INTEGRATED PEST MANAGEMENT PLAN FOR CERTAIN VECTORS IN SAN JOAQUIN COUNTY, CA 2008

San Joaquin County
Mosquito & Vector Control District
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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 due mainly to pesticide resistance, potential or probable effects of certain 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 (or class of 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 detected in several species of mosquitoes in San Joaquin County.

Potential effect(s) of pesticides on non-target organisms

An important aspect of the potential 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 can be 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 potential 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 re-registration and availability of many pesticides.

Public awareness

People are becoming more aware of and concerned about the potential negative 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.

<u>Information</u>
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.

<u>Thresholds</u>
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.

<u>Surveillance</u>
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 abatement, natural control, and physical control (habitat modification). 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 and authorized 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***
- ***To the extent possible, 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 and the U.S.***
- ***Capable of being tested in a controlled environment prior to full-scale field use***

Combining and integrating control tactics (continued)

Legal abatement

Legal abatement is the process of preventing 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 abatement 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.*

Natural control

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.*

Physical control

Physical control, or habitat modification, 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. Additionally, the District routinely reviews and comments on proposed projects within San Joaquin County being considered by the various city and county departments, thus providing opportunities to "design out" vector breeding conditions prior to construction and development.*

IPM in practice

By carefully monitoring vector populations, arbovirus activity and complaints from San Joaquin County-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 Public Health or the California Department of Pesticide Regulation in one or more areas of pest or 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 Public Health inspect the District's administration and 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 (AMCA), the Mosquito and Vector Control Association of California (MVCAC), and the Society of Vector Ecologists (SOVE); organizations committed to the development and promotion of integrated pest management techniques for its member agencies and the public.
- 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 the California Department of Public Health and the University of California on various research and surveillance 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 and are considered in the District's operational surveillance and control procedures. Currently (2008), the District provides operational surveillance and/or control for multiple species of mosquitoes and ticks. Other pests and vectors are considered on a case-by-case basis by the District's Board of Trustees and professional staff.

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. Additionally, certain species of ticks are known vectors of babesiosis, ehrlichiosis, and Lyme disease.

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 and ticks. 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

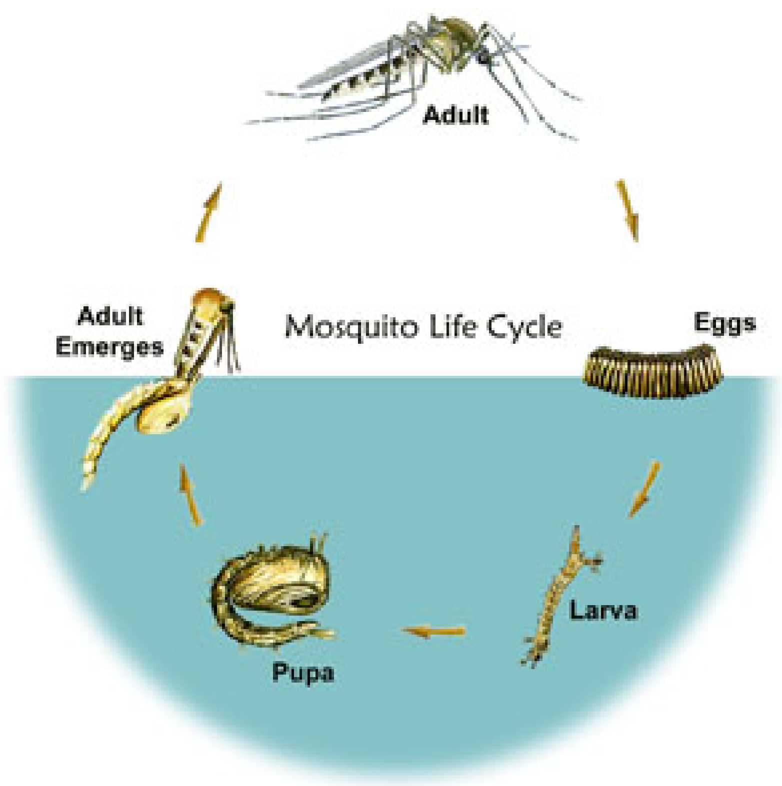
Genus *Culiseta* Felt:
Culiseta incidens (Thompson) – the cool weather mosquito
Culiseta inornata (Williston) – the large winter mosquito
Culiseta particeps (Adams)

Genus *Orthopodomyia* Theobald:
Orthopodomyia signifera (Coquillett)

General information

Mosquitoes present both a pest and public health problem for humans, domestic animals, and wildlife within San Joaquin County. Several locally found species are involved in the transmission of important pathogens, including West Nile virus (WNV), 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 wildlife habitat and managed 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 West Nile Virus (WNV), western equine encephalomyelitis (WEE), St. Louis encephalitis (SLE), and canine heartworm and has experienced several outbreaks of these diseases in both humans and animals since 1930. The primary vector of WNV and WEE 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 mosquito-borne encephalitis during the period 1945 to 1984 for San Joaquin County totaled 80 for WEE and 36 for SLE. WEE virus was detected in sentinel chicken flocks and adult mosquito pools during the period 1993 – 1997, but no human or equine cases were reported. WNV was originally detected in the USA in 1999 in New York City. The virus was first detected in San Joaquin County in 2004 and resulted in three (3) human and 19 equine cases that year. WNV has been routinely detected in mosquito pools, dead birds, sentinel chicken flocks, humans and equines throughout most of San Joaquin County and adjacent counties since 2004.
- Imported (exotic) cases of human malaria are reported to the District periodically by San Joaquin County Public Health Services. The malaria vector, *Anopheles freeborni*, is found throughout the District and in several 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. Locally-transmitted cases of canine heartworm are routinely reported to the District by local veterinarians.

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 seen as an example of chemical misuse, not a result of mosquito control applications.

Idiopathic Environmental Illness (IEI), often referred to as multiple chemical sensitivity (MCS), is now a recognized medical phenomenon. A working definition of IEI is: An acquired disorder with multiple recurrent symptoms, associated with diverse environmental factors, tolerated by the majority of people, and not explained by any known medical or psychiatric/psychological disorder. 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 or complaints in the past (e.g., beekeepers, organic growers).

Adulticide (chemicals applied to control adult mosquitoes) 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 adult mosquito 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. In certain conditions, District technicians implement the “spray on, spray off” technique to avoid direct treatments to sites where residents have requested limited spraying of their property. Additionally, the District maintains a list of names and addresses of residents who wish to be notified in advance of operational spray activities.

Potential problems of chronic chemical exposure

Problems resulting from chronic exposure to chemicals are 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 and naled, have been used routinely for over 50 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., *Bacillus sphaericus*, methoprene), are used in specific habitats and 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 to the extent practical. This can be achieved by continually reviewing and improving tactical mosquito control 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 aircraft and vehicle-mounted ULV equipment, with the sprays capable of drifting beyond the target zone. ULV adulticides used in San Joaquin County are either organophosphate, botanical pyrethrin or synthetic pyrethroids, with pyrethrin and pyrethroid adulticides generally synergized with piperonyl butoxide (PBO). These materials are applied during periods of adult mosquito activity and favorable meteorological conditions. Some residents of the District and local special interest groups have provided comments 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. Comments from special interest groups and requests for service from local residents have 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), and at very low pesticide dosage and application rates. It is assumed that these actions reduce the impact to known non-target populations.

Risks of larviciding

Controlling a brood of mosquitoes in the larval stage 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 sub-lethal toxicity to non-target organisms. However, using biorational materials (e.g., Bti, Bs) 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 arbovirus' is described in a separate section (see California Mosquito-Borne Virus Surveillance & Response Plan, April 2008).

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 known 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 1,400 square miles) is considered viable for human use and/or habitation. Mosquitoes are monitored throughout the year.

Control efforts are justified when mosquito populations create a nuisance, or are determined to be capable of vectoring an arbovirus. A nuisance mosquito bothers people and domestic animals, typically in or around homes and other developed areas, and in recreational areas. Economically, mosquitoes can reduce property values, slow economic development of an area, reduce tourism, or adversely affect the health of pets and 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), western equine encephalitis (WEE), and West Nile virus (WNV). 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, 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 (2008), the District utilizes a threshold value of 0.1 larvae per dip (≥1 larvae in 10 dips) for consideration of a form of mosquito control, i.e., mosquito fish planting, larviciding, etc.

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 that 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, *Anopheles* and *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 an observation 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-style light trap (NJLT), encephalitis virus surveillance (EVS) trap, baited Fay trap, and gravid trap.

- Up to 48 EVS traps are used at different times during the year. The traps are used to collect adult *Culex pipiens and Cx. tarsalis* mosquitoes for use as mosquito pools, which are either tested in the District's laboratory or sent to the CDPH 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 and are generally used in urban and suburban settings where *Culex pipiens* have been detected.

Monitoring telephone service requests and resident complaints

The third method of ascertaining a mosquito problem is through telephone and website service requests and resident complaints. The District maintains several different listed telephone numbers, including a toll-free line that residents and visitors can call to request mosquito control services; additionally, residents are encouraged to use District's website at www.sjmosquito.org to seek assistance also. 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.

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 mosquito populations, citizen complaints, and 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, and arbovirus activity in the environment less important. Although the adult mosquito population is at or above a tolerance threshold for other conditions, the District may not implement certain control actions 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 humans, domestic animals, mosquito pools, dead birds 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 inornata*, in the winter months, it would be a significant public health risk for the species *Culex tarsalis* during the months of April through November.
- 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 with the use of a larvicide. Larvae of the species *Aedes sierrensis* can 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 near future. 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 most commonly used biocontrol agents used by the District is the mosquitofish *Gambusia affinis.*

Biological control utilizing mosquito-eating fish

The District utilizes two (2) species of mosquito-eating fish as biocontrol agents, the western mosquitofish *Gambusia affinis*, and to a lesser extent, the guppy *Poecilia reticulata.* The mosquitofish is the most extensively used biocontrol agent for mosquitoes in San Joaquin County and most of California. This fish, which feeds on mosquito larvae and other small aquatic invertebrates, 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 can incorporate the use of guppies. During the 1990’s, concerns of placing mosquito-eating fish in habitats where endangered or threatened species exist were raised by the United States Fish and Wildlife Service. In response to those concerns, the District 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 were used to identify appropriate and inappropriate sites for use of mosquitofish as a biocontrol agent. Care is taken to place mosquitofish 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 semi-naturally occurring supplies of mosquitofish. Mosquitofish were originally introduced into California in the 1920's, and have been dispersed throughout the state for mosquito control purposes ever since. Although the fish is considered non-native specie, mosquitofish are endemic throughout San Joaquin County and most of California's Central Valley. Locally, mosquitofish are found in rivers, creeks, sloughs, reservoirs, drainage canals, irrigation ditches, stock ponds, and other similar aquatic sites. District personnel routinely collect mosquitofish from these types of sites for use in mosquito breeding 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 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 residential, commercial and agricultural mosquito sources. 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

Mosquitofish 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 some situations, mosquito larvae production outruns the increase in fish population that would be necessary for control.

Biocontrol utilizing other agents and organisms

The District has tested the water mold fungus *Lagenidium giganteum* as a biocontrol agent in freshwater wetlands and rice fields. Because *L. giganteum* has been proven non-toxic to mammals, plants, fish, birds, and non-target aquatic organisms, this material has the potential to be used as a mosquito larvicide. To date (2008), there is no commercially-available material for use on a broad scale basis.

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, thin film larvicides, and insect growth regulators. Organophosphate and pyrethroid compounds are used mainly for controlling adult mosquitoes, while microbial, thin film larvicides and insect growth regulators are 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 and specialized ULV spray equipment, and is typical of what is used in agricultural and public health pest control 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 classes of pesticides used as 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* is active both day and night. Treatments directed at *Cx. erythrothorax* could miss major portions of the *Ae. vexans* population if commingled. 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 generally 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 at sunset or at sunrise, depending on mosquito species activity and the application site conditions. Ideal ULV adulticiding conditions usually include moderate air temperature (60-80ºF), relative humidity of 30-80%, the presence of a thermal inversion layer above ground level, and wind currents of 10 mph or less. These conditions keep the spray or fog in close ground contact and allow for a semi-uniform downwind dispersal of material. Air temperatures and wind speed/direction information is determined prior to application using several available weather websites. Wind direction and speed are also measured and recorded by the applicator at the treatment site.

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 laboratory 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, ranging from slightly toxic to highly toxic, and the individual insecticide labels include the signal words "Caution", "Warning", or "Danger", which corresponds to their level of toxicity. The District generally utilizes adulticides that are labeled with the signal word Caution, which is considered the least toxic.

Techniques used to adulticide

Aerial and ground adulticiding are the most commonly used methods of controlling adult mosquitoes in San Joaquin County. Aerial and 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.

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 ten (10) mosquitoes per trap night in urban, suburban, and rural residential areas. When service requests for adult mosquitoes from the public have been confirmed by one or more recognized surveillance techniques.
- When an arbovirus (e.g. WNV) has been detected in an area where vector species are evident.

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. Aerial and 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 aerosols is that they do not require large amounts of diluents for application and are therefore 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 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 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. Larvicides are used to kill immature mosquito populations. Larvicides are applied by aircraft, vehicle-mounted, and hand-held 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 (2008), 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 to complete 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.

Insecticides used as larvicides

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.

Legal Abatement

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 the California Health and Safety Code.

Mosquito sources that can require legal abatement resolution generally involve aquatic conditions that are man-made/managed. 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 habitat modification, 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 storm water. 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 and implementation 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 and justify the merits of each project. In certain cases, other government agencies (e.g. California Department of Public Health, U.S. Agricultural Stabilization and Conservation Service, local reclamation districts) assisted with the design and implementation of the projects.

At this point in time (2008), the District is not involved in the development 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.

<u>Mosquito producing habitats considered for physical control</u>

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:

- Artificial containers, such as flowerpots, cans, barrels, and tires. Mosquito species found in these types of artificial 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.
  The District has an extensive program that addresses urban container mosquito breeding 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 in unincorporated areas, 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 (BMPs) for the prevention of mosquitoes.
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 BMPs 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 current 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 BMPs 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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