

Public Health Pesticide Applicator Training Manual

MOSQUITOES

Mosquitoes are in the family Culicidae of the order Diptera and, as a result, are similar in appearance. However, in many important characteristics the anophelines (*Anopheles* spp.) differ from the culicines (all 12 other mosquito genera occurring in the United States) (Table 3-1). Mosquitoes pass through four distinct stages in their life cycle: egg, larva, pupa and adult. Prodigious numbers of mosquitoes can hatch simultaneously under the proper conditions. In rapidly developing broods, survival of the immature stages can be quite high, but estimates for many species indicate that immature survival is normally less than five percent. But five percent of millions still represents a sizable number of mosquitoes. Irrespective of population densities, if they transmit disease or preferentially feed on humans, which many species do, they become appropriate targets for control activities. This chapter deals with the bionomics of mosquitoes, and reviews surveillance practices and approved control methods.

I. DEVELOPMENTAL STAGES

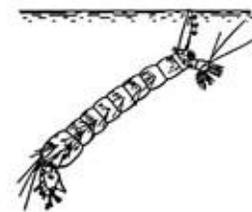
Immature Stages

Eggs. White in color when first deposited, mosquito eggs darken within 12 to 24 hours. Those of most species appear similar when seen by the naked eye, with the exception of the *Anopheles* spp. whose eggs have floats attached to each side. However, when viewed with magnification, eggs of different species can be seen to vary from canoe-shaped to elongate or elongate-oval in shape, laid singly by some species and glued together to form rafts in others. The incubation period (elapsed time between oviposition and hatch) is dependent on environmental and genetic factors and varies considerably among different species.



Permanent and standing water breeding species deposit their eggs directly on the water surface and these may hatch in one to three or four days depending on temperature. Many floodwater and container-breeding species deposit their eggs on moist soil or other wet substrates. These eggs may hatch within a few days after being flooded or the fully developed larva may remain within the egg for up to a year or more depending on immersion conditions. These quiescent eggs accumulate over time due to continued oviposition by blood-fed females and when finally hatched off by temporary flooding, along with more recently deposited eggs, can attain the numbers described in the opening paragraph.

Larvae. Larvae (wigglers or wrigglers) of all mosquitoes live in the water. Near the last abdominal segment in most species is a **siphon** or air tube that serves as a respiratory apparatus when the larva suspends vertically below the water surface. Larvae of *Anopheles*, however, breathe through a cluster of small abdominal plates, which causes them to lie flat and closely appressed to the underside of the water surface when not diving. Larvae of



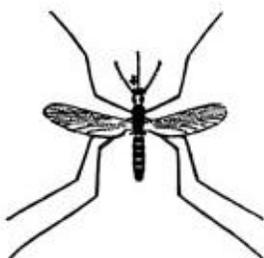
some species are predaceous (e.g., *Toxorhynchites* and *Psorophora*) and prey on other invertebrates, including mosquito larvae. Most larvae are filter feeders, ingesting anything smaller than about 10 microns by vibrating their mouth brushes and sweeping in particulate matter and small organisms from the surrounding water. Depending on the species and environmental conditions, mosquitoes may take anywhere from three to four days up to several weeks to complete larval development. Mature 4th instar larvae molt to the pupal stage.



Pupa. Unlike most other insects, mosquito pupae can be very active and are often called “tumblers” because of their rapid, tumbling-like movement when disturbed. Mosquito pupae breathe through two respiratory “horns” when at the water’s surface, do not feed, and typically transform into an adult in two or more days.



Adult Mosquitoes



Adult mosquitoes are terrestrial and capable of flight. With piercing-sucking mouthparts the female feeds mostly on animal blood and plant nectar. Male antennae have dense bristles and mouthparts are modified from those of the female and are used only to suck nectar and plant secretions, where no piercing is required. The adults of some species remain within a few hundred feet of where they spent the larval stage, whereas others may migrate up to 50 miles or more. Eggs develop a few days after females take a blood meal.

Females oviposit on the water, in crevices in the soil, on other favored substrates or special niches that are or will subsequently be flooded, such as natural and artificial containers or tree holes, and the cycle repeats itself. Females of some floodwater species may live up to a month after they emerge, whereas those of some permanent or standing water species can survive for several months by overwintering as mated, engorged adults. Some species, including those whose eggs require freezing temperatures, are limited to a single generation per year whereas others have multiple generations.

II. BIONOMICS AND HABITAT

Those casually acquainted with mosquitoes may believe that all types are much the same and, indeed, the similarities between species is considerable. There are, however, many differences in appearance from species to species and even among some varieties within species. These morphological differences, especially notable in the larval and adult stages, permit accurate identification of most species. Behavioral differences permit various species to occupy numerous ecological niches with relatively little overlapping. Thus, knowledge of the source or breeding habitat of mosquitoes can provide strong clues to their identification.

Mosquito control is an exacting technology requiring knowledge of the behavioral and habitat differences among species in order to plan and affect abatement of mosquito problems. The trained worker first identifies the problem species. With identity established, useful correlations are immediately available because of the wealth of information that has been accrued, especially in the case of medically important mosquito species. For example, along with identification of the species by recognition of the adult mosquito, the type of breeding habitat and where to search for larvae become readily apparent in most cases. If the species is single-brooded each year, or emergence of adults occurs within a restricted period, an exhaustive search for larvae after adults are on the wing might be wasteful of time and effort and, accordingly, not the procedure of choice. Thus, a working knowledge of the behavior and habitats frequented by various species aids in determining the kinds of survey and control strategies best suited for the task.

Mosquitoes are not adapted to life in moving waters. Where they occur in flowing streams they occupy the quiet pools and seepage areas. Aquatic environments differ chiefly in the chemistry of the waters - acid or alkaline, fresh, salt or brackish - whether natural or manmade habitat, in the amount or type of vegetation present, and whether shady or sunny. *Coquillettidia perturbans*, *Mansonia dyari* and *Ma. titillans*, for example, are found in association with specific aquatic plants - water lettuce, water hyacinth and cattails. *Weomyia* spp. are found in association with bromeliads and pitcher plants. In this regard, the distinctive egg-laying habit of each species of mosquito determines its larval habitat. Although some species utilize more than one type of habitat, most mosquitoes can be categorized in general terms by their preference for either permanent water, floodwater, transient water or artificial container and treehole habitats. These categories can be combined into two major larval habitat categories: standing water (permanent and transient) and floodwater (including natural and artificial containers as well as floodwater).

Standing water species deposit their eggs (either singly or in rafts) on the surface of permanent or transient pools of shallow, standing water. They usually produce several generations (broods) each year,

and overwinter or survive harsh environmental circumstances as mated, engorged females. In contrast, floodwater species deposit their eggs out of the water but in locations subject to periodic flooding, such as damp soil in depressions or inside tree holes, crab holes and artificial containers. They produce one to several broods annually and overwinter or survive harsh environmental circumstances in the egg stage. Since habitats can change quickly, as when a fresh water pool becomes stagnant, the current habitat conditions may not always be what an inspector expects. Such temporary forced changes because of spatial, chemical or temporal factors, contributes to association with multiple habitat types .

Standing Water Mosquitoes

Permanent water group. Mosquito groups readily assigned to the permanent water group are *Anopheles*, *Culex (Melanconium)* spp., *Cx. salinarius*, *Cx. territans*, *Coquillettidia* spp. and *Mansonia* spp. The following permanent water habitat types and resident genera as described in the Florida Public Health Pest Control Applicator Training Manual are more or less typical of those found throughout the nation.

Freshwater marsh: Mosquito species often found in freshwater marshes include: *An. walkeri*, *An. crucians*, *Ps. columbiae*, *Cx. nigripalpus*, *Cx. salinarius*, *Cx. tarsals*, *Cx. erraticus* and *Cx. peccator*.

Lakes: Where vegetation occurs only in a narrow band along the lakeshore, larvae are confined to this littoral zone, but when supporting many species of floating or emergent plants larvae may be found throughout the lake wherever cover is afforded and in marshy areas around the lakes including: *An. crucians*, *An. quadrimaculatus* spp. complex, *An. walkeri*, *Ur. sappharina*, *Ur. lowii*, *Cx. salinarius*, *Cx. nigripalpus*, *Cx. erraticus*, *Cx. peccator*, *Cq. perturbans*, *Ma. dyari* and *Ma. titillans*.

Ponds and seepage areas: There is no clear distinction between a pond and a lake except that ponds are generally smaller. Grassy woodland ponds, or fluctuating ponds occupy shallow depressions and are filled by rainwater or surface run-off. They are usually of uniform depth but the area they cover will vary, depending on rainfall. Sinkhole ponds are usually quite deep and may be covered with vegetation or free of all except marginal plants. Both types of ponds may contain larvae of *An. crucians*, *An. quadrimaculatus* spp. complex, *Cs. inornata*, *Cs. melanura*, *Cx. nigripalpus*, *Cx. quinquefasciatus*, *Cx. restuans*, *Cx. salinarius*, *Cx. erraticus*, *Cx. peccator*, *Cx. pilosus*, *Cx. territans* and *Ae. canadensis*.

The seepage areas around hillsides and ponds or streams most often breed *An. punctipennis*, *An. quadrimaculatus* spp. complex, *Ae. sticticus* and *Ps. ferox*.

Springs: Mosquito breeding in springs is restricted to the quiet edges where vegetation affords cover for the larvae and there is little if any water movement. The only species recorded from this habitat in Florida are *An. quadrimaculatus* spp. complex and *An. perplexens*.

Swamps: Swamps differ from marshes principally in having dense cover from larger trees. The most common species of mosquito larvae found here are *An. crucians*, *An. quadrimaculatus* spp. complex, *Cs. melanura*, *Ae. canadensis*, *Mansonia* spp. and *Cq. perturbans*.

Transient water group. Mosquito groups readily assigned nationally to the transient water group are *Cx. quinquefasciatus*, *Cx. tarsalis*, *Cx. restuans*, *Cs. inornata* and *Cs. melanura*. The following specific habitat types and resident genera described in Florida are more or less typical of those found throughout the nation.

Salt or brackish water ditches: The ditches adjacent to salt water marshes contain many species of grasses and support a large mosquito fauna including: *Ae. taeniorhynchus*, *Ae. sollicitans*, and *An. bradleyi*.

Borrow pits and canals: These man-made bodies of open water produce more mosquitoes as they silt-in and become overgrown with vegetation. They yield: *An. quadrimaculatus* spp. complex, *Cs. inornata*, *Ps. columbiae*, *Ae. canadensis*, *Cx. nigripalpus*, *Cx. quinquefasciatus*, *Cx. restuans*, *Cx. salinarius*, *An. albimanus*, *Cq. perturbans* and *Mansonia* spp.

Freshwater drainage ditches: In pastures, at the bottom of road shoulders, in old fields, and in lowland groves, freshwater ditches will often yield the following species of mosquito larvae: *Ps. columbiae*, *Cx. nigripalpus*, *Cx. pilosus*, *Cx. erraticus*, *Cx. quinquefasciatus*, *An. crucians*, *An. walkeri*, *Ae. atlanticus*, *U. sappharina*, *U. lowii*, *Ps. ciliata* and *Ae. sollicitans*.

Floodwater Mosquitoes

Floodwater group. Mosquito groups readily assigned nationally to this floodwater group are *Ae. sollicitans*, *Ae. taeniorhynchus*, *Ae. tormentor / atlanticus*, *Ae. thelcter*, *Ae. dorsalis*, *Ae. nigromaculis*, *Ae. vexans*, *Ps. ferox* and *Ps. columbiae*. The following specific habitat types and resident genera described in Florida are more or less typical of those found throughout the nation.

Mangrove swamp: In the transitional zone from normal high tide to above all but the highest spring and storm tides, the heaviest mosquito breeding occurs because plant and grass cover keep moisture conditions suitable for egg laying. Eggs are usually laid on sloping sides of potholes, ditches, sloughs, marsh edges or on the sides of small depressions, and sometimes over extensive level grass-

covered areas. The eggs of some species require alternate flooding and drying before hatching will occur. Species most often occurring are *Ae. taeniorhynchus*, *Ae. sollicitans*, *An. atropos* and *Cx. nigripalpus*.

Salt marsh: Salt-tolerant herbaceous plants and typical salt grasses dominate this type of habitat. Extensive areas are often covered by a single plant species such as salt grass *Distichlis spicata*, or by *Batis maritima* or *Salicornia perennis*. It is in association with one of these plants or with black mangrove, *Avicennia nitida*, that breeding of *Ae. taeniorhynchus* and *Ae. sollicitans* occurs.

Rain and floodwater pools: These pools form the breeding place for a large number of species, especially *Psorophora* and *Aedes*. The pools disappear in dry weather and support no true aquatic vegetation, though usually a layer of leaves and other detritus settles on the bottom. Mosquito species found in this habitat are *Ps. johnstonii*, *Ps. pyginaea*, *Ae. atlanticus*, *Ae. dupreei*, *Ae. fulvus pallens*, *Ae. infirmatus*, *Ae. mitchellae*, *Ae. sticticus*, *Ae. tormenter*, *Ae. vexans*, *Ae. cinereus*, *Cx. atratus*, *Cx. pilosus*, *Cx. bahamensis* and *Cx. nigripalpus*.

Artificial container and treehole group. Mosquito groups readily assigned nationally to the artificial container and treehole group are *Ae. aegypti*, *Ae. triseriatus*, *Ae. sierrensis*, *Ae. albopictus*, *Cx. quinquefasciatus*, *Toxorhynchites* spp. and *Orthopodomyia* spp. The following specific habitat types and resident genera described in Florida are more or less typical of those found throughout the nation.

Tree holes: Tree holes or rot cavities support a rather extensive and unusual mosquito fauna, with many species breeding almost exclusively in this habitat. Resident species are *An. barberi*, *Tx. rutilis rutilis*, *Tx. septentrionalis*, *Ae. triseriatus*, *Ae. hendersoni*, *Or. signifera*, *Or. alba*, *Ae. thibaulti* and *Ae. albopictus*.

Crab holes: Along the eastern coast the holes of the large land crab, *Cardisonza guanhumii*, serve as the larval habitat for *De. cancer* and *Cx. opisthopus*.

Artificial containers: Several species breed in man-created situations around human dwellings. Tin cans, fish pools, cisterns, rain barrels, gutters and old tires, etc., containing water serve as excellent larval habitat. Species most often encountered are *Ae. aegypti*, *Ae. triseriatus*, *Cx. quinquefasciatus*, *Cx. restuans*, *Cx. salinarius*, *Cx. nigripalpus*, and *Ae. albopictus*.

That many species are found in multiple habitat types and some in very specialized habitats illustrates the complexity of the problem faced by control agencies. While habitat association with many

species is quite specific, others thrive in a variety of situations. Thus, the detection of adults of these latter species in routine surveys does not provide an immediate indication of the related breeding site(s).

III. MOSQUITO SAMPLING AND SURVEILLANCE

Surveys are essential for the planning, operation, and evaluation of an effective mosquito control program, whether for the prevention of mosquito-borne diseases or to reduce mosquito populations to levels permitting normal activities without undue discomfort. Initial surveys identify the species of mosquitoes present and provide general information on locations, densities and disease potential. With this knowledge it may be possible to determine life cycles and feeding preferences, predict larval habitats, adult resting places and flight ranges, and perhaps even make preliminary recommendations for control programs.

The next step is to embark on a formal surveillance program in which routine monitoring of mosquito presence is conducted. A basic inspection program usually addresses adult and larval population density and species composition, rainfall and tide monitoring, and breeding site locations. Additional specialized surveillance may be conducted to detect arboviral presence in birds and mosquito populations, operation of ovitraps (e.g., for *Ae. aegypti* and *Ae. albopictus* surveillance), or sampling of floodwater mosquito eggs to locate breeding sites. This information not only provides justification for source reduction and insecticide applications, but it also serves as an on-going indicator of the effectiveness of these activities and continually adds to the database of knowledge concerning mosquitoes in the area. Such inspections do not determine the absolute population of mosquitoes, but they can show fluctuations in relative mosquito abundance and diversity over time in the various habitats visited.

Mapping. Reasonably accurate and comprehensive maps are essential in conducting a mosquito control operation. Maps provide information for field survey and control activities, program evaluation, and reporting and budgeting purposes. They show elevations, streets, roads, railroads, as well as ponds, lakes, streams, sewage lagoons, flooded woodlots and other breeding areas and are used for orientation and for locating and plotting larval breeding places and adult sampling stations.

When large areas are involved, a master map may be needed for planning drainage and other field operations. The master map will indicate the control areas, the possible flight range of mosquitoes from breeding sites, and the potential degree of penetration into populated areas. Larval and adult sampling stations can be indicated by symbols and numbers. Counts made at these stations at weekly or biweekly intervals provide information for current evaluation of the mosquito problem at any time by

indicating the abundance of mosquitoes, species involved, flight range and habitat, and disease potential. This information identifies areas requiring high priority for treatment.

Narrative descriptions, sometimes necessary for exact location description, are simplified whenever possible. For example, "NW corner of 15th Street and 9th Avenue" is a brief description which leaves no doubt as to the location. There may be some areas that are difficult to accurately locate (e.g., marshlands). However, maps can be subdivided into numbered or named areas for easy reference and Global Positioning System (GPS) coordinates are very reliable. Some common methods of subdividing maps involve the utilization of geographical features, artificial grids, or a combination of both to set boundaries on areas that are indexed for easy reference and filing. To avoid cluttering, the larger areas may be further subdivided by the use of transparent overlays, again employing geographical features or a grid. Once the area of inspection is delineated by reference to index numbers, additional location data can be conveyed most clearly by the use of cards that include a rough sketch of the area or incorporated into a GIS format.

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 that 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 and 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 serves 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.

Mosquito Egg Surveys

Egg surveys are carried out primarily to determine the exact breeding locations of mosquitoes. *Aedes* and *Psorophora* mosquitoes lay their eggs on damp soil in places subject to intermittent flooding. Two types of egg surveys may be conducted for these genera: sod sampling and egg separation.

Sod sampling. Sod samples, usually containing 8 square inches of soil and vegetation, are trimmed to a thickness of about an inch and stored for a week or more to allow the embryos time to develop within the eggs. The sod samples are then placed in glass jars and flooded with water and the larvae are identified after they hatch - which might require several sequential floodings and dryings to get sufficient cumulative hatch. In larval surveys,



sod sampling delineates breeding areas, especially when sampling is done during times when breeding is not occurring.

Egg separation. Egg separation machines can be used for separating mosquito eggs from soil and debris by mechanical agitation, washing, screening, or sedimentation of debris and flotation of the eggs in saturated salt solution. Sod or soil samples are cut in the field with a sharp trowel around a 6 inches square template, placed in plastic bags and stored (sometimes for months) in a cool room. The various species and densities of *Aedes* and *Psorophora* can be identified by microscopic examination of live or preserved eggs using taxonomic keys for mosquito eggs.

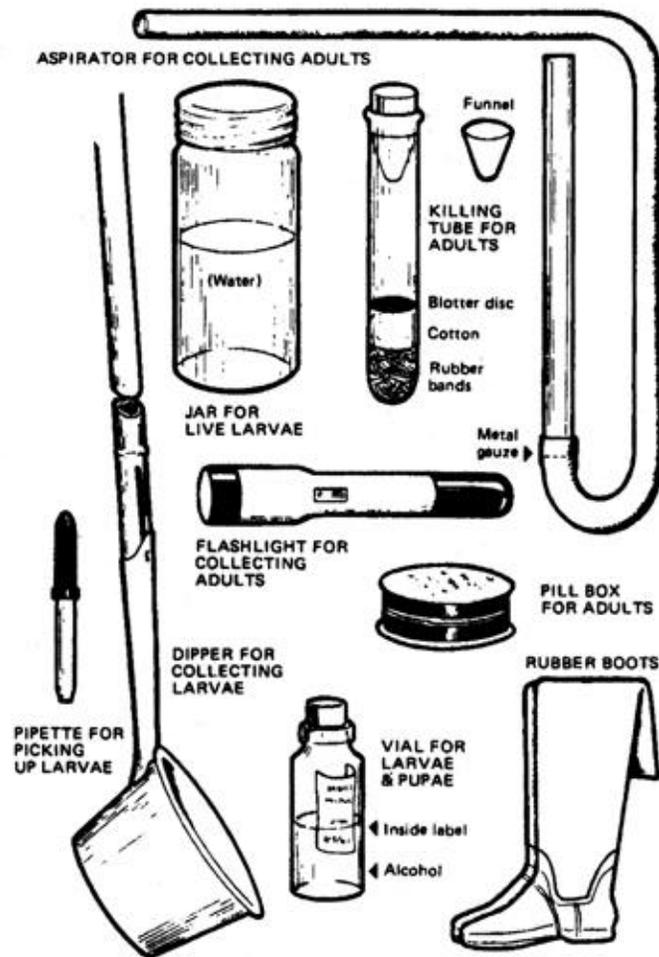
Oviposition trap. Collections of mosquito eggs in oviposition traps are used to detect and monitor container-breeding mosquitoes such as *Ae. triseriatus*, *Ae. aegypti* and *Ae. albopictus*. The oviposition trap can easily be made out of food cans (#10, 3 lb coffee cans) or pint jars painted black inside and outside. The traps are placed in shaded areas at a height no greater than 1.2 m and filled with water and a few dried leaves placed at the bottom of the container. An oviposition substrate made of a strip of various materials (seed germination paper, muslin, formica, balsa wood, wooden tongue depressor, etc.) is then placed vertically inside the container with the water covering about half of it. Gravid females use this substrate to lay eggs just above the water level. Traps are checked every 10 to 14 days to prevent them from becoming breeding sources. If larvae are found in the trap then the water should be dumped and the trap reset. The ovipositional substrate is periodically collected and returned to the laboratory in ziplock bags. Samples are kept cool and moist during transportation, taking care to avoid too much moisture which could cause eggs to begin hatching. Eggs or the resulting 4th instar larvae are then identified.

Larval and Pupal Surveillance

Before beginning a survey, obtain information about the general breeding behavior and habitats of the species known or suspected to be in the area. An experienced person may be able to spot the probable mosquito breeding places in a specific area by rapid reconnaissance. These areas are carefully numbered and marked on the map. To determine the specific breeding sites and establish permanent larval sampling stations requires a more detailed inspection. Larval surveys to determine the exact areas in which the mosquitoes breed and their relative abundance are of special value in control operations.

Equipment. A white enameled or plastic dipper about 4 inches in diameter (1 pint or 350 ml capacity) is frequently used for collecting mosquito larvae. The handle of the dipper may be extended to a convenient length by inserting a suitable piece of wood dowel or PVC pipe. Specially designed dippers can be created so that their capacity can be directly related to the amount of water surface examined. Thus, the number of larvae per square foot or meter can be computed with reasonable accuracy.

Dip procedure. 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 casting 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. The stroke is ended just before the dipper is full since larvae will be lost if the dipper is filled to the point that it runs over. Where clumps of erect vegetation are present, it is best to press the dipper into a clump with one edge depressed so that the water flows from the vegetation into the dipper. Culicine larvae such as *Ae. vexans* or *Ae. sollicitans* or species of *Psorophora* are less likely to be oriented to an edge and thus require a quicker, chopping motion of the dipper as they are more likely to dive below the surface when disturbed.



The inspector records the number of dips made and the number of larvae found, by instar if warranted, and transfers specimens by pipette to small vials of alcohol for later identification. It is possible to get a rough idea of the breeding activity by computing the average number of larvae of each species per dip. The number of dips required will depend on the size of the area and the relative larval density, but for convenience is often in multiples of ten. Inspection should be made at weekly or bi-weekly intervals during the mosquito breeding season, as areas that are entirely negative at one time may rapidly become heavily infested.

Inspections for certain species require variations in the procedure described above. For example, *Coquillettidia* larvae remain below the surface throughout much of their development attached by the siphon to the stems of emergent vegetation. These larvae are found by pulling up aquatic plants (cattail,

sedges, pickerelweed, etc.), washing or shaking them in a pan of water, and searching the bottom muck and debris.

Inspection for *Ae. triseriatus*, *Ae. sierrensis*, etc., breeders involves searching tree holes and artificial containers, such as tires. These containers are often too small for an ordinary dipper, but water can be siphoned into a dipper or pan where the larvae can be seen.

Adult Surveillance

Adult mosquito surveillance permits evaluation of the incidence of mosquitoes within residential areas where they might bite people, and shows the relative abundance of various species. Using this information and reference material in relation to breeding sites and habits of the resident species, vector control specialists can determine the need for a control program and conduct an effective search for larval breeding places. Interpreting these observations provides also the justification for applying or withholding control measures.

Landing and biting collections. The required equipment for this method of adult mosquito survey is simple and inexpensive and consists of an ethyl acetate-charged collecting tube or power aspirator, pill boxes, cages for live collections, field record forms or notebook, pencil, flashlight and map. Although most districts use battery operated mechanical aspirators, a simple mouth suction aspirator can be made from a section of plastic (or glass) tubing 12 inches long with an inside diameter of about 5/8 of an inch. Cover one end of the tube with a bobbinet or fine wire screening and then insert it into a piece of rubber tubing two to three feet long. Small pill or salve boxes are convenient for holding dead mosquitoes until they can be identified. A wisp of crumpled soft tissue or lens paper will prevent subsequent damage to the specimens.

Collecting mosquitoes as they bite or land on the surveyor's body is a convenient method of sampling populations. While the subject sits quietly for a designated period of time, usually five to 10 minutes, collect the mosquitoes with an aspirator and place them in the collection jar for later identification. It is customary to make landing collections near sundown as this crepuscular period is the most active time for most mosquitoes. Some individuals are more attractive to mosquitoes than others, so the same person or bait animal might be used throughout a certain survey series. Make collections at about the same time of day and for the same duration, so that activity rates at different stations may be compared to show trends in mosquito populations. In areas where mosquito-borne disease occurs, landing rates are preferable to biting rates.

Insect sweep net collection. Use insect nets to collect mosquitoes from grass and other vegetation. This type of collection is valuable in determining species that rest in these habitats during the

daytime, such as *Ae. vexans* and *Ae. sollicitans*. Power vacuum collectors or aspirators perform the same function.

Bait trap collections. When other collection methods are inadequate, animal baited traps, alone or with dry ice, can be used to trap mosquitoes. Make a portable mosquito bait trap utilizing this principle from a 12-inch lard can or bucket with inwardly directed screen funnels and baited with young chickens, pheasants, house sparrows, other birds or about 2 to 3 lb of dry ice wrapped in newspaper. Commercial traps are available that convert propane into carbon dioxide to achieve similar attraction.

Truck trap collections. Some organized mosquito control districts use the basic truck trap, which consists of a large funnel-shaped frame covered with screen and mounted over the roof of a light truck with the large end forward. When driven at low speed (10 - 15 mph) for a fixed distance, mosquitoes caught in the collection bag represent a reasonably unbiased sample in terms of variables in attraction.



Daytime resting collection. Adults of most mosquito species are inactive during the day, resting quietly in dark, cool, humid places. Although fairly labor intensive, careful inspection of daytime shelters can give an indication of the population density of these mosquitoes. This method is especially useful for anopheline mosquitoes and is commonly used for *An. quadrimaculatus* spp. complex. It is also helpful in estimating populations of some culicines such as *Cx. pipens*. Because this method does not rely on host-seeking behavior, it is considered to be less biased than others that may be selective for mosquitoes in certain physiological stages. Natural resting stations include houses, stables, chicken houses, privies, culverts, bridges, caves, hollow trees, and overhanging banks along streams.

A few species of mosquitoes (e.g., *Anopheles* spp.) can be sampled using artificial resting stations such as the red box shelter, which is a 1 x 1 x 1 foot, wooden box with one side open, painted flat black on the outside and red on the inside. Such stations are placed near the suspected breeding places in shaded, humid locations, normally on the ground not facing easterly. Mosquitoes enter the shelters at dawn, probably in response to change in light intensity and humidity, and ordinarily do not leave until dusk.

Light trap collections. Light attracts many mosquito species, making it possible to utilize this response for sampling adult populations between dusk and dawn. Mosquito light traps attract adults from a considerable distance when they are placed in locations remote from competing light sources. To make the trap even more attractive, place a 2 lb block of dry ice wrapped in newspaper above the trap. The trap should be located 30 or more feet from buildings in open areas near trees and shrubs and away from

other lights, areas open to strong winds or industrial plants giving off smoke or gas. Moonlight may reduce the effectiveness of the traps. The light should be 5.5 to 6 feet above the ground when mounted on a post or hung from a tree. The trap can be operated on a regular schedule from one to seven nights per week, being turned on just before dark and turned off after daylight. Remove the collection each morning for sorting and identification.

The New Jersey mosquito light trap has been widely used in obtaining data on the density and species composition of mosquito populations. It is powered by 110v ac and is placed near a continuous supply of power.

The battery-operated Centers for Disease Control (CDC) Miniature Light Trap was developed for portability to conduct live mosquito catches in remote areas where standard electric power is not available. As the mosquitoes respond to the attractants they are blown downward through a screen funnel into a killing jar or a mesh bag suspended below the trap. It collects a high percentage of mosquitoes in proportion to other insects and many more females than male specimens, a desirable feature in collecting mosquitoes for virus studies. You can also use the EVS or black can light trap developed by California State Health Department personnel.



Different species of mosquitoes have wide differences in their reactions of to light. Light trap collections are often used to complement other methods of sampling mosquito populations. These traps can be converted to monitor densities of mosquitoes not attracted to light by removing the light and using only carbon dioxide as the attractant. With light as an attractant these traps have proven very useful in measuring densities of some of the culicine mosquitoes, such as *Ae. sollicitans*, *Ae. vexans*, and *Cq. perturbans*. Some anophelines, especially *An. walkeri*, are also readily taken in light traps. The use of carbon dioxide only as a attractant collects large densities of *Ae. canadensis*, *Ae. fitchii*, *Ae. stimulans* and *Ae. intrudens*. However, members of the *An. quadrimaculatus* and *Cx. pipiens* species complexes, and *Ae. aegypti* are seldom taken in significant numbers. Light trap collections may fluctuate with the dark and bright phases of the moon, being greatest during the dark phases. The effect of moonlight can be offset to some extent by placing traps in locations shaded from the moon.

Gravid trap collections This trap has proven to be very effective in capturing large numbers of undamaged gravid *Culex* mosquitoes. Gravid traps can easily be built, are light weight, portable and run on one 6 volt gel cell rechargeable battery. One gallon of attractant (infusions made from grass, rabbit pellets, manure, etc.) placed in a black tray draws gravid females to the trap to oviposit. While flying above the attractant's surface, the mosquitoes are drawn into the collection chamber by an air current

created by a motorized fan. The mosquitoes are captured live and then can be used for virus isolation studies or species density information.

Using Mosquito Survey Data

Data from the preliminary reconnaissance surveys are correlated with reported disease prevalence or complaints of pest mosquitoes. But it is only after reviewing all of this information that the health office or mosquito control supervisor can make an intelligent decision as to the need for a control program and the type of control operations which will be most effective and economical.

Inspections that have been continued routinely once a mosquito control project is under way are used to evaluate progress. Success or failure of a mosquito control project cannot be measured in terms of the number of feet of ditches constructed or the number of gallons of insecticides used. While these statistics may be useful for some purposes, it is the actual density of mosquito populations that is significant. If the density is reduced to a satisfactory level, the routine surveys will reflect this reduction and document the accomplishment. On the other hand, if mosquito populations remain high, these results will spur intensified efforts to obtain the desired level of control. Additionally, for comparison, it is advisable to inspect some comparable (untreated) breeding areas at regular intervals to determine the normal fluctuation of various species throughout the season.

The correlation between mosquito annoyance and numbers captured in light traps has been established in many localities. In one state, for example, it was determined that general annoyance did not ordinarily occur until the number of female mosquitoes of all species exceeded 24 per trap per night. Similar criteria can be worked out for other areas and also for various species. Meaningful action thresholds can provide justification for application decisions.

Counts of mosquito larvae are a bit more difficult to correlate with pest problems or disease hazards. However, larval surveys reveal the specific sources of mosquito production. This information is invaluable to the control supervisor who can then apply effective larvicides to the right places at the right times to keep adult mosquito populations below disease vectoring or annoyance levels. Data over a period of time may also serve to justify the use of permanent control measures, such as source reduction. Expensive operations, such as filling and draining, should be undertaken only when careful inspection of each area has shown its role in the production of the vector or pest species that are important in the locality.

Arbovirus Surveillance in Vertebrate Hosts

Effectiveness of mosquito control programs where mosquito-borne diseases are a concern clearly depend upon early detection of disease and prompt and skilled response. Enzyme-linked immunosorbent

assay (ELISA) and polymerase chain reaction (PCR) methodology for testing reservoir bloods for SLE, EEE and other arboviruses give results fairly quickly. Surveillance methods leading to such tests include: frequent communication with other mosquito-control workers, health-care workers, and veterinarians; collecting and bleeding wild birds; and, use of sentinel flocks of chickens, quail, or pheasants.

Communicating with other professionals. State arbovirus surveillance committees maintain frequent contact with public health and veterinary laboratories to collect and report information on mosquito-borne arbovirus activity. In addition, mosquito-control personnel keep in touch with local health-care personnel and veterinarians about indications of arbovirus activity in the area. If cases are suspected, that information is passed along. It is important to note that not all cases of encephalitis are mosquito-borne. Caution must be exercised in reacting to initial reports, and appropriate agencies need to work closely to get laboratory confirmation of suspected cases.

Sampling Wild Bird Populations. Pesticide applicators may be required to collect blood from birds on a regular basis. If a wild bird is infected with a mosquito-borne virus, the serology results will be positive. However, the positive result does not indicate the time of exposure. Therefore, information from yearlings or birds which previously tested negative is much more informative. Young birds can be taken from the nest, bled, and returned to the nest. Bleeding nestling birds has some advantages, but timing is critical and care must be taken not to injure the young birds. Sampling personnel must also ensure that the adult birds do not abandon the nestlings after they have been bled. An obvious advantage to bleeding nestling birds is that the age and travel history of the nestling is known, and, therefore, a positive result can be tied to a very narrow time frame and specific geographical location.

Use mist nets, baited traps or cannon nets to capture juvenile and adult birds alive. For special studies, birds can be shot. The appropriate state and federal permits are required before collecting birds with any of these methods. Furthermore, banding permits are required if one wishes to band birds before they are released.

Mist nets. Mist nets are perhaps the most common means of collecting wild birds. The most popular nets are about 40 feet long and 7 feet high, commonly supported by metal poles and suspended 4 to 5 feet above the ground. These nets are made of materials which are difficult to see, causing the birds to become entangled in the fibers. The mosquito control worker can then remove the birds, draw blood samples, and release them at the site. Some districts band some or all of the birds prior to release.

Baited Traps. Bait-traps are especially useful in trapping sparrows, grackles, doves, quail, and pigeons. The bait (grain, seed or both) is scattered around the trap to attract birds. Additional bait is

placed in the trap to lure the birds inside to get to the bait. Bait-traps are usually equipped with large hinged openings so that the trapped birds can be removed easily. Elevated bait-traps, which may be more attractive to some species of birds, are used where cats or other predators pose a threat.

Cannon nets. These devices are used to collect large numbers of blackbirds, pigeons, ducks, cowbirds, and other birds that travel and feed in large flocks. They are the only realistic way to capture some species alive. The cannon net is designed so that one edge is anchored to the ground and the other is attached to rocket projectiles that carry the net over feeding birds. Because cannon nets are expensive and require several people to remove birds quickly to avoid injuring them, this is are probably the least-used trap method.

Shooting. This expensive and time-consuming method is available when other methods are inadequate. The collector must purchase the appropriate hunting licenses. Furthermore, all game laws must be obeyed and collections can only be made during regular hunting seasons. In addition, since the birds (usually waterfowl) are killed, non-specific blood reactions could interfere with antibody-testing. Although this technique may yield valuable information, especially on the overwintering of viruses, it is used sparingly.

Sentinel flocks. Chickens, quail, pheasant or other birds are retained in outdoor cages in specific sampling areas and bled periodically to monitor arbovirus activity. These sentinel birds are raised in a mosquito-free environment and tested prior to placement in to ensure that they have not been exposed to arboviral activity elsewhere. If the sentinel bird tests positive after being placed in an area, it is a sure sign of arbovirus activity in the area. A supply of unexposed birds should be readily available to replace those that become infected. To adequately sample large areas requires numerous sentinel flocks, so this method can be costly.

Monitoring other animals. Monitoring selected amphibians, mammals and reptiles that have been shown to circulate arboviruses or form antibodies after virus exposure is sometimes practical. When the overwintering mechanisms for the viruses, the importance of these animals as reservoirs, and the bionomics of the viruses are clearly understood, they will become an important source of information.

Blood Collection

Field procedures. Quickly remove wild birds from nets and bait-traps to minimize the risk of injury and place them directly into holding cages. Bleed them one at a time. Take a blood sample from the large vein in the neck (jugular) or wing, mix it with diluent in a properly-labeled vial and store in an ice chest. Then release the unharmed bird. The appropriate collection data includes: date and location;

species, sex, and age of the bird; state laboratory number; band number (if applicable); name of the collector and any other relevant information.

Laboratory procedures. The vials containing blood and diluent are spun in a centrifuge until the serum has properly separated from the blood cells. The serum is then transferred to a clean, properly-labeled vial and refrigerated at 33 to 40 degrees F until it is ready for shipment to the testing laboratory in a watertight container packed with ice (not dry ice).

Arbovirus Surveillance in Mosquitoes

Perhaps the best early-warning method available is the isolation of virus from wild mosquitoes. Since female mosquitoes must feed on an infected animal before they can pick up the virus, collect female mosquitoes that have had at least one blood meal - as indicated by an abdomen engorged with fresh or partially digested blood meals or containing eggs. There are a number of sampling methods and procedures that will help to increase the ratio of engorged and gravid *Culex*, but this is more difficult with *Aedes*, *Anopheles*, *Culiseta*, *Coquillettidia* or *Psorophora*. Aspirate *Culex* from dark closets, cabinets, or other areas of abandoned homes and vacant buildings, whose open windows or doors are attractive to *Culex* mosquitoes seeking places to rest during the day. If the buildings are sampled on a regular basis the mosquitoes collected probably will have fed on a variety of hosts. Gravid traps are also useful for collecting gravid specimens of adult *Culex* as well.

Light traps and carbon dioxide-enhanced traps can be used effectively in wooded areas, storm drains, catch basins, manholes, tire piles, etc., but they tend to collect many mosquitoes that have not had a blood meal. Resting boxes can be used to collect some important vector species (e.g., anophelines), but they do not necessarily bias the collection toward gravid or engorged females, and they do not normally collect large numbers of mosquitoes.

Transporting mosquitoes. Store live mosquitoes in a cool, moist container, and identify and pool them as soon as possible. An ice chest containing a small amount of ice (not dry ice) is ideal for transporting mosquitoes, taking care that the mosquitoes do not get wet during shipment.

Holding, identifying and pooling collections. Once in the laboratory, mosquito collections may be refrigerated or frozen, but should not be left outside the refrigerator for extended periods of time during identification. Mosquitoes from each collection are identified separately and a fixed number, usually 50 of the same species, placed in a properly labeled container for shipping to the laboratory in the same manner as bird bloods. Use a chill table to identify, sort and pool adult mosquito samples to keep specimens cool and preserve viruses that might be present in them

IV. CONTROL

While it is not possible to provide a concise, generic overview of all mosquito control programs in the United States, there are certain components that virtually all operational programs include as they are inherent to the principles and practices of Integrated Pest Management (IPM). Traditionally an overriding concept in organized mosquito control, the IPM acronym was not used in this sense a century ago when mosquito control was in its infancy. Typical IPM programs use a combination of resource management techniques that include source reduction, habitat modification, biocontrol, larviciding and adulticiding all based on surveillance data as to need and timing of application. Continuing education, for both employees and the general public, is also an important component of most mosquito control programs. This has resulted in a better informed public and increased professionalism among mosquito control workers where significant progress has been made in attempting to reduce pesticide use and risk.

An important consideration in the practice of mosquito control is the advisability, whenever possible, to target control operations against immature populations. These stages are usually concentrated, relatively immobile and therefore occupy minimum acreage compared to adults, which may rapidly disperse over large areas. By targeting the immatures, it is possible to minimize the area treated and often avoid treating populated areas. Conversely, targeting adult mosquitoes requires highly visible and extensive applications of adulticides within residential and urban areas. Although the adulticides registered for this use are safe, when used according to the label, achieving good larval control and at the same time minimizing the use of adulticides is environmentally and client friendly, and appreciated by the public.

Most states have specific regulations governing the decision to apply pesticides for mosquito control. These usually involve the collection of data that substantiates the need for the application. Thus, standardized ULV operation on a fixed schedule is not allowed in most areas. Each application must be justified by documentation of increased mosquito activity, such as trap collections, landing or biting counts, telephone complaints, etc. This documentation must be available for inspection upon demand.

The use of pesticides for mosquito control is considered a temporary form of control. Since it is unreasonable to expect to completely eliminate the next generation by treating the current generation, the process may have to be repeated time and again. This is true for chemical treatment of both immature and adult populations of mosquitoes. The need for this type of temporary control can be reduced by implementing permanent control measures whenever and wherever possible. Permanent control measures are discussed in the next section - source reduction. They include land and water management approaches that prevent breeding. Where successful, they can be permanent in nature - perhaps requiring

limited maintenance from time to time. Although this activity may escape the attention of the public, it is extremely effective in easing the management burden of protecting the public from mosquitoes.

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 often 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.

Sanitation. Containers of all types, man-made structures such as cisterns, roof gutters and discarded tires are capable of producing prodigious numbers of mosquitoes, including species that can transmit several mosquito-transmitted pathogens. Removal of debris and regular inspection, when conducted on a continuous basis, 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 homesites (peridomestic). Mosquito control agencies support educational programs that call attention to the hazards and recommend individual effort on residential area cleanup.

Water management. Prevention of breeding can be accomplished by removing surface waters from productive sites to reduce oviposition, manipulating shoreline water levels, or flooding areas in which mosquitos oviposit in the soil. These approaches have been used for decades and involve ditching, diking, daily water management manipulating, and retrofitting of catch basins and storm drains to manage the aquatic habitat. Experience has demonstrated this can be harmful to the ecology of the affected habitats if practiced without due concern for the long term consequences of habitat manipulation. Therefore, permits are required to initiate new projects of this nature, but in many areas maintenance of existing schemes is allowed without permits.

An excellent example of this 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 ovipositional opportunities for the salt marsh mosquito on the impounded marsh and effectively reduces their populations. 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 flapgated culverts to re-connect 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 stormwater runoff or rainfall can create freshwater mosquito breeding problems in 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 whereby 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 ft 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 impacts occur to the marsh.

Larvicides

The application of chemicals to kill immature mosquitoes by ground or aerial applications is typically more effective and target specific than adulticiding, yet less permanent than source reduction. Several materials in various formulations are labeled for mosquito larviciding, including some biorational pesticides: the diptera-specific bacteria *Bacillus thuringiensis israelensis* (*Bti*) and *Bacillus sphaericus*; the insect growth regulator methoprene (IGR, Altosid®) and the chitin synthesis inhibitor diflubenzuron (Dimilin®). Also labeled for mosquito control are the organophosphate temephos (Abate®), several oils (petroleum based Golden Bear® and mineral based Bonide®), a monomolecular film (Agnique®), and natural pyrethrins.

The timing of larvicide application is dependent on the nature of the control agent. Temephos, for example, kills larvae at all stages and thus can be applied when convenient. Bacteria must be consumed by the larvae and are usually applied well before the 4th instar to ensure that consumption occurs. The IGR, methoprene, mimics an essential hormone present in high concentration in early instar larvae but in very low concentration in 4th instar larvae. Exposure of 4th instar larvae to methoprene upsets the physiological molting process and kills mosquitoes in the subsequent pupal stage. Altosid is formulated as a slow release insecticide so that application in the 2nd or 3rd instar will result in an adequate concentration of methoprene during the 4th instar. Diflubenzuron affects the ability of the larvae to reattach their muscles to the exoskeleton during the molting process and thus is effective throughout the entire larval life. Monomolecular films, such as Agnique, prevent the insect from remaining at the surface of the water by reducing surface tension. Under these conditions larvae of all stages and pupae deplete their energy reserves trying to stay at the surface and succumb to exhaustion.

The oils kill larvae and pupae by suffocation, because the insect is not able to obtain air through the siphon at the oily surface.

Thus, each larvicide has very specific applications and may be more effective against one species or group than another. Each label (the law when using pesticides) is different and special attention must be given to a full understanding of the provisions of the label for each chemical being considered for use in mosquito control programs. The label prescribes application methods and rates, habitat restrictions, personal and environmental exposure limits, etc. Pesticide applicators must be knowledgeable of the label contents and abide by the label.

Important characteristics for larvicides include specificity for mosquitoes, minimal impact on non-target organisms and, in many instances, ability to penetrate dense vegetative canopy. Larvicide formulations (e.g., liquid, granular, solid) must be accurately applied and appropriate to the habitat being treated. Larvicidal applications, when based on accurate surveillance data are an important component of an integrated mosquito control operation. Accuracy of application coverage is important, as failure to expose even a relatively small portion of a breeding area can result in the emergence of a large mosquito brood and lead to the need for immediate broad-scale adulticiding.

Adulticides

The ground or aerial application of chemicals to kill adult mosquitoes is usually the least efficient mosquito control technique and is considered the last resort in managing mosquito populations that have reached the adult stage in spite of efforts to intervene in the larval stage. The tendency of poorly funded or misguided mosquito control organizations to use only adulticiding and bypass the other, often more effective options available, conflicts directly with accepted practice. Nevertheless, adulticiding, when based on concurrent surveillance data, is an extremely important part of the IPM approach when undertaken with the appropriate label amount of insecticide. 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. Ground or aerially applied thermal application of adulticides is also used in some areas but to a much lesser degree.

Mosquito adulticiding with ULV application differs fundamentally from efforts to control many other adult insects. For good adult mosquito control, the fine ULV droplets (high concentration) must drift through the habitat and impinge on flying mosquitoes in order to provide optimal control benefits. The technique lends itself to the criticism that non-target organisms can be impacted by these control measures. While this is a constant consideration for control programs, especially those relying heavily on aerial adulticiding, experience demonstrates that when applied according to the label (the law) these

adulticides have minimal effect on non-target organisms and provide important benefits to the local economy and health of residents.

Barrier treatments, typically applied as high volume (low concentration) liquids with hand-held spray equipment using compounds with residual characteristics, are common in some U.S. locations and their use is growing. This technique is especially attractive to individual homeowners living near mosquito producing habitats where residual chemicals applied to the vegetation along property borders can provide relief to the residents.

Space sprays, generated by portable ULV equipment, often is used to provide indoor mosquito control in houses, tents, trailers, warehouses, etc., with. For small enclosures, commercial aerosol (bug bomb) applications are also highly effective. These applications require close review of the label to ensure the safety of inhabitants and pets when they re-enter after completion of the application. This technique relies on the movement of fine droplets throughout the enclosed space in order to impinge on the mosquitoes. Alternatively, in certain circumstances residual applications of insecticides are placed on interior walls to kill mosquitoes that subsequently rest on the treated surfaces. Residual treatments, common overseas, are not routinely used in the United States for mosquito control but some pesticides are labeled for this usage.

Adulticides labeled for mosquito control include several organophosphates - malathion, naled, chlorpyrifos and fenthion. Some natural pyrethrins, synthetic pyrethroids (permethrin, resmethrin and sumithrin) and a carbamate (bendiocarb) also are registered for this use. As with other pesticides, the specific attributes and methods of use for adulticides are listed on the label. It is incumbent on the pesticide applicator to perform as directed by the label (it is the law).

Biological Control

Biocontrol is the use of biological organisms to control pests, in this case insect pests. Biocontrol is popular in theory because of its potential to be host-specific with virtually no non-target effects. Overall, larvivorous fish are the most extensively used biocontrol agent for mosquito control. Predacious 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. Other biocontrol agents have been tested for use by mosquito control but to date have not generally been operationally feasible. These include the predacious mosquito *Toxorhynchites*, predacious copepods, the parasitic nematode *Romanomermis* and the fungus *Laegenidium giganteum*. Biocontrol certainly holds the possibility of becoming a more important tool and playing a larger role in mosquito control in the future when improved technology and more attractive economics may enhance their usefulness.

By-products of biological control agents are marketed as biorational pesticides for mosquito control. These products include dead bacterial spores that are highly toxic to mosquito larvae and a few other aquatic dipteran species, but innocuous to non-target organisms. While not biological agents *per se*, these products and the physiologically effective insect growth regulators have been instrumental in creating environmentally friendly options for control of larval mosquito populations.

Personal Protection

The public and the pesticide applicator 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 crepuscular periods at sunset and dawn. This is a time of day when attractiveness to mosquitos 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 light colored clothing which is less attractive to mosquitoes, and long sleeves and apply a repellent to the exposed skin - carefully following the manufacturer's directions on the label - remember the label is the law. Remove water-holding containers from the yard, clean roof gutters and use other physical means to reduce peridomestic breeding at home. Avoid known mosquito habitats, if possible, and keep personal exposure to a minimum. In the United States residents are fortunate that mosquito-borne disease transmission to humans is relatively rare, and infected persons often do not have overt symptoms. Thousands of infections could, theoretically, occur annually without causing clinical symptoms, but in a low percentage of cases infection can lead to disease. So, prudence is the watchword. Personal protection is a means to reduce the probability of infection.

There are other reasons for the relatively low incidence of human involvement with mosquito-borne diseases in the United States. But we often overlook the obvious by building homes at the margins of wetlands, thereby multiplying the probability of mosquito encounter and with it - infection. Yet, affordable housing, proper screening, indoor plumbing, air conditioning and television all contribute to reducing human exposure to mosquitoes even in high mosquito density areas. Societies in tropical and subtropical climates are sometimes less fortunate in terms of the physical protection from mosquitoes that are afforded by their surroundings.

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Table 3-1. Genera and important mosquito species in the United States (**Family Culicidae**).

Subfamily Anophelinae (anophelines)	
Genus <i>Anopheles</i> 17 spp.	<i>albimanus, bradleyi, crucians, franciscanus, freeborni, hermsi, psuedopunctipennis, punctipennis, quadrimaculatus spp.complex, walkeri</i>
Subfamiliae Culicinae (culicines)	
Genus <i>Aedes</i> 81 spp.	<i>aegypti, abserratus, albopictus, atlanticus, canadensis, cataphylla, cinereus, communis, deserticola, dorsalis, excrucians, fitchii, hexadontus, increpitus, monticola, nigromaculis, punctor, sierrensis, sollicitans, spencerii, sticticus, stimulans, taeniorhynchus, triseriatus, trivittatus, varipalpus, vexans</i>
Genus <i>Coquillettidia</i> 1 spp.	<i>perturbans</i>
Genus <i>Culex</i> 29 spp. & subspecies	<i>erraticus, nigripalpus, peccator, pipiens, pilosus, quinquefasciatus, restuans, salinarius, stigmatosoma, tarsalis</i>
Genus <i>Culiseta</i> 8 spp.	<i>incidens, inornata, melanura</i>
Genus <i>Deinocerites</i> 3 spp.	<i>cancer, mathesoni, pseudes</i>
Genus <i>Haemogogus</i> 1 spp.	
Genus <i>Mansonia</i> 2 spp.	<i>dyari, titillans</i>
Genus <i>Orthopodomyia</i> 3 spp.	<i>signifera, alba</i>
Genus <i>Psorophora</i> 15 spp.	<i>ciliata, columbiae, cyanescens, ferox, signipennis</i>
Genus <i>Toxorhynchites</i> 2 subspecies	
Genus <i>Uranotaenia</i> 3 spp. & subspecies	<i>sappharina</i>
Genus <i>Wyeomyia</i> 4 spp.	<i>mitchellii</i>