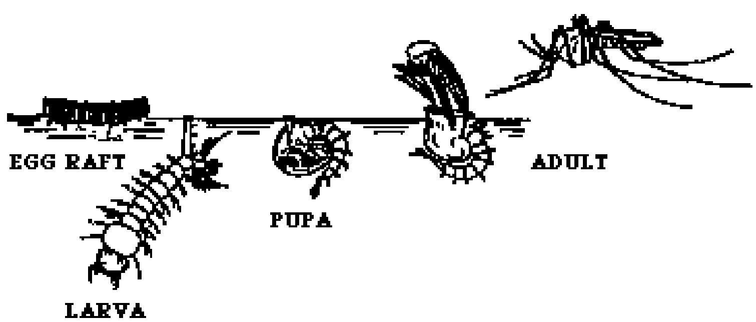
HOW TO START A MOSQUITO CONTROL PROGRAM
IN
YOUR TOWN, ALABAMA

STEP-BY-STEP INSTRUCTIONS AND RESOURCES TO PROTECT THE PUBLIC HEALTH FROM MOSQUITO-BORNE DISEASES



William B. Johnston, DVM, DACVPM
State Public Health Veterinarian
Alabama Department of Public Health
Division of Epidemiology

In cooperation with the
Alabama Cooperative Extension System &
Alabama Vector Management Society

PREFACE

The majority of municipalities and counties in Alabama are, unfortunately, lacking in effective mosquito control programs. When evidence of mosquito-borne diseases and outbreaks of arthropod-transmitted encephalitis (arboviruses) are reported in areas of the state, local officials have historically felt the huge void of not being prepared or knowledgeable in knowing how to combat the public health threat. This booklet is prepared in the hope that small towns and communities in Alabama can learn to establish a local program suited to their individual needs. A review of mosquito biology, life cycles, and habitat of the most common mosquitoes of public health significance is provided, as well as suggested control measures. Mosquito-borne diseases are discussed to highlight the importance of mosquito control. Most importantly, perhaps, is a list of resources, public agencies, and mosquito experts for communities to contact for assistance. This booklet seeks to aid local officials in starting a mosquito control program, but it's a learning process - not simple and cheap. The use of brand names and any mention or listing of commercial products, services, resources, or contacts in this booklet does not imply endorsements by the Alabama Department of Public Health or discrimination against similar products or services not mentioned. William B. Johnston, DVM, DACVPM

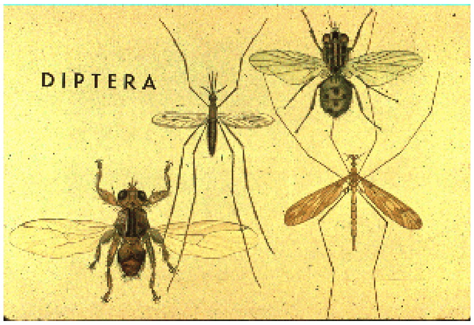
TABLE OF CONTENTS

ACKNOWLEDGMENTS

This booklet is based in large part on a similar manual produced by Dr. Jerome Goddard, Medical Entomologist for the Mississippi Department of Health, and also is a compilation of the following mosquito control resources and the helpful guidance of Gary Mullen, PhD, Ken Tennessen, PhD, and Kelly Micher, M.S., who have consistently and unselfishly responded to requests for assistance. A special thanks to Kelly Micher for editing and technical assistance. Resources: *Guidelines for Arbovirus Surveilance in the United States*, CDC; *Florida Mosquito Control*. Univ. of Florida; *Vector-Borne Disease Control*, CDC; *Surveillance and Response Procedures for Mosquito-Borne Arbovirus Emergencies*, Illinois Dept. Public Health; American Mosquito Control Association,New Brunswick, NJ; *CDC Guidelines for West Nile Virus Surveillance*; State Public Health Vector Control Coordinator Conference; Florida A&M Univ.; *Community Mosquito Control*, Madison County (AL) Health Dept.; *Mosquito Handbook: A Guide to Identification &*

Management, TVA.**;** *Mosquito Control To Fit Your Town*; Wellmark, Inc.(nee Zoecon)

INTRODUCTION



MOSQUITO CONTROL AND PUBLIC HEALTH

Mosquitoes are insects belonging to the order Diptera, the True Flies. Like all True Flies, they have two wings, but unlike other flies, their wings have scales and their mouthparts (in female mosquitoes) form a long piercing-sucking proboscis. Males differ from females by having feathery antennae and mouthparts not suitable for piercing skin. Nectar is their principal food source.

There are over 2500 different species of mosquitoes throughout the world, of which 150 species occur in the United States and 56 species occur in Alabama. Each of the species has a Latin scientific name, such as *Culex tarsalis. Culex* is the "generic" name of a group of closely related mosquitoes and *tarsalis* is the "species" name which represents a group of individuals that are similar in structure and physiology and capable of interbreeding. These names are used in a descriptive manner so that the name tells something about this particular mosquito. Some species have what are called "common names" as well as scientific names, such as *Ochlerotatus sollicitans*, the "Black salt marsh mosquito."

"Mosquito" is a Spanish or Portuguese word meaning "little fly" while "zancudos," a Spanish word, means "long-legged." The use of the word "mosquito" is apparently of North American origin and dates back to about 1583. In Europe, mosquitoes were called "gnats" by the English, "Les moucherons" or "Les cousins" by French writers, and the Germans used the name "Stechmucken" or "Schnacke." In Scandanavian countries mosquitoes were called by a variety of names including "myg" and "myyga" while the Greeks called them "konopus." In 300 B.C., Aristotle referred to mosquitoes as "empis" in his "Historia Animalium" where he documented their life cycle and metamorphic abilities. Modern writers used the name *Culex* and it is retained today as the name of a mosquito genus. What is the correct plural form of the word mosquito? In Spanish it would be "mosquitos", but in English "mosquitoes" (with the "e") is correct.

Mosquito control is undergoing major changes in Alabama. Instead of just routinely spraying malathion out of trucks several nights weekly, mosquito control personnel are now trying to get the most control with the least amount of pesticides. This involves carefully timing and strategically placing insecticides aimed at the adult mosquitoes, as well as larviciding water sources for larval mosquitoes.

Mosquitoes and the diseases they carry have played an important role in our history. Epidemics of mosquito-borne diseases were once common in the United States. Outbreaks of yellow fever occurred as far north as Philadelphia during the Colonial Period, and epidemics took many lives in Mobile until 1905. Dengue fever was prevalent along the Gulf Coast until 1945. Tombstones of Alabamians who died during epidemics can be seen in many old cemeteries in our state. Although these diseases have disappeared from Alabama, their mosquito vectors have not. If these disease agents were reintroduced into Alabama, they could be transmitted by the yellow fever mosquito (*Aedes aegypti*) and the newly-introduced Asian tiger mosquito (*Aedes albopictus*).

At one time, malaria was well established in the continental United States, especially in the southern states. Eradication of malaria from the United States is attributed more to the short transmission season due to our temperate climate and the use of window screens in homes than to government mosquito control efforts. Cases of malaria are still reported annually in Alabama among travelers and military personnel returning from abroad. Alabama has several mosquito species, such as *Anopheles quadrimaculatus*, that can transmit the disease agent to people should malaria ever become re-established in our state. Notable medical scientists William Gorgas and Walter Reed studied yellow fever and malaria in Mobile, and their findings helped eradicate the two diseases from North America.

Eastern equine encephalitis (EEE) occurs almost every year in Alabama, and epidemics in horse and emu populations cycle every 4-5 years with over 95% fatality rates. The last human fatality from EEE in the states was in 1996; Alabama's lone case in 2001 survived after a long recovery period. Around 50% of the people ill from EEE may die, and another one-third will suffer long-term neurological signs like convulsions and seizures. Other mosquito-borne diseases, like LaCrosse and St. Louis Encephalitis (SLE), are still serious threats in Alabama. The detection of West Nile virus in birds, horses, and people in Alabama during 2001 underscores the need for effective mosquito control programs throughout the state. The first two cases of WNV were detected in the state during 2001, with one fatality, and the virus is expected to become endemic in the Southeast. The last major outbreak of SLE in Alabama occurred in 1975, with 78 cases and many fatalities. The southern house mosquito, *Culex quinquefasciatus*, is believed to be the most important vector (carrier) of this disease. This mosquito can be found breeding in drainage ditches and artificial containers around houses all over the state.

With the elimination of many deadly mosquito-borne diseases from the United States, our control efforts are now mainly aimed at pest mosquitoes rather than disease vectors. However, increasing travel by U.S. citizens into countries where dengue fever and malaria are prevalent, and the immigration of people from those countries into the United States, increases the likelihood of these diseases being reintroduced. Mosquito control continues to be an important program in public health because of the presence of EEE, West Nile virus, LaCrosse, SLE, and the potential for the reintroduction of other mosquito-borne diseases into Alabama.

Human activities can greatly affect the ecology of mosquito populations. The movement of large segments of our population into suburban and rural areas increases human and domestic animal exposure to mosquitoes such as *Ochlerotatus triseriatus* and *O. canadensis*. The construction of man-made lakes and the use of irrigation agriculture has increased the numbers of many mosquitoes such as malaria mosquitoes (*Anopheles*) and the dark rice field mosquito (*Psorophora columbiae*). The increased use of non-degradable plastic, glass, and aluminum containers and non-recappable radial tires has increased populations of container breeding mosquitoes such as the yellow fever mosquito (*Aedes aegypti*). Expanding international trade has increased the chance of introducing new mosquito species into our areas, as has recently happened with the Asian tiger mosquito (*Aedes albopictus*).

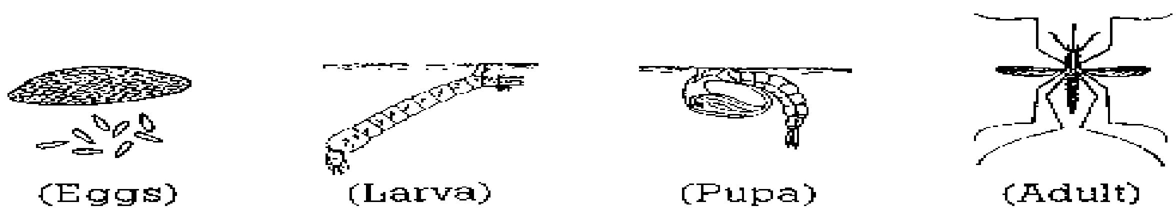
Mosquito control strategies have changed considerably over the past few decades. Diesel oil and inorganic poisons such as Paris green (copper-aceto-arsenite) were the basic tools of early mosquito larva control efforts. Large scale ditching operations were undertaken along many coastal areas in order to eliminate breeding sites. Many of these ditches can still be seen in our marshes, particularly in Baldwin and Mobile counties. Various chlorinated hydrocarbons, organochlorines, organophosphates, pyrethrins and synthetic pyrethrins have been extensively used in the fight against both adult and larval mosquitoes.

However, with the growth of ecological consciousness in the early 1960s, people began to realize the environmental damage that accompanied the use of these broad spectrum chemicals, especially those that did not break down in nature. Many mosquito populations became resistant (immune) to the chemicals commonly used. We also began to realize the impact of indiscriminate ditching upon our marshes, the nursery grounds of commercial fish, shrimp, and oysters.

In the past few years, major advances have been made in the area of biological mosquito control. This strategy involves the use of natural predators, parasites and pathogens to kill mosquito larvae. The World Health Organization, for instance, has used mosquito fish (*Gambusia affinis*) for decades to fight malaria in many parts of the world. These mosquito fish are abundant in Alabama waters and are very effective predators of mosquito larvae. Many other biological control agents have been discovered including fungi, protozoans, bacteria, round worms, and flat worms. Presently, only Bti and Gambusia are commercially available.

LARVICIDING VS. ADULTICIDING

There are an estimated 125 city and county mosquito control programs in operation within Alabama. Twenty years ago, almost all of these programs relied exclusively upon adulticiding for mosquito control - and three-fourths of them used only malathion. Recent evidence from chemical sales indicates less use of malathion, with more and more mosquito control personnel using Permanon[R] (permethrin) or Scourge[R] (resmethrin).
Routine mosquito spraying has been a mainstay of mosquito control in Alabama for a long time. During the mosquito season, fog trucks roll up and down the urban streets one or two times per week. Continuous exposure to pesticides does not kill all mosquitoes; those that can survive the pesticide treatment are resistant



to the chemical. Surviving mosquitoes can reproduce and pass this resistant trait along to the next generation. Eventually, the pesticide is no longer effective.

Adulticiding operations also continuously expose the public to pesticides. The effects of these chemicals may be particularly severe for those people who already suffer from asthma or other respiratory problems. Applicator personnel are in danger of overexposure if proper safety precautions are not carefully practiced. Pesticide labels carry warnings about their toxicity to wildlife. Sometimes it becomes a question of which presents the biggest threat - mosquitoes or the chemicals used to control them.

Larvicide programs are targeted at controlling the mosquito larvae <u>before</u> they leave the water. This strategy can be the most effective, most economical, and safest method to control mosquitoes. Programs that concentrate only on adult mosquitoes are attempting to solve a problem that has gotten out of hand. After all, it is the adult mosquito, not the larva, that passes along diseases such as encephalitis to its human victims .

Any time we can avoid using chemical pesticides to solve our problems, we reduce the chance of damaging our environment and, consequently, ourselves. A larvicide program allows the use of biological methods to control pests without jeopardizing non-pest and beneficial organisms. If fog trucks can remain parked until really needed (relying upon them as a back-up system during severe outbreaks of mosquitoes), then not only do we reduce the chance of pesticide resistance buildup, we also lessen the risk of chemical exposures to the public.

We must also compare larviciding and adulticiding from an economical standpoint. Setting up an adulticiding program can cost as much as $30,000 for the purchase of a fogging machine and truck. Small towns may spend from $4,000 - $6,000 per year for pesticide and formulation oils. Operational and maintenance costs must also be figured into the estimate. Therefore, the expense of an adulticide program is beyond the reach of many small towns and communities. A larvicide program, on the other hand, can be conducted within a town by using one or two backpack sprayers (ranging from about $100 each for a sprayer that only sprays liquid, to $700 each for backpacks that distribute liquid, granules, pellets and dust) and a couple of gallons of Bti, (about $20 -$25 per gallon) depending upon the size of the town and the extent of the breeding areas. Granular Bti is about $2 per pound. Alternatively, the organophosphate Abate[R] may also be used in a larviciding program for about $2 -$3 per pound in areas without fish and other natural predators. Methoprene (Altosid[R]) is another excellent and cost-effective larvicide. Initial material costs are higher than most Bti products or Abate, however, because of an extended residual , the cost per day is comparable to thse other products. Newer labeling states that methoprene is target-specific and does not harm mammals, waterfowl, or beneficial predatory insects. Altosid has even been recommended by the World Health Organization for use in drinking water supplies to control container-breeding mosqsuitoes in developing countries. Non-target studies have reported that methoprene has very little effect, if any, on 35 species of non-target organisms and can be applied to fish habitats. Agnique[R] is a biodegradable oil emulsion sprayed as a larvicide. Its mode of action is to suffocate mosquito larvae as they float at the surface to breath. Agnique is also safe to use in fish habitats and in the presence of biological predators.

INTEGRATED MOSQUITO CONTROL

The best mosquito control program is an integrated program that includes point source reduction of breeding areas, routine larviciding in those breeding areas that cannot be eliminated, and adulticiding only when necessary .In this present day of environmental consciousness, municipal leaders must try to use integrated methods of mosquito control and not just routine spray with a fogging truck.

The first phase in any mosquito control program is to sponsor a spring clean-up campaign. Picking up and hauling away all rubbish piles, broken down washing machines, junk cars, bottles and cans from around houses will eliminate many domestic mosquitoes that breed right in our backyard. Activities such as cleaning out clogged street drains and culverts, cleaning up illegal dump sites, and mowing around sewage treatment lagoons will also eliminate many mosquito breeding sites. These efforts will save time and money that would otherwise have to be spent controlling mosquitoes breeding in these sites. Some communities have successfully recruited retired seniors (e.g., RSVP), scouts, and civic groups to aid in surveying for breeding sites and visiting homeowners.

Wetlands are considered valuable resources and are protected habitats. Therefore, many areas where mosquitoes breed cannot or should not be eliminated or altered. Mosquitoes breeding in permanent water areas or temporary flood water areas can be controlled by using biological larvicides. Larvicides such as Bti, methoprene, and Agnique will effectively control mosquito larvae when applied as needed without killing the natural predators of mosquitoes. Permanent water areas generally harbor many species of fish and insects that feed on mosquito larvae. Altering drainage ditches will often destroy these natural predators, allowing mosquitoes to breed unchecked as soon as water pools up again.

A good adulticiding operation is a backup system, used when mosquito populations have gotten out of hand for some reason. Perhaps local breeding habitats formed after heavy rains had been overlooked by the larviciding technician.; or, an unseasonal emergence of mosquitoes may have occurred during warm weather, or cases of encephalitis may have been detected. These situations may require the use of an adulticide to contain the problem. Mosquitoes do not recognize city, county, or state boundaries, and sometimes large "sensitive" areas cannot be larvicided. Mosquitoes can migrate from these areas and become a problem in your community. On the Gulf Coast, salt marshes are expansive and not easily or economically monitored and larvicided. Salt marsh species will migrate up to 20 miles, and will affect inland communities as well as those on the coast. Adulticiding may suddenly become necessary and the best method of control available to reduce the influx of huge numbers of mosquitoes from other areas. If the fog truck has been parked, being used only when necessary, then the program manager can feel confident that the chemical will be fast and effective, encountering no problems with resistance among mosquito populations .

MOSQUITO BIOLOGY AND ECOLOGY

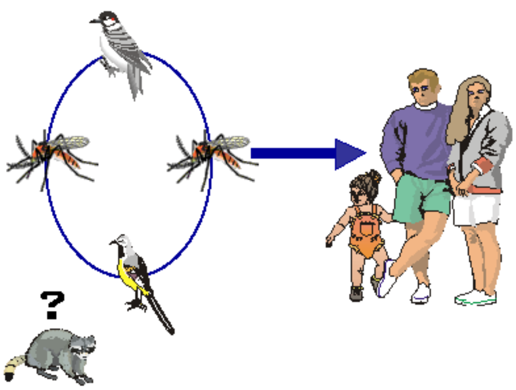
At least fifty-six species of mosquitoes are found in Alabama. The majority of these species have little impact upon our daily lives because they are rarely encountered by most people. They prefer to take blood from sources other than humans, or they are not important vectors of diseases that affect us or our domestic animals and only a nuisance.

Most mosquito programs are primarily concerned with controlling only three or four mosquito species. Every mosquito program in Alabama is concerned with urban mosquitoes such as the southern house mosquito (*Culex quinquefasciatus*) and the Asian tiger mosquito (*Aedes albopictus*). The total list of problem species differs, however, from one section of the state to the other. For example, salt marsh mosquitoes (*Ochlerotatus sollicitans*) are of major importance along the Gulf Coast, while malaria mosquitoes (*Anopheles quadrimaculatus*) are prime concerns along the Tennessee Valley area.

Mosquito species differ in their breeding habitats, biting behavior, flight range and in many other ways. Therefore, different strategies are needed to control different species of mosquitoes. Yearly town clean-up campaigns, for example, are very effective in reducing populations of Asian tiger mosquitoes that breed predominately in artificial containers. Malaria mosquitoes (*Anopheles*) and Eastern Equine Encephalitis mosquitoes (*Culiseta melanura*) usually prefer permanent bodies of water, such as marsh or swamp areas, requiring different control tactics. Therefore, it is very important for mosquito control personnel to know exactly what species of mosquito is found within their area in order to develop an effective control strategy.

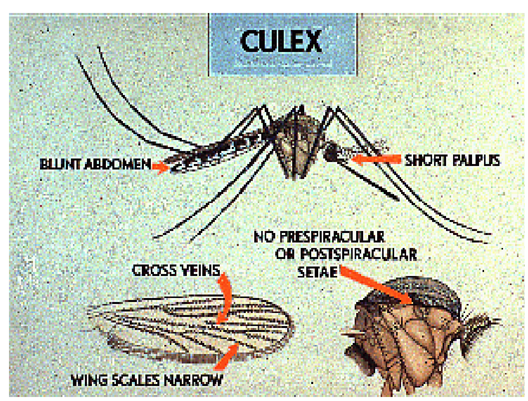
DISEASE CYCLES

Eastern Equine Encephalitis



Eastern Equine Encephalitis (EEE) virus is maintained in nature by circulating between birds and mosquitoes. Birds are the primary hosts and mosquitoes, particularly *Culiseta melanura*, are the vectors from bird to bird. *Culiseta melanura* rarely feed on humans though. People usually become involved as dead end hosts when fed upon by infected salt marsh mosquitoes (*O. sollicitans*), inland flood water mosquitoes (*Aedes vexans*), *Coquillettidia perturbans*, and a few other species. The disease will affect persons of any age, with young children and infants being the most susceptible. Mortality rate may be over 50% , and children surviving the disease often suffer from some degree of mental retardation, paralysis, or seizure disorders. Horses are often severely affected by the disease during outbreaks - often close to a 100% fatality rate. However, a horse vaccine is available, and newer recommendations from the Alabama Department of Agriculture and Industries are to vaccinate horses every 6 months.

West Nile Virus



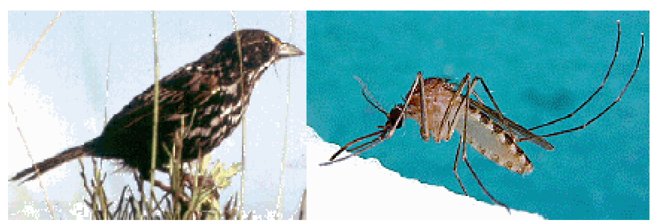
West Nile Virus (WNV) was first detected in the United States in 1999 in New York City, when 68 people became ill and 8 died. Movement of the virus southward was by migrating birds and by 2001, WNV was identified in 60 dead birds, 4 horses, and 2 people in Alabama. WNV is maintained in nature much like EEE with a bird-mosquito cycle. Several *Culex spp.*, including the common house mosquitoes *Culex pipiens* and *Culex resturans,* and also *Culex salanarius,* are the principle vectors to people. WNV appears to be most dangerous to the elderly or immune-compromised patient. Since WNV has been demonstrated to amplify in the Asian tiger mosquito in the lab (the fastest-increasing species of mosquito in the Southeast), it is assumed that WNV will be permanently established in Alabama. In contrast to other mosquito-borne viruses, WNV also kills many birds in the U.S., especially crows, blue jays, and raptors. Surveillance efforts to detect the presence of WNV, therefore, can target the reporting and testing of those 3 types of dead birds. WNV does not cause as serious illness as some other arboviral diseases (e.g., EEE, SLE). In fact, only one out of every 150-200 people exposed to the virus will become ill, and less than 10% of clinically ill patients will die. Still, the public's perception and reaction to local reports of WNV cases cause much anxiety and fear in communities. Local officials are, then, often barraged by the public to provide mosquito control to "protect" them.

LaCrosse Encephalitis

In contrast to most other mosquito-borne viruses that are a risk in Alabama, LaCrosse maintains its cycle in nature via a rodent-mosquito cycle. Usually, the mosquito vector is the tree-hole mosquito (*Ochlerotatus triseriatus*) and the reservoir is the gray squirrel. Control efforts are obviously different for this disease, because it will focus on plugging tree holes where mosquitoes breed in small amounts of acidic rainwater. Alabama recorded its first confirmed cases of LaCrosse in 1995 and it has surfaced almost every year since. LaCrosse may also result in permanent convulsive disorders in affected children. The fact that LaCrosse generally attacks children under 12 years old brings extra demands on local officials by parents that control measures be implemented.

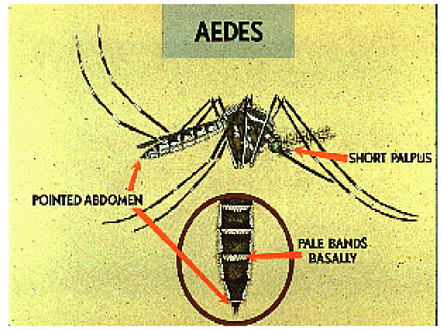
St. Louis Encephalitis

The St. Louis Encephalitis (SLE) virus circulates naturally among birds and is transmitted by *Culex spp.* mosquitoes. Humans can become infected only if bitten by an infected mosquito. As in most other mosquito-borne viruses, humans are actually "dead end" hosts, meaning that the virus in human blood never reaches a level high enough to infect a biting female mosquito to continue the cycle. Not all people infected with the virus develop clinical disease. However, the virus may produce abrupt fever, nausea, vomiting, and severe headache in humans within 5-7 days after being bitten. Fatality rates range from 2- 20% with most deaths occurring in people 60 years of age or older. Outbreaks of SLE usually occur in mid summer to early fall. Since wild birds and back-yard domestic fowl are the reservoirs of this virus, urban areas where large bird populations and abundant *Culex spp*. mosquitoes are found together are prime sites for a disease outbreak.



A major SLE outbreak occurred in Birmingham, Alabama, in 1975. Numerous people were affected and many cases resulted in death. The threat of another outbreak occurring is a real one. Good mosquito control practices must be developed in our state to be prepared for prompt local response to the next outbreak.

Dengue



The Dengue virus can be transmitted from person to person by the Yellow Fever mosquito (*Aedes aegypti*) and the Asian tiger mosquito (*Aedes albopictus*). Other than humans, no known bird or mammal reservoir exists for Dengue. Contrary to most other mosquito-borne viruses, a mosquito can become infected with the virus by feeding on a person with the disease, then the virus must go through an eight to ten day incubation period in the mosquito before it becomes infective. The mosquito will then remain infective for the rest of its life.

Symptoms include sudden onset of high fever, severe headache, backache, and joint pains. The disease is so painful that it is sometimes referred to as "breakbone fever". A skin rash may also appear Infection may be very mild or completely without symptoms. In some areas, however, a complication called "dengue hemorrhagic fever" and "dengue shock syndrome" cause a high fatality rate, especially among children. The disease has been raging in Mexico and Central and South America for the last 10 years. It is literally "knocking at the door" in the Southeast U.S., with cases frequently occurring along the U .S. - Mexican border .

Canine Heartworm Disease

Canine heartworm disease is a serious canine disease in the South. Almost 100% of unprotected dogs over five years old are infected. Mosquito vectors that feed on an infected dog take in immature worms (first stage larva) with the dog's blood. The immature worms undergo development within the mosquito, reaching an infective state (third state larva) in 9 to 14 days after entering the mosquito. These infective larvae can be transmitted to an uninfected dog when the mosquito feeds. The worms migrate to the dog's heart and grow into adults .These adult worms produce first stage larvae that circulate within the dog's blood and are taken up by feeding mosquitoes to continue the cycle. The southern house mosquito (*Culex quinquefasciatus*) is the primary vector of dog heartworm in Alabama, although several other mosquitoes are involved. Over 100 people have been documented to have developed a disseminated pneumonitis of the lungs by infection with the immature heartworm (microfiliariae).

MOSQUITO LIFE CYCLES

Understanding life cycles of target mosquito species is a key step in developing an effective control program. Information on flight patterns and periods of peak mosquito activity helps the adulticide technician decide when and where to spray in order to kill the most mosquitoes for the money. The larvicide technician will become even more aware of the behavior and biology of the local mosquitoes. He or she will be encountering the mosquitoes first hand, visiting their breeding sites, observing their numbers and developmental stages, and gauging the response of the larvae to the larvicide used.

Mosquitoes can be divided into three major breeding groups -permanent water breeders, flood water breeders, and artificial container/tree hole breeders. *Anopheles*, *Culiseta melanura*, and many *Culex* mosquitoes select permanent water bodies, such as swamps, ponds, lakes and ditches that do not usually dry up. Flood water

mosquitoes lay eggs on the ground in low areas subject to flooding. During heavy rains, water collecting in these low areas covers the eggs which may hatch from within minutes up to a few hours. Salt marsh mosquitoes (*Ochlerotatus sollicitans*), inland flood water mosquitoes (*Aedes vexans*), and dark rice field mosquitoes (*Psorophora columbiae*) are included in this group. Artificial container/tree hole breeders are represented by yellow fever mosquitoes (*Aedes aegypti*), Asian tiger mosquitoes (*Aedes albopictus*), the tree hole mosquito (*Ochlerotatus triseratus*) and the cannibalistic mosquito (*Toxorhynchites rutilus*). Several species of *Anopheles*, and *Culex* may also occasionally oviposit in these areas. Some of these species lay eggs on the walls of a container above the water line. They are flooded when rains raise water levels of a container. Other species oviposit directly on the water surface.

Female *Anopheles* mosquitoes generally lay eggs on the surface of the water at night. Each batch usually contains 100-150 eggs. The *Anopheles* egg raft is cigar-shaped, about 1 mm long, and bears a pair of air-filled floats on the sides. Under favorable conditions, hatching occurs within one or two days.

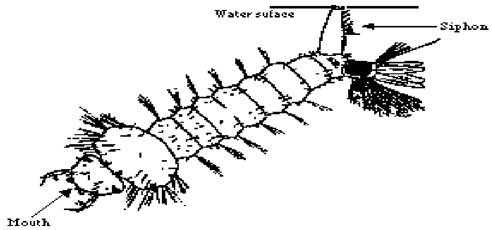
Aedes mosquitoes lay their eggs on the moist ground around the edge of the water or on the inside walls of artificial containers just above the water line. When *Aedes* eggs are first laid, they will die if they become too dry .However, after the embryo in the egg develops, the eggs can withstand dry conditions for long periods of time. This trait has allowed *Aedes* mosquitoes to use temporary water bodies for breeding such as artificial containers, periodically flooded salt marshes or fields, tree holes, and storm water pools. *Aedes* mosquitoes have been carried to many parts of the world as dry eggs in tires, water cans or other suitable containers. The Asian tiger mosquito (*Aedes albopictus*) was introduced into the United States in shipments of used truck tire casings imported from Taiwan and Japan in 1985. This mosquito was probably brought into Mobile, Alabama, in truck tire casings bought from a Texas used tire dealer. Once these tires were stacked outside and began to collect rainwater, the eggs hatched. Now the Asian tiger mosquito is throughout the eastern states.

Culex mosquitoes lay batches of eggs that are attached together to form little floating rafts. On close inspection of a suitable breeding site, these egg rafts can often be seen floating on the surface of the water. Large numbers of egg rafts will tell the technician that a large population of larvae will be hatching out within one or two days. This information will help the larvicide technician decide what action to take to control the potential mosquito problem.

Egg Raft
Typical of all *Culex* and *Culiseta* species

Some larvicide agents are more effective on very young mosquito larvae, while other agents offer better control of older mosquito larvae. Bti spores must be eaten by larvae in order to work and must be used during periods of mosquito development when larvae are actively feeding. It is important to understand a little about the basic biology of larvae and pupae in order to prescribe the best control approach.

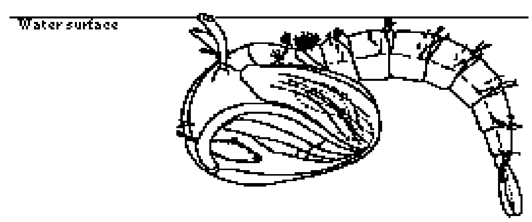
Anopheles larvae lie parallel to the water surface, supported by small notched organs on the thorax and



clusters of float hairs along the abdomen. *Culex* and *Aedes* larvae hang from the surface film with the heads pointed downward. Larvae feed either by slowly sweeping surface bacterial film toward the mouth, using a pair of mouth brushes, or by moving backwards and forwards through the water to produce a current just below the surface that flows toward the mouth. They generally feed upon smaller particles, rejecting the larger ones. To be effective against *Anopheles* larvae, a larvicide must remain on the surface of the water for a long period of time. The particles of the larvicide must be small enough to be accepted by mosquito larvae.

Mosquito larvae are air breathers and therefore must come up to the surface periodically for oxygen. *Anopheles* larvae breath through a pair of openings called spiracles on the end of the abdomen. *Culex* and *Aedes* larvae have air tubes on the end of the abdomen.

Mosquito larvae undergo molts (shedding the outer skin). These skins can often be seen floating on the surface of the water. The thick head capsule "hardens " shortly after the molt, becoming non-elastic. Therefore, larvae must shed the old skin so that they can grow. During each molt, the head of a larva will swell, increasing in width by about 50%. The period between molts is called an instar. The final or fourth instar, when larvae have reached their largest size, is the stage used for species identification. A larvicide technician should be careful to include these fourth instar larvae in collections that are to be immediately identified. Otherwise, larvae must be allowed to molt into 4th instars, which are almost ½ inch long. Mosquito larvae are commonly called "wigglers." The larval stage will last from 7 -10 days under optimum conditions for many mosquito species.



Fourth instars will then molt into pupae. While resting, the pupae will float at the surface of the water. Pupae do not feed, and therefore are not affected by larvicides that must be eaten. However, pupae must come to the water's surface to breathe through their two respiratory trumpets. Generally, pupae will lie still, floating at the surface. If disturbed, they will swim forward or dive to the bottom by rapidly flexing their abdomen equipped with two paddles. Mosquito pupae are commonly called "tumblers."

The pupal skin splits along the back and an adult mosquito emerges. This is a critical stage in mosquito survival. Should the emerging adult fall over while leaving its skin, it will become trapped on the water surface and die. The newly emerged adult mosquito must dry its wings and separate and groom its head appendages before it can flyaway.

MOSQUITO BREEDING SITES

Artificial Containers

Just about anything that holds water will breed mosquitoes. Old washing machines, boats, horse troughs, steel drums, cisterns, plastic containers, glass bottles, and aluminum cans are just a few examples of artificial containers where mosquitoes are found.

Used tires make excellent mosquito breeding sites, and tire piles are a tremendous problem for towns and cities. They usually hold water and the dark, rough inner wall is an ideal egg laying surface for species such as the yellow fever mosquito (*Aedes aegypti*) and the Asian tiger mosquito (*Aedes albopictus*). Finding ways to properly dispose of used tires is one of the most difficult problems facing mosquito control agencies today. Buried tires hold air .Unless whole tires are buried very deeply in landfills, they will work their way back to the surface. Whole tires also take up valuable landfill space. Therefore, many landfills will not accept used tires or will charge several dollars per tire to take them. As a result, many tires are being illegally dumped in wooded areas, vacant lots, gullies, and other secluded sites. Often local mosquito problems can be traced to one of those hidden tire piles. Shredding tires into small pieces before disposing of them in landfills seems to be one of the best answers to the problem. However, tire shredding equipment is expensive. Very few cities or counties can afford to purchase and operate shredders or lease the services of shredder companies. There is now a new Alabama law governing the storage, transport, and disposal of old automobile tires. Mayors and city council members can direct any questions they have about cleaning up tire piles to the County Enforcement Officer appointed by the county commission as authorized by the Scrap Tire Act. Those officers are authorized to write citations for violations of the Act. If offers require further assistance, they can contact the ADPH, Bureau of Environmental Services or ADEM, depending on the nature of the problem. The Solid Waste Rules can be found at: www.alabamaadministrative code/. Once there, click on Browse the Code, click on “420," then look for 420-3-5 Solid Waste Collection and Transportation Rules.

Ideally, used tires should be stored under a rain shelter. A mobile tire shredder can then be brought in to grind up stockpiles of tires on site and then the shredded tires can be properly land-filled. Newer approvals have been granted for using tire chips on-site for sewage field lines.
Alternately, tires may be cut in half and stacked outside with the curve facing upward to prevent the collection of water. Measured success in controlling tire breeding mosquitoes has been shown using granular Bti. The granules can be broadcast over tire piles with seed or fertilizer spreaders. Many granules will fall down into the tires where mosquitoes breed. Penetration in piles up to six tires deep has been obtained.

Some types of artificial containers cannot be disposed of or removed because they serve some useful purpose. In these situations, mosquito breeding must be controlled by applying Bti, methoprene, or other suitable larvicides or by preventing adult mosquitoes from entering these containers and laying their eggs. For example, cisterns used to collect rainwater should have well screened tops. Small animal watering pans should be emptied and cleaned at least weekly. Livestock watering troughs should also be drained weekly if mosquito breeding is found. Bti can be applied to many types of artificial containers that are not used as sources of drinking water, such as bird baths, water gardens, and urns in cemeteries. *Gambusia affinis* (mosquito fish) can also be placed in water gardens, using 25-50 minnows for every 8 ft. diameter of surface area.

Tree Holes

Tree holes provide breeding sites for a variety of mosquitoes. The major species is the tree hole mosquito (*Ochlerotatus triseriatus*) vector of LaCrosse encephalitis. Parks and hardwood stands in towns can be surveyed for tree holes and marked on habitat maps. These holes can be treated with Bti, methoprene, bonide, golden bear, or other suitable larvicide, and sealed with a tree patch material, or filled with sand, mud, and mortar.

Water Drainage Systems

Water drainage systems that carry rainwater out of towns and cities are both man-made and natural. Culverts, storm drains and roadside ditches that become clogged, allowing water to pool, will become mosquito breeding areas. Keeping these areas cleaned out, removing weeds and silt, will help prevent mosquito problems. This is particularly true for those areas that hold water for a week or two after a rain but are dry during other times. Such areas will breed flood water mosquitoes but will not hold water long enough for large populations of natural mosquito predators to become established.

Ditches that always hold water may have populations of fish, beetle larvae, dragonfly naiads, and other organisms that feed on mosquitoes. These predators help keep mosquito populations under control. If these ditches were cleared out, eliminating natural communities of predators, a mosquito problem may develop in an otherwise non-problem site. Mosquitoes will be among the first organisms to return to the pools that from in a cleaned out ditch following a rain. In the absence of predators, the mosquitoes will develop undisturbed unless closely watched by the larviciding technician.

Permanent ditches should be sampled with a dipper to determine the number of mosquito larvae and pupae living there. Collections should be made along the edges of pooled areas, especially around clumps of weeds and in shaded areas. The larvicide technician should also look for predaceous fish and insects living in the ditch. One or two mosquito larvae per dipper may not be a problem, especially if large numbers of predators are found. If large numbers of mosquito larvae are present, the site will need to be treated with Bti, methoprene, or Agnique to help the natural predators maintain control of the mosquito population. Bti, methoprene, and Agnique will prevent adults from developing from larvae without affecting the other organisms. Promising new technology on the horizon include using acoustic larvicide instruments that rupture the air pockets in larvae with ultrasonic frequencies. The phenomenon was observed by a 16-year-old boy working on a high school science project in 2001. Prototypes are already developed for use in draining ditches, underground sewers, and smaller areas.

Natural permanent water drainage areas should be inspected and treated as described for permanent water ditches. Disturbing these natural areas may result in more problems than will be solved. Major mosquito problems will often be found in ditches that are polluted with discharge from malfunctioning septic tanks. The southern house mosquito (*Culex quinquefasciatus*) prefers a breeding site polluted with sewage. These mosquitoes are very important vectors of St. Louis Encephalitis. The common house mosquitoes (*Culex pipiens/resturans*), primary vectors of West Nile virus, also prefer these filthy, organic sites for breeding. Bti should be applied to these sites more frequently (weekly) than for non-polluted sites and at recommended higher dosages (but still within label rates).

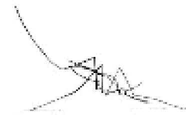
Ponds, Lakes and Lagoons

Generally, well-maintained ponds and lakes produce very few mosquito problems. Large numbers of fish and other mosquito predators are usually found in these sites. Keeping weeds mowed around banks of catfish ponds, sewage waste lagoons, and lakes will help prevent mosquito breeding. If mosquito breeding is found at these sites, it will probably be along the marshier side of the water body. The area around the dam end is usually too steep to provide suitable mosquito breeding habitats. Marshy areas can be treated with Bti or Agnique as needed. *Gambusia* mosquito fish can also be placed in larger bodies of problem water at the rate of 5,000 per surface acre. Even though the minnows cost around 10 cents each, placing them in a pond at the city park at the beginning of mosquito season may be more economical in the long run than larviciding and adulticing all summer.

Marshes and Swamps

Swamps are permanent water habitats that produce *Anopheles spp.*, *Culiseta melanura,* and other permanent water breeding mosquitoes. Freshwater marshes, especially those subject to temporary flooding, will often yield species such as the inland flood water mosquito (*Aedes vexans*). Salt marshes are breeding sites of the salt marsh mosquito (*O. sollicitans*). Marshes and swamps are large areas to treat and may require larvicide application by plane or boat. Smaller sites can be covered by ground. Formulations of Bti and methoprene have proven to be very successful in these areas. Agnique, which forms a film over the water and prevents larvae from breathing (without hurting other predators) is another larvicide option if vegetation is not too dense. The area that must be treated varies depending upon the flight range of the problem mosquito species. Generally, mosquitoes breeding in swamp areas do not range far. Salt marsh mosquitoes, on the other hand, have a flight range of up to twenty miles.

Flood water Sites



A town should be surveyed following a heavy rain in order to locate sites where flood water collects. Locations of these sites should be recorded on habitat maps. Flood water areas are temporary water sites, and therefore usually do not contain large numbers of natural predators. Accordingly, these sites will breed several species of floodwater mosquitoes if water remains for a week or longer. Such areas should be treated a few days after a rain and closely watched for mosquito breeding.

HABITAT MAPPING AND RECORD KEEPING

Habitat maps and records of mosquito populations and application methods used are valuable sources of information to the larvicide technician. The following describes one method of mapping and keeping records of mosquito breeding activities. However, improvements and variations of this method can be made or unique methods devised by each mosquito control person.

A habitat map should show all known water areas within a town, including artificial containers and flood water areas. In the beginning of the larvicide program, all known water areas can be recorded upon photocopied quarter mile quadrants of a town street map or aerial photograph.

The best way to conduct a habitat survey is by foot, inspecting each site for evidence of mosquito breeding. This insures a thorough inspection and allows the inspector to become familiar with the area. Both mosquito positive and mosquito negative sites should be recorded. Positive sites should be distinguished from negative sites by placing a small star (★) next to those sites where mosquitoes were found. Water sites can be recorded by type, using a numerical code. Later, when making routine larviciding rounds, the technician can then quickly determine locations and types of water habitats in an area at a glance. He or she will know which of these sites were positive during the initial survey.

Habitat maps can be verified during the first couple of larvicide applications. Newly discovered sites should be added. Locations of ditches and storm drains, and tree lines can be checked. When the technician feels comfortable with the accuracy of the maps, photocopies can be made and the master copy kept on file. During each larviciding trip, a set of these copies can be used as field maps. Notations concerning the day's activities can be recorded on each quadrant as the larvicide technician visits each site. Maps showing each week's activities can be kept on file for future reference on mosquito breeding trends. Plotting complaint calls on the habitat map also offers helpful information as to where spray efforts may need to be targeted.

Some people choose to laminate each quadrant map. During routine visits to breeding sites, the technician can make notations on these maps in grease pencil. These maps should be kept in a metal clipboard with a cover in order to prevent smudging the grease pencil. Information should be transferred from the laminated maps to regular copies and filed for future reference.

Keeping records on each site can be useful. Knowing information such as previous larvicide treatments, past estimates of mosquito numbers, life stages found, and when a site was wet or dry will allow the technician to predict when a particular site will become a problem. This information can be useful in other ways. Many vector-bome diseases occur in cycles. Knowing something about breeding trends of local mosquito species over the past few years may indicate the likelihood of a disease outbreak. Any advance warning of a potential epidemic would allow mosquito control technicians to take precautions such as larviciding an area more frequently or , if necessary , fogging adult populations.

MOSQUITO CONTROL

COMPLAINT CALLS

The public can provide a valuable service by calling in mosquito problems. Complaint calls can help pinpoint large populations of mosquitoes. Spray efforts can be aimed at these "hot spots " when needed, rather than spraying the entire town. Instead of dreading to hear citizens' complaints, encourage community members to notify the local mosquito control agency when mosquitoes get out-of-hand. Those complaint calls can then be plotted on a large map to provide information on probable areas to target.

If manpower allows, turn complaint calls into service requests. Gather as much information as possible over the phone, including the name, address, and phone number of the caller, time of day or night that the mosquitoes are biting, and areas of standing water that the resident may know about. When possible, arrange an inspection when the resident is home. This is a good opportunity to educate the homeowner on mosquito biology and control, source reduction and personal protective measures. Plan on collecting adult mosquitoes or have the resident save a few. This will help identify the species and aid in locating the breeding source(s). Conduct a thorough inspection of the yard and adjacent yards. Talk with the resident during the inspection and collect samples as you inspect. Taking the time to help educate residents will help to reduce the number of call-back inspections. Empower the homeowner. Leave literature on mosquito control and offer sound suggestions and advice. Getting residents to change their behavior can help eliminate neighborhood mosquito problems.

Record the date, location, density, stage of development, and habitat. Save a sample for identification and create a breeding site card for locations that will need regular monitoring and treatment. Include information on adult mosquito rates encountered and the decided treatment. Keep the information in a file system for rechecks and control activities, historical information, and for legal purposes.

BIOLOGICAL CONTROL

Many organisms have been or are being evaluated as potential biological control agents for mosquitoes. A few of these agents have been used to control mosquitoes for years. The World Health Organization has used the mosquito fish (*Gambusia affinis*) in many parts of the world since the 1940s. A nematode parasite (*Romanomermis culicivorax*), at one time commercially available, has been used in many areas for mosquito control with measured success. The bacteria Bti (*Bacillus thuringiensis israeliensis*) has been on the market for several years and is one of the most successful biological control agents currently used.

Each biological control agent has certain merits and restrictions. In order to use a biological control agent successfully, the larvicide technician must have a basic knowledge of the biology of each agent used. Some biological control agents are limited by salinity , temperature, or organic pollution. Some are more effective on certain types of mosquitoes than others. These agents also differ in the ways in which they can be formulated, transported, stored, and applied. All of these factors must be considered when choosing the proper biological control agent for a specific habitat or to control a specific mosquito.

Natural Mosquito Control Organisms

As mentioned earlier, natural habitats, permanent water bodies, and even artificial containers that have held water for a long time support populations of mosquito predators. These predators include beetle larvae, certain fly larvae, aquatic bugs, dragon fly and damsel fly naiads, and fish. During routine surveillance of mosquito habitats, the larvicide technician should look for and become familiar with these organisms that feed on mosquito larvae in the wild. The occurrence of dead mosquito larvae or pupae in previously untreated sites may indicate the presence of a naturally occurring pathogen or parasite.

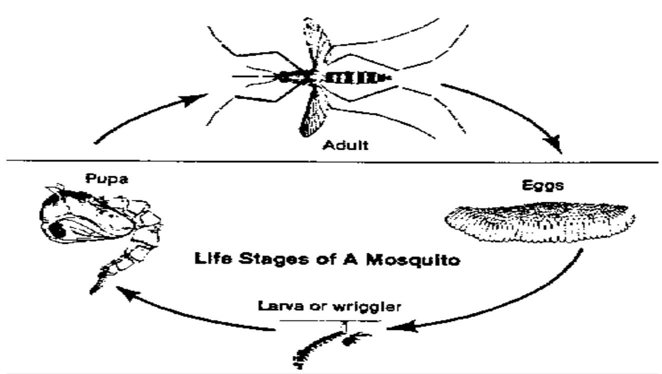
Use of "hard" chemical larvicides (e.g., bonide, golden bear) will also kill many of these natural mosquito control agents. However, the larvicide agents recommended in this manual, such as Bti, if used according to label recommendations, do not affect these other organisms. Mosquito predators will still be around to help maintain some measure of control over mosquito populations at those sites.

MOSQUITO SURVEILLANCE

COLLECTION, SURVEY AND MAPPING METHODS

Purpose of Mosquito Surveillance

Mosquito surveillance should be a routine part of any mosquito control program. A good surveillance program will provide two types of information. 1) a list of the local mosquitoes (including distribution and population size estimates) and, 2) the effectiveness of the control strategies being used. Routine surveillance can keep control personnel informed about locations of major breeding areas, helping to identify problem sites where control should be concentrated. Carefully interpreted survey data can provide vital information. For instance, large numbers of *Culex* egg rafts around the edge of ditches or *Aedes* eggs on oviposition strips are indicators that these breeding sites should be watched closely the next few days. Treatment should be timed to catch the heavy crop of resulting larvae during the period of their life cycle when they are active feeders. Heavy adult catches in light traps stationed near treated areas may indicate that an important breeding site has been overlooked in the surveyor that mosquitoes are migrating in from other areas, depending upon the species captured.



Mosquito Egg Surveys

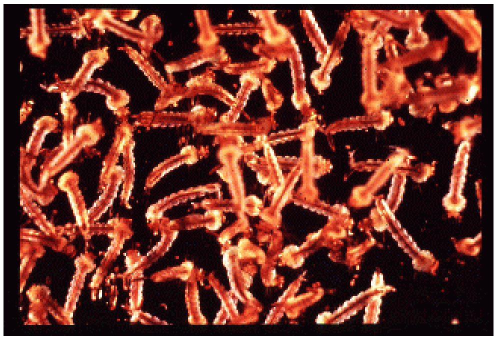
Oviposition jars are useful tools for collecting information on many container breeding mosquitoes, such as the Asian tiger mosquito (*Aedes albopictus*) the yellow fever mosquito (*Aedes aegypti*) and the tree hole mosquito (*O. triseriatus*). Counting eggs collected from an ovitrap will give a good indication of the number of Aedes larvae that will hatch in an area following the next rain. Some eggs can be quickly identified to species under a microscope.
The oviposition jar should be a black plastic or glass jar , or even an aluminum can that has had the top cut out and painted black. The oviposition jar is fitted with a strip of felt covered paper or masonite hardboard clipped to the side. The jar is filled about half way up with water . Female mosquitoes are attracted to both the black jar and the water, and they will lay eggs on the rough surface of the strip just above the water line rather than the smooth surface of the jar .A hole punched in the side of the jar about two inches from the rim will prevent water from flooding the eggs during heavy rains, thereby causing many of them to hatch. One recommended method is to attach an oviposition jar to both sides of a piece of white painted board. This arrangement reduces the chance of oviposition jars being turned over, and, also, the contrast of black jars against the white boards seem to attract mosquitoes more readily.

Larval Surveys

Most of the equipment required to conduct a larval surveillance program can be purchased in a local hardware store. A white plastic or a metal dipper is excellent for collecting water from artificial containers and small water bodies that are easy to reach. Larvae can then be gathered from the dipper with a medicine dropper and placed in a small jar, containing a little water, to be preserved later. Long-handled white graduated dippers can be bought from companies that supply mosquito control equipment. These are useful for sampling ditches, margins of lakes and streams, and hard to reach areas. Kitchen strainers and fine mesh aquarium nets are also good for collecting large numbers of larvae. The contents of the net or strainer can be washed into a white enamel or plastic pan and the large larvae removed with a medicine dropper. Large meat basters are ideal devices for getting samples from tree holes or artificial containers with restricted openings. Three or four foot length sections of plastic tubing can also be used to siphon large amounts of water from tires and other similar breeding habitats. The end of the siphon can be placed in a strainer or large white pan to catch the larvae. A flat-weighted metal can with a string attached is an essential tool for collecting samples from storm drain ports protected by heavy metal gratings.

Descriptive information should be written down for each larval sample collected. Accurate descriptions of habitats sampled, including those places where no mosquitoes are found, are equally important. By having a good background on the type of local areas that breed mosquitoes, future routine surveys can be conducted efficiently, concentrating upon those areas that are known breeding sites. However, occasionally a thorough survey of all water areas should be conducted to ensure that previously unproductive areas have not become mosquito breeding sites.

Estimates of population densities of larvae can be obtained by counting the number of larvae per dip, using a standard size dipper. Three to five dips should be taken and counted at each site. The number of dips counted and number of larvae in each dip should be recorded. Information on the life stage of larvae and pupae can also be recorded. By noting numbers of larvae in each instar or size category (small, 0-5; medium, 5-15; large, 15+), number of pupae per dip, and water temperature, the investigator will be able to make an educated guess as to when mosquitoes will emerge and what control efforts should be used. Generally, larvae develop faster at higher temperatures. Large numbers of pupae indicate that a large number of adults will emerge within a few days. Since pupae do not feed, use of Bti or other products that must be eaten by mosquitoes will not control them. On the other hand, if most larvae are small, it may be eight to fourteen days before adults emerge, depending upon the species and the temperature. The investigator may decide that in this case an application of Bti is suitable. Large numbers of pupal skins floating on the surface is a sign that adult mosquitoes have recently emerged. The experienced investigator will also be able to determine the genus of many larvae based upon a few key characteristics. This knowledge will be useful in selecting the right larval control agent. For example, *Bacillus sphaericus* is highly effective on *Culex* mosquitoes but not *Anopheles* mosquitoes.



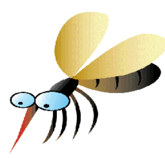
Adult Mosquito Surveys

Adult mosquito surveillance is a very important part of any mosquito program. Adult surveillance will provide information on the effectiveness of the larvicide program. However, the presence of some adult mosquitoes does not mean that larviciding efforts are not working. No program will be successful in totally eradicating mosquitoes. The objective is to control mosquito populations, keeping their numbers at an acceptable level. Also, several species, such as the salt marsh mosquito (*Ochlerotatus sollicitans*) are capable of flying long distances and can move into an area from distant breeding sites.

Information that can be gained from a routine adult mosquito surveillance include:

1. Checklist of adult mosquito species in the local area.
2. Estimate of adult mosquito population density and distribution.
3. Indication of the presence of breeding sites that were overlooked.
4. Identification of sites where larviciding efforts need to be stepped up.

The equipment needed to collect adult mosquitoes is generally more complicated and expensive than that required for collecting larvae. Adult mosquitoes are very fragile. They readily lose legs, scales and wings when handled roughly, making identification difficult or impossible. The special collection equipment described below is designed to capture adult mosquitoes with minimum damage.



Daytime Resting Stations

Adult mosquitoes, especially *Anopheles* can be found during the daytime resting in both natural and artificial shelters. These areas include houses, barns, sheds, bridges, culverts, hollow trees, overhanging cliffs, and foliage. Counts of mosquitoes utilizing daytime resting shelters can give a good indication of population density .Mosquitoes found in these shelters can be easily collected with an aspirator. In areas where no resting shelters are found, an investigator may install an artificial shelter such as a wooden box so that these sites can be routinely sampled. Many mosquitoes that do not usually bite can be collected in this way.

Light Traps

Several types of light traps are commonly used. The CDC light trap, developed by the Centers for Disease Control and Prevention utilize a 6 volt battery; a smaller version runs on four "D" cell batteries. Mosquitoes are attracted to a small light at the top of the trap and are then sucked into a net at the bottom of the trap by a fan. The traps are usually set out and turned on at dusk and picked up at dawn. Timing devices can be installed on the traps so that they will only run during those hours of peak mosquito activity , conserving batteries. Only selected species of mosquitoes are attracted by light traps; catches tend to be smaller during a full moon, and sample sizes are very disappointing during high winds and rainy conditions. Since mosquitoes are attracted to carbon dioxide (CO_2), catches can be increased by hanging a container of dry ice near the light trap.

The new Jersey light trap is a larger metal device, usually located at a permanent sampling station. This trap is often equipped with a timing device that turns it on during selected hours on certain days of the week. It works on the same general principal as the CDC light trap, except that it uses 110 AC power and mosquitoes are sucked into a paper cup inside a jar containing a killing agent such as a piece of pest strip. The paper cup prevents mosquitoes from coming into direct contact with the pest strip . Generally, New Jersey traps require little maintenance.

Oviposition Traps

Oviposition traps are available through some supply companies. These devices are similar to oviposition jars in that they provide a black plastic container partially filled with water as an attractant. Female mosquitoes visiting the trap to lay eggs are sucked into a net by a small fan motor like those used on many light traps. Oviposition traps are very selective for female *Culex* mosquitoes. The catch data is not comparable to light trap data. These traps are not commonly used by mosquito control agencies.

Preserving Adult Mosquitoes

Adult mosquitoes should be handled very carefully to prevent them from losing scales, legs, or wings. Collections taken from a New Jersey light trap using a pesticide strip in a killing jar are usually dead within the perforated paper cup. These mosquitoes should be gently shaken from the cup into a small tissue-lined cardboard jewelry box or equivalent container. Mosquitoes should be arranged evenly over the tissue and one layer deep. A piece of tissue should be placed on top of the mosquitoes to prevent them from being shaken about. A label containing the necessary sample information should be placed on top of the last layer of tissue and the lid secured on the box with a rubber band. Only specimens from one trap should be placed in each box. If many mosquitoes are captured in a single trap, extra boxes can be used to hold the specimens and these boxes bound together with a rubber band.

Mosquitoes can be removed from net bags of light traps with an aspirator. An alternative is to remove the net bag, tie the top, and place it in an airtight container such as an ice chest with an open bottle of chloroform. Ice or frozen reusable ice packets can be used to "freeze" adult mosquitoes within an ice chest. This process takes longer than the chloroform method and some mosquitoes may revive after being removed from the cold ice chest. Some mosquito control districts - especially when shipping mosquitoes to the lab for live virus isolation - use dry ice (C02), which both kills and preserves the mosquitoes.

Killed mosquitoes can be shaken from the net bags onto a piece of paper or into a small pan and then transferred to a small collection box. Adult mosquitoes should not be handled, if possible. When it is necessary to pick them up, use a pair of forceps, grabbing each mosquito gently by a group of legs.

Mosquitoes can be mailed by placing the collection boxes in a larger, sturdy container and filling loose spaces around the collection boxes with paper. The lid should be carefully secured and the container marked "fragile". As an extra precaution, a wisp of cotton can be placed on top of the upper tissue layer of each collection box and replace the lid. This will help prevent the mosquitoes from being shaken around inside the collection boxes. These steps may seem to be a little extreme. However, it is necessary to provide the identifying entomologist with good quality samples in order that correct identifications can be made. This is especially important when adult collections are first being made from an area and a reference collection and species list is being compiled. A partial list of qualified entomologists for mosquito identification is provided in the back of this booklet under “Resources.”

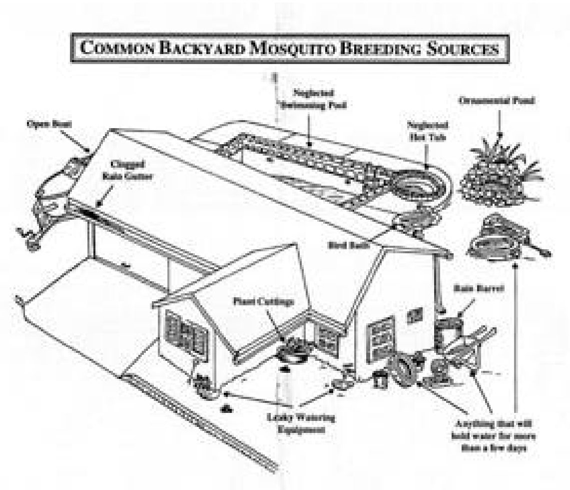
ATTACKING THE PROBLEM WHEN IT IS IDENTIFIED

HOMEOWNER/INDIVIDUAL CONTROL

Mosquito control can be divided into two areas of responsibility: individual and public. Chemical control of mosquitoes around the home may be accomplished with the use of repellents or space sprays. Repellents are substances that make a mosquito avoid biting people. Several repellents are effective against mosquitoes. All insect repellents must have the active ingredient appear on the label; examples are DEET and pyrethroids. Always advise the public to check the label before buying and using. For instance, only DEET concentrations under 10% should be used on children.

Oil of citronella is another type of mosquito repellent for space repelling. Oil of citronella is the active ingredient in many of the candles, torches, or coils which may be burned to produce a smoke which repels mosquitoes. These are useful outdoors only under windless conditions. Their effectiveness is somewhat less than repellents applied to the body or clothing.

Space sprays may be used to kill mosquitoes present at the time of treatment. The major advantage of space treatment is immediate knockdown, quick application, and relatively small amounts of materials required for treatment. Space sprays are most effective indoors. Outdoors, the insecticide particles disperse rapidly and may not kill many mosquitoes. The major disadvantage of space spraying is that it will not manage insects for long periods of time.



Mosquitoes can be killed inside the house by using a flit gun or a household aerosol space spray containing synergized pyrethrum or synthetic pyrethroids (allethrin, resmethrin, etc.). Only insecticides labeled for flying insect management should be sprayed into the air. Best results are obtained if doors and windows are kept closed during spraying and for 5-10 minutes after spraying. Again, with any pesticides, always advise the public to follow directions on the label. Homeowners may use hand-held foggers or fogging attachments on tractors or lawn mowers for temporary relief from flying mosquitoes. Pyrethrins or 5% malathion can be fogged outdoors.

Most of the mosquito problems that trouble homeowners and the general population cannot be eliminated through individual efforts, but instead, must be managed through an organized effort.

PUBLIC CONTROL

Source Reduction

Source reduction is the elimination of mosquito breeding sites. Reducing the amount of breeding areas in a town will save the larviciding and adulticiding technicians both time and work. A spring cleanup drive involving schools, citizen groups, and town maintenance and sanitation departments can help get rid of bottles, cans, tires, stagnant drainage ditches, and other sites that produce mosquitoes. Many types of breeding sites, however, cannot or should not be eliminated. Mosquitos in these areas will have to be controlled by applications of a suitable larvicide. Improper drainage of wetlands and indiscriminate ditching can create more mosquito problems than were there to begin with.

Larviciding

Larviciding, or killing the mosquito while in the larval stage (pupal stage included), is one of the most common methods of mosquito control used today. It is considered the best course of action for mosquito control after source reduction. When mosquitoes are in their immature stages, they are concentrated in a relatively small or fixed area (captive audience). The kill occurs before mosquitoes are out fling, causing biting nuisances, and capable of transmitting diseases to people, pets, and domestic animals. However, every body of standing water need not be larvicided. Several factors must be considered before larviciding. These include the mosquito species, larval density, stage of development, relative proximity to populate areas, size of the area, seasonality, susceptibility, equipment and larvicides selected by the program, the larvicide formulation, environmental issues, jurisdiction, rain and wind conditions, and cost.

The best pesticide is one that is extremely specific, affecting only the target pest and nothing else in the environment. It must eliminate the pest quickly before it becomes a threat and before it reproduces. It has to be easily applied, reasonably inexpensive, and non-toxic to human, domestic animals and wildlife. Finding all of these characteristics in a single pesticide has been the goal of many researches. A small group of *Bacillus* bacteria have been developed into a line of pesticides that are remarkably close to this idealistic model. Some manmade chemicals like methoprene and Agnique are also commercially available that will prevent the adult mosquito from forming, but not harm natural organisms or the environment.

Bti (*Bacillus thuringiensis israeliensis*) is a strain of bacteria that was isolated from a dead mosquito larvae found in Israel in 1977. It proved to be a very effective killing agent of mosquito larvae and black flies. It was also lethal to several species of midges, but had no adverse effect upon other insects, fish, or laboratory animals. Bti has since been developed into wettable powder, liquid, granular, capsule, and briquette formulations that are commercially available to mosquito control personnel. It has also been formulated with growth regulators and monomolecular films.

Wettable powders are not widely used. Liquids are probably the most common and versatile formulations of larvicides on the market. Liquid Bti is packaged in 2.5,5, and 30 gallon containers. It generally comes in two strengths, 600 and 1200 international toxic units. This material can be mixed with water and applied by hand sprayer, truck mounted sprayer, or ultra low volume fog machine.

The hand portable sprayer provides the best way to apply Bti to many urban breeding sites. It is important to purchase a sprayer that is comfortable and easy to carry for several hours. Sprayers equipped with backpack or shoulder straps should be considered. The spray unit should hold two to four gallons and be equipped with a wand that has an adjustable nozzle.

Try not to disturb the water surface when applying Bti, methoprene, or Agnique. A soft sweeping mist coverage is better than a strong stream. Bti spores are effective when they are on the surface where larvae generally filter feed. If the water is churned up by spraying a hard stream of material, many spores may sink rather than remain at the surface. Methoprene, on the other hand, is absorbed and does not have to be ingested by the larvae. It does not kill larvae immediately, so they remain in the food chain. Like Bti, Agnique works better when it remains a solid, continuous film over the water. Be sure to spray around grassy edges and shaded areas where larvae tend to concentrate.

Label application rates for liquid Bti are based on the surface area of the water being treated, not depth. Application rates of ½ to 2 pints per acre are generally recommended, depending on strength of the formulation used (check the label for specifics). The proper rate needed at each site depends on several factors, including predominant larval stage, larvae density , water quality , type of water habitat, and amount of plants growing in the water .

Early stage larvae are more readily killed by Bti than late stages. Lower dosage rates can be used when larva are mainly early stages, but the higher recommended dosage should be applied to populations of late third stage larvae. The higher the concentration of spores at the surface, the greater likelihood that the older larvae will pick up a few spores. Bti is less effective against the late instars; plus pupae do not feed and are therefore not affected by Bti, unless they fed upon it prior to pupating. Methoprene, however, is very effective against the fourth stage larvae. Agnique and some other harsher oils, bonide and golden bear are options when only pupae are present, it is too late to use Bti or methoprene, and a quick kill is required. The residual effect of most oil formulations for killing late stage instars and pupae is about 5-7 days.

Younger larvae will be feeding actively for a week or more and, therefore, have plenty of opportunity to ingest a few Bti spores, even when applied at the lower dosage rate. The higher application rate should be used when larval population density is high, regardless of predominant instar present. Mosquito larvae are very efficient filter feeders. Large numbers of larvae will quickly filter out all of the spores applied at low rates before all larvae have a chance to feed on the material.

The higher recommended rates should be used in water polluted with septic tank discharge or that has a heavy growth of algae. These waters generally have higher concentrations of suspended food particles. In this case, Bti spores are competing with food particles. Using the higher dosage rate increases the chance that larvae will pick up at least some of the spores along with all of the food particles. Lower dosage rates can be used in clear, open water conditions (ponds, pools, drainage ditches, flood water) but higher dosage rates should be sprayed in heavily shaded water.

Granular Bti or liquid methoprene are generally applied to areas covered by thick vegetation, such as salt marshes and weedy ditches. They have also been used in flooded pastures, irrigated fields and tire piles. If Bti granules are applied to large areas of open water, winds can push them against one shore. This formulation consist of spores attached to a carrier made from ground and sized corn cob particles. The carrier floats, keeping much of the material at the surface where most larvae feeding occurs. Different companies make different size corn cob particles. As a rule, smaller particles can fall through thick grass better, but may be more likely to stick to wet blades. Larger granules can be broadcast further and are less affected by wind.

Ground application of granular Bti can be made with many types of manual or mechanical seed or fertilizer spreaders that use a whirling disk. Horn seeders have not proven to be as effective. Generally, recommended application rates range from 2 to 10 pounds per acre (check the label) .The actual rate required at each site is largely dependent upon the same factors discussed for application of liquid formulations. Generally, treatment should be repeated every seven days.

Bti is also formulated into briquets. The brand name is Bactimos^{R}. They are usually more expensive than liquid and granular formulations. Cost per acre is about $15-$50. However, these floating briquets will give up to thirty days of treatment under normal conditions. Briquets can be used in many habitats where mosquitoes breed. They can be anchored to tree limbs or weights with string to prevent them from floating away. Usually, one briquet will treat about 100 square feet of water surface, regardless of depth. Up to 4 briquets per 100 square feet may be required in heavily polluted water. Briquets can be applied to areas that flood during rainy periods such as woodland pools. These briquets will float when the area is flooded, releasing Bti. Effectiveness of the Bti will not be reduced by dry periods.

Using Insect Growth Regulators

Insect growth regulators (IGR) are a group of chemicals that kill insects by interfering with their normal process of growth and development. Methoprene is an IGR that affects mosquitoes. The material can be applied to any larval stage. However, results are not immediate. Larvae will not die, but will continue their growth process and pupate. Pupae that develop from exposed larvae will die and adults will not emerge. Methoprene is only effective when applied to the larval stage. Any pupae that are present in the water during application will not die and will successfully emerge as adults.

Methoprene comes in liquid concentrate (5% and 20%), pellets, a new granular formula, 30-day briquets, and 150-day extended briquet formulations (brand name Altosid[R]). Applications of methoprene should be made at the start of the mosquito season. Briquets can be tossed into the water. They will sink to the bottom and slowly release the IGR. The liquid can be mixed with sand and sprayed. Residual effects ranges from 7-10 days for liquid to 30-150 days, depending on the formulation. Briquets are designed to withstand wet and dry period to extend the residual effect through periods of heavy rainfall, flooding, etc. Mosquito control personnel must maintain current knowledge about approvals and use of larvicides, and are encouraged to attend annual training conferences offered in the state.

Liquid Bti and Altosid can be mixed to create Duplex[R] at rates of 6:1 to 12.5:1. It is mixed with sufficient water to spray at a rate of 2-16 ox./acre surface area. One popular formula is to mix a 9:1 tank mix using 45 oz. Bti to 5 oz. Altosid5% and 50 gallons of water and spray 7 gallons an acre of the mixture (about one gallon a minute using conventional pump sprayers).

Adulticiding (Spray Trucks)

Only selected chemicals are approved for use in a thermofogging unit or ultra low volume (ULV) units in Alabama. Consult the Alabama Department of Agriculture and Industries (Montgomery, Alabama, 334/240-7242) for a current list of approved chemicals, mixing rates and application rates. Different formulations are used in thermofogging units than are used for ULVs. Be sure you purchase the correct formulation for your machines.

Always read the chemical label before buying, mixing and loading, applying, and storing insecticides. Most of the adulticides available are restricted use pesticides and must be purchased and applied under the direct supervision of a certified pesticide applicator. All applicators should review and carry the chemical labels and Material Safety Data Sheets (MSDS) with them while conducting control activities. Insecticide labels and MDSDs contain important information concerning the application rate, personal protection measures, statements of practical treatments, environmental hazards and storage and handling procedures. **THE LABEL IS THE LAW 11**

Adulticiding should be conducted after sunset. Chemicals sprayed during the day will be carried upward by thermal currents. Also during the day, mosquitoes generally are resting out of reach of pesticide in protective foliage, while bees are exposed as they gather nectar .We should try to kill mosquitoes, not bees. Spray trucks should be driven slowly; usually 10 mph. Great efforts should be made to drive the entire evening at the same speed. This assures application of the chemical at a uniform rate.

Machines must be kept in proper working order and calibrated yearly. Both flow rate and droplet size should be calibrated in ULV machines, and flow rate in thermofoggers. Alabama Vector Management Society or Alabama Cooperative Extension Service (334)844-6389 can aid in training and contacts for ULV calibration. When using corrosive chemicals, flush your machine after each use. Technicians should practice worker safety .Pesticide lines should be routed outside of the cab.

Adulticiding should only be done when necessary .Routine adulticiding wastes chemical, exposes public to chemicals unnecessarily, and promotes the buildup of mosquito populations resistant to the chemicals.

Empowering Mosquito Control Personnel

Mayors and city council members should take an active role in mosquito control to insure efficiency and limit liabilities. If a lawsuit alleges that a town's fogging truck caused a respiratory problem among residents, then the chemical used better have been applied correctly with a properly calibrated machine. Otherwise, the municipality may be liable. Efforts should be made to train mosquito control personnel by occasionally sending them to workshops and seminars on mosquito control. One such workshop is the annual Mosquito and Vector Control Workshop put on by the Alabama Vector Management Society and other agencies. This meeting is usually held in March of each year. Some distributors of mosquito control products have on site training programs and will come to a county and assist local officials at no cost. In addition, mosquito control workers should read this publication, as well as others available through the Alabama Cooperative Extension Service concerning safe and effective mosquito control.

Mosquito Control and the Public

Providing public information and soliciting public support is vital to the success of any mosquito control effort. Communities should be made aware of the effects they have upon local mosquito populations. Efforts should be made to inform the public of the problems caused by artificial containers around their homes. They should be encouraged to clean up their neighborhoods; rid their yards of breeding sites; promote town clean-up drives and sponsor mosquito seminars for schools and local organizations; provide information on larviciding activities in their area and remind people of the potential public health threat mosquitoes represent. Educational pamphlets and mosquito control brochures are available from the Alabama Department of Public Health, Division of Epidemiology, Post Office Box 303017, Montgomery, Alabama 36130-3017 (Ph. 334/206-

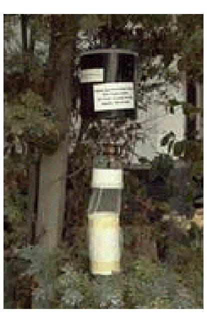
5969). Invite citizens to call in complaints concerning severe mosquito problems. Mosquito control is a public effort. Without the help and support of citizens, mosquito control personnel will be fighting a losing battle.

When arboviral surveillance measures indicate the presence of disease-causing viruses in an area, the proper local response can be gauged by following the CDC Guidelines listed below, according to the level of risk. When significant bird or domestic animal illness or positive tests occur in an area, intensive adulticiding is required to quickly kill the infected adult mosquitoes. Other control measures like source reduction, larviciding, public education, and health alerts should be instigated at the same time, but quick knock-down of the adult mosquitoes is also necessary when the public's health is obviously threatened.

Exhaustive public relations and communications may be necessary in a community immediately before spraying, and local officials must convince the public that emergency adulticiding is a much less risk than exposure to the disease viruses. For instance, synthetic pyrethroids used in adulticiding have quick knock-down, but dissipate within 2 hours and have no residual effects. Even the pesticide with the most residual effect used (malathion) has a higher LD50 (the minimum dosage that would kill 50% of laboratory mice) than caffeine and salt; which means that dose-for-dose, caffeine and salt are more toxic than malathion. Toxicity studies in the laboratory are conducted assuming that people are 10X more sensitive to pesticides than animals by all possible routes of exposure (i.e., dermal, ingestion, inhalation). The margin of exposure (MOE) that EPA uses for people over the observable adverse effect level in animals is actually 100X higher. Every risk/benefit model studied for mosquito spraying and residential exposures in short vs. long-term spraying, aerial vs. ground spraying, and using various EPA-approved pesticides has revealed no adverse human health effects. Those studies prompted the following statement from EPA at the 2002 State Public Health Vector Control Conference. "Toxic effect due to spraying of malathion at approved levels is considered a highly improbable event."

Sure, continual spraying of pesticides in a community without regard to integrated mosquito control using source reduction and larviciding as first lines of defense is not recommended. However, in a public health emergency situation in which people are determined to be at immediate risk of exposure to disease-causing viruses, adulticiding is a necessary evil. Citizens who display extreme anxiety over adulticiding for mosquitoes or residents with chemical sensitivities may be referred to the following resources for up-to-date unbiased information about pesticides:

1.National Pesticide Telecommunications Network (NPTN)1-800858-PEST or http://nptn.orst.edu
2. Environmental Protection Agency http://www.epa.gov/pesticides/factsheets/skeeters.htm
3. American Mosquito Control Association http://www.mosquito.org
4. Centers for Disease Control and Prevention (CDC) http://www.cdc.gov/ncidod/dvbid/index.htm



RESOURCES & CONTACTS FOR MOSQUITO CONTROL

Pesticide Licensing & Certification
AL Dept. Agriculture & Industries, Pesticide Management
Licensing..(334)240-7241, 7242
Certification...(334)240-7243, 7261
Study Materials for Certification.......AL Cooperative Extension System
Request ANR#430 "Public Health Pest Control"..(334)8441592
ULV Sprayer Calibration
AL Cooperative Extension System...(334)844-4940
AL Vector Management Society......................Kevin Humphries............................(256)535-6549
Sources for Larvicides and Adulticides
Adapco...1-888-400-9085
Aventis Environmental Science..1-850-929-9116
Clarke Mosquito Control Products...1-800-323-5727
Cheminova...1-800-548-6113
Cognis Corporation...(513)482-2953
Mosquito Control, Inc..(318)323-3535
Summit Chemical..1-800-227-8664
Valent...(813)805-2321
VoPak...1-800-888-4897
Wellmark (Zoecon Products)..1-800-877-6374
Sources for Mosquito Traps for Surveillance
John W. Hock Co..(352)378-3209
Bioquip..(310)324-0620
Contract Spraying (Emergency Adulticiding)
U.S. Air Force.(910th Airlift Wing, Youngstown AF Reserve, Vienna, OH).....(330)609-1412,1965
Clarke Mosquito Control..1-800-323-5727
Mosquito Control, Inc...(318)323-3535
Helicoptor Applicator, Inc...(717)337-1370
Training Opportunities for Mosquito Control Personnel
AL Cooperative Extension System..(334)844-6389
AL Vector Management Society.........Kevin Humphries, Sec.-Treas.......................(256)535-6549
ADAPCO..1-888-400-9085
CLARKE Mosquito Control..1-800-323-5727
VOPAK..1-800-888-4897
Educational Brochures and Door Hangers
AL Dept. Public Health, Div. Epidemiology...(334)206-5969
Gambusia (mosquito fish)... Ken's Hatchery, Alapaho GA...............(229)532-6135
Entomology Consultants for Surveillance or Species Identification
FL A&M, Public Health Entomology & Education CenterPanama City, FL....(850)872-4184
Bruce Furlow..................Pensacola,FL.. ....(850)595-3147
Miichael Womack, PhD..........................Macon, GA...................................(912)471-2742
Gary Mullen, PhD..........................Auburn University...................................(334)844-2550
Ed Cupp, PhD..............................Auburn University....................................(334)844-5006

Ken Tennessen, PhD....................TVA................. ....(256)386-3651
Kelly Micher, M.S....................Mobile County Health Dept............................(251)690-8124

Tire Dump Problems

County Commissioner Office for Enforcement Office..........................local phone book
ADPH, Bureau of Environmental Services..(334)206-5373
AL Dept. Environmental Management.........Ombudsman....................1-800-533-2336