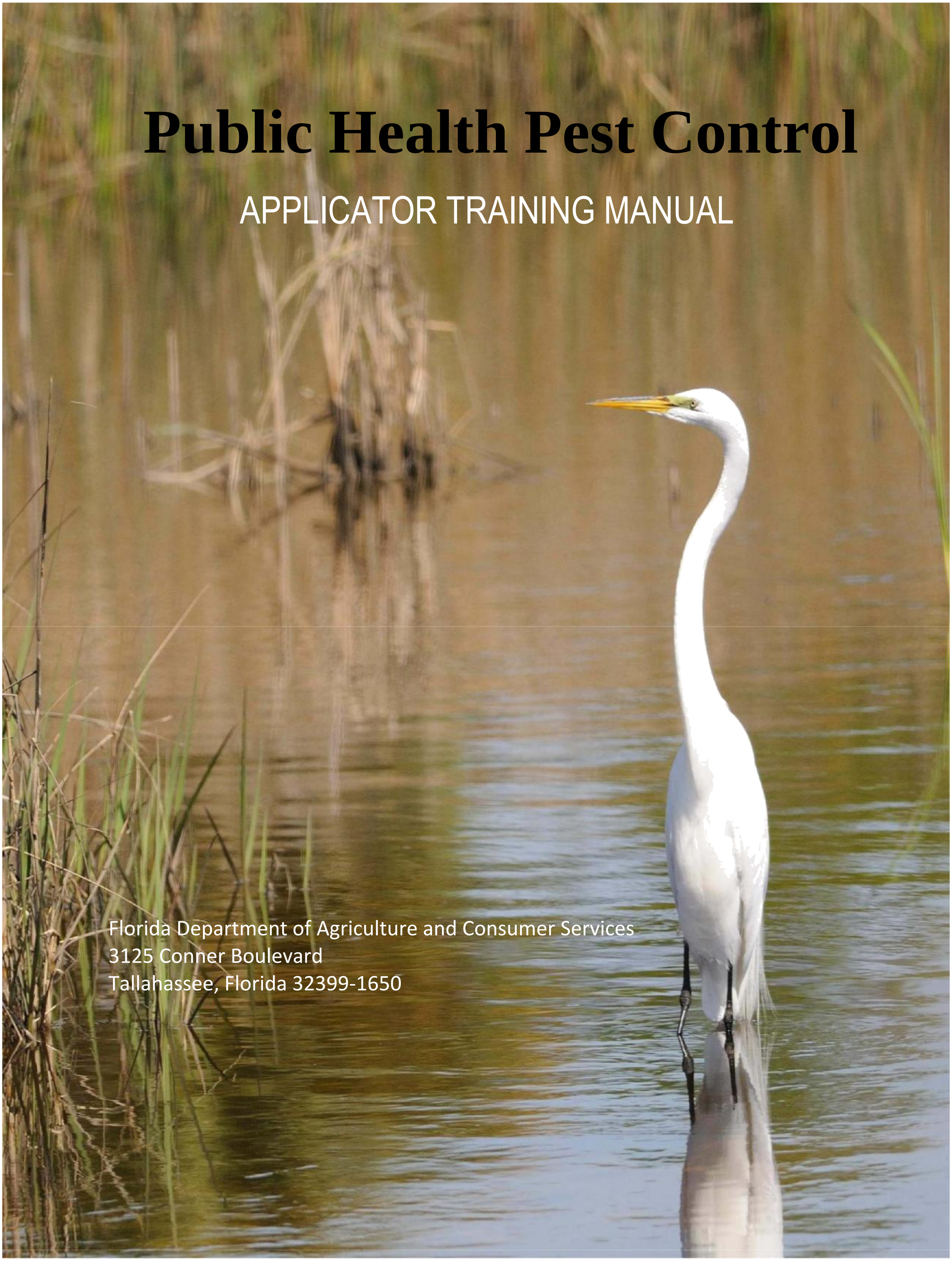
Public Health Pest Control

APPLICATOR TRAINING MANUAL



Florida Department of Agriculture and Consumer Services
3125 Conner Boulevard
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Acknowledgements

In accordance with Florida Administrative Code Chapter 5E-13.040, all persons who apply or supervise the application of a pesticide intended to control arthropods on property other than their own individual residential or agricultural property must be licensed to do so with a Public Health Pest Control (PHPC) license or work under the supervision of a licensed applicator. In order to obtain the PHPC license, applicants must score 70% or above on two exams administered by the Florida Department of Agriculture and Consumer Services (FDACS): the General Standards (Core) exam and the Public Health Pest Control exam. This Public Health Pest Control Manual, in conjunction with the Core Manual “Applying Pesticides Correctly” published by University of Florida, will provide general information necessary to meet U. S. Environmental Protection Agency and Florida standards for certification as a pesticide applicator in the commercial category, Public Health Pest Control.

The original Public Health Pest Control Manual was prepared by Elisabeth Beck of the Florida Department of Health and Rehabilitative Services (HRS), Office of Entomology. Technical assistance was provided by Dr. Andrew Rogers, retired, HRS, and the late Dr. Maurice Provost, Florida Medical Entomology Laboratory. The manual was edited and produced by the IFAS Editorial Department under the supervision of JoAnn Pierce. Appreciation is expressed to the U. S. Department of Health and Human Services (USHHS), and to extension specialists in neighboring states for valuable ideas and visual aids. Credit is due to the late Paul J. Hunt, and John Gamble, East Volusia Mosquito Control District, and Thomas M. Loyless, Bureau of Entomology and Pest Control (BEPC) of FDACS for photographs of equipment and habitats.

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The last edition was updated and revised in May 2001 by Thomas M. Loyless, FDACS, with assistance from Edsel M. Fussell, Florida Keys Mosquito Control District, Mark Latham, Manatee County Mosquito Control District and Stephen Sickerman, FDACS (currently with the South Walton Mosquito Control District).

This edition was updated and revised in 2011 by Dr. Yongxing “Peter” Jiang, with assistance from Dr. Dave Daiker, Angela Weeks-Samanie, and Joe Claborn of the Florida Department of Agriculture and Consumer Services, Dr. Jeff Stivers, Collier Mosquito Control District, and Dr. Rui-de Xue, Anastasia Mosquito Control District.

The Department would like to extend a special thanks to Joe Claborn for the cover photograph of the St. Marks River and mosquito breeding habitats.

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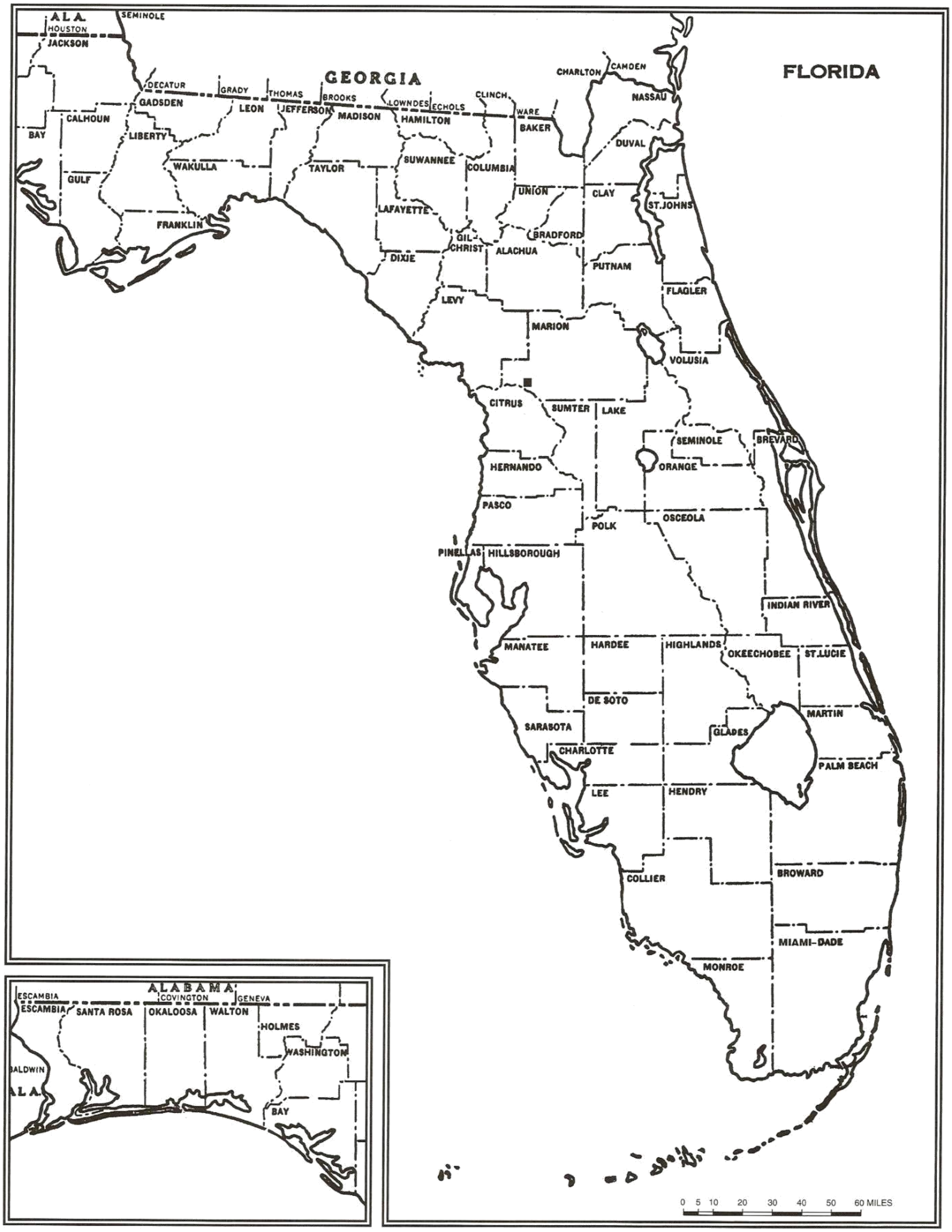

Figure 1. **Florida and its counties**

Introduction

The State of Florida has made great progress in reducing the hordes of malaria-carrying *Anopheles* and salt marsh mosquitoes which, in years past, harassed visitors and Floridians alike. Many miles of salt marsh stretching down the east and west coasts of the State have been ditched or impounded by the mosquito control districts, making the coastal areas habitable and opening them to development for housing and as tourist resorts.

There is no question that the control of salt marsh mosquitoes has made a major contribution to the development of the tourist industry in this state; without this control, tourists would not have repeatedly visited to enjoy the beaches and attractions. Figure 2 gives a good picture of the relationship, showing the steady rise in income from tourism plotted against the steady decline of the major salt marsh pest mosquito, *Aedes taeniorhynchus*.

Mosquitoes occur throughout the world, breeding in almost every known aquatic habitat except very swift currents and in open bodies of water. Wherever they occur, mosquitoes are, for humans, at best an annoyance and at worst vectors of deadly diseases. Over 3,000 species have been described worldwide and they display a broad range of habitats. Larvae may be found in such diverse places as the grassy margins of ponds, land crab holes, and aquatic plants. Depending on the species, eggs may be laid singly or in rafts, on water or on damp soil where they hatch in subsequent flooding. Flight ranges also vary among species from a few hundred feet to more than eighty miles with favorable winds. Hibernation or overwintering in different species may be in the egg stage, as larvae, or as adults. Each of these variations among species can affect the efficiency of any measure utilized to control them.

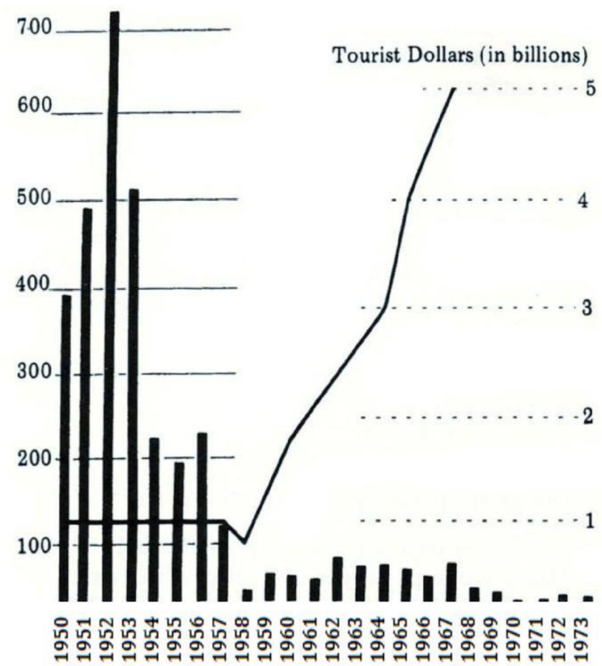

Figure 2. **Average number of female** *Aedes taeniorhynchus* **per light trap**

History of Mosquito Control in Florida

Florida is the leading tourism destination in the United States, and, in terms of dollars spent, it is the number one vacation destination in the world.

Florida, with more than 1,200 miles of coastline, a warm subtropical climate, and heavy rainfall, produces an unusually rich fauna, including 80 species of mosquitoes.

We often forget that Florida was not always a vacation paradise where people could escape for warmth, recreation and relaxation. As little as 100 years ago, many parts of Florida were considered unbearable, thanks in large part to legions of mosquitoes. Pestilence and disease raged, and many people said the State could not be developed. When Congress was debating the merits of statehood for Florida, John Randolph of Virginia stated that Florida could never be developed, nor would it ever be a fit place to live. He described the land as a "land of swamps, of quagmires, of frogs and alligators and mosquitoes."

The battle with the mosquito, however, was a long, tough fight and there were many casualties. The mosquito was such a plague when the Spaniards arrived that they named what today is Ponce de Leon Inlet, "Barro de Mosquitoes." Since the time of the earliest maps, some of Florida's inlets, lagoons, and sections have borne the name Mosquito. In the 18th Century, the part of Florida lying between the St. Johns River and the coastal lagoons north of Cape Canaveral was called "The Mosquito Country," or "The Mosquitoes."

In 1824, when Mosquito Country became a county which included a large portion of peninsular Florida, government officials could think of no more appropriate name than "Mosquito County." Today, that county is known as Orange County and is home for many of our major attractions in and around Orlando.

For many years settlements in Florida were restricted to the northern tier of the state. The peninsular portion of Florida was a series of swamps, lakes, rivers, and hammocks populated mostly by hoards of mosquitoes and other biting insects.

Although northern Florida was settled, it was anything but a pleasant place to live. It suffered from disease, hardship, and poverty; the major cities of Jacksonville, St. Augustine, Tallahassee and Pensacola were known as the "malaria belt."

Summer routinely brought swarms of mosquitoes and deadly fevers to the region. Commerce was seriously curtailed and those who could afford it fled to the north for relief. Those forced to stay behind faced the threat and certainty of disease. One of the worst sieges of disease was the yellow fever epidemic in 1877 in Jacksonville and Fernandina Beach. It was described by historians as the State's worst holocaust. Fernandina Beach, with a population of 1,632, had 1,146 persons ill with the fever. Twenty-four died. In 1887, yellow fever epidemics raged in Key West, Tampa, Plant City, and Manatee. The 1888 epidemic in Jacksonville saw 10,000 persons (out of a population of 26,700 in Duval County) flee the city in carriages, drays, wagon trains, and ships.

All of that has changed thanks to mosquito control. Consider, for example, the success story of mosquito control at Sanibel Island. On Florida's rapidly expanding southwest coast, Sanibel is one of the resort jewels our State offers, fantastic weather, incredible sunsets, great beaches, and fine resorts. Sanibel has it all. But without mosquito control, it would be virtually uninhabitable. In fact, the island was once so heavily infested with mosquitoes that bred in the vast grassy marshes that the local postman had to make his rounds in July dressed like an Eskimo in a parka and netting.

Anti-Mosquito Association Formed

No organized effort was made to control mosquitoes in Florida as a way of preventing malaria until World War I when the U.S. Army, U. S. Public Health Service, and the State Board of Health set up a program of drainage and larviciding at Camp Johnson, near Jacksonville. In 1919, the State Board of Health, the city of Perry, and the Burton Swartz Cypress Company jointly set up a malaria control project in the city of Perry, one of the most malarious areas of the State. At that time the Perry project was one of the largest malaria control projects in the country and was the first non-military control project in Florida.

Mosquito control in Florida was given impetus in 1922 by the formation of the Florida Anti-Mosquito Association (FAMA) (now known as the Florida Mosquito Control Association, FMCA), with Dr. J. Y. Porter, the State's first Health Officer, serving as its president. The Indian River County Mosquito Control District was established in 1925, followed by St. Lucie Mosquito District in 1926, Broward County Mosquito Control District in 1934 and Dade County Mosquito Control District in 1935. By 1975, there were 52 mosquito control districts in Florida, and that number has remained fairly constant to the present day.

From the depression year of 1933 until funds were withdrawn in 1941, many malaria control projects were performed with funding from the Civil Works Administration, Emergency Relief Administration of the Works Progress Administration. During this period, more than 1,500 miles of drainage ditches were dug throughout the state to eliminate mosquito breeding habitats.

In 1941, a Bureau of Malaria Control was created within the Division of Health and in 1942, the U.S. Public Health Service set up the first Malaria Control in War Areas project in Florida near Tallahassee. Similar projects were then established around all military bases in the state. A program of DDT residual house spraying in malarious areas of Florida was supported by U.S. Public Health Funds from 1945 through 1949.

Division of Entomology Created

In 1946, the Bureau of Malaria Control was abolished and a Division of Entomology was created within the Bureau of Sanitary Engineering. In 1953, the Division was raised to Bureau status. In 1976, the Bureau of Entomology became the Office of Entomology and in 1986, became Entomology Services in the Department of Health and Rehabilitative Services. The program was moved to the Department of Agriculture and Consumer Services (DACS) in 1992, where it is now known as the Bureau of Scientific Evaluation and Technical Assistance (BSETA). The functions of the BSETA include promoting control of insects of public health importance, serving as advisors and consultants for mosquito control districts, and administering all state funds appropriated for nonagricultural arthropod control work. State laws were passed in 1925, 1929, and 1941 which set up methods for establishing self-taxing mosquito control districts and in 1949, a State law was passed that provided State aid to districts in the form of insecticides, materials, equipment, personnel, and vehicles.

In 1953, the State Legislature passed a second State aid law whereby any board of county commissioners or mosquito control district that places funds in its budget for control of "arthropods of public health importance", would, upon proper certification, receive funds directly from the State of up to 75 percent of the funds appropriated by the county or district. These funds were to be used for permanent control measures; additional appropriations were given as matching funds for either permanent or temporary control measures.

This act has been amended several times. At present, it provides that a county or district shall be eligible, upon approval of the Department of Agriculture and Consumer Services, to receive state funds. The amount and type of State aid currently available to mosquito control agencies is described in Chapter 5E-

13. 030 Florida Administrative Code (F.A.C.)

Entomological Research Center Established

In 1953, the legislature appropriated money to establish the Entomological Research Center at Vero Beach to study the biology and control of arthropods of public health importance in Florida. The center was dedicated in 1956 and has become world renowned for the excellence of its facilities and its research. In 1973, the name was changed to the Florida Medical Entomology Laboratory and, in 1979, it was transferred to the University of Florida, Institute of Food and Agricultural Sciences.

The John A. Mulrennan, Sr. Public Health Entomology Research and Education Center (JAMS PHEREC), formally the West Florida Arthropod Research Laboratory, was established at Panama City in 1963. Its primarily mission was to study the biology and control of the "dog fly," known elsewhere as the stable fly (*Stomoxys calcitrans*), which plagues people on the Gulf beaches in summer, and to test the efficacy of various insecticides on mosquitoes and other arthropods. In 1992, JAMS PHEREC was transferred to Florida Agricultural and Mechanical University, College of Engineering Sciences, Technology and Agriculture, but its overall mission remains unchanged.

MOSQUITOES

How to Recognize a Mosquito

Mosquitoes are insects with long slender bodies, narrow wings with a fringe of scales on the hind margin and along the veins, and long, very thin legs. In females, the elongate proboscis is firm and usually adapted for piercing and sucking blood. Male mosquitoes cannot suck blood, and survive on nectar. Females are also required to feed on nectar of various plants to obtain sugar for energy, but rely on a blood meal for egg-laying.

There are four life stages: egg, larva, pupa, and winged adult. Eggs may be laid singly or in rafts, deposited in water, on the sides of containers where water will soon cover them, or on damp soil where they must undergo a maturing process before they can hatch when flooded by rainfall or high tides. Mosquitoes of the genus *Mansonia* deposit their eggs on the underside, and, less so, on the upper side of floating aquatic plants such as water lettuce and water hyacinth. After the eggs hatch, the larvae or wrigglers begin to feed on very small plant and animal particles, going through four growth stages or instars before becoming pupae. With the exception of species in the genera *Mansonia* and *Coquillettidia*, larvae of other species all breathe air at the surface of the water. Species of *Mansonia* and *Coquillettidia*, in contrast, have a sharp pointed siphon which pierces the roots and stems of aquatic plants to obtain oxygen from the plant. The pupal or tumbler stage is comparatively brief, does not feed, and is active only if disturbed. Upon maturation, the pupa emerges from the surface of the water, splits the chitinous pupal skin and the adult emerges. After a brief time on the surface to dry its wings, the adult flies away.

Classification

In order to make it clear exactly which animal among the many kinds one is speaking or writing about, scientists have devised a system of classification and naming in which each kind of animal known to science is given a name consisting of two words. The first name is the name of the genus and is written with a capital letter. Mosquito publications, however, often abbreviate the genus name using a two-letter abbreviation, for instance, *Ae*. for *Aedes* and *Cx.* for *Culex*. The second name is a specific name and begins with a small letter. Together they form the species name which is always either italicized or underlined (to indicate italics). The classification of the mosquito which transmitted malaria in the southeastern United States is shown below:

Kingdom - Animalia	(all animals)
Phylum - Arthropods	(all animals with paired, jointed appendages and exoskeletons)
Class - Insecta	(all insects; three main body divisions and six legs)
Order - Diptera	(true flies, all two-winged flies with the hind wings reduced to knobbed structures called halteres)
Family - Culicidae	(all mosquitoes)
Genus - *Anopheles*	

Species - *Anopheles quadrimaculatus* Say (Say is the person who first described the species)

Currently, 80 species of mosquitoes, belonging to 12 different genera, have been recorded in Florida. These mosquitoes inhabit a wide variety of aquatic habitats, and the biology of each of these species is unique in some way. Unique distinctions between species include larval habitat, host preferences, and flight ranges, and will be discussed in more detail in the section focusing on various mosquito species. The differences in appearance (morphological differences) are discussed in the section on identification.

Importance to Health and Economy

In years past, malaria, yellow fever, and dengue were present in the State in epidemic proportions. Through mosquito control, these diseases are now no longer endemic. However, *Anopheles* *quadrimaculatus*, which transmits malaria and *Aedes aegypti*, which vectors both yellow fever and dengue, are still present in large numbers, and if persons carrying the disease in their bloodstreams should come into Florida from other areas, it would be possible for mosquitoes to bite them and become infected. In this way, a new cycle of these diseases could begin.

Although secondary infections may result from scratching mosquito bites, and there are people who are allergic to the bites, the chief medical concern in Florida at the present time is the possibility of an arthropod- borne encephalitis epidemic. Viruses of Eastern Equine Encephalitis, Western Equine Encephalitis, St. Louis Encephalitis, California Encephalitis and Venezuelan Equine Encephalitis have been found in mosquitoes in the State.

Eastern Equine Encephalitis Eastern Equine Encephalitis (EEE) is an enzootic disease that was first recognized in Massachusetts, in 1831 when 75 horses died of an encephalitic illness. The casual agent, Eastern Equine Encephalitis virus (EEEV), is an alphavirus that was first isolated from infected horse brains in the 1930s and currently occurs in focal locations of the eastern United States including Florida.
EEE is capable of infecting a wide range of animals including mammals, birds, reptiles and amphibians. The virus is maintained in natural cycles involving birds and *Culiseta melanura* in freshwater swampy areas with a peak of activity between May and August. In this usual cycle of transmission, the virus does not escape from the swampy areas because the mosquito species, *Culiseta melanura*, prefers to feed upon birds and does not usually bite humans or other animals. However, transmission of EEEV to mammals occurs via bridge vectors because they bring the virus from avian populations to mammalian populations. These bridge vectors include *Coquillettidia perturbans, Aedes atlanticus, Culex nigripalpus, Cx. quinquefasciatus* and *Aedes solicitants*. These species feed on both birds and mammals and can transmit the virus and cause disease in people, horses, dogs and some birds such as pheasants, quail, ostriches and emus.

Most persons infected with EEEV have no apparent illness. However, symptoms of severe cases of EEE include sudden onset of headache, high fever, chills, and vomiting. The illness may then progress to disorientation, seizures, or coma. EEE is one of the most severe mosquito-transmitted diseases in the United States with approximately 33% mortality and significant brain damage in most survivors.

Despite there having been only 81 human cases documented in Florida in the past fifty years (1957-2008), the State averages over 70 reported equine cases each year. In years when conditions favor the spread of EEE, the number of reported cases can exceed 200, with over 90% of the affected horses dying. The distribution of EEE cases have predominantly been in areas north of Lake Okeechobee, including panhandle areas (Walton, Holmes, Jackson, Leon, Jefferson, Madison and Escambia Counties); the lower St. Johns River areas (Duval, Volusia, Flagler, Putnam and Clay Counties); and the green swamp region area (Lake, Orange, Pasco, Polk, Osceola, Pinellas, Hillsborough and Manatee Counties).

A vaccine is available for horses, but not for humans. Preventive measures should include effective mosquito control and avoidance of mosquito bites by using insect repellent, wearing protective clothing, and staying indoors while mosquitoes are most active.

St. Louis Encephalitis St. Louis Encephalitis (SLE) was first recognized in the vicinity of St. Louis, Missouri and the neighboring St. Louis County in 1933 when an encephalitis epidemic broke out. Over 1,000 cases were reported to the local health departments and the newly constituted National Institute of Health. St. Louis encephalitis virus (SLEV), a flavivirus, is one mosquito-transmitted viral disease that is of great medical importance in North America. During summer, SLEV is maintained in a mosquito-bird cycle, with periodic amplification by birds and *Culex* mosquitoes.

Normally less than 1% of SLEV infections in humans are clinically apparent and the vast majority of infections remain undiagnosed. The occurrence and severity of SLE in humans is strongly dependent on age. The case fatality rate in Florida SLE epidemics has ranged from 4-30 percent. Deaths were almost exclusively among people age 50 and older. It is not uncommon for those surviving severe cases of SLE to suffer long-term residual neurological damage, which include paralysis, memory loss, or deterioration of fine motor skills.

Major SLE outbreaks occurred in Florida in 1959, 1961, 1962, 1977 and 1990. The epicenter of the outbreaks in 1961 and 1962 was the Tampa area. In 1961, there were 25 cases with 7 deaths and in the following year, there were 222 cases with 43 deaths. One very interesting discovery made at the time was that the SLE virus was vectored by *Culex nigripalpus*, a species which had not been previously implicated in disease transmission. In other parts of the United States, SLE is transmitted by *Culex quinquefasciatus* and *Culex tarsalis*. In addition to the illnesses and deaths caused this epidemic also greatly reduced tourism business. The reductions were estimated to be as high as $40 million, which added an enormous economic loss to the human loss and suffering.

West Nile Encephalitis In 1999, a new form of encephalitis was discovered in the New York City area. Known as West Nile Encephalitis (WNE), it is believed to have been brought in from the Middle East by unknown means and, previous to its introduction, had never been identified from the Western Hemisphere. West Nile Virus (WNV) is a flavivirus that was first isolated in 1937 from a woman in the West Nile province of Uganda in Central Africa. WNV was first found in the United States in 1999 during an outbreak of the disease involving humans, birds and horses in

New York and New Jersey. Since then, the virus has spread and by the end of 2004, it had been detected in 48 states and close to 30,000 human cases had been confirmed through 2009 nationwide. WNV was first detected in Florida in the summer of 2001 when it was found in a dead crow in eastern Jefferson County. Twelve human cases were reported in the State that year. In 2002, 35 human cases of WNV illness were detected in Florida. The peak occurred in 2003 with 99 human cases confirmed. In recent years, there have been only a few cases annually. Since its initial WNV activity, the virus has been reported in all 67 Florida Counties.

Like SLEV, to which it is closely related, WNV is maintained in a mosquito-bird cycle in nature. *Culex quinquefasciatus* and *Culex nigripalpus* are two major vectors of WNV in Florida. However, unlike SLE, WNV causes high mortality in certain bird species, most notably crows, jays, hawks and owls. It is also pathogenic in horses. More than 1,000 cases of equine WNV infection were confirmed in Florida from 2001-2009.

The peak period of WNV transmission in Florida is from July to September and most seriously affects people older than 50 years of age. Most people bitten by a WNV-infected mosquito will not show any sign of illness. Of those who become clinically ill, about 20 percent will display mild symptoms including fever and lethargy and less than 1% experiences the neuroinvasive form of the illness. Symptoms appear between 3 and 14 days after the bite of an infected mosquito.

The national fatality rate has generally been 2 to 5 percent. In Florida, case fatality rates range from 4% for all cases to 7% among those who develop the neuroinvasive form of the disease.

To prevent epidemics of encephalitis, a surveillance program was established in the early seventies. This surveillance includes gathering data on cases of horses with encephalitis; checking the blood sera of wild birds, sentinel chicken flocks, and small mammals for the presence of encephalitis antibodies; keeping a record of central nervous system diseases reported from Florida hospitals; and checking mosquitoes from certain areas of the State during the summer and fall to screen for encephalitic viruses.

Mosquito Species in Florida

Each species of mosquito has not only certain specific morphological characteristics, but also physiological characteristics and habits which are distinctive to that species. For each species, there is, for instance, a preferential egg-laying site, a normal flight distance/range, a preferred host animal or plant. In addition, there is a definite temperature tolerance at each stage of development. This range of tolerated temperatures may be very wide or very narrow, depending on the species. There is typically a maximum temperature above which the animal will die, a minimum below which it will die, and an optimum temperature at which maximum development takes place in a minimum of time. Both temperature and humidity are critical for adult mosquitoes. In most insects, the longer the optimum temperature is maintained, the greater the number of generations the insect may produce at a given place in a season.

Florida mosquitoes breed mainly in the summer. Exceptions include *Anopheles punctipennis*, *Culex restuans* and *Culex salinarius*, which breed all year-round but reach peak numbers in late spring. In north Florida, most mosquito populations are lower in winter because of the colder temperatures, while in south Florida, the reduced mosquito breeding associated with winter is due to a lack of rainfall. Of the 80 species of mosquitoes found in Florida, 36 occur throughout the State. Some of the remaining species occur in most of the southeastern United States and the extreme southern limit of their range falls in northwest Florida or as far south as central Florida. Other species which are of tropical origin cannot be found north of the sub-tropical area of Florida - that is, the area south of a line from Punta Gorda across to Lake Okeechobee, then north along the coastal counties through Brevard County (see Figure 3). A few of these species are found only in the tropical zone, south Dade County and the Florida Keys.

Figure 3. **Fanual Zones**

Figure 4. **Mangrove Swamps**

Figure 5. **Salt Marsh**

Mosquitoes and Their Production Sites in Florida

Certain areas of Florida are characterized by generally poor drainage. Muck, marl and other soils perpetually saturated or subject to flooding make up nearly half of the total land area of the State. These vast areas of wetlands, together with thousands of grassy lake margins, constitute an enormous potential area for mosquito breeding.

Mosquitoes are not adapted to life in moving waters and where they occur in flowing streams they occupy the quiet pools and seepage areas. Aquatic environments differ chiefly in: (1) chemistry of the waters -acid or alkaline, fresh, salt or brackish; (2) whether natural or man-made; (3) amount of vegetation, or type of vegetation present; and (4) whether shady or sunny. The distinctive ovipositing habits of each species of mosquito determine its larval habitat.

Types of Mosquito Habitats

Types of aquatic habitats are not always clearly separate and definable, but in general they may be classified as follows:

Salt Water or Brackish

Mangrove Swamps (Figure 4). – It is in the transitional zone from the usual level of high tide to levels above all but the highest spring and storm tides that the heaviest mosquito breeding occurs, because plant and grass cover keep moisture conditions suitable for egg laying. Eggs are usually laid on sloping sides of potholes, ditches, sloughs, marsh edges or on the sides of small depressions. In some cases, however, egg-laying occurs in extensively grass-covered level areas. The eggs of some species require alternate flooding and drying before hatching will occur. Species most often occurring in these areas include:

Aedes taeniorhynchus
Aedes sollicitans
Anopheles atropos
Culex nigripalpus

Salt Marshes (Figure 5) . - North of Daytona Beach on the east coast and north of Port Richey on the west coast of Florida, the mangrove swamps are largely replaced by grassy salt marshes. Salt-tolerant herbaceous plants and typical salt grasses dominate this type of habitat. Extensive areas are often covered by a single species such as salt grass *Distichlis spicata*, or by *Batis maritima* or *Salicornia perennis*. It is in association with one of these plants or with black mangrove, *Avicennia nitida* that breeding of the following species occurs:

Aedes taeniorhynchus
Aedes sollicitans

Figure 6. **Salt or Brackish ditch**

Salt or Brackish Ditches (Figure 6). - The ditches which lie adjacent to salt water marshes contain many species of grasses and support a larger mosquito fauna including:

Aedes taeniorhynchus
Aedes sollicitans
Aedes atlanticus
Psorophora columbiae
Anopheles bradleyi
Culex pilosus
Psorophora howardii
Psorophora ciliata

Figure 7. **Freshwater Marshes**

Freshwater Marshes (Figure 7). - Nearly all coastal areas have both freshwater marshes and brackish areas, often adjacent to each other. The shoreline along the western coast from Pasco County to Franklin County is bordered by coastal marshes, with little or no beach. In the Everglades, sawgrass marshes cover more than 1.25 million acres, with *Cladiurn jamaicense* the dominant low ground cover plant. Mosquito species often found in freshwater marshes include:

Anopheles walkeri
Anopheles crucians
Psorophora columbiae
Culex nigripalpus
Culex salinarius
Culex tarsalis
Culex erraticus
Culex peccator

Figure 8. **Freshwater Lake**

Lakes (Figure 8). - There are two general types of lakes in Florida, sand bottom and silt bottom. Sand bottom lakes are more numerous but they do not afford as many mosquito habitats as the silt bottom lakes. Vegetation, usually composed of emergent grasses, occurs only in a narrow band along the margin and larvae are confined to this littoral zone. Silt bottom lakes are frequently bordered by cypress trees and many species of floating or emergent plants. The lake bottom consists of a layer of organic detritus made up of decaying vegetation and the lake usually has a fairly heavy cover of vegetation composed of such plants as water hyacinths or bonnets. Mosquito larvae are more common near shore but may be found throughout the lake wherever cover is afforded. Species likely to be found in lakes and marshy areas around lakes include:

Anopheles smaragdinus
Anopheles crucians
Anopheles quadrimaculatus

Anopheles walkeri
Uranotaenia sapphirina
Uranotaenia lowii
Culex salinarius
Culex nigripalpus
Culex erraticus
Culex peccator
Coquillettidia perturbans
Mansonia dyari
Mansonia titillans

Ponds and Seepage Areas (Figure 9). - There is no clear distinction between a pond and a lake except that ponds are generally smaller. Grassy woodland ponds or fluctuating ponds occupy shallow depressions and are filled by rainwater or surface run-off. They are usually of uniform depth but the area they cover will vary, depending on rainfall. Sinkhole ponds are usually quite deep and may be covered with vegetation or free of all except marginal plants. Both these types of ponds may contain larvae of:

Anopheles crucians
Anopheles quadrimaculatus
Culiseta inornata
Culiseta melanura
Culex nigripalpus
Culex quinquefasciatus
Culex restuans
Culex salinarius
Culex erraticus
Culex peccator
Culex pilosus
Culex territans
Aedes canadensis canadensis

The seepage areas around hillsides and ponds or streams most often breed:
Anopheles punctipennis
Anopheles georgianus
Anopheles quadrimaculatus
Aedes sticticus
Psorophora ferox

Springs (Figure 10). - Mosquito breeding in springs is restricted to the quiet edges where vegetation affords cover for the larvae and there is little if any water movement. The only species recorded from this habitat in Florida are:

Anopheles quadrimaculatus
Anopheles perplexens


Figure 9**. Ponds and Seepage Areas**

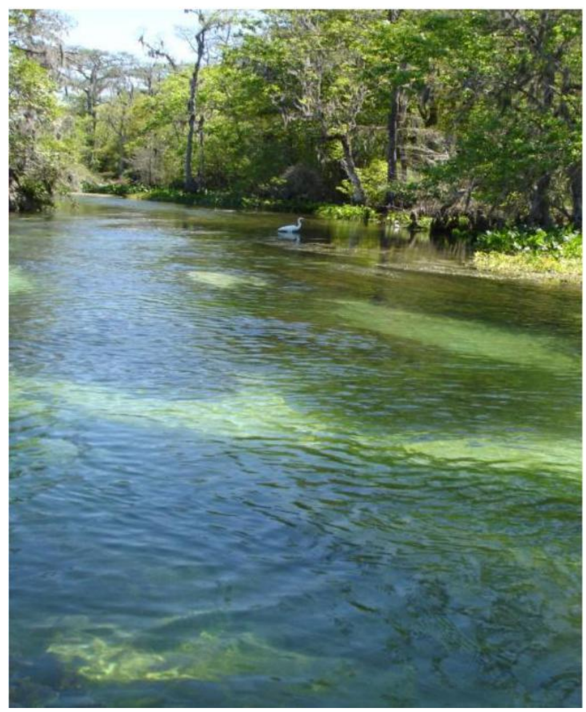
Figure 10**. Springs**

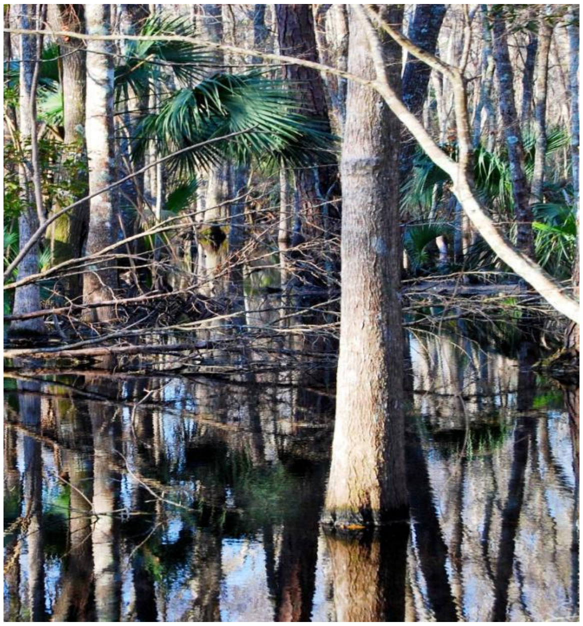

Figure 11**. Swamps**

Swamps (Figure 11). - Swamps differ from marshes principally in having a more dense cover made up of larger trees such as cypress, red maple, and tupelo. The most common species of mosquito larvae found in swamps are:

Anopheles smaragdinus
Anopheles maverlius
Anopheles inundatus
Anopheles diluvialis
Anopheles crucians
Anopheles quadrimaculatus
Culiseta melanura
Aedes canadensis
Mansonia species
Coquillettidia perturbans

Borrow Pits and Canals (Figure 12). - These man-made bodies of open water produce more mosquitoes as they silt-in and become overgrown with vegetation. They yield this variety of species:

Anopheles maverlius
Anopheles quadrimaculatus
Culiseta inornata
Psorophora columbiae
Aedes canadensis
Culex nigripalpus
Culex quinquefasciatus
Culex restuans
Culex salinarius
Anopheles albimanus
Coquillettidia perturbans
Mansonia species

Figure 12. **Borrow Pits and Canals**

Specific Aquatic Plant Associations (Figure 13). - Species of mosquitoes found in association with specific aquatic plants are:

Coquillettidia perturbans
Mansonia dyari
Mansonia titillans

Bromeliads and pitcher plants
Wyeomyia vanduzeei
Wyeomyia mitchellii
Wyeomyia haynei
Culex biscaynesis

arrowhead

Figure 13. **Aquatic Plants**

water hyacinth

pickerelweed

water lettuce

cattail

Figure 14. **Rain and Flood Water Pool**

Rain and Floodwater Pools (Figure 14). - These transient pools form the breeding place for a large number of species, especially among the *Psorophora* and *Aedes*. The pools disappear in dry weather and support no true aquatic vegetation, though there is usually a layer of leaves and other detritus settled on the bottom. Mosquito species found in this habitat are:

Psorophora johnstonii
Psorophora pygmaea
Aedes atlanticus
Aedes dupreei
Aedes fulvus pallens
Aedes infirmatus
Aedes mitchellae
Aedes sticticus
Aedes tormenter
Aedes vexans
Aedes cinereus
Culex atratus
Culex pilosus
Culex bahamensis
Culex nigripalpus

Figure 15. **Tree Holes**

Tree Holes (Figure 15). - Tree holes or rot cavities support a rather extensive and unusual mosquito fauna, with many species breeding almost exclusively in this habitat. They are:

Anopheles barberi
Toxorhynchites rutilis rutilis
Toxorhynchites rutilis septentrionalis
Aedes triseriatus
Aedes hendersoni
Orthopodomyia sianifera
Orthopodomyia alba
Aedes thibaulti
Aedes albopictus

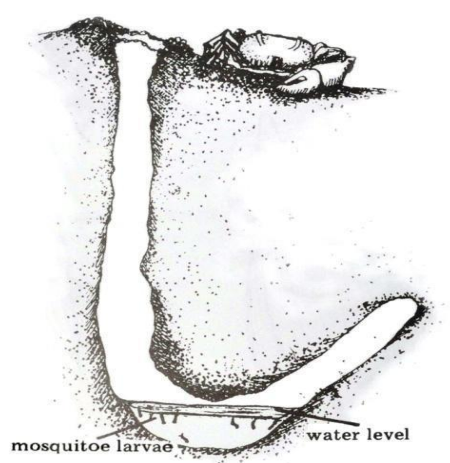

Figure 16. **Land Crab Holes**

Crab holes (Figure 16). - Along the eastern coast of Florida south of St. Johns County the holes of the large land crab, *Cardisorna guanhumi* , serve as larval habitat for:

Deinocerites cancer
Culex opisthopus

Freshwater Drainage Ditches (Figure 17). - Freshwater ditches in pastures, at the bottom of road shoulders, in old fields, and in lowland groves will often yield the following species of mosquito larvae:

Psorophora columbiae
Culex nigripalpus
Culex pilosus
Culex erraticus
Culex quinquefasciatus
Anopheles crucians
Anopheles walkeri
Aedes atlanticus
Uranotaenia sapphirina
Uranotaenia lowii
Psorophora ciliata
Aedes sollicitans

Figure 17. **Freshwater Ditch**

Artificial Containers (Figure 18). - Several species breed in man-made situations around human dwellings. Tin cans, fish pools, rain barrels, bird baths, and old tires containing water serve as the larval habitat. Species most often encountered are:

Aedes aegypti
Aedes triseriatus
Culex quinquefasciatus
Culex restuans
Culex salinarius
Culex nigripalpus
Anopheles quadrimaculatus
Aedes albopictus

Figure 18. **Artificial Containers**

Identification

Mosquitoes can be collected as either larvae or as adults and many species can be identified in either life phase. It is important to determine what species are present and their relative abundance so that mosquito control personnel will know what their problem mosquitoes are and where they are breeding. Only in this way can they most efficiently use the control tools available. Every person who works in mosquito control should be able to recognize the common problem species in their area.

All mosquito species in Florida fall into one of these subfamilies: Toxorhynchitinae (genus *Toxorhynchites*); Anophelinae (genus *Anopheles*); or Culicinae (the other ten genera).

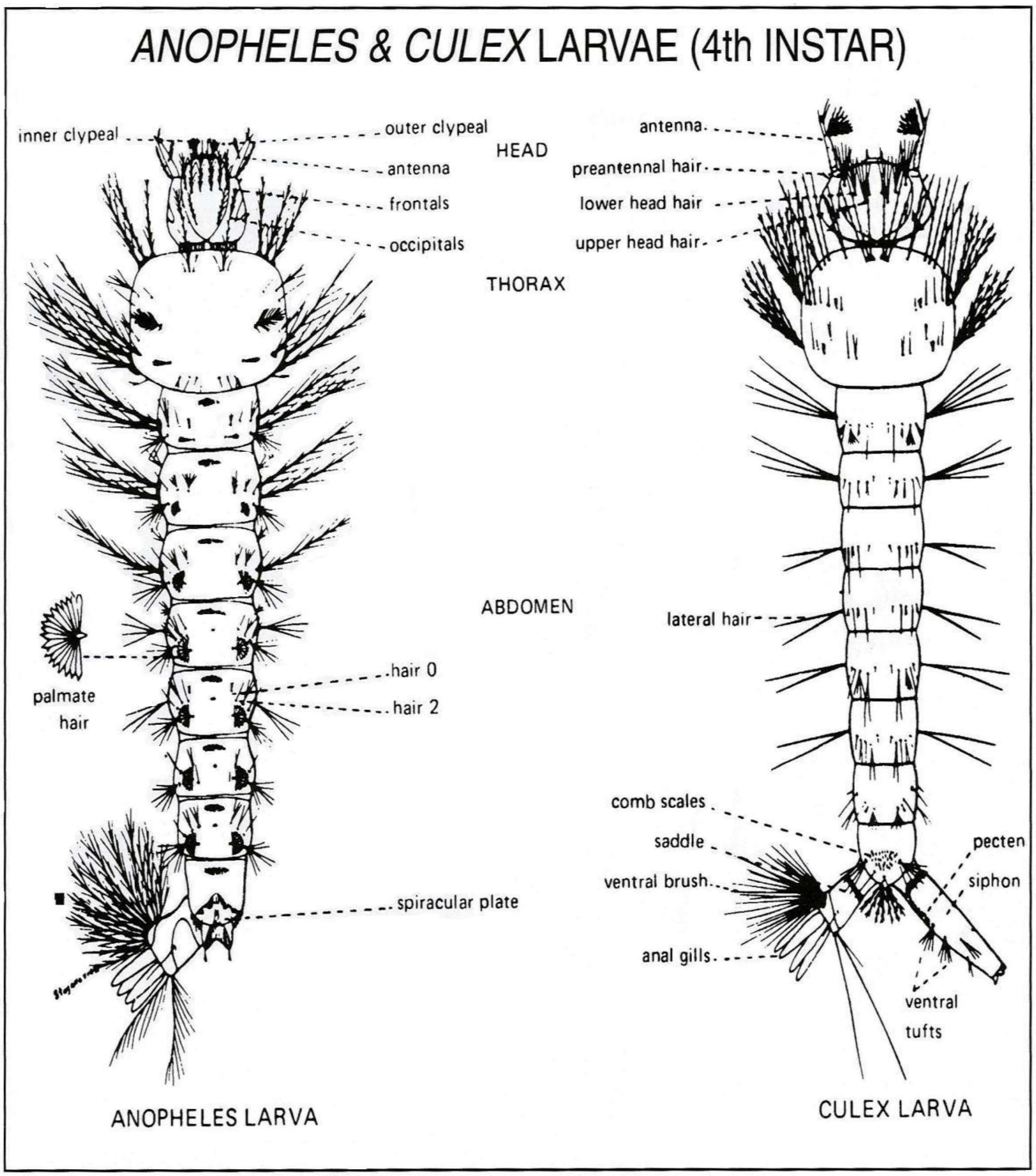

Figure19. **Fourth Stage of** ***Anopheles*** **and** ***Culex*** **Larvae**

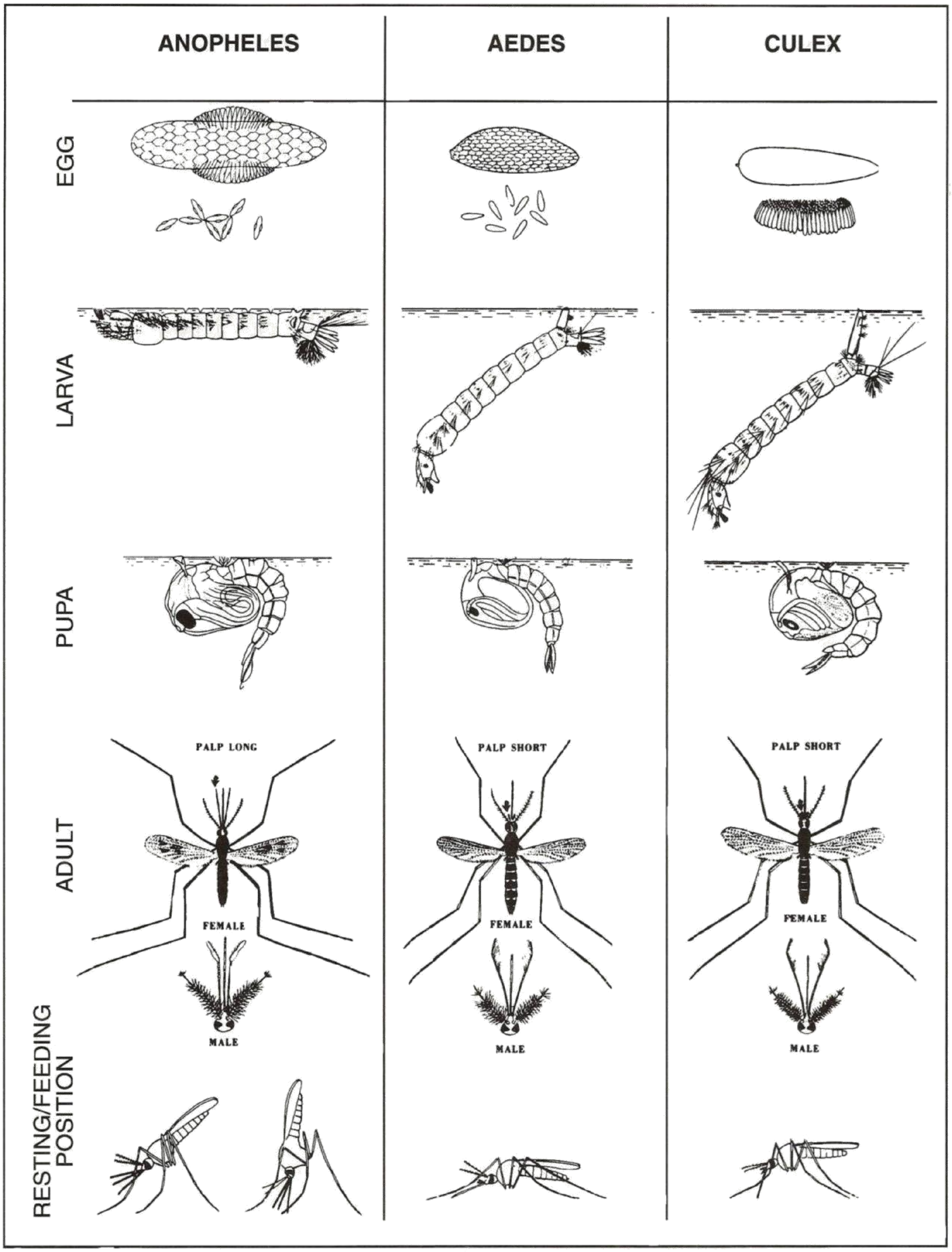

Figure 20**. Characteristics of Anophelines and Culicines**

The larvae of *Toxorhynchitis* are found in tree holes or artificial containers. They are very large and predacious, feeding on such mosquito larvae and other small animals as they occur in their breeding place. They have an almost square head and the hairs on the thorax and abdomen arise from heavily chitinized plates. The females do not take blood as adult mosquitoes, but feed only on plant nectar and juices.

Anopheline larvae (Figure 19) are characterized by the absence of a siphon, and the presence of a palmate (palmetto-shaped) hair dorsally on each side of, at least, segments IV-VI of the abdomen. Anopheline larvae usually lie parallel to the surface of the water.

Culicine larvae always have a siphon (Figure 19) which may or may not bear a pecten, a row of spines. They do not have palmate hairs. These larvae usually lie with the head downward at a 45 degree angle to the water surface.

With practice it may be possible to identify some species as adults or as fourth instar larvae with the unaided eye or a hand lens. However, because it is easy to misidentify in the field, samples should be taken into the laboratory to be verified under a microscope. A stereoscopic microscope to be used for adult and larval identification should have a magnification range of 10X to 40X, the lower power for use in sorting specimens that are readily identifiable and the higher power for detail work. Specific identification of difficult larval characteristics or male terminalia may require magnifications of up to 400X.

Larval Morphology

The characters used in the identification of genera of mosquitoes found in Florida are clearly labeled in Figure 19. By studying these illustrations it will be possible to key fourth instar larvae to genus, using Figure 22.

Adult Morphology

The external anatomy of an adult female mosquito is shown in Figure 21. The Pictorial Key to the 12 genera found in Florida (Figure 23) makes it possible to identify females to genus by comparing distinctive features. You simply follow the character in each pair which fits the specimen you are identifying, following the lines down until you reach the correct choice which names the genus.

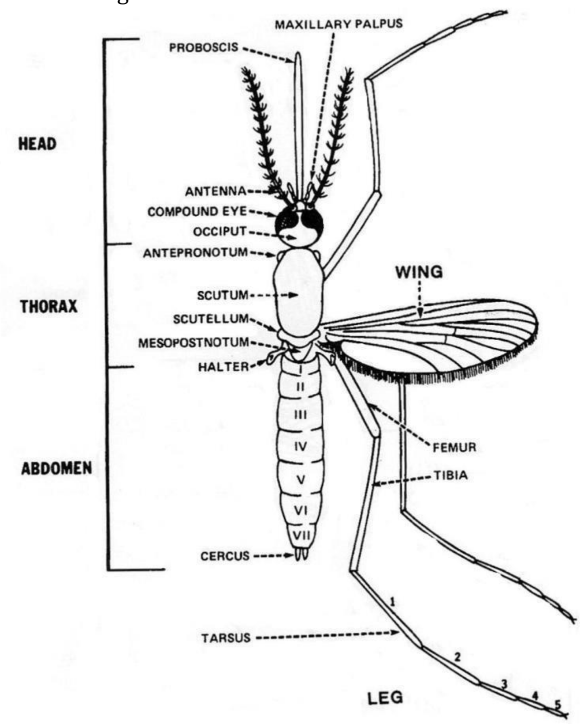

Figure 21. **External anatomy of adult female**

Some Problem Species of Mosquitoes in Florida

Common Problem Mosquitoes

The primary pest mosquitoes in Florida are the salt marsh species, *Aedes taeniorhynchus* and *Ae. sollicitans*. *Ae. taeniorhynchus* is a small black and white mosquito with distinct narrow white rings on the tarsi and on the proboscis. Wing scales are all dark. *Ae. taeniorhynchus* is the predominant species, produced in huge numbers, all around the coast of Florida.

Eggs are usually deposited on damp soil where ground vegetation is thick. Sod samples have yielded up to 100 million eggs per acre. The larval embryo is fully developed in about three days and is ready for hatching as soon as it is flooded by the tides or rainfall. The longer the period is before hatching, the greater the chance of the embryo dying, although some of the eggs will hatch after many months.

The length of time passed as a larva, before pupation, depends on temperature and available food, and ranges from four days to four weeks. The pupal stage may last from 30 hours to several days, depending on temperature. Emergence from a breeding area may go on for several days. Mating may occur during the general flight activity of a newly hatched brood. The adult rests for at least six to eight hours and after dark, a large number will migrate, flying as far as 25 miles, usually downwind and parallel to the coast. Migration may be repeated on a second or third night and then the brood settle down to feed, rest, and lay eggs. Adults feed on nectar as an energy source.

A blood meal, taken only by females, serves as a source of protein for egg production, although some *Ae. taeniorhynchus* are capable of laying eggs without the first blood meal, by utilizing protein carried over from the larval stage. This species is active chiefly after sunset. During the day the mosquitoes rest on the ground where grass or leaves offer a dark, moist, cool hiding place. However, if a stimulus reaches them, they will fly to it. It is not uncommon that if you go where they are in the daytime, they will be stimulated to bite you.

Aedes sollicitans occurs around the entire coast of Florida, but is more common in the northern half of the State. In localized situations, it may outnumber *Ae. taeniorhynchus*. *Ae. sollicitans* is somewhat larger than *Ae. taeniorhynchus* and is more golden brown with wider, pale bands on tarsi and proboscis. The wing scales are mixed light and dark. Each abdominal segment has a median longitudinal band of pale scales in addition to the pale basal transverse band. This species has a life history similar to that of *Ae. taeniorhynchus*, breeding in the salt marsh, but the larvae have also been found in great numbers in coastal swales and inland in brackish waters. The adults usually rest during the day, but the females are persistent biters and will attack at any time of night or day.

The exact seasonal distribution of the salt marsh species is dependent on the tides and on rainfall, but usually each year they begin to emerge in large numbers in May and continue through October.

The other main problem species in Florida include the flood-water species (*Psorophora columbiae*, *Ps. ferox, Aedes atlanticus*, *Ae. infirmatu*s, and *Ae. mitchellae*) which breed in intermittently flooded areas of fresh water, as well as *Culex nigripalpus, Cx. quinquefasciatus* and *Cx. salinarius*, which usually breed in more permanent fresh water habitats such as ponds and ditches. In many areas of Florida, *Coquillettidia perturbans* emerges in enormous numbers, and in central and south Florida, *Mansonia dyari* is a serious pest. In the spring, *Aedes canadensis* and *Ae. sticticus* emerge in large numbers in northwest Florida, although they are comparatively rare in the rest of the state.

Other Problem Mosquitoes

Aedes aegypti is a small, dark, mosquito easily recognized by the silvery-white lyre-shaped marking on the thorax and the silvery-white bands on the tarsi. Historically, it was one of the most common domestic mosquitoes, laying its eggs on the sides of containers such as tin cans, tires, vases, small pools, tree holes and yard plantings of certain bromeliads. Its numbers, however, have been drastically reduced in north and central Florida by, as yet, unknown factors related to the recent introduction of *Aedes albopictus*, (see narrative of *Aedes albopictus* below). The embryos develop in two to four days and will hatch when flooded. The cycle from egg to adult may be completed in 10 days in warm weather.

The adults feed warily, often biting the ankles. They never fly more than a few hundred feet from the emergence site. Because this mosquito is the vector for both yellow fever and dengue fever, campaigns have been instituted in various countries of this hemisphere to eradicate the species, including a project within the last three decades to eliminate them in this state. The project was discontinued, however, before completion and *Ae. aegypti* became at least as common, if not more numerous, than before the eradication project.

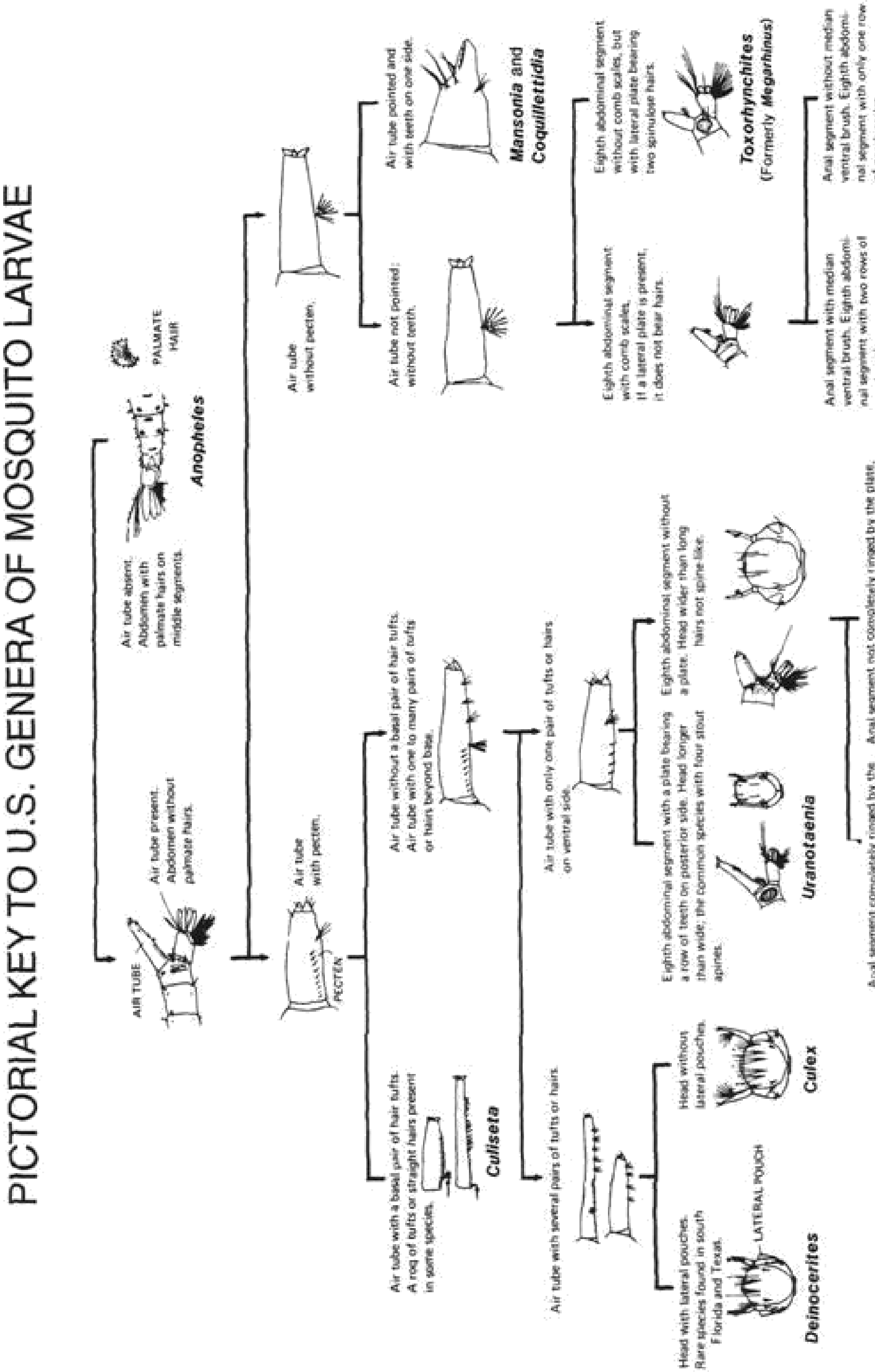

Figure 22. **Pictorial Key to U.S. Genera of Mosquito Larvae**

PICTORIAL KEY TO UNITED STATES GENERA OF FEMALE MOSQUITOES

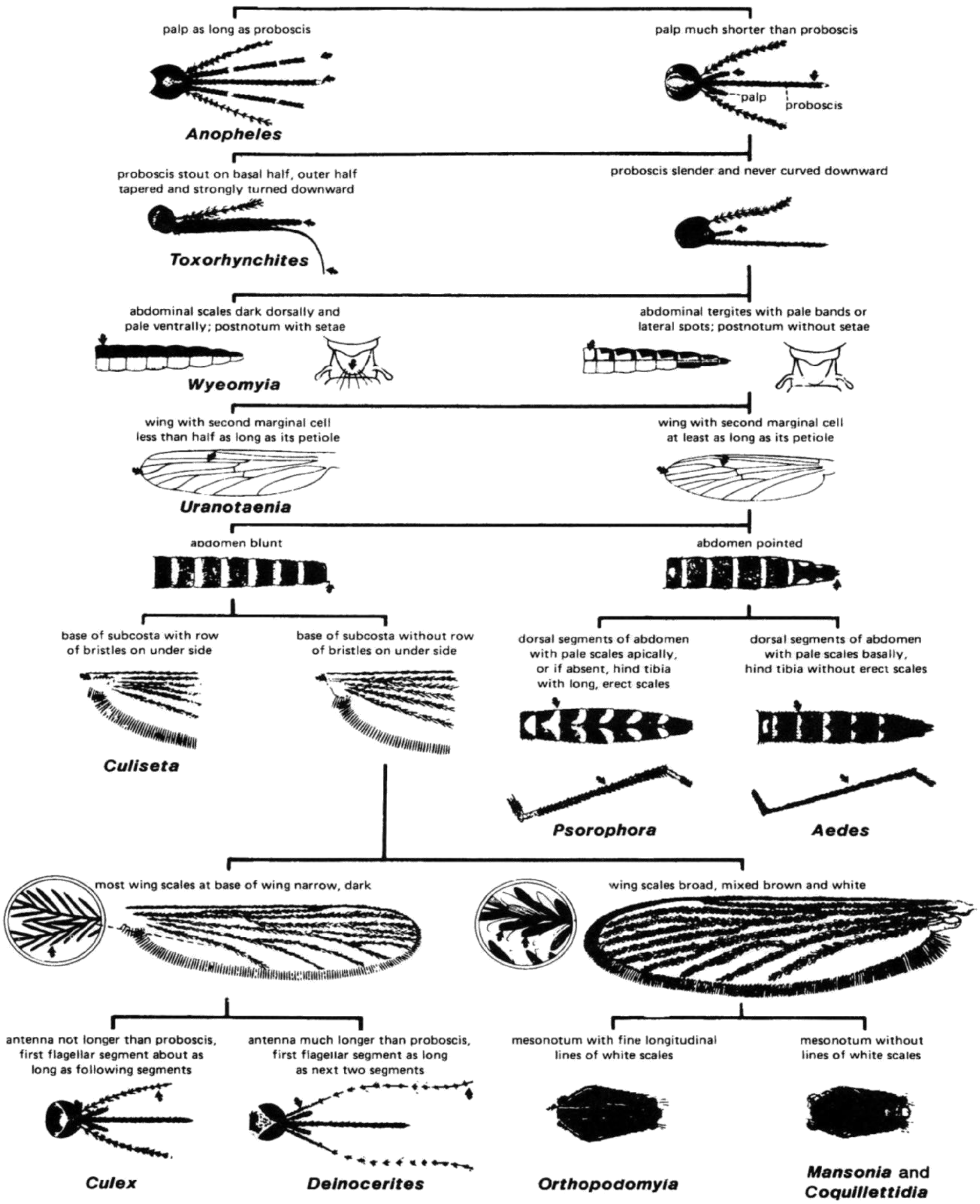

Figure 23. **Pictorial Key to U.S. Genera of Female Mosquitoes**

Aedes albopictus, "the Asian Tiger Mosquito", was introduced from Asia into Florida in 1986 and has expanded its range to every part of the State but the middle and lower keys. In northern and central Florida, *Ae. albopictus* is replacing the related species, *Aedes aegypti*, in areas where the two mosquitoes share breeding sites. Similar to *Ae. aegypti* in size, appearance, and habits, this mosquito can be identified by the single, silver, longitudinal line on the thorax and by the strongly contrasting silver and jet black body coloration. An aggressive daytime biter, *Ae. albopictus* is considered a major vector of dengue in Asia. While dengue has disappeared from Florida for many years, the recent introduction of this mosquito into the U.S. has some officials concerned about the increased potential for epidemics of this viral disease.

The larvae of *Aedes triseriatus* are usually found in water collected in rot cavities of trees, although they frequently occur in artificial containers along with *Ae. aegypti*, and *Ae. albopictus*. The adult is dark with a conspicuous area of white shiny scales on each side of the thorax. Near their breeding place these mosquitoes will attack man during the day or early evening and their bite is painful and lasting.

Aedes mitchellae is similar in appearance to *Ae. taeniorhynchus* in being black with pale rings on the proboscis and tarsi. It differs in having the femora and tibiae speckled with pale scales and in having a longitudinal stripe or patches of pale scales on the abdomen in addition to the pale basal abdominal bands on each segment. It breeds in stump holes and flood-water pools. *Ae. mitchellae* is a severe biter, common in the northern and panhandle areas of Florida.

Aedes atlanticus is a dark, medium-sized, species which has a distinct median pale stripe running the length of the thorax. This mosquito lays its eggs on damp soil and the larvae develop in the shallow pools following rainfall. The adults bite readily, even in sunlight. It is often found in association with *Ae. infirmatus*, which has a broader pale stripe that extends only about two-thirds the way back on the thorax. This species bites readily.

Aedes canadensis canadensis, which has pale rings both at the base and tip of the tarsal segments, is a common nuisance flood-water mosquito in the northern section of Florida. *Aedes vexans*, distinguished by its very narrow pale tarsal bands and by basal abdominal bands which are notched medially on the posterior border, is common throughout most of the state. It usually feeds in shady places during the day, but is often particularly annoying at dusk and after dark. The larvae are often found in large numbers in irrigated groves.

Psorophora mosquitoes commonly breed in flood-water and include *Ps. ciliata*, a very large shaggy black and yellow species commonly called the "feather-legged gallinipper". *Ps. ferox* is a smaller purplish mosquito with conspicuously white tips on the hind legs (tarsal segments 5, 4 and part of 3); and *Ps. Columbiae is* a large black and white species distinguished by a pale subapical ring on each femur. *Psorophora columbiae* is one of the most troublesome pests in Florida. It will bite viciously any time of the day or night, but is especially active at night. It has been known to feed in such numbers in the everglades that cattle were lulled by loss of blood and suffocation. The adults emerge in huge numbers from improved pastures and irrigated groves and from woodland pools, roadside ditches, and swales.

There are three main problem *Anopheles* mosquitoes in Florida. *Anopheles crucians* adults have distinct areas of pale scales on the wing. This species breeds chiefly in the slightly acidic waters of cypress swamps and in ponds and lakes. It has been found naturally infected with malaria, but is not considered an important vector of the disease since it apparently prefers to feed on large mammals rather than man.

Anopheles quadrimaculatus is the most common and widespread member of a larger species complex consisting of 5 morphologically distinct but similar species. Although very similar in appearance, they can be separated with great care and differ somewhat in their preferred habitat and range.
Anopheles quadrimaculatus breeds mostly in stagnant alkaline fresh water which has emergent or floating vegetation or debris. It was the primary vector of malaria in the southeastern United States. The adults are characterized by having four, more or less, distinct spots on the wings. They feed actively on man and animals, chiefly at night or sometimes in the day in dark areas in and around buildings. There may be as many as 10 generations in a season.

Anopheles atropos larvae are found in permanent brackish to salt pools and marshes. The adults, entirely brownish black, will attack man readily, even in bright sunlight. The species is not considered a disease vector.

Culiseta inornata, a very large species breeding in pools, ditches and occasionally in artificial containers, is primarily a late fall and winter breeder in Florida. The adults apparently prefer to feed on livestock, but also will attack man.

Culiseta melanura, a smaller, very dark species, breeds in small permanent bodies of water, particularly in freshwater swamps. Females feed chiefly on birds and the species is considered to be the primary vector of Eastern Equine Encephalitis from bird to bird.

Coquillettidia perturbans is the most common and wide-ranging of the mosquitoes whose larvae breathe by piercing the roots or stems of aquatic plants with their siphon. This species has been identified in every county in Florida. Many aquatic plants may serve as host to this species, including water lettuce, water hyacinths, and cattails. Although the females usually feed at night, they have been known to feed on man during the day in shady areas where they are resting. This species is suspected of being an important secondary vector of EEE to horses and man. *Cq. perturbans* is a fairly large species with a golden brown coloration, while the other two species are smaller, darker, and are very difficult to distinguish from each other. *Mansonia titillans* larvae also attach to a number of different aquatic plants, but *Ma. dyari* in Florida has been found associated primarily with water lettuce.

The *Culex* mosquitoes all breed in fresh water habitats such as pools, ditches, and ponds. *Culex quinquefasciatus* larvae are often associated with foul water such as effluents of sewage treatment plants, which have been found producing these mosquitoes by the thousands. The larvae are also taken in catch basins, cesspools, polluted ditches and ponds, and in containers holding water in homes and around buildings. The adults are distinguished by having a pale basal band on each abdominal segment rounded on the apical margin so that the band is wider in the middle and narrower on each side. The females are said to show a preference for bird blood, but they often get into homes and feed readily on man at night. In some areas of the country, this species is the primary vector of St. Louis Encephalitis (SLE).

Culex salinarius larvae are often found associated with *Cx. nigripalpus* larvae, and have been collected occasionally from small ground depressions and stump holes. Emergences are concentrated in the cooler months. The females will bite readily outdoors and sometimes enter buildings to feed on man. The species is characterized by golden scaling on the entire seventh abdominal segment.

Culex nigripalpus is a small black mosquito with white lateral abdominal patches. It breeds in permanent or semi-permanent waters where there is an abundance of decaying leaves and vegetation. Larvae have also been found in brackish water. This species usually bites outdoors. It was formerly believed to be of little medical importance, but during the St. Louis Encephalitis epidemic in the Tampa Bay area in 1961 and 1962, it proved to be a primary vector of the disease. Since that time extensive studies of the life history of this mosquito have been carried out at the Florida Medical Entomology Laboratory at Vero Beach. This mosquito is readily taken in light traps.

Culex restuans larvae occur in a variety of freshwater habitats. In Florida, adults appear primarily during cooler weather. Females will sometimes come into homes and bite after dark, but they are not a primary nuisance, preferring birds to humans. The adult is similar *to Cx. quinquefasciatus* except that the abdominal bands are straight on the apical margin and the thorax often has four small patches (spots) of pale scales.

In contrast to these previously mentioned species, some species of mosquitoes are not a big problem, but may be extremely annoying in local areas where they breed. For instance, *Deinocerites cancer*; which breeds almost exclusively in water collected in land crab holes, will bite humans who come to their breeding habitat. Three species of *Wyeomyia*, small mosquitoes which breed in water collected in plants, occur in Florida. One of these, *Wy. vanduzeei*, which breeds in bromeliads, will feed and be very annoying if humans come into their vicinity.

Mosquito Control Practices

Responsibilities of a Mosquito Control Director

The qualifications for a mosquito control director, depending on the size of the local budget for mosquito control, are set out in the Mosquito Control Rules, Chapter 5E-13, F.A.C.. It is the duty of the director to plan, supervise, and direct the execution of the county or district arthropod control program. This makes the director responsible for every aspect of the working program, including:

1) Determining the extent of the problem and locating the breeding areas.
2) Planning appropriate projects and controls to alleviate the problems.
3) Preparing and submitting for approval the monthly reports as required by Chapter 5E-13, F.A.C.
4) Purchasing equipment and materials, providing for maintenance, and maintaining inventory records.
5) Hiring and assigning necessary personnel.
6) Seeing that all work is carried out in a safe, effective and efficient manner in compliance with the Federal, state, and local laws and all regulations pertaining to mosquito control.
7) Evaluating the results the program achieves and providing for surveillance of breeding conditions in the county or district.
8) Establishing good public relations for mosquito control.
9) Continually improving his knowledge and abilities through local and national associations, meetings and publications.

A mosquito control director must be able to depend on the abilities and integrity of his supervisors and equipment operators. The supervisor of a crew operating heavy equipment or applying insecticides must give his crew clear and complete instructions, must see that all safety precautions are adhered to, and that all equipment is kept in good working condition.

In the final analysis, the success of a program often depends on the correct application of insecticides, on the ability and willingness of the applicator to use the materials and equipment as instructed and to immediately report malfunction of equipment. This ensures the correct dosage is applied without endangering the applicator, the public or the environment. It is important for every ground equipment operator and pilot to know how to safely use his equipment, how to calibrate and check it, and how to maintain it. Accurate record keeping is an essential for evaluating the effectiveness and efficiency of insecticide adulticiding.

Continuing Education

In order to do the best possible job in any field, it is necessary that employees know of new methods and materials that can help them to better accomplish their purpose. Each new employee should be fully trained for his job -what he is expected to do, how he is to do it, and why. It is good practice to have refresher and updating courses on insecticide usage and safety practices for all employees. This is especially important for employees holding PHPC certifications, as this license is renewed through the accrual of 16 hours of continuing education every 4 years.

The director of the program should keep up with new developments in mosquito control through reading technical journals and pamphlets, by talking with representatives of equipment and chemical companies, and by belonging to and attending meetings of associations in his field. One of the most useful journals for directors is the Journal of the American Mosquito Control Association (AMCA). Annual meetings of the AMCA and the Florida Mosquito Control association (FMCA) will also prove helpful, both as a source of new ideas and for an exchange of information and ideas with other directors.

Planning the Project

Before any control effort is made, the director must know the extent of the problem in his area. He must know what species are involved, the level of annoyance from mosquitoes, and the location of breeding areas. Even after the initial survey, routine checking (surveillance) will be needed because of seasonal variations in the fauna, because of changes in the topography, and as a means of evaluating how the projects are progressing.

To identify the problem, larvae and adults should be collected throughout the area. To ensure effective control, it is very important to be able to identify the location for each collection. Collecting sites may be identified by an address, such as "fish pond at 634 Lane Avenue", by description such as "in pasture pond at intersection of State Road 84 and U.S. 1", or by using a map or GIS coordinates. Additional data on the collection site such as a list of dominant vegetation or evidence of gross pollution is useful. Larval collections are usually made with a long-handled dipper and counts are based on the number of larvae per dip. The larvae are usually preserved in alcohol for later identification in the laboratory.

In marshes, larval dipping is sometimes done from a hovering helicopter, making it possible to check breeding areas not otherwise accessible to the inspector.

Adult mosquito surveys are most often made using light traps. The New Jersey trap is operated using a standard household current and is a good choice when convenience and long-term monitoring from a permanent site are important. New Jersey traps, however, tend to also collect larger organisms, i.e. beetles, moths and frogs, which can damage the collection and make identification difficult (Figure 24). The CDC miniature light trap, (Figure 24) baited with dry ice to release carbon dioxide will usually capture much larger numbers of mosquitoes and may attract some species which do not usually come to the New Jersey trap in significant numbers. CDC traps are compact and highly portable but are operated by batteries which need fairly frequent recharging or replacing. It is important to note that traps are selective and only give an indication of what species are present and their relative abundance.

Figure 24. **CDC miniature light trap (left) and New Jersey light trap (right)**

Other methods of judging the extent of the mosquito problem include landing rate counts -the number of mosquitoes which land per minute -and collecting by aspirator in fixed resting stations such as culverts, sheds or houses. The number of telephone complaints received by the mosquito control office is also an index of the magnitude of the problem, but should be relied upon only when followed up by inspection or when taken from individuals who have a proven history of reliability.

In locating breeding areas and in planning source reduction projects, the director must have accurate knowledge of the topography of his district. For example, his program must be aware of the size and position of streams, lakes and roads and the elevation throughout the area. In addition, he will want to know the location of recreational areas, wildlife reserves, state and national parks, large bridges, towers and power lines. Among the maps which will be especially useful are: shaded relief maps, road maps, population maps, soil maps, drainage maps, and aerial photographs. Plans for engineering projects for mosquito control can be shown as map overlays, and areas to be sprayed by plane can be marked on the maps for the pilot's use.

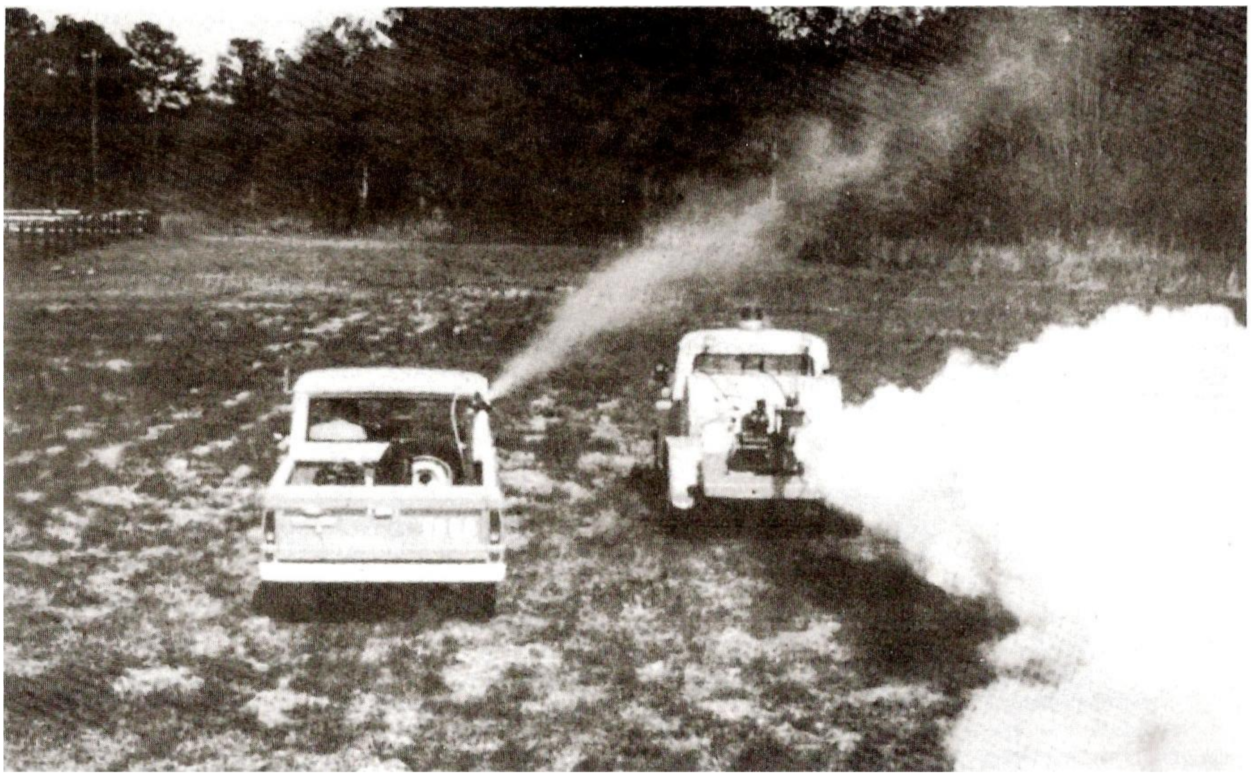

Figure 25. **Comparing ULV (left) and Thermal Fogging (right)**

Equipment for Mosquito Control

Each mosquito control district is different and will need a different combination of vehicles and other equipment.

Larviciding Equipment - One of the oldest methods of mechanical application of larvicides is by knapsack/backpack sprayer or by using a hand-operated granular applicator. In the interest of covering a larger area more quickly, manual application has been largely replaced by more mechanized methods. However, the knapsack sprayer is still often used in urban areas, along drainage ditches and in catch basins where it is desirable to make a very localized larvicide application. With the exception of applications made to roadside ditches and other areas readily accessible to ground vehicles (i.e. trucks), larviciding of large areas is usually done by making applications from airplanes and helicopters.

Adulticiding Equipment - Control of adult mosquitoes is usually accomplished through fogging, spraying, or by ultra-low volume (ULV) spraying. Mosquito control districts in Florida may own a variety of vehicles and equipment such as: cars, station wagons, jeeps, fog trucks, tractors, draglines, bulldozers, backhoes, pick-up trucks, airplanes, and helicopters.

Tractors, bulldozers, and backhoes are used in diking, filling, and impounding, as well as in operating a sanitary landfill in such a way that it does not breed flies or mosquitoes. This type of control activity can be considered habitat reduction.

A variety of fogging and spraying equipment is available and includes mist blowers, "cold foggers", thermal fog generators, and ULV machines.

Aircraft equipped for conventional spraying, or adapted for ULV applications are widely used throughout the State, both for larviciding and adulticiding. Helicopters are often used both for larviciding and adulticiding and may be used for both larval surveys and for applying larvicides. However, fixed-wing aircraft, both single and multi-engine, are the aircraft most commonly used by the control districts for both adulticiding and larviciding. Use of fixed-wing aircraft is the most efficient means to adequately treat large areas of land.

Calibration of ULV Machines and Checking Droplet Size

ULV application of pesticides is a method whereby the insecticide, usually a technical or undiluted material, is broken up into very small droplets. Most equipment uses the air blast of a blower to break up the droplets and transport them away from the vehicle, but some machines use other methods to produce and move the small droplets. The primary reason a piece of equipment must be calibrated is to make sure it is operating in an effective manner and discharging the insecticide in the correct amounts according to label recommendations of the particular insecticide.

The calibration of ULV equipment is a relatively simple process since it requires a minimum amount of equipment. A timepiece, preferably a stop watch, and two containers (one to collect the insecticide and one for measuring) should be sufficient to measure insecticide flow. Obviously, when discharging only ½ to 4 fl. Oz/min (15 to 125 ml/min) as with ULV sprayers, a measuring container calibrated for small amounts is required. A glass container marked in milliliters (ml) or tenths of a fluid ounce is ideal.

To calibrate ULV equipment, first, disconnect the insecticide line from the nozzle and place the tip of the line in a container to collect the discharge. Start the machine and when it is operating at the desired pressure, etc., set the flow meter or digital readout about mid-scale of where you think it should be for the desired discharge. While the material is being discharged into the collection container, move the discharge line to the calibrated measuring container for a predetermined time, usually 1min. At the end of that time, move the discharge line back to the collection container and record the amount that was discharged into the measuring container. If the discharge is too much, reduce the setting and repeat the procedure; if it is too little, increase the setting. Repeat the entire procedure as many times as necessary until the permanent mosquito control projects such as ditching, machine is dispensing the recommended volume per minute. Repeat at the same setting as a check. If the discharge is satisfactory, reconnect the insecticide line to the nozzle. The recommended discharge in fl. oz/min for a particular insecticide is shown on the insecticide label.

If the machine is equipped with the older ball type flow meter control system, the temperature of the insecticide at the time of calibration should be noted since the amount of material being discharged at a particular flow meter setting will vary according to the temperature of the insecticide. If the temperature in actual operation is less than when calibrated, the discharge will be less and in order to discharge the correct amount of insecticide, the flow meter setting will have to be increased. For example, when spraying malathion with the Leco generator, a 5°F difference in temperature will result in a 1/2 fl. oz. difference in discharge. Therefore, when discharging 2 fl. oz/min, there is an unacceptable 25% error in discharge. Variations in temperature do not affect all insecticides equally. Some equipment manufacturers offer tables or curves which indicate the flow meter setting for several insecticides at various temperatures and discharge rates. In machines which have positive displacement pumps, such as the variable flow and constant flow control systems, insecticide temperature is not a factor.

The insecticidal distribution system of the ULV machine should be flushed with approximately one pint of isopropyl alcohol following each time the unit is used.

Once a ULV machine has been calibrated to deliver the correct dosage of an insecticide, it is necessary to determine whether the insecticide is being dispersed in the correct droplet sizes. Instructions for testing droplet size are given on some insecticide labels.

Recent improvements in testing for droplet size include the use of a stand with a wooden arm to which slides are attached. The arm is dropped through the insecticide coming from the machine. This mechanism gives a more uniform deposition rate than waving the slides by hand; however, it works only with machines that use a blower to propel the droplets from the nozzle.

Since droplet size varies with flow rate, different formulations, and formulation pressure, as well as, to some extent, with temperature, it is important to check droplet size frequently. It is recommended that droplet size be checked each time the unit is put into service following repairs or maintenance. The droplet size should be verified every 100 hours of operation or as often as necessary to ensure it is producing droplets in the required range.

Calibration of Thermal Fog Equipment - Since thermal foggers discharge much greater volumes than ULV equipment, a larger measuring container must be used. Because of the low viscosity of the dilute insecticide solution, the temperature of the solution is not a factor in determining discharge rates.

Maintenance of Equipment - The importance of proper maintenance cannot be overemphasized. Machine breakdown is both annoying and expensive. Because timing is often of great importance in adult mosquito control, a machine failure can completely destroy the value of any specific operation. An instruction manual and a parts manual should be available for each piece of equipment and they should be kept at hand. Both the machine operator and his supervisor should be familiar with their contents.

Methods of Mosquito Control

Premises Sanitation

The need to prevent mosquito breeding in water holding containers around homes and businesses is well known, but unfortunately has not received much emphasis in recent years. Each mosquito control director should use the media available to him to educate the general public in the need to see that jars, cans, old tires and other junk, bird baths and water-holding plants do not breed mosquitoes. Removing these items or dumping any water in them is a simple step that can be taken to help combat certain species of mosquito.

Land and Water Management

Land and water management methods do, in many instances, alter the environment and are, therefore, subject to the environmental permitting process. In the past, ditching in the salt marshes to provide water circulation and to make the marshes available to fish which feed on mosquito larvae has been widely and successfully carried out in Florida. Another effective method of salt marsh mosquito control has been diking and creating an impoundment which covers the surface of the marsh with shallow water and prevents salt marsh mosquitoes from laying eggs, since they are laid on damp soil and not on water.

Unless specifically exempt, most dredging and filling activities require permits if the activity is to be in "submerged lands or the transitional zone of submerged lands" as defined by the vegetation indices listed in Chapter 17-4, Florida Administrative Code.

The application for a permit is submitted to the Department of Environmental Protection who in turn sends copies to other state agencies and the U.S. Army Corps of Engineers. The applicable water management district should also be contacted to determine if a permit from them is required. A local permit is not usually needed, but this should be investigated.

Existing projects which need maintenance may be exempt from the permitting process, especially if the spoil is to be placed on an upland site as defined in Chapter 17- 4, F.A.C.

The Department of Agriculture and Consumer Services, Bureau of Scientific Evaluation and Technical Assistance, will assist mosquito control districts in developing permit applications so that water management work may remain an essential element of mosquito control programs.

Chemical Control

Throughout the world the chemical control of mosquitoes has significantly reduced human illness and death, and has greatly improved human comfort by rapidly and effectively reducing vector species and pest populations. Although the use of chemical materials has been a publicly sensitive issue, chemical insecticides have been responsible not only for creating a healthier environment for human beings, but also for making it possible to develop and utilize land areas previously considered unfit for human habitation.

Chemical insecticides are used in Florida both as larvicides and as adulticides. With certain exceptions, no chemicals may legally be used for these purposes unless they have been approved by the Environmental Protection Agency (EPA) and registered by the Florida Department of Agriculture and Consumer Services.

Larvicides

Three categories of larvicides are used extensively for larval control in Florida. These include contact larvicides (certain organophosphate and hormone mimics), surface control agents (surface oils and films), and stomach toxins (microbial larvicides).

Temephos belongs to the class of insecticides known as organophosphates (OP). Temephos is currently the only OP registered for use as a larvicide in Florida. Like the other OPs, the mode of action is to inhibit cholinesterase in the peripheral and central nervous systems of the larval mosquitoes. Temephos has a relatively low to moderate acute toxicity compared to other organophosphate insecticides. Registered formulation types containing temephos include granular and emulsifiable concentrates. Product labels typically bear either the signal word “WARNING” or the signal word “CAUTION”, indicating they are of lower irritancy or toxicity. Temephos products are labeled for use in many habitats including tidal marshes, woodland pools, polluted water, tires, and as a pre-hatch treatment.

Methoprene is a juvenile hormone (JH) analog which can be used as a larvicide, since it can regulate insect growth. Methoprene will not control adult insects. Juvenile hormone must be absent for a pupa to molt to an adult. Methoprene effectively inhibits the transformation of a pupa to the adult insect. It is considered a biochemical pesticide because rather than controlling mosquito larvae through direct toxicity, methoprene interferes with an insect's life cycle and prevents it from reaching maturity or reproducing. Therefore, EPA lists methoprene as a biopesticide, and its labels bear the signal word "Caution".

Larviciding Oils form a coating on the top of the water and drown larvae, pupae, and emerging adult mosquitoes. Surface oils are considered one of the most effective tools for pupal control and can control newly emerged adults that are resting on the water surface when drying their wings. Over all, they have a low toxicity when used according to the label with minimal detrimental effects to non-target organisms. EPA has also assigned larviciding oils a "CAUTION" signal.

Monomolecular surface films such as Arosurf MSF and Agnique MMF are utilized as larvicides and pupicides of mosquitoes. They are biodegradable and spread spontaneously over the surface of the water to form an ultra-thin film. Their mode of action is physical rather than chemical. These compounds lower the water surface tension, preventing suspension of the larvae and pupae at the water surface, subsequently suffocating them. They also interfere with emergence of the adults. Monomolecular films, used according to label directions for larva and pupa control, pose minimal risks to the environment and human health. Because they do not last very long in the environment, they are usually applied only to standing water. Typical sites of application include roadside ditches, woodland pools, or containers which contain few non-target organisms.

***Bacillus thuringiensis israelensis (Bti) and Bacillus sphaericus* (*BS*)** are microbial larvicides that occur naturally in soils and aquatic environments globally. The active ingredients of *Bti* formulations are delta-endotoxin crystals produced by various species of bacteria. Mosquito larvae eat the *Bti* product that is made up of the dormant spore form of the bacterium and an associated pure toxin. The toxin disrupts the gut in the mosquito by binding to receptor cells present in insects, but not in mammals. *Bti* is registered as a pesticide for control of mosquito larvae in outdoor areas such as irrigation ditches, flood water, standing ponds, woodland pools, pastures, tidal water, fresh or saltwater marshes, and storm water retention areas. Extensive testing shows that *Bti* does not pose risks to wildlife, non-target species, or the environment, when used according to label directions.

Bacillus sphaericus is another bacterial larvicide that occurs naturally and is found throughout the world. *BS* acts in a manner similar to *Bti.* The bacteria are ingested by the mosquito larvae and the toxin disrupts the gut in the mosquito by binding to receptor cells present in insects but not in mammals. *BS* toxins are much slower acting than *Bti* toxins but their effectiveness is more persistent. Both *Bti* and *BS* are classified as Biopesticides by EPA and both bear the "CAUTION" signal word in their product labels.

Adulticides

Currently, two classes of pesticides are widely used for the majority of adulticiding operations in Florida. These are the organophosphates (OP) and pyrethroids. The OP used in Florida includes malathion, naled and chlorpyrifos. The pyrethroids consist of pyrethrum, pyrethrins, permethrin, resmethrin, lambda-cyhalothrin, cyfluthrin and D-phenothrin. Etofenprox, a pyrethroid-like compound, was recently registered and has been used to a small extent.

Malathion is an organophosphate (OP) insecticide that has been registered for use in the United States since 1956. Malathion kills mosquitoes because it is converted inside the mosquito into mala-oxon, which inhibits an important central nervous system enzyme called acetylcholinesterase (AChE). AChE breaks down the neurotransmitter, acetylcholine. When this enzyme is inhibited by an OP, the neurotransmission cannot cease and the nerve is over stimulated. Ultimately, this overstimulation leads to paralysis and death in the mosquito. All organophosphate insecticides share this mode of action.

Malathion can be applied using both ground and aerial equipment to control adult mosquitoes. Malathion is a very effective chemical control agent and when applied in accordance with the label recommended rate and safety precautions, this compound poses no unacceptable risks to human health or the environment.

Naled is also an OP pesticide that is primarily used for aerial adulticiding in Florida. It has a similar mode of action again adult mosquito to malathion. Naled is highly toxic to insects, and therefore is typically applied at less than an ounce per acre. Like malathion, the risks from naled to humans, birds, and fish are not unacceptable. However, because of the invertebrate toxicity of this compound, there are risks to non-target invertebrates, including beneficial insects such as honeybees. For that reason, EPA has established specific precautions on the label to reduce such risk.

Pyrethrins are naturally-occurring compounds derived from members of the chrysanthemum family. Pyrethrins act on sodium channels through which sodium is pumped to cause excitation and nerve transmission. They prevent the sodium channels from closing, resulting in continual nerve impulse transmission, tremors, and eventually, muscle paralysis and death. Since they are naturally occurring compounds and break down rapidly in sunlight, they are considered as environment-friendly adulticides and have few negative residual effects.

Pyrethroids are synthetic chemical insecticides whose structures mimic the natural insecticide pyrethrum. Permethrin, resmethrin**,** and sumithrin are synthetic pyrethroids commonly used in Florida to control adult mosquitoes. Pyrethroids, like pyrethrins, kill insects by overexciting their nervous system. When used appropriately, pyrethroids used in mosquito control programs should not pose unreasonable risks to wildlife or the environment. Pyrethroids, when applied at mosquito control rates, are low in toxicity to mammals, and are practically non-toxic to birds. However, pyrethroids are toxic to fish and to bees. For that reason, EPA has established specific precautions on the label to reduce such risks, including restrictions that prohibit the direct application of products to open water or within 100 feet of lakes, streams, rivers or bays.

Other Control Methods

The Department of Agriculture and Consumer Services has for many years stressed the importance of permanent control, but because chemical insecticides have been questioned by environmentalists in recent years, additional emphasis has been put on research to find alternative methods of controlling mosquitoes. Biological control of a population through an increase in predators or pathogens affecting the organism to be controlled has been practiced in mosquito control for many years. For instance, digging minnow-access ditches into a salt marsh or stocking mosquito breeding areas with fish, which feed on larvae are two such means to control mosquitoes. However, opposition by special interest groups and recently enacted legislation restricting the construction of ditches, have all but eliminated this biological control method for mosquito control.

Researchers are also continuing to study bacterial, protozoan, fungal, algal, and viral diseases of mosquito larvae. It is hoped that a number of effective biological control agents may be discovered from these efforts.

Mosquito control programs may also apply herbicides to kill aquatic weeds that provide protection and, in certain species, oxygen for the larvae. Research is also underway to determine the feasibility of using the sterile male technique to control mosquito populations. At the Florida Medical Entomology Laboratory, researchers are studying lethal genes as a hope for genetic control. But at the present time, none of these methods are available and effective in practical control operations.

Whatever methods of control may be used by a district, it is of the utmost importance that they be chosen carefully and used with utmost safety. This is especially true in the use of chemical insecticides. Only materials labeled for that particular use can be utilized. These products should also be applied at the lowest effective concentration, in strict accordance with the label. The equipment used to apply the insecticide should be properly calibrated and carefully checked, and the applicator should be fully trained in the safe handling and application of the material used. The importance of using chemicals in the recommended manner (i.e. proper rate, correct vehicle speed and swath width) so that it is safe both to the environment and to the applicator cannot be overemphasized. Insecticides should be used only when absolutely necessary and never on a routine basis.

Integrated Mosquito Management (IMM)

The most effective programs in mosquito control are based on a combination of methods. These include water/habitat management, chemical control and biological control. This multi-tooled approach is called "integrated control." To use integrated control effectively, it is necessary to have a broad understanding of the insects to be controlled and the factors which influence population size. In this way, costly chemical controls can be used only when really needed and when they will be most effective.

In 2009, the American Mosquito Control Association (AMCA) drafted a new policy document on Integrated Mosquito Management (IMM). This document was made available to EPA to help guide its deliberations regarding National Pollutant Discharge Elimination System (NPDES) permits. This document is also discusses Best Management Practices (BMP) that, when practiced by mosquito control agencies, will serve as a basis for developing an **Integrated Mosquito Management (IMM)** approach to mosquito control in Florida. **IMM** is the use of a combination of biological, chemical, educational and physical control methods in order to maintain targeted mosquito species or populations of mosquitoes at acceptable levels.

Legal Aspects of Mosquito Control

Mosquito control districts and programs are established and operated under the authority provided in the Mosquito Control Law, Chapter 388 Florida Statutes (F. S .), and the Mosquito Control Rules, Chapter 5E-13, Florida Administrative Code (F.A.C.). Chapter 388 F.S. provides local governmental entities authority to conduct arthropod control on public land, under conditions specified in the law.

Performance of control measures on private property requires permission of the owner. In cases where the owner will not control arthropod breeding on his property and refuses to permit the mosquito control district to do so, it may be necessary to use the authority provided in Chapter 386 F.S., Particular Conditions Affecting Public Health. District Directors are encouraged to work with the local Department of Health officials and the homeowner to amicably resolve and minimize potential health threats.

The Federal Insecticide, Fungicide, and Rodenticide Act of 1972 requires that the EPA be certain that all personnel handling hazardous or restricted chemicals be trained to do so correctly and safely, and that they be certified as pesticide applicators by a responsible state or federal agency.

The state agency to administer the certification is appointed by the governor of each state. In Florida, the Department of Agriculture and Consumer Services has been designated as the lead agency, and shall be responsible for certifying the commercial pest control operators and mosquito control personnel making pesticide applications in the State. The law requires that every person applying pesticides for mosquito control, with certain exemptions, be certified or be supervised by a certified applicator.

A mosquito control director is responsible for upholding a number of laws and regulations related to the safe use of pesticides and application equipment by program employees. The director should ensure that all applicators read and understand pesticide labels, that they wear and maintain appropriate personal protective equipment (PPE), that they follow the recommended procedures in storing and mixing chemicals, and in disposing of empty containers, that they are well trained in proper operation of equipment, and that they know and use good driving habits.

The director is also responsible for securing adequate insurance for the district, and meeting the requirements of the Social Security Act, "Right to Know" law, and the Occupational Safety and Health Act (OSHA).

Public Relations and Dealing with Negative Impacts

To build a really effective mosquito control program the general public must be made aware of the need for mosquito control, the methods by which it is accomplished, and the need for their support and cooperation. How well a program is explained to the public will determine not only the amount of tax money the program receives, but the cooperation received from land owners on whose property it is necessary to work. It will influence the concern and cooperation citizens give in trying to keep their premises free of receptacles which might breed mosquitoes.

The public image of a mosquito control district is created in three ways -through public coverage such as newspaper stories and radio and television announcements and programs, by talking before civic organizations, schools and other groups, and by dealing with individuals through telephone calls, letters or personal contact.

The word "relations" in public relations indicates that a relationship should exist and that the process involves an exchange of information to and from the public. Telephone calls and letters from the public give the director an indication of where the mosquitoes may be present at nuisance or public health concern levels, how the public is reacting to the control measures being used, and what the public wants done that is not being done. This is invaluable information and the director should follow-up complaints with either an inspection or surveillance. In addition, every employee of the district should be aware that the image they create as they go about their job determines how the public feels about mosquito control. Courtesy and safety in driving, patience and consideration in dealing with questions and problems, and care when working on other people's property will give the public a favorable view of the program.

Wherever a large scale mosquito control program operates some negative impacts, both real and perceived, will occur. Groups that occasionally oppose some or all mosquito control activities include environmental organizations, beekeepers, public lands managers, aquaculturists, organic farmers, concerned citizens, and chemically sensitive or chronically ill individuals.

A mosquito control director has a responsibility to work with these groups to achieve a compromise acceptable to all concerned. The first step is opening the lines of communication and to developing trust. Often, the main problem is a lack of understanding on both sides. Through education the concerned party may better understand the need for, and minimal impact of control operations and the mosquito control director may realize how small changes in the operation may significantly decrease the possibility of adverse effects. Beekeeping is a good example. Honey bees are susceptible to organophosphates such as the adulticides naled, chlorpyrifos, and malathion, and the larvicide temephos. As a result, adulticiding during times of high bee activity and larviciding over bee yards may have an impact on the honey bee populations. Most aerial adulticiding is now performed early in the morning before bees leave the hive to forage, or in the evening or at night when bees are back in the hives, thus minimizing any impacts. In addition, mosquito control personnel advise local beekeepers as to which areas will have high, low, or no aerial activity allowing them to locate their bee yards in "safe" areas. Beekeepers are encouraged to inform mosquito control when they plan to move their hives. If mosquito control is aware of bee yards in or close to areas regularly treated, they can tailor the operations to avoid impacts on the bees, such as switching larvicides from temephos to a safer material, such as methoprene or Bti.

Many mosquito control programs maintain a listing of concerned citizens. Often these individuals understand the need for mosquito control operations but are fearful of exposure to any chemicals, despite education and assurances from scientific experts. In most cases, the solution to this problem is simple: the district can call the concerned citizen(s) to inform them of upcoming spray operations in their area. The citizen can then take whatever precautions they deem necessary to avoid exposure, and they feel mosquito control has made an effort to work with them.

Arthropods of Public Health Importance

Mosquito control directors will often be asked to identify, provide advice and possibly help in controlling arthropods other than mosquitoes. Usually, the questions relate to insects which bite or sting, but it is not uncommon to receive questions about arthropods which are annoying because of their abundance.

Among the insects which are frequently reported as annoying are the blind mosquitoes (Chironomidae) which may emerge from lakes of Florida in such huge numbers that they make outdoor living impossible and may even be a traffic hazard. These insects are very similar to mosquitoes in appearance, but they do not have scales on the wings and the adults do not feed on blood. When very large populations of these insects occur, it would be virtually impossible for an individual to control these insects. A mosquito control district can, however, cover a large enough area with adulticides to give temporary relief.

The lovebugs (Bibionidae) are another major annoyance in Florida. They fly into roadways in such large numbers during peak emergences that windshields are quickly covered with spattered insects. The worst period is usually April through May, with a secondary occurrence in September. Inside homes there are sometimes populations of booklice (Psocidae) large enough to create an annoyance by crawling on the skin. These insects are not true lice and do not bite.

A number of people have entomophobia, a fear of insects, and “suffer” from bites and crawling insects on the skin which are often imagined rather than real.

Certain insects and arachnids are feared because they can give a painful bite or sting. Those which inject venom by biting include the black widow spider, the brown recluse spider (not usually found in Florida) and certain ticks. Those which inject venom by stinging include scorpions, wasps, bees and fire ants. The venom produces irritation at and around the site of the injection. When the person is allergic to the venom, more severe reactions may result including anaphylactic shock and even death.

The urticating caterpillars inject their venom through hollow body hairs. When a person brushes against the hairs, venom passes from blades at the base of the hair into the skin of the individual, producing a very painful sting. The puss moth caterpillar, saddleback, and IO moth caterpillar are the most commonly encountered stinging caterpillars.

There also are a number of insects which shed wing scales or hairs that may cause allergic reactions in some individuals. Symptoms include itching and dermatitis in sensitive individuals. The mouthparts of many insects such as bedbugs, lice, some flies, mites and ticks are constructed for blood sucking and in many instances a blood meal is required for the female before eggs can be developed and laid.

Dog flies (a.k.a., stable flies), sand flies, horse or deer flies, fleas, chiggers and bird mites do not inject venom when biting, but their saliva may be very irritating or painful. Most of these insects do not usually transmit diseases.

The larvae from a few fly species have been known to survive internally in man, but these cases are usually the result of accidental infestation and occur infrequently. However, both flies and the screw worm may lay their eggs in wounds or in the nostrils of man, and the maggots can cause a very serious health problem if not promptly treated by a skilled physician.

The role of mosquitoes in disease transmission has been previously discussed. However, a number of other insects are also involved in the spread of human diseases.

Some examples of mechanical or passive transmission of diseases would include the spreading of "pink eye" or conjunctivitis by eye gnats, the spread of typhoid and intestinal diseases by house flies and the potential spread of pathogenic and food poisoning organisms by cockroaches.

Aside from mosquitoes, the arthropod vectors of diseases most likely to be encountered in Florida are ticks and fleas. Although endemic typhus, spread by rat fleas, was once widespread in the State, it is no longer a concern here.

Rocky Mountain spotted fever, Lyme disease, human ehrlichioses and tularemia are human diseases which are vectored by ticks. The usual vector of Rocky Mountain spotted fever, the American dog tick, *Dermacentor variabilis*, occurs in Florida, but the disease itself is almost unheard of in the State. Lyme disease is caused by a spirochete and is found primarily in the northeast and pacific coast areas of the U.S. The disease is vectored by *Ixodid* ticks. The human ehrlichioses are a complex of tick-borne rickettsial diseases that are generally mild but may become serious if not treated early. Cases of tuleremia do occur, but in Florida most of these have been traced to dermal contact with infected rabbits, and not tick bites.

A few cases of tick paralysis have been recorded in Florida, usually in children who were found to have one or more ticks attached near the hairline on the neck. Careful removal of the ticks has been followed by a swift recovery from the paralysis.

Mosquito Control directors should learn to recognize the more common of these annoying or dangerous arthropods, and should be able to provide information on their life histories and control when requested. *The Florida Insect Control Guide* will be especially useful for this purpose.

Control of Other Arthropods by Mosquito Control Districts

In instances where insects other than mosquitoes breed in such numbers as to be a serious nuisance or a health hazard to the public, the mosquito control district will often be called on to control these insects or other arthropods. The most frequent problems encountered are sand flies, dog flies, midges (blind mosquitoes), house flies and other filth flies, and eye gnats.

Sand Flies (Figure 26). - These small biting midges of the genus *Culicoides* are a pest in many areas of Florida, although the coastal species cause more annoyance than the freshwater species. Much research has been directed toward finding methods and materials to effectively control these pests, but with the exception of water management, no really satisfactory method has been found. The only solution is to keep their breeding areas flooded completely, or to fill them and construct bulkheads at the shoreline.

Several chemical insecticides can be very effective in killing sand fly larvae, but some of these materials are also highly toxic to the aquatic fauna and other wildlife. Panasol, a petroleum solvent, can be used effectively as a larvicide and with safety to non-target species; but because of the large volume required for coverage, this larvicide is practical only for treating shorelines. Research is being conducted with IGR compounds, and they are showing promise as larvicides for sand flies.

When sand fly adults are a problem in populated areas, it is possible to fog or spray and control them, but new adults move in from the periphery so rapidly that relief is very temporary. In addition, the results often do not justify the cost. Unless the problem can be resolved by impounding or filling the breeding area, the only real solution at the present time is for people to try to remain inside air-conditioned buildings when populations are high. If the flies get indoors, household aerosols will provide control. Repellents offer some protection for several hours when one must be outside, but do not repel these insects as well as they do mosquitoes. Fortunately, these insects are seasonal in nature.

Stable Flies (Figure 27). - Also known as dog flies, stable flies are a major pest along the northwest Gulf coast from Wakulla County through Escambia. The flies have a known flight range of up to 70 miles. In the past, the State had a modest appropriation to carry out control operations which would supplement the control operations of the counties. Counties in the stable fly area should have organized inspection and surveillance protocols for stable fly outbreaks. Beaches must be inspected daily for adult flies, starting at 8:00 a.m. and at least once or twice more during the day, as long as north winds prevail. Stable fly larvae should be controlled where possible by management of plant and animal wastes to destroy the larvae without the use of sprays. This can be done by spreading waste materials thinly at intervals so that they dry quickly.

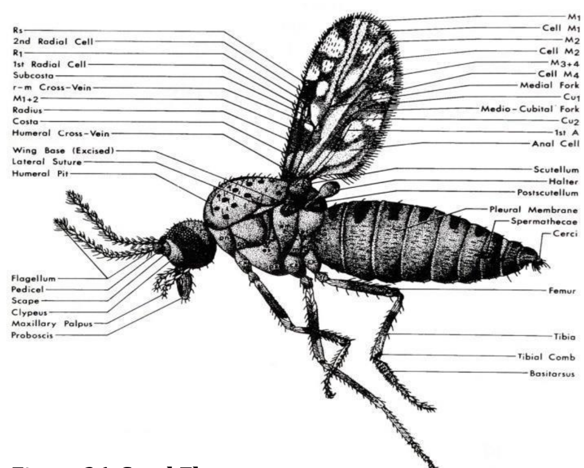

Figure 26. **Sand Fly**

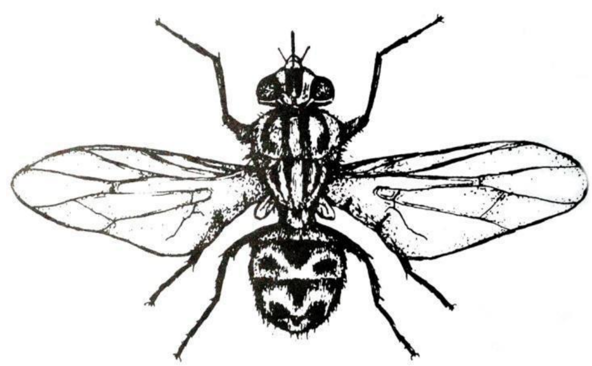

Figure 27. **Stable Fly**

Blind Mosquitoes (Chironomidae) (Figure 28). - These mosquito-like insects do not bite, nor carry disease. However, they are a nuisance when they emerge in such large numbers that they make outdoor activities unpleasant or impossible. Blind mosquitoes have also been known to come to homes in such huge numbers, attracted by the lights, that they enter every time a door is opened.

Most complaints about midges come from the lake regions in Polk, Orange, Lake, Highlands, and Seminole counties, from sites along the St. Johns River or its tributaries, or from the vicinity of man-made lakes at apartment or condominium sites. Organic pollution, including sewage treatment effluents, canning wastes and fertilizer carried off by ground water, is responsible for the heavy production.

In the past there have been several programs for control of midge larvae with various insecticides. At present, most efforts are directed toward control of adult midges.

House Flies (Figure 29). - House flies and other filth flies are capable of breeding in almost any warm, moist organic matter such as animal manure, garbage, or decomposing foods. Control of house flies and other filth flies is usually best accomplished by good sanitation, and the arthropod control districts are called in only when an unusual situation causes a problem population -such as an improperly managed landfill. House flies have developed resistance to many of the chlorinated hydrocarbon and organophosphate insecticides. It is best to consult the most recent recommendations for control before treating for flies.

Eye Gnats (Figure 30). - Until the last decade, eye gnats were only a localized and temporary problem in the State. However, with conversion of vast tracts of woodlands in west Florida into farms for growing soybeans and other crops, eye gnats have become a significant problem. With eye gnats, as with many problem insects, adulticiding offers, at best, temporary relief. Newly emerged adults quickly reinfest the sprayed areas. IGR compounds have shown promise in current research for control of the larval stage.

Miscellaneous Insects. Mosquito control districts often receive calls from private citizens seeking information on how to control other certain household pests, such as fleas, roaches, ticks, etc. Although controlling these types of pests may not fall under the mission of the program it is a good public relations step to have the information at hand to give them. The Florida Cooperative Extension Service, University of Florida's website (http://edis.ifas.ufl.edu/topic_guide_ig_household_pests_and_pests_of_man), is an excellent source of up-to-date information on control.

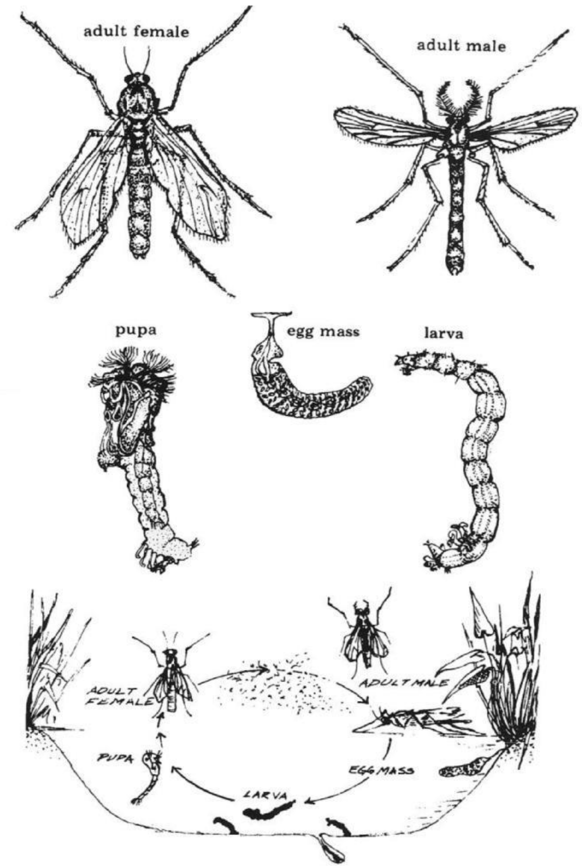

Figure 28. **Blind mosquito life cycle**

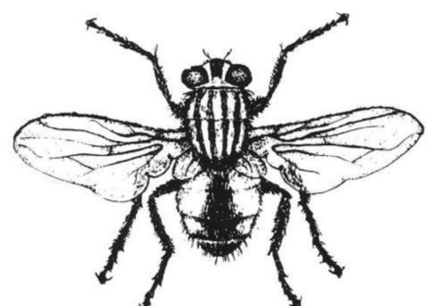

Figure 29. **House Fly**

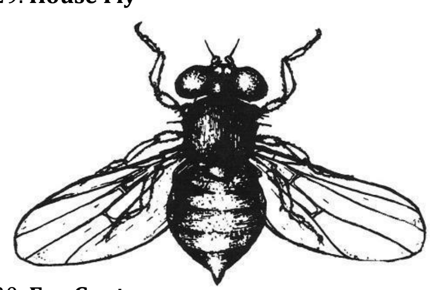

Figure 30. **Eye Gnat**

GLOSSARY

Arbovirus: Arthropod-borne viral disease agent transmitted biologically by insects.

Arthropod: An animal of the phylum Arthropoda characterized by having a hard exoskeleton, body with a number of segments arranged longitudinally and paired jointed appendages. The phylum Arthropoda includes insects, spiders, mites, ticks, scorpions, centipedes, millipedes, etc.

Calibration: The adjustment of pesticide application equipment to apply a pesticide formulation at a desired application rate.

Cuticle: Thin, multilayered tissue covering insects and other arthropods. The outside layer is composed of proteins, waxes and "cement", while layers beneath contain chitin along with proteins and waxes penetrated by numerous pores and glands.

DACS: Florida Department of Agriculture and Consumer Services.

Ditching: Creating ditches or furrows into a salt marsh to provide water circulation and to make the marsh available to fish.

Eastern Equine Encephalitis (EEE): Eastern equine encephalitis is a viral disease that is spread to horses and humans by infected mosquitoes. The causative agent, eastern equine encephalitis virus (EEEV), is an alphavirus that was first isolated from infected horse brains in 1930s and currently occurs in focal locations of the eastern United States including Florida

Enzootic: Animal diseases which are commonly present in a locality.

Exoskeleton: The hard or tough external covering of arthropods to which their muscles are attached and which serves the same function as the bony skeleton of humans.

FAMA: Florida Anti-Mosquito Association.

Family: A group of related genera within an order.

Fauna: Animal life of a given area.

Faunal Zones: is a generic term for the list of animal species occurring in a particular region. Fauna can refer to a prehistoric collection of animals, as might be inferred from the fossil record, or to a modern assemblage of species living in a region. More locally, a faunation refers to the communities of individuals of the various animal species and occurring in a particular place.

Flora: Plant life of a given area.

FMCA: Florida Mosquito Control Association.

FMEL: Florida Medical Entomology Laboratory, University of Florida, Institute of Food and Agricultural Sciences.

Genus (genera): A group of species considered more closely related to one another than to members of another genus (plural is "genera"); the first word in the scientific name of a species is the name of the genus.

Impoundment: Coverage of the surface of a marsh with shallow water to prevent exposing substrate for salt march mosquito egg laying.

Insect Growth Regulator (IGR): Synthetic insecticide which prevents normal development or causes delayed mortality of insects by disrupting a natural physiological process.

Integrated Mosquito Management (IMM): The use of a combination of biological, chemical, educational and physical control methods in order to maintain targeted species or populations of mosquitoes at an acceptable level.

Label: General and technical information about a pesticide product in the form of printed material attached to or printed on the pesticide container.

Labeling: Technical information about a pesticide in the form of printed material provided by the manufacturer, including labels, flyers, handouts, leaflets and brochures.

Landing Rate Count: A method of determining adult mosquito levels by counting all mosquitoes that land on the visible portion of the body during a one minute period. Results are expressed as numbers of mosquitoes per minute.

Mosquito Control Law: Chapter 388 Florida Statutes (F. S.) makes provision for arthropod control to be conducted on public land with certain conditions to be met.

Mosquito Control Rules: Chapter 5E-13, Florida Administration Code (F.A.C) to spell out mosquito control law.

Palpus (pl. palpi): Five-segmented paired sensory appendages projecting from the base of the proboscis.

PHEREC: The John A. Mulrennan, Sr. Public Health Entomology Research and Education Center, Florida A & M University.

PPE: Personal protective equipment.

Proboscis: Extended mouth structure of insects; the piercing mouth parts of a female mosquito which is made up of a sheath-like structure (labium) enclosing piercing and sucking structures.

Seepage: Movement of water through the soil to form a pool on the surface.

St. Louis Encephalitis (SLE): Arboviral infection normally maintained in rural or urban areas as an enzootic cycle among wild birds by *Culex* mosquito vectors. During mid to late summer, viral levels in the wild bird populations may be high enough for transmission to humans by the same vector species.

Subfamilies: A taxonomic category of related organisms ranking between a family and a genus.

Tarsus (tarsi): The last segments of an insect's legs; the "feet" of an insect (plural is tarsi).

Ultra-low volume (ULV): A spray application of a pesticide that is a technical or undiluted material and broken up into very small droplets.

West Nile Virus (WNV): A flavivirus that is transmitted by mosquitoes.

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