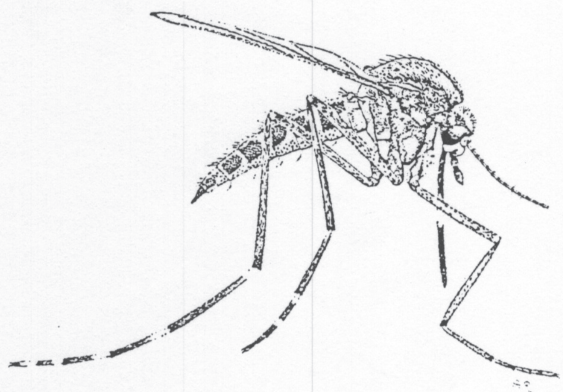
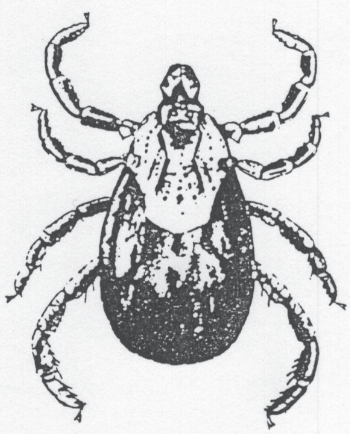
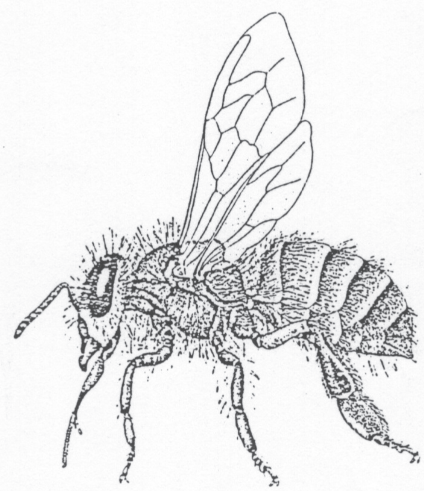
Integrated Pest Management Plan for Specified Vectors Found In San Joaquin County, California 1998





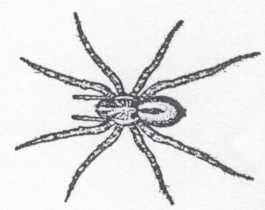


San Joaquin County
Mosquito & Vector Control
District
7759 South Airport Way
Stockton, California

Objectives

At the end of the instructional program the learner will be able to:

1. State a simple definition of IPM.
2. List the four control options used in IPM and give an example of each.
3. Diagram and explain the four-step process of implementing an IPM program.
4. List at least two reasons why pest control is important to schools.
5. Explain how IPM can reduce the need for pesticides.
6. Explain why cooperation is so important to the success of an IPM program.
7. List one thing he can do to assist with the implementation of an IPM program in his school.



Post-Test

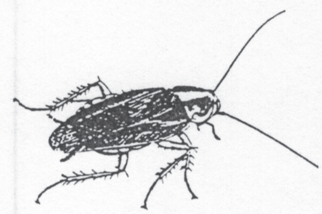
Module 1: An Introduction

Take this test after viewing the video, completing the note-taking sheets and discussing the study questions. The post-test measures mastery of the content presented. If you receive a score of less than 100 percent, we recommend that you watch the video again and retake the test.

Directions: Circle the letter corresponding to the best answer for each of the following statements.

1. IPM is an approach to managing pest problems that is:
   a. anti-chemical
   b. pesticide friendly
   c. based on biological control
   d. environmentally sensitive

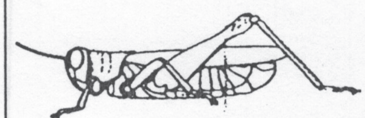
2. IPM takes advantage of the following pest control tactics:
   a. non-chemical and organic controls only
   b. sanitation, physical/mechanical controls, biological controls, and pesticides
   c. physical/mechanical controls and pesticides only
   d. all available techniques except pesticides



3. The correct order of steps in implementing an IPM program is:
   a. Identify the problem, inspect the facility, evaluate the results, and take action.
   b. Evaluate results, identify the problem, inspect the facility, and take action.
   c. Inspect the facility, identify the problem, take action, and evaluate the results.
   d. Identify the problem, inspect the facility, take action, and evaluate the results.

4. Pest control is important to schools for which of the following reasons:
   a. health and safety of students
   b. reducing structural repair costs
   c. keeping buildings and grounds looking nice
   d. all of the above

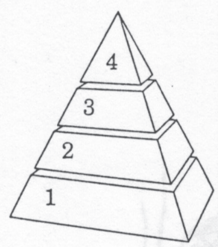
Notes



Module 1: An Introduction

Directions: Complete the blanks as you view the videotape. Use the margin to jot down additional notes or questions you may have.

1. IPM stands for Integrated pest management.
2. IPM is an environmentally sensitive approach to managing pest problems that takes advantage of all suitable pest control options.
3. IPM tries to decrease the need for chemical Control by increasing use of other methods.
4. The first step in implementing an IPM program is conducting an inspection.
5. The second step in implementing an IPM program is Identication the problem.
6. The third step in implementing an IPM program is taking Action.
7. The fourth step in implementing an IPM program is evaluate progress through on-going monitoring and communication.
8. The control options defined by the IPM pyramid are:
   1. sanitation controls
   2. Physical /mechanical controls
   3. Biological controls
   4. chemical controls



9. All pests need food, water and Hanbridgn.
10. A successful IPM program depends on Cooperation from everyone involved.
11. The fourth step in implementing an IPM program is evaluate progress through on-going monitoring and communication.
12. Three reasons pest control is important to your school are:
    a. health and Safety reasons
    b. reduction of structural Repair costs
    c. aesthetics of buildings and grounds

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Integrated Pest Management (IPM)

Integrated pest management, referred to as IPM, is ***a*** sustainable approach, or plan, to managing public health pests and vectors, by combining biological, chemical, legal, natural and physical control tactics in a way that minimizes economic, health and environmental risks. IPM can also be considered as a systematic approach to public health pest management, which combines a variety of surveillance and control practices. With regards to implementing a plan to control vectors, IPM can be defined as socially acceptable, environmentally responsible and economically practical protection of the public's health and well being.

For the purposes of this plan, a *pest* is defined as any organism that is unacceptably abundant. A *vector* is an organism (such as an insect or other arthropod) which 1) transports and transmits a parasite (including disease causing pathogens) from one host to another, 2) causes direct harm or injury without transmitting a parasite, or 3) causes significant annoyance to humans and/or animals. The words *pest* and *vector* are used interchangeably for the purposes of the District's surveillance and control plans for specific vectors.

History of IPM for vector control within the San Joaquin County Mosquito and Vector Control District

The development of integrated pest management strategies for control of certain vectors found in the District is mainly due to pesticide resistance, potential or probable effects of pesticides on non-target organisms, government regulation, and public awareness.

Pesticide resistance

Most pest and vector species have short life cycles, a wide geographic range, and large populations. Consequently, there is a substantial genetic diversity found in vector populations. When these populations are all treated with the same chemical, a few individuals are not killed because they are genetically resistant. These individuals survive to reproduce, quickly resulting in localized resistant populations, which can then spread. Consequently, higher and higher doses of chemicals are needed to control vector populations, and finally new chemicals must be developed. Then the cycle begins again, resulting in increased costs, increased amount of chemical-use, and decreasing effectiveness of products. Resistance to organochlorine and organophosphate insecticides has been found in several species of mosquitoes in San Joaquin County.

Effect(s) of pesticides on non-target organisms

An important aspect of the effects of pesticides on non-target organisms is the loss of non-pest, or beneficial organisms. Some organisms that are killed at the time of a pesticide application are actual parasites or predators of the target species. When the beneficial specie(s) population is impacted, the imbalance can then create larger outbreaks of the target specie. Other effects include groundwater contamination and wildlife kills.

Government regulation

Because of the problems associated with pesticides, there has been an increase in environmental activism, education, and regulation. Periodic modifications of the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), and the development and implementation of the Federal Environmental Pesticide Control Act (FEPCA) have restricted the reregistration and availability of many pesticides.

Public awareness

People are becoming more aware of and concerned about the effects of chemicals on our environment. The impact of the use of pesticides on drinking water and food production, as well as the impact in homes and landscapes has become a significant social concern. Many people have begun to wonder if there are ways to reduce or eliminate pesticide use in non-agricultural settings.

Important IPM plan components

The District's IPM plan includes the components of information, thresholds, and surveillance.

Information

Information is a fundamental component of the District's IPM program for two reasons. First, because an understanding of the local ecosystem and environment is essential to preventing vector problems. Second, because IPM relies upon close monitoring of vector populations in order to determine when a population has reached a public health or nuisance threshold.

Thresholds

Thresholds are developed from research that takes into account the potential public health threat caused by the presence of the vector at a known level of population and incidence of arbovirus transmission. Other information used in developing thresholds includes human and domestic animal population data, complaints and/or requests for service, weather conditions, local and state-wide arbovirus data, vector competence, vector population dynamics and control costs.

Surveillance

Surveillance is the primary method of monitoring vector populations to determine if a public health or nuisance threshold is reached. It refers to the periodic and systematic sampling of vectors in the field in order to estimate population levels. Past surveillance records and field inspection data, current and future weather conditions and other factors are used to predict the onset and severity of a vector outbreak. In some cases, monitoring of populations of beneficial organisms is performed as well.

Combining and integrating control tactics

As a concept and practice, there is an emphasis on the combination and integration of pest management tactics, such as biological control, chemical control, legal control, natural control, and physical control. Following is basic information about each type of control tactic:

Biological control

Biological control is the intentional use of natural predators, parasites or pathogens to achieve desired reductions in pest and vector population levels. The use of biological control is a primary method of control if the use of other control methods presents environmental concern and current vector populations are low or tolerable.

The use of biological control organisms and strategies is limited to those that have been researched and field tested against target and non-target organisms. In addition, any biological control organism to be considered for use by the District will also be recognized by appropriate federal, state, and local agencies.

Chemical control

Chemical control is the intentional use of specific chemical compounds (pesticides) to quickly kill a known vector population. Chemical control is performed to obtain immediate control when biological and physical control methods fail to maintain vector populations at or below a tolerable level. Chemical control is also used to prevent an epidemic of vector-borne disease when emergency control measures are needed to rapidly suppress vector populations to levels that either disrupt or terminate disease transmission to humans or domestic animals.

The use of conventional pesticides in the District's IPM program may differ from that of a "traditional" chemical-based pest control program. Under the District's IPM plan, an attempt is made to choose materials that are:

- *Only one of the many actions taken during the arbovirus or pest cycle to manage vector species.*
- *Specific, as near as possible, to the vector species.*
- *Used at the lowest effective rate.*
- *Short-lived in the environment.*
- *Be least toxic to beneficial organisms and humans.*
- *Alternated with other chemicals and techniques to help prevent resistance.*
- *Formulated, labeled and accepted for use as a vector control agent by regulatory agencies in California.*
- *Capable of being tested in a controlled environment prior to full-scale field use.*

Combining and integrating control tactics (continued)

<u>Legal control</u>

Legal control is the control of vectors through the enactment of legislation that enforces control measures or imposes regulations to prevent the production, introduction, or spread of pests and vectors. Legal control includes the use of federal, state and local guidelines and laws designed to prevent the creation and/or harborage of pests and vectors.

The District regularly enforces the California Health and Safety Code, which specifically addresses the creation and/or harborage of vectors and vector breeding sites.

<u>Natural control</u>

Natural control is a pest management strategy in which the environment is disturbed as little as possible. Reliance is placed on naturally occurring parasites, predators, and diseases to control vectors.

One scientific definition of natural control is "the maintenance of a fluctuating population density within definable upper and lower limits over a period by the combined affects of abiotic and biotic elements in the environment".

Natural control is sometimes difficult to implement or assess due to the amount of man-made or manipulated vector sources found in the District. Natural control is advocated for sites that are remote and undisturbed, to the least amount practical, for the individual vector specie being contemplated for control.

<u>Physical control</u>

Physical control, or environmental manipulation, is achieved by altering the major ecological components of the vector's environment associated with the establishment and production of the vector's immature stages. The primary operational objective of physical control is to reduce the vector carrying capacity of a site to preclude the use of control methods that would adversely impact the environment and wildlife.

The District complies with requirements, as specified, of any general permit issued to the California Department of Health Services as the lead agency, pertaining to physical environmental modification to achieve pest and vector prevention.

IPM in practice

By carefully monitoring vector populations, arbovirus activity and complaints from area residents, the District, using IPM, institutes management measures when specific conditions indicate that they are needed. In other words, the District determines how serious a problem is and what management options are available before any action is taken. This contrasts with routine, or "calendar" preventive chemical treatments, treatments performed "just in case", or treatments in response to any pest or vector presence regardless of how small the infestation or population.

Using IPM requires the District to understand the biology and ecology of locally and regionally found pests and vectors, and how different pest and vector populations develop. Additionally, the District must know what the control options are in each specific pest and vector management case, and what the return on investment of these control options is along with the potential impact on the environment and public health.

This means that the District will spend more time observing and interpreting the potential impact of pest and vector populations. The resulting benefits from reduced costs of chemical inputs, a cleaner environment, and decreased resistance problems can offset the extra work.

Quality assurance, quality control

The District utilizes quality assurance and control measures to insure that the IPM plan is administered and operated properly.

- The individual plan components of Information, Thresholds, and Surveillance are reviewed periodically to insure they are relevant and effective.
- Individual control tactics are continually evaluated with and against known and suspect vector species.
- Supervisory, management and professional staff oversees specific field operations routinely.
- District employees and contractors responsible for the administration and implementation of the IPM plan are certified by either the California Department of Health Services or Department of Pesticide Regulation in one or more areas of vector control, and receive ongoing training in current vector control and integrated pest management techniques.
- The San Joaquin County Agriculture Commissioner and California Department of Health Services routinely inspect the District's operations for compliance with local, state and federal laws and regulations.
- The District routinely evaluates materials and methods used in vector control to insure they are of high quality and effectiveness. Testing of control agents and techniques are performed in a controlled setting prior to full field implementation.
- The District is an active member of the American Mosquito Control Association and the Mosquito and Vector Control Association of California; organizations committed to the development and promotion of integrated pest management techniques for its member agencies.
- The District receives feedback from vector control service recipients and local residents regarding the level and quality of service provided. This information is received from complaints, requests for service, and other forms of communication with the public.
- The District collaborates with University of California research programs with regards to vector surveillance and control, endangered species, arbovirus detection, and integrated pest management program development.

Vector biology and control

Vector species in San Joaquin County are numerous, but only a few are considered in the District's operational surveillance and control program. Currently (1998), the District provides operational surveillance and/or control for 17 species of mosquitoes, three (3) species of ticks and two (2) species of bees.

Within San Joaquin County, mosquitoes are considered vectors because of their ability to cause annoyance and potentially transmit diseases such as encephalitis, heartworm, and malaria. Certain species of ticks are vectors of babesiosis, ehrlichiosis, and Lyme disease. Feral bees are considered a vector in certain situations when they swarm or colonize in human-use areas.

The biology of vectors is a broad subject relating to life processes, structure, physiology, behavior, environmental adaptation, population dynamics, and genetics. Individual vector behavior in the environment is discussed in further detail in the following modules on mosquitoes, ticks, and bees. Also described in the modules is biological descriptions and identification of individual species.

MODULE 1
MOSQUITOES

IPM plan for the control of mosquitoes

This section is intended to serve as basic information needed to implement the District's integrated pest management program for mosquitoes. Full consideration must be given to threatened and endangered species, natural and cultural resources, and human health and safety. Recommendations herein must be evaluated and applied in relation to these broader considerations.

Biology and identification of mosquitoes

There are five (5) genera of mosquitoes in San Joaquin County: *Aedes, Anopheles, Culex, Culiseta, and Orthomodomyia.* Within these genera, there are 17 individual mosquito species. Listed below are the individual genus and species descriptions:

Genus *Aedes* Meigen:
- *Aedes dorsalis* (Meigen) – the brackish water mosquito
- *Aedes melanimon* Dyar
- *Aedes nigromaculis* (Ludlow) – the irrigated pasture mosquito
- *Aedes sierrensis* (Ludlow) – the western tree hole mosquito
- *Aedes vexans* (Meigen) – the inland floodwater mosquito
- *Aedes washinoi* Lanzaro and Eldridge

Genus *Anopheles* Meigen:
- *Anopheles franciscanus* McCracken
- *Anopheles freeborni* Aitken – the western malaria mosquito
- *Anopheles punctipennis* (Say) – the woodland malaria mosquito

Genus *Culex* Linnaeus:
- *Culex erythrothorax* Dyar – the tule mosquito
- *Culex pipiens* Linnaeus – the northern house mosquito
- *Culex stigmatosoma* Dyar – the banded foul water mosquito
- *Culex tarsalis* Coquillett – the western encephalitis mosquito

Genus *Culiseta* Felt:
- *Culiseta incidens* (Thompson) – the cool weather mosquito
- *Culiseta inornata* (Williston) – the large winter mosquito
- *Culiseta particeps* (Adams)

Genus *Orthopodomyia* Theobald:
- *Orthopodomyia signifera* (Coquillett)

General information

Mosquitoes present both a pest and public health problem for humans and domestic animals within San Joaquin County. Several locally found species are involved in the transmission of important pathogens, including western equine encephalitis (WEE), St. Louis encephalitis (SLE), malaria, and canine heartworm. Other species, although not involved with direct transmission of pathogens, create annoyance and discomfort to humans and animals. Additionally, mosquitoes can create economic losses, due to weight loss in livestock, loss of recreation opportunities, medical costs due to disease, and reduced real estate values.

Because mosquitoes breed in aquatic sites, these locations are considered the primary surveillance area for their immature stages, and thus are targeted as the preferred mosquito control zone. Adult mosquitoes will migrate from the site where they emerged from their immature stage for the purpose of seeking a blood meal, mating, laying eggs, and completing their life cycle.

Benefits and risks of mosquito control

Benefits - mosquito control for pest species

A benefit of mosquito control which has greatly contributed to San Joaquin County's growth and prosperity is the tremendous progress made in controlling pestiferous mosquito species, especially those that breed in irrigated agricultural sources, industrial and municipal waste sites, and more recently, in areas used as environmental habitat and seasonal wetlands. Although some of these mosquito species do not always present an acute threat of arbovirus transmission to humans, they significantly affect human comfort, animal health, and the local economy. The fact that much development occurs near mosquito producing and environmentally sensitive habitats puts increasing pressure on the District to maintain an effective control program.

Benefits - mosquito control for disease vectors

The most important benefit of mosquito control is the targeting of mosquito species that transmit mosquito-borne diseases.

San Joaquin County is considered an endemic area for WEE, and has experienced several outbreaks of the disease in both humans and animals since 1930. The primary vector of WEE and SLE is the encephalitis mosquito *Culex tarsalis,* which is found throughout the District and all adjacent counties. In 1930 and 1931, there were approximately 170 cases of encephalomyelitis in horses and mules. Between 1939 and 1941, there were five (5) human cases of WEE reported. During the period 1945 to 1950, San Joaquin County experienced 22 human cases of WEE and 11 human cases of SLE. Another disease outbreak in 1952 resulted in 48 cases of WEE and three (3) cases of SLE in humans. Human cases of encephalitis during the period 1945 to 1984 for San Joaquin County totaled 80 for WEE and 36 for SLE. Finally, WEE virus has been detected in sentinel chicken flocks and adult mosquito pools for the last five (5) years (1993 – 1997).

Imported cases of human malaria are reported to the District regularly by San Joaquin County Public Health Services. The malaria vector, *Anopheles freeborni*, is found throughout the District and in most adjacent counties.

The western tree hole mosquito, *Aedes sierrensis* is the primary vector of canine heartworm, and is found throughout most of San Joaquin County and several adjacent counties. Canine heartworm, *Dirofilaria immittis,* is endemic to the Central Valley and adjacent Sierra Nevada mountain range.

Risks - human health concerns

A consideration associated with the overall use of pesticides, of which mosquito control is a part, is the potential human health risk of pesticide exposure. In the last several years, more evidence has been evaluated concerning the impact on humans from a half-century of exposure to synthetic chemicals and other environmental contaminants. Human health problems associated with the affects of severe exposure to organophosphate pesticides include irreversible neurological defects, memory loss, mood changes, infertility, and disorientation. However, this is an example of chemical misuse, not a result of mosquito control applications.

Benefits and risks of mosquito control (continued)

Idiopathic Environmental Intolerance (IEI), often referred to as multiple chemical sensitivity, is now a recognized medical phenomenon. As much as 10% of the U.S. population could be described as having some degree of IEI. However, as yet there is no clinical medical test to demonstrate pesticide sensitivity. There is no reason to doubt that IEI individuals can become ill from mosquito control spraying. Thus, mosquito control operations are potential targets for disputes with chemically sensitive individuals. IEI persons typically become ill following exposure to irritating agent(s). It is unknown whether this illness is physiological, psychological, or both.

Chemical trespass

The concept of chemical trespass (i.e., applying chemicals to an individual or their property against their wishes) is a very sensitive and sometimes controversial issue. However, statutory law permits the applications of mosquito control chemicals in the public domain. The potential for conflict is obvious, and this has been the basis for some claims in the past (e.g., beekeepers, organic growers).

Adulticide drift in particular invites claims of chemical trespass. Most agricultural and structural pest control pesticide labels specify minimal or no drift, yet, in certain situations, mosquito control technicians realize that effective control is achieved when there is drift. Adulticides, when applied with ultra-low-volume (ULV) sprayers, have been shown to drift beyond the primary target zone. Ecologically sensitive "No Spray Areas", as well as other sites, are candidates for inadvertent drift. Such data suggest the need for buffer areas around no spray zones and careful attention to meteorological conditions when spraying to minimize drift to areas not intended for such treatment.

Potential problems of chronic chemical exposure

Problems resulting from chronic exposure to chemicals is a general public health issue, because everyone is exposed daily to chemical and pesticide residues in food, water, and air. In regard to chronic exposure to chemicals, animal endocrine and immune system dysfunction studies have provided evidence that synthetic pesticides and industrial chemicals in very low quantities, after repeated exposures, may affect these functions. While mosquito control is implicated in these instances, it is part of the total chemical and insecticide use picture. However, it should be noted that organophosphate insecticides, such as malathion, have been used routinely for over 40 years in San Joaquin County without any documented chronic affects.

Since it is currently impossible to predict the long-term consequence of human exposure to synthetic mosquito control compounds, a prudent strategy is for the District to reduce all unnecessary chemical applications. To this degree, the District should apply pesticides after adequate surveillance verifies its need, and to also consider alternatives that reduces the need for chemical applications.

Comparing adulticiding versus larviciding

Both adulticide and larvicide chemicals may impact non-target species. Larvicides, which can be quite target specific (e.g., Bti, methoprene), are used in specific habitats and

Benefits and risks of mosquito control (continued)

under certain conditions. ULV applications of adulticides are more broadly distributed thus impacting both the target area and potentially other nearby areas through drift. Such movement can be a problem when the spray drifts into environmentally sensitive lands where chemicals are restricted or not allowed. It is generally believed that larvicides impact the environment less than adulticides. The District will continue its efforts in developing larval surveillance and control programs and minimize any adulticide drift to non-target areas. This can be achieved by continually reviewing and improving operations. When larval or adult control has not worked effectively, a thorough assessment will be conducted, so that the overall level of control can be improved. Larval control will almost always allow some mosquitoes to emerge, mostly due to the failure of the inspection program to identify a mosquito brood or a lack of thorough treatment coverage. Likewise, adulticiding is by no means 100% effective.

Risks of adulticiding

Adulticides are dispersed primarily with vehicle-mounted ULV equipment, with the sprays capable of drifting long distances. ULV adulticides used in San Joaquin County are either organophosphate, botanical pyrethrin or synthetic pyrethroids synergized with piperonyl butoxide. They are applied during periods of adult mosquito activity and favorable meteorological conditions. Some residents of the District and local special interest groups have provided their concerns about potential human and environmental hazards associated with the use of chemicals to control mosquitoes, including ULV applied adulticides. However, the District regularly receives requests from individuals and groups requesting ULV spraying in their area. This has generated greater accountability by the District when applying pesticides and some tighter environmental restrictions have occurred at the federal and state levels.

Bees, other pollinators, and insectivores may be impacted by adulticiding also. The District adulticides when most bees, other pollinators, and insectivores are at rest or inactive, generally late night (after sunset) or early morning (before sunrise). It is assumed that this reduces the impact to known non-target populations.

Risks of larviciding

Controlling a brood of larval mosquitoes, when concentrated in the water is easier and more efficient than controlling dispersed adults. Some of the environmental risks associated with the use of larvicides include both direct and sublethal toxicity to non-target organisms. However, using biorational materials (e.g., Bti, Bs, and methoprene) minimizes non-target effects because of the specificity of these materials to mosquito larvae.

Surveillance

Mosquito surveillance is a prerequisite to an effective, efficient, and environmentally sound mosquito control program. Surveillance is used to define the nature and extent of the mosquito population and as a guide to daily mosquito control operations. It provides the data needed to comply with state regulations regarding the justification for treatments, and it provides a basis for evaluating the potential for transmission of mosquito-borne diseases.

Surveillance is combined with an on-going program for monitoring meteorological and environmental factors that may influence mosquito population change; for example: rainfall and ground water levels, temperature, relative humidity, tidal changes, storm water and wastewater management, and land use patterns.

The program that monitors the transmission of mosquito-borne encephalitis virus and other arboviruses is described in a separate section.

Mosquito surveillance program

The District has taken the following steps to develop the mosquito surveillance program, as part of the overall mosquito control effort:

1. Definition of the mosquito problem(s)
2. Definition of the parameters on which the control program is based
3. Identification of the appropriate survey methods as decision-making aids regarding where and when to implement control

Defining the mosquito problem(s)

There are 17 species of mosquitoes found in San Joaquin County. All are important enough as pests or vectors to warrant control. Most species are found throughout the District for the majority of the calendar year. Most species are found in developed areas, including urban, suburban, and rural residential. The entire area of San Joaquin County (approximately 1,445 square miles) is considered viable for human use and habitation. All species are monitored throughout the year.

Control efforts are justified when mosquitoes pose a nuisance, or is an economic or health-related pest or vector. A nuisance mosquito bothers people, typically in or around homes and other developed areas, and in recreational areas. Economically, mosquitoes can reduce property values, slows economic development of an area, reduces tourism, or adversely affects livestock and poultry production.

One definition of a health-related mosquito problem is the ability of a mosquito to transmit infectious disease. In San Joaquin County, this definition includes mosquitoes that can vector canine heartworm, malaria, St. Louis encephalitis (SLE), and western equine encephalitis (WEE). Any mosquito that bites or annoys humans can be considered a health problem, particularly for individuals that are allergic to mosquito bites or which suffer from entomophobia (i.e., a fear of insects).

Surveillance of mosquito problems

In addition to identifying the target mosquito species, the District collects information as to the type and kind of mosquito problems that are created. In San Joaquin County, temporal and spatial changes in mosquito populations and the problems that mosquitoes cause, are measured by monitoring three (3) factors: immature mosquito populations, adult mosquito populations, and resident complaints and requests for service.

Monitoring immature mosquito populations

Typically, the application of biological control agents and larvicides in locations where physical control is not an option is preferred to adulticiding. This procedure minimizes the area treated and the amount of resources (bio-control agents or chemicals) required. Because the District's mosquito control program utilizes several different types of control strategy, information and data regarding mosquito breeding sites and larval monitoring are collected. The District maintains a permanent record of each mosquito-breeding site, along with information on larval development found at each inspection.

Immature mosquitoes are sampled using a variety of methods and equipment. Mosquito larvae and pupae are collected with dippers, nets, aquatic light traps, suction devices, and container evacuation methods. The most commonly used apparatus is the standard one-pint dipper, using standardized dipping techniques. The dipper is used as a survey tool simply to determine the presence of larvae. Standardized dipping methods are used when mosquito densities are to be quantified, usually in values taking additional dipper samples from specific areas in the counting habitat and number of larvae in each dip. In most cases, the District's control program uses the measure of larval density as a basis for control action. At this time (1998), the District utilizes a threshold value of 0.1 larvae per dip for consideration of a form of mosquito control, i.e., larviciding.

To maximize the usefulness of immature mosquito surveillance data, the District monitors certain environmental parameters such as rainfall and mountain snow pack. In certain areas of San Joaquin County, tide levels are also monitored. Rainfall and tide changes dictate when certain areas will need to be inspected for mosquito larvae. Mountain snow pack levels can translate to adequate agriculture irrigation supplies and river flows capable of creating seepage problems.

Monitoring adult mosquito populations

The District uses one or more methods to measure adult mosquito populations before a control decision is made. The two (2) methods used most often are landing/resting rates and mechanical trap counts. The purpose of monitoring adult mosquitoes is 1) to determine where adults are most numerous, 2) to substantiate telephone service request claims of a mosquito problem, 3) to provide data that satisfies District policy and state regulation for applying adulticides (e.g., the pest or vector must be present at the treatment site), and 4) to determine the effectiveness of different control methods.

Landing/resting rates are a frequently used method for measuring adult mosquito activity. For the mosquito genera *Aedes* and *Anopheles*, the landing rate technique comprises a count of the number of mosquitoes than land on a person in a given amount of time. Resting rates are a method of measuring the activity of *Culex*, and to a lesser degree, *Culiseta* species of mosquitoes. The quantity of adult mosquitoes found resting on walls, under eaves, in culverts and pipelines, and in dense vegetation is measured by area, i.e., the number of mosquitoes per square foot. The specific method used to determine landing or resting rates could vary. Important variables are the time of day at which observations are made, the length of time observations is made, and the portion of body and/or number of sites examined. Emphasis is placed on using the same protocol at given sites, and to use the same inspector to assess landing or resting counts at the same site from one date to the next.

Mechanical traps are used extensively throughout the District on a continuous, year-round basis to monitor adult mosquito populations. Mechanical traps include the standard New Jersey Light Trap (NJLT), Centers for Disease Control (CDC) trap, encephalitis virus surveillance (EVS) trap, Fay trap, and gravid trap.

- Approximately 45 New Jersey Light Traps (NJLT) are used in urban, suburban and rural areas, operating year-round, seven days per week from dusk to dawn. Trap collections are made on Wednesday of each week, and collection reports are generally available by Thursday afternoon. NJLT data is used by District staff for operational and scientific purposes, and is submitted to the California Department of Health Services for compilation with other vector control agency data.
- Up to 36 CDC or EVS traps are used at different times during the year. The traps are used to collect adult *Culex tarsalis* mosquitoes for use as mosquito pools, which are sent to the Viral and Rickettsial Disease Laboratory for encephalitis virus detection. EVS traps are also used to assess pre- and post-treatment populations of adult mosquitoes to determine control effectiveness.
- Fay traps are used for special purpose monitoring, i.e., in the spring to measure localized populations of *Aedes sierrensis.*
- Gravid traps can be used to selectively sample gravid female mosquitoes that are seeking suitable oviposition sites.

Monitoring telephone service requests and citizen complaints

The third method of ascertaining a mosquito problem is through telephone service requests and citizen complaints. The District maintains several different listed telephone numbers, including a toll-free line that citizens can call to request mosquito control services. Service requests are also received at numerous community fairs where the District operates an information booth. The District responds to an average of 1,000 service requests per year in urban, suburban, and rural areas of San Joaquin County.

Surveillance (continued)

Service requests generally are related to specific mosquito species, although the mosquitoes that cause service requests vary considerably from one area to the next. Telephone service requests and citizen complaints are always verified as to their validity prior to any control action being implemented. District personnel substantiate mosquito activity by assessing larval and adult mosquito populations using the techniques described earlier.

Thresholds

The District utilizes the term "tolerance threshold" when determining if or when mosquito control should be implemented. Tolerance threshold is the population density of mosquitoes at which control measures should be implemented to prevent an increasing population from reaching an intolerable level. The data from sampling and monitoring is used to help decide at which infestation level to initiate control activities. This decision level is based on larval and adult populations, citizen complaints, the potential for disease outbreaks, and the risk of control activities to non-target organisms.

Action levels are different for each situation. In some areas, a public health or general annoyance condition does not occur until the number of adult female mosquitoes exceeds 10 per trap night. Other action levels that have been used are landing rates averaging more than two mosquitoes in one minute, and dipper counts averaging 0.1 larvae per dip. Action levels for urban, suburban, and rural residential areas can be lower than for remote, uninhabited areas, or areas of low human use.

Adult mosquito threshold(s)

Adult mosquitoes are measured by the use of the three techniques identified in the section "Surveillance". Because the District operates the mosquito surveillance and control program year round, the tolerance threshold can be changed by many factors. Examples of the many factors that change the adult mosquito tolerance threshold are listed below:

- As weather conditions change in late fall and early winter, human activity in the outdoors is reduced. Although the adult mosquito population is at or above a tolerance threshold for other conditions, the District may not implement control action because the mosquito population will not create an annoyance or public health problem.
- Generally, adult mosquito control is implemented when populations of the encephalitis mosquito *Culex tarsalis* reach a level of 10 females per trap night. However, if encephalitis virus has been detected in mosquito pools or sentinel chicken flocks, the District may initiate adulticiding at a lower number of adult mosquitoes per trap night.
- High populations (≥10-mosquitoes/trap night) of certain species, i.e., *Culex erythrothorax*, would not necessarily require control action if the population were found in a low human-use or remote area.

Immature mosquito threshold(s)

Immature mosquitoes are generally measured by the use of the dipping technique identified in the section "Surveillance". Because the District operates the mosquito surveillance and control program year round, the tolerance threshold can be changed by many factors. Examples of the many factors that change the immature mosquito tolerance threshold are listed below:

- Although an immature mosquito population of 0.1 larvae per dip (one larvae in 10 dips) is not seen as a large problem with certain species, i.e., *Culiseta*

Thresholds (continued)

inornata, it would be a significant public health risk for the species *Culex tarsalis* during the months of April through October.

- Relatively small populations of larvae (<1 larvae per dip) of the species *Culex pipiens* can be tolerated in a rural waste water impoundment, but would be unacceptable if found in a suburban area swimming pool.
- The larvae of the mosquito species *Aedes nigromaculis* can develop rapidly into more mature stages in warm weather, generally requiring immediate treatment, normally with the use of pesticides. Larvae of the species *Aedes sierrensis* mature much slower, allowing for aspects of naturalistic control to be considered as a method of IPM.

Biological control

The use of biological organisms or their byproducts to control mosquitoes is termed biological control, or biocontrol. Biocontrol is defined as the study and utilization of parasites, pathogens, and predators to control mosquito populations. Generally, this definition includes natural and genetically modified organisms, and means that the agent must be alive and able to attack the mosquito. The overall premise is simple: biocontrol agents that attack mosquitoes naturally are grown in a controlled or cultured environment, and then released into the environment, usually in far greater numbers than they normally occur, and often in habitats that previously were devoid of them, so as to control targeted mosquito species.

Biocontrol is not a magic bullet for the District's mosquito control program, now or in the 21st century. It is considered a set of tools that are used when it is economically feasible. When combined with other control methods, i.e., chemical, legal, physical, etc., biocontrol agents can provide short, and occasionally, long-term control. Biocontrol, as a conventional control method, is aimed at the weakest link of the life cycle of the mosquito. In most cases, this is the larval stage. The two (2) most commonly used biocontrol agents used by the District are mosquito eating fish, and to a lesser degree, a mosquito-specific parasitic fungus.

Biological control utilizing mosquito-eating fish

The District utilizes two (2) species of mosquito-eating fish as biocontrol agents, the western mosquito fish *Gambusia affinis*, and the guppy *Poecilia reticulata.* The mosquito fish is the most extensively used biocontrol agent for mosquitoes in San Joaquin County. This fish, which feeds on mosquito larvae, can be placed in a variety of permanent and semi-permanent fresh water habitats. In areas where water quality is substandard, i.e., untreated sewage water, the District incorporates the use of guppies. Recently, concerns of placing mosquito-eating fish in habitats where endangered or threatened species exist have been raised. Due to these concerns, the District has sponsored both University of California, as well as in-house research into the ecological relationships of mosquito fish and other aquatic species. The results of this research are used to identify appropriate and inappropriate sites for use of mosquito fish as a biocontrol agent. Care is taken to place mosquito fish in habitats where endangered or threatened species are sensitive to further environmental perturbation. An example of an area considered inappropriate for use with mosquito fish is seasonally flooded vernal pools. These sites may contain populations of *Lepidurus packardi*, the vernal pool tadpole shrimp, *Branchinecta lynchi,* the vernal pool fairy shrimp, *Branchinecta longiantenna*, the longhorn fairy shrimp, and *Branchinecta conservatio*, the conservancy fairy shrimp. These shrimp are federally listed species, and must be protected from District control procedures.

The District utilizes both cultured as well as naturally occurring supplies of mosquito fish. Mosquito fish were introduced into California in 1922, and have been dispersed throughout the state for mosquito control purposes ever since. Although the fish is considered an non-native specie, mosquito fish are endemic throughout San Joaquin County and California's Central Valley. Local mosquito fish populations are found in rivers, creeks, sloughs, reservoirs, drainage canals, irrigation ditches, stock ponds, and other similar aquatic sites. District personnel routinely collect mosquito fish from these types of sites for use in mosquito sources such as temporarily flooded agricultural lands, rice fields, agriculture ponds and ditches, and other similar sources. Also, the District has constructed and operates a large mosquito fish rearing facility at the City of Lodi's White Slough Water Treatment Plant. This facility is used to mass rear mosquito fish for use in rice fields and flooded agricultural fields. The site utilizes reclaimed municipal wastewater as the growing medium for the fish.

Advantages of using mosquito-eating fish compared with other control methods

Fish are suitable for controlling mosquito strains resistant to chemical insecticides. *Gambusia* and *Poecilia* have other advantages for mosquito control:

- Their small size (usually less than 5 cm) allows them to penetrate easily most sites of pool inhabiting mosquito larvae.
- They feed heavily on mosquito larvae and pupae when these are available; they are diverse feeders, capable of persisting at high densities when mosquito larvae are absent.
- They multiply rapidly; under favorable conditions, a single female produces an average of 200-300 young per season.
- Being live bearers, *Gambusia* and *Poecilia* do not require special oviposition (egg-laying) site.
- They tolerate wide ranges of temperatures and salinity, as well as moderate sewage pollution.
- They may be used effectively in combination with other control techniques, such as bacterial pesticides, other biological control organisms, and some chemical pesticides.

Limitations of using mosquito-eating fish compared to other control methods

Mosquito fish have definite limitations. For example, they can seldom inhabit two important larval sites-small containers and highly polluted water. In temporary water sites, repeated introduction of fish will be required.

Mosquito-eating fish can harm beneficial organisms (e.g., other fish or insect predators) by eating their eggs and young or by superior competition for food. Their release carries the potential to reduce or eliminate non-target species.

Larvivorous fish may be preyed upon by larger fish. Their vulnerability to fungi and other pathogens may keep their populations in check.

Where larvivorous fish are harvested or removed, their populations could be reduced to a level inadequate for mosquito control.

Mosquito-eating fish may prefer food other than mosquito larvae. In many situations, mosquito larvae production far outruns the increase in fish population that would be necessary for control.

Biocontrol utilizing the fungus *Lagenidium giganteum*

The District utilizes the water mold fungus *Lagenidium giganteum* as a biocontrol agent in freshwater wetlands and rice fields. Because *L. giganteum* has been

Biological control (continued)

proven non-toxic to mammals, plants, fish, birds, and non-target aquatic organisms, this material is used as a mosquito larvicide.

<u>Biocontrol utilizing other agents and organisms</u>

There is ongoing research on other biocontrol agents and organisms for mosquito control. Species of predacious mosquitoes in the genus *Toxorhyncites* have been studied in several eastern states with various levels of success reported. Predacious copepods, other species of freshwater fish and invertebrates are also being investigated. If other agents or organisms are proven capable and cost-effective for use in San Joaquin County mosquito habitats, the District will incorporate them as they become available.

Chemical control

Chemical control is the intentional use of specific chemical compounds (insecticides) to quickly kill adult and immature mosquitoes. Insecticides labeled for mosquito control fall into two (2) categories, adulticides (applied to control adult mosquitoes), and larvicides (applied to control larvae and/or pupae). These compounds consist of the insecticide groups of organophosphate, pyrethroid, microbial, biochemical and larviciding oil. Organophosphate and pyrethroid compounds are used mainly for controlling adult mosquitoes, while microbial, biochemical, and larviciding oil is used for controlling immature mosquitoes.

Chemical control utilizing adulticides

Adulticides are used to quickly kill adult mosquito populations. Adulticides are applied by aircraft, hand-held, and vehicle mounted-sprayers. Aircraft spraying is performed using conventional spray equipment, and is typical of what is used in agricultural spraying. The District utilizes professional contract aerial spraying companies for this operation. The District also uses hand-held and vehicle-mounted conventional low-volume (LV) and ultra-low-volume (ULV) sprayers to apply adulticides. Hand-held and vehicle-mounted sprayers are operated by District personnel.

The efficiency of adulticiding is dependent upon a number of integrated factors. First, the mosquito species to be treated must be susceptible to the insecticide applied. Some species of mosquitoes in San Joaquin County and surrounding areas are resistant to certain adulticides, thus affecting the selection of chemicals. Insecticide applications must be made during periods of adult mosquito activity. This factor is variable with mosquito species. For example, *Culex erythrothorax* is diurnal (most active during the day and up to dusk), while *Aedes vexans* are active both day and night. Treatments directed at *Cx. erythrothorax* could miss major portions of the *Ae. vexan* population. Adulticiding should be timed when the mosquitoes are flying and exposed to the applied chemicals.

The chemical application has its own set of conditions that determine success or failure. The application must be at a dosage rate that is lethal to the target specie and applied with the correct droplet size. Whether the treatment is ground or aerial applied, it must distribute sufficient insecticide to cover the prescribed area with an effective dose. Typically with ground applications, highly vegetated or residential habitats may reduce the effectiveness of control even with the maximum insecticide dosage applied, due to the obstructions preventing the function of wind movement and its ability to sufficiently carry insecticide droplets to the target specie.

Environmental conditions may also affect the results of adulticiding. Wind determines how the ULV droplets will be moved from the sprayer into the treatment area. Conditions of no wind will result in the material not moving from the application point. High wind, a condition that inhibits mosquito activity, will quickly disperse the insecticide too widely to be effective. Light wind conditions are the most desirable, moving the material effectively through the treatment area and proving less inhibiting to mosquito activity.

ULV applications are not performed during warm daylight hours. Thermal conditions cause the small (<30 microns in diameter) droplets to quickly rise, moving them away from the target zone. Generally, applications are made between sunset and sunrise, depending on mosquito species activity and the application site conditions. Ideal adulticiding conditions usually include moderate air temperatures of 60-80°F (16-27°C), relative humidities of 30-80%, the presence of a thermal inversion layer at 20-30 feet above ground level, and a sustained unidirectional breeze of 5 mph or less. These conditions keep the spray or fog in close ground contact and allow for a uniform downwind dispersal of material. The District utilizes atmospheric measuring equipment during ULV spraying to insure proper application of adulticides. Temperature inversion is calculated by measuring air temperatures at ground level and 20 feet. Wind direction and speed are also measured and recorded.

District operations, maintenance and technical staff routinely inspect and calibrate adulticiding equipment to insure proper insecticide flow rates and droplet size development. Periodically, caged adult mosquitoes, as sentinels, are staged in an area planned for adulticiding treatment. Upon completion of the treatment, the sentinel mosquitoes are collected and analyzed in the District's lab to determine individual species susceptibility, overall population mortality, and to assess the swath dimensions of the equipment used.

Insecticides used as adulticides

Insecticides used as adulticides by the District must be labeled for use as a mosquito control agent and be registered for sale and use in California. In addition, insecticides selected must be considered as the least toxic for the intended use and target area. Insecticides are generally ranked by their toxicity, from slightly toxic to highly toxic, and the individual insecticide labels include the signal words Caution, Warning, and Danger, which corresponds to their level of toxicity. The District utilizes adulticides that are labeled with the signal word Caution, which is considered the least toxic.

Following are the adulticides currently used (1998) by the District, along with benefit and risk information relative to each chemical:

- BIOMIST 4+12 ULV; EPA Reg. No. 8329-34; active ingredients are permethrin and technical piperonyl butoxide. In California, permethrin, and piperonyl butoxide are general-use pesticides and pesticide components, and are used in agricultural, public health, and structural pest control programs. The BIOMIST 4+12 ULV label contains a **Caution** warning, indicating it is a slightly toxic material. This material can be applied to all targeted species. Permethrin is similar to other pyrethroids in providing rapid knockdown and quick kill of adult mosquitoes. However, permethrin also provides some residual activity when applied directly to surfaces. The benefits of using permethrin include a rapid adult mosquito knockdown, it is odorless and non-corrosive, it has very low mammalian toxicity, and it is practically non-toxic to birds. Permethrin is rapidly absorbed onto organic matter in aquatic sites resulting in very low aqueous concentrations.

Chemical control (continued)

Permethrin is available in ready-to-use formulations. Risks or disadvantages include the residual activity of permethrin, although deposition rates are actually too low to cause problems. Permethrin, like other pyrethroids, is toxic to fish, but with low use rates, the risk to fish welfare is minimal. The relatively high cost of permethrin compared to some adulticides can be a disadvantage. A risk of this synthetic material is the potential of some insects to more quickly develop resistance to it other categories of pesticides.

- <u>FYFANON® ULV</u>; EPA Reg. No. 4787-8; active ingredient is malathion. In California, malathion is a general-use insecticide, and is used in agricultural, public health, and structural pest control programs. The FYFANON®ULV label contains a **Caution** warning, indicating it is a slightly toxic material. While this material can be applied to all targeted mosquito species, it is least effective against *Culex tarsalis, Aedes melanimon, and Aedes nigromaculis* due to organophosphate pesticide resistance, requiring an alternative chemical selection for effective control of these species. The benefits of using this formulation of malathion are its relatively low cost in comparison to other adulticides, its safety and ease of use. It exhibits low mammalian toxicity, is only moderately toxic to birds and is variably toxic to aquatic organisms. It breaks down rapidly in the environment. The risks of using malathion are its inefficiency in controlling some adult mosquitoes at labeled rates. It also has a strong odor, a propensity to cause automobile paint damage and has a slow knockdown of adult mosquitoes.
- <u>PYROCIDE® 7396</u>; EPA Reg. No. 1021-1569; active ingredients are pyrethrins and technical piperonyl butoxide. In California, pyrethrins and piperonyl butoxide are general-use pesticides and pesticide components, and are used in agricultural, public health, and structural pest control programs. The PYROCIDE® 7396 label contains the **Caution** warning, indicating it is a slightly toxic material. This material can be applied to all targeted mosquito species. The benefits of using this material are that treatments result in the rapid kill of adult mosquitoes, and there is low risk of mosquitoes developing resistance to the chemicals. This material is capable of being applied in most areas, including crop, non-crop, and residential. Also, because pyrethrins are short-lived in the environment, there is little, if any potential for residual chemical buildup. Risks of using pyrethrins are that it is very toxic to fish. A disadvantage of this material is that it is very expensive, and sometimes in short supplies.

Chemical control (continued)

- <u>PYRENONE® CROP SPRAY</u>; EPA Reg. No. 4816-490; this material is similar to Pyrocide® 7396, however, it is generally applied in a water-based mixture with conventional spray equipment. Please refer to the section on Pyrocide® for additional information.
- <u>SCOURGE®INSECTICIDE with SBP-1382®</u>; EPA Reg. No. 432-716; active ingredients are resmethrin and piperonyl butoxide. In California, resmethrin and piperonyl butoxide are general-use pesticides and pesticide components, and are used in public health and structural pest control programs. The SCOURGE® INSECTICDE with SBP-1382® label contains the **Caution** warning, indicating it is a slightly toxic material. This material can be applied to all targeted mosquito species. Resmethrin is a first generation synthetic pyrethroid like permethrin. Benefits of resmethrin are that it provides rapid knockdown, very low mammalian toxicity, degrades very rapidly in sunlight, is practically non-toxic to birds, and provides little or no residual activity. Resmethrin exhibits little toxicity to bees under field application conditions. Based on laboratory studies, the half-life of resmethrin in water varies from 19 to 37 minutes (based on pH and salinity) with full decomposition in 205 minutes. Additionally, the solubility of resmethrin in water is extremely low. Risks of using resmethrin include the potential for toxicity to fish based on laboratory studies. However, with rapid photodegradation in water and low use rates for mosquito control, the risk to fish welfare is minimal. The relative high cost of resmethrin compared to other adulticides may also be a disadvantage.

Techniques used to adulticide

Ground adulticiding is the most commonly used method of controlling adult mosquitoes in San Joaquin County. Ground adulticiding generally consists of dispersing an insecticide as a space spray in the air column which then drifts through the habitat where adult mosquitoes are flying, or in some cases, where they are resting. Much of the language on insecticide labels does not address the requirement for drift. This type of application is contradictory to everything agricultural applicators strive for when trying to stick pesticides to plants. The District utilizes the technique of ultra low volume (ULV) cold aerosol spraying as a mosquito control insecticide space spray.

Another form of treatment for adults from the ground is conventional space spraying, using conventional spray equipment such as compressed air hand sprayers, vehicle-mounted wind turbine (blower) sprayers, and vehicle-mounted power sprayers. This type of application is for small sites with light infestations of adult mosquitoes. Applications of insecticide are generally made during daylight hours in various types of weather conditions.

Chemical control (continued)

The District adulticides only when it has been determined that control is essential for the health and welfare of the public. To this extent, at least one of the following criteria is met and documented prior to the implementation of adulticiding:

- When a population of adult mosquitoes is either demonstrated by a quantifiable increase in, or sustained elevated mosquito population level as detected by standard surveillance methods.
- Where adult mosquito population(s) build to levels exceeding five mosquitoes per trap night in urban/suburban areas, or 10 mosquitoes per trap night in rural areas. In some areas and under certain conditions, adult mosquito populations exceeding five mosquitoes per trap hour during crepuscular periods.
- When service requests for adult mosquitoes from the public have been confirmed by one or more recognized surveillance techniques.

Risks and benefits of ground ULV adulticiding

Any mosquito adulticiding activity that does not follow reasonable guidelines including timing of application, avoiding sensitive areas, and strict adherence to the pesticide label, risks affecting non-target insect species. Ground adulticiding, however, is a very effective technique for controlling most mosquito species in most areas economically and with negligible non-target effects. It is the methodology normally recognized by most mosquito control programs in California.

A benefit of ULV cold aerosols is that they do not require large amounts of diluents for application and are therefor much cheaper, and may be environmentally safer. The spray plume is nearly invisible, does not create a traffic problem, and may not be perceived as an undesirable function.

Risks associated with ULV cold aerosols include the problems related to applying pesticides undiluted. The material is being handled and transported in a concentrated form. The droplet spectrum is rather wide (sub-micron to >50 microns in diameter), can be difficult to change and may settle into non-target areas more readily than other types of sprays.

Any discussion of risk versus benefits needs to note that this form of control has been in extensive use throughout California for many years. There have not been any glaring adverse impacts attributed to ground adulticiding when it is done properly. The simple observance of population growth in San Joaquin County and the state's high standing in tourism destinations speak loudly of the benefits of this technique and mosquito control in general.

Chemical control using larvicides

The District relies almost exclusively on larviciding as the primary means of chemical mosquito control, and resorts to adulticiding when all other IPM methods fail. The overall success of the District's mosquito control program is sometimes measured by the frequency of larviciding compared to adulticiding.

Chemical control (continued)

Larvicides are used to kill immature mosquito populations. Larvicides are applied by aircraft, vehicle-mounted, and backpack-style sprayers. Aircraft spraying is performed using conventional spray equipment, and is typical of what is used in agricultural spraying. The District utilizes professional contract aerial spraying companies for this operation. The District also uses hand-held and vehicle mounted conventional low- and high-volume sprayers to apply larvicides. Hand-held and vehicle-mounted sprayers are operated by District personnel.

The efficiency of larviciding is dependent upon a number of integrated factors. First, the mosquito species to be treated must be susceptible to the insecticide applied. Currently (1998), all species of mosquitoes in San Joaquin County are susceptible to the larvicides registered for use in California and used by the District. Insecticide applications must be made during periods of immature mosquito susceptibility, i.e., larvae too young or old may not be affected by the larvicide. This factor is variable with mosquito species. For example, during warm summer months the pasture mosquito *Aedes nigromaculis* is capable of complete metamorphosis in less than four days, while the northern house mosquito *Culex pipiens* would require up to 10 days completing its life cycle. Certain larvicides used to treat *Cx. pipiens* would not be as effective as for *Ae. nigromaculis.* Larviciding should be timed when the mosquitoes are susceptible and in an environment allowing exposure to the applied chemicals.

The chemical application has its own set of conditions that determine success or failure. The application must be at a dosage rate that is lethal to the target specie and applied with the correct formulation, i.e., liquid, granule, dust, etc. Whether the treatment is ground or aerial applied, it must distribute sufficient insecticide to cover the prescribed area with an effective dose. Typically with both air and ground applications, highly vegetated habitats may reduce the effectiveness of control even with the maximum insecticide dosage applied, due to the obstructions preventing the material from reaching the target site and specie.

Environmental conditions may also affect the results of larviciding. Wind and air temperatures may affect the deposition of droplets on the target site, and water quality can affect the chemical's viability to adequately kill the larvae. Conditions of no wind will result in the material reaching the intended application site.

District operations, maintenance, and technical staff routinely inspect and calibrate larviciding equipment to insure insecticide flow rates and swath size. Periodically, caged immature mosquitoes, as sentinels, are staged in an area planned for larviciding treatment. Upon completion of the treatment, the sentinel mosquitoes are collected and analyzed to determine individual species susceptibility, overall population mortality, and to assess the swath dimensions of the equipment used.

<u>Insecticides used as larvicides</u>

Insecticides used as larvicides by the District must be labeled for use as a mosquito control agent and be registered for sale and use in California. In addition, insecticides selected must be considered as the least toxic for the intended use and target area. Insecticides are generally ranked by their toxicity, from slightly to highly toxic, and the individual insecticide labels include the signal words Caution, Warning, and Danger, which corresponds to their level of toxicity. The District utilizes larvicides that are labeled with the signal word Caution, which is considered the least toxic.

Following are the larvicides currently (1998) used by the District, along with benefit and risk information relative to each chemical:

- ALTOSID®BRIQUETS; ALTOSID®XRBRIQUETS; ALTOSID® PELLETS; ALTOSID®LIQUID LARVICIDE; EPA Reg. No.'s 2724-375-64833, 2724-448-64833, 2724-448-64833, 2724-392-64833; active ingredient is methoprene. In California, methoprene is a general-use pesticide, and is used in agricultural, public health and structural pest control programs. The ALTOSID® BRIQUET, XR BRIQUET, PELLETS, and LIQUID LARVICIDE labels contain a **Caution** warning, indicating they are slightly toxic materials. This material can be applied to all targeted species. Methoprene is similar to other insect growth regulating compounds in preventing targeted species from completing metamorphosis. Methoprene does not immediately kill immature mosquitoes, but does provide some residual activity based on individual formulations. The benefits of using methoprene include: its classification as a biorational control agent; is target specific; it does not harm mammals, waterfowl, or beneficial predatory insects. Disadvantages of using methoprene include: its relatively high cost; the inability to control late instar and pupae stages.
- DIMILIN®25W Insect Growth Regulator; EPA Reg. No. 400-465; active ingredient is diflubenzuron. In California, diflubenzuron is a general-use pesticide, and is used in agricultural, forestry, and public health pest control programs. The DIMILIN®25W label contains a **Caution** warning, indicating it is a slightly toxic material. This material can be applied to all targeted species. Diflubenzuron is similar to other insect growth regulating compounds in preventing targeted species from completing metamorphosis. Diflubenzuron does not immediately kill immature mosquitoes. The benefits of using diflubenzuron include: this agent is considered a biorational material, conducive to integrated pest management; can be applied in small quantities; have no undesirable effects on humans and wildlife. Disadvantages or risks of using this material include: cannot be applied to environmentally sensitive sites; does not control the pupae stage of the targeted species; cannot be applied to most crop sites.
- Mosquito Larvicide GB-1111; EPA Reg. No. 8898-16; active ingredient is petroleum distillate. In California, petroleum distillate as a mosquito larvicide is a specific-use pesticide, and is used in public

health pest control programs. The Mosquito Larvicide GB-1111 label contains a **Caution** warning, indicating it is a slightly toxic material. This material can be applied to all targeted species. Petroleum distillate immediately kills immature mosquitoes. The benefits of using petroleum distillate include: this material immediately kills the larvae and pupae stage of the targeted species; is short-lived in the environment; is easy to apply. The disadvantages or risks of using this material include: the material is expensive to use in relation to other larvicides; is toxic to fish and other aquatic organisms; can leave unsightly residues on application sites.

- VectoBac®12AS; VectoBac®G; EPA Reg. No.'s 275-102 and 275-50; active ingredient is *Bacillus thuringiensis*, subspecies *israelensis*. In California, *Bacillus thuringiensis* is a general-use pesticide, and is used in agricultural, forestry, and public health pest control programs. The VectoBac® 12AS and VectoBac® G labels contain a **Caution** warning, indicating they are slightly toxic materials. This material can be applied to all targeted species. *Bacillus thuringiensis*, subspecies *israelensis* generally kills larval stages of mosquitoes within 24 hours of application. The benefits of using these materials include: specificity to mosquito larvae at label rates; can be applied to sensitive habitat; is safe to humans and wildlife; is easy to apply. The disadvantages or risks of using these materials include: the active ingredient does not provide residual control; does not provide control to the pupae stage of targeted species; the shelf life of mixed material is short-lived.
- VectoLex®CG; EPA Reg. No. 275-77; active ingredient is *Bacillus sphaericus* Serotype H5a5b. In California, *Bacillus sphaericus* is a specific-use pesticide, and is used in public health pest control programs. The VectoLex®CG label contains a **Caution** warning, indicating it is a slightly toxic material. This material can be applied to all targeted species. *Bacillus sphaericus* generally kills after 24 hours of application. The benefits of using this material include: specificity to mosquito larvae; can be applied to sensitive habitat; is safe to humans and wildlife; works well in poor water quality conditions. Disadvantages or risks of using this material include: is specific to the mosquito genus *Culex*; is difficult to apply by ground equipment to foul water sites; cannot be applied to crop sites.

Legal control

The District relies on local, state, and federal statutes to regulate excessive mosquito breeding on private and public lands. Using provisions of the California Health and Safety Code, the District can legally require property owners to reduce or eliminate mosquito breeding when it becomes a public nuisance.

Legal abatement of mosquitoes generally follows a multi step process, whereby the owner of mosquito-producing land is contacted and asked to take steps to reduce the occurrence of mosquito development. In most cases, this request is performed in an informal meeting between District staff and the landowner on the property where the problem exists. Generally, the landowner is given a reasonable amount of time (10 – 30 days) to correct the problem. In the event the problem continues, the District will notify the landowner in writing that the problem still exists, and the mosquito breeding conditions must be corrected immediately. If the problem is not corrected, the District can initiate legal abatement proceedings per §2270 of the California Health and Safety Code.

Mosquito sources that can require legal abatement resolution generally involve agricultural operations and poor water and/or land management. Examples of mosquito breeding conditions that have required legal abatement in the past include:

- Over-irrigation of pasture land, resulting in excessive mosquito breeding conditions and multiple broods of mosquitoes per irrigation.
- Poor maintenance and management of agricultural, industrial and municipal waste ponds, resulting in excessive weed growth and mosquito development.

To insure that residents and landowners of San Joaquin County receive proper information on water management, irrigation techniques, waste pond management, etc., the District maintains a collection of reference materials regarding mosquito control. Recommendations and information from the University of California Cooperative Extension and other agencies is made available to anyone needing information on preventing mosquitoes in various situations.

Additionally, the District annually notifies each known owner of an agricultural, industrial or municipal waste pond of the pond management criteria to prevent mosquito development.

Physical control

Physical control, also known as source reduction or permanent control, is another form of control utilized in the District's IPM plan. Physical control is usually the most effective of the mosquito control techniques available and is accomplished by eliminating, or significantly reducing, mosquito breeding sites. The primary operational objective of physical control is to reduce the mosquito carrying capacity of a source to preclude the use of control methods that would adversely impact the environment and wildlife. This can be as simple as properly discarding old containers which hold water or as complex as developing a regional drain system for irrigated agricultural land. Physical control is important in that its use can virtually eliminate the need for pesticide use in and adjacent to the affected habitat.

From a historical perspective, the development of large-scale physical control projects occurred in San Joaquin County between 1945 and 1978. Initially, these projects were designed to reduce the production of *Aedes, Anopheles,* and *Culex* mosquito species in agricultural and natural mosquito breeding sources. Entomological data was used to support/justify the merits of each project. In certain cases, other government agencies (i.e., California Department of Health Services, Agricultural Stabilization and Conservation Service) assisted with the design and implementation of the projects.

At this point in time (1998), the District is not involved in construction of new physical control projects because of environmental restrictions associated with obtaining permits. However, the District is involved in performing maintenance on existing physical control projects. This maintenance includes vegetation control within drainage channels and along access roads and trails. To prevent damage to endangered plants during maintenance activities, the District reviews each site and identifies specific species requiring protection. The District uses the documents *Endangered Plants of California* published by California Department of Fish and Game, and *San Joaquin County Multi-Species Habitat Conservation and Open Space Plan* published by San Joaquin Council of Governments.

Over the past several decades, urban development has occurred in areas of San Joaquin County where drainage ditches have existed as the primary method of physical mosquito control. As these drainage systems are expanded to meet modern storm water management specifications, maintenance by the District may no longer be necessary. In many cases, maintenance responsibility has been taken over city and county public works departments and integrated into their comprehensive storm water management programs.

Mosquito producing habitats considered for physical control

There are many types of mosquito breeding sources in San Joaquin County capable of being reduced by physical control techniques. Generally, only man-made or managed mosquito sources are considered for physical control. Following is a representative listing of mosquito breeding sources and recommendations for physical control:

- An artificial container, such as flowerpots, cans, barrels, and tires. Mosquito species found in containers include *Culex pipiens, Culex stigmatosoma, Culex tarsalis, Culiseta incidens,* and *Culiseta inornata.* A container breeding mosquito problem can be solved by properly disposing of such materials, covering them or tipping them over to ensure that they do not collect water.

Physical control (continued)

The District has an extensive program that addresses urban container breeding mosquito problems through house-to-house surveillance and formalized education programs. For management of used tires, the California Integrated Waste Management Board oversees storage sites with more than 500 tires. That agency also has developed regulations regarding the storage of waste tires with regards to vector control. These regulations include the provision of the local vector control agency being involved with the permit process required to store used tires. For individual household waste systems, the District coordinates with San Joaquin County Public Health Services, Environmental Health Division to correct leaking plumbing systems and septic tanks.

- Agricultural, industrial, and municipal storm water and waste ponds and retention basins. Mosquito species found in these types of sources are generally *Culex pipiens, Culex stigmatosoma,* and to a lesser degree, *Culex tarsalis.* Pond management options which are effective in controlling mosquitoes include periodic draining, providing deep water sanctuary for larvivorous fish, minimizing emergent and standing vegetation, and maintaining steep banks. The District routinely advises property owners on the best management practices for ponds to reduce mosquito development. In addition, the District provides localized vegetation management on most ponds to discourage mosquito oviposition sites.

- Irrigated agriculture lands. Almost all of the 17 local mosquito species are found in these sources. Proper water management, land preparation, and adequate drainage are the most effective means of physically controlling mosquitoes in these types of sources. The District provides technical assistance to landowners that are interested in reducing mosquitoes by developing drainage systems on certain lands. Additionally, several state and federal programs provide both financial and technical assistance in developing efficient irrigation and drainage facilities for private land. These programs not only improve the value of the property, but assist in controlling mosquito development.

<u>Recommendations for future physical control projects</u>

Because of the comprehensive nature of physically manipulating mosquito-breeding sources, the following recommendations are made with regards to future physical control projects.

With regards to development of environmentally sensitive sites, such as seasonal wetlands and endangered species habitat that is capable of breeding mosquitoes:

1. The landowners should be required to work with the District in developing Best Management Practices (BMP) for the prevention of mosquitoes.

Physical control (continued)

2. Continued research on the ecosystem effects of physical control on fresh water wetlands is needed.
3. A federal and state mandate for interagency cooperation and understanding to insure that both mosquito control and natural resource aspects of development are fully considered, and that BMP's are implemented. This is especially important given the current federal, state, and local efforts to implement mitigation banking as a permitting tool in local and regional development.
4. Urban and suburban development should not be planned for areas being contemplated for wetland development. Although each city and the county have created a general plan, development is planned near environmentally sensitive sites and future wetland areas.

With regards to development of storm water and wastewater facilities capable of breeding mosquitoes:

1. Ideally, all agencies or parties involved in regulating storm water and wastewater facilities should add BMP's to minimize, and where possible eliminate, mosquito production in those facilities.
2. All agencies involved with regulating storm water and wastewater facilities should recognize that the use of reclaimed water wetlands, while providing habitat for fish and wildlife as well as other ecological benefits can create mosquito-breeding habitat. This fact should be taken into account in system design and management.

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