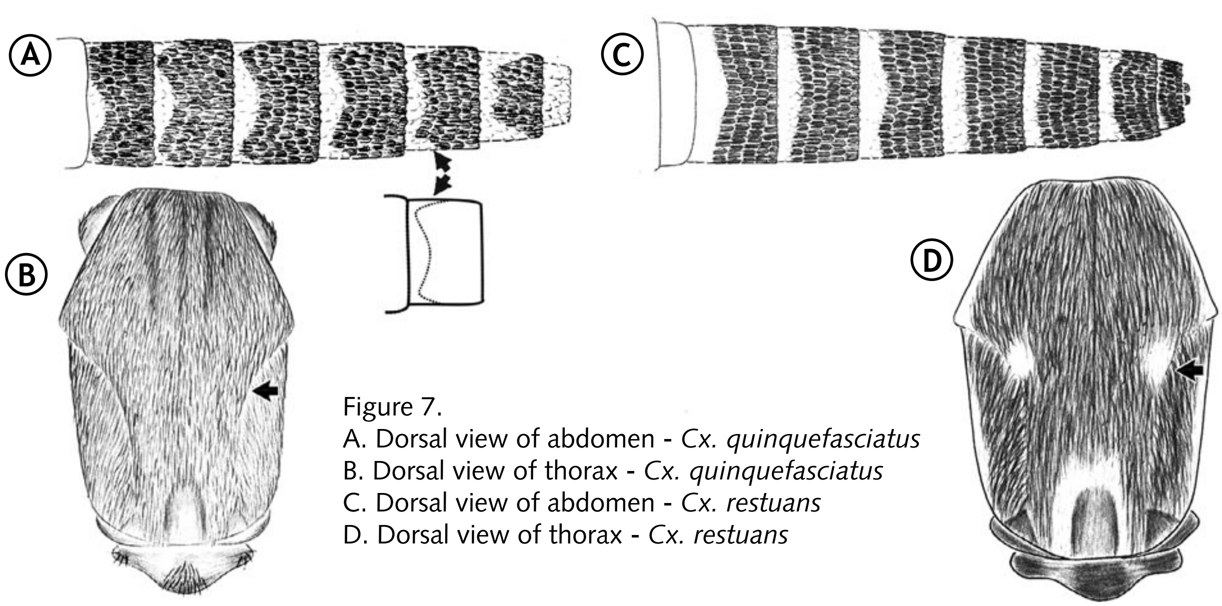
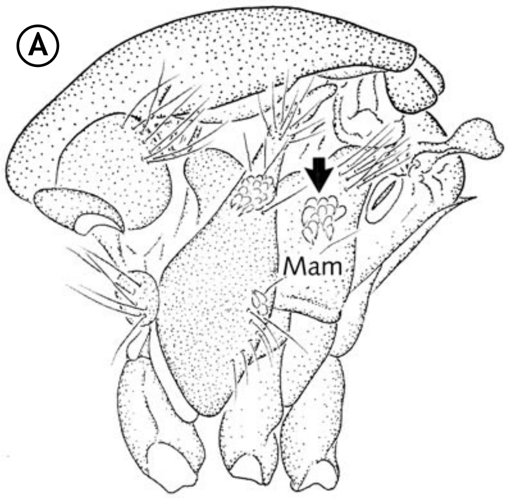


Figure 7.
A. Dorsal view of abdomen - *Cx. quinquefasciatus*
B. Dorsal view of thorax - *Cx. quinquefasciatus*
C. Dorsal view of abdomen - *Cx. restuans*
D. Dorsal view of thorax - *Cx. restuans*

8(1'). Mesanepimeron with large patch of broad, pale scales (Fig. 8a)...***Cx. erraticus***

8'. Mesanepimeron unscaled, or with few narrow scales (Fig. 8b)...9



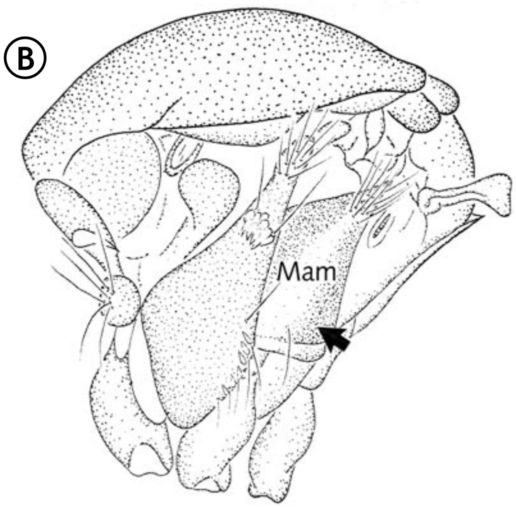
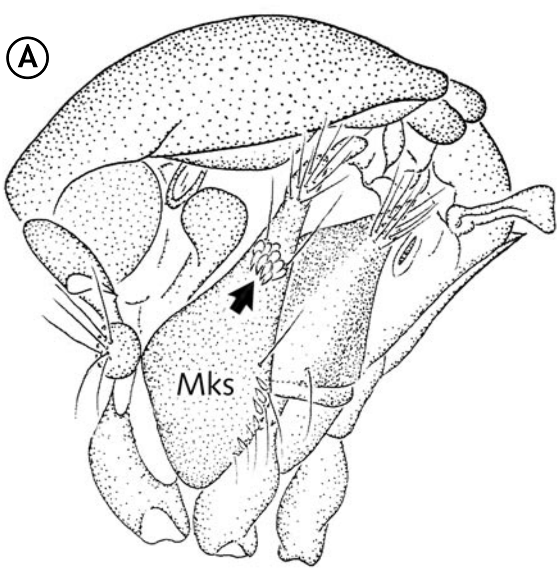


Figure 8.
A. Lateral view of thorax - *Cx. erraticus*
B. Lateral view of thorax - *Cx. peccator*

9(8). Upper mesokatepisternum with patch of more than five scales (Fig. 9a)..***Cx. peccator***

9'. Upper mesokatepisternum usually lacking scales, never with more than three scales (Fig. 9b)..........................***Cx. pilosus***



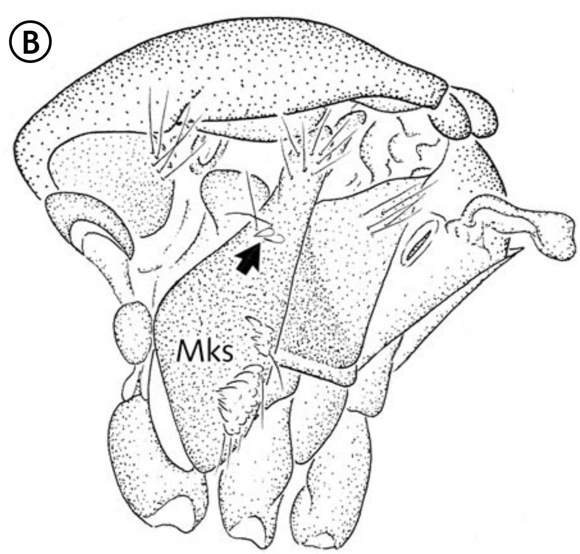


Figure 9.
A. Lateral view of thorax - *Cx. peccator*
B. Lateral view of thorax - *Cx. pilosus*

Psorophora Adults

1. Wing scales dark and pale on all veins (Fig. 1a); femora with more or less distinct, narrow, subapical band of pale scales (Fig. 1b)....2

1'. Wing scales all dark or with few pale scales on costa and subcosta (Fig. 1c); femora without subapical pale band (Fig. 1d)....3

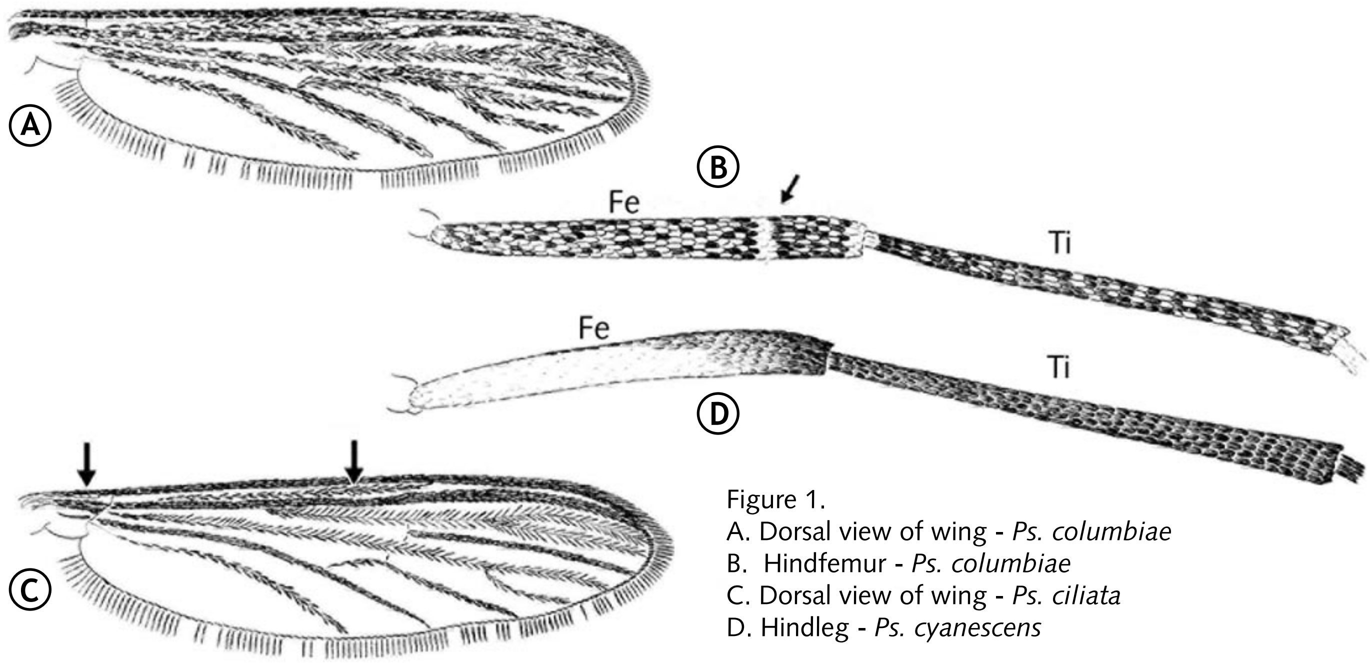


Figure 1.
A. Dorsal view of wing - *Ps. columbiae*
B. Hindfemur - *Ps. columbiae*
C. Dorsal view of wing - *Ps. ciliata*
D. Hindleg - *Ps. cyanescens*

2(1). Hindtarsomere 1 with pale-scaled rings at base and middle (Fig. 2a); dark and pale wing scales in no definite pattern (Fig. 2b)....***Ps. columbiae***

2'. Hindtarsomere 1 largely pale-scaled (Fig. 2c); wing with definite areas of pale and dark scales (Fig. 2d)....***Ps. discolor***

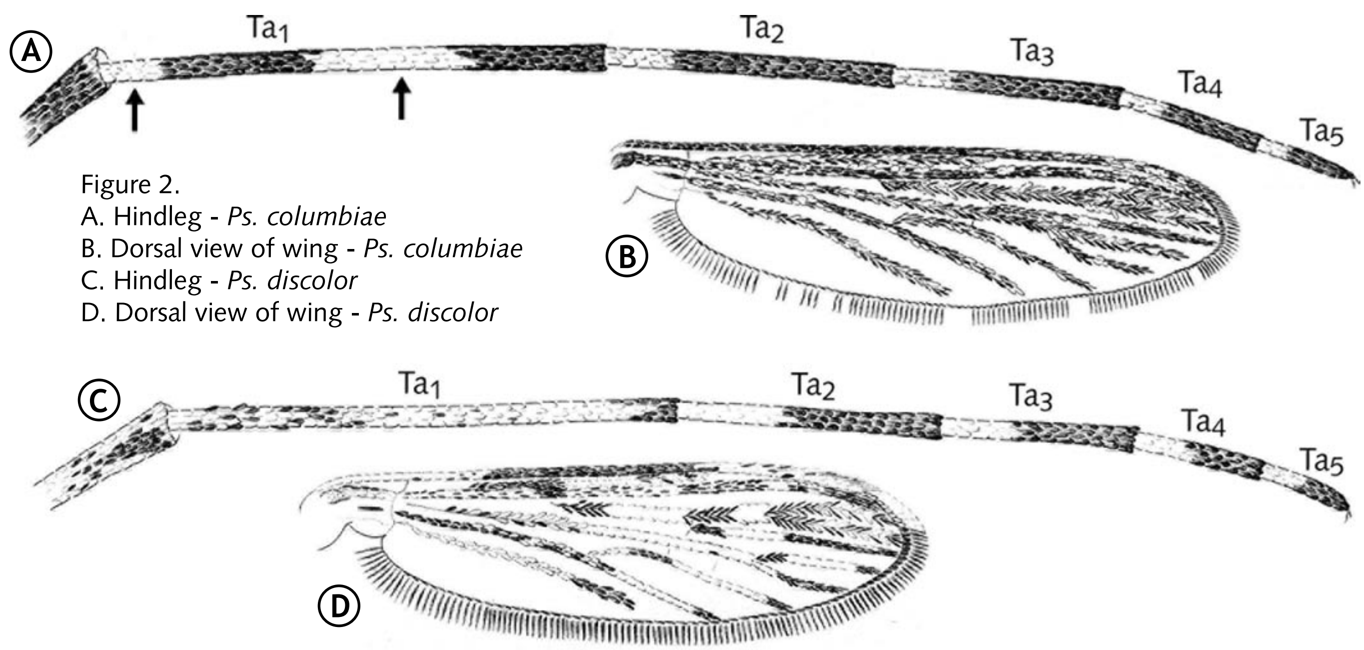


Figure 2.
A. Hindleg - *Ps. columbiae*
B. Dorsal view of wing - *Ps. columbiae*
C. Hindleg - *Ps. discolor*
D. Dorsal view of wing - *Ps. discolor*

3(1’). Apices of hindfemur and tibia with long, erect scales, shaggy in appearance; hindtarsomere 5 not entirely pale-scaled (Fig. 3a)..4

3’. Apices of hindfemur and hindtibia usually without erect scales (Fig. 3b), if somewhat shaggy, then hindtarsomere 4 or 5 entirely pale-scaled (Fig. 3c)..5

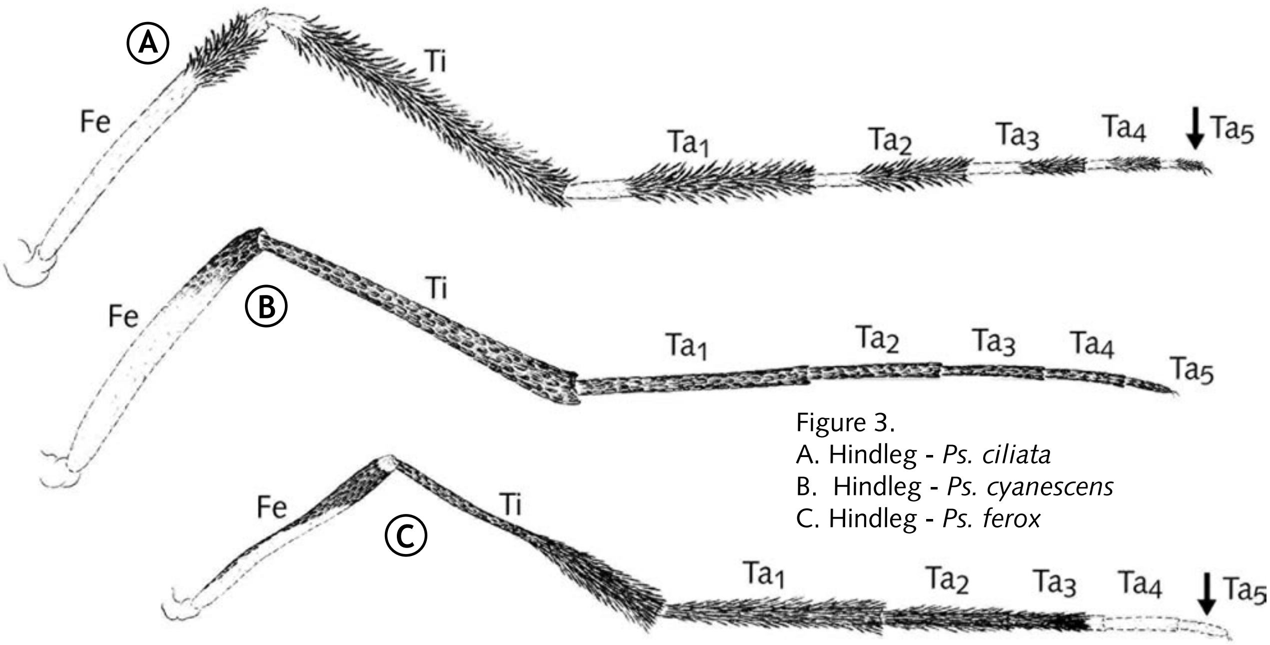


Figure 3.
A. Hindleg - *Ps. ciliata*
B. Hindleg - *Ps. cyanescens*
C. Hindleg - *Ps. ferox*

4(3). Scutum with a narrow median longitudinal stripe of golden scales (Fig. 4a); proboscis yellow-scaled in distal 0.5, except labella (Fig. 4b)..***Ps. ciliata***

4’. Scutum with a median longitudinal stripe of black scales (Fig. 4c); proboscis dark-scaled (Fig. 4d)..***Ps. howardii***

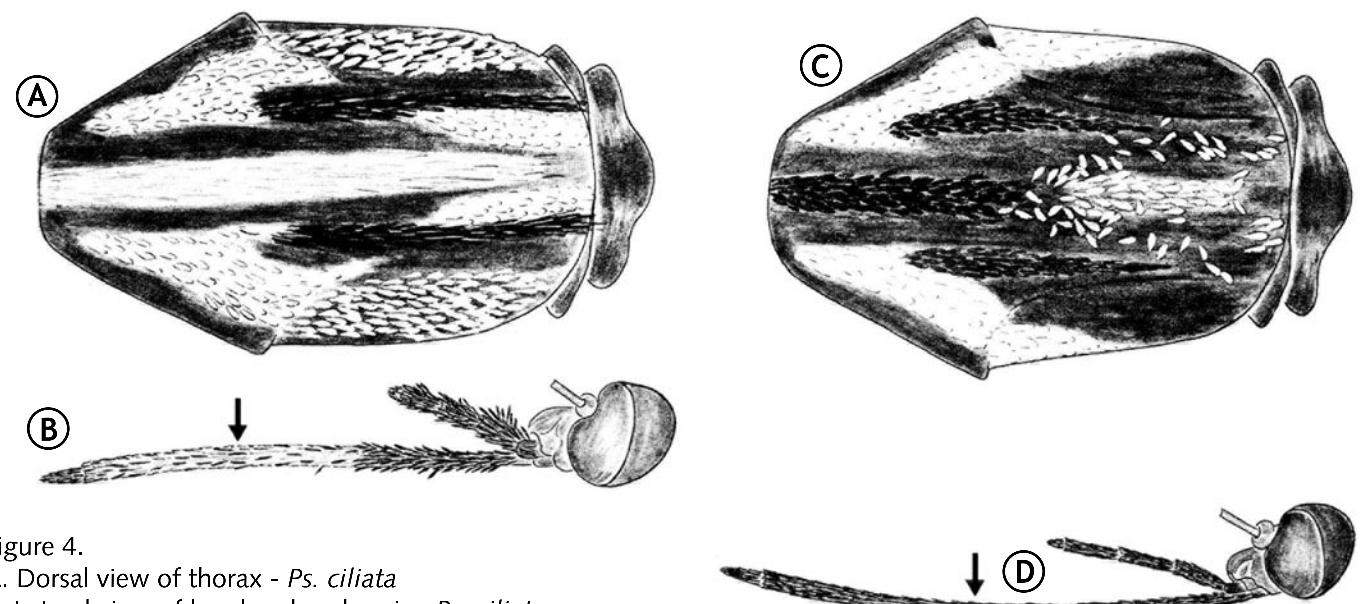


Figure 4.
A. Dorsal view of thorax - *Ps. ciliata*
B. Lateral view of head and proboscis - *Ps. ciliata*
C. Dorsal view of thorax - *Ps. howardii*
D. Lateral view of head and proboscis - *Ps. howardii*

5(3'). Hindtarsomeres dark-scaled (Fig. 5a); abdominal terga with dorsal patches of golden scales (Fig. 5b)..***Ps. cyanescens***

5'. Hindtarsomeres with at least some pale scaling (Fig. 5c); abdominal terga with pale to yellow scales, if present, restricted to apicolateral corners (Fig. 5d)..6

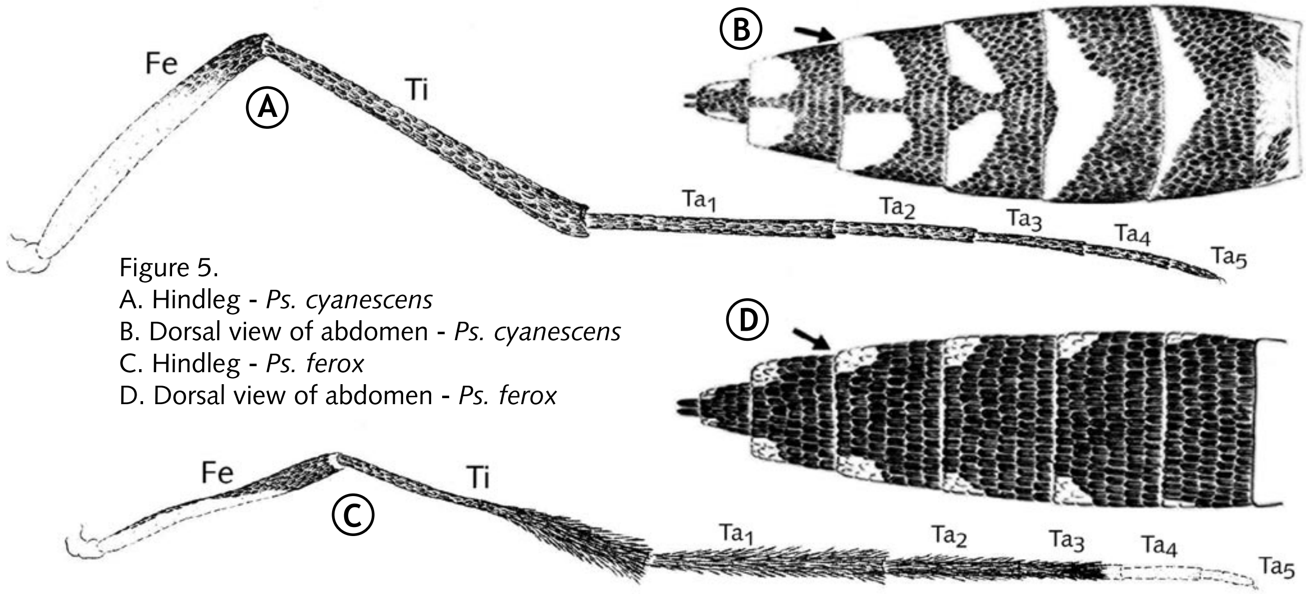


Figure 5.
A. Hindleg - *Ps. cyanescens*
B. Dorsal view of abdomen - *Ps. cyanescens*
C. Hindleg - *Ps. ferox*
D. Dorsal view of abdomen - *Ps. ferox*

6(5'). Only hindtarsomere 4 pale-scaled on at least one side, other hindtarsomeres dark-scaled (Fig. 6a)..7

6'. Hindleg with tarsomeres 4, 5, and often part of tarsomere 3 pale-scaled (Fig. 6b)..8

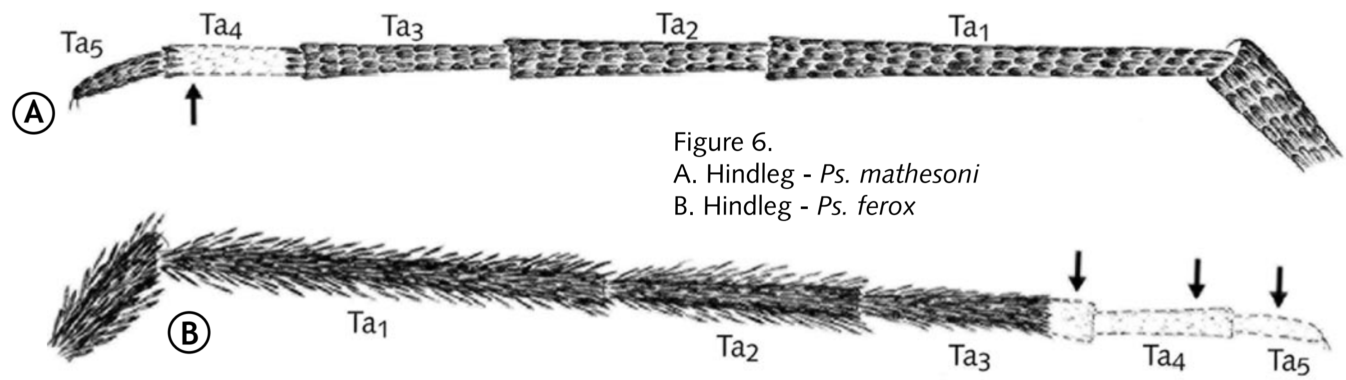


Figure 6.
A. Hindleg - *Ps. mathesoni*
B. Hindleg - *Ps. ferox*

7(6). Scutum entirely covered with yellowish-white scales (Fig. 7a)..***Ps. johnstonii***

7'. Scutum with broad median longitudinal stripe of dark scales, with pale yellow or grayish-white scales laterally (Fig. 7b)..***Ps. mathesoni***

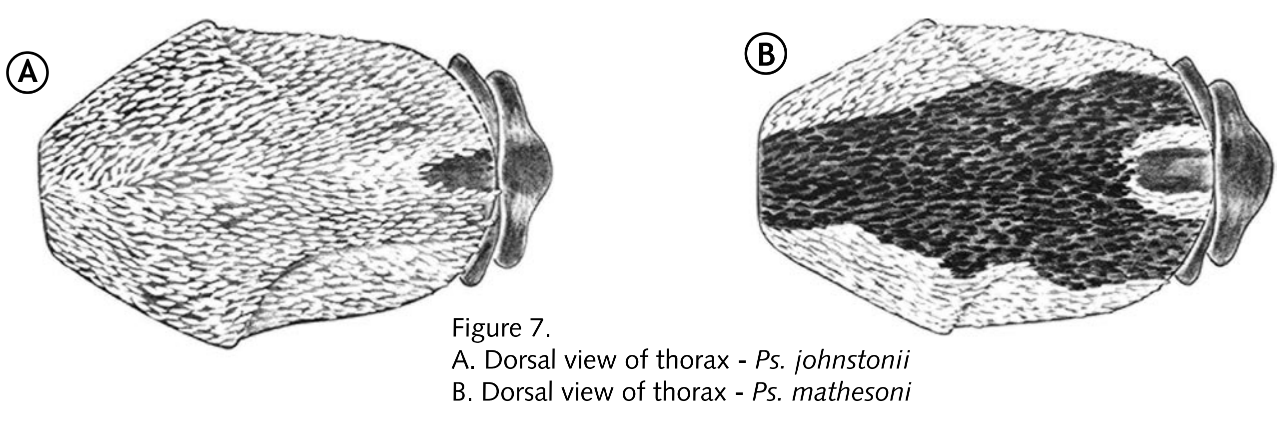


Figure 7.
A. Dorsal view of thorax - *Ps. johnstonii*
B. Dorsal view of thorax - *Ps. mathesoni*

8(6’). Scutum clothed with a scattered mix of dark brown and golden yellow scales (Fig. 8a); abdominal tergum I with purplish scales medially (Fig. 8b)......***Ps. ferox***

8’. Scutum with a broad median longitudinal stripe of dark scales, with pale yellow or grayish-white scales laterally (Fig. 8c); tergum I with pale scales medially (Fig. 8d)......9

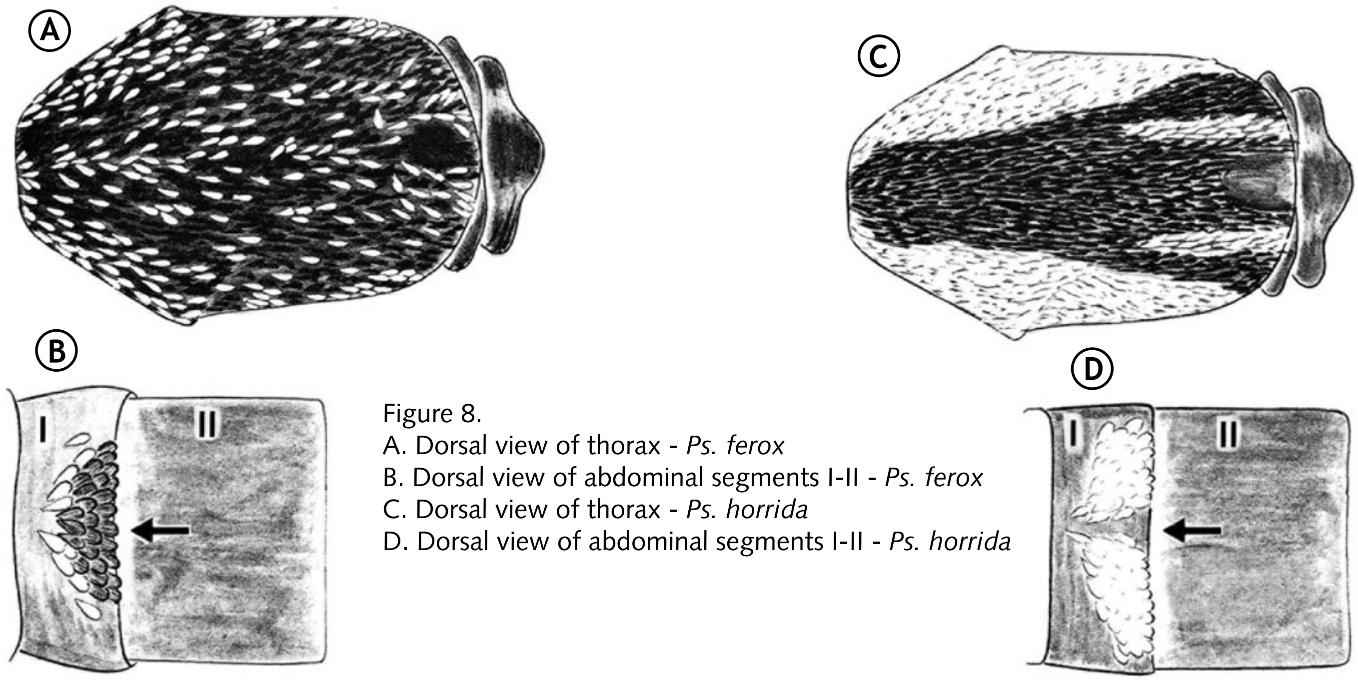
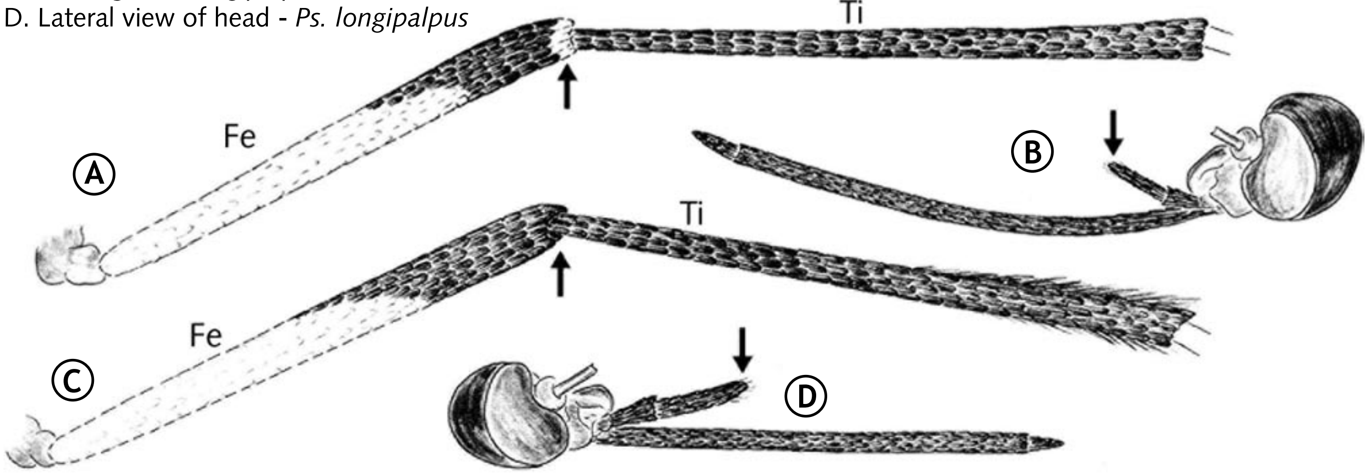


Figure 8.
A. Dorsal view of thorax - *Ps. ferox*
B. Dorsal view of abdominal segments I-II - *Ps. ferox*
C. Dorsal view of thorax - *Ps. horrida*
D. Dorsal view of abdominal segments I-II - *Ps. horrida*

9(8’). Pale kneespots present on femora (Fig. 9a); palps less than 0.3 as long as proboscis (Fig. 9b)......***Ps. horrida***

9’. Pale kneespots absent on femora (Fig. 9c); palps a little more than 0.3 as long as proboscis (Fig. 9d)......***Ps. longipalpus***

Figure 9.
A. Hindleg - *Ps. horrida*
B. Lateral view of head - *Ps. horrida*
C. Hindleg - *Ps. longipalpus*
D. Lateral view of head - *Ps. longipalpus*



Culiseta Adults

1. Dorsum of abdomen with distinct basal, pale bands (Fig. 1a); wing with pale and dark scales intermixed on anterior veins (Fig. 1b)..***Culiseta inornata***

1'. Dorsum of abdomen without basal, pale bands (Fig. 1c); wing scales entirely dark (Fig. 1d)...***Culiseta melanura***

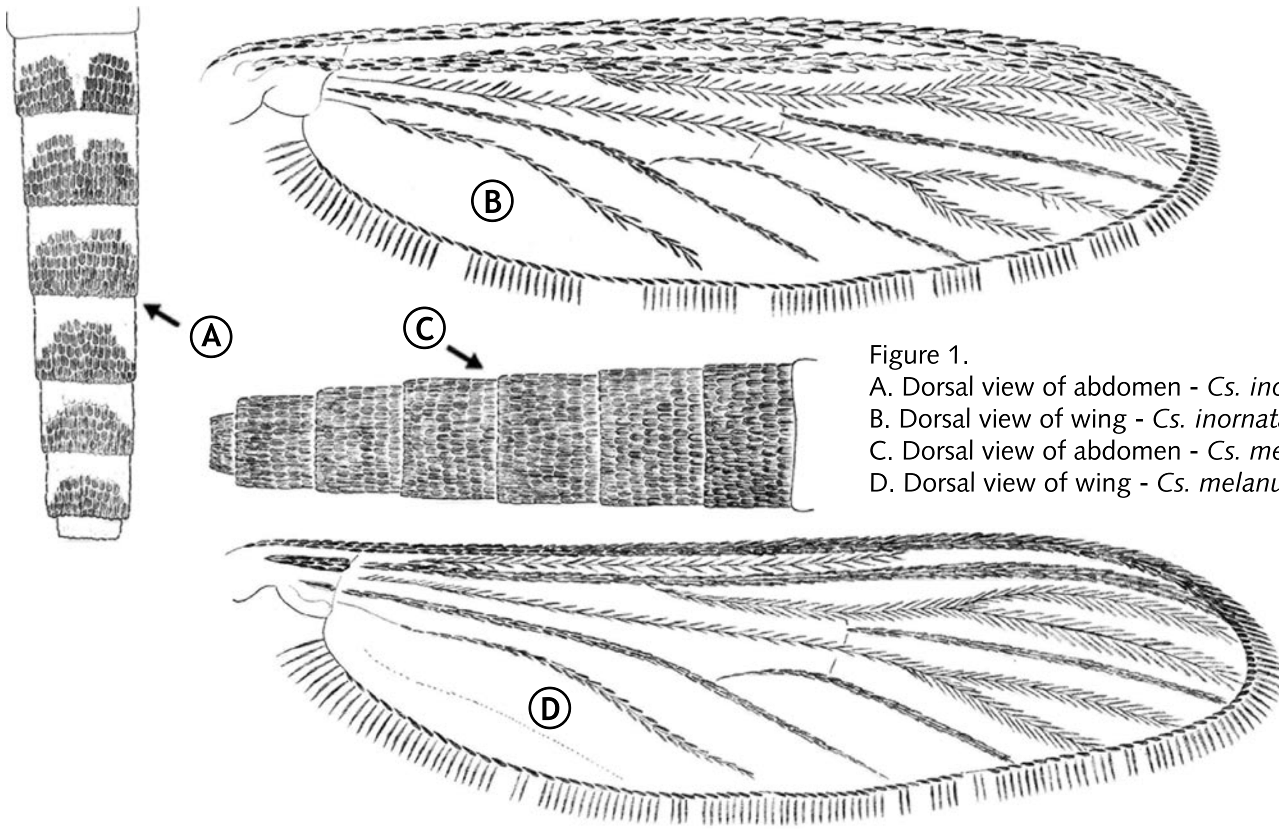


Figure 1.
A. Dorsal view of abdomen - *Cs. inornata*
B. Dorsal view of wing - *Cs. inornata*
C. Dorsal view of abdomen - *Cs. melanura*
D. Dorsal view of wing - *Cs. melanura*

Mansonia Adults

1. Apex of abdominal segment VII with row of short, dark spiniforms (Fig. 1a); ventral surface of proboscis mostly dark-scaled (Fig. 1b)..***Mansonia titillans***

1'. Apex of abdominal segment VII without spiniforms (Fig. 1c); ventral surface of proboscis with patch of pale scales (Fig. 1d)...***Mansonia dyari***

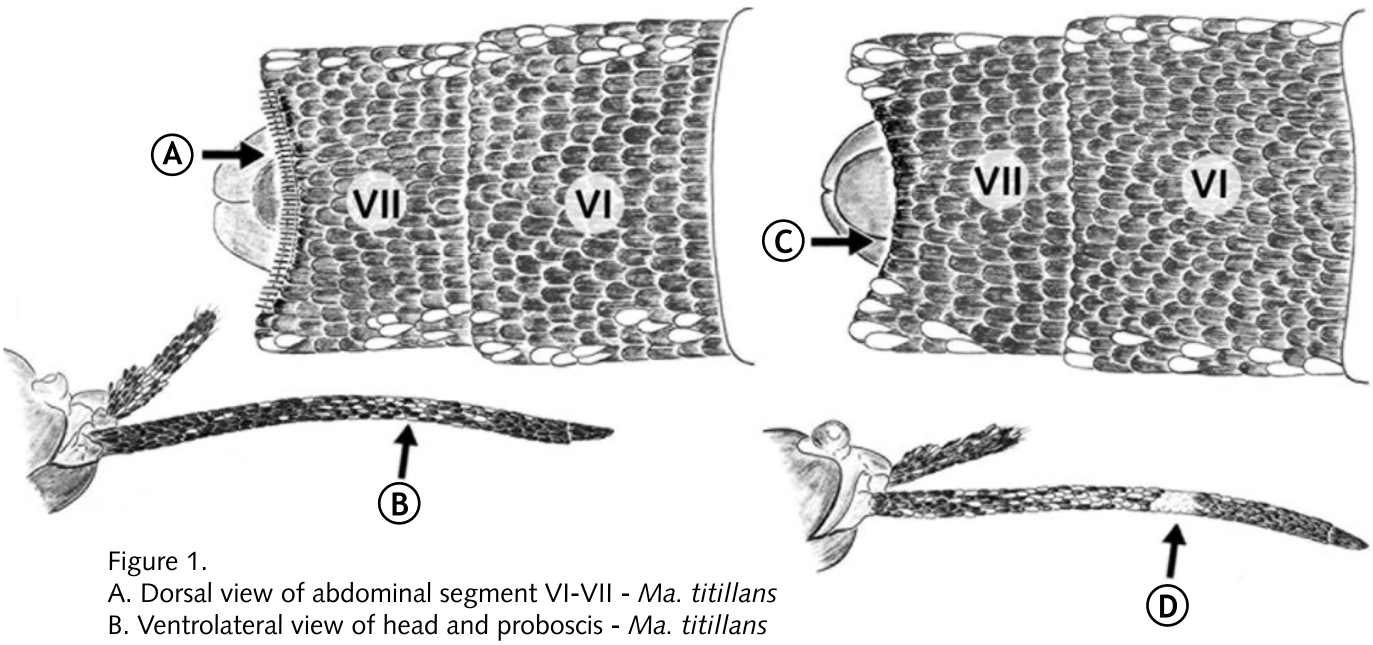


Figure 1.
A. Dorsal view of abdominal segment VI-VII - *Ma. titillans*
B. Ventrolateral view of head and proboscis - *Ma. titillans*
C. Dorsal view of abdominal segment VI-VII - *Ma. dyari*
D. Ventrolateral view of head and proboscis - *Ma. dyari*

Orthopodomyia Adults

1. Lower mesokatepisternal setae 0-2 (Fig. 1a); base of wing vein R_{4+5} usually dark-scaled (Fig. 1b)...***Orthopodomyia alba***

1'. Lower mesokatepisternal setae 4 or more (Fig. 1c); base of wing vein R_{4+5} usually with patch of pale scales (Fig. 1d)....................................***Orthopodomyia signifera***

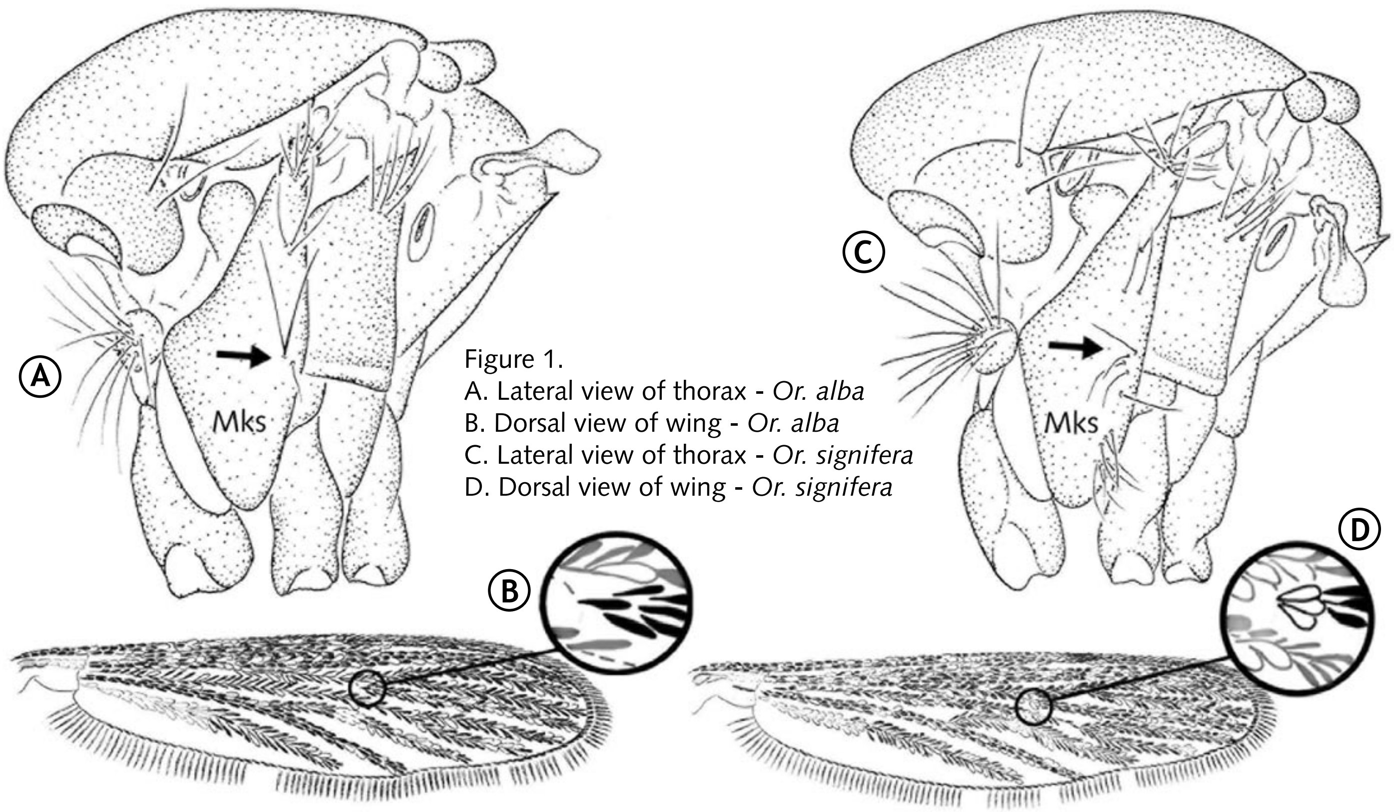


Figure 1.
A. Lateral view of thorax - *Or. alba*
B. Dorsal view of wing - *Or. alba*
C. Lateral view of thorax - *Or. signifera*
D. Dorsal view of wing - *Or. signifera*

Uranotaenia Adults

1. Hindtarsomeres 4 and 5, and apical part of 3, pale-scaled (Fig. 1a)......................................***Uranotaenia lowii***

1'. Hindtarsomeres all dark-scaled (Fig. 1b)..***Uranotaenia sapphirina***

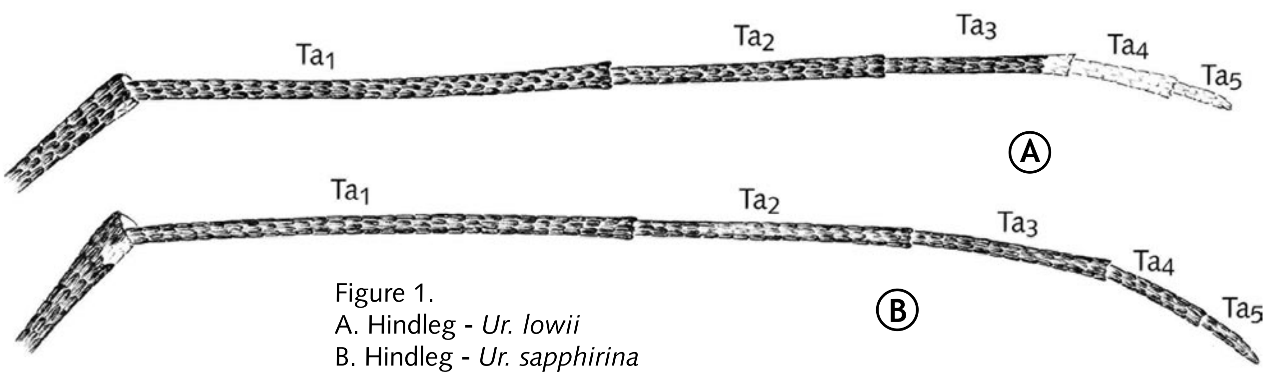


Figure 1.
A. Hindleg - *Ur. lowii*
B. Hindleg - *Ur. sapphirina*

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