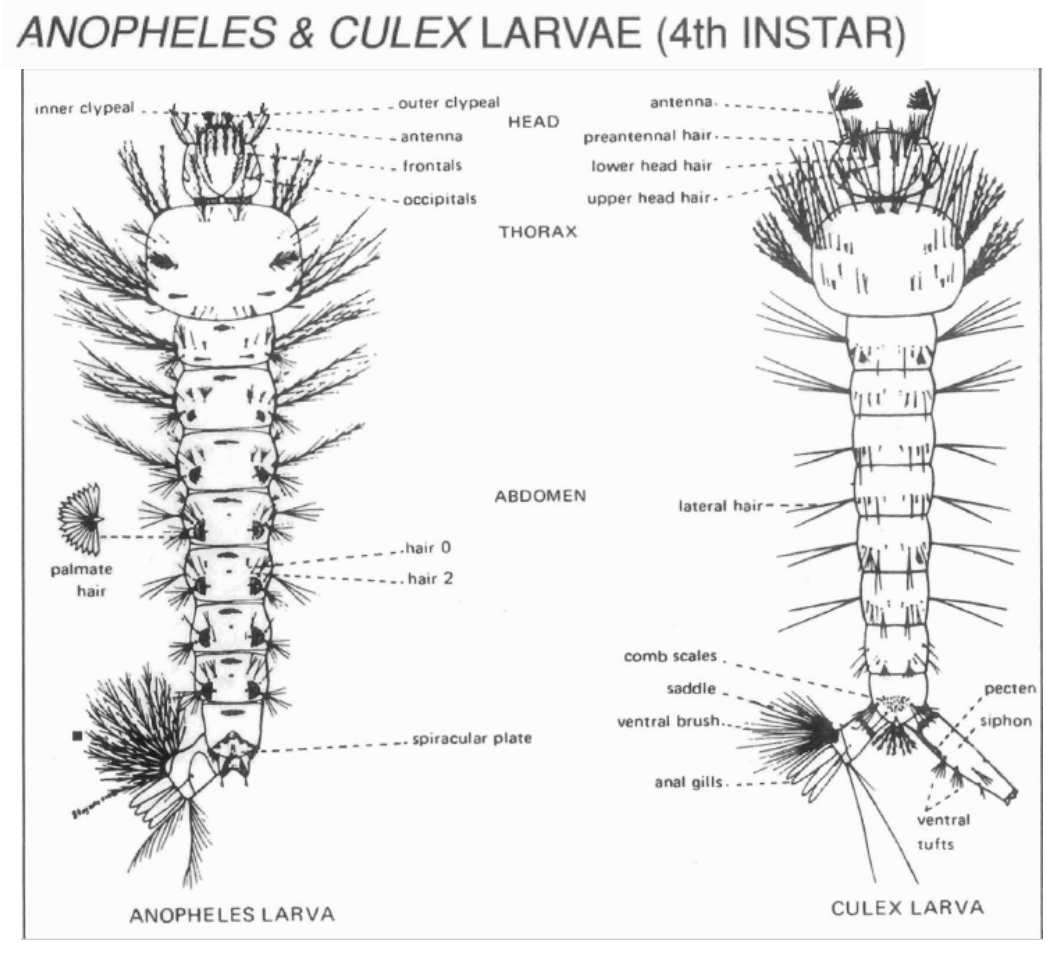
Georgia Mosquito State Exam Study Guide

- Over 3, 000 species of mosquitoes have been described worldwide
    - 150 species representing 14 genera in the US
    - 12 of the 14 that exist in North America are present in Georgia
    - 63 species are known to occur in Georgia
- Undergo complete metamorphosis. These stages of development are egg, larva, pupa and adult.
- Usually collected as larva or adults.
- Belong to the order of Diptera in the family of Culicidae
- All members of the order of Diptera are true flies. Like all true flies, adult mosquitoes have only one pair of wings (rather than the usual 2 found on most insects.
- Only female mosquitoes feed on blood. Male mosquitoes have an elongated proboscis (mouth part), but they DO NOT feed on blood.
- Male mosquitoes: have bushy antennae and long palpi
- Female mosquitoes: few bristles on their antennae and with the exception of *Anopheles* mosquito, have short palpi
- Mosquito species in Georgia fall into one of 3 subfamilies:
    1. Toxorhynchitinae (genus *Toxorhynchites*)
    2. Anophelinae (genus *Anopheles*)
    3. Culicinae (the remaining 10 genera)
- Larvae: have 3 distinct body regions: head, thorax, and abdomen.



- Larvae pass through 4 stages or instars. At the end of each molt, the larvae shed their skins (molt) and increase in size. At the end of the 4th instar, they molt again and become a pupae.
- Larvae will stop feeding towards the end of the 4th instar.
- Larvae move about either by rapid flexures of the body or by slower propulsion due to the movement of mouth brushed.
    - Rapid flexure movement is used as a diving reaction to sudden light changes, water disturbances, or to move from the bottom up to the water surface.
    - Slower brush propulsion moves the larvae along the surface or the bottom.
- Larval feeding behavior is variable among different species. However, most species are indiscriminate, filter feeders and ingest all suspended particulate matter that is small enough to be swallowed. Particles ingested typically range from 1-50 microns.

Pupae

- Have 2 body regions: 1) expanded cephalothorax (cephalo meaning head. Head and thorax are fused) and 2) an elongate abdomen.
- Unlike most holometabolous insects (insects that undergo complete metamorphosis), mosquito pupae can be very active. They are often called tumblers because of their rapid, tumbling-like movement when disturbed.
- Surface film agents can be used to treat areas with pupae present.

Adults

- Have 3 distinct body regions: head, thorax, and abdomen
- The adult mosquitoes mouthpart, the proboscis, projects downward and forward from the lower, front margin of the head.
- Adult mosquito's thorax: bears the wings and legs and has a variety of scales and hairs or bristles on the upper surface and sides.
    - Long, slender legs arise from the lower side of the thorax and consist of 5 sections
        - Coxa (short and conical in shape)
        - Trochanter (this part of the leg is hinge-like)
        - Femur (long portion of the leg)
        - Tibia (slender in shape)
        - Tarsus (tarsus is made of 5 segments. The first tarsal segment is the longest and often equals the length of the tibia)

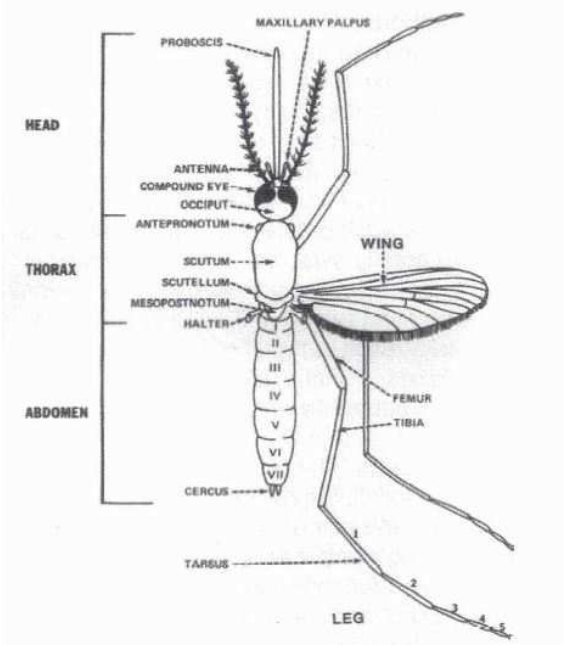


Figure 6B. The external anatomy of an adult female mosquito.

Adult Mosquito Characteristics

- Only females feed on blood. Males DO NOT feed on blood.
- Common characteristics between most mosquitoes species
    - Adult mosquitoes are terrestrial and capable of flight.
    - Males antennae have dense bristles and their mouthparts are modified to suck nectar and plant secretions, where no piercing is required.
    - Flight habits vary considerably
    - *Aedes albopictus* (Asian tiger mosquito) has become one of the most common in Ga and is the most domesticated of all the mosquitoes.
- *Aedes albopictus* breeds primarily in and around human habitations and flies short distances. Usually a block or 100-200 yards.
- Most anophelines have a maximum flight range of about 1 mile.
    - However, *Aedes vexans* and *Ochlerotatus solicitans* can fly 10 to 20 miles or more. Knowing the flight range of a pest species is critical to locationg its breeding site and targeting control efforts.

Mosquito Ecology and Identification

- For practical purposes, the numerous species of mosquitoes can be grouped on the basis of similarities in their larval habitat preferences, which generally reflect other important aspects of their bionomics and ecology, e.g., oviposition habits, developmental patterns, seasonal density and dispersal.
- The Centers for Disease Control and Prevention's Mosquitoes of Public Health Importance and Their Control proposes the following groups:
    1. Permanent pool group
    2. Transient water group
    3. Floodwater group
    4. Artificial container & tree-hole group

Permanent Pool Group

- Mosquito species belonging to this group generally are found in bodies of quiet, fresh water exposed to sunlight and containing an abundance of surface vegetation and flotage at the air-water-plant interface.
- Typical habitats are shallow margins of ponds, lakes and smaller impoundments, the defining characteristic being a degree of permanency.
- Such habitats are particularly suitable for
    - *Anopheles spp.,*
    - *Coquilleffidia spp.,*
    - *Culex salinarius*
    - *Cx. territans*
    - *Mansonia spp.*
- The mosquito species inhabiting permanent waters deposit their eggs on the water surface, singly in the case of Anopheles
- *Adult females in the general Culex, Coquilletidia and Mansonia* deposit their eggs in rafts, with some variation in place of oviposition in *Mansonia*
- Such sites are sheltered from wave action and are always in the presence of vegetation suitable for larval attachment or protection.
- Larval production generally is continuous in these species with several generations per year.
- Most *Anopheles* and *Culex* overwinter as adult females, but some, e.g., *Anopheles walker* may overwinter in the egg stage
- *Mansonia* and *Coquillettidia* overwinter as larvae attached to the roots of plants.
- *Coquillettidia perturbans* is an important freshwater swamp species that can cause considerable annoyance in same areas of Georgia.
    - The larvae of this species have highly modified air tubes which are inserted into the roots of some aquatic plants.
    - Air is obtained directly from the plant, and the larvae never come to the water surface.
- Permanent bodies of water with stands of cattails and other emergent vegetation often support large populations of *Coquillettidia perturbans*.
- Except for *Coquillettidia* and *Mansonia*, the effective flight ranges of permanent pool species are relatively short, usually within a mile or so of the breeding area.

The Transient Water Group

- The members of this group are mostly *Culiseta spp.,* some *Culex*, and occasionally *Anopheles*.
- Their habits are similar to those in the permanent pool group, but they seem to be more often associated with pools of temporary nature as opposed to species with affinity for ponds and lakes.
- Typical sites are roadside ditches, borrow pits, canals, ground pools, clogged streams, irrigated lands, etc.
- Some species associated with such habitats include
    - *Culex quinquefasciatus*
    - *Culex restuans*
    - *Culiseta inornata*
    - *Culiseta* melanura.
- If water remains sufficiently long, *anophelines* frequently become established in later season, particularly such species as *Anopheles crucians and Anopheles punctipennis*.
- *Culiseta melanura,* the black tailed mosquito, is a particularly important member of this group.
    - The larval habitats for this mosquito are swamps and hardwood bottoms.
- ***Culiseta melanura* does not typically bite humans, but transmits the eastern equine encephalitis virus from bird to bird, other, less host-specific: species may then transfer the pathogen to humans.**

The Floodwater Group

- ***Aedes, Ochlerotatus* and *Psorophora* generally deposit their eggs singly on damp soil associated with salt marshes, grassy or woodland depressions, road side ditches or along vegetated shorelines that are intermittently flooded.**
- When flooded after a period of desiccation, the eggs hatch if conditions (temperature, pH, oxygen concentration, etc.) are favorable;
- otherwise, the eggs might remain dormant and viable on the soil until a more favorable inundation
- Typically, large numbers (broods) are produced during a hatching; larval development is uniform; and adults might appear as early as six days after flooding.
- Many of these pests will appear and disappear at varying intervals throughout the summer.
- Some species produce a single brood, particularly in northern portions of the country, but many species of *Aedes, Ochlerotatus* and *Psorophora* produce multiple broods in a given year.
- Floodwater mosquitoes typically overwinter in the egg stage.
- These species are particularly troublesome pests and some characteristically fly long distances from larval habitats, e.g., 5-20 mites in the case of *Ochlerotatus taeniorhynchus, Ochlerotatus sollicitans* and *Psorophora columbiae.*
- The woodland species such as *Ochlerotatus atlanticus/tormentor* and *Psorophora ferox* tend to remain near the larval habitat.
- Some important vectors and pest species in this ecologic group are
    - *Ochlerotatus sollicitans*
    - *Ochlerotatus taeniorhynchus*
    - *Ochlerotatus atlanticus/tamentor*
    - *Anopheles vexans*
    - *Psorophora ferox*
    - *Psorophora columbiae*

The Artificial container and Tree-Hole Group

- Characteristic of this group are members of the genera *Aedes, Ochlerotatus*, with the more important being *Aedes albopictus and Ochlerotatus*.

- *Aedes aegypti* was once the more important member of this group in Georgia, but the introduction of *Aedes albopictus* has led to the near elimination of *Aedes aegypti* through competitive forces that are not completely understood.
- *Aedes albopictus*, the Asian tiger mosquito, was first found in Houston, TX

Common Problem Species in Georgia

- The need for accurate mosquito identification is an important aspect of an integrated mosquito control program.
- To efficiently and effectively reduce a pest population in an integrated manner, it is critical to properly identify the pest, so the corresponding larval habitats can be targeted for surveillance and control procedures.
- Mosquito identification, while challenging, is not as difficult as the identification of most other insect groups
    - Identification to the species is possible for both late instar larvae and adult females, the two most commonly collected stages of mosquitoes.
    - Adult males are rarely identified because they lack the blood-feeding behavior of females.

- *Ochlerotatus taeniorhynchus* (Black saltmarsh mosquito),
    - is a small black and white mosquito
    - distinct narrow white rings on the tarsi and on the proboscis
    - cross bands of white scales on the upper side of the abdomen.
    - Wing scales are all dark.
    - *Oc. taeniorhynchus* is the predominant species, produced in huge numbers along the coast of Georgia.
- A blood meal, taken only by females, serves as a source of protein for egg production,
    - although some *Oc. taeniorhynchus* are capable of laying their first batch of eggs without first blood feeding 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, which means if you go where they are in the daytime they will be stimulated to bite you.
- *Ochlerotatus sollicitans* , Tan saltmarsh mosquito
- After the two salt marsh species, *Aedes albopictus* (Asian tiger mosquito), may be the State's most widespread nuisance species
- *Culex quinquefasciatus*, Southern house mosquito
    - larvae are often associated with foul water such as effluents of sewage treatment plants
    - which have been found producing these mosquitoes by the thousands.
- *Anopheles quadrimaculatus*: Common malaria mosquito
    - was the primary vector of malaria in the southeastern United States.
    - This species has probably been responsible for the transmission of almost all human malaria that has occurred east of the Rocky Mountains
- *Ochlerotatus triseriatus* : Eastern tree-hole mosquito
- *Psorophora columbiae* (formerly *Ps. confinnis*), Dark rice field mosquito
    - large black and white species
    - distinguished by a pale subapical ring on each femur.
- *Psorophora columbiae* is one of the most troublesome pests in Georgia;

- it will bite viciously any time of the day or night, but is especially active at night.
- The adults emerge in huge numbers from improved pastures, woodland pools, roadside ditches, irrigation waters and temporary rain pools.

Mosquitoes as Vectors of Disease

West Nile Virus

- While the precise mode of entry will likely never be known,
  - the most plausible circumstances indicate that infected birds were imported, thereby introducing the virus to North America.
  - More than 60 clinical human cases occurred in the New York City area in late summer of 1999, while subsequent serosurveys suggested that there actually had been several thousand subclinical human infections following a widespread die-off of American crows in the region
- West Nile virus was detected in mosquitoes, birds, horses and humans in Georgia for the first time during 2001.
- The symptoms of severe infection (West Nile encephalitis or meningitis) include
  - headache, high fever, neck stiffness, stupor,
  - disorientation, coma, tremors, convulsions,
  - muscle weakness paralysis.
- Symptoms of severe disease may last several weeks, although some neurological effects can be permanent.
- An estimated 1 in 150 persons infected with the West Nile virus will develop a more severe form of disease.
- Clinical signs of WN virus infection also have been observed in horses, even though most horse infections are asymptomatic. Horse mortality has run in the range of 25-30%.

Transmission Cycle of West Nile Virus

- As with Eastern equine encephalitis virus and St. Louis encephalitis virus, West Nile virus exists
- primarily as an infection of bird populations and is transmitted from bird to bird by several species of mosquitoes.
  - The principal route of human infection with West Nile virus is through the bite of an infected mosquito.
  - Mosquitoes become infected when they feed on infected birds, which may circulate the virus in their blood for a few days.
  - The virus eventually moves into the mosquito's salivary glands.
  - During subsequent blood meals, the virus may be injected into humans and animals, where it can multiply and possibly cause illness.
  - Mosquitoes are capable of transmitting the virus to another animal 10-14 days after feeding on an infected bird.

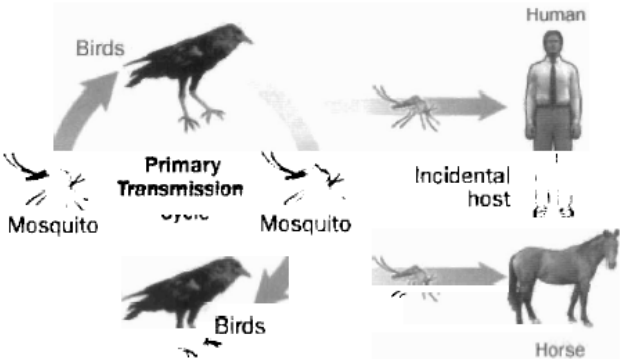


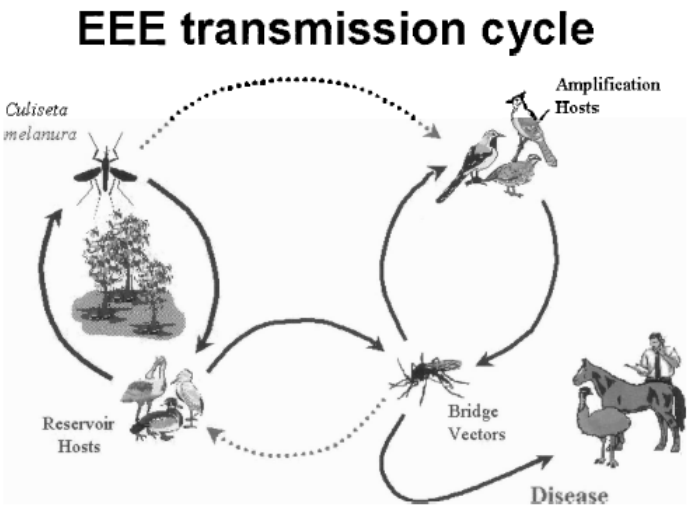
Figure 14. West Nile Virus cycle.
(Image from *American Family Physician*, Vol. 68 No. 4)

West Nile Virus Mosquito Vectors

- Mosquitoes serve as primary vectors of WN virus. In the United States, WN virus has been isolated from at least 36 mosquito species, primarily from three genera, *Aedes, Culex* and *Ochlerotatus*
- Among the numerous other species that have produced WN virus positive pools are several common species in Georgia, *including Aedes albopictus, Ochlerotatus triseriatus* and *Ochlerotatus japonicus.*

Eastern Equine Encephalitis (EEE)

- The cycle primarily involves the fresh-water swamp mosquito, *Culiseta melanura*.
- Virus activity is confirmed by encephalitis monitoring programs conducted by health departments and mosquito control districts.
- Mosquitoes taking bird blood meals during this period of high viremia can become infected.
- Once infected, mosquitoes remain infected for life.
- Birds produce antibodies that eliminate the virus after a few days of infection.



LaCrosse Encephalitis (LAC)

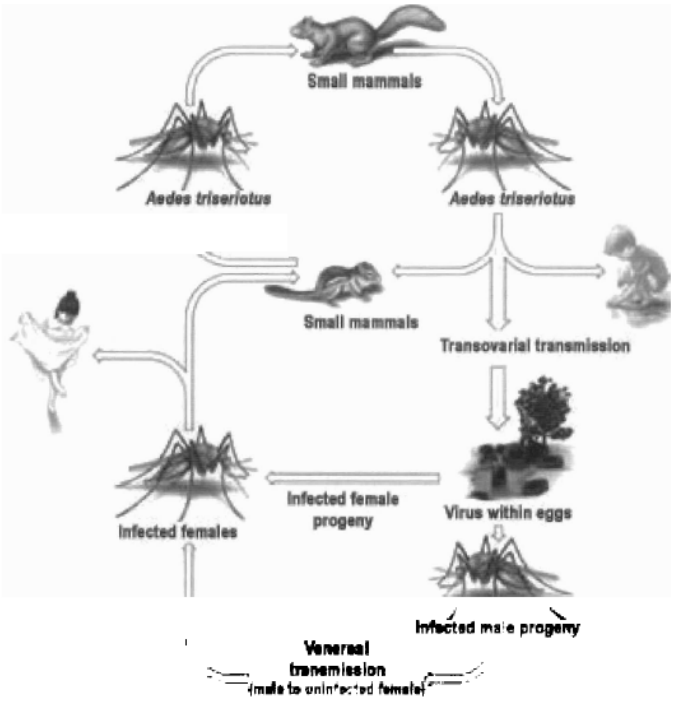


Figure 16. LaCrosse encephalitis transmission cycle.
(Image from ASM News, Barry Beaty)

Mosquito Vectors of LaCrosse Encephalitis

- The primary vector of LAC virus is *Oc. triseriatus*

St. Louis Encephalitis

- Once infected, the mosquito can transmit the virus each time it takes, or attempts to take, a blood meal for the duration of its life.

Dengue

- Dengue is transmitted in the U.S. by *Ae. aegypti* in a mosquito-human-mosquito cycle.
- After biting an infected person, the female mosquito requires eight to 10 days for viral development before it is capable of transmitting the virus to humans.
- Once infected, the mosquito remains infective for the remainder of its life.
- Presently, there is no vaccine available to prevent dengue infection.

Yellow Fever

- As with dengue, the Yellow Fever virus is transmitted in urban areas by *Ae. aegypti*, with *Ae. albopictus* and *Oc. japonicus* as potential vectors as well.

Dog Heartworm

- Infection rates in some states have been reported to be as high as 80 percent in dogs over 2.5 years old, and almost 100 percent in dogs over 5 years old that are left unvaccinated

Acquired Immune Deficiency Syndrome (AIDS)

- Currently, there is no scientifically based, credible evidence to suggest or imply that mosquitoes or other biting arthropods can transmit the virus to humans.
- Is that enough evidence to say that it is impossible for insects to transmit the virus to humans, either biologically or mechanically (for example, infected blood on the mouthparts)?
    - While that question may not have been fully answered to the satisfaction of some members of the general public, it is safe to say that the involvement of blood feeding insects and other arthropods is biologically insignificant, if, in fact, it occurs at all.

Integrated Mosquito Management

- The four overlapping aims of mosquito control are to
    - prevent mosquito bites,
    - keep mosquito populations at acceptable densities,
    - minimize mosquito-vertebrate contact
    - reduce the longevity of female mosquitoes.
- The most effective and efficient manner to produce these results is usually based on a combination of the following practices:
    - Education/Communication
    - Surveillance
    - Source Reduction
    - Larviciding & Adulticiding

Education/Communications

- Organized mosquito control should include a clear and continuous public education and public relations program.
- Control effectiveness will depend in a large part on public support
- Part of the education aspect is to communicate to the public the importance of sanitation

Sanitation

- The need to prevent mosquito breeding in water-holding containers around homes
- and businesses is well known and has received much emphasis in recent years.
- Each mosquito control director should use the media available to educate the general public about the need to ensure that buckets, cans, old tires, boats, tarps and other debris and possessions do not breed mosquitoes.
- Containers of all types and man-made structures such as cisterns, roof gutters and discarded tires are capable of producing large numbers of mosquitoes, including species that can transmit disease.
- Removal of debris and regular inspection, when conducted on a continuous basis, permanently reduces breeding in such sites.
- Typically, mosquito control related sanitation efforts are best accomplished by homeowners and residents who through their own actions have created mosquito breeding around their homes.
- Mosquito control agencies often support educational programs that call attention to the hazards of mosquito populations and recommend individual efforts on residential-area cleanup.
- Amnesty programs for used tires, while expensive, are excellent programs that can permanently reduce the number of larval habitats in any community.

Education.

- A relatively new aspect of education and outreach involves targeting our youth through the public education system.
- There is a belief among public health specialists that sometimes the education of a child about mosquito biology and control is more effective than targeting their parents.
- Children are more impressionable and are more likely to act after seeing a presentation about mosquito abatement concepts. By teaching children early about the importance of eliminating standing water and mosquito biology in general, they are more likely to carry these concepts through to their parents and to their adult life.
- Other educational techniques involve showing educational previews at movie theaters prior to the main event and using mascots at community events to emphasize the importance of mosquito prevention and maintain community awareness.

Personal Protection.

- Preventing mosquito bites is the most important and effective way to negate the negative effects of mosquitoes and in particular, prevent disease transmission.
- The public must consciously adopt personal behavior practices that reduce the probability of receiving infective mosquito bites.
    - For example, most, but not all, vectors are quite active during the crepuscular periods at sunset and dawn. This period is a time of day when attractiveness to mosquitoes should be minimized.
- Staying indoors as much as possible, especially if there is an alert situation in connection with mosquito-borne disease, is one way to avoid contact.

- If it is necessary to go outside, wear loose fitting, light-colored clothing (which is less attractive to mosquitoes and most biting flies), pants and long sleeves, and apply a repellent to the exposed skin - carefully following the manufacturer's directions on the label.
- While there are a variety of products labeled as repellents, products containing DEET (N,NDiethyl-meta-toluamide)
    - continue to be the most common and are safe, effective and long lasting.
    - There are a great number of products available that contain this material in varying concentrations.
    - The most important aspect to remember about DEET is that it is very effective and a small amount of product goes a long way.
    - Products are typically available with concentrations of active ingredient ranging from 5% -100%.
    - DEET is not typically recommended for children less than 2 months of age and products containing less than 30% DEET are recommended for older children.
    - When applying any repellent to children, adults should put a small amount on their hands and then rub it onto the child while avoiding their hands, eyes and mouth.
    - When people are removed from mosquito populations they should wash the skin that repellent has been applied to with soap and water, regardless of the product.
    - Most people do not need the higher concentrations of DEET unless they are going to be exposed to extreme mosquito populations for an extended period with limited opportunities for reapplication.
    - Under normal circumstances when people are only outside for short periods of time, the lower concentrations are just as effective as the higher concentrations.
    - Complete coverage of all exposed skin is critical as mosquitoes are amazingly effective at locating untreated areas.
- In 2005, the CDC revised their recommendations for mosquito repellents and added two
- materials:
    - Picaridin (IR-3535)
    - Oil of Lemon Eucalyptus [p-methane 3,8-diol (PMD)].
        - The label for oil of lemon eucalyptus specifies that it should not be used on children under 3 years of age.
- When using any of these products, it is essential to follow the label instructions.

Surveillance

- Surveillance is the act of searching for mosquito habitats and populations.
- Mapping
    - Maps provide information for field survey and control activities, program evaluation, and reporting
- Record Keeping
    - In order to avoid comparing dissimilar parameters, inspections should be consistent both in method and location.
    - Keeping clear, accurate records is as important as the data gathering itself.

- Surveillance records are managed in a manner that ensures subsequent inspections can be conducted in a similar manner by others less familiar with the area. They usually include the
  - inspector's name,
  - date of inspection,
  - sampling method
  - exact location in addition to the data collected.
- Data recording forms and devices promote uniformity, which makes records easier to read, interpret and summarize, and serve as a reminder to the inspector to record all pertinent information.
- In the absence of data recorders, standardized formats lead to more consistently accurate transcription of the data into the permanent records.

Surveillance Options and Techniques

- Mosquito larvae of some species are usually found near surface vegetation or
- debris.
- In larger ponds or bodies of water, these larvae are ordinarily confined to the shoreline areas
- where it is necessary to proceed slowly and carefully in searching for mosquito larvae as disturbance of the water or shadows may cause the larvae to dive to the bottom.
- *Anopheline* larvae are collected by a skimming movement of the dipper with one side pressed just below the surface
- *Culicine* larvae such *as Ae. vexans* or *Oc. sollicitans* or species of *Psorophora* require a quicker chopping motion of the dipper, as they are more likely to dive below the surface when disturbed.

Adult Surveillance

- It is customary to make landing collections near sundown as this crepuscular period is the most active time for most mosquitoes.
- Insect Sweep Net Collection
  - Use insect nets to collect mosquitoes from grass and other vegetation.
  - This type of collection is valuable in assessing species that rest in these habitats during the daytime, such as *Ae. vexans* and *Oc. sollicitans*.
  - Power vacuum collectors or aspirators perform the same function
- Bait Trap Collection
  - When other collection methods are inadequate, animal-baited traps, alone or with dry ice, can be used to trap mosquitoes.
- Light Trap Collection
  - With light as an attractant these traps have proven very useful in measuring densities of some of the *Culicine* mosquitoes, such *as Oc. sollicitans, Ae. vexans* and *Coquillettidia perturbans.*
- Gravid Trap Collection
  - This trap has proven to be very effective in capturing large numbers of gravid *Culex* mosquitoes.
  - Gravid traps have proven highly effective in catching large numbers *of Cx. quinquefasciatus* for WNV surveillance studies in Georgia

Source Reduction

- Source reduction ranges from the simple overturning of a discarded bucket or disposing of waste tires to complex water-level manipulations in marshes.
- The removal or reduction of mosquito breeding habitat is the most effective and economical long-term method of mosquito control.
- These efforts often minimize or even eliminate the need for mosquito larviciding in the affected habitat and greatly reduce adulticiding in nearby areas.
- The topic of sanitation is covered under education/communication and should be covered as part of source reduction as well.
- Often times the primary mosquito pests encountered in communities are container-breeding species, particularly *Ae. albopictus*.
- The most effective technique to reduce their populations is through education and the elimination of breeding sites in communities and neighborhoods.
- Educational mailings and news clips should target individual home owners to inform them of the importance of eliminating breeding sites around a home or neighborhood.
    - In particular, these materials would include information about the removal of used tires, maintenance of raingutters, emptying of buckets and other debris,
    - checking tarps and plastics of all types for water holding depressions and in general a constant vigilance toward the removal of standing water.
- Water Management
    - Prevention of mosquito development can be accomplished by removing surface waters from productive sites to reduce oviposition, manipulating shoreline water levels or flooding areas in which mosquitoes oviposit on the soil.
    - These approaches have been used for decadesand involve ditching, diking, daily water management manipulation and retrofitting of catch basins and storm drains to manage the aquatic habitat.
    - However, experience has demonstrated these techniques can be harmful to the ecology of the affected habitats if practiced without due concern for the entire ecosystem.
    - Consequently, permits are required to initiate new projects of this nature. Maintenance of existing schemes is often allowed without additional permits. Maintaining an open line of communication with local governmental regulatory agencies is critical.
    - An excellent example of the water management approach is impoundment management as practiced in coastal areas impacted by intermittent tidal activity.
        - Salt marshes producing salt-marsh mosquitoes are impounded by construction of dikes to contain water pumped onto the marsh surface from the adjacent estuary.
        - This eliminates oviposition opportunities for the salt-marsh mosquitoes on the impounded marsh and effectively reduces mosquito populations.
            - For example, in Florida, 40,000 acres of impoundments have been constructed on the east coast, and a concerted effort has been made to manage these controlled marshes as natural resource sites.
        - Rotational impoundment management (RIM) is a technique developed to minimally flood the marsh during the summer months and to use flap-gated culverts to reconnect impoundments to the estuary for the remainder of the year, thus allowing the marsh to support its many natural functions.

        - While such impoundments usually control salt-marsh mosquitoes adequately, occasional influx of storm water runoff or rainfall can create freshwater-mosquito breeding problems in these impoundments.
    - The salt marshes are also good examples of a variety of ditching approaches for mosquito control. An acceptable form of salt-marsh source reduction is open marsh water management (OMWM).
        - This is a technique wherein mosquito producing locations on the marsh surface are connected to deep water habitat (e.g., tidal creeks, ponding areas, deep ditches, etc.) with shallow ditches.
        - Mosquito broods are thus controlled without pesticide use by providing access for naturally occurring larvivorous fish to the mosquito producing depressions or, conversely, by draining these locations before adult mosquitoes can emerge.
    - Alternatively, OMWM can also provide hydrological connections between marsh and estuary that enhance natural resources, such as waterfowl and fisheries, and benefit mosquito control.
    - The use of shallow ditching (approximately 3 feet or less in depth) rather than the deep ditching used in years past is considered more environmentally acceptable because with shallow ditches, fewer unnatural hydrological.

Larviciding

- Elimination of sites where larvae are developing is the most effective intervention for controlling mosquito populations

Biological Control

- use of biological organisms or products to control pests, in this case insect pests.
- Biocontrol, as it is commonly called, is popular in theory because of its potential to be host-specific with few nontarget effects while being safe to the environment.
- The most widely used biological control agents are the various biological larvicides produced from the bacteria *Bacillus thuringiensis* subsp. *israelensis* (Bti).
- Larvivorous fish have been a longtime standard as biological control agents against mosquito
- larvae.
    - Predaceous fish, such as *Gambusia affinis* and other top minnows (*Poeciliidae*) and killifish (*Cyprinodontidae*) that occur naturally in many aquatic habitats, can be collected (or in some cases propagated) and placed in permanent or semi-permanent water bodies for larval control.

Adulticiding

- Adulticides are often applied as ultra-low-volume (ULV) sprays in which small amounts (3 fluid ounces or less per acre) of insecticide are dispersed either by truck-mounted equipment or from fixed-wing or rotary aircraft.
- The fine ULV droplets (high concentration of active ingredient but very low dosage/acre) must drift through the habitat and contact flying mosquitoes in order to provide optimal control benefits.
- These applications are typically programmed to occur between dusk and shortly after dawn, when most beneficial insects are resting.
- The typically targeted size droplet range for ground ULV applications is 10-25 microns with aerial applications targeting the 15-30 micron range.

- However, a variety of conditions and factors are involved in these ranges, including product, nozzle type and weather conditions to name a few.
- The most important consideration is to follow the product label recommendations.

Adulticiding Equipment

- Control of adult mosquitoes is usually accomplished today through the use of ultra-low volume (ULV) fogging
- The calibration of ULV equipment is relatively simple
- 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.
- 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. Industry representatives are valuable resources when working with the proper calibration of equipment

Insecticide Resistance

- It is extremely important when lower than expected mortality is observed that application rates, techniques and conditions are evaluated to assure that all aspects of an application are being conducted properly and are conducive to an efficacious application.
- It is recommended that mosquito control programs that suspect insecticide resistance in a mosquito population contact the Centers for Disease Control or the Cooperative Extension Public Health specialist.
- In addition, it is prudent to rotate the type of insecticide, active ingredient and corresponding mode of action of the insecticides used against an insect population

Pesticide Use

- Pesticides can be either "specific" or "broad spectrum." Specific pesticides are effective against
- certain insects or insects at particular stages. These types of insecticides are usually non-toxic to humans
- and other animals. Broad-spectrum pesticides can have deleterious effects on non-target organisms.
- Whether specific or broad-spectrum pesticides are used, the type pesticide and the timing, rate, and
- location of its application can control the effects on non-target organisms.

Pesticide Risk

- Whether or not a substance poses a risk to humans or other organisms depends on two factors:
    - how toxic the substance is
    - the amount to which an organism is exposed.
- The EPA considers both toxicity and exposure data in determining whether to approve a pesticide for use.

Pesticide Safety: Larvacides

- *Bacillus thuringiensis* subsp*. israelensis* (Bti) is a biological insecticide that is highly effective, yet virtually non-toxic to non-targets.
    - This material is registered under various trade names such as Vectobac ®, Aquabac ® or Teknar®.
- Temephos is an organophosphate insecticide that has been registered under the trade name Abate® for many years.
    - Temephos interrupts the function of the nervous system by interfering with key enzymes controlling the synaptic transmission of nerve impulses.
    - Temephos is slightly toxic to humans and other mammals. It is a broad-spectrum insecticide and as such can be highly toxic to other invertebrates, some birds, and fish if misused.