MONITORING PLAN
FOR MOSQUITO LARVICIDES AND ADULTICIDES

Prepared by

Mosquito and Vector Control Association of California

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ACRONYMS

°F	degrees Fahrenheit
µg/cm^2	micrograms per square centimeter
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
ATVs	all-terrain vehicles
BMPs	Best Management Practices
Bti	*Bacillus thuringiensis*
CAC	County Agricultural Commissioner
CDFG	California Department of Fish and Game
CDPH	California Department of Public Health
CFR	Code of Federal Regulations
DGEIS	Draft Generic Environmental Impact Statement
DPR	Department of Pesticide Regulation
EEC	expected environmental concentrations
FIFRA	Federal Insecticide, Fungicide, and Rodenticide Act
IPM	Integrated Pest Management
ITUs	International Toxic Units
IVM	Integrated Vector Management
Mg/L	milligrams per liter
MRP	Monitoring and Reporting Plan
MVCAC	Mosquito and Vector Control Association of California
NPDES	National Pollutant Discharge Elimination System
PBO	piperonyl butoxide
ppb	parts per billion
ppm	parts per million
PUR	Pesticide use report
RED	Reregistration Eligibility Decision
RUP	Restricted-use pesticide
SWRCB	State Water Resources Control Board
TIE	toxicity identification evaluation
U.S. EPA	United States Environmental Protection Agency
ULV	Ultra-Low Volume
URS	URS Corporation
USFWS	U.S. Fish and Wildlife Service
UV	Ultraviolet

1.1 INTRODUCTION

Mosquito control agencies in California follow an integrated pest management (IPM) approach that strives to minimize the use of pesticides and their impact on the environment while protecting public health. These agencies determine what is appropriate in their districts, and follow response plans that use surveillance tools to determine the extent of the problem and guide treatment decisions, with an emphasis on source reduction and control of mosquitoes in their immature stages. They have chosen to use the least toxic materials available for control of the larval stages, focusing on bacterial larvicides, growth regulators and surface films rather than organophosphates or pyrethroids. Control of adult mosquitoes may become necessary under some circumstances, such as in the event of a disease outbreak (documented presence of infectious virus in active host-seeking adult mosquitoes), or lack of access to larval sources leading to the emergence of large numbers of biting adult mosquitoes. Current levels of adulticide use are much lower than they were through the 1980s. However, the scope of control for adult mosquitoes in California has increased since 2004, when West Nile virus reached epidemic levels and dispersed to all 58 counties (Armijos et al. 2005; Hom et al. 2005). West Nile virus is a mosquito-borne viral disease, with cases varying from asymptomatic to serious neurological symptoms and death. There is no specific treatment for West Nile virus—prevention is key. Human West Nile virus cases for California counties over the years total 2874 and are shown in Figures 1-1 through 1-6. In 2008, there were 445 reported human cases in the State, which represented 32.8 percent of the total human cases reported in the United States. West Nile virus also adversely impacts many species of birds and can cause serious illness and death in horses. Mosquito control remains the only effective method of limiting the threat of this virus to public health. Control of adult mosquitoes through the application of adulticides is an essential tool in responding to spread of viral diseases (Gubler et al. 2000; Kramer 2005).

1.2 NPDES PERMIT FOR MOSQUITO LARVICIDE AND ADULTICIDE APPLICATIONS

Mosquito larvicide and adulticide applications are regulated under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA). Following the recent decision by the Sixth Circuit Court of Appeals, these applications will also require coverage under the NPDES. The Court's decision held that applications of pesticides to, over, and around waterways that could result in deposition of pesticide residuals into waters of the United States may qualify as pollutants and require NPDES permits. Currently, representatives of mosquito control districts are working with the State Water Resources Control Board (SWRCB) to develop a combined statewide permit that would cover the application of both mosquito larvicides and adulticides. In February 2009, SWRCB staff met with members of MVCAC, which represents the vast majority of governmental mosquito control programs in the state. California Department of Pesticide Regulation (DPR) and California Department of Public Health (CDPH) representatives were also present at the meeting, which was held to discuss MVCAC's need for a mosquito adulticide permit as a result of the Sixth Circuit Court's ruling. Subsequently, representatives of MVCAC, SWRCB, DPR, and DPH formed a technical committee to facilitate drafting the permit.

Representatives of the United States Environmental Protection Agency (U.S. EPA) Region IX joined the technical committee after its initial formation.

Although the SWRCB initially intended to adopt an adulticide permit and later revise the larvicide permit (resulting in two separate permits), representatives of MVCAC encouraged adoption of a combined permit that includes both larvicide and adulticide applications. In February 2010, the SWRCB agreed to prepare a combined permit, and requested that MVCAC propose a monitoring approach that covers both larvicides and adulticides.

1.3 OBJECTIVES OF THIS MONITORING PLAN

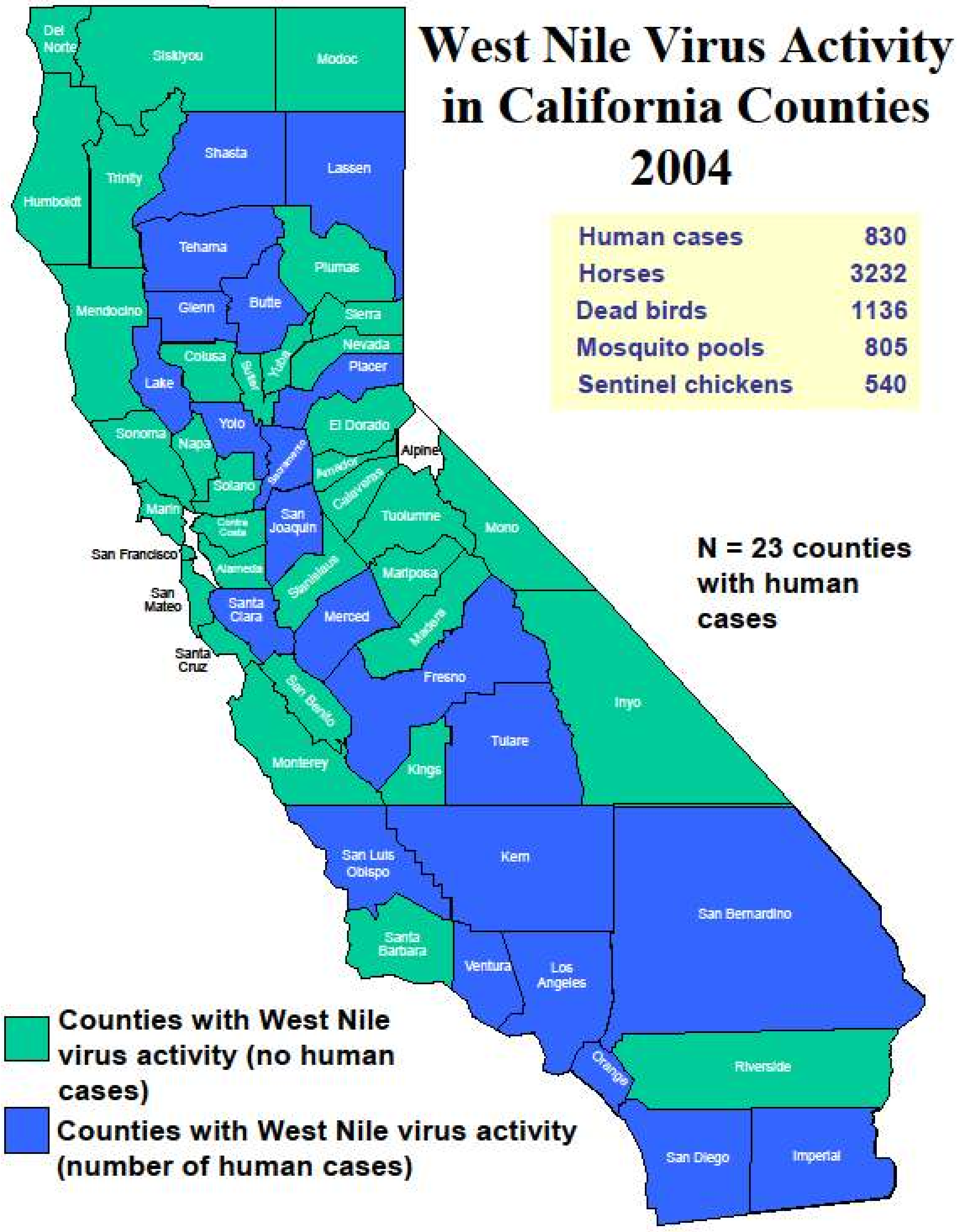
The SWRCB identified the following key questions to focus the monitoring program:

1. Does the pesticide residue from spray applications cause an exceedance of receiving water limitations or monitoring triggers?
2. Does the pesticide residue, including active ingredients, inert ingredients, and degradates, in any combination, cause or contribute to an exceedance of the "no toxics in toxic amount" narrative toxicity objective?

To assist in answering these questions, the SWRCB envisions a process that will use existing data, determine the critical gaps in knowledge, and develop a monitoring program to address key areas of uncertainty. Towards this end, the SWRCB has requested that MVCAC review available data and draft a Conceptual Monitoring Program for consideration by the technical committee.

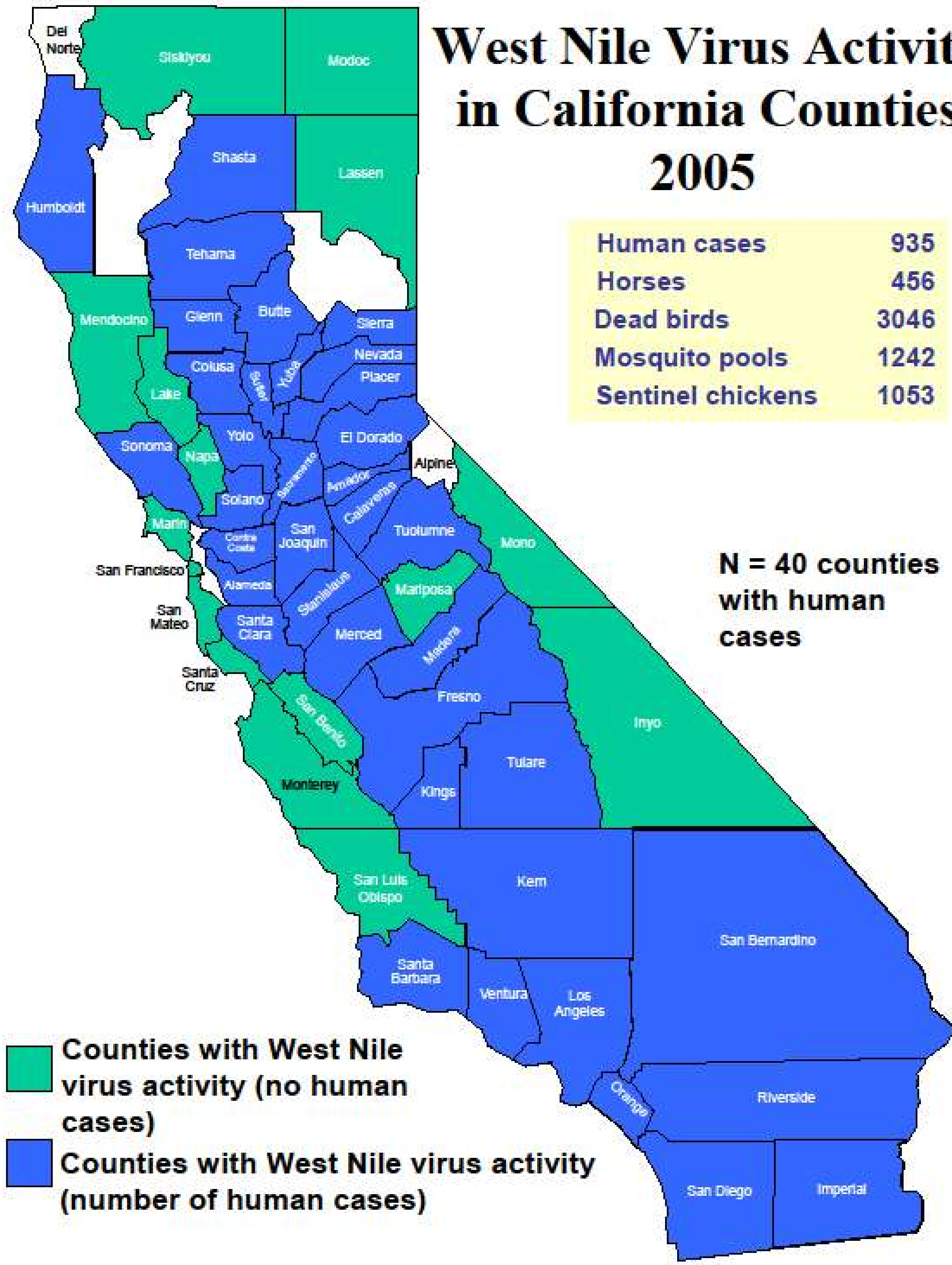
The goals of this Monitoring Program are to:

- Summarize recent data on use of larvicides and adulticides by MVCAC members;
- Summarize the findings of studies addressing the environmental fate of the materials used in mosquito control and their potential impacts on aquatic organisms;
- Identify the data gaps and informational needs to answer the key questions; and
- Develop a monitoring and reporting program (MRP) to collect data to help answer the key questions.



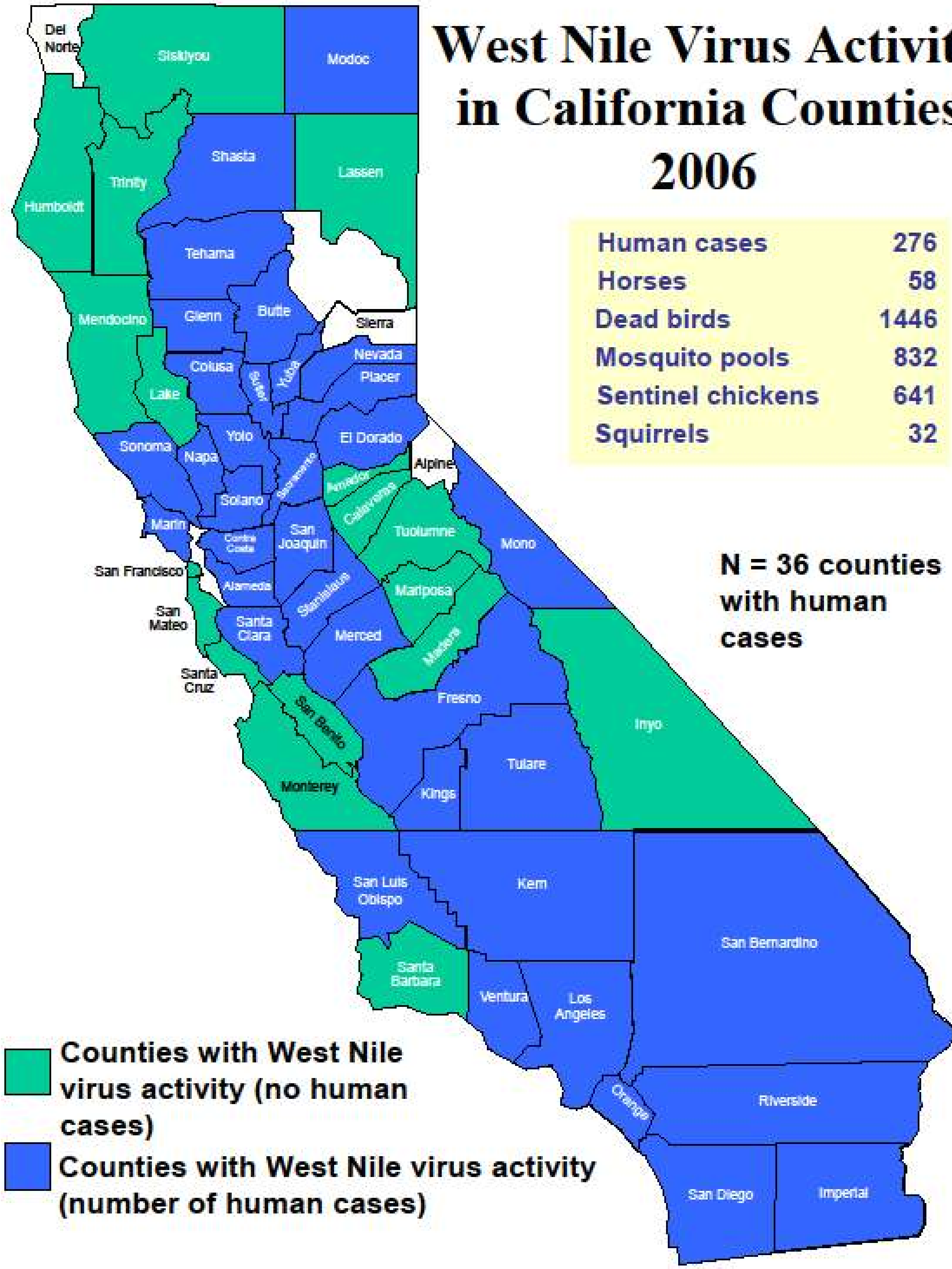
Source: http://www.westnile.ca.gov/

Figure 1-1. 2004 West Nile Virus Cases in California



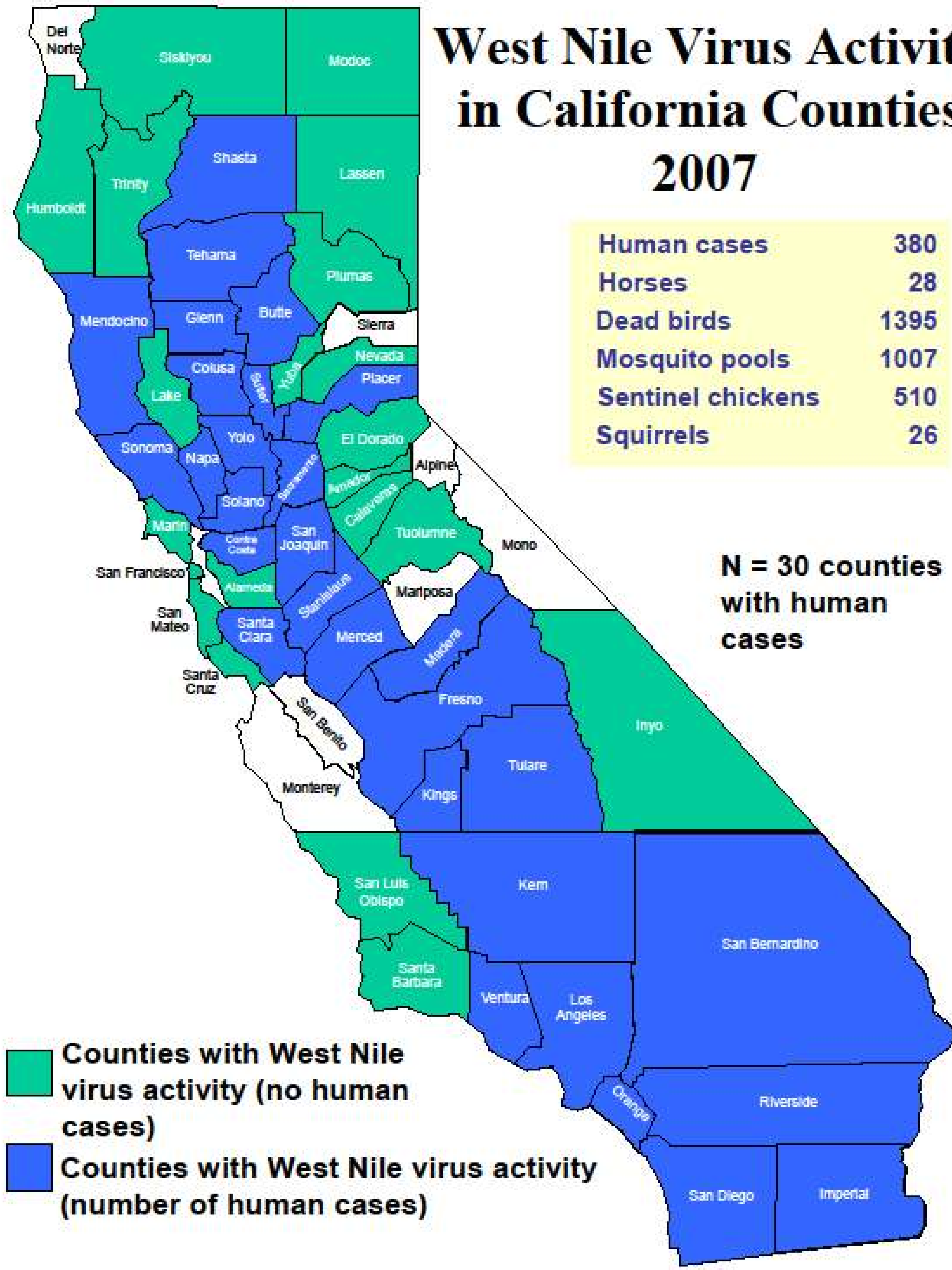
Source: http://www.westnile.ca.gov/

Figure 1-2. 2005 West Nile Virus Cases in California



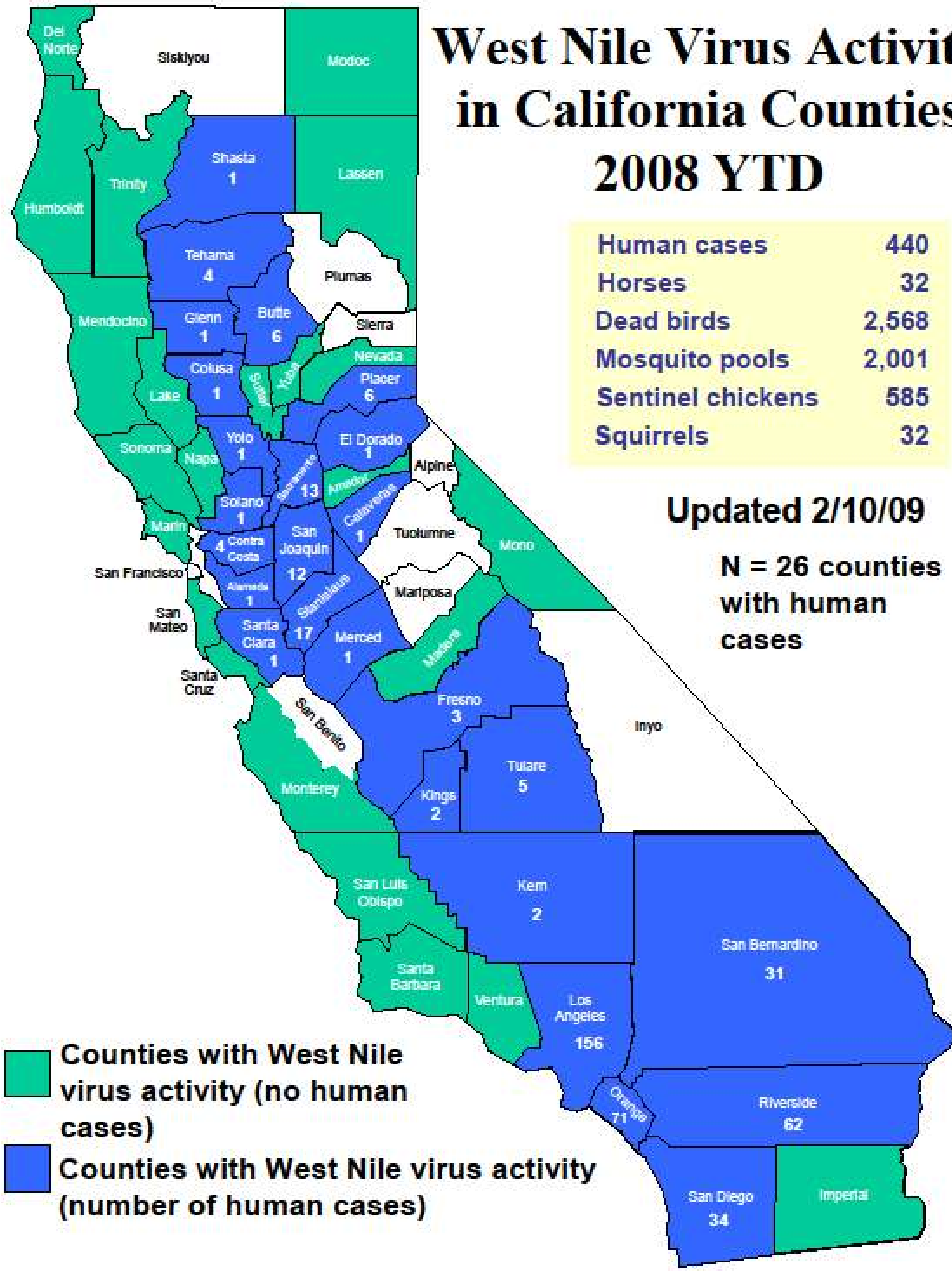
Source: http://www.westnile.ca.gov/

Figure 1-3. 2006 West Nile Virus Cases in California



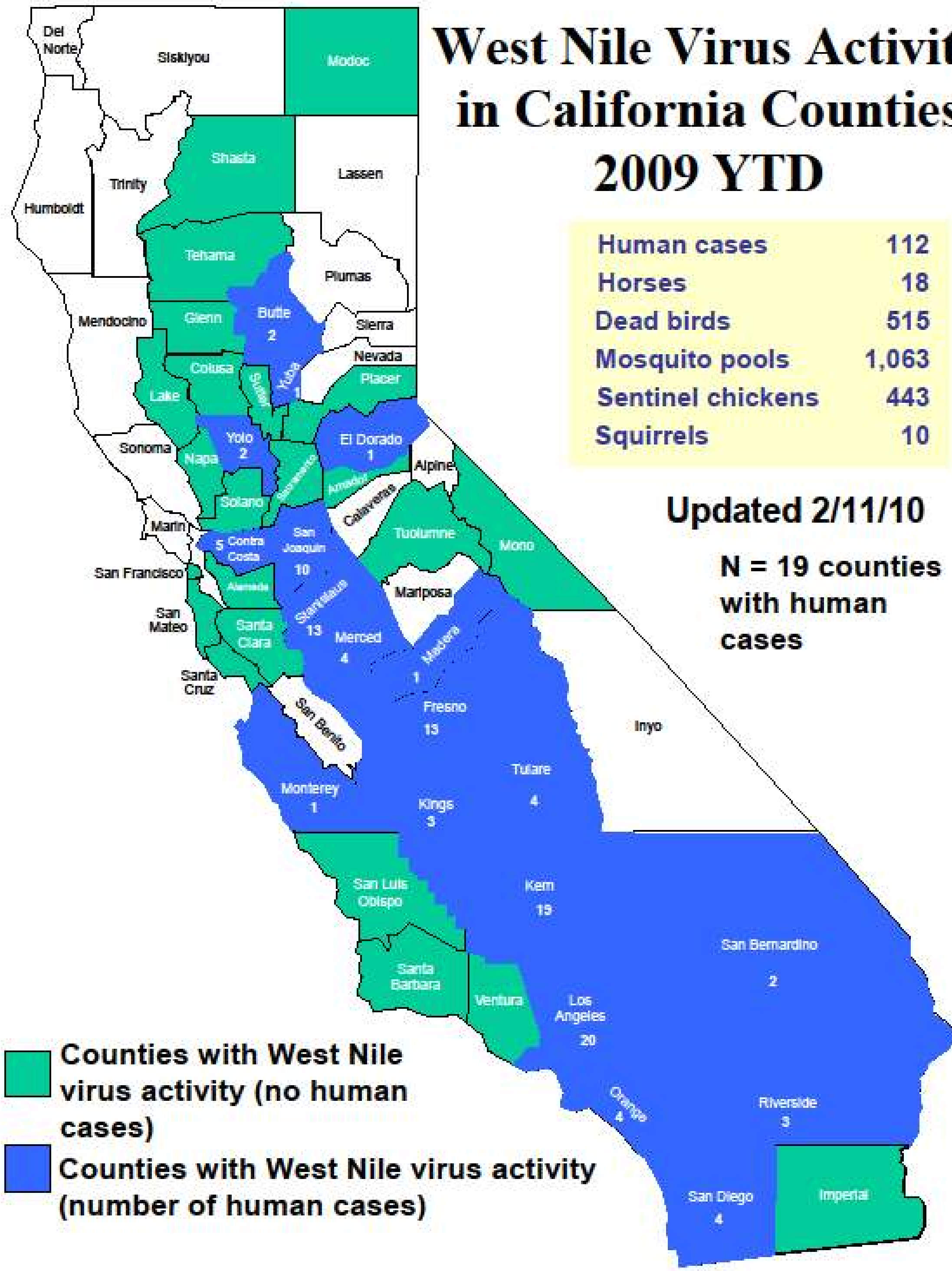
Source: http://www.westnile.ca.gov/

Figure 1-4. 2007 West Nile Virus Cases in California



Source: http://www.westnile.ca.gov/

Figure 1-5. 2008 West Nile Virus Cases in California



Source: http://www.westnile.ca.gov/

Figure 1-6. 2009 West Nile Virus Cases in California

2.1 OVERVIEW OF MOSQUITO CONTROL IN CALIFORNIA

The primary objective of mosquito control is the protection of people from the discomfort and diseases resulting from mosquito bites. The most frequently contracted diseases associated with mosquitoes in California are West Nile fever, West Nile neuroinvasive disease, St. Louis encephalitis, and western equine encephalomyelitis (see Table 2-1).

Table 2-1. Most Important Mosquito-Borne Disease Pathogens in California, the Diseases that Result from Infections, and the Primary Vectors

Pathogen	Disease	Vectors
California encephalitis virus	California encephalitis	*Aedes melanimon*
St. Louis encephalitis virus	St. Louis encephalitis	*Culex tarsalis, Cx. quinquefasciatus*
Western equine encephalomyelitis virus	Western equine encephalomyelitis	*Culex tarsalis*
West Nile virus	West Nile fever, West Nile neuroinvasive disease	*Culex tarsalis, Cx. pipiens, Cx. quinquefasciatus*
Plasmodium vivax, P. falciparum	Malaria	*Anopheles freeborni, An. punctipennis*
Dirofilaria immitis	Dog heartworm	*Aedes* spp.

Source: CDPH 2008

Mosquito control is accomplished through direct or indirect human intervention to eliminate or reduce the size of mosquito populations in a given area. Effective and long-lasting control can be accomplished by scientifically planned management and control strategies that are applied in a timely manner to achieve significant reductions in mosquito populations. These strategies fall into several categories, as described below and summarized in Table 2-2.

- **Physical Control.** Physical control is the preferred method of reducing mosquito populations. Physical control means the modification and management of the environment to discourage production or survival of mosquitoes. Most of these methods involve water management, and are done cooperatively with private landowners, water-rights holders, and/or other agencies charged with protection and management of lakes, ponds, rivers, streams, marshes, and swamps.
- **Chemical Control.** Chemical control is the application of insecticides (including microbial, biochemical, and surface films) to adult or larval habitats of mosquitoes. Generally, chemical control of larvae is preferred over chemical control of adult mosquitoes because larvicides can be applied in a highly directed manner. Larval control also has few effects to non-target organisms, because larvicides in use today by MVCAC members are generally highly selective.
- **Protective Measures.** Personal protective measures are the steps individuals can take for themselves and their families to protect them from mosquito bites. The use of mosquito repellents, the wearing of clothing that minimizes the amount of skin exposed to mosquitoes, window and door screens, and avoidance of situations (e.g., being out-of-doors at dusk) are

all examples of personal protective measures. If similar methods are applied by a mosquito abatement agency (establishment of treated barriers, selective vegetation removal, etc.) then the term "area protective measures" is used.

Table 2-2. Summary of Natural Mosquito Population Limiting Factors and Mosquito Abatement Strategies

NATURAL POPULATION LIMITING FACTORS	
Biological limiting factors	Pathogens, parasitism, predation, competition
Physical limiting factors	Adults – air temperature, relative humidity, protective shelter Larvae – water temperature, dissolved salts/pollutants, currents, habitat
CHEMICAL CONTROL METHODS	
Adulticides	Organophosphates, pyrethrum, synthetic pyrethroids
Larvicides	Microbials, biochemicals, surface films
PHYSICAL CONTROL METHODS	
Aquatic habitats	Water management, vegetation management, physical design
Terrestrial habitats	Field grading, effective building codes, air conditioning
BIOLOGICAL CONTROL METHODS	
Releases of agents	Pathogens, parasites, predators (primarily *gambusia*)
Conservation of agents	Proper water management, use of selective insecticides that leave predator populations intact
AREA PROTECTIVE MEASURES	
Public relations	Literature, public education, mosquito-proofing of public buildings
Area control	Mosquito barrier treatments (very limited areas)
PERSONAL PROTECTIVE MEASURES	
Personal measures	Repellents, protective clothing, staying indoors
Home control	Draining of water, use of mosquitofish
Source: CDPH 2008	

In California, IPM, or integrated vector management (IVM), uses a combination of all the above methods for the most ecologically sound method of mosquito control. Principles of insecticide use in IPM include:

- Use of monitoring to direct control efforts and minimize pesticide applications
- Taking advantage of biological, and physical,factors to control mosquito popuations and minimize pesticide applications
- Utilizing appropriate thresholdsfor pesticide application decisions
- Applying insecticides in a manner that minimizes harm to non-target organisms.
- Choosing control materials with the lowest toxicity to nontarget organisms while still effectively controlling mosquitoes

- Using insecticides to treat specific sites where mosquitoes are being produced and are causing annoyance or creating a public health problem.
- Applying insecticides selectively to the proper life stage of the mosquito (e.g., egg, larva, pupa, or adult).
- Applying insecticides in a manner that will minimize personal hazard to the applicator and other persons in the vicinity.

By definition, an IPM approach involves procedures for minimizing potential impacts to the environment and water quality. Agencies employ these principles by first determining the species and abundance of vectors through evaluation and then use the most efficient, effective, means of control.

In California, tax-supported mosquito-abatement or vector-control districts are tasked with controlling mosquito populations and preventing vector-borne diseases. Most of these districts belong to the MVCAC, which currently has more than 60 members representing mosquito- and vector-control programs. Many of these districts are in the Central Valley of California, where mosquitoes are a particularly serious problem. Approximately 36 million Californians (about 85 percent of the total population of the state) are protected from mosquitoes and associated diseases by the efforts of some type of organized mosquito abatement program (CDHP 2008). Statewide coverage of MVCAC members by county is shown on Figure 2-1, and MVCAC members are listed in Table 2-3.

The State's pesticide regulations provide special procedures for vector control agencies operating under cooperative agreements. The application of pesticides by vector control agencies is regulated by a special arrangement among the CDPH, DPR, County Agricultural Commissioners (CACs), and vector control agencies. Vector control agencies are not directly regulated by DPR. Instead, supervisors or applicators are licensed by CDPH. Pesticide use by vector control agencies is reported to the CAC in accordance with a 1995 Memorandum of Understanding among DPR, DHS, and CACs for the Protection of Human Health from the Adverse Effects of Pesticides, and with cooperative agreements entered into between CDPH and vector control agencies, pursuant to Health and Safety Code Section 116180.

Historically, MVCAC agencies have usually viewed using larvicides as less effective or less economical than physical control, water management, or biological control; and as more effective than using adulticides. However, this view developed long ago, when the values of wetlands were not as widely recognized as they are today, and when relative control costs were different. To some extent, this philosophy has been evolving in recent decades as more selective larvicides have become available, and as physical and biological control have become more constrained by regulatory requirements. Although it can be difficult to compare the relative environmental impacts of different control strategies, it is now increasingly common to primarily use selective larvicides in relatively undisturbed sites, and to emphasize physical control and biological control primarily in man-made or disturbed areas.

2.2 Mosquito Larvicides and Use in California

Vector control agencies regularly inspect areas of standing water for immature mosquitoes to determine the local conditions. The action level or threshold is determined by each mosquito control program and varies according to local conditions. When a threshold is exceeded, control measures are generally determined using a decision process such as that described in Appendix A. When it is determined that use of larvicides are warranted, the most appropriate larvicide is selected taking into account the following factors:

- Selectivity and toxicity to nontarget organisms (whenever possible choose products with least impact to nontarget organisms)
- If the site is difficult to access or to minimize disturbance to sensitive habitat, a slow release product may be selected to minimize application frequency.
- Time release pellets and briquets (similar in form to charcoal briquets) are very expensive and generally not cost-effective to use on large sites).
- Consideration of which mosquito species are present (some products do not work as well on certain species).
- Sensitive habitat such as vernal pools and/or presence of special-status species may limit the use of some larvicides.
- Thick vegetation, tire piles, or log piles may require a heavy granule to deliver the material to the water.
- Rotating products to avoid resistance.

Selecting the proper class of larvicide and the formulation are both important in pesticide resistance management. For example, use of sub-lethal dosages (below the lower end of the label-recommended application rates) may encourage resistance. Insects with inherent tolerances for weakly applied pesticides may survive to produce tolerant offspring. Also, use of extended-release formulations beyond their recommended use period may encourage resistance by exposing mosquitoes to sub-lethal concentrations of active ingredients.

2.2.1 Larvicide Application Methods and Materials Used in California

Because of the wide range of mosquito sources within each member agency, and the variety of pesticide formulations described above, each agency uses a variety of techniques and equipment to apply larvicides, including hand-held sprayers and spreaders with a power backpack; from truck- or all terrain vehicle (ATV)-mounted spray rigs; and in very large or inaccessible areas, from helicopters or other aircraft. Application methods for the various formulations of each active ingredient are described in Table 2-4.

Ground Application Equipment. The larvicides can be applied with pick-up trucks or ATVs. A chemical-container tank, high-pressure, low-volume electric or gas pump, and spray nozzle are mounted in the back of the truck bed, with a switch and extension hose allowing the driver to operate the equipment and apply the larvicide from the truck's cab. The ATVs have a chemical container mounted on the vehicle, a 12-volt electric pump supplying high–pressure, low-volume flow, and booms and/or hoses and spray tips allowing for application while steering the vehicle. ATVs are ideal for treating areas such as agricultural fields, pastures, and other off-road sites. Additional training in ATV safety and handling is provided to employees before operating these machines.

Additional equipment used in ground applications includes hand-held sprayers and backpack blowers. Hand-held sprayers (hand cans) are standard 1- or 2-gallon garden-style pump-up sprayers used to treat small, isolated areas. Backpack sprayers are gas-powered blowers with a chemical tank and calibrated proportioning slot. Generally, a pellet or small granular material is applied with a backpack sprayer or “belly grinder” machine designed to distribute pellets or granules.

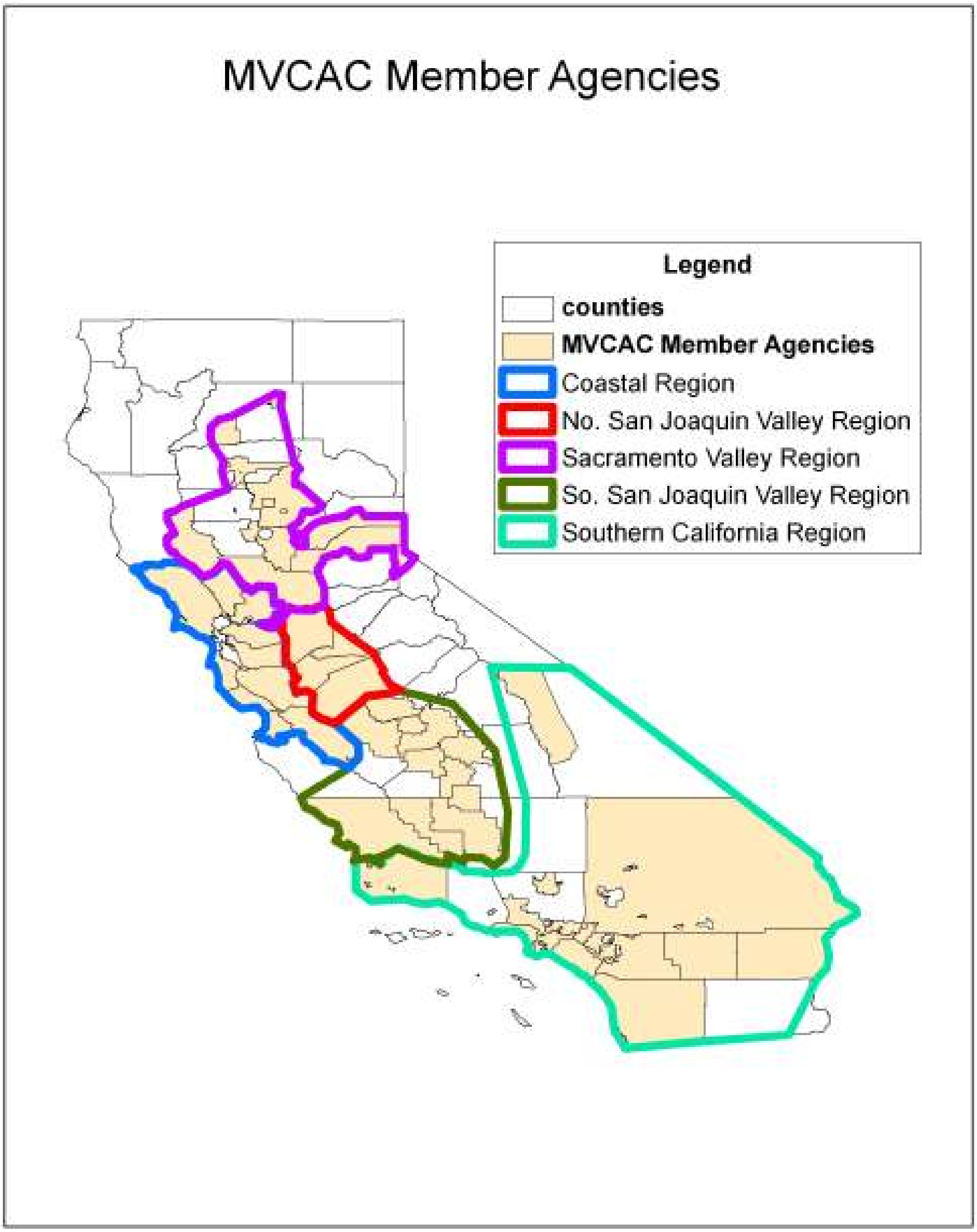


Figure 2-1. MVCAC Member Agencies

Table 2-3. Typical Mosquito Adulticide Application by District for 2008 (Varies by Year)

Region	District	Acres per year	Number of Applications	Minimum Acres per Site	Maximum Acres per Site	Repeated Applications per Site	Application by Air	Application by Truck	Application by Handheld Device	Sites Treated
Coastal	Alameda MAD	10	1	<1	10	1	no	no	yes	wetlands
	Alameda VCD									
	Contra Costa	620 to 18,400	8 to 44	<1	thousands	1 to 3 times (rarely)	no	yes	yes	all
	Marin-Sonoma	8,300	517	<1	few blocks	1 times	no	yes	yes	all
	Napa	22,000	200	3	100	1 to 5 times	no	yes	yes	rural
	North Salinas		5	1		1 to 5 times	no	yes	yes	rural, wetland
	San Benito	5	1 to 5	1	4	1 times	no	yes	yes	agricultural, wetlands, forest (treeholes)
	San Francisco									
	San Mateo			<1	15,000		no	yes	yes	
	Santa Clara	1,600	1 to 2	<1	1,600	1 to 2 times	no	yes	yes	urban
	Santa Cruz									
	Solano	17,871	355	<1	1,000		no	yes	yes	agricultural wetlands, urban

Table 2-3. Typical Mosquito Adulticide Application by District for 2008 (Varies by Year)

Region	District	Acres per year	Number of Applications	Minimum Acres per Site	Maximum Acres per Site	Repeated Applications per Site	Application by Air	Application by Truck	Application by Handheld Device	Sites Treated
Sacramento Valley	Burney Basin	121,065	60	14,000	106,000	weekly to bi-weekly	yes	yes		agricultural, rural
	Butte County	325,000	1,700	1	25,000		yes	yes		agricultural, urban, forest, wetlands
	Colusa	121,062	821	5,000	15,000	1 to 2 times per week for 16 weeks	yes	yes		rice, wetlands, rural
	Durham									
	El Dorado County	10	1 to 3	1		1 times	no	yes	yes	rural
	Glenn County	many	141			1 to 2 times per week all summer	no	yes		rice, rural, cities
	Valley-Wide District	many	169			1 to 2 times per week all summer	no	yes		rice, rural, cities
	Lake County	31,000	800	<1		5 to 8 times	no	yes	yes	treeholes, rice, wetlands, urban, rural
	Nevada County									
	Oroville									
	Pine Grove	205 sq mi	54			weekly	no	yes		pasture, rice, wetlands, treeholes, urban, rural

Table 2-3. Typical Mosquito Adulticide Application by District for 2008 (Varies by Year)

Region	District	Acres per year	Number of Applications	Minimum Acres per Site	Maximum Acres per Site	Repeated Applications per Site	Application by Air	Application by Truck	Application by Handheld Device	Sites Treated
	Placer County	108,664	387	1	7,000		yes	yes		treeholes, rice, wetlands, urban, rural
	Sacramento-Yolo	350,000 to 1 million	300 to 1,000	10	60,000	up to 25	yes	yes	yes	rice and others
	Shasta	164,600	360			1 to 4 times per season	no	yes		mostly urban, also ag and wetlands
	Sutter Yuba	541,180	978	<1	13,000	1 times to weekly	yes	yes	yes	pasture, rice, wetlands, treeholes, urban, rural
	Tehama County	100,000	450			1 to 8 times	no	yes		pasture, rice, wetlands, treeholes, urban, rural
North San Joaquin Valley	East Side	91,685	921			depends	yes	yes		urban, agricultural, pasture, treeholes
	Merced County	94,740	56	600	4,250	depends	yes			pasture, rice, wetlands, treeholes, urban, rural
	Saddle Creek	58,000	12	500 average	880	2 times weekly	no	yes		urban (golf course) wetlands, treeholes

Table 2-3. Typical Mosquito Adulticide Application by District for 2008 (Varies by Year)

Region	District	Acres per year	Number of Applications	Minimum Acres per Site	Maximum Acres per Site	Repeated Applications per Site	Application by Air	Application by Truck	Application by Handheld Device	Sites Treated
	San Joaquin County	780,000	92			6 times	yes	yes		agricultural, urban, golf course
	Turlock	77,954	240	3	4,160	1 to 10 times	yes	yes		urban, agricultural, wetlands
South San Joaquin Valley	Coalinga-Huron									
	Consolidated	20,135	554	0.023	365.8	1 to 13	no	yes	yes	urban, wetlands, rural
	Delano	60	2	20	40	1	no	yes		agricultural
	Delta	10,000	126	0.5	160	1 to 7 times	no	yes	yes	urban, ag
	Fresno	250	25	<1	10	1	no	yes	yes	irrigated pasture
	Fresno Westside	42,119	490				yes	yes	yes	
	Kern	50,000	267	200	200	2 to 3 times per year	no	yes	yes	urban, agricultural
	Kings	5,000	100	<1	50	2 to 3 times in a row	yes	yes	yes	all
	Madera	58,000	907	1	60	2 times per month	no	yes		agricultural, urban
	San Luis Obispo									
	Tulare	17,235	57	20	640	1 to 3 times per season	yes	yes		urban, suburban, agricultural

Table 2-3. Typical Mosquito Adulticide Application by District for 2008 (Varies by Year)

Region	District	Acres per year	Number of Applications	Minimum Acres per Site	Maximum Acres per Site	Repeated Applications per Site	Application by Air	Application by Truck	Application by Handheld Device	Sites Treated
	West side	102	11	1	20	1 to 5 times		yes	yes	urban
Southern California	Antelope Valley	0	0	never fog						
	Coachella Valley	17,596	67	15	150	5 to 10 times, depending on virus and mosquito activity	yes	yes		urban, wetland, agricultural
	Compton Creek	0	0	never fog						
	Greater Los Angeles	<2,480	20	<0.1	1920	2 to 7 times	no	yes		urban, wetlands, mausoleum, rural
	June Lake Pub. Util.	0	0	never fog						
	Long Beach	7,700	4	4	1920	4	no	no	yes	storm drain, urban
	Los Angeles Co West	0	0	never fog						
	Santa Barbara Co.	0	0	never fog						
	Mammoth Lakes	prob don't fog								
	Moorpark	0	0	never fog						

Table 2-3. Typical Mosquito Adulticide Application by District for 2008 (Varies by Year)

Region	District	Acres per year	Number of Applications	Minimum Acres per Site	Maximum Acres per Site	Repeated Applications per Site	Application by Air	Application by Truck	Application by Handheld Device	Sites Treated
	Northwest	7,000	30	5	250	1 to 7 times	no	yes	yes	urban, wetlands, parks, lakes
	Orange County	5,885	211	3.5	111	3 to 4 times (storm drains 2 times/ month)	no	yes	no	urban, wetland, storm drains
	Owens Valley	10,231	92	<1	>500	10 to 12 times	no	yes	yes	mostly agricultural, some urban
	Riverside	100	45	7	20		no	no	yes	urban, rural
	San Bernardino	100	300			3	yes	no	yes	dairy ranch, chicken ranch
	San Gabriel	159.5	2	19.5	95	1 or 2 (not all sites every year)	no	yes	yes	urban, parks
	West Valley	0	0	never fog						
	San Diego									

Table 2-4. Label Requirements and Label Application Rates by Formulation						
Active Ingredient	**Formulation Trade Name**	**EPA Reg. No.**	**% AI**	**% AI (2nd)**	**Label Application Rates for Mosquito Control**	**Label Requirements Relevant to Mosquito Control/Surface Water**
Bacillus Sphaericus (*Bs*)[1]	VECTOLEX CG BIOLOGICAL LARVICIDE	73049-20	7.5	--	5-20 lbs of formulation/acre. Use higher rates (10 to 20 lbs/acre) in areas where extended residual control is necessary, or in habitats having deep water or dense surface cover.	For agriculture/crop sites, apply uniformly by aerial or conventional ground equipment. Reapply as needed after 1 to 4 weeks. Avoiding spray drift at the application site is the responsibility of the applicator. The interaction of many equipment and weather related factors determine the potential for spray drift. Do not apply directly to finished drinking water reservoirs or drinking water receptacles when water is intended for human consumption.
	VECTOLEX WDG BIOLOGICAL LARVICIDE	73049-57	51.2	--	0.5-1.5 lbs formulation/acre (8oz-24oz product/acre). Use higher rates (1 to 1.5 lbs/acre) in areas where extended residual control is necessary, or in habitats having deep water or dense surface cover.	Apply uniformly by aerial or conventional ground equipment. Reapply as needed after 1-4 weeks. Do not apply directly to finished drinking water reservoirs or drinking water receptacles when water is intended for human consumption.
	VECTOLEX WSP BIOLOGICAL LARVICIDE	73049-20	7.5	--	1 pouch/50 sq.ft. Treat on basis of surface area of potential mosquito breeding sites by placing one (1) VectoLex Soluble Pouch for up to 50 square feet of treatment area.	Re-apply as needed after 1 to 4 weeks. Do not apply directly to finished drinking water reservoirs or drinking water receptacles when water is intended for human consumption.
Bacillus Thuringiensis, Subsp. *Israelensis* (*Bti*)[2]	VECTOBAC TECHNICAL POWDER	73049-13	100	--	0.455 to 0.91 billion ITUs per acre in mosquito habitats and 0.91 to 1.82 billion ITUs per acre in polluted water and sewage lagoons. (Product is equivalent to 2.275 billion ITUs per pound of undiluted powder.)	Powder must be diluted before application by suitable aerial or ground equipment. A 7 to 14 day interval between applications should be employed. Do not apply directly to finished drinking water reservoirs or drinking water receptacles when water is intended for human consumption.

Table 2-4. Label Requirements and Label Application Rates by Formulation

Active Ingredient	Formulation Trade Name	EPA Reg. No.	% AI	% AI (2nd)	Label Application Rates for Mosquito Control	Label Requirements Relevant to Mosquito Control/Surface Water
	VECTOBAC-12 AS	73049-38	11.61	--	0.25 to 2.0 pt formulation/acre. Use higher rate in polluted water and when late 3rd and early 4th instar larvae predominate, mosquito populations are high, water is heavily polluted, and/or algae are abundant.	Do not apply when weather conditions favor drift from treated areas. Apply in conventional ground or aerial application equipment with quantities of water sufficient to provide uniform coverage of the target area. Do not apply directly to finished drinking water reservoirs or drinking water receptacles when water is intended for human consumption.
	AQUABAC 200G	62637- 3	2.86	--	2.5 - 10.0 lbs formulation/acre. When late third and early fourth instar larvae predominate, larval populations are high, or water is heavily polluted and/or algae are prevalent, use 10-20 lbs product/acre	Uniformly apply AQUABAC (200 G) in conventional aerial and ground application equipment. Use a seven to fourteen-day interval between applications. Do not apply directly to finished drinking water reservoirs or drinking water receptacles when water is intended for human consumption.
	TEKNAR HP-D	73049-404	1.6	--	0.25-1.0 pt formulation/acre; 1.0-2.0 pt product/acre for water polluted with sewage, water with moderate organic content and water with a high level of suspended solids. Use lowest rate when 1st to 3rd instar larvae are predominant and highest rate when late 3rd to early 4th instar larvae are predominant in the mosquito population.	Apply TEKNAR HP-D when larvae are in 1st to early 4th instar. Larvicidal action is expected within 24 hours. Reapply as needed. When using standard spray equipment, use adequate volume of water to insure good coverage and penetration. Avoid spray drift. Do not apply directly to finished drinking water reservoirs or drinking water receptacles when water is intended for human consumption.
	VECTOBAC-G BIOLOGICAL MOSQUITO LARVICIDE GRANULES	73049-10	2.8	--	2.5-10 lbs formulation/acre; 10-20 lbs product/acre when late 3rd and early 4th instar larvae predominate, mosquito populations are high, water is heavily polluted (sewage lagoons, animal waste lagoons), and/or algae are abundant.	Apply uniformly by aerial or ground conventional equipment. Avoid spray drift. A 7 to 14 day interval between applications should be employed. Do not apply directly to finished drinking water reservoirs or drinking water receptacles when water is intended for human consumption.

Table 2-4. Label Requirements and Label Application Rates by Formulation

Active Ingredient	Formulation Trade Name	EPA Reg. No.	% AI	% AI (2nd)	Label Application Rates for Mosquito Control	Label Requirements Relevant to Mosquito Control/Surface Water
Bacillus Sphaericus (Bs) and *Bacillus Thuringiensis, Subsp. Israelensis (Bti)*	VECTOMAX CG BIOLOGICAL LARVICIDE	73049-429	2.7 [1]	4.5 [2]	5-20 lbs formulation/acre. Use higher rates (10 to 20 lbs/acre) in areas where 4th instar *Aedes* or *Ochlerotatus* spp. larvae predominate, or very high densities of late instar larvae are present, or under conditions where local experience indicates the need for higher rates to achieve extended residual control.	Avoid spray drift. Do not apply directly to finished drinking water reservoirs or drinking water receptacles when water is intended for human consumption.
	VECTOMAX WSP BIOLOGICAL LARVICIDE	73049-429	2.7 [1]	4.5 [2]	1 pouch/50 sq.ft.	Re-apply as needed. Under typical environmental conditions and treatment areas, re-apply after 1-4 weeks. For storm drains, catch basins, retention, and detention and seepage ponds, re-apply after 6-8 weeks. Do not apply directly to finished drinking water reservoirs or drinking water receptacles when water is intended for human consumption.
	VECTOMAX G BIOLOGICAL LARVICIDE/GRANULES	73949-429	2.7 [1]	4.5 [2]	5-20 lbs formulation/acre. Use higher rates (10 to 20 lbs/acre) in areas where 4th instar *Aedes* or *Ochlerotatus* spp. larvae predominate, or very high densities of late instar larvae are present, or under conditions where local experience indicates the need for higher rates to achieve extended residual control.	Avoid spray drift. Do not apply directly to finished drinking water reservoirs or drinking water receptacles when water is intended for human consumption.

Table 2-4. Label Requirements and Label Application Rates by Formulation

Active Ingredient	Formulation Trade Name	EPA Reg. No.	% AI	% AI (2nd)	Label Application Rates for Mosquito Control	Label Requirements Relevant to Mosquito Control/Surface Water
Monomolecular film[3]	AGNIQUE MMF MOSQUITO LARVICIDE & PUPICIDE	53263-28	100	--	0.2 – 1.0 gallons/acre for fresh and brackish water; 0.35 – 1.0 gallons/acre for polluted waters. The lower rate is recommended when only pupae control id desired and in sites with no emergent vegetation and low organic content. Use higher rates when emergent or surface vegetation is present. The more vegetation or the drier the vegetation, the higher the required rate.	This product may be applied by both ground and aerial applications. No dilution is required and a fan spray is recommended. Do not pour or inject a stream spray directly into water. The high end of the dosage rate is recommended when treating habitats where multi-directional winds of 10 mph or greater are expected to persist. If persistent unidirectional winds of 10 mph or greater are expected, the displacement of the surface film may result in poor control.
	AGNIQUE MMF G	53263-30	32	--	7.0-21.5 lbs formulation/acre. The lower rate is recommended when only pupae control is desired and in sites with no emergent vegetation and low organic content. Use higher rates when emergent or surface vegetation is present. The more vegetation or the drier the vegetation, the higher the required rate.	For large areas with dense vegetation, it is recommended that the application is made in several locations.
Petroleum Distillates[4]	BVA 2 MOSQUITO LARVICIDE OIL	70589- 1	97	--	3-5 gallons/acre depending on dense vegetation and weeds	This product is toxic to fish and other aquatic organisms. Do not apply directly to water (except when applied for mosquito larvae control; then only in shallow areas around the border.) Consult your State Fish and Game Agency before applying this product.
	BVA SPRAY 13	55206- 2	100	--	None indicated	This product is toxic to fish. This product is intended for formulation into end-use products for spray use, mosquito larvae control, and for use a diluent in mosquito adulticides.

Table 2-4. Label Requirements and Label Application Rates by Formulation

Active Ingredient	Formulation Trade Name	EPA Reg. No.	% AI	% AI (2nd)	Label Application Rates for Mosquito Control	Label Requirements Relevant to Mosquito Control/Surface Water
	MOSQUITO LARVICIDE GB-1111	8329- 72	98.7	--	3 gal/acre or less. Under special circumstances, such as extremely dense vegetation or water of high organic content, rates to a maximum of 5 gal/acre may be used.	Use particular care to avoid damage when spraying over areas containing fish or wildlife. This product is toxic to fish and other aquatic organisms. Do not apply directly to water (except when applied for mosquito larvae control; then only around the borders of these areas and in shallow water).
(S)-Methoprene	ZOECON ALTOSID PELLETS	2724-448	4.25	--	2.5-5 lbs formulation/acre (marshes, pools, ponds, treeholes, ect.) or 5-10 lbs/acre (waste treatment and settling ponds, ditches, storm drains, catch basins, ect.) Use lower application rates when water is shallow, vegetation and/or pollution are minimal, and insect populations are low. Use higher rates when water is deep (>2 ft), vegetation, pollution, and/or organic debris or water flow are high, and insect populations are high.	Apply ALTOSID Pellets up to 15 days prior to flooding, or at any stage of larval development after flooding or in permanent water sites. Fixed wing aircraft or helicopters equipped with granular spreaders may be used. The pellets may also be applied using ground equipment which will achieve good, even coverage. Continue treatment through the last brood of the season.
	ZOECON ALTOSID WSP	2724-448	4.25	--	One pouch per catch basin. For other mosquito breeding sites, one pouch will treat single containers or treatment sites of up to 135 sq ft of surface area.	Continue treatment through the last brood of the season.
	ZOECON ALTOSID BRIQUETS	2724-375	8.62	--	one ALTOSID® Briquet per 100 sq ft in non-(or low-) flow, shallow depressions (up to two ft in depth). Use one additional ALTOSID® Briquet per two feet of water depth in areas deeper than two feet.	Apply ALTOSID® Briquets at the beginning of the mosquito season. Continue treatment through the last brood of the season. Water flow may increase the dissolution of the briquet thus reducing the residual life of the briquet. Inspect areas of water flow to determine appropriate retreatment intervals. If briquets become covered by obstructions such as debris, vegetation, and loose sediment as a result of high rainfall or flow, normal dispersion of the active ingredient can be inhibited.

Table 2-4. Label Requirements and Label Application Rates by Formulation

Active Ingredient	Formulation Trade Name	EPA Reg. No.	% AI	% AI (2nd)	Label Application Rates for Mosquito Control	Label Requirements Relevant to Mosquito Control/Surface Water
	ZOECON ALTOSID LIQUID LARVICIDE MOSQUITO GROWTH REGULATOR	2724-392	5	--	3 to 4 fl oz per acre. Formulation contains 0.43 lb/gal (51 .3 g/liter) active ingredient.	For aerial applications, use sufficient water to give complete coverage. Do not apply when weather conditions favor drift from areas treated. For ground application, mix in appropriate volume of water.
	ZOECON ALTOSID XR ENTENDED RESIDUAL BRIQUETS	2724-421	2.1	--	*Aedes, Ochlerotatus,* and *Psorophora* spp.: One briquet per 200 sq ft in in non-(or low-) flow, shallow depressions (< 2 feet in depth). Culex, *Culiseta* and *Anopheles* spp.: Place 1 briquet per 100 sq ft. For storm water drainage areas, place 1 briquet per 100 sq ft of surface area up to 2 ft deep. In areas that are deeper than 2 ft, use 1 additional briquet per 2 ft of water depth.	Place in lowest area of the mosquito breeding sites. Placement of ALTOSID® XR Briquets should be at or before the beginning of the mosquito season and can be applied prior to flooding when sites are dry or on snow and ice in breeding season sites prior to spring thaw.
	ZOECON ALTOSID LIQUID LARVICIDE CONCENTRAT E	2724-446	20	--	3/4 to 1 fl oz per acre (55 to 73 ml/hectare). Formulation contains 1.72 lb/gal (205.2 g/l) active ingredient.	For aerial applications, use sufficient water to give complete coverage. Do not apply when weather conditions favor drift from areas treated. For ground application, mix in appropriate volume of water.

Table 2-4. Label Requirements and Label Application Rates by Formulation

Active Ingredient	Formulation Trade Name	EPA Reg. No.	% AI	% AI (2nd)	Label Application Rates for Mosquito Control	Label Requirements Relevant to Mosquito Control/Surface Water
	ZOECON ALTOSID XR-G	2724-451	1.5	--	*Aedes, Anopheles,* and *Psorophora* spp.: Apply ALTOSID XR-G® at 5 - 10 lb/acre. *Culex, Culiseta, Coquillettidia,* and *Mansonia* spp.: Apply ALTOSID XR-G® at 10-20 lb/acre. Within these ranges, use lower rates when water is shallow [< 2 feet (60 cm)] and vegetation and/or pollution are minimal. Use higher rates when water is deep [> 2 feet (60 cm)] and vegetation and/or pollution are heavy.	Applications should be continued throughout the entire season to maintain adequate control.
	ZOECON ALTOSID SBG SINGLE BROOD GRANULE	2724-489	0.2	--	*Aedes, Anopheles,* and *Psorophora* spp.: Apply at 5-10 lb/acre. *Culex, Culiseta*: Apply at 10-20 lb/acre. Within these ranges, use lower rates when water is shallow [< 2 feet (60 cm)] and vegetation and/or pollution are minimal. Use higher rates when water is deep [> 2 feet (60 cm)] and vegetation and/or pollution are heavy.	ALTOSID® SBG is designed for single brood mosquito larvae and applications should be made within 3 to 5 days of expected pupation. Rotary and fixed-wing aircraft equipped with granular spreaders may be used. Ground equipment, which will achieve even coverage, may also be used. Apply uniformly and repeat application as necessary. Applications should be continued throughout the entire season to maintain adequate control.

Table 2-4. Label Requirements and Label Application Rates by Formulation

Active Ingredient	Formulation Trade Name	EPA Reg. No.	% AI	% AI (2nd)	Label Application Rates for Mosquito Control	Label Requirements Relevant to Mosquito Control/Surface Water
Temephos	ABATE 2-BG	8329- 71	2	--	2.5-5 lbs/acre (0.05-0.1 lbs a.i./acre) for non-potable water (stagnant, saline and temporary water bodies), moist areas, woodland pools; 10 lbs/acre (0.2 lbs a.i./acre) for swamps, marshes, tidal waters, intertidal zones; 25 lbs/acre (0.5 lbs a.i./acre) for highly polluted water, waters high in organic content, areas demonstrated to have resistant mosquitoes, habitats having deep water or dense surface cover, or where monitoring has confirmed a lack of control at recommended application rates.	This product is toxic to aquatic organisms such as stoneflies, water fleas, and shrimp. Non-target aquatic organisms in waters treated with this product may be killed. Some populations reestablish rapidly, but diversity may be affected. Avoid use of maximum application rate in ecologically sensitive areas. This product may be applied only by public vector control agencies. This product may not be reapplied within 7 days of the date of the initial application unless monitoring indicates that larval populations have reestablished, or weather conditions have rendered initial treatments ineffective. Apply with conventional air or ground equipment. Do not allow this product to drift. Do not apply with a belly grinder.
	5% SKEETER ABATE	8329-70	5	--	2 lbs/acre (0.1 lbs a.i./acre) for non-potable water (stagnant, saline and temporary water bodies), moist areas, woodland pools; 4 lbs/acre (0.2 lbs a.i./acre) for swamps, marshes, tidal waters, intertidal zones; 10 lbs/acre (0.5 lbs a.i./acre) for highly polluted water, waters high in organic content, areas demonstrated to have resistant mosquitoes, habitats having deep water or dense surface cover, or where monitoring has confirmed a lack of control at recommended application rates.	This product is toxic to aquatic organisms such as stoneflies, water fleas, and shrimp. Non-target aquatic organisms in waters treated with this product may be killed. Some populations reestablish rapidly, but diversity may be affected. Avoid use of maximum application rate in ecologically sensitive areas. This product may be applied only by public vector control agencies that have entered into and operate under a cooperative agreement with the California Department of Health Services pursuant to Section 2426 of the Health and Safety Code. This product may not be reapplied within 7 days of the date of the initial application unless monitoring indicates that larval populations have reestablished, or weather conditions have rendered initial treatments ineffective. Do not allow this product to drift. Do not apply with a belly grinder.

Table 2-4. Label Requirements and Label Application Rates by Formulation

Active Ingredient	Formulation Trade Name	EPA Reg. No.	% AI	% AI (2nd)	Label Application Rates for Mosquito Control	Label Requirements Relevant to Mosquito Control/Surface Water
	ABATE 4-E INSECTICIDE	8329- 69	44.6	--	0.5 - 1.0 fl oz/acre (0.015 - 0.031 lbs a.i./acre) for non-potable water (stagnant, saline and temporary water bodies), highly polluted water, moist areas, woodland pools, swamps, marshes, tidal waters, intertidal zones; 1.5 fl oz/acre (0.0469 lbs a.i./acre) for waters high in organic content, areas demonstrated to have resistant mosquitoes, habitats having deep water or dense surface cover, or where monitoring has confirmed a lack of control at recommended application rates. (Contains 4 lbs. of Temephos per gallon.)	Avoid use of maximum application rate in ecologically sensitive areas. This product may be applied only by public vector control agencies. This product may not be reapplied within 7 days of the date of the initial application unless monitoring indicates that larval populations have reestablished, or weather conditions have rendered initial treatments ineffective. Apply with a uniform spray in sufficient water for good coverage. Do not allow this product to drift. Do not apply with a belly grinder. The following drift management requirements must be followed to avoid off-target drift movement from aerial applications. 1.) The distance of the outermost nozzles on the boom must not exceed 3⁄4 the length of the wingspan or rotor. 2.) Nozzles must always point backward parallel with the air stream and never be pointed downwards more than 45 degrees.
Spinosad (a mixture of spinosyn A and spinosyn D)	NATULAR G	8329-80	0.5	--	3.5 - 6.5 lb/acre (0.018 - 0.033 lb ai/acre) for temporary standing water, other freshwater sites, and dormant rice fields; 9 lb/acre (0.045lb ai/acre) for freshwater swamps and marshes and marine/costal areas; 6.5 - 9 lb/acre (0.033 - 0.045 lb ai/acre) for stormwater drainage systems and wastewater; and up to 20 lb/acre in waters high in organic content, deep-water mosquito habitats or those with dense surface cover, and where monitoring indicates a lack of kill at typical rates.	This product is toxic to aquatic invertebrates. Non-target aquatic invertebrates may be killed in water where this pesticide is used. Do not apply when weather conditions favor drift from treated areas. Drift from treated areas may be hazardous to aquatic organisms in neighboring areas. Do not re-apply within 7 days of the initial application unless monitoring indicates that larval populations have reestablished or weather conditions have rendered initial treatments ineffective. Do not apply to water intended for irrigation.

Table 2-4. Label Requirements and Label Application Rates by Formulation

Active Ingredient	Formulation Trade Name	EPA Reg. No.	% AI	% AI (2nd)	Label Application Rates for Mosquito Control	Label Requirements Relevant to Mosquito Control/Surface Water
	NATULAR 2EC	8329-82	20.6	--	1.1 - 2 fl oz/acre (0.018 - 0.033 lb ai/acre) for temporary standing water and other freshwater sites; 2.8 fl oz (0.045lb ai/acre) for freshwater swamps and marshes and marine/costal areas; 2 - 2.8 fl oz (0.033 - 0.045 lb ai/acre) for stormwater drainage systems and wastewater; and up to 6.4 fl oz/acre in waters high in organic content, deep-water mosquito habitats or those with dense surface cover, and where monitoring indicates a lack of kill at typical rates.	This product is toxic to aquatic invertebrates. Non-target aquatic invertebrates may be killed in water where this pesticide is used. Do not apply when weather conditions favor drift from treated areas. Do not re-apply within 7 days of the initial application unless monitoring indicates that larval populations have reestablished or weather conditions have rendered initial treatments ineffective. Do not apply to water intended for irrigation. NATULAR 2EC should be diluted with water. The following spray drift management requirements must be followed to avoid off-target drift movement from applications. 1.The boom width must not exceed 75% of the wingspan or 90% of the rotor blade. 2.Nozzles must always point backward, parallel with the air stream, and never be pointed downward more than 45 degrees. 3.Making applications at the lowest height that is safe reduces exposure of droplets to evaporation and wind. 4.Do not apply when wind speed favors drift beyond the treatment area.
	NATULAR XRG	8329-83	2.5	--	5 to 20 lb per acre (5 to 20 g/100 sq ft of water surface). Within this range, use lower rates when water is shallow, vegetation and/or pollution are minimal, and mosquito populations are low. Use higher rates when water is deep, vegetation and/or pollution are high, and mosquito populations are high.	This product is toxic to aquatic invertebrates. Non-target aquatic invertebrates may be killed in water where this pesticide is used. Apply prior to flooding as a prehatch application to areas that breed mosquitoes, or at any stage of larval development after flooding. Do not apply to water intended for irrigation. Do not allow this product to drift onto neighboring crops or non-crop areas. Fixed wing aircraft or helicopters equipped with granular spreaders or conventional ground application equipment can be utilized. Reapply after 30 days.
	NATULAR T30	8329-84	8.33	--	1 tablet per 100 sq ft in non- or low-flow, shallow depressions (up to 2 feet in depth). 6 g/tablet	This product is toxic to aquatic invertebrates. Non-target aquatic invertebrates may be killed in water where this pesticide is used. Natular T30 can be applied prior to flooding, on snow and ice in breeding sites prior to spring thaw, or at anytime after flooding in listed sites. Continue treating through the last brood of the season.

Table 2-4. Label Requirements and Label Application Rates by Formulation

Active Ingredient	**Formulation Trade Name**	**EPA Reg. No.**	**% AI**	**% AI (2nd)**	**Label Application Rates for Mosquito Control**	**Label Requirements Relevant to Mosquito Control/Surface Water**
	NATULAR XRT	8329-85	6.25	--	1 tablet per 100 sq ft in non- or low-flow, shallow depressions (up to 2 feet in depth). 40 g/tablet	This product is toxic to aquatic invertebrates. Non-target aquatic invertebrates may be killed in water where this pesticide is used. Natular XRT tablets can be applied prior to flooding, on snow and ice in breeding sites prior to spring thaw, or at any time after flooding in listed sites. Do not apply to water intended for irrigation.

There are several advantages of using ground application equipment, both when on foot and when conveyed by vehicles. Ground larvicide application allows applications while in proximity to the actual treatment area, and consequently treatments to only those microhabitats where larvae are actually present. This also reduces both the unnecessary pesticide load on the environment and the financial cost of the amount of material used, as well as its application. Both the initial and maintenance costs of ground equipment are generally less than those for aerial equipment. Ground larvicide applications are less affected by weather conditions than are aerial applications.

Ground larvicide application is impractical for large or densely wooded areas. There is also a greater risk of chemical exposure to applicators than there is during aerial larvicide operations. Damage may occur from the use of a ground vehicle in some areas. Ruts and vegetation damage may occur, although both conditions are reversible and generally short-lived. Technicians are trained to recognize sensitive areas and to use good judgment to avoid significant impacts.

Aerial Application Equipment. When several large areas are simultaneously producing mosquito larvae at densities exceeding treatment thresholds, then helicopters or other aircraft may be used to apply any of the larvicides discussed above. Many agencies contract with independent flying services to perform aerial applications, with guidance to the target site provided by MVCAC agency staff. A few agencies make applications with their own aircraft. The number and extent of serial application of larvicides differs among agencies, from only a few times each year, covering a few hundred acres, to more frequent or extensive operations in districts in the central valley.

There are three advantages to using fixed- or rotary-wing (helicopter) aerial larvicide application equipment compared to ground application. First, it can be more economical for large target areas with extensive mosquito production. Second, by covering large areas quickly, it can free staff to conduct other needed surveillance or control. Third, it can be more practical for remote or inaccessible areas, such as islands and large marshes, than ground larvicide application. However, maintaining aircraft or contracting for aerial applications is expensive; and, in addition to the timing constraints inherent in most larvicide use, the potential application window can be very narrow for aerial activities due to weather conditions.

2.2.2 Larvicide Active Ingredients Used in California

Eight active ingredients are registered for use as mosquito larvicides in California: *Bacillus thuringiensis israelensis (Bti)*; *Bacillus sphaericus* (*B. sphaericus*); alpha-isooctadecyl-omega-hydroxypoly(oxyethylene); petroleum distillates; spinosad, diflubenzuron, methoprene, and temephos. For these active ingredients, multiple formulations are available for use in mosquito control. Table 2-5 gives a list of the products used for control of mosquito larvae by MVCAC member agencies.

Microbial larvicides are bacteria that are registered as pesticides for control of mosquito larvae in outdoor areas such as irrigation ditches, flood water, standing ponds, woodland pools, pastures, tidal water, fresh- or saltwater marshes, and stormwater retention areas (U.S. EPA 2007a). The

Table 2-5. Reported Pesticide Use of Larvicides for Public Health Pest Control by Formulation

Active Ingredient	Formulations	EPA Reg. No.	2008 Active Ingredient (pounds)	2008 Percentage Use by Formulation
Bacillus Sphaericus (Bs)[1]	VECTOLEX CG BIOLOGICAL LARVICIDE	73049- 20	8525	41.3%
	VECTOLEX WDG BIOLOGICAL LARVICIDE	73049- 57	3107	15.1%
	VECTOLEX WSP BIOLOGICAL LARVICIDE	73049- 20	309	1.5%
	VECTOLEX CG BIOLOGICAL LARVICIDE	275- 77	1452	7.0%
	VECTOLEX WDG BIOLOGICAL LARVICIDE	275- 135	7130	34.6%
	VECTOMAX CG BIOLOGICAL LARVICIDE	10324- 99	93	0.5%
	VECTOMAX G BIOLOGICAL LARVICIDE/GRANULES	71532- 22- 55146	6	0.03%
	VECTOMAX WSP BIOLOGICAL LARVICIDE	1839- 190- 56952	9	0.04%
Bacillus Thuringiensis, Subsp. *Israelensis* (Bti)[2]	VECTOBAC TECHNICAL POWDER	73049- 13	6523	10.8%
	VECTOBAC 12AS BIOLOGICAL LARVICIDE	73049- 38	37337	62.1%
	AQUABAC 200G	62637- 3	412	0.7%
	TEKNAR HP-D	73049- 404	80	0.1%
	VECTOBAC G BIOLOGICAL LARVICIDE GRANULES	73049- 10	14108	23.4%
	BMP 144 (200G) MOSQUITO BIOLARVICIDE GRANULE	62637- 3	105	0.2%
	SUMMIT BTI BRIQUETS	6218- 47	15	0.03%
	TEKNAR HP-D LARVICIDE	2724- 365- 64833	9	0.02%
	TEKNAR HP-D LARVICIDE	70051- 51	310	0.5%
	VECTOBAC 12AS AQUEOUS SUSPENSION BIOLOGICAL LARVICIDE	275- 102	133	0.2%
	VECTOBAC TECHNICAL POWDER	275- 54	61	0.1%
	VECTOBAC WDG BIOLOGICAL LARVICIDE	73049- 56	212	0.4%
	VECTOBAC-12 AS	275- 66	612	1.0%
	VECTOBAC-G BIOLOGICAL MOSQUITO LARVICIDE GRANULES	275- 50	54	0.1%
	VECTOMAX CG BIOLOGICAL LARVICIDE	10324- 99	156	0.3%
	VECTOMAX G BIOLOGICAL LARVICIDE/GRANULES	71532- 22- 55146	9	0.02%
	VECTOMAX WSP BIOLOGICAL LARVICIDE	1839- 190- 56952	15	0.02%
	ZOECON TEKNAR HP-D	2724- 365- 50809	13	0.02%
	ZOECON TEKNAR HP-D LARVICIDE	2724- 365- 64833	5	0.01%
Monomolecular film[3]	AGNIQUE MMF MOSQUITO LARVICIDE & PUPICIDE	53263- 28	11652	91.3%
	AGNIQUE MMF G	53263- 30	666	5.2%
	AGNIQUE MMF MOSQUITO LARVICIDE AND PUPICIDE	2302- 14	363	2.8%
	AROSURF MSF	42943- 8	80	0.6%
Petroleum Distillates[4]	BVA 2 MOSQUITO LARVICIDE OIL	70589- 1	28707	2.0%
	BVA SPRAY 13	55206- 2	--	--
	MOSQUITO LARVICIDE GB-1111	8329- 72	1335326	90.8%
	MOSQUITO LARVICIDE GB-1111	8898- 16	99801	6.8%
	MOSQUITO LARVICIDE GB-1111	71236- 1	7263	0.5%
	MOSQUITO LARVICIDE GB-1356	8898- 16	164	0.0%
	PYRETHRINS/PIPERONYL BUTOXIDE CONCENTRATE 5%-25%	432- 612	17	0.0%
Diflubenzuron	DIMILIN 25W COTTON	37100- 8- 400	0.97	3.5%
	DIMILIN 25W INSECT GROWTH REGULATOR	400- 465	26.34	96.3%
	DIMILIN 25W INSECT GROWTH REGULATOR	37100- 8- 400	0.05	0.2%
Methoprene[5]	ZOECON ALTOSID PELLETS	2724- 448	717	12.4%
	ZOECON ALTOSID PELLETS WSP	2724- 448	195	3.4%
	ZOECON ALTOSID BRIQUETS	2724- 375	47	0.8%
	ZOECON ALTOSID LIQUID LARVICIDE MOSQUITO GROWTH REGULATOR	2724- 392	52	0.9%
	ZOECON ALTOSID XR EXTENDED RESIDUAL BRIQUETS	2724- 421	77	1.3%
	ZOECON ALTOSID LIQUID LARVICIDE CONCENTRATE	2724- 446	1178	20.4%
	ZOECON ALTOSID XR-G	2724- 451	555	9.6%
	ZOECON ALTOSID SBG SINGLE BROOD GRANULE	2724- 489	23	0.4%
	ALTOSID PELLETS	2724- 448- 64833	174	3.0%
	AQUAPRENE BRIQUETS	75318- 9	15	0.3%
	AQUAPRENE TOSSITS	75318- 10	2	0.0%
	AQUAPRENE XL GRANULES	75318- 7	4	0.1%
	EXTINGUISH PLUS	2724- 496	55	0.9%
	RF-9805	2724- 489	50	0.9%
	ZOECON 9010 GR	2724- 451	179	3.1%
	ZOECON ALTOSID PRO-G INSECT GROWTH REGULATOR	2724- 451	1	0.0%
	ALTOSID BRIQUETS	2724- 375	119	2.1%
	ALTOSID LIQUID LARVICIDE	2724- 392	263	4.6%
	ZOECON ALTOSID PELLETS	2724- 448- 50809	6	0.1%
	ZOECON ALTOSID PELLETS	2724- 448- 64833	585	10.1%
	ALTOSID XR EXTENDED RESIDUAL BRIQUETS	2724- 421- 50809	46	0.8%
	ALTOSID XR EXTENDED RESIDUAL BRIQUETS	2724- 421- 64833	2	0.0%
	ZOECON ALTOSID BRIQUETS	2724- 375- 64833	31	0.5%
	ZOECON ALTOSID LIQUID LARVICIDE CONCENTRATE	2724- 446- 64833	70	1.2%
	ZOECON ALTOSID LIQUID LARVICIDE MOSQUITO GROWTH REGULATOR	2724- 392- 64833	82	1.4%
	ZOECON ALTOSID XR ENTENDED RESIDUAL BRIQUETS	2724- 421- 64833	192	3.3%
	ZOECON RF-292 BRIQUET	2724- 421	79	1.4%
	ZOECON RF-330 ALTOSID PELLETS	2724- 448	894	15.5%
	ZOECON RF-437 MOSQUITO GROWTH REGULATOR SR-20	2724- 446	87	1.5%
Temephos	ABATE 2-BG	8329- 71	601	87.9%
	5% SKEETER ABATE	8329- 70	77	11.3%
	ABATE 4-E INSECTICIDE	8329- 69	5	0.8%

Source: DPR PUR Database

Notes:

[1] Bacillus Sphaericus, Serotype H-5A5B, Strain 2362

[2] Reported as Bacillus Thuringiensis (Berliner); Bacillus Thuringiensis (Berliner), Subsp. Israelensis, Serotype H-14; or Bacillus Thuringiensis (Berliner), Subsp. Israelensis, Serotype H-14

[3] Alpha-Isooctadecyl-Omega-Hydroxypoly(Oxyethylene)

[4] Reported as either Petroleum Distillates or Refined Petroleum Distillates

[5] Reported as either Methoprene or S-Methoprene

Formulations in red are included in the NPDES permit material list.

microbial larvicides concentrates registered for use in California contain *Bacillus sphaericus* (*B. sphaericus*) and *Bti*. These concentrates include fermentation solids, bacterial spores, and insecticidal toxins. Their mode of action requires that they be ingested to be effective.which means they cannot be used to control mosquitoes at some life stages (late 4th instar larvae and pupae). .

Bti concentrates are made up of the dormant spore form of the bacterium and an associated pure toxin. The toxin disrupts the gut in mosquito larvae by binding to receptor cells (U.S. EPA 2007a). *Bti*. organisms produce five different microscopic protein pro-toxins packaged inside one larger protein container or crystal. The crystal is commonly referred to as delta (d-) endotoxin. This toxin consist of five proteins that are released only under extremely alkaline conditions. Mosquitoes are unique in having very alkaline conditions within the midgut (the stomach of vertebrates contains acid). When a mosquito larva ingests the d-endotoxin, the five proteins are released in the alkaline environment of the insect larval gut. The five proteins are converted into five different toxins by specific enzymes present in the gut of mosquito larvae. Once converted, these toxins destroy the gut wall, which leads to paralysis and death of the larvae. *Bti* is toxic to larval stages of all genera of mosquitoes, and to black flies (Simuliidae). Black flies are vicious biters that feed on the blood of humans and other mammals. They are a vector of river blindness (*Onchocerca volvulus*) in Africa and a serious pest inflicting painful bites in other parts of theworld. The dependence on alkaline conditions and the presence of specific enzymes gives this material a high degree of specificity for mosquitoes and black flies. Bti is also used for control of chironimids, but much higher levels are needed for effective control.

Bti concentrates account for 3.4 percent by mass of the material applied (Figure 2-2), and 65.6 percent by acreage covered (Figure 2-3) for larvicide applications by California vector control districts in 2008.

B. sphaericus spores contain a protein that damages and paralyzes the gut of mosquito larvae that ingest the spores, thus starving the larvae (U.S. EPA 1999). *Culex* species are the most sensitive to *Bacillus sphaericus*, followed by *Anopheles* and some *Aedes* species. In California, *Culex* spp. and *Anopheles* spp. may be effectively controlled. Several species of *Aedes* have shown little or no susceptibility, and salt marsh *Aedes* species are not susceptible. *B. sphaericus* differs from *Bti* in being able to control mosquito larvae in highly organic aquatic environments, including sewage waste lagoons, animal waste ponds, and septic ditches.

B.sphaericus concentrates accounts for 1.3 percent by mass of the material applied for larval mosquito control in California by vector control districts (Figure 2-2), and 9.3 percent of the acreage covered by larvicide applications in 2008 (Figure 2-3: note that acreage is counted repeatedly for multiple applications made at the same locations).

Spinosad was first registered for use in California in 1996 for use as an agricultural insecticide, and more recently, registration has been approved for the use of mosquito control in California in areas such as dormant rice fields, wastewater, and temporary standing water (DPR 2010a). Spinosad is a biologically derived insecticide produced from the fermentation of *Saccharopoly spora spinosa*, a naturally occurring soil organism. Spinosad is a mixture of spinosyn A and spinosyn D; commercial formulations contain a spinosyn A to spinosyn D ratio of approximately

85:15. Spinosad activates the central nervous system of insects through interaction with neuro-receptors and causes continuous stimulation of the insect nervous system (Kollman 2002, Clarke Mosquito Control 2009). The U.S. EPA has classified spinosad as a “reduced risk” compound because it is an alternative to more toxic, organophosphate insecticides (DPR 2002).

Water surface film larvicides spread across water surfaces and disrupt larval respiration, killing mosquitoes and some other classes of air-breathing aquatic insects. These are the only currently registered larvicides used by member agencies that are effective against mosquito pupae. Therefore, when timely larval control is not possible or not successful, pupal control can usually be achieved using these products. This reduces the need for applications of adulticides.

There are two types of water surface films available for control of immature mosquitoes in California: monomolecular films, and petroleum distillates. Monomolecular films are low-toxicity pesticides that spread a thin film on the surface of the water that makes it difficult for mosquito larvae, pupae, and emerging adults to attach to the water's surface, and cause them to drown (U.S. EPA 2007a). The monomolecular film used in California for the control of mosquito larvae is alpha-isooctadecyl-omega-hydroxypoly(oxyethylene) This chemical accounts for a relatively small portion of the mosquito larvicide use both by mass and by acreage in 2008 (0.8 and 0.6 percent, respectively; Figures 2-2 and 2-3).

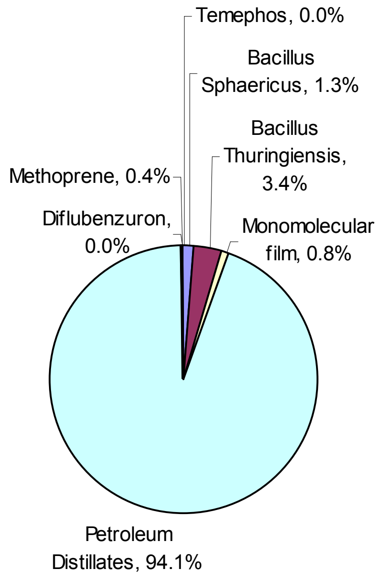
Specially-derived petroleum distillates are mineral oils that are used to form a coating on top of water to drown larvae, pupae, and emerging adult mosquitoes. Petroleum distillates have been used for many years nationwide to kill aphids on crops and orchard trees, and to control mosquitoes (U.S. EPA 2007a). Petroleum distillates account for 13.9 percent of the acreage treated for immature mosquitoes. These products are heavier than other control materials and therefore account for a larger proportion of the total (94.1 percent) mass of materials applied. (Figures 2-2 and 2-3).

Methoprene and diflubenzuron are insect growth-regulating compounds that are added to water to disrupt the normal maturation process of mosquito larvae. Methoprene products used in mosquito control are applied as briquets, pellets, sand granules, and liquids. The liquid and pelletized formulations can be applied by helicopter and fixed-wing aircraft or ground-based equipment (U.S. EPA 2007a). Methoprene is applied either in response to observed high populations of mosquito larvae at a site, or as a sustained-release product that can persist for 4 months or longer if a site has limited accessibility and has regularly produced immature mosquitoes in the past.

Diflubenzuron is a restricted-use pesticide because it is potentially toxic to aquatic invertebrates (the sale and use of this compound is restricted to certified pesticide applicators or person under their supervision) (U.S. EPA 1997). Methoprene was used as a larvicide more extensively than diflubenzuron (9.1 percent by acreage in contrast to 0.4 percent in 2008 (Figure 2-3). This is because methoprene has a much lower toxicity for nontarget invertebrates. Diflubenzuron is not proposed for future use under the new permit.

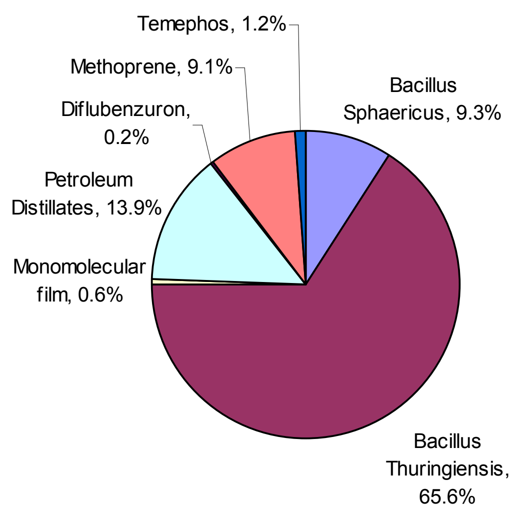
Temephos is an organophosphate pesticide registered by the U.S. EPA to control mosquito larvae, and it is the only organophosphate with larvicidal use. Although temephos is labeled for use in areas of standing water, shallow ponds, swamps, marshes, and intertidal zones (U.S. EPA 2007a), MVCAC member agencies primarily apply temephos to manmade sources such as tire piles, utility vaults, and cemetery urns. Mosquito control products containing temephos are not labeled for application to agricultural lands or pasture and are not used in such sites. Temephos is also used to help prevent mosquitoes from developing resistance to the bacterial larvicides. Temephos provides effective control of mosquito larvae in highly polluted water (containing high levels of decaying organic matter, such as rotting leaves or manure) (Clarke Mosquito Control, n.d.). Temephos is applied in either liquid or granular form and, is applied by backpack sprayers (U.S. EPA 2007a). Temephos accounts for a small percentage of larvicide use by both mass and acreage in 2008 (0.04 and 1.2 percent, respectively; Figures 2-2 and 2-3), and only 11 of the 62 MVCAC member districts applied temephos in 2008. Individual applications averaged less than 10 acres each.

Figure 2-2. Reported Use for Public Health Pest Control for Larvicide, 2008 Statewide



Note: Based on pounds of active ingredient.

Figure 2-3. Acreage Treated for Public Health Pest Control for Larvicides, 2008 Statewide



Notes: Acreage estimated based on at maximum label application rate.
Acreage is counted each time repeated applications are made at the same site.

2.2.3 Larvicide Application Locations and Frequency

Mosquito larvicides may be applied in a variety of locations, including irrigation ditches, roadside ditches, flood water, standing pools, woodland pools, snowmelt pools, pastures, stock ponds, duck ponds, catch basins, stormwater retention areas, tidal water, creeks, marshes, and rice fields. Locations may be urban, suburban, agricultural, recreational, or wildlife refuge areas, and application sites may vary in size from a fraction of an acre to several thousand acres. In some cases, treatment may be limited to the edge of water bodies or tidal marshes; in other cases treatment would occur over entire water bodies. Treatment frequency for larvicides can be weekly (for hot weather and liquid formulations that have little or no residual) to once every 3 months (for moderately small sites that are hard to reach like a heavily vegetated marsh treated with pellets or granules). Types of locations, frequency, and size of application sites vary by region.

This section provides a description of typical larvicide applications by region. It should be noted that typical applications made in the past may not be representative of those made in the future, and that patterns may change based on factors such as climate, disease surveillance, resistance, and cost-effectiveness. Information in this section is based on the DPR pesticide use data by county for 2008 (the most recent currently available year). West Nile virus activity and the availability of emergency control funds may also be factors in the amounts used from year to year. As shown in Table 2-5, many different formulations are used for each active ingredient.

Coastal Region

MVCAC agencies within the Coastal Region are shown in Figure 2-1. Larvicides used in this region in 2008 include *B. sphaericus, Bti,* monomolecular film, petroleum distillates, and methoprene, according to the California Department of Pesticide Regulation, Pesticide Use Report data (Table 2-6). Temephos was generally not applied. *B. sphaericus* was applied in relatively large quantities, while films and oils were applied in relative low quantities. Overall larvicide use, by mass, was less in the Coastal Region in comparison to other regions.

Sacramento Valley Region

MVCAC agencies within the Sacramento Valley Region are shown in Figure 2-1. Larvicides used in this region include *B. sphaericus, Bti,* monomolecular film, petroleum distillates, methoprene, and temephos (Table 2-6). Diflubenzuron was generally not applied. Most of the temephos used by MVCAC agencies was applied in the Sacramento Valley Region. *Bti* and methoprene were also used in larger-than-average quantities.

Northern San Joaquin Valley

MVCAC agencies within the Northern San Joaquin Valley Region are shown in Figure 2-1. Larvicides used in this region in 2008 include *B. sphaericus, Bti,* monomolecular film, petroleum distillates, methoprene, and temephos (Table 2-6). Diflubenzuron was applied in trace quantities. Monomolecular film was applied relatively rarely, while petroleum oils were applied in larger quantities.

Table 2-6. Regional Use of Larvicides for Public Health Pest Control

Year	Active Ingredient	Sacramento Valley[1]		Coastal[2]		North San Joaquin Valley[3]		South San Joaquin Valley[4]		Southern California[5]	
		lbs of ai	% for Region	lbs of ai	% for Region	lbs of ai	% for Region	lbs of ai	% for Region	lbs of ai	% for Region
2008	*Bacillus Sphaericus*	2,428	11.8 %	6,372	30.9%	4,127	20.0%	1,268	6.1%	6,405	31.0%
	Bacillus Thuringiensis, Subsp. Israelensis[6]	22,475	37.4 %	2,146	3.6%	15,619	26.0%	15,698	26.1%	4,220	7.0%
	Monomolecular film	1,257	9.9%	245	1.9%	108	0.8%	5,893	46.2%	5,211	40.8%
	Petroleum Distillates	47,299	3.2%	108,523	7.4%	452,739	30.8%	800,878	54.4%	62,307	4.2%
	Diflubenzuron	1	3.7%	--	--	9	31.2%	8	29.7%	10	35.4%
	Methoprene	2,009	34.8 %	1,053	18.2%	1,341	23.2%	577	10.0%	794	13.7%
	Temephos	625	91.5 %	0.05	0.0%	34	5.0%	19	2.8%	5	0.7%

Source: DPR PUR Database

Notes:

[1]Counties of Shasta, Tehama, Butte, Lake, Glenn, Colusa, Sutter, Yuba, Placer, El Dorado, Yolo, Sacramento, and Nevada
[2]Counties of Sonoma, Marin, Napa, Solano, Contra Costa, Alameda, San Mateo, Santa Clara, Santa Cruz, Monterey, and San Benito

[3]Counties of San Joaquin, Stanislaus, Merced, and Calaveras

[4]Counties of Madera, Fresno, Kings, Tulare, Kern, and San Luis Obispo

[5]Counties of Mono, Inyo, Santa Barbara, Ventura, Los Angeles, San Bernardino, Orange, Riverside, and San Diego
[6] Reported as Bacillus Thuringiensis (Berliner); Bacillus Thuringiensis (Berliner), Subsp. Israelensis, Serotype H-14; or Bacillus Thuringiensis (Berliner), Subsp. Israelensis, Serotype H-14

ai = active ingredient

lbs = pounds

% = percent

Southern San Joaquin Valley

MVCAC agencies within the Southern San Joaquin Valley Region are shown in Table 2-3. Larvicides used in this region in 2008 include *B. sphaericus, Bti,* monomolecular film, petroleum distillates, methoprene, and temephos (Table 2-6). Diflubenzuron was applied in trace quantities. Petroleum distillates and monomolecular films were applied in much larger quantities relative to other regions.

Southern California

MVCAC agencies within the Southern California Region are shown in Table 2-3. Larvicides used in this region in 2008 include *B. sphaericus, Bti,* monomolecular film, petroleum distillates, diflubenzuron, and methoprene (Table 2-6). Temephos was also applied in trace quantities. Monomolecular films were applied in larger-than-average quantities.

2.2.4 Methods to Control Adverse Effects to Surface Water

- BMPs are practices employed to control potential adverse effects to surface waters. Generally, the BMPs used are determined by the label requirements, although additional measures may be used.

For spinosad formulations, the following practices are recommended to minimize the potential for resistance development in insects:

  - Base insecticide use on comprehensive IPM programs.
- Do not use less than the labeled rates.
- Routinely evaluate applications for loss of effectiveness.
- Rotate with other labeled effective mosquito larvicides that have a different mode of action.
- Use insecticides with a different mode of action (different insecticide group) on adult mosquitoes so that both larvae and adults are not exposed to products with the same mode of action.
- In dormant rice fields, standing water within agricultural/crop sites, and permanent marine and freshwater sites, do not apply more than a maximum label application frequency.

Additional requirements specified by formulation on product labels are shown in Table 2-4.

2.2.5 Other Uses of the Active Ingredients in Mosquito Larvicides

Many pesticides used as larvicides can be used for other purposes in California, which is important to consider when developing a monitoring program. When an active ingredient is detected in the water, it may be difficult to determine whether it came from a mosquito control application, an unrelated application, or from multiple sources. Temephos is the only mosquito larvicide that was used in California during 2008 solely for public health purposes.

Residential pesticide sources are especially difficult to determine, because their use is not reported to or quantified by DPR. DPR estimates that approximately two-thirds of pesticide use in California is unreported. Note that total reported use does not include use by homeowners, which may comprise the majority of the use for certain pesticides, especially in urban and suburban areas (Moran 2005).

Table 2-7 shows the proportion of each active ingredient that is used for vector control, as a percentage of total reported use in California during 2007 and 2008. Although vector control uses may include uses other than mosquito larvicide, it is assumed that the vast majority of public health use of the formulations shown in Table 2-5 is to control mosquito larvae.

B. sphaericus was first registered by the U.S. EPA in 1991 for use against mosquito larvae. *B. sphaericus* is used on rice, fruit trees, walnuts, almonds, corn, asparagus, cotton, dates, and other crops. It is also applied to alfalfa, pastures, agricultural drainage systems, animal drinking water, fodder grasses, irrigation systems, swimming pools, ornamental ponds and fountains, catch basins, wastewater, bilge water, industrial processing water, industrial waste disposal systems, solid wastes sites, garbage dumps, and on tidal areas, swamps, marshes, bogs, intermittently flooded areas, standing water, and by mosquito abatement districts (DPR 2010b).

An isolate of *Bacillus thuringiensis* was first registered by the U.S. EPA in 1961 for use as an insecticide (U.S. EPA 1998). The subspecies *israelensis (Bti)* was first registered as an insecticide in 1983. One formulation of *Bti* is used in California for controlling knats on primarily in greenhouse crops, including peppers, tomatoes, celery, cabbage, leafy vegetables, cauliflower, walnuts, almonds, dates, corn, asparagus, bananas, fruit trees, and other crops. It is applied for mosquito control on rice, alfalfa, pastures, animal drinking water, ornamental nurseries, ornamental ponds, irrigation systems, swimming pools, drainage systems, lakes, streams, swamps, marshes, tidal areas, standing water, polluted or stagnant water, sewage systems, intermittently flooded areas, catch basins, domestic dwellings, and by mosquito abatement districts and by ULV application (DPR 2010b).

Spinosad was first registered for use in California in 1996 for use as an agricultural insecticide (DPR 2002). Spinosad is used on a variety of crops, ornamental plants, greenhouses, ornamental lawns, and gardens; rangeland, pastures, animal husbandry premises, dairy barns, silos, and cattle; industrial sites, cracks and crevices, rights-of-way, recreation areas, golf courses, outdoor buildings and structures, and household or domestic dwellings (DPR 2010b).

Monomolecular films are used on ornamental ponds, pastures, irrigation systems, drainage systems, drinking water systems, intermittently flooded areas, catch basins, lakes, ponds, reservoirs, tidal areas, marshes, and standing water, industrial waste disposal systems, polluted and stagnant water, and sewage systems (DPR 2010b).

Specially refined petroleum distillates or mineral oils are applied to a wide variety of crops, trees, and ornamental plants; to swamps, marshes, and intermittently flooded areas; are used as an adjuvant for pesticides; and are applied by mosquito abatement districts (DPR 2010b). Dormant oils are widely used in the Central Valley on tree crops.

Methoprene was first registered by the U.S. EPA in 1975 (U.S. EPA 2007a). Methoprene is used indoors and outdoors at domestic dwellings, in flea and tick treatments for cats and dogs, for crack and crevice treatments, and on outdoor buildings and structures, recreation areas, swimming pools, golf courses, ornamental lawns, ornamental ponds, and shrubs. Methoprene is used at animal husbandry premises, on cattle, barnyards, rangeland, pastures, fallow land, and in animal drinking water. It is used at industrial sites, on highway rights-of-way, industrial waste disposal systems, industrial/commercial ponds, wastewater, and bilge water. Methoprene can be

Table 2-7. Total Reported Pesticide Use and Public Health Pest Control Use of Larvicides, Statewide

Active Ingredient	2008		
	Total Reported Use (lbs of ai)	Reported Use for Vector Control	
		lbs of ai	% of Total Use
Bacillus Sphaericus[1]	21,442	20,630	96%
Bacillus Thuringiensis, Subsp. *Israelensis*[2]	62,573	53,057	85%
Monomolecular film[3]	12,878	12,761	99%
Petroleum Distillates[4]	2,949,383	1,472,021	50%
Diflubenzuron	31,349	27	0.1%
Methoprene[5]	6,152	5,607	91%
Temephos	684	684	100%

Notes:

[1] Bacillus Sphaericus, Serotype H-5A5B, Strain 2362

[2] Reported as Bacillus Thuringiensis (Berliner); Bacillus Thuringiensis (Berliner), Subsp. Israelensis, Serotype H-14; or Bacillus Thuringiensis (Berliner), Subsp. Israelensis, Serotype H-14

[3] Alpha-Isooctadecyl-Omega-Hydroxypoly(Oxyethylene)

[4] Reported as either Petroleum Distillates or Refined Petroleum Distillates

[5] Reported as either Methoprene or S-Methoprene

applied to irrigation systems, orchards, crops, berries, fruit trees, and rice. It is also used in drainage systems, swamps, marshes, intermittently flooded areas, catch basins, polluted stagnant water, sewage systems, and applied by mosquito abatement districts (DPR 2010b).

Temephos was registered by the U.S. EPA in 1965 to control mosquito larvae (U.S. EPA 2007a). Temephos is used on lakes, ponds, reservoirs, swamps, marshes, tidal areas, intermittently flooded areas, catch basins, drainage systems, irrigation systems, ornamental ponds, wastewater, polluted and stagnant water, and is applied by mosquito abatement districts (DPR 2010b).

2.3 MOSQUITO ADULTICIDES AND USE IN CALIFORNIA

Chemical control of adult mosquitoes is implemented when mosquito populations reach a level that is thought by health officials to represent an unacceptable increase in the risk of disease transmission to humans or domestic animals, or when biting mosquitoes become intolerable to the local population. The action level or threshold is determined by each mosquito control program and varies according to local conditions. When a threshold is exceeded, control measures are generally determined using a decision process such as that described in Appendix B. The threshold for adult mosquito control is variable and depends on several local factors, including (CDPH, 2005):

- The presence and intensity of mosquito-borne disease in the region;
- The abundance of vector species populations.
- The tolerance of local citizens to nuisance mosquito populations;

This section describes the application methods used for adulticides in California, the materials applied, and the measures taken to prevent adverse impacts to the water quality and beneficial uses of surface water bodies.

2.3.1 Application Methods

There are two basic techniques used by MVCAC members for applying mosquito adulticides:

1. **Barrier Application.** Adulticides are sprayed onto vegetation or other surfaces to leave a residue of adulticide intended to kill mosquitoes that land on that surface. Barrier application is typically done with backpack sprayers that produce large droplets that immediately fall out of the air onto the intended surface. Barrier-type applications kill mosquitoes and some "non-target" insects only where directly applied. Barrier applications are not made over or adjacent to water bodies; therefore, the barrier applications are not considered application of an aquatic pesticide, and are not the focus of this monitoring program.

2. **Ultra-Low-Volume (ULV) Application.** Adulticides are sprayed into the air with the intent of killing mosquitoes that are flying in the sprayed area. ULV application is typically done with truck-mounted sprayers, but can be done with handheld sprayers or

aircraft. ULV produces very small droplets that typically hang in the air for up to an hour. Effective droplet sizes range from 5 to 30 microns, but a typical droplet spectrum produces a larger range of droplet sizes. The small droplet size maximizes the surface area available to impact mosquitoes in flight, and keeps the material suspended in the atmosphere for long periods of time (up to an hour) with minimal deposition. The amount of material applied is typically less than 2 ounces of total product per acre, and contains less than 0.04 to 0.1 ounce of active ingredient. Aerial movement of the product is an essential part of the application. Applications are made when environmental conditions ensure their effectiveness (ideally, a slight breeze of 2 to 10 miles per hour; temperature great than 50 degrees Fahrenheit [°F]; and presence of a temperature inversion). ULV applications are made with truck-mounted equipment or aerially, from helicopters or fixed-wing aircraft. Adulticides are typically applied from aircraft when the area in which adult mosquitoes need to be controlled cannot be covered adequately and quickly enough with ground-based equipment. Localized ULV applications (such as tree holes) may also be made with a backpack or handheld sprayer. According to CDPH, spray drift may occur for a distance generally up to a half mile via truck-mounted applications, and more than a mile for aerial applications from the path or point of application (distances are highly variable depending on climatic conditions and topography). Most spray applications occur in the evening or early morning, when female mosquitoes are seeking a blood meal, and many other arthropods, particularly pollinators, are inactive. By definition, ULV uses the smallest possible amount of adulticide that will kill adult mosquitoes.

Thermal fogging has been used in the past by MVCAC member agencies, but is no longer used. In this method, the insecticides are usually mixed in oil and applied in late evening, at night, or early morning when the air is calm.

For the remainder of this document, all references to adulticide applications and adulticides, refer to ULV mosquito control applications unless otherwise specified.

2.3.2 Materials Used in California for Control of Adult Mosquitoes

Six active ingredients are commonly used as mosquito adulticides: pyrethrins, permethrin, resmethrin, phenothrin, malathion, and naled. Two additional ingredients have been registered for use as adulticides in California: prallethrin and etofenprox. For most of these active ingredients, multiple formulations are available for use in mosquito control (Table 2-8).

As shown in Table 2-8, some formulations have been used for mosquito adulticide for many years, while other formulations expected to be used in 2010 have only more recently become available.

Pyrethrins are naturally occurring products distilled from the flowers of Chrysanthemum species. The six individual pyrethrins compounds are pyrethrin I, pyrethrin II, cinerin I, cinerin II, jasmolin I, and jasmolin II. Pyrethrins account for 21.9 percent by mass of the material applied for adult mosquitoes in California by vector control districts in 2008 (Figure 2-4), and 79.4 percent of the acreage covered by adulticide applications (Figure 2-5: note that acreage is counted repeatedly for multiple applications made at the same locations).

Pyrethroids are synthetic compounds that are chemically similar to the pyrethrins, but have been modified to increase their stability and activity against insects, while minimizing their effect on nontarget organisms. Pyrethrins and pyrethroids act by causing a persistent activation of the sodium channels on insect neurons. These materials are relatively non-toxic to mammals and birds, but may be toxic to fish and invertebrates. The pyrethroids most used for adult mosquito control in California include sumithrin (phenothrin), resmethrin, and permethrin (see Figures 2-4 and 2-5).

Deltamethrin is a mosquito adulticide that is used to a limited extent in California, but is used as a barrier application and not a ULV application; therefore, deltamethrin is not included in tables and figures associated with this section. Public health uses also include other vectors such as yellow jackets; therefore, it is not possible to distinguish from the DPR PUR database how much is used for mosquito control. However, the total amount used is negligible relative to other mosquito adulticides and it is not used over or adjacent to water bodies. Formulations used for mosquitoes include Suspend SC Insecticide (primarily used), and K-Othrine SC Insecticide.

Insecticides containing pyrethrins and pyrethroids usually also contain piperonyl butoxide (PBO) as a synergist. PBO interferes with the insect's ability to detoxify pyrethrins and pyrethroids, thus enhancing the product's effectiveness. MGK-264 may also be used as a synergist in formulations with pyrethrins and synthetic pyrethroids. MGK-264 is known to inhibit microsomal enzymes in insects by binding directly to these enzymes, and thereby inhibiting the breakdown of other pesticides such as pyrethrins and pyrethroids.

Etofenprox is a synthetic pyrethroid-like chemical, differing in structure from pyrethroids in that it lacks a carbonyl group and has an ether moiety, whereas pyrethroids contain ester moieties.

Naled and malathion are organophosphate insecticides, and are used in rotation with pyrethrins or pyrethroids to avoid the development of resistance. Naled is the most commonly used material for this purpose. Because application rates are high relative to other adulticides, naled accounts for a large proportion of adulticide use by mass (66.8 percent), but a much smaller proportion by acreage (6.1 percent) (see Figures 2-4 and 2-5). Malathion use has declined over the past several years and accounted for 4.3 percent of adulticide application by mass in California in 2008 (Figure 2-4), and 0.2 percent of the acreage covered by adulticide applications (Figure 2-5).

Table 2-8. Reported Pesticide Use for Public Health Pest Control by Formulation

Active Ingredient	Formulations	U.S. EPA Reg. No.	2008		2007		2006		2005	
			Active Ingredient (pounds)	Percentage Use by Formulation	Active Ingredient (pounds)	Percentage Use by Formulation	Active Ingredient (pounds)	Percentage Use by Formulation	Active Ingredient (pounds)	Percentage Use by Formulation
Pyrethrin	Aquahalt Water-Based Adulticide	1021-1803	1,071.6	9.7%	263.8	3.0%	28.6	0.2%	--	--
	Evergreen Crop Protection EC 60-6	1021-1770	6,205.4	56.4%	4,516.2	51.6%	7,746.6	59.0%	3,433.6	38.1%
	Prentox Pyronyl Crop Spray	655-489	135.0	1.2%	6.5	0.1%	9.0	0.1%	8.9	0.1%
	Prentox Pyronyl Oil Concentrate #525	655-471	46.6	0.4%	34.6	0.4%	79.0	0.6%	201.2	2.2%
	Prentox Pyronyl Oil Concentrate Or-3610-A	655-501	2.8	0.0%	5.0	0.1%	4.5	0.0%	--	--
	Pyrenone 25-5 Public Health Insecticide	432-1050	1,477.7	13.4%	1,730.7	19.8%	1,856.1	14.1%	670.8	7.4%
	Pyrenone Crop Spray	432-1033	206.3	1.9%	167.5	1.9%	444.7	3.4%	428.0	4.7%
	Pyrocide Concentrate 7394	1021-1572	--	--	107.2	1.2%	--	--	--	--
	Pyrocide Mosquito Adulticide 7453	1021-1803	--	--	--	--	--	--	--	--
	Pyrocide Mosquito Adulticiding Concentrate For ULV Fogging 7395	1021-1570	662.0	6.0%	844.9	9.7%	1,225.3	9.3%	1,736.9	19.3%
	Pyrocide Mosquito Adulticiding Concentrate For ULV Fogging 7396	1021-1569	1,133.8	10.3%	1,026.0	11.7%	1,402.5	10.7%	2,256.9	25.0%
	Drione Insecticide*	432-992	2.5	0.0%	2.5	0.0%	28.9	0.2%	15.8	0.2%
	Evergreen Emulsifiable 60-6*	1021-1091	0.4	0.0	--	--	147.7	1.1%	--	--
	Haymaker II Fogging Insecticide*	40208-5	--	--	--	--	--	--	1.8	0.02%
	Permanone Ready-To-Use Insecticide*	4816-755	--	--	--	--	--	--	1.0	0.01%
	Prentox Exciter*	655-489	2.6	0.0%	13.9	0.2%	45.8	0.3%	143.7	1.6%
	Pyrenone*	9319-50046	--	--	--	--	27.5	0.2%	43.9	0.5%
	Pyrenone 25-5 M.A.G.C.*	4816-514	26.2	0.2%	29.8	0.3%	77.5	0.6%	52.9	0.6%
	Pyrenone Crop Spray Insecticide*	4816-490	4.9	0.0%	2.1	0.0%	1.8	0.0%	21.8	0.2%
	Pyrocide Mosquito Adulticiding Concentrate For ULV Fogging, F-7088*	1021-1185	15.3	0.1%	--	--	--	--	--	--
Permethrin	Allpro Aqualuer 20-20	769-985	368.8	19.7%	--	--	--	--	--	--
	Allpro Evoluer 4-4 ULV	769-982	14.8	0.8%	50.5	5.8%	--	--	--	--
	Aqua-Kontrol Concentrate	73748-1	--	--	--	--	--	--	--	--
	Aqua-Reslin	432-796	57.0	3.0%	22.2	2.6%	0.8	0.1%	38.2	3.2%
	Biomist 4+12 ULV	8329-34	198.7	10.6%	139.1	16.0%	147.9	15.9%	154.0	13.0%
	Biomist 4+4 ULV	8329-35	5.8	0.3%	54.3	6.3%	33.4	3.6%	23.1	2.0%
	Kontrol 2-2	73748-3	--	--	--	--	--	--	--	--
	Kontrol 4-4	73748-4	237.5	12.7%	--	--	--	--	--	--
	Kontrol 30-30 Concentrate	73748-5	--	--	--	--	--	--	--	--
	Permanone 31-66	432-1168	847.0	45.1%	391.4	45.2%	468.3	50.4%	585.4	49.5%
	Permanone Ready-To-Use Insecticide	432-1277	3.5	0.2%	--	--	--	--	--	--
	Prentox Perm-X UL 4-4	655-898	--	--	49.4	5.7%	57.1	6.2%	--	--
	Dragnet FT Termiticide*	279-3062	100.3	5.3%	148.4	17.1%	180.5	19.4%	269.2	22.8%
	Dragnet SFR Termiticide/Insecticide*	279-3062	38.5	2.1%	--	--	--	--	--	--
	Permanone Insect Repellant*	432-1112	1.1	0.1%	--	--	--	--	--	--
	Permanone Ready-To-Use Insecticide*	432-1182	--	--	11.3	1.3%	18.9	2.0%	112.5	9.5%

Table 2-8. Reported Pesticide Use for Public Health Pest Control by Formulation

Active Ingredient	Formulations	U.S. EPA Reg. No.	2008		2007		2006		2005	
			Active Ingredient (pounds)	Percentage Use by Formulation	Active Ingredient (pounds)	Percentage Use by Formulation	Active Ingredient (pounds)	Percentage Use by Formulation	Active Ingredient (pounds)	Percentage Use by Formulation
Permethrin (continued)	Permethrin 10% Rapid Kill Insecticide Concentrate*	47000-103	3.3	0.2%	--	--	--	--	--	--
	Prentox Perm-X 1E*	655-898	--	--	--	--	20.5	2.2%	--	--
	Zoecon RF-191 Fogger*	2724-292	--	--	--	--	0.7	0.1%	--	--
Resmethrin	Scourge Insecticide With Resmethrin/Piperonyl Butoxide 18%+54% Mf Formula II	432-667	--	--	28.7	13.8%	--	--	--	--
	Scourge Insecticide With Resmethrin/Piperonyl Butoxide 4%+12% Mf Formula II	432-716	1.0	0.8%	--	--	--	--	--	--
	Prentox Resmethrin 0.5% RTU*	655-779	1.3	1.0%	--	--	0.4	0.1%	--	--
	Sbp-1382/Piperonyl Butoxide Insecticide Concentrate 18% + 54% Mf Formula II*	432-667	12.3	9.8%	16.6	8.0%	0.2	0.1%	44.7	5.9%
	Scourge Insecticide With Sbp-1382/Pb 18% + 54% MF Formula II*	432-667	5.7	4.6%	0.8	0.4%	--	--	20.6	2.7%
	Scourge Insecticide With Sbp-1382/Pb 4%+12% MF Formula II*	432-716	--	--	5.0	2.4%	3.3	0.7%	1.2	0.2%
	Scourge Insecticide With Sbp-1382/Piperonyl Butoxide 4% + 12% MF Formula II*	432-716	104.3	83.1%	155.4	74.7%	216.2	47.9%	548.2	72.2%
	Scourge Insecticide With Sbp-1382/Piperonyl Butoxide 18% + 54% MF Formula II*	432-667	--	--	--	--	--	--	1.5	0.2%
	Scourge Insecticide With Sbp-1382/Piperonyl Butoxide 18% + 54% MF Formula II*	432-667	0.8	0.7%	1.5	0.7%	231.5	51.3%	135.8	17.9%
Phenothrin (Sumethrin)	Anvil 10+10 ULV	1021-1688	917.3	60.8%	184.8	34.1%	471.3	97.1%	349.8	54.3%
	Anvil 2+2 ULV	1021-1687	69.8	4.6%	36.8	6.8%	13.5	2.8%	294.3	45.7%
	Aqua Anvil Water-Based Adulticide	1021-1807	165.0	10.9%	18.2	3.4%	--	--	--	--
	Duet Dual-Action Adulticide	1021-1795	354.9	23.5%	302.0	55.7%	--	--	--	--
	Multicide Fogging Concentrate 2798*	1021-1795	--	--	0.4	0.1%	--	--	--	--
	Multicide Fogging Concentrate 2807*	1021-1807	0.8	0.1%	--	--	--	--	--	--
Prallethrin	Duet Dual-Action Adulticide	1021-1795	71.0	100.0%	60.4	99.9%	--	--	--	--
	Multicide Fogging Concentrate 2798*	1021-1795	--	--	0.1	0.1%	--	--	--	--
Etofenprox	Zenivex E20	2724-791	--	--	--	--	--	--	--	--
Naled**	Trumpet EC Insecticide	5481-481	30,415.5	90.6%	42,349	100.0%	19,659	99.7%	26,600	100.0%
	Dibrom Concentrate*	5481-480	3,149.1	9.4%	--	--	54	0.3%		
Malathion	Fyfanon ULV Mosquito	67760-34	--	--	--	--	--	--	--	--
	Prentox Malathion 50% Emulsifiable Insecticide	655-598	230	10.7%	117	5.4%	8	0.2%	6	0.1%
	Clean Crop Malathion ULV Concentrate Insecticide*	34704-18	204	9.6%	26	1.2%	20	0.6%	457	4.8%
	Cythion Insecticide "The Premium Grade Malathion"*	241-208	--	--	94	4.4%	29	0.9%	109	1.2%
	Cythion ULV Insecticide*	241-208	--	--	--	--	--	--	4	0.0%
	Fyfanon ULV*	67760-34	907	42.4%	1,654	77.0%	2,758	84.6%	7,424	78.6%
	Fyfanon ULV*	4787-8	423	19.8%	--	--	--	--	911.4	9.6%
	Malathion 8EC*	51036-214	197	9.2%	77	3.6%	24	0.7%	--	--
	Red-Top Malathion 8 Spray*	2935-83	--	--	--	--	325	10.0%	345	3.7%
	Wilbur-Ellis Malathion 8 Spray*	2935-83	176	8.2%	179	8.4%	96	2.9%	190	2.0%

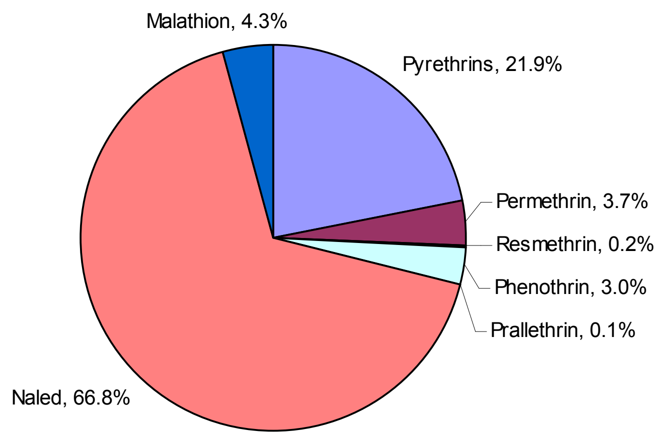
Source: DPR PUR Database

Notes:

* Formulation is not expected to be used after permit is adopted.

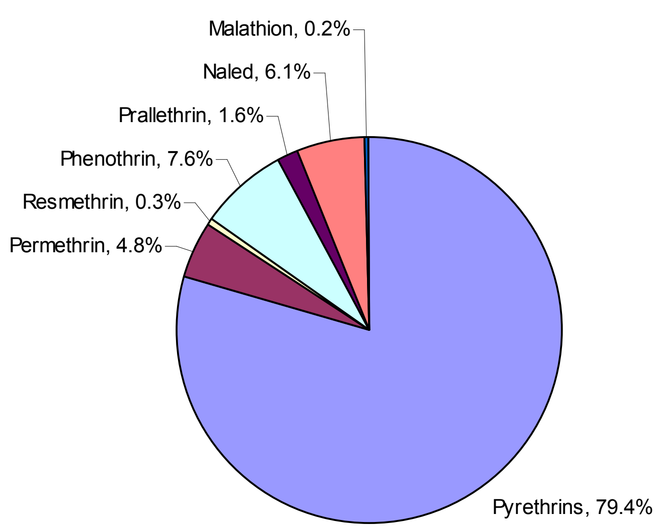
** Naled use for 2008 adjusted for San Joaquin County per personnal comm. Eddie Lucchesi (2010)

Figure 2-4 Reported Use for Public Health Pest Control by Active Ingredient, 2008 Statewide



Note: Based on pounds of active ingredient.
Naled use adjusted for San Joaquin County per personnal comm. Eddie Lucchesi (2010)

Figure 2-5 Acreage Treated for Public Health Pest Control by Active Ingredient, 2008 Statewide



Notes: Acreage estimated based on at maximum label application rate.
Acreage is counted each time repeated applications are made at the same site.
Naled use adjusted for San Joaquin County per personnal comm. Eddie Lucchesi (2010)

The active ingredients currently used for control of adult mosquitoes have been deliberately selected for lack of persistence and minimal effects on nontarget organisms when applied at label rates for ULV mosquito control. Formulation is a major factor in determining a pesticide's persistence in the environment, and products used for agriculture or forestry are sometimes formulated to increase their longevity. The products applied as ULV sprays for adult mosquito control are not formulated for persistence, because their purpose is to kill active adult mosquitoes in flight.

Table 2-9 shows the current list of products to be permitted.

2.3.3 Adulticide Application Locations and Frequency

Mosquito adulticides may be applied in a variety of locations, including ditches, storm drains, wetlands, tidal marshes, woodlands, rice fields, neighborhoods, tree holes, overgrown areas, and golf courses. Locations may be urban, suburban, agricultural, recreational, or wild refuge areas, and application sites may vary in size from a fraction of an acre to several thousand acres. In some cases, treatment may be limited to the edge of water bodies or tidal marshes; in other cases treatment would occur over entire water bodies. Types of locations, frequency, and size of application sites can vary significantly by region. Typically, larger areas are covered by adulticide application, and more frequent applications are needed in the Sacramento and San Joaquin Valleys, where mosquito problems tend to be worse.

This section provides a description of typical adulticide applications by region. It should be noted that typical applications made in the past may not be representative of those made in the future, and that patterns may change based on factors such as climate, disease surveillance, resistance, and cost-effectiveness. Information in this section is based on surveys of individual districts for 2009 applications (Table 2-8), as well as the DPR pesticide use data by county for 2007 and 2008 (the most recent currently available years). Years 2007 and 2008 were relatively dry; therefore, data for 2005 and 2006 (wet years) were also reviewed to determine whether there were significant differences in usage. West Nile virus activity and the availability of emergency control funds may also be factors in the amounts used from year to year. As shown in Table 2-8, although there were some differences in the amounts used, the general trends were similar between years.

Coastal Region

MVCAC agencies within the Coastal Region are listed in Table 2-3. Adulticides that MVCAC agencies reported used in this region in 2009 include pyrethrins, permethrin, resmethrin, and phenothrin. Marin-Sonoma also applied etofenprox in 2009. However, in 2007-2008 only use of pyrethrins adulticides was substantial, according to the DPR PUR data (Table 2-10). In 2008, resmethrin was applied at relatively low quantities, and permethrin, phenothrin, and prallethrin were applied in trace amounts during both years. Organophosphate adulticides are generally not applied. Many agencies do not apply adulticides every year, and at most application sites, adulticides are not typically applied more than once a year. At some application sites, adulticides may be applied up to five times a year under certain conditions. Unlike other regions, adulticide applications in this region include tidal marshes. Applications are made by truck or handheld equipment; aerial applications generally are not used in this region for adult mosquito control.

Table 2-9. Label Requirements and Label Application Rates by Formulation for Adulticides

Active Ingredient	Formulation Trade Name	U.S. EPA Reg. No.	% A.I.	% PBO	% MGK-264	Label Application Rates	Label Requirements Relevant to Mosquito Control/Surface Water
Pyrethrins	Pyrocide Mosquito Adulticiding Concentrate For ULV Fogging 7396	1021-1569	5	25	--	Max: 0.0025 lb of pyrethrins and 0.0125 lb of PBO per acre.	For terrestrial uses, do not apply directly to water, or to areas where surface water is present, or to intertidal areas below the mean high water mark.
	Pyrocide Mosquito Adulticiding Concentrate For ULV Fogging 7395	1021-1570	12	60	--	Max: 0.0025 lb of pyrethrins and 0.0125 lb of PBO per acre.	Do not apply directly to water, or to areas where surface water is present, or to intertidal areas below the mean high water mark.
	Evergreen Crop Protection EC 60-6	1021-1770	6	60	--	Max: 0.0025lb of pyrethrins per acre. Recommended: 0.002 to 0.0025 lb of pyrethrins per acre.	Except as specified in the directions for use, do not apply directly to water, to areas where surface water is present, or to intertidal areas below the mean high water mark. Do not apply when wind speed favors drift beyond the area intended for treatment.
	Aquahalt Water-Based Adulticide	1021-1803	5	25	--	Max: 0.0025 lb a.i./acre per day and 0.0625 lb a.i./acre per year. Recommended: 0.0009 to 0.0025 lb of pyrethrins and 0.0045 to 0.0125 lb of PBO per acre.	Application during the cool hours of the night or early morning is usually preferable, with a minimum application temperature of 50°F. Apply only when ground wind speed is greater than 1 mph.
	Pyrocide Mosquito Adulticide 7453	1021-1803	5	25	--	Max: 0.0025 lb a.i./acre per day and 0.0625 lb a.i./acre per year.	For terrestrial uses, do not apply directly to water, or to areas where surface water is present, or to intertidal areas below the mean high water mark.
	Pyrenone Crop Spray	432-1033	6	60	--	Max: 0.05 lb of pyrethrins per acre. Max for control of mosquitoes: 0.0025 lb of pyrethrins per acre.	For terrestrial uses, do not apply directly to water, or to areas where surface water is present, or to intertidal areas below the mean high water mark.
	Pyrenone 25-5 Public Health Insecticide	432-1050	5	25	--	Max: 0.0025 lb of pyrethrins per acre in any given 24-hour period and 0.0625 lb of pyrethrins per acre in any given season.	For terrestrial uses, do not apply directly to water, or to areas where surface water is present, or to intertidal areas below the mean high water mark. Apply when ground wind speed is greater than 1 mph.
	Prentox Pyronyl Oil Concentrate #525	655-471	5	25	--	Max: 0.0025 lb of pyrethrins and 0.0125 lb of PBO per acre.	For terrestrial uses, do not apply directly to water, or to areas where surface water is present, or to intertidal areas below the mean high water mark.
	Prentox Pyronyl Crop Spray	655-489	6	60	--	Max: 0.05 lb of pyrethrins per acre. Max amount for control of adult mosquitoes: 0.002 to 0.0025 lb of pyrethrins per acre.	For terrestrial uses, do not apply directly to water, or to areas where surface water is present, or to intertidal areas below the mean high water mark.
	Prentox Pyronyl Oil Concentrate OR-3610-A	655-501	3	6	10	Max: 0.0025 lb of pyrethrins per acre. Recommended: 0.0021 to 0.0025 lb of pyrethrins per acre.	For terrestrial uses, do not apply directly to water, or to areas where surface water is present, or to intertidal areas below the mean high water mark.
Permethrin	Permanone 31-66	432-1250	31.28	66	--	Max: 0.007 lb of permethrin per acre per application and a total of 0.18 lb of permethrin per acre in any given season. Recommended: 0.0035 to 0.007 lb permethrin per acre.	For best results, treat when mosquitoes are most active and weather conditions are most conductive to keeping the fog in the air column close to the ground; for example, when temperatures are cool, and wind speeds are equal to or greater than 1 mph.
	Permanone Ready-To-Use Insecticide	432-1277	3.98	8.48	--	Max: 25 applications at 0.007 lb of permethrin per acre (not to exceed a total of 0.18 lb of permethrin per acre) in any given season. Recommended: 0.0035 to 0.007 lb permethrin per acre.	Application during the cooler hours of the night or early morning is recommended. Best results are expected by application when weather conditions favor an inversion of temperatures in the area treated. For best results, treat when mosquitoes are most active and weather conditions are conducive to keeping the fog in the air column close to the ground; for example, when temperatures are cool, and wind speeds are equal to or greater than 1 mph.
	Aqua-Reslin	432-796	20	20	--	Max: 25 applications at 0.007 lb of permethrin per acre (not to exceed a total of 0.18 lb of permethrin per acre) in any given season.	Do not apply over bodies of water (lakes, rivers, permanent streams, natural ponds, commercial fish ponds, swamps, marshes, or estuaries), except when necessary to target areas where adult mosquitoes are present, and weather conditions will facilitate movement of applied material away from the water in order to minimize incidental deposition into the water body.
	Prentox Perm-X Ul 4-4	655-898	4	4	--	Max: 0.007 lb of permethrin per acre in a 24 hour period. Do not apply more than 0.18 lb of permethrin per acre per year to any site.	Application during the cooler hours of the night or early morning is recommended. Best results are expected by application when weather conditions favor an inversion of temperatures in the area treated. For best results, treat when mosquitoes are most active and weather conditions are conducive to keeping the fog in the air column close to the ground; for example, when temperatures are cool, and wind speeds are equal to or greater than 1 mph.

Table 2-9. Label Requirements and Label Application Rates by Formulation for Adulticides

Active Ingredient	Formulation Trade Name	U.S. EPA Reg. No.	% A.I.	% PBO	% MGK-264	Label Application Rates	Label Requirements Relevant to Mosquito Control/Surface Water
Permethrin	Aqua-Kontrol Concentrate	73748-1	20	20	--	Max: 0.18 lb of permethrin per acre per year to any site. Recommended: from 0.00175 to 0.007 a.i./acre.	Both ground and aerial applications should be made when meteorological conditions are conducive to keeping the spray cloud close to the ground, such as when an air temperature inversion is present. Applications during the cool hours of early morning or evening are preferable. Air temperatures should be greater than 50°F when conducting all types of applications. Application in calm air conditions is to be avoided. Apply only when ground wind speed is greater than 1 mph. Do not apply when wind speed exceeds 10 mph. Do not re-treat a site more than once in 12 hours.
	Kontrol 2-2	73748-3	2	2	--	Max: 0.18 lb of permethrin per acre per year to any site. Recommended: from 0.00175 to 0.007 a.i./acre.	Both ground and aerial applications should be made when meteorological conditions are conducive to keeping the spray cloud close to the ground, such as when air temperature inversion is present. Applications during the cool hours of early morning or evening are preferable. Air temperatures should be greater than 50°F when conducting all types of applications. Application in calm air conditions is to be avoided. Apply only when ground wind speed is greater than 1 mph. Do not apply when wind speeds exceed 10 mph. Do not re-treat a site more than once in 12 hours.
	Kontrol 4-4	73748-4	4.6	4.6	--	Max: 0.18 lb of permethrin per acre per year to any site. Recommended: from 0.00175 to 0.007 a.i./acre.	Both ground and aerial applications should be made when meteorological conditions are conducive to keeping the spray cloud close to the ground, such as when air temperature inversion is present. Applications during the cool hours of early morning or evening are preferable. Air temperatures should be greater than 50°F when conducting all types of applications. Application in calm air conditions is to be avoided. Apply only when ground wind speed is greater than 1 mph. Do not apply when wind speeds exceed 10 mph. Do not re-treat a site more than once in 12 hours.
	Kontrol 30-30 Concentrate	73748-5	30	30	--	Max: 0.18 lb of permethrin per acre per year to any site. Recommended: from 0.00175 to 0.007 a.i/acre.	Both ground and aerial applications should be made when meteorological conditions are conducive to keeping the spray cloud close to the ground, such as when air temperature inversion is present. Applications during the cool hours of early morning or evening are preferable. Air temperatures should be greater than 50°F when conducting all types of applications. Application in calm air conditions is to be avoided. Apply only when ground wind speed is greater than 1 mph. Do not apply when wind speeds exceed 10 mph. Do not re-treat a site more than once in 12 hours.
	Allpro Evoluer 4-4 ULV	769-982	4	4	--	Recommended: 0.001 to 0.007 lb of permethrin per acre.	Both aerial and ground applications should be made when the wind is less than 10 mph. Do not apply this product within 100 feet (30 meters) of lakes and streams. For best results, treat when mosquitoes or insects are most active and weather conditions are conductive to keeping the fog close to the ground (e.g., cool temperatures and wind speed are not greater than 10 mph). Applications during the cool hours of night or early morning are usually preferable.
	Allpro Aqualuer 20-20	769-985	20.6	20.6	--	Max: 0.007 lb of permethrin per acre. Max for application using backpack or truck-mounted mist blower equipment: 0.1 lb permethrin per acre.	Both aerial and ground applications should be made when the wind is less than 10 mph. Do not apply this product within 100 feet (30 meters) of lakes and streams. For best results, treat when mosquitoes or insects are most active and weather conditions are conductive to keeping the fog close to the ground (e.g., cool temperatures and wind speed are not greater than 10 mph). Applications during the cool hours of night or early morning are usually preferable.
	Biomist 4+12 ULV	8329-34	4	12	--	Max: 0.007 lb of permethrin per acre in a 24-hour period; 0.18 lb of permethrin per acre per year. Ground ULV application: 0.0017 to 0.007 lb of permethrin and 0.005 to 0.021 lb of PBO per acre.	For best results treat when mosquitoes are most active and weather conditions are conducive to keeping the spray cloud close to the ground. An inversion of air temperatures and a light breeze is preferable. Application in calm air conditions is to be avoided. Apply only when ground wind speed is greater than 1 mph. Air temperatures should be greater than 50°F when conducting all types of applications.
	Biomist 4+4 ULV	8329-35	4	4	--	Max: 0.007 lb of permethrin per acre in a 24-hour period; 0.18 lb of permethrin per acre per year. Ground ULV application: 0.00175 to 0.007 lb of permethrin per acre.	For best results apply when mosquitoes are most active and weather conditions are conducive to keeping the spray cloud close to the ground. An inversion of air temperatures and a light breeze is preferable. Application in calm air conditions is to be avoided. Apply only when ground wind speed is greater than 1 mph. Air temperature should be greater than 50°F when conducting all types of applications.

Table 2-9. Label Requirements and Label Application Rates by Formulation for Adulticides

Active Ingredient	Formulation Trade Name	U.S. EPA Reg. No.	% A.I.	% PBO	% MGK-264	Label Application Rates	Label Requirements Relevant to Mosquito Control/Surface Water
Phenothrin	Anvil 2+2 ULV	1021-1687	2	2	--	Max: 0.0036 lb of Sumithrin™ per acre in a 24-hour period; 1.0 lb of Sumithrin™ per acre in any site in any year. Ground ULV application: 0.0012 to 0.0036 lb a.i./acre	IN CALIFORNIA: This product is to be applied by County Health Department, State Department of Health Services, Mosquito and Vector Control or Mosquito Abatement District personnel only. For best results, apply when mosquitoes are most active and weather conditions are conducive to keeping the fog close to the ground. Application in calm air conditions is to be avoided. Apply only when ground wind speed is greater than 1 mph. Air temperature should be greater than 50°F when conducting all types of applications. Use a clean, well-maintained, and properly calibrated fogger. Fog downwind.
	Anvil 10+10 ULV	1021-1688	10	10	--	Max: 0.0036 lb of Sumithrin™ per acre in a 24-hour period; 1.0 lb of Sumithrin™ per acre in any site in any year. Ground ULV application: 0.0012 to 0.0036 lb a.i./acre	IN CALIFORNIA: This product is to be applied by County Health Department, State Department of Health Services, Mosquito and Vector Control or Mosquito Abatement District personnel only. For best results, apply when mosquitoes are most active and weather conditions are conducive to keeping the fog close to the ground. Application in calm air conditions is to be avoided. Apply only when ground wind speed is greater than 1 mph. Air temperature should be greater than 50°F when conducting all types of applications. Use a clean, well-maintained, and properly calibrated fogger. Fog downwind.
	Aqua Anvil Water-Based Adulticide	1021-1807	10	10	--	Max: 0.0036 lb of phenothrin per acre in a 24-hour period. Do not exceed 1.0 lb of Sumithrin® per acre in any site in any year. Ground ULV application: 0.0012 to 0.0036 lb of Sumithrin® and PBO per acre.	IN CALIFORNIA: This product is to be applied by County Health Department, State Department of Health Services, Mosquito and Vector Control or Mosquito Abatement District personnel only. For best results, apply when mosquitoes are most active and weather conditions are conducive to keeping the fog close to the ground. Application in calm air conditions is to be avoided. Apply only when ground wind speed is greater than 1 mph. Air temperature should be greater than 50°F when conducting all types of applications.
Phenothrin and Prallethrin	Duet Dual-Action Adulticide	1021-1795	5 / 1	5	--	Max: 0.0036 lb of Sumithrin® or 0.0008 lb of prallethrin per acre in a 7-day period; 0.094 lb of Sumithrin® or 0.021 lb of prallethrin in any site in a year. Ground ULV application: 0.0003 to 0.0008 lb of Prallethrin and 0.0012 to 0.0036 lb of Sumithrin® and PBO per acre.	IN CALIFORNIA: This product is to be applied by County Health Department, State Department of Health Services, Mosquito and Vector Control or Mosquito Abatement District personnel only. For best results, apply when mosquitoes are most active and meteorological conditions are conducive to keeping the spray cloud close to the ground. Application in calm air conditions is to be avoided. Apply only when ground wind speed is greater than 1 mph. Air temperature should be greater than 50°F when conducting all types of application.
Resmethrin	Scourge Insecticide With Resmethrin/Piperonyl Butoxide 18%+54% MF Formula II	432-667	18	54	--	Max: 0.007 lb of resmethrin per acre; 0.18 lb of resmethrin per acre in any given season. Application rates: 0.001 to 0.007 lb of resmethrin per acre	All types of applications should be conducted at temperatures of 50°F or higher. Apply when ground wind speeds are equal to or greater than 1 mph. Do not exceed 25 applications at 0.007 pound of resmethrin per acre (not to exceed a total of 0.18 pound of resmethrin per acre) in any given season. More frequent applications may be made to prevent or control a threat to public and/or animal health determined by a state, tribal, or local health or vector control agency on the basis of documented evidence of disease-causing agents in vector mosquitoes, or the occurrence of mosquito-borne disease in animal or human populations, or if specifically approved by the state or tribe during a natural disaster recovery effort.
	Scourge Insecticide With Resmethrin/Piperonyl Butoxide 4%+12% MF Formula II	432-716	4	12	--	Max: 0.007 lb of resmethrin per acre; 0.18 lb of resmethrin per acre in any given season. Application rates: 0.00117 to 0.007 lb of resmethrin per acre	For best results, apply when insects are most active and meteorological conditions are conducive to keeping the spray cloud in the air column close to the ground. An inversion of air temperatures and a light breeze is preferable. Application during the cooler hours of the night or early morning is recommended. Do not exceed 25 applications at 0.007 pound of resmethrin per acre (not to exceed a total of 0.18 pound of resmethrin per acre) in any given season. More frequent applications may be made to prevent or control a threat to public and/or animal health determined by a state, tribal, or local health or vector control agency on the basis of documented evidence of disease-causing agents in vector mosquitoes, or the occurrence of mosquito-borne disease in animal or human populations, or if specifically approved by the state or tribe during a natural disaster recovery effort.

Table 2-9. Label Requirements and Label Application Rates by Formulation for Adulticides

Active Ingredient	Formulation Trade Name	U.S. EPA Reg. No.	% A.I.	% PBO	% MGK-264	Label Application Rates	Label Requirements Relevant to Mosquito Control/Surface Water
Etofenprox	Zenivex E20	2724-791	20	0	--	Max: 0.007 lb of etofenprox per acre. Recommended: 0.00175 to 0.0070 lb of etofenprox per acre.	Apply when wind is greater than 1 mph. Do not apply when wind speeds exceed 10 mph. A temperature inversion is preferable to keep the fog close to the ground, and applications should be made when labeled insects are most active. Conduct applications when temperatures are between 50 and 95°F. Do not re-treat a site more than once in 3 days; make no more than two applications to a site in any one week, or 25 applications in one year. More frequent treatments may be made to prevent or control a threat to public and/or animal health determined by a state, tribal, or local health or vector control agency on the basis of documented evidence of disease-causing agents in vector mosquitoes, or the occurrence of mosquito-borne disease in animal or human populations, or if specifically approved by the state or tribe during a natural disaster recovery effort.
Malathion	Prentox Malathion 50% Emulsifiable Insecticide	655-598	50	0	--	Not listed	For terrestrial uses, do not apply directly to water, or to areas where surface water is present, or to intertidal areas below the mean high water mark. Do not apply where weather conditions favor drift from areas treated. Do not contaminate water when disposing of equipment washwaters.
	Fyfanon ULV Mosquito	67760-34	96.5	0	--	Max: 0.23 lb a.i./acre per day.	Do not contaminate water, food, or feed by storage or disposal. Do not re-treat a site more than 3 times in any one week Apply only when weather conditions are favorable. Wind and rising air currents may cause undesirable spray drift.For enhanced knock-down effects against mosquitoes, Fyfanon ULV Mosquito can be mixed with a synergized pyrethrins emulsifiable concentrate (6 percent pyrethrins + 60 percent PBO) in accordance with the most restrictive of label limitations and precautions indicated on both this and the tank-mixed product.
Naled	Trumpet EC Insecticide	5481-481	78	0	--	Max: 0.59 lb per acre of naled within a 7-day period; 10.73 lb per acre of naled a.i./acre) per year. Adult Mosquito Control Ultra Low Volume (ULV) Aerial Application: 0.05 to 0.1 lb a.i./acre (recommended) Adult Mosquito control ULV Ground Application: 0.02 lb a.i./acre (recommended). In conditions of high pest pressure and/or heavy foliage, a maximum of 0.1 lb a.i./acre may be applied.	Before making the first application in a season, consult with the primary State agency responsible for regulating the pesticides to determine if permits are required or regulatory mandates exist. Do not apply over bodies of water (e.g., lakes, swamps, rivers, permanent streams, natural ponds, commercial fish ponds, marshes, or estuaries), except when necessary to target areas where adult mosquitoes are present, and weather conditions will facilitate movement of applied material away from the water in order to minimize incidental deposition into the water body. Spray during periods when wind speed is between 1 and 15 mph, at ground level and when thermal activity is low. Do not apply when ambient temperature is less than 50ºF. Do not apply when it is raining in the treatment area. Do not treat any site more than 1 time per day.

Notes:
°F = degrees Fahrenheit
lb = pound
mph = miles per hour
A.I. = Active Ingredient
BMPs = Best Management Practice
MGK-264 = N-Octyl bicycloheptene dicarboximide
PBO = Piperonyl Butoxide
ULV = Ultra Low Volume

Table 2-10. Regional Use for Public Health Pest Control during 2007 and 2008

Year	Active Ingredient	Sacramento Valley[1]		Coastal[2]		North San Joaquin Valley[3]		South San Joaquin Valley[4]		Southern California[5]	
		lbs of a.i.	% for Region	lbs of a.i.	% for Region	lbs of a.i.	% for Region	lbs of a.i.	% for Region	lbs of a.i.	% for Region
2008	Pyrethrins	3,825	34.8%	158	1.4%	5,969	54.3%	966	8.8%	76	0.7%
	Permethrin	1,177	62.7%	0.2	0.0%	504	26.9%	88	4.7%	65	3.5%
	Resmethrin	33	26.2%	4	3.2%	--	--	2	1.3%	87	69.3%
	Phenothrin	850	56.3%	0.07	0.0%	438	29.0%	98	6.5%	118	7.8%
	Prallethrin	65	92.1%	< 0.01	0.0%	0.6	0.8%	5	7.1%	--	--
	Naled[6]	22,959	68.4%	--	--	10,605	31.6%	--	--	--	--
	Malathion	1,331	62.2%	--	--	176	8.2%	197	9.2%	434	20.3%
2007	Pyrethrins	5,390	61.6%	102	1.2%	2,707	30.9%	463	5.3%	26	0.3%
	Permethrin	825	95.1%	0.1	0.0%	--	--	3	0.3%	39	4.5%
	Resmethrin	69	32.9%	--	--	0.4	0.2%	0.8	0.4%	137	66.1%
	Phenothrin	439	80.9%	0.1	0.0%	8	1.5%	22	4.0%	74	13.6%
	Prallethrin	59	97.3%	< 0.01	0.0%	2	2.6%	0.09	0.1%	--	--
	Naled	32,128	75.9%	--	--	10,221	24.1%	--	--	--	--
	Malathion	1,774	82.6%	--	--	172	8.0%	84	3.9%	117	5.4%

Source: DPR PUR Database

Notes:

[1]Counties of Shasta, Tehama, Butte, Lake, Glenn, Colusa, Sutter, Yuba, Placer, El Dorado, Yolo, Sacramento, and Nevada

[2]Counties of Sonoma, Marin, Napa, Solano, Contra Costa, Alameda, San Mateo, Santa Clara, Santa Cruz, Monterey, and San Benito

[3]Counties of San Joaquin, Stanislaus, Merced, and Calaveras

[4]Counties of Madera, Fresno, Kings, Tulare, Kern, and San Luis Obispo

[5]Counties of Mono, Inyo, Santa Barbara, Ventura, Los Angeles, San Bernardino, Orange, San Diego and Riverside

[6]Naled use for 2008 adjusted for San Joaquin County (Lucchesi 2010)

ai = active ingredient

lbs = pounds

% = percent

Sacramento Valley Region

MVCAC agencies within the Sacramento Valley Region are listed in Table 2-3. Adulticides that MVCAC agencies reported using in this region include pyrethrins, permethrin, phenothrin, prallethrin, malathion, and naled. In 2007 and 2008, the DPR PUR data also included applications of resmethrin in this region (Table 2-10). Because mosquito problems tend to be more severe in this region, all districts in this region apply adulticides every year, and multiple applications are made at many sites (typically weekly, sometimes twice a week or every 2 weeks for about 4 months during the summer). About half of the agencies use aerial applications in addition to applications by truck or handheld sprayers. Sites in this region where adulticide applications are made include rice fields, which is not typical of other regions.

Northern San Joaquin Valley

MVCAC agencies within the Northern San Joaquin Valley Region are listed in Table 2-3. Adulticides that MVCAC agencies reported using in this region in 2009 include pyrethrins, permethrin, and phenothrin. In 2007, permethrin use was not included in the DPR PUR data, but a small amount of phenothrin, prallethrin, and resmethrin were included (Table 2-10). In 2008, permethrin was applied, as well as a more significant quantity of phenothrin. Organophosphate adulticides are generally not applied in both years, except in San Joaquin County, where naled use was reported, and in Stanislaus County, where malathion use was reported. As with the Sacramento Valley Region, this region tends to have severe mosquito problems. As such, all districts in this region apply adulticides every year, and multiple applications are made at many sites (typically weekly, sometimes twice a week or every 2 weeks for about 4 months during the summer). Most of the agencies use aerial applications in addition to applications by truck or handheld sprayers.

Southern San Joaquin Valley

MVCAC agencies within the Southern San Joaquin Valley Region are listed in Table 2-3. Adulticides that MVCAC reported using in this region in 2009 include pyrethrins, permethrin, and phenothrin. Organophosphate adulticides are generally not applied; however, Kings Mosquito Abatement District did report applying naled. In 2007, the DPR PUR data included a very small amount of resmethrin and prallethrin in this region (Table 2-10). No use of naled was reported to DPR in 2007, but use of malathion was reported in this region (Table 2-10). In 2008, resmethrin, prallethrin, and malathion were also applied. Most districts in this region apply adulticides every year, and multiple applications may be made (up to 13 times per year at some sites). Most agencies use only truck and handheld applications, but some also use aerial application.

Southern California

MVCAC agencies within the Southern California Region are listed in Table 2-3. Adulticides that MVCAC reported used in this region in 2009 include pyrethrins, permethrin, resmethrin, and phenothrin. Malathion was the only organophosphate adulticide reported for use in this region in

2007 and 2008 (Table 2-10). Most districts in this region apply adulticides every year, and multiple applications may be made (up to five times per year at some sites). Applications are made by truck or handheld equipment, although Coachella Valley also uses aerial application.

2.3.4 Methods to Control Adverse Effects to Surface Water

BMPs are used to control adverse effects to surface waters. Generally, the BMPs used are determined by the label requirements, although additional measures may be used. For mosquito adulticide formulations, control measures include the following:

- Application over bodies of water (lakes, rivers, permanent streams, natural ponds, commercial fish ponds, swamps, marshes, or estuaries) is avoided, except when necessary to target areas where adult mosquitoes are present, and when weather conditions facilitate movement of applied material away from the water in order to minimize incidental deposition into the water body. Application is avoided when wind speed favors drift beyond the area intended for treatment.
- Both ground and aerial applications are made when mosquitoes are most active and when meteorological conditions are conducive to keeping the spray cloud close to the ground, such as when an air temperature inversion is present. Applications during the cool hours of early morning or evening are preferred, with a minimum application temperature of 50 degrees °F. Application in calm air conditions (<1 mph) or high winds (per label instructions) is avoided.
- For terrestrial uses, application is avoided: directly to water; to areas where surface water is present; or to intertidal areas below the mean high water mark.

Additional BMPs specified by formulation on product labels are shown in Table 2-9.

2.3.5 Other Uses of the Active Ingredients and Synergists in Mosquito Adulticides

Most pesticides used as adulticides are also used for a wide variety of other purposes in California, which is important to consider when developing a monitoring program. When an active ingredient is detected in the water, it may be very difficult to determine whether it came from a mosquito control application, an unrelated application, or from multiple sources. Residential pesticide sources are especially difficult to determine, because their use is not reported to or quantified by DPR. DPR estimates that approximately two-thirds of pesticide use in California is unreported.

Table 2-11 shows the proportion of each active ingredient that is used for vector control, as a percentage of total reported use in California for 2005, 2006, 2007, and 2008. Although vector control uses may include uses other than mosquito adulticides, it is assumed that the vast majority of public health use of the formulations shown in Table 2-8 is to control adult mosquitoes. Note that total reported use does not include use by homeowners, which may comprise the majority of the use for certain pesticides, especially in urban and suburban areas (Moran 2005).

Table 2-11. Reported Pesticide Use, Statewide

Year	Metric	Pyrethrins	Permethrin	Resmethrin	Phenothrin	Prallethrin	Naled*	Malathion
2008	Total Reported Use (lbs of a.i.)	18,782	344,204	269	1,601	100	155,046	478,103
	Reported Use for Vector Control (lbs of a.i.)	10,995	1,876	125	1,509	71	33,565	2,138
	% Use of Total for Vector Control	59%	1%	47%	94%	71%	22%	0%
2007	Total Reported Use (lbs of a.i.)	17,357	418,224	448	587	60	132,929	470,195
	Reported Use for Vector Control (lbs of a.i.)	8,751	867	208	543	60	42,349	2,146
	% Use of Total for Vector Control	50%	0.2%	46%	92%	100%	32%	0.5%
2006	Total Reported Use (lbs of a.i.)	19,560	669,445	656	533	0.009	196,143	410,320
	Reported Use for Vector Control (lbs of a.i.)	13,128	928	452	485	0.0001	19,713	3,259
	% Use of Total for Vector Control	67%	0.1%	69%	91%	0.6%	10%	0.8%
2005	Total Reported Use (lbs of a.i.)	14,218	554,619	958	696	1.5	225,863	426,218
	Reported Use for Vector Control (lbs of a.i.)	9,017	1,182	759	645	--	26,600	9,446
	% Use of Total for Vector Control	63%	0.2%	79%	93%	--	12%	2.2%

* Naled use for 2008 adjusted for San Joaquin County (Lucchesi 2010).

Pyrethrins were first registered in the United States for use as an insecticide in the 1950s. Pyrethrins are used on many agricultural crops; on livestock and animal husbandry premises; for treatment of commercial and industrial facilities and storage areas where raw and processed food/feed commodities are stored or processed; and for wide-area mosquito abatement in areas that include aquatic habitats. They are also used on outdoor household areas, pastureland, aquatic area or standing water, and for hospitals, recreational areas, ULV applications, and mosquito abatement programs (U.S. EPA 2006a; DPR 2009).

Permethrin has been registered by the U.S. EPA since 1979, and is currently registered and sold in a number of products such as household insect foggers and sprays, tick and flea sprays for yards, flea dips and sprays for cats and dogs, termite treatments, agricultural and livestock products, and mosquito abatement products. Permethrin is also used at urban areas, household gardens, recreation areas, golf courses, hospitals, zoos, pastureland, and animal husbandry areas (DPR 2009).

Resmethrin has been registered by the U.S. EPA since 1967, and is used to control flying and crawling insects in the home, lawn, garden, and industrial sites. It can also be used to control insects on ornamental plants (outdoor and greenhouse use), on pets and horses, and as a mosquitocide. Resmethrin is also used at commercial and industrial areas, warehouses, urban areas, and golf courses, and on aquatic areas or standing water, and selected agricultural crops. Because of its toxicity to fish, resmethrin is a restricted-use pesticide (RUP) for the purpose of public health mosquito abatement, and is available for this use only by certified pesticide applicators or persons under their direct supervision (U.S. EPA 2006b).

Phenothrin has been registered by the U.S. EPA since 1976, and is used to control adult mosquitoes, and as an insecticide in transport vehicles such as aircraft, ships, railroad cars, and truck trailers. It is also used as an insecticide and miticide in commercial, industrial, and institutional nonfood areas, in homes and gardens, in greenhouses, and in pet quarters and on pets, and is used in urban areas, outdoor residential areas, around buildings and structures, at recreational areas, golf courses, zoos, and for agricultural crops (DPR 2009).

Prallethrin is a synthetic pyrethroid with fast knock-down activity against household insect pests. It is used in household insecticide products against mosquitoes, houseflies, and cockroaches. Prallethrin also has veterinary uses in the treatment of domestic pets. Prallethrin has an exciting effect on mosquitoes, and is added to Duet (the only prallethrin-containing adulticide product used in California) primarily for this property rather than its inherent toxicity. Prallethrin has been applied in urban areas, outdoor residential areas, recreational areas, golf courses, around building and structures, and at areas of standing water (DPR 2009).

Etofenprox is a pyrethroid-like insecticide registered by the U.S. EPA since 2001. It is used as an indoor non-food crack and crevice insecticide, a spot treatment for pets, and as an outdoor fogger to control a variety of insect pests. Etofenprox is used in backyards, patios, barns, picnic areas, and other areas where flying and crawling insects are a problem. It is also used as a mosquito adulticide (U.S. EPA 2007c).

Malathion is an organophosphate insecticide that has been registered for use in the United States since 1956. It is used in agriculture, indoor and outdoor household areas, residential gardens, food-processing areas, animal husbandry premises, and in public health pest control programs (DPR 2009).

Naled is an organophosphate insecticide that has been registered since 1959 for use in the United States. In addition to use for controlling adult mosquitoes, naled also has indoor and outdoor general use, and is used on food and feed crops, farms, dairies, pastureland, and in greenhouses and over standing water (DPR 2009).

3.1 MOSQUITO LARVICIDES

Mosquito control agencies in California moved away from the use of organophosphate insecticides in the 1970's. Today, MVCAC member agencies have chosen to use materials that are highly selective and have minimal toxicity for nontarget organisms. For most of the active ingredients in mosquito larvicides, a substantial amount of data is available on fate, transport, and aquatic toxicity. Available data on fate and transport for each active ingredient are summarized in Table 3-1.

3.1.1 Bacillus Thuringiensis

Persistence of Bti is low in the environment, usually lasting 1 to 4 days due to sensitivity to ultraviolet (UV) light (Table 3-1). The amount of toxins contained within *Bti* products is reported indirectly as the result of at least two different bioassays, and is difficult to equate to one another. Prepared volumes of toxins are applied to living mosquito larvae and the resulting mortality produces through formulae numerical measures known as International Toxic Units (ITUs) and *Ae. aegypti* International Toxic Units (AA-ITUs). These measures are only roughly related to observed efficacy in the field, and are therefore inappropriate to consolidate and report on like other toxicants (active ingredients). There is currently no chemical test that will differentiate Bti from mosquito control products from other spore forming bacilli existing in the environment.

Bti applied at label rates has virtually no adverse effects on applicators, livestock, or wildlife, including beneficial insects, annelid worms, flatworms, crustaceans, mollusks, fish, amphibians, reptiles, birds, or mammals (deBarjac et al. 1980; Garcia et al. 1981; Gharib and Hilsenhoff 1988; Holck and Meek 1987; Knepper and Walker 1989; Leclair et al. 1988; Marten et al. 1993; Merritt et al. 1989; Molloy et al. 1992; Miura et al. 1980; Mulla et al. 1983; Mulla et al. 1982; Purcell 1981; Reish et al. 1985; Siegel et al. 1987; Tietze et al. 1993,1992,1991; Tozer and Garcia 1990). However, non-target activity on larvae of some insect species closely related to mosquitoes and found with mosquito larvae in aquatic habitats has been observed. There have been reported impacts in larvae belonging to the midge families Chironomidae, Ceratopogonidae, and Dixidae (Anderson et al. 1996; Molloy 1992; Mulla et al. 1990; Rodcharoen et al. 1991; Tozer and Garcia 1990). These non-target insect species, taxonomically closely related to mosquitoes and black flies, apparently contain the necessary gut pH and enzymes to activate delta-endotoxins. However, the concentration of *Bti* required to cause these effects is 10 to 1,000 times higher than maximum allowed label rates for mosquito control.

Table 3-1. Persistence of the Active Ingredients of Mosquito Larvicides

Class	Active ingredient	Half-life	Degradation Method (and Matrix)	Reference
Microbial[1]	*Bacillus Sphaericus*	0.5-2 weeks	not reported (formulated product)	EPA 1999
	Bacillus Thuringiensis	1 - 4 days	UV light (foliage)	EPA 1998
		several months	not reported (soil)	EPA 1998
Surface agents	Monomolecular film[2]	5 - 7 days	not reported (water)	EPA 2007a
		5 - 22 days	not reported (water)	Cognis Corporation 2004
	Petroleum Distillates[3]	2 - 3 days	not reported (water)	EPA 2007b
Insect growth regulator	Diflubenzuron	2 days	aerobic metabolism (soil)	EPA 1997
		3.7 - 11.3 days	photolysis (soil)	EPA 1997
		34 days	anaerobic metabolism (water)	EPA 1997
		30 - 80 days	hydrolysis, pH 5-9 (water)	EPA 1997
		80 days	photolysis (water)	EPA 1997
		5.8 - 60 days	not reported (field data)	EPA 1997
	Methoprene[4]	rapid	photolysis (water and soil)	EPA 2001
		<1 day	photolysis (water)	ASTDR 2005
		<13 days	photolysis (water)	Csondes 2004
		10 - 14 days	aerobic and anaerobic metabolism (soil)	EPA 1991
		>150 days	not reported (briquettes in water)	Csondes 2004
Organophosphate	Temephos	rapid	not reported (natural waters)	EPA 2000
		>7 days	not reported (field data)	ASTDR 2005
Insect neuro-disruptor	Spinosad	0.84 - 0.96 day	photolysis (water)	Kollman 2002
		8.68 - 9.44 days	photolysis (soil)	Kollman 2002
		>30 days	hydrolysis, pH 7-9 (water)	Kollman 2002
		14.5 - 17.3 days	aerobic metabolism (soil)	Kollman 2002
		161 - 250 days	anaerobic metabolism (soil)	Kollman 2002

Notes:

[1] Formal environmental fate data is not generally required for microbial pesticides because it is not usually needed and it is difficult to evaluate due to the potential for microbial growth under suitable environmental conditions (EPA 1998).

[2] Alpha-Isooctadecyl-Omega-Hydroxypoly(Oxyethylene)

[3] Reported as either Petroleum Distillates or Refined Petroleum Distillates

[4] S-Methoprene is the active ingredient of Methoprene.

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Bacterial spores of *Bti* are uniquely toxic to nematoceran Diptera (mosquitoes, midges, blackflies, psychodids, and ceratopogonids) (Lacey and Mulla 1990). That result was reported after reviewing *Bti* studies conducted using a variety of *Bti* formulations, and under a variety of test conditions. Lacey and Mulla (1990) concluded that *Bti* was a highly selective larvicide that produced minimal adverse impact on the environment. Garcia et al. (1981) tested a total of 23 species of aquatic organisms other than mosquito larvae using various formulations of *Bti* in his laboratory. No mortality was observed for these species with the exception of *Chironomus maturus* and a *Simulium* sp. (black fly), which showed a degree of susceptibility similar to that of mosquito larvae. Miura et al. (1980) found *Bti* at rates used for mosquito control to be very safe to organisms associated with mosquito breeding habitats. A total of 28 species or species groups were treated with the bacterium under simulated or field conditions, with no adverse effects observed, except for chironomid larvae, which were slightly affected. However, the effect was so light that the population in the field continuously increased after the treatment. Miura et al. (1981) found *Bti* and *Bacillus sphaericus*, when applied at rates used for mosquito control, was very safe to organisms associated with mosquito breeding habitats, including the natural enemies of mosquito larvae. When various aquatic organisms were exposed to the bacteria under laboratory or field conditions, no adverse effect was noted on the organisms, with the exceptions of chironomid and psychodid larvae. Chironomid larvae were slightly affected by *Bti* treatment at a rate used for mosquito control, but pyschodid larvae were only affected at the higher concentration (50 parts per million [ppm]).

Exposure of brook trout (*Salvelinus fontinalis)* fry to 4,500 and 6,000 milligrams per liter (mg/L) Teknar (a liquid formulation of Bti) (more than 50 times the allowed label rate for mosquito control) for 45 minutes resulted in 20 and 86.4 percent mortality, respectively (Fortin et al., 1986). Some species of chironomids are also susceptible to *Bti*, but at doses 10 to 1,000 times higher than those used to control mosquito larvae (Becker and Margalit, 1993; Mulla et al., 1990b). *Bti* has been used extensively for control of mosquitoes in Germany without affecting populations of chironomids (Becker and Margalit 1993)

A number of *B. thuringiensis* fermentation-based products tested at high-dose levels have shown intrinsic toxicity to nontarget organisms. Investigations conducted to determine the source of the nontarget activity have implicated heat-labile soluble substances contaminating the technical material. Toxic effects have been seen in aquatic invertebrate *Daphnia magna*, the honeybee, some beneficial insects and fish (rainbow trout, bluegill) studies, with Daphnia being the most sensitive indicator of toxicity. The impurities are found in the supernatant fluids separate from the delta-endotoxins. The toxicity does not appear to be due to the heat-stable beta-exotoxin, because autoclaving of the test material renders the supernatant fluids innocuous. The heat-labile, soluble toxic impurities have thus far been seen in *B. thuringiensis* subspecies *kurstaki*, *aizawai*, and *israelensis*, but may possibly be present in other *B. thuringiensis* varieties. Damgaard (1995) reported varying levels of at least one soluble exotoxin in all commercial *B. thuringiensis* products tested (FEMS Immunology and Medical Microbiology 12:245-250). *B. thuringiensis* subspecies *aizawai*-based products show the greatest negative effects on nontarget organisms. With *B. thuringiensis* subspecies *kurstaki*, the manifestation of the toxin(s) appears to be at least partly related to production methodology, especially the composition of the growth media used in industrial fermentation. In response to concerns, the manufacturer of VectoBac has completed continuous 10-day exposure tests on *Daphnia magna* with the active ingredients found in VectoBac products (fermentation solids and solubles produced by *Bti* strain AM65-52).

Results indicated that the LC_{50} is higher than 50 ppm for *Daphnia magna* when exposed continuously for 10 days. Based on maximum label rates of VectoBac products, expected environmental concentrations (EEC) of active ingredients do not exceed 1 ppm immediately following application, based on a conservative assumption of a water depth of 10 cm. Therefore, application of VectoBac at label rates will not result in AI concentrations approaching 10 percent of the LC_{50} for *Daphnia magna* (DeChant2010).

3.1.2 Bacillus Sphaericus (Bs)

Isolation and identification of the primary toxin in *B. sphaericus* responsible for larval activity has demonstrated that it is a protein with a molecular weight of 43 to 55 kD. A standard bioassay similar to that used for *Bti* has been developed to determine preparation potencies. The bioassay uses *Culex quinquefasciatus* 3rd to 4th instar larvae. In contrast to *Bti*, field evaluations of VectoLex-CG (a commercial formulation of *B. sphaericus*) have shown environmental persistence for several weeks (Table 3-1; Mulla et al. 1988).

B. sphaericus has a very low toxicity for fish, and all aquatic invertebrates Levels that effective control mosquito larvae are many levels of magnitude below those which affect other organisms. Acute aquatic freshwater organism toxicity tests were conducted on bluegill sunfish, rainbow trout and daphnids. The 96-hour LC_{50} and No Observable Effect Concentration (NOEC) value for bluegill sunfish and rainbow trout was greater than 15.5 mg/LL; the 48-hour EC 50 and NOEC value for daphnids was greater than 15.5 mg/L. Acute aquatic saltwater organism toxicity tests were conducted on sheepshead minnows, shrimp and oysters. The 96-hour LC_{50} value for both sheepshead minnows and shrimp was 71 mg/L, while the NOEC value was 22 mg/L for sheepshead minnows and 50 mg/L for shrimp. The 96-hour EC_{50} value for oysters was 42 mg/L with an NOEC of 15 mg/L. The LC_{50} and NOEC value for immature mayflies was 15.5 mg/L. Additional studies on various microorganisms and invertebrates, specifically cladocerans, copepods, ostracods, mayflies, chironomid midges, water beetles, backswimmers, water boatmen, giant water bugs, and crawfish, have shown no adverse effects or negative impacts (Holck and Meek 1987; Miura et al. 1981; Mulla et al. 1984; Rodcharoen et al. 1991; Walton and Mulla 1991; Key and Scott 1992; Tietze et al. 1993). Furthermore, Ali (1991) states that although *B. sphaericus* is known to be highly toxic to mosquito larvae, *B. sphaericus* does not offer any potential for midge control.

Applications of B. sphaericus also leave populations of mosquito predators intact and do not cause secondary effects when treated larvae are consumed by other insects. Key and Scott (1992) conducted laboratory studies with *Bacillus sphaericus* on the grass shrimp *Palaemonetes pugio* and the mummichog *Fundulus heteroclitus*. Their study indicated that both *Bti* and *B. sphaericus* larvicides have large margins of safety. In a study by Aly and Mulla (1987), aquatic mosquito predators were fed with *Cx. quinquefasciatus* 4th instar larvae intoxicated with either *Bti* or *Bacillus sphaericus* preparations. Although the mosquito larvae contained large amounts of the bacterial preparations in their gut, no effect upon longevity or ability to molt was observed in the backswimmer *Notonecta undulata*, in naiads of the dragonfly *Tarnetrum corruptum*, or in naiads of the damselfly *Enallagma civile*. Equally, the reproduction of *N. undulata* and the predation rate and ability to emerge normally in *T corruptum* and *E. civile* were not affected by ingestion of large amounts of bacterial toxins.

3.1.3 Spinosad

Spinosad is rapidly and extensively photolyzed in water with a half life of less than one day (Table 3-1 and Goudie 2010). Photolysis results in degradates that are orders of magnitude less toxic than spinosad. Spinosad is moderately to strongly sorbed by soil particles (Goudie 2010).

Acute LC 50 values for bluegill and sheepshead minnow are greater than 5,000 ppb and 7,000 ppb, respectively, and the chronic NOAEC values for trout and sheepshead minnow are both greater than 1,000 ppb (Goudie 2010). Hertlein et al (2010) stated that no negative impacts were observed for individual mosquito fish held in water containing up to 50,000 ppb of spinosad. This material also has low acute toxicity for fresh and saltwater invertebrates, with an acute EC 50 of greater than 10,000 ppb for daphnia (Goudie 2010). The acute EC50 for oysters was greater than 300 ppb (Goudie 2010). Laboratory studies demonstrate some toxicity for some aquatic invertebrates under chronic exposure, but residues dissipate rapidly and are rapidly degraded by photolysis with a half life in water of less than half a day (Goudie 2010). Stark and Vargas (2003) reported a decline in *Daphnia pulex* when exposed to Spinosad in the laboratory. However, the organisms were held in a continuous renewal system, with fresh spinosad added every 24 hours. Mortality also occurred in daphnia held in plexiglass enclosures at a field site during applications of spinosad (Duchet et al 2008) However, mortality occurred immediately after the applications and the authors also noted that the spinosad dissipated rapidly from the water column and was detected at 4 to 13 percent of the initial concentrations (8 to 33 µg/L) in water 4 days after its application (Duchet et al 2008). Hertlein et al. (2010), reporting an unpublished study by Laddoni (2006) noted slight impacts on non-mosquito insects (Dyticsidae, Hesteridae, Libelluledae, Notonectidae) were observed in an artificial pond treated with 50 ppb or 50 g/ha of spinosad. But this is far below field use rates and the authors concluded that spinosad was minimally disruptive to nontargets when applied near field use rates (15-25 ppb).

3.1.4 Monomolecular Film

Agnique is the trade name for a recently reissued surface film larvicide, comprised of ethoxylated alcohol. Molecular film larvicides spread across water surfaces and disrupt larval respiration, killing mosquitoes and some other classes of air-breathing aquatic insects. Reported half-lives of monomolecular films in water range from 5 to 22 days (Table 3-1), and Agnique has an average persistence in the environment of 5 to 21 days at label application rates (Oester 2010). A number of efficacy and nontarget studies had been conducted on this material when it was registered under the name Aerosurf. Minor proprietary changes in preparation did not apparently change any of the material's potential environmental impacts; therefore, the earlier literature is referenced.

Most published studies conducted with this larvicide tested application rates of 3 to 100 times the maximum label rate. At these rates, no observable effect on mortality or development was noted in tests on green tree frogs, seven species of fresh and salt water fish, two species of shrimp, five species of water beetle, or one species each of fairy shrimp, crayfish, snail, polychaete worm, mayfly naiad, copepod, ostracod, or midge. In addition, no effect was seen on five species of plants. Air (surface) breathing insects were temporarily adversely impacted. Waterboatmen, backswimmers, and one species of water beetle exhibited increased mortality at application rates above label limits. In addition, a clam shrimp, a crab, an amphipod, and one species of isopod exhibited minor to significant increases in mortality at levels several times the highest application rate allowed by the label (Oester 2010).

3.1.5 Petroleum Distillates

Petroleum distillates ore effective in many situations in which monomolecular films do not give effective control. These materials also break down much more rapidly than monomolecular films (2-3 days as opposed to 21 days) which further decrecreases their impact to nontarget organisms (Table 3-1).

The safety of petroleum distillates for nontargets has been demonstrated by both laboratory and field studies. Three studies by Tietze et al. (1991, 1992, 1994) tested three species of fish (Inland Silversides, Mosquitofish, and Sheepshead Minnows), and a range of microorganisms and concluded that petroleum distillate formulation GB-1111is not toxic to the tested organisms at label application rates. Mulla and Darwazeh (1981) tested with GB-1111 in small experimental ponds and found that benthic invertebrates (including mayflies, dragonflies, and damselflies) were unaffected, while populations of surface-breathing insects were temporarily reduced, following application of this larvicide. Miles et al. (2002) completed an independent study of non-target effects of GB-1111, with financial assistance from the U.S. Fish and Wildlife Service (USFWS), on the tidal marshes of the Don Edwards National Wildlife Refuge in San Francisco Bay near Newark, California, and observed the following effects: 1) surface-breathing insect populations were reduced at the time of treatment; 2) this effect did not persist beyond a few days (no residual pesticide effects); 3) those potentially affected animals with high mobility left the site, while some of those that could not leave died (especially water boatmen (Corixidae)); and 4) overall populations of invertebrate species were not affected, apparently because of recolonization from neighboring untreated sites.

3.1.6 Methoprene

s-Methoprene is a very short-lived material in nature, with a half-life less than 13 days in water (Table 3-1), two days in plants, and 10 days in soil (Wright 1976; La Clair et al. 1998). It degrades quickly in soil or groundwater and exposed water (Wright 1976). Eighty percent of the material is removed by degradation within 13 days of application to water (U.S. EPA 1991). Methoprene is applied at very low concentrations for mosquito control. The manufacturer has developed a number of formulations to maintain an effective level of the active material in the mosquito habitat (0.5 to 3.0 parts per billion [ppb[1]]; (Scientific Peer Review Panel 1996) for a practical duration, thus minimizing the cost and potential impacts associated with high-frequency repeat applications (see Table 2-4). Rate of release and data generated under laboratory and field conditions with methoprene mosquito product formulations, including slow release briquet formulations, indicate a maximal rate of release of ≤4 ppb (U.S. EPA 2001). Ross et al. (1994) conducted microcosm studies which applied 5 sustained release methoprene formulations at maximum label application rates to tanks containing water 6 inches deep. Methoprene concentrations were measured 1, 2, 4, 7, 14, 21, 28 and 35 days after treatment, and the highest methoprene concentration measured was 6 ppb.

Methoprene is a material with very high specificity in its mode of action. Exhaustive reviews of the published literature on this material attest to its lack of adverse environmental impact (Mian and Mulla 1982; Scientific Peer Review Panel 1996; Glare and O'Callaghan 1999; Office of the Minnesota Legislative Auditor 1999; U.S. EPA 2001). The acute, short-term toxicity of ZR-515 (methoprene) was also tested on 35 aquatic organisms, including Protozoa, Platyhelminths, Rotatoria, Annelida, Arthropoda, Mollusca, Chordata and Thallophyta, and LC_{50} values of 0.9 to 5.0 ppm were calculated (250 to 1,000 times label rates) (Miura and Takahashi 1973). Dosages used for larval mosquito control produced no adverse effect on the organisms tested, except for some sensitivity in the aquatic Diptera (flies) in the families Chironomidae, Ephydridae, and Psychodidae.

Bircher and Ruber (1988) assessed the toxicity of methoprene to all lifecycle stages of the salt marsh copepod (*Apocyclops spartinus*) at concentrations ranging from 100 to 10,000 ppb. In general, the copepods were resistant to concentrations of methoprene used to control mosquitoes, but early larval stages did show some mortalities (the calculated 48-hour LC_{50}, adjusted for control mortality, was 800 ppb). Christiansen et al. (1977) showed a reduction in survival of larvae of the mud-crab *Rhithropanopeus harrisii* (Gould) in the laboratory under a range of salinity and temperature conditions, when exposed to 10, 100, and 1,000 ppb methoprene, levels 5 to 500 times field application rates. McKenney and Mathews (1988) reported that larval survival, growth, and energy metabolism of an estuarine shrimp *Palaemonetes pugio* were altered by exposure to 100 ppb of methoprene (50 times greater than application rates). However, Wirth et al. (2001) reported no observed differences in the percent successfully hatching or larval mortality 3 days post hatch in *P. pugio* exposed for 96 hours to 1000 ppb. In addition, in 2005, Suffolk County conducted 4-day static renewal toxicity tests on grass shrimp (*Palaemonetes pugio*) using water collected 30 minutes after aerial application of methoprene for mosquito control and observed no toxicity. Similar investigations have been carried out with *Leander tenuiconis*, an estuary shrimp that occurs in Australian intertidal marshes. Methoprene was nontoxic at field application levels in 96-hour toxicity tests (Brown et al. 1996). The LC_{50} of methoprene for *L tenuiconis* (14,320 ppb) in these tests was 1,790 times field concentrations when applied at label rates. The authors concluded that methoprene could be safely applied in situations where the shrimp were present and that no mortality of shrimp was likely at the levels applied for mosquito control. Further laboratory work by Brown et al. (2000), found that the dose lethal to mosquitoes (*Culex annulirostris*) was 3,000 times below the LC_{95} for shrimp (*Caradina indistincta)*. Zulkosky et al. (2005) investigated potential effect of methoprene runoff to larval lobsters (*Homarus americanus*) in continuous flow-through systems for 48 hours: methoprene was not toxic at the highest concentration tested (10 micrograms per liter [µg/L] or 10 ppb). Laboratory studies with fish demonstrated that methoprene had no effect on the survival of adult and juvenile rainbowfish (*Melanotaenia duboulayi*) (Brown 2002). No effect was observed on swimming performance of rainbowfish when exposed to up to ten times effective field concentrations of applications made for mosquito control (Hurst et al. 2007).

Methoprene does not have adverse effects on amphibians. Tests conducted on various life stages of different amphibian species (*Bufo woodhousei*, *Rana catesbeiana* and *Rana pipiens*) found no adverse effects from acute or chronic exposures at the highest dose tested. Acute studies on

R. catesbeiana and *R. pipiens* larvae indicate LC_{50} values >10,000 ppb and *B. woodhousei* adult LC_{50} values >1,000 ppb (highest dose tested). Chronic studies on *B. woodhousei* indicate a 22-day LC_{50} >1,000 ppb and LC_{50} > 1,000 ppb for *R. catesbeiana* and *R. pipiens*. (U.S. EPA 2001).

One early field study assessing applications of technical (pure powdered) methoprene on a Louisiana coastal marsh yielded ambiguous results (Breaud et al. 1977). Highly significant declines were observed in the occurrence of 14 invertebrates immediately following the application, including selected life stages and species of amphipods, shrimp, mayflies, dance flies, midges, freshwater snails, damselflies and dragonflies, and water beetles. However, the abundance of five other invertebrates significantly increased including water boatmen, moth flies, two species of crawfish, and predaceous diving beetles. No statistically significant difference was seen between the test and control populations of another 28 aquatic organisms. Interpretation of this study is difficult in part because of the mixed nature of the results, which may simply indicate the complexity of ecosystem dynamics in marshlands. Also, the application rate (28 gm AI/ha technical powder) was at least twice the highest label rate of active ingredient allowed today, and was effectively much higher when the encapsulation and other coatings on modern formulations are considered. The relevance of Breaud et al.'s entire experiment as a legitimate field study may be called into question, as the properties of technical grade methoprene powder render it unfit for any type of direct field application under current label restrictions.

Since the publication of Breaud et al. (1977), there have been numerous field studies using currently available mosquito control products containing methoprene, in which no detectable effect was observed in aquatic invertebrates. For example, no detectable mortality occurred in Talitridae amphipods exposed to aerial applications of Altosid to a Florida mangrove swamp in 1999 (Lawler et al. 1999b). A similar study assessed applications of a sustained release formulation of methoprene and a combined liquid formulation of Bti and methoprene (duplex) to tidal wetlands of San Francisco Bay. No difference was seen in growth or development of corixid beetles, and no difference in the number of nontarget insects inhabiting treated versus untreated plots (Lawler et al. 2000). The authors also monitored brine flies at treated and untreated sites using sentinel cages, and sampled populations with sweep nets. No decline was observed in flies relative to controls collected by sweep nets. Caging of sentinels was unsuccessful at assessing impacts, since none of the caged flies survived at untreated sites or treated ones.

Aerial applications of liquid methoprene on saltmarsh habitat have also been assessed in Australia (Russell et al. 2009). Changes in assemblages of invertebrates through time were observed in both treated and untreated (control) plots. No significant effects were seen on arthropods in ephemeral pools. There was no significant difference in abundance of nonmosquito dipterans (flies), heteropterans (true bugs), and hymenopterans (primarily ants) in treated versus untreated sites. Some differences were observed in copepod populations during the treatment period, but these were short-term or inconsistent between localities or between sampling method. The authors concluded that applications of Bti and methoprene to salt marshes do not affect the structure or composition of assemblages of nontarget arthropods (Russell et al. 2009).

Published studies on nontarget impacts of methoprene for mosquito control were reviewed most recently by Davis (2007) and by Davis and Peterson (2008). The authors also carried out an ecological risk assessment of mosquito larvicides in a series of ponds at the Benton Lakes National Wildlife Refuge in Montana. *Bti* and methoprene were applied directly to water as liquids, and aquatic arthropods were sampled following the applications. No overall treatment effects were observed on aquatic nontarget invertebrates collected in D-shaped net samples. A linear model was then fitted to each of the response variables to determine multivariate treatment effects. Data indicated a possible acute impact on amphipods immediately following application, but no significant effect at 7 to 28 days. No trend was seen across dependant groups of nontarget organisms, and there were no persistent biological effects.

Careful review of these and other studies, and the recent reviewers listed above leads to the conclusion that: 1) applications of methoprene (especiallytechnical powder) at rates significantly higher than allowed by the label can adversely impact a number of aquatic animals; 2) animal species are not extirpated (locally eliminated) by repeated methoprene use except at application rates far higher than those used for mosquito control; 3) emergence of adults of some fly species (specifically, some types of midges) can be temporarily reduced at application rates similar to those used for mosquito control; 4) larval flies affected by methoprene are not killed at label application rates, but are prevented from becoming adults; 5) for species that are affected by methoprene, recolonization and reestablishment of populations from neighboring sites is fast once intense control was relaxed; 6) the patchy distribution of mosquito larvae leads to maintenance of untreated refugia for non-targets, speeding recolonization; and 7) no bioaccumulation of methoprene has been seen in animals that have eaten mosquito or midge larvae treated with methoprene.

3.1.7 Temephos

Temephos is an extremely hydrophobic material with low solubility. It adsorbs rapidly onto organic material in the water and degrades to low or undetectable concentrations (U.S. EPA 2000). The Registration Eligibility Decision (RED) cites a study submitted by the registrant in which temephos was monitored in sediments following field applications for mosquito control over a 3-year period. The active ingredient became undetectable in sediment after 24 hours (U.S. EPA 2000) (Table 3-1). Temephos breaks down rapidly in water through photodegradation and bacterial degradation (U.S. EPA 2000). The liquid and BG formulation products are designed to deliver the active ingredient to the water surface in order to maximize exposure of mosquito larvae. Lores et al. (1985) found that concentrations in water of 15 to 60 ppb immediately following the application declined to 2 to 5 ppb within 24 hours. Sanders et al. (1981) reported similar results. Pierce et al. (1989) examined aerial application of liquid formulation of temephos to a mangrove swamp in Florida, and found the material had become undetectable 4 hours after the application in intertidal water. It persisted in simulated intertidal pools for 72 hours.

Temephos is a cholinesterase inhibitor with low toxicity for vertebrates at the levels used for mosquito control (U.S. EPA 2000). However, it is toxic to insects and some other invertebrates (Brown et al. 1996), and the margin of safety between concentrations effective for mosquito control and levels at which nontarget impacts occur is much narrower than that of s-methoprene or the bacterial larvicides (Brown 1999, Lawler et al. 1999, Hurst et al. 2007).

Temephos is slightly to moderately toxic to fish (U.S. EPA 2000); however, field applications result in concentrations of temephos far lower than that at which fish are affected. Field studies have repeatedly demonstrated a lack of impact on fish inhabiting treated sites. Mulla et al. (1964) reported that temephos was nontoxic to mosquito fish that were confined in screened cages for one week in artificial ponds treated with 0.1 pound per acre AI. Similarly, no significant mortality was observed in juvenile snook (*Centroponzis undecimalis*) or sheepshead minnow (*Cyprinodon variegatus*) caged in a mangrove swamp treated with aerial applications of liquid temephos (Pierce et al. 1989). Tietze et al. (1999) demonstrated in Tietze et al., 1991 laboratory tests that liquid formulations of temephos were nontoxic to young mosquitofish (3 to 5 days old) at field application rates. Mosquitofish exhibited no mortality when exposed to up to 100 times field application rates.

Temephos is highly toxic to aquatic invertebrates, but many groups are only impacted at concentrations far above those used for mosquito control applications (U.S. EPA 2000). Von Windeguth and Patterson (1966) conducted laboratory tests on temephos and fenthion (another organophosphate) to determine margin of safety for treatment of midges in a lake. The dose of fenthion used for midges was above that which caused mortality in shrimp and amphipods. Abate (temephos) was less toxic to most aquatic nontarget organisms than fenthion and not toxic to shrimp (*Palomonetes paladosus*) and amphipods (*Hyalella azteca*) at concentrations used for mosquito control applications (LD_{50} was 1 ppm and 0.65 ppm, respectively). Neither product was toxic to fish at levels necessary to kill midge larvae (0.25 lb AI per acre). In field tests, they reported that no noticeable mortality was observed for Odonates (dragonflies), copepods, ostracods, or shrimp (Von Windeguth and Patterson 1966).

Temephos does have an immediate impact on some groups of planktonic crustaceans, with copepods and brachiopods (cladocera) being more sensitive than amphipods or ostracods. Fortin et al. (1987) studied the impact of temephos on non-target organisms in rectangular manmade pods. Application of temephos resulted in an immediate reduction in populations of copepods and cladocerans, but populations began to recover within 3 days and had reached pre-treatment levels within 2 to 3 weeks. Ostracopods in the ponds were not affected. Helgen et al. (1988) also reported sharp reductions in populations of calanoid copepods (*Diaptomus leptopus*) and cladocreans (*Daphnia pulex*, *Simocephalus* sp., and Chydoridae) following applications of temephos. Copepods exhibited varying degrees of recovery. However, some cladocerans remained absent from the treated area for up to 35 days. In an open field setting, Lawler et al. (1999) reported that aerial applications of temephos to a mangrove swamp in Florida resulted in no observable effect on survival of amphipods (Talitridae), the primary nontarget organism present.

Temephos is a broad-spectrum insecticide, and has been used operationally to control midges and black flies for many years. However, the concentration that effectively controls mosquito larvae is well below that needed for control of other insects. In addition, midges and black flies are found in different habitats than larval mosquitoes. The larval stage of most midges develop in sediment at the bottom of water bodies, while black flies develop attached to hard surfaces in swift moving rivers and streams. Materials commercially available for midge control are heavy and designed to release their active ingredients on the floor of the water body, those for control of black flies are placed in flowing streams and allowed to move down with the current.

Several studies have evaluated effects on nontarget insects. A field study of repeated applications of temephos to a saltmarsh in New Jersey concluded that species richness, diversity, and community structure of aquatic insects was unaffected (Campbell and Denno 1976). Stoneflies and mayflies are particularly susceptible to temephos and the label carries a prohibition against applying Abate in habitats containing these organisms.

Many of the studies of nontarget effects have looked at organisms inhabiting saltmarsh environments or flowing streams (Pinkney et al. 1999; Ward et al. 1976; Lawler et al. 1999 Brown et al. 1999). However, in California, temephos has not been used in salt marshes or in flowing streams for many years.

3.2 MOSQUITO ADULTICIDES

For most of the active ingredients in mosquito adulticides, a substantial amount of data is available on fate, transport, and aquatic toxicity. Available data on fate and transport for each active ingredient are summarized in Table 3-2. This table also includes the toxicity-based Receiving Water Monitoring Trigger levels adopted by the SWRCB. These trigger levels are based on the acute water quality objectives when available. When no water quality objective is available, the trigger values are based on the lowest freshwater LC_{50} divided by a factor of 10.

This section focuses on data collected specifically in studies done on ULV application of mosquito adulticides. As discussed in Section 2.3, most active ingredients in adulticides are also used for many other purposes, and a substantial amount of data has been collected for other uses. However, the characteristics of ULV applications are quite different from other applications, such as those made for agricultural crops. These differences can have dramatic differences in the fate and transport of the active ingredients. Some of these differences include:

Table 3-2. Persistence of the Active Ingredients of Mosquito Adulticides

Class	Active ingredient	Half-life		Degradation Method (and Matrix)	Reference
Pyrethrins (naturally occurring chemicals in pyrethrum)	Pyrethrins[1]	< 1	day	Photolysis (water and soil)	U.S. EPA 2006a (RED), Gunasekara 2005
		14-17	hrs	Hydrolysis, pH 9 (water)	U.S. EPA 2006a (RED)
		86.1	days	Anaerobic metabolism (soil)	U.S. EPA 2006a (RED)
		10.5	days	Aerobic metabolism (soil)	U.S. EPA 2006a (RED)
		1.8 – 97	days[2]	Volatilization (soil)	Gunasekara 2005
		"slow"		Hydrolysis, neutral or acidic	U.S. EPA 2006a (RED)
Pyrethroids (synthetic)	d-phenothrin (Sumithrin®)	6.5	days	Photolysis (water)	U.S. EPA 2008 (RED)
		18.6 – 25.8	days	Aerobic metabolism (soil)	U.S. EPA 2008 (RED)
		36.1	days	Aerobic metabolism (water)	U.S. EPA 2008 (RED)
		173.3	days	Anaerobic metabolism (water)	U.S. EPA 2008 (RED)
		stable		Hydrolysis, all pH levels	U.S. EPA 2008 (RED)
	Resmethrin	22	minutes	Photolysis (seawater)	U.S. EPA 2006b (RED)
		47	minutes	Photolysis (distilled water)	U.S. EPA 2006b (RED)
		198	days	Aerobic metabolism (soil)	U.S. EPA 2006b (RED)
		37	days	Aerobic metabolism (water)	U.S. EPA 2006b (RED)
		stable		Anaerobic metabolism (soil)	U.S. EPA 2006b (RED)
		> 89	days	Hydrolysis, pH 5 – 9	U.S. EPA 2006b (RED)
	Permethrin	stable		Hydrolysis, pH 5 – 7	U.S. EPA 2009a (RED), Imgrund 2003
		242	days	Hydrolysis, pH 9	Imgrund 2003
		125 – 350	days	Aquatic degradation, pH 9	U.S. EPA 2009a (RED)
		113 – 175	days	Anaerobic degradation (water)	U.S. EPA 2009a (RED)
		51 – 100	days	Photolysis, pH 5 (water)	Imgrund 2003
		< 3 – 197	days	Anaerobic degradation (soil)	Imgrund 2003

Table 3-2. Persistence of the Active Ingredients of Mosquito Adulticides

Class	Active ingredient	Half-life		Degradation Method (and Matrix)	Reference
		3.5 – 113	days	Aerobic degradation (soil)	Imgrund 2003
		104 – 324	days	Photolysis (soil)	Imgrund 2003
		< 2.5	days	Sediment/seawater degradation	Imgrund 2003
		1.8 – 20.4	hours	Streams, pH 7.0 – 7.5, 13 – 15°C	Imgrund 2003
		19.6 – 27.1	hours	Photolysis, ponds (water)	Imgrund 2003
	Prallethrin	25	days	Photolysis (soil)	Sumitomo Chemical 2009
		13.6	hours	Photolysis (water)	Sumitomo Chemical 2009
	Etofenprox	4.4	days	Photolysis (soil)	Central Life Sciences 2009
		1.7	days	Photolysis (water)	Central Life Sciences 2009
Synergist for pyrethrins& pyrethroids	Piperonyl Butoxide (PBO)	8.4	hours	Photolysis (water)	U.S. EPA 2006c (RED)
		"very slow"		Hydrolysis & aerobic/anerobic metabolism	U.S. EPA 2006c (RED)
Organophosphates	Naled	< 2	days	Hydrolysis & biodegradation (water & soil)	U.S. EPA 2006d (RED)
		"high"		Volatilization (soil)	U.S. EPA 2006d (RED)
	Dichlorvos (DDVP) (degradation product of Naled)	0.88 – 11.6	days	Hydrolysis, pH 5 – 9	U.S. EPA 2006e (RED)
		8.9 – 10.2	days	Photolysis (water)	U.S. EPA 2006e (RED)
		15.5 – 16.5	hours	Photolysis (soil)	U.S. EPA 2006e (RED)
		10.18	hours	Aerobic metabolism (soil)	U.S. EPA 2006e (RED)
		6.3	days	Anaerobic metabolism (soil)	U.S. EPA 2006e (RED)
	Malathion	0.1 – 11	days	Aerobic metabolism (soil)	U.S. EPA 2009b (RED), Newhart 2006
		0.67 – 42	days	Photodegradation (water)	U.S. EPA 2009b (RED)
		1 – 14	days	Aerobic metabolism (water)	U.S. EPA 2009b (RED)
		persistent		Anaerobic degradation (water)	U.S. EPA 2009b (RED)

Table 3-2. Persistence of the Active Ingredients of Mosquito Adulticides

Class	Active ingredient	Half-life		Degradation Method (and Matrix)	Reference
		1.4 – 147	days	Aerobic degradation (water)	Newhart 2006

Note:
[1] Pyrethrins are a mix of Pyrethrin I, Pyrethrin II, Cinerin I, Cinerin II, Jasmolin I, and Jasmolin II
[2] Estimated value

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- ULV applications are designed to maximize the duration of the pesticide in the air, rather than deposition on surfaces;
- ULV applications are designed to use drift to increase coverage; and
- Adulticides are often applied adjacent to or over water bodies.

Because of these differences, data from studies done on agricultural applications or other types of applications may have limited relevance for mosquito control applications. Therefore, MVCAC and the SWRCB agreed it was important to compile and review the results of studies done specifically on ULV applications of mosquito adulticides.

3.2.1 Pyrethrins (in Formulations with PBO)

Pyrethrins are composed of a mixture of six compounds: pyrethrin I and II, cinerin I and II, and jasmolin I and II. As shown in Table 3-2 the photolysis half-life in water and soil is less than one day, and the hydrolysis half-life in water is 14 to 17 hours. They adsorb strongly to soil surfaces and are generally considered immobile in soils; therefore, the potential to leach into groundwater is considered low. Pyrethrins quickly adsorb to suspended solids in the water column, and partition into the sediment. Non-degraded pyrethrins are likely to bind to sediment, because they persist under anaerobic conditions (U.S. EPA 2006a).

Pyrethrins are contact poisons that can quickly penetrate the neural system. Although pyrethrins have an effective “knockdown” action (induction of temporary paralysis), they do not necessarily have high killing properties by themselves. These compounds are moderately persistent under certain environmental conditions, but are quickly metabolized under other conditions, such as in the presence of sunlight. In order to delay the metabolic action (inhibition of microsomal enzymes) so that a lethal dose is assured, the synergist PBO is added to the mosquito adulticides (U.S. EPA 2006a).

3.2.1.1 Receiving Water Monitoring Triggers

The SWRCB has adopted a Receiving Water Monitoring Trigger for pyrethrins of 0.32 μg/L, based on freshwater aquatic life toxicity data from U.S. EPA’s Office of Pesticides’ Ecotoxicity Database. The SWRCB identified the lowest LC_{50} of 3.2 μg/L based on toxicity to rainbow trout during a 96-hour test, and their monitoring trigger value is one-tenth of that value (see Table 3-3).

The SWRCB has a Receiving Water Monitoring Trigger for PBO of 0.34 μg/L when applied in a pyrethrins formulation, which is also based on toxicity data from U.S. EPA’s Office of Pesticides’ Ecotoxicity Database. The SWRCB monitoring trigger value is one-tenth of the lowest LC_{50} of 3.4 μg/L, based on toxicity to bluegill sunfish during a 96-hour test (see Table 3-3).

Table 3-3. Summary of Existing Study Results for ULV Applications

Active Ingredient	Product	Method of Application	Application Rate	Monitoring Trigger in ppb (water)	Field Results in ppb (water)	Field Results in ppb (sediment)	Time Sampled	Type of Sample	Notes	Reference
Pyrethrin	Evergreen Crop Protection EC 60-6	Aerial	2.8 g/ha AI	0.32	<0.5 @ 1, 12, and 24 hr 0.213, jasmolin II @ 36 hrs		1, 12, 24, 36 hours	H_2O 2-6 cm below surface Cotton pads	1 river, 7 creeks and a pond Jasmolin not detected at 24 hrs but appeared @ 36 hr, from another source	Schleier et al. 2008
	Evergreen Crop Protection EC 60-6	Aerial	2.8 g/ha AI	0.32	Average 0.270; <0.2 – **3.77** (Imm.) <0.2 @ 16-23 hrs		Immediately (1 to 6 hours) 16 to 23 hours	H_2O Mid-depth 10 sites	No significant increase after multiple applications	Larry Walker & Assoc. 2006
	Evergreen Crop Protection EC 60-6	Aerial	2.8 g/ha AI	0.32	<0.05	Average 184.51; <1 – 403	10 to 34 hours	H_2O 10-20 cm below surface and Sediment	No water caused significant mort in 7 days (for Ceriodaphnia dubia) Sediment in samples taken before spray was toxic to Hyalella	Weston et al. 2006
	Pyrocide™ 5%	Truck	0.118 L/min; 16 kph truck speed 1-31 µm droplets	0.32	<20		1 hour	Water column	No significant mortality in caged mosquito larvae, mosquitofish or invertebrates sampled Analytical method not specified (UC Davis) Permethrin and malathion were also applied to wetlands during this study	Jensen et al. 1999
	Pyrenone 25-5 Public Health Insecticide	Truck	0.458 g AI/ha	0.32		Average 4.9; <2 - 33.1 after Spray #5 Average 3.2; <2 - 34.5 after spray # 11	within 12 hours	Sediment only	23 & 33 µg/kg in 2 of 6 tanks after spray #5; 34.5 µg/kg in 1 of 6 tanks after spray #11; Detection limits 2 µg/kg – CDFG lab No accumulation of pyrethrins in water or sediment	Lawler et al. 2008
PBO (with Pyrethrins)	Evergreen Crop Protection EC 60-6	Aerial	28 g/ha PBO	0.34	0.012-0.172 @ Princeton site 0.073 – **1.274** @ Colusa site		1, 12, 24, 36 hours	H_2O and Sediment	Background concentration = 0.008 µg/L at Princeton and 0.218 µg/L at Colusa. For water, 36 hrs after Tx PBO returned to pre Tx levels or near that level (0.012 @ 36 hrs for 1 site). Results were 0.172 & 1.274 @ 1 hr after	Schleier et al. 2008
	Evergreen Crop Protection EC 60-6	Aerial	28 g/ha PBO	0.34	Average **2.036**; <1.0 – **20** ppb (Imm.) Average **0.853**; <1.0 – **4.2** @ 16-23 hrs		Imm. (1 to 6 hours) 16 to 23 hours	H_2O Mid-depth 10 sites		Larry Walker & Assoc. 2006
	Evergreen Crop Protection EC 60-6	Aerial	28 g/ha PBO	0.34	Average **1.96**; **0.44 - 3.92**	Average 22.05; <1 – 61.4	10 to 34 hours	H_2O 10-20 cm below surface and Sediment	Prior to application, PBO was <0.01 to 0.2 µg/L	Weston et al. 2006
	Pyrenone 25-5 Public Health Insecticide	Truck	0.458 g AI/ha	0.34		Average 4.76; <2 – 14.9 after spray #5 Average 0.37; <2 – 2.55 after spray #11	within 12 hours	Sediment only	No accumulation of PBO in water or sediment	Lawler et al. 2008
	Pyrenone 25-5 Public Health Insecticide	Truck	Biweekly application 9/9-10/13	0.34	Average 0.01; <0.01 – 0.08 <0.01 @ 1 week	Average 0.392; <2 – 3.27 <2 @ 1 week	12 hours 1 week after last application	Water and Sediment	PBO detected in H_2O after spray #2, #3, & #8 @ 0.04,0.06, 0.08 ppb on 3 of 18 samples taken; PBO detected in sediment after spray #6 & #7 @ 3, 3.27 ppb in 2 of 18 samples Peak sediment concetrations were fourfold below effective synergistic concentration Returned to baseline by 1 week 8 biweekly applications, no accumulation	Amweg et al. 2006
Permethrin	Permanone	Truck	0.4 L/ ha; Wt AI not given	0.03	<0.07 – **9.4** @ surface; <0.07 @ 20 cm (2-4 hr)		2-4 hrs, 12 hrs	Filters and H_2O column	3 applications; Droplet size not characterized; Permeth by truck, Naled by plane	Pierce et al. 2005

Table 3-3. Summary of Existing Study Results for ULV Applications

Active Ingredient	Product	Method of Application	Application Rate	Monitoring Trigger in ppb (water)	Field Results in ppb (water)	Field Results in ppb (sediment)	Time Sampled	Type of Sample	Notes	Reference
			Max label rate is 8 g AI/ha		<0.07 @ 12 hr				5.1 to 9.4 ppb in surface microlayer of canal but not detected at 20 cm. Occurred during last sampling event.	
	Biomist	Truck	0.148 L/min; 16 kph truck speed; 1-31 micron droplet size	0.03	<20		1 hr	Water column	No significant mortality in caged mosquito larvae, mosquitofish or invertebrates sampled. Analytical method not specified (UC Davis)	Jensen et al. 1999
	AquaReslin	Truck	7.8 g AI/ha	0.03				Sampled inverts	No significant effect on aquatic or terrestrial inverts	Davis & Peterson 2008
Resmethrin	Scourge	Aerial		0.028	Average **0.037**; <0.005 – **0.293**		30 min; time series of 20 min to 96 hrs	Water 6 in. below surface	1:3 ratio of the pyrethroid resmethrin to the synergist piperonyl butoxide (PBO); Analytical Method: Zimmerman et al. 2001 Values return to pre Tx levels by 9 hrs post Tx (time series)	Abbene et al. 2005
	Scourge	Aerial		0.028					Doses used in the spray were not directly toxic to estuarine grass shrimp (*Palaemonetes pugio*) and did not affect their ability to capture prey under controlled conditions; mortality seen in the field could have been caused by low dissolved oxygen alone.	Suffolk County 2006
	Scourge	Aerial or Truck		0.028	<0.0005 – **0.98**		<1 hr	Water column	Detected in 5 of 10 locations	Zulkowsky 2005
	Scourge	Truck		0.028	<0.005		<2 hrs	Water column	6 sites	Abbene et al. 2005
PBO (with Resmethrin)	Scourge	Aerial		0.24	Average **4.361**; <0.005 – **59.8**		30 min; time series of 20 min to 96 hrs	Water 6 in. below surface	Values return to pre Tx levels by 96 hrs post Tx (time series)	Abbene et al. 2005
	Scourge	Aerial or Truck		0.24	<0.0005 – **15**		<1 hr	Water column	Detected in 9 of 10 locations; still present at three locations in samples collected 3 days after a Scourge spray	Zulkowsky 2005
	Scourge	Truck		0.24	<0.005 – 0.017		<2 hrs	Water column	6 sites	Abbene et al. 2005
d-Phenothrin (Sumithrin)	Anvil 10+10 ULV	Aerial		0.14	ND		Not given	water	6 sites	Mass. Dep of Ag 2006
	Not given	Aerial or Truck		0.14	<0.5 – **1.1**		Not given	water	32 locations and 68 samples; 2 detections (0.55and 1.1 ppb) New York City Department of Health	Suffolk County 2006
	Anvil	Truck		0.14	0.0011 @ Imm. <0.0005 @ 1 to 10 days		Imm., 1, 2, 3, 10 day	Water column	1.1 ng/L immediately post treatment No det @ 1 hr PT @ 2 other sites	Zulkowsky 2005
	Anvil 10+10 ULV	Truck	4 g AI/ha	0.14				Sampled inverts	Reductions in aquatic nontarget populations did not suggest any trends or persistent deleterious biological effects following a single adulticide application.	Davis & Peterson 2008
PBO (with Sumithrin)	Anvil 10+10 ULV	Aerial		180	ND 0.12		Not given	water	6 sites	Mass Dep of Ag 2006
	Not given	Aerial or Truck		180	<0.5 – 1.03		Not given	water	32 locations and 68 samples; 1 detection - New York City Department of Health	Suffolk County 2006

Table 3-3. Summary of Existing Study Results for ULV Applications

Active Ingredient	Product	Method of Application	Application Rate	Monitoring Trigger in ppb (water)	Field Results in ppb (water)	Field Results in ppb (sediment)	Time Sampled	Type of Sample	Notes	Reference
PBO (with Sumithrin) (cont)	Anvil	Truck		180	0.02 @ Imm. 0.00033 – 0.057 @ 1 day <0.0005 to 0.007 @10 day		Imm., 1, 2, 3, 10 day	Water column		Zulkowsky 2005
Naled	Dibrom liquid concentrate	Aerial	0.128 lb/acre	16	<0.05 – **20.15** <0.05 @ 12 hr		0 – 12 hrs; 27 min peak conc	Water column samples 2.5 cm below surface; Pads, 200ml dishes	On pads: 0.622 – .90 μg/cm; Average 0.761 μg/cm; Persist 9 hours in water Copepod mortality; No fish mort Dibrom liquid concentrate – 85 percent naled, 14 lb naled/gal Fixed wing aircraft	Tucker et al. 1987
	Dibrom-14	Aerial	21.3 g/ha tech product	16	<0.05 @ surface <0.05 – 0.19 @ subsurface		2 – 4 hrs; 12 hrs	Water surface and 20 cm below surface Filter pads	Naled below threshold; Dichlorovos remains up to 12 hours but below threshold Dichlorovos at surface: 1.3 ppb @ 1/18 sites; and at subsurface: 0.08 – 0.56 ppb @ 4/18 sites Dichlorovos at subsurface: 0.05 – 0.33 ppb @ 3/9 sites at 12 hrs	Pierce et al. 2005
	Dibrom	Aerial	0.12 lb/acre (142 g/ha)	16	<0.05 – **20.15** 3.01 @ 0.7 hrs		0 – 12.45 hrs	Water 1 cm below surface; Filter papers on raft and dock	30 minutes after application, the concentration of naled in the water was 20.15 μg/L, decreasing to 0.2 μg/L at 6.45 hours and non detectable at 12.45 hours (detection limit of 0.05 μg/L). The peak concentration of dichlorvos was 2.22 μg/L approximately 30 minutes after application, and was still detectable at 12.45 hours (0.28 μg/L). Sampling occurred at -0.67, 0, 0.45, 0.70, 0.95, 1.45, 1.95, 2.45, 3.45, 4.45, 6.45, 8.45, and 12.40 hrs after application	Wang et al. 1987
	Dibrom liquid concentrate	Truck	0.025 lb/acre	16	<0.05 – 0.71 <0.05 @ 12 hr		0 – 12 hrs; 15 min peak conc	Water column	Significant mortality in copepods held in sentinel cages in the treated area and exposed to naled by aerial application. No significant mortality observed for juvenile fish Persists 4 hrs in water Dibrom liquid concentrate – 85 percent naled, 14 lb naled/gal	Tucker et al. 1987
Malathion	Cythion liquid concentrate	Aerial	0.241 lb/acre	0.1	<0.05 – **5** <0.05 @ 48 hrs		0 – 48 hrs; 84 min peak conc	H_2O column; Pads, 200 ml dishes	No mortality fish or copepods Cythion liquid concentrate – 91 percent malathion, 9.33 lb malathion/gal Fixed wing aircraft	Tucker et al. 1987
	Cythion	Aerial	0.19 lb/acre (213 g/ha)	0.1	<0.05 – **5**		0 – 48.4 hrs	Water 1 cm below surface; Filter papers on raft and dock	After malathion application, the peak concentration of 5 μg/L was detected at 1.4 hours, and malathion was still detected (0.22 μg/L) at 22.4 hours but was below the reporting limit of 0.05 μg/L at 48.4 hours. Sampling occurred at -1.87, 0, 0.15, 0.40, 0.65, 0.90, 1.40, 1.90, 2.40, 4.35, 8.35, 12.40, 18.17, 24.40, and 48.40 hrs after application	Wang et al. 1987

Table 3-3. Summary of Existing Study Results for ULV Applications

Active Ingredient	Product	Method of Application	Application Rate	Monitoring Trigger in ppb (water)	Field Results in ppb (water)	Field Results in ppb (sediment)	Time Sampled	Type of Sample	Notes	Reference
Malathion (cont)	Cythion liquid concentrate	Truck	0.050 lb/acre	0.1	<0.05 – **1.3** <0.05 @ 18 hrs		0 – 48 hrs; 15 min peak conc	Water column	Cythion liquid concentrate – 91 percent malathion, 9.33 lb malathion/gal; Persists 4 -18 hrs	Tucker et al. 1987
	Cythion	Truck	0.236 L/min; 16 kph truck speed	0.1	ND – **6**		1 hr	Water column	Analytical method not specified (UC Davis)	Jensen et al. 1999

Note:
Wang et al. (1987) may be describing the same aerial application event as the Tucker et al. (1987).

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3.2.1.2 Studies on Pyrethrins and PBO Adulticide Applications

Following aerial applications of Evergreen Crop Protection EC 60-6 (6 percent pyrethrins, 60 percent PBO) in Sacramento for West Nile virus, Larry Walker Assoc. (2006) reported results of water testing on samples from 10 waterways within the treatment area. Treated areas were sprayed nightly for 3 days. One additional application occurred 9 days prior to the 3-day event at selected locations. Samples were taken immediately after application (within 1 to 6 hours), and the next day (16 to 23 hours after the application). Pyrethrins concentrations were detected between 0.234 to 3.77 µg/L from 9 of 26 samples collected immediately after the application. The average concentration for samples collected 1 to 6 hours after application was 0.270 µg/L. Pyrethrins were not detected (<0.2 µg/L) 16 to 23 hours after each spray event. Piperonyl butoxide was detected in water from 14 of the 25 samples collected after the application; this reporting limit (1.0 µg/L) was greater than the SWRCB monitoring trigger of 0.34 µg/L. Concentration of PBO ranged from <1.0 to 20 µg/L (average 2.036 µg/L) immediately after application. PBO concentrations ranged from <1.0 to 4.2 µg/L with an average of 0.853 µg/L in samples taken between 16 and 23 hours after application. Of the 31 samples taken between 16 and 23 hours after application, PBO was detected in 11 samples. Water samples were tested eight days following aerial applications, from four sites. No PBO was detected in any of these samples, therefore, the duration of persistence of PBO appears to be greater than 16 hours, but less than 1 week.

Testing was also carried out by Weston et al. (2006) following the same applications. Prior to aerial spraying, pyrethrins were not detected in water or sediment samples and PBO was not detected in sediment samples. However, PBO was detected at 0.2 µg/L in 2 of 4 water samples. Pyrethrins were not detected in water samples taken 10 to 34 hours after the spray applications. Pyrethrins were detected in sediment samples after aerial spraying at concentrations ranging from 93.1 to 403 micrograms per kilogram [µg/kg] in 4 of 6 samples. PBO was detected in water (0.44 to 3.92 µg/L, all 7 samples) and sediment (16 to 61.4 µg/kg, for 4 of 6 samples) at 10 to 34 hours after application. The PBO levels detected in water were above the SWRCB monitoring trigger of 0.34 µg/L. Neither water nor sediment was tested at later intervals, so the duration of persistence could not be determined in this study. Laboratory tests were conducted to determine the effects of short-term chronic exposure of *Ceriodaphnia dubia* to water collected after the spray events, following U.S. EPA protocol. No significant differences in mortality were observed. In addition, sediment toxicity tests were performed with the amphipod *Hyalella azteca,* and toxicity was observed in samples collected both before and after application.

The authors concluded that pyrethrins and PBO should present little risk to aquatic organisms due to the low toxicity and lack of long-term persistence, but that PBO had the potential to enhance toxicity of other pesticides, especially pyrethroids, already present in the environment. Weston et al. performed additional laboratory tests to determine the effect of PBO on toxicity of pyrethroids present on sediment, and found that even by removing 80 percent of the overlying water and replacing it with fresh PBO solution daily, within 24 hours, over 30 percent of PBO is lost, most likely to photodegradation. The results indicated that most sediments present at the creeks used for this study already contained concentrations of pyrethroids acutely lethal to *H. azteca* from urban uses not related to mosquito control activities.

Water and soil deposition of pyrethrins following aerial applications was evaluated at two sites in California by Schleier et al. (2008). Water was sampled after aerial applications of pyrethrins and PBO in irrigation ditches at one site (Princeton) and in static ponds at another (Colusa). Pyrethrins were not detected following spray events at either site (the reporting limit was 0.5 µg/L or less depending on parameter, which is greater than the SWRCB monitoring trigger of 0.32 µg/L). PBO was detected at low levels and decreased exponentially with time. Average concentrations were below the SWRCB monitoring trigger of 0.34 µg/L at the Princeton site and average concentrations dropped below this trigger at the Colusa site within 36 hours. Average PBO concentrations were 0.0125 to 0.0199 micrograms per square centimeter (µg/cm^2) on ground deposition pads, and 0.1723 to 1.274 µg/L in water samples, immediately following the applications. Within 36 hours of the applications, PBO had decreased to background levels in water. Concentrations of PBO decreased 77 percent between 1 and 12 hours after the spray event. The authors concluded that the amounts of pyrethrins and PBO deposited on the ground and in water after aerial ULV insecticide applications are probably lower than those estimated by previously published studies to predict exposure and risk.

Deposition of pyrethrins following truck-mounted application was evaluated in large seasonal wetlands in California (Jensen et al. 1999). Pyrethrins were not detected (<20 µg/L) in surface waters 1 hour after ULV applications, but the reporting limit was greater then the SWRCB monitoring trigger for pyrethrins of 0.32 µg/L. The authors found no significant differences in macroinvertebrate abundance and biomass or species diversity in areas treated with any of the materials when compared with untreated ponds. No mortality occurred in mosquitofish held in sentinel cages in treated ponds. Similarly, no difference in mortality was observed for mosquito larvae held in sentinel cages in treated ponds when compared with untreated ones. The authors concluded that ULV applications for adult mosquito control were not likely to significantly affect aquatic insects or fish in these habitats.

Lawler et al. (2008) evaluated pyrethrins and PBO in sediment following multiple applications of pyrethrins from truck-mounted equipment in the Colusa and Sacramento National Wildlife Refuges in California (see Table 3-4). Stock tanks were filled with a layer of soil overlain with 1,150 liters of water. Zooplankton (*Daphnia magna*) were held in sentinel cages in the water column and mayfly larvae (*Callibaetis californicus*) were placed in cages at the bottom of each tank, where they were in contact with sediment. ULV applications of pyrethrins were made from truck-mounted equipment twice weekly for six weeks. Pyrethrins concentration in sediments and sentinel survival were evaluated after applications 5 and 11. No pyrethrins were detectable in 4 of 6 tanks after five spray events. Pyrethrins were found at low concentrations (23.1 and 33.1 µg/kg) in 2 of 6 tanks. There was no evidence of accumulation in sediments. After 11 spray events, sediment in 4 of 6 tanks (including one that had held residues after spray 5) contained no detectable amount of pyrethrins (<2 µg/kg), one had pyrethrins concentrations at 4 µg/kg, and another at 34.5 µg/kg.

PBO concentrations ranging from 8.37 to 14.9 µg/kg were seen in 5 of 6 tanks after five applications, but in only 2 of 6 tanks after 11 applications (1.93 and 2.55 µg/kg). There was no significant difference in mortality for mayfly larvae held in sentinel cages on the sediment. Likewise, there was no significant difference in mortality seen in *D. magna* held in the water column. They concluded that applications of pyrethrins and PBO at rates used for mosquito control did not have detectable effects on the indicator species. The persistence of PBO in sediment was not evaluated in this study. PBO-synergized pyrethrins had no detectable effect on the survival of *D. magna* held in tanks in the spray area, even after 11 biweekly spray events.

Table 3-4. Published Studies Assessing the Effects of Multiple Applications of ULV Mosquito Adulticides

Active Ingredient	Product	Sample Type	Time Sampled	Results	Notes	Reference
Pyrethrins and PBO	Pyrenone 25-5	Sediment	Immed. After the 5th and 11th spray	Level of pyrethrins and PBO did not increase significantly from the 5th to 11th spray event	Sediment in 6 stock tanks tested after 5 and 11 spray events[a]	Lawler et al. 2008
Pyrethrins and PBO	Evergreen	Water mid-depth; 10 sites under an aerial application	16-23 hours 8 days	No significant increase in concentration of AI or PBO Decrease to ND (<0.2 ppb AI and <1.0 ppb PBO) 8 days after spraying ceased	3 consecutive spray events occurring once per night; 1 additional event occurring 9 days prior at select locations.	Larry Walker Assoc. 2006 SYVCD report
Pyrethrins and PBO	Pyrenone 25-5	Water + sediment	12 hours 1 week 1 week	Under RL 1 wk after 8th spray event	8 spray events Sampled 1 week after last one[b]	Amweg et al. 2006

Notes:

[1] Lawler et al. (2008) found no accumulation of pyrethrins or PBO in sediment after multiple spray events by truck mounted equipment.

- Pyrethrins were only detectable in sediment in 2 tanks after the 5th spray event, and 2 after the 11th
- Concentrations of pyrethrins in sediment were not significantly higher after the 11th spray event than after the 5th one, and in some cases were actually lower after the 11th event.
- PBO was detected in fewer tanks after 11 (2 of 6) biweekly spray events than after the fifth event (5 of 6).
- Concentrations of PBO were lower after the 11th event than after only 5 events
- Four of 6 tanks had no detectable PBO
- The persistence of PBO in sediment was not evaluated in this study
- PBO-synergized pyrethrins had no detectable effect on the survival of *Daphnia* held in tanks in the spray area, even after 11 biweekly spray events

[2] Amweg et al. (2006) reported that levels of pyrethrins and PBO in water or sediment was below reporting limits when sampled one week after the last of eight weekly spray events.

References

Amweg, E. L., D. P. Weston, C. S. Johnson, J. You and M. J. Lydy. 2006. Effect of piperonyl butoxide on permethrin toxicity in the amphipod *Hyalella azteca*. Environmental Toxicology and Chemistry 25 (7):1817-1825.

Lawler, S. P., D. A. Dritz, C. S. Johnson, and M. Wolder. 2008. Does synergized pyrethrin applied over wetlands for mosquito control affect *Daphnia magna* zooplankton or *Callibaetis californicus* mayflies? *Pest Manag Sci* 64: 843-847.

Amweg et al. (2006) evaluated deposition of PBO in water and sediment following truck-mounted applications of synergized pyrethrins to a freshwater wetland in Colusa County in 2004. PBO was detected in 2 of 18 sediment samples above the reporting limit of 2.0 μg/kg, at 3.27 and 3.0 μg/kg, respectively. PBO was detected in 3 of 10 samples of water at concentrations above the reporting limit of 0.01 μg/L, ranging from 0.04 to 0.08 μg/L. The highest concentrations of PBO were observed in samples obtained within 12 hours of spraying; concentrations in water and sediment were below the reporting limit in samples taken one week after the last ULV application (Amweg et al. 2006). Concentrations in water samples were below the SWRCB monitoring trigger of 0.34 μg/L.

Several papers were published documenting that ULV-applied mosquito adulticides do not accumulate in water or sediment during repeated applications. Chemical testing was conducted following multiple spray events in 2006 by Amweg et al. There was no increase in the level of pyrethrins or PBO following multiple daily spray events, and the concentration had returned to background level when samples taken one week after the last application were tested. Similarly, Lawler et al. (2008), reported that the concentration of pyrethrins and PBO in tanks within a treated area were not significantly higher after 11 applications than in samples taken after the fifth application. In many cases, the concentrations were actually lower following the 11th spray event than after the fifth spray event. Accumulation of PBO was evaluated by Amweg et al. (2006). PBO did not accumulate in water or sediment, even after eight biweekly applications by truck-mounted equipment over the course of two months.

3.2.2 Pyrethroids (in Formulations with PBO)

Pyrethroids are synthetic compounds that are chemically similar to the pyrethrins, but have been modified to increase their stability and activity against insects, while minimizing their effect on nontarget organisms. Pyrethrins and pyrethroids act by causing a persistent activation of the sodium channels on insect neurons. These materials are relatively non-toxic to mammals and birds, but may be toxic to fish and invertebrates. These products break down rapidly and do not persist in the environment. Photolysis and microbial activity are responsible for the majority of this decomposition; hydrolysis also plays a role under some conditions (pH 9). Pyrethroids are hydrophobic, and adsorb quickly onto particles of soil and organic material suspended in the water column, which reduces their bioavailability (Coats et al. 1989).

As shown in Table 3-4, pyrethroid formulations generally include the synergist PBO. Most studies on PBO used in adulticides have been conducted on formulations with pyrethrins (discussed above in Section 3.2.1), resmethrin (discussed below in Section 3.2.2.1), and phenothrin (discussed below in Section 3.2.2.3). The SWRCB has a Receiving Water Monitoring Trigger for PBO of 0.24 μg/L when applied in a resmethrin formulation, based on toxicity data from the U.S. EPA's Office of Pesticides' Ecotoxicity Database. The SWRCB identified the lowest LC_{50} of 2.4 μg/L based on toxicity to rainbow trout during a 96-hour test, and their monitoring trigger value is one-tenth of that value (see Table 3-3). For PBO applied in formulations other than pyrethrins or resmethrin, the SWRCB has a Receiving Water Monitoring Trigger for PBO of 180 μg/L. The SWRCB identified the lowest LC_{50} of 1,800 μg/L based on toxicity to rainbow trout during a 96-hour test (U.S. EPA's Office of Pesticides' Ecotoxicity Database), and their monitoring trigger value is one-tenth of that value (see Table 3-3).

3.2.2.1 Permethrin

Permethrin is a Type I pyrethroid (i.e., it lacks a cyano group at the α carbon position of the alcohol moiety) with the primary target organ being the nervous system of insects, which then causes muscle spasms, paralysis, and death (U.S. EPA 2009a). Reported half-lives in surface water range from 1.8 hours to <2.5 days (see Table 3-2).

The SWRCB has adopted a Receiving Water Monitoring Trigger for permethrin of 0.03 µg/L, based on the California Department of Fish and Game's (CDFG's) ambient water quality criterion for freshwater aquatic life.

Pierce et al. (2005) evaluated deposition after two permethrin ULV applications made with truck-mounted equipment on Key Largo, Florida. They collected samples in the Atlantic Ocean and Florida Bay on either side of the treated area, including measurement of pesticide residues on glass fiber pads set on floats above the water surface, and water collected from the surface microlayer and 20 centimeters below the surface. Water was sampled from a canal running through the treated area following a third application. With the exception of a 0.07 µg/L sample from the bay, permethrin was not detected in the offshore samples; however, was detected in samples of the water surface microlayer taken from the canal. Detection of permethrin occurred in samples of the surface microlayer taken 2 to 4 hours after the applications (5.1 to 9.4 µg/L). Samples taken below the water surface did not contain detected residues. Within 12 hours of the application, permethrin was undetected in either surface microlayer or subsurface water. The application was carried out shortly before the arrival of a hurricane, and droplet size was not reported. This is the only published study in which significant amounts of pesticide were detected following an application by truck-mounted equipment. This study did not measure PBO concentrations.

Deposition of permethrin following truck-mounted application was evaluated in large seasonal wetlands in California (Jensen et al. 1999). Permethrin was not detected (<20 µg/L) in surface waters 1 hour after ULV applications, but the reporting limit was greater then the SWRCB monitoring trigger for pyrethrins of 0.32 µg/L. The authors found no significant differences in macroinvertebrate abundance and biomass or species diversity in areas treated with any of the materials when compared with untreated ponds. No mortality occurred in mosquitofish held in sentinel cages in treated ponds. Similarly, no difference in mortality was observed for mosquito larvae held in sentinel cages in treated ponds when compared with untreated ones. The authors concluded that ULV applications for adult mosquito control were not likely to significantly affect aquatic insects or fish in these habitats.

Davis and Peterson (2008) measured family diversity, richness, and evenness 1, 7, 14, and 28 days after truck application of permethrin. Most response variables showed no significant treatment effect, although there were some reductions in number of individuals. The authors concluded that the reductions in aquatic nontarget populations did not suggest any trends or persistent deleterious biological effects following a single adulticide application. Significant differences for the pond study were found on the dates closest to the spray event.

3.2.2.2 Resmethrin and PBO

Resmethrin degrades rapidly when exposed to light (photolysis); however, when not subject to photolysis, resmethrin tends to be more environmentally persistent. Resmethrin has low mobility and has a high affinity to bind to soils/sediments and organic carbon. Resmethrin works by interacting with sodium channels in the peripheral and central nervous system of target organisms (U.S. EPA 2006b). Reported half-lives in water range from 22 minutes (photolysis in seawater) to 37 days (aerobic metabolism) (see Table 3-2).

The SWRCB has adopted a Receiving Water Monitoring Trigger for resmethrin of 0.028 μg/L, based on toxicity data from the U.S. EPA's Office of Pesticides' Ecotoxicity Database. The SWRCB identified the lowest LC_{50} of 0.28 μg/L based on toxicity to rainbow trout during a 96-hour test, and their monitoring trigger value is one-tenth of that value (see Table 3-3).

The SWRCB has adopted a Receiving Water Monitoring Trigger for PBO of 0.24 μg/L when applied in a resmethrin formulation, based on toxicity data from the U.S. EPA's Office of Pesticides' Ecotoxicity Database. The SWRCB identified the lowest LC_{50} of 2.4 μg/L based on toxicity to bluegill sunfish during a 96-hour test, and their monitoring trigger value is one-tenth of that value (see Table 3-3).

Evaluation of ULV applications of the pyrethroid resmethrin have been carried out in Suffolk County New York (Abbene et al. 2005). These studies are part of the Draft Generic Environmental Impact Statement (DGEIS) for the Suffolk County Vector Control and Marsh Management Long Term plan, and include field studies to assess the effects of truck-mounted and aerial applications on aquatic organisms.

Deposition of resmethrin following truck-mounted applications in fresh and salt water marshes was assessed at 6 sites by Abbene et al. (2005). Resmethrin was not detected in water samples from any site (<0.005 μg/L). The synergist, PBO was detectable at low levels (0.008 μg/L and 0.017 μg/L) in 2 of 6 water samples taken immediately after the application.

Deposition of resmethrin following aerial applications by helicopter was assessed in the same report (Abbene et al. 2005). Applied materials were detected in some water samples taken within 30 minutes of the application. PBO was detected more frequently than resmethrin, and detection of PBO was more common after helicopter applications (83 percent) than following those carried out by truck (33.3 percent). The average concentration of resmethrin following helicopter applications was 0.037 μg/L (slightly above the SWRCB- monitoring trigger of 0.028 μg/L). The average concentration of PBO was 4.361 μg/L, also above the SWRCB-monitoring trigger of 0.24 μg/L. The highest concentrations were found in some samples collected from surface water within 1 hour of helicopter applications (59.8 μg/L PBO and 0.293 μg/L resmethrin). The authors carried out a series of sample collections after two spray events to evaluate the persistence of the materials in water. Resmethrin displayed an exponential decrease and was not detected (<0.005 μg/L) within 9 hours of the application. PBO was not detected (<0.005 μg/L) in samples taken 96 hours after the application (Abbene et al. 2005). One site included two repeat weekly applications of resmethrin follow an application of methroprene the prior week. Concentrations of resmethrin and PBO measured after the second application were lower than those measured after the first application.

The same study included effects of aerial applications of resmethrin and PBO on two aquatic organisms: the sheepshead minnow (*Cyprinodon variegatus*) and the estuarine grass shrimp (*Palaemonetes pugio*) (Suffolk County 2006). The field study faced problems with low dissolved oxygen and high temperature, which compromised their ability to detect toxicity that may have been due to pesticide exposure. Therefore, dosing experiments and prey capture tests were conducted in the laboratory to measure toxicity of the applied products. These tests demonstrated that the doses used in the spray were not directly toxic to grass shrimp and did not affect their ability to capture prey under controlled conditions. Further laboratory experiments demonstrated that all of the mortality seen in the field could have been caused by low dissolved oxygen alone, using a U.S. EPA time-to-death approach. Furthermore, their data showed that the chemicals used had very low persistence in the water column, as discussed above. Resmethrin was never detected in sediment and was not detected in samples from surface water taken more than 2 hours after the spray. PBO was last detected in samples taken 48 hours after the spray.

Another study, part of the same DGEIS, evaluated benthic community structure, and found that benthic population differences could not be attributed to the application of pesticides, but were more likely due to environmental differences (Suffolk County 2006).

Zulkosky et al. (2005) sampled freshwater ponds, salt marshes, tidal inlets and embayments, and marine coastal water off Staten Island, New York within an hour after mosquito control applications of Scourge (resmethrin). In 2002, resmethrin was detected in five of ten locations at concentrations ranging from 0.0017 to 0.98 µg/L (detection limit of 0.0005 µg/L), and was detected at two of ten locations above the SWRCB- monitoring trigger of 0.028 µg/L. PBO was detected in all but one location at concentrations ranging from 0.0006 to 15 µg/L, and was detected at three of ten locations above the SWRCB- monitoring trigger of 0.24 µg/L. PBO was still present at three locations in samples collected three days after a Scourge spray. No information was provided on application methods at each site.

3.2.2.3 Phenothrin (Sumithrin) and PBO

New York City Department of Health sampled 32 locations for phenothrin and PBO before and after spraying events during the mosquito adulticide applications that occurred during July through September 2000. Out of the 68 post-application samples collected by the City, only two had concentrations of either phenothrin or PBO greater than the 0.5 µg/L reporting limit: 1.10 µg/L for phenothrin on August 18, 2000, at Mt. Loretto Pond on Staten Island; and 1.03 µg/L for PBO and 0.55 µg/L for phenothrin for a sample collected on August 5, 2000, at Alley Park Pond in Queens (Suffolk County 2006).

The Zulkosky et al. (2005) study described above in Section 3.2.2.2 also included phenothrin applied as Anvil. In 2002, phenothrin was not detected in either spray event (detection limit of 0.0005 µg/L). PBO was detected in all samples at concentrations ranging from 0.0003 to 0.0007 µg/L. In 2003, phenothrin was detected at 0.0011 µg/L immediately after spray application, but was not detected in samples collected one to ten days after spraying Anvil. PBO was detected at 0.020 µg/L immediately after spraying Anvil and was found at concentrations ranging from <0.0005 to 0.007 µg/L 10 days later.

The Massachusetts Department of Agricultural Resources (2008) conducted a study where phenothrin was applied aerially as Anvil 10+10 ULV to six sites. There were no detections of phenothrin during this study; however, PBO was detected at concentrations (0.12 µg/L) below the monitoring trigger.

The Davis and Peterson (2008) study described above in Section 3.2.2.1 also included phenothrin applied as Anvil 10+10 ULV. The authors concluded that the reductions in aquatic nontarget populations did not suggest any trends or persistent deleterious biological effects following a single adulticide application.

3.2.3 Organophosphates

Naled and malathion are organophosphates used for mosquito adulticides. These materials work by inhibiting the enzyme acetylcholinesterase. Organophosphates have low persistence in the environment, and degradation occurs by reaction with photochemically produced hydroxyl radicals and by hydrolysis and biodegradation (U.S. EPA 1999).

3.2.3.1 Malathion

Malathion is a broad-spectrum organophosphorous pesticide that is soluble in water and therefore does not tend to associate with sediment. Malaoxon is the primary metabolite of malathion, and under certain conditions, is formed as an environmental breakdown product of malathion (U.S. EPA 2009b [RED]). As shown in Table 3-2, reported half-lives for water range from 0.67 day (photodegradation) to 147 days (anaerobic degradation).

The SWRCB has adopted a Receiving Water limit for malathion of 0.1 µg/L, based on U.S. EPA's ambient water quality criterion for freshwater aquatic life (Table 3-3).

Tucker et al. (1987) evaluated deposition and nontarget effects for truck-mounted and aerial applications of malathion in an estuary in east-central Florida. Deposition in filter pads was measured after application, and concentrations in water were measured in 12 samples up to 48 hours after application. Malathion concentrations in water peaked at 5 µg/L 84 minutes after aerial application. Malathion concentrations peaked at 1.3 µg/L 15 minutes after truck application and remained detected for up to 18 hours. Sentinel cages containing calanoid copepods (*Acartia tonsa*) and three species of juvenile fish were deployed in the treated area. No significant mortality was observed in copepods or fish exposed to truck-mounted or aerial applications of malathion.

In what may have been the same study, Wang et al. (1987) investigated the fate of malathion after aerial ULV applications of mosquito adulticides at a salt marsh in Florida. After application, the peak malathion concentration of 5 µg/L was detected at 1.4 hours, and was still detected (0.22 µg/L) at 22.4 hours at concentrations above the SWRCB- monitoring trigger (0.1 µg/L) but was below the reporting limit of 0.05 µg/L at 48.4 hours.

Deposition of malathion following truck-mounted application was evaluated in large seasonal wetlands in California (Jensen et al. 1999). Malathion was detected at levels above the SWRCB monitoring trigger of 0.1 µg/L 1 hour after application (6 µg/L). The authors found no significant differences in macroinvertebrate abundance and biomass or species diversity in areas treated with any of the materials when compared with untreated ponds. No mortality occurred in mosquitofish held in sentinel cages in treated ponds. Similarly, no difference in mortality was observed for mosquito larvae held in sentinel cages in treated ponds when compared with untreated ones.

3.2.3.2 Naled

The SWRCB has adopted a Receiving Water Monitoring Trigger for naled of 16 µg/L, based on toxicity data from the U.S. EPA's Office of Pesticides' Ecotoxicity Database (Table 3-3).

Tucker et al. (1987) (described above in 3.2.3.1) also evaluated deposition and nontarget effects for truck-mounted and aerial applications of naled. The maximum concentration of naled in water samples following truck applications (0.71 µg/L) occurred 15 minutes after the application. The concentration in water decreased exponentially after this; detected concentrations persisted for 4 hours. No significant mortality was observed in copepods or fish exposed to truck-mounted applications of either product. The same study evaluated deposition of these materials following applications made from aircraft (Tucker et al. 1987). The maximum concentration of naled in water samples following aerial applications (20.15 µg/L) occurred 27 minutes after the application. The concentration in water decreased exponentially after this; detected concentrations persisted for 9 hours. Deposition rates for naled from aerial applications were much higher (47 to 68 percent) than those resulting from ground applications (21 to 22 percent). The authors reported significant mortality in copepods held in sentinel cages in the treated area and exposed to naled by aerial application. No significant mortality was observed for juvenile fish held in the treated area. This is the only report of significant mortality in aquatic organisms following a ULV application. The size of droplets released is not given and the amount of material recovered from glass filter pads placed on the ground was unusually high. Perhaps the conditions of the applications resulted in a greater proportion of the product reaching the ground.

In what may have been the same study, Wang et al. (1987) (described above in Section 3.2.3.1) also investigated the fate of naled after aerial ULV applications of mosquito adulticides at a salt marsh in Florida. Approximately 30 minutes after application, the concentration of naled in the water was 20.15 µg/L, decreasing to 0.2 µg/L at 6.45 hours, and was not detected at 12.45 hours (detection limit of 0.05 µg/L). The peak concentration of dichlorvos (breakdown product of naled) was 2.22 µg/L approximately 30 minutes after application, and was still detectable at 12.45 hours (0.28 µg/L). With the exception of the peak concentration, naled concentrations were below the SWRCB- monitoring trigger (16 µg/L).

Deposition of naled during aerial applications was also evaluated in Pierce et al. (2005) (study described in 3.2.2.1 above). Naled was detected in low concentrations (0.19 µg/L) in the water surface microlayer at 1 of 18 sites. It was not detected in subsurface water (detection limit 0.05 µg/L). Residues were not detectable in the water surface microlayer 12 hours after the application. Dichlorovos, a breakdown product of naled, and itself a registered pesticide, was detected at 2 to 4 hours after the application. Trace amounts were still detectable at 10 to 12 hours post-treatment.

4.1 NPDES PERMIT REQUIREMENTS AND KEY QUESTIONS

The current permit includes a Monitoring and Reporting Program (MRP) by the SWRCB staff. The SWRCB draft MRP identified the following key questions to focus the initial monitoring program:

1. Does the pesticide residue from spray applications cause an exceedance of receiving water limitations or monitoring triggers?

2. Does the pesticide residue, including active ingredients, inert ingredients, and degradates, in any combination cause or contribute to an exceedance of the "no toxics in toxic amount" narrative toxicity objective?

To assist in answering these questions, the SWRCB and MVCAC envision a process that will use existing data, determine the critical gaps in knowledge, and develop a monitoring program to address key areas of uncertainty. Because existing data are insufficient to set Receiving Water Limitations for most of the active ingredients in adulticides, the SWRCB has established Receiving Water Monitoring Triggers that would be used in combination with toxicity testing to determine potential impacts to beneficial uses of affected surface water bodies.

The SWRCB has indicated that initial studies should focus on the adulticides most commonly used in California, using application sites that represent the "highest use" scenario in terms of frequency of application, size of application areas, and application methods. This monitoring plan incorporates that approach; however, it must be recognized that the "highest use" study results are intended to represent the maximum impact, and are not expected to be typical of adulticide applications for many areas where they may be applied once a year or less, and on a smaller scale.

4.2 DO EXISTING DATA ANSWER KEY QUESTIONS?

4.2.1 Mosquito Larvicides

The key questions in the draft adulticide permit do not specifically apply to larvicides. As described in Section 3.1, because mosquito larvicides are applied directly to water, many more aquatic toxicity studies (both laboratory and field studies) have been conducted for larvicides than for adulticides. Receiving water monitoring triggers have only been adopted for temephos,

The results of the studies described in Section 3.1 indicate that the majority of the larvicides used by MVCAC member agencies are unlikely to cause significant adverse impacts to aquatic ecosystems, due to their high specificity for mosquitoes and short persistence in surface waters.

Evidence indicates that chironomid larvae (which are closely related to mosquitoes) are the only nontarget aquatic species that may be affected at concentrations of *Bti* used for mosquito control. Observed effects on chironomids were slight and populations in the field continuously increased after the treatment. *Bacillus sphaericus* has not been found to have adverse effects on chironomids or any other aquatic species at levels used for mosquito control. While high doses and/or chronic exposure of spinosad may adversely effect some aquatic invertebrates, the short term exposure at levels used for mosquito control are unlikely to have significant effects.

Although evidence indicates that application of monomolecular films and petroleum distillates may result in reductions to populations of surface-breathing insects at the time of treatment, it is unlikely that overall populations of invertebrate species are affected as populations recover quickly due to recolonization from neighboring sites.

Methoprene is a material with very high specificity in its mode of action, and exhaustive reviews of the published literature on this material attest to its lack of adverse environmental impact. The concentrations of methoprene applied for mosquito larvae control are unlikely to affect nontarget aquatic species, except for some fly species closely related to mosquitos. For species that are affected by methoprene, recolonization and reestablishment of populations from neighboring sites is fast once intense control is relaxed.

Among the materials available for control of mosquito larvae, temephos has the narrowest margin of impact and the greatest potential for effects to nontarget organisms. However, it is an effective method of control in isolated sources that may be difficult to treat by other means, such as sources with high concentrations of organic material, and ones in which other less toxic alternatives have failed to produce adequate levels of control. Temephos was in widespread use in California for control of larval mosquitoes from 1965 into the mid 1980s. The microbial pesticides, methoprene, and surface oils are used much more frequently now and have largely replaced temephos as the method of choice for larval sources in water of the U.S. Temephos is more widely used in other parts of the U.S. such as Delaware, New Jersey, New York, Maryland, and Florida.

As shown in Table 2-6, most temephos use for mosquito control in California occurs in the Central Valley. None of the southern California agencies use temephos; and only one county in northern coastal California has used temephos for larval mosquito control in manmade sources, on a limited basis. MVCAC agencies hope not to need to apply temephos in the future if other methods can achieve adequate control; however, temephos applications may be necessary in some situations. Field studies indicate that temephos does have an immediate impact on some groups of planktonic crustaceans with copepods and brachiopods (cladocera) being more sensitive than amphipods or ostracods, and that population recovery can be variable. Data indicate that temephos does not persist longer than about one day in surface water and sediment.

4.2.2 Mosquito Adulticides

4.2.2.1 Pyrethrins (Formulations with the Synergists PBO and MGK-264)

As discussed in Sections 2.2.2 and 2.2.3, pyrethrins are the most frequently used mosquito adulticides in California. As discussed in Section 3.2.1, there is already a considerable amount of data on the fate, transport and toxicity of pyrethrins and PBO from studies conducted on ULV applications of mosquito adulticides in California. Five field studies evaluated effects of ULV application of pyrethrins adulticides in California, and four of these studies also measured PBO concentrations.

URS was unable to find any published studies that included measurement of the synergist MGK-264 in ULV applications of pyrethrins pesticides used for mosquito control. As shown in Table 2-9, MGK-264 is used as a synergist in only one formulation that MVCAC agencies plan to use as a mosquito adulticide in the future (Prentox Pyronyl Oil Concentrate # OR-3610A). As shown in Table 2-8, use of this formulation has been negligible (comprising 0 to 0.1 percent of pyrethrins adulticide use statewide).

Exceedance of Receiving Water Monitoring Triggers

As shown in Table 3-3 and discussed in Section 3.2.1.1, three studies measured the levels of pyrethrins in surface water following aerial applications and two studies measured the levels following truck applications. Pyrethrins concentrations greater than the trigger were detected in only one of these studies (Larry Walker and Associates 2006), within 6 hours after application. Other studies measured pyrethrins within 12 hours of application and they did not detect pyrethrins. Therefore, existing data indicate that the pyrethrins trigger may be exceeded under some conditions.

As shown in Table 3-3 and discussed in Section 3.2.1.2, three studies measured PBO in surface water following aerial applications of pyrethrins formulations with PBO, and one study following truck application. PBO concentrations greater than the trigger were detected in all three of the aerial application studies, but not in the truck application study. All three of the aerial application studies used the formulation Evergreen Crop Protection EC60-6, which contains 60 percent PBO, the highest concentration used in any of the pyrethrins formulations as shown in Table 2-9. The truck application studies both used Pyrenone 25-5 Public Health Insecticide, which contains only 25 percent PBO. Therefore, existing data indicate that the PBO trigger is likely to be exceeded in some instances after aerial applications, and more data are needed for truck applications.

Toxicity

As shown in Table 3-3 and discussed in Section 3.2.1, three studies investigated aquatic toxicity following ULV applications of pyrethrins. One study using laboratory toxicity tests on samples after aerial application found no significant mortality to *Ceriodaphnia dubia* following aerial application, and inconclusive results for *Hyalella azteca* (sediment collected prior to application was toxic to *H. azteca*) (Weston 2006). The author concluded that PBO had the potential to enhance toxicity of other pesticides already present. Another study found no significant mortality in caged mosquito larvae or mosquitofish after truck application, and no significant difference in macroinvertebrate abundance, biomass, or species diversity (Jensen et al. 1999). Another study (Lawler et al. 2008) used caged organisms (*Daphnia magna* and *Callibaetis californicus*) to evaluate toxicity after multiple applications, and found no significant difference in mortality.

While existing data indicate that aquatic life may not be significantly impacted by ULV application of pyrethrins/PBO application for mosquito control, more data are needed to confirm this, especially in locations where other sources of pyrethrins and/or pyrethroids may already be present.

Spatial and Temporal Extent

As shown in Table 3-3 and discussed in Section 3.2.1, pyrethrins were detected in water in two of four studies, and in sediment in both of those two studies. While in one study pyrethrins were not detected within the first 24 hours, but were detected at 36 hours, it is likely that the source of this detection was not the adulticide application (Schleier et al. 2008). Larry Walker and Associates (2006) detected pyrethrins in samples collected from 1 to 6 hours after application, but not in samples collected from 16 to 23 hours after application. Water testing was also carried out by Weston et al. (2006) following the same applications. Pyrethrins were not detectable in any samples taken from 10 to 34 hours after the spray applications. Pyrethrins were detected in sediment samples collected in two studies, but persistence was not evaluated. As shown in Table 3-2, the photolysis and hydrolysis half-lives in water are less than one day. While available data indicate that pyrethrins are not likely to persist after the first day or two in the water column, additional investigation is necessary to determine when peak concentrations and subsequent decay rates are likely to occur.

As shown in Table 3-3 and discussed in Section 3.2.1, PBO was detected in water in all four studies in which it was measured following applications of adulticides containing pyrethrins and PBO. Larry Walker and Associates (2006) found higher concentrations in samples collected within 1 to 6 hours after aerial application than in samples collected 16 to 23 hours after application, and no PBO was detected in samples collected eight days after application. Following the same application events, Weston et al. (2006) detected PBO above the monitoring trigger in all seven water samples and in four of six sediment samples collected 10 to 34 hours after application. Neither water nor sediment was tested at later intervals, so the duration of persistence could not be determined in this study. In another study, Schleier et al. (2008) found that concentrations of PBO in water decreased 77 percent between 1 and 12 hours after a spray event, and returned to background levels within 36 hours. These studies evaluated aerial applications of the formulation Evergreen Crop Protection EC60-6, which contains 60 percent PBO, the highest concentration used in any of the pyrethrins formulations as shown in Table 2-9. Amweg et al. (2006) found the highest concentrations of PBO in samples obtained within 12 hours of spraying; concentrations in water and sediment were below the reporting limit in samples taken one week after the last ULV application. This study used Pyrenone 25-5 Public Health Insecticide, which contains 25 percent PBO. While available data indicate that PBO in pyrethrins formulations are likely to peak within a few hours after application, and PBO may persist several days, additional investigation is necessary to better define when peak concentrations are likely to occur, and to characterize subsequent decay rates.

Minimal data are available on the spatial extent of pyrethrins or PBO in water bodies following ULV applications of mosquito adulticides.

Repeated Applications

As described in Section 2.3.3, pyrethrins formulations may be used over 25 times in the same season at various locations in the Central Valley.

The pyrethrins formulations for which fate and transport studies have been conducted for repeated applications include Pyrenone 25-5 Public Health Insecticide (Lawler et al. 2008 and

Amweg et al. 2006) and Evergreen Crop Protection EC 60-6 (Larry Walker and Associates 2006 and Weston et al. 2006). Evergreen Crop Protection EC 60-6 contains 60 percent PBO, which is the highest PBO content of any of the currently used adulticide formulations that include pyrethrins.

As discussed in Section 3.1.3, three field studies measured water and/or sediment concentrations after repeated ULV adulticide applications. None of these studies found significantly higher concentrations of pyrethrins or PBO after multiple applications (up to 11 applications) as compared to the initial application. One of these studies (Lawler et al. 2008) also used caged organisms (*Daphnia magna* and *Callibaetis californicus*) to evaluate toxicity after multiple applications, and found no significant difference in mortality. No studies evaluated the higher number of applications known to occur at some locations in the Central Valley (over 20), and no studies are available on *Hyalella azteca*, which is known to be more sensitive to pyrethroids than most other aquatic organisms.

4.2.2.2 Pyrethroids (Formulations with the Synergist PBO)

ULV field studies have been done for the pyrethroid adulticides used most in California, (permethrin, phenothrin, and resmethrin), but no field data are available for the lesser used pyrethroids (phenothrin, prallethrin, or etofenprox).

4.2.2.2.1 Permethrin

As shown in Table 3-3 and discussed in Section 3.2.1.2, three field studies investigated the effects of permethrin adulticides, but none of these studies measured PBO. One of these studies (Jensen et al. 1999) used the formulation with the higher PBO content (Biomist 4+12 ULV). All other permethrin formulations contain equal proportions of permethrin and PBO. Biomist 4+12 ULV contains three times as much PBO; between 2005 and 2008 it comprised 10 to 16 percent of permethrin adulticide use in California. Although this study did not measure PBO concentrations, it did investigate toxicity.

Exceedance of Receiving Water Monitoring Triggers

The permethrin trigger was exceeded in one of the two studies that measured permethrin concentrations in water. Both of these studies were conducted after truck applications; no aerial application studies for permethrin are available. The study that did not detect permethrin (Jensen et al. 1999) used an analytical method with detection limits significantly higher than the trigger (20 ppb vs. 0.03 ppb).

Toxicity

Two studies evaluated potential effects to aquatic organisms after truck application of permethrin adulticide. One study (Jensen et al. 1999) found no significant differences in macroinvertebrate abundance and biomass or species diversity, and no significant differences in mortality occurred in mosquitofish or mosquito larvae held in sentinel cages. The other study (Davis and Peterson 2008) measured family diversity, richness, and evenness 1, 7, 14, and 28 days after truck application of permethrin. Most response variables showed no significant treatment effect, although there were some reductions in the number of individuals. The authors concluded that the reductions in aquatic nontarget populations did not suggest any trends or persistent deleterious biological effects following a single adulticide application. Significant differences were found on the dates closest to the spray event.

Spatial and Temporal Extent

In the one study in which permethrins were detected (Pierce et al. 2005), they were detected on the surface microlayer in samples collected 2 to 4 hours after application, but were not detected at a depth of 20 cm or in any samples collected 12 hours after application.

Repeated Applications

As described in Section 2.3.3, permethrin formulations may be used over 25 times in the same season, at various locations in the Central Valley. No published field studies have evaluated the effects of repeated applications of permethrin adulticides.

4.2.2.2.2 Resmethrin and PBO

As shown in Table 3-3 and discussed in Section 3.2.2.2, three field studies investigated the effects of resmethrin adulticides two of which measured PBO.

Exceedance of Receiving Water Monitoring Triggers

The resmethrin trigger was exceeded in the two studies that measured resmethrin concentrations in water; both of these studies included aerial application. Resmethrin was not detected after truck application in one of these studies.

PBO was detected above the trigger in both studies. One of these studies (Abbene et al. 2005) detected PBO after aerial application but not after truck application.

Toxicity

One study (Abbene et al. 2005) evaluated potential effects to aquatic organisms after aerial application of resmethrin adulticide with PBO (Scourge). Results of field studies were confounded by low dissolved oxygen and high temperatures, which were found to have been the likely causes of toxicity. Another study conducted on the same applications evaluated benthic community structure. This study found that benthic population differences could not be attributed to the application of pesticides, but were more likely due to environmental differences (Suffolk County 2006).

Spatial and Temporal Extent

Abbene et al. (2005) found the highest concentrations in samples collected from surface water within 1 hour of helicopter applications. The authors carried out a series of sample collections after two spray events to evaluate the persistence of the materials in water. Resmethrin displayed an exponential decrease and was not detected within 9 hours of the application. PBO was not detected in samples taken 96 hours after the application (Abbene et al. 2005). In a related study (Suffolk County 2006), resmethrin was not detected in samples from surface water taken more than 2 hours after the spray, and PBO was last detected in samples taken 48 hours after the spray.

Zulkosky et al. (2005) detected resmethrin in five of ten locations within an hour after mosquito control applications of Scourge. PBO was detected in all but one location, and was still present at three locations in samples collected three days after a Scourge spray.

There are limited data on spatial extent. In both of the previous studies, PBO was detected more frequently (in up to 83 percent of samples) than resmethrin (in up to 50 percent of samples).

Repeated Applications

The Abbene et al. (2005) study included one site with two weekly applications of resmethrin. Concentrations of resmethrin and PBO measured after the second application were lower than those measured after the first application.

4.2.2.2.3 Phenothrin (Sumithrin) and PBO

As shown in Table 3-3 and discussed in Section 3.2.2.3, four field studies investigated the effects of phenothrin adulticides, and three of these studies measured PBO.

Exceedance of Receiving Water Monitoring Triggers

As discussed in Section 3.2.2.3, the phenothrin monitoring trigger was exceeded in two of 68 water samples collected by the New York City Department of Health following mosquito adulticide applications (Suffolk County 2006). However, the phenothrin trigger was not exceeded in either of the other two studies that measured phenothrin concentrations in water; these studies included both aerial and truck application. PBO concentrations also did not exceed the trigger in any of the three studies.

Toxicity

Davis and Peterson (2008) measured family diversity, richness, and evenness 1, 7, 14, and 28 days after truck application of phenothrin. Most response variables showed no significant treatment effect, although there were some reductions in number of individuals. The authors concluded that the reductions in aquatic nontarget populations did not suggest any trends or persistent deleterious biological effects following a single adulticide application.

Spatial and Temporal Extent

Zulkosky et al. (2005) detected phenothrin in some samples immediately after spray application, but not in samples collected one to ten days after spraying Anvil. PBO was detected immediately after spraying and was still found in some samples ten days later.

There are limited data on spatial extent. Generally, PBO was detected much more frequently (up to 100 percent of samples collected immediately after sampling) than phenothrin.

Repeated Applications

None of the studies reviewed included repeated application to the same site.

4.2.2.3 Organophosphates

4.2.2.3.1 Malathion

As shown in Table 3-3 and discussed in Section 3.2.3.1, three field studies investigated the effects of malathion adulticides.

Exceedance of Receiving Water Monitoring Triggers

All three studies detected malathion concentrations that exceeded the SWRCB trigger, including both truck and aerial applications.

Toxicity

Tucker et al. (1987) found no significant mortality in copepods or fish in sentinel cages exposed to truck-mounted or aerial applications of malathion. Jensen et al. (1999) found no significant differences in macroinvertebrate abundance and biomass or species diversity, and no mortality occurred in mosquitofish or mosquito larvae held in sentinel cages after truck application.

Spatial and Temporal Extent

Tucker et al. (1987) evaluated deposition and nontarget effects for truck-mounted and aerial applications of malathion in an estuary in east-central Florida. Malathion concentrations in water peaked at 5 µg/L 84 minutes after aerial application. Malathion concentrations peaked at 1.3 µg/L 15 minutes after truck application and remained detected for up to 18 hours.

In what may have been the same study, Wang et al. (1987) investigated the fate of malathion after aerial ULV applications of mosquito adulticides at a salt marsh in Florida. After application, the peak malathion concentration of 5 µg/L was detected at 1.4 hours, and was still detected (0.22 µg/L) at 22.4 hours at concentrations above the SWRCB- monitoring trigger (0.1 µg/L), but at 48.4 hours, was below the reporting limit of 0.05 µg/L.

There are limited data on spatial extent.

Repeated Applications

None of the studies found included repeated application to the same site.

4.2.2.3.2 Naled

As shown in Table 3-3 and discussed in Section 3.2.3.2, three field studies investigated the effects of naled adulticides.

Exceedance of Receiving Water Monitoring Triggers

Two of the three studies detected naled concentrations that exceeded the SWRCB trigger. One of these studies (Tucker et al. 1987) included both truck and aerial applications; the trigger was not exceeded after truck application but was exceeded after aerial application.

There are limited data on spatial extent.

Toxicity

Tucker et al. (1987) found significant mortality in copepods, but not in fish in sentinel cages exposed to truck-mounted or aerial applications of malathion.

Spatial and Temporal Extent

Tucker et al. (1987) found the maximum concentration of naled in water samples following truck applications (0.71 μg/L) 15 minutes after the application. The concentration in water decreased exponentially after this; detected concentrations persisted for 4 hours. The same study evaluated deposition of these materials following applications made from aircraft (Tucker et al. 1987). The maximum concentration of naled in water samples following aerial applications (20.15 μg/L) occurred 27 minutes after the application. The concentration in water decreased exponentially after this; detected concentrations persisted for 9 hours.

In what may have been the same study, Wang et al. (1987) detected naled 30 minutes after application, when the concentration was 20.15 μg/L, decreasing to 0.2 μg/L at 6.45 hours, and not detected at 12.45 hours. The peak concentration of dichlorvos was 2.22 μg/L approximately 30 minutes after application, and it was still detectable at 12.45 hours (0.28 μg/L).

Pierce et al. (2005) detected naled in the water surface microlayer at one of eighteen sites. It was not detected in subsurface water. Residues were not detected in the water surface microlayer 12 hours after the application. Dichlorovos, a breakdown product of naled, was detected at 2 to 4 hours after the application. Trace amount were still detectable at 10 to 12 hours post-treatment.

Repeated Applications

None of the studies reviewed included repeated application to the same site.

4.3 MONITORING OBJECTIVES

Based on the existing information summarized in Section 4.2, the following monitoring objectives are proposed to help answer the key questions identified by the SWRCB and MVCAC:

- Focus first on "highest use" scenarios (sites with high frequency of application, large area covered, maximum application rates, formulations with high percentage of PBO (relevant for pyrethrins and pyrethroids), and applications over/near water)
- Focus on aerial application, as available data indicate that deposition tends to be higher for aerial application than for truck application
- Include various types of sites representative of statewide applications (urban, agricultural, wetlands)
- Characterize chemistry

Section 5 describes the focused research study program to achieve these objectives.

This section describes the focused research study approach by MVCAC to answer the key questions and meet the study objectives identified in Section 4.

5.1 MONITORING APPROACH FOR LARVICIDES

Monitoring and reporting requirements for mosquito larvicide applications are described in Attachment C (Monitoring and Reporting Program) of the existing NPDES permit for vector control. These requirements are summarized in table C-1 under B. Monitoring Requirements for Larvicides and the MVCAC Monitoring Coalition will follow these guidelines to ensure compliance with the permit. The Coalition will monitor for the visual, physical, and chemical components of Table C-1.

As described in Sections 3.1 and 4.2.1, adequate data exist for most of the larvicides used by MVCAC to characterize aquatic toxicity. The evidence indicates that most larvicides, when used at label application rates, are not likely to have significant adverse effects on nontarget aquatic organisms. In addition, because larvicides are applied directly to water bodies for control of mosquito larvae, the permit would apply for residual concentrations that remain after the treatment period; evidence indicates that while limited potential effects may occur with some larvicides during the treatment period, the persistence of most larvicides is very short and significant residues are not likely to remain after the treatment period.

5.2 MONITORING APPROACH FOR ADULTICIDES

Monitoring and reporting requirements for mosquito adulticide applications are described in Attachment C (Monitoring and Reporting Program) of the existing NPDES permit for vector control. These requirements are summarized in table C-2 under B. Monitoring Requirements for Adulticides and the MVCAC Monitoring Coalition will follow these guidelines to ensure compliance with the permit. The Coalition will monitor for the visual, physical, and chemical components of Table C-2.

5.3 SELECTION OF MONITORING PARAMETERS

The monitoring program will focus on evaluating the products with the highest percentages of the active ingredients as highlighted in Attachment C-Monitoring and Reporting Program of the permit.

Pyrethrins Formulations

Pyrethrins are the most commonly used mosquito adulticides in California, comprising approximately 77.1 percent of acreage treated in 2008 (estimated assuming maximum application rates). The percentage by weight is smaller, because the application rate for pyrethroids is lower than other pesticides such as organophosphates.

A pyrethrins formulation with a relatively high ratio of PBO to active ingredient (such as Evergreen Crop Protection EC 60-6, Pyrenone Crop Spray, or Prentox Pyronyl Crop Spray) will be selected for the monitoring program, and PBO concentrations in surface water will also be monitored.

Organophosphates

Because application rates are high relative to other adulticides, naled accounts for a large proportion of adulticide use by mass (74.9 percent in 2008), but a much smaller proportion by acreage (estimated 8.8 percent) (see Figures 2-4 and 2-5).

Malathion use has declined over the past several years; it accounted for less than 4 percent of adulticide application by mass in California in 2008, and an estimated 0.2 percent of the acreage covered by adulticide applications.

Pyrethroids

The pyrethroids most used for adult mosquito control in California are phenothrin (sumithrin) and permethrin (see Figures 2-4 and 2-5). Monitoring of pyrethroid formulations will include analysis of PBO if present. Etofenprox is a relatively formulation available to vector control districts and anticipated use should increase in future seasons and this increase will facilitate appropriate monitoring. The permethrin formulation monitored will be that with the highest proportion of PBO (currently Biomist 4+12 ULV); all formulations of phenothrin currently used contain the same ratio of PBO to active ingredient.

5.4 SELECTION OF REPRESENTATIVE LOCATIONS

5.4.1 Types of Applications

As described in Section 2.3.1, ULV applications for adult mosquito control may be made by air, truck, or handheld equipment. MVCAC proposes that the monitorning program focus on aerial applications. Handheld applications are limited and small scale, and generally do not occur over water. As discussed in Section 3, available data indicate that deposition rates are likely to be higher for aerial applications than for truck applications.

5.4.2 Types of Sites

As described in Section 2.3.2, ULV applications for adult mosquito control may be made in a variety of locations, including but not limited to ditches, storm drains, wetlands, tidal marshes, woodlands, rice fields, neighborhoods, tree holes, overgrown areas, and golf courses. Locations may be urban, suburban, agricultural, recreational, or wildlife refuge areas and application sites may vary in size from a fraction of an acre to several thousand acres. The MRP will focus on large application sites in urban, wetland, and agricultural areas.

5.4.3 Examples of Representative Sites

Table 5-1 and Figures 5-1, 5-2, and 5-3 show examples of potential monitoring sites that may be used to represent pyrethrins and PBO applications, based on recent adulticide use patterns. Because the nature of mosquito control and the application materials and frequency may change from year to year, these sites should be considered only as potential examples, not as proposed monitoring sites. Due to these variables, specific monitoring sites can not be pre-selected at this time. Based on historical control needs, the Coalition anticipates most site selection and monitoring to occur June-Sep. Representative monitoring sites will be selected each year based on expected pesticide use, frequency of application, available water quality data in the region, information on other potential sources of toxicity, and availability of appropriate reference sites. An example of recent available monitoring data for one of the potential sites (Brack Tract) is provided in Table 5-2.

Table 5-1. Potential Monitoring Sites for Pyrethrins/PBO

Site	District	Adulticide Formulations Typically Used	Aerial Application Frequency	Type of Site	Approximate Size of Application Area
Gustine Spray Block 39	Merced County	Pyrenone 6-60, Evergreen 6-60, or Pyronyl 6-60	3 to 6 times/year	Wetlands and agriculture	1,800 acres
Brack Tract	San Joaquin County	Evergreen 60-6, Trumpet EC	Up to 6 times/year	Wetlands, irrigated pasture, and agriculture	2,000 to 5,000 acres
City of Colusa	Colusa	Pyrenone 6-60, Evergreen 6-60, or Pyronyl 6-60, Trumpet EC	Up to 3 times a year	Residential and agricultural	2,240 acres

Table 5-2 2009 Monitoring Data from Irrigation Lands Program for Brack Tract

Analyte and Unit	Count	Min	Max	Average	Percentage Detected
Aldicarb µg/L	3	0.2	0.2	0.2	0%
Aldrin µg/L	3	0.005	0.005	0.005	0%
Ammonia as N mg/L	3	0.26	0.33	0.3	100%
Arsenic,Total µg/L	3	12	15	13.7	100%
Atrazine µg/L	3	0.25	0.25	0.25	0%
Azinphos methyl µg/L	3	0.05	0.05	0.05	0%
Boron,Total µg/L	3	120	130	126.7	100%
Cadmium,Dissolved µg/L	3	0.011	0.05	0.037	33%
Cadmium,Total µg/L	3	0.02	0.04	0.03	100%
Carbaryl µg/L	3	0.035	0.035	0.035	0%
Carbofuran µg/L	3	0.035	0.035	0.035	0%
Chlordane µg/L	3	0.005	0.005	0.005	0%
Chlorpyrifos µg/L	3	0.0075	0.0075	0.0075	0%
Copper,Dissolved µg/L	3	0.44	0.9	0.6	100%
Copper,Total µg/L	3	1.5	2.6	1.9	100%
Cyanazine µg/L	3	0.25	0.25	0.25	0%
DDD(p,p') µg/L	3	0.005	0.005	0.005	0%
DDE(p,p') µg/L	3	0.005	0.005	0.005	0%
DDT(p,p') µg/L	3	0.005	0.005	0.005	0%
Demeton-s µg/L	3	0.05	0.05	0.05	0%
Diazinon µg/L	3	0.01	0.01	0.01	0%
Dichlorvos µg/L	3	0.05	0.05	0.05	0%
Dicofol µg/L	3	0.05	0.05	0.05	0%
Dieldrin µg/L	3	0.005	0.005	0.005	0%
Dimethoate µg/L	3	0.05	0.05	0.05	0%
Dissolved Solids,Total mg/L	3	660	1100	847	100%
Disulfoton µg/L	3	0.025	0.025	0.025	0%
Diuron µg/L	3	0.2	0.61	0.35	67%
E. coli MPN/100 mL	3	28	49	41	100%
Endosulfan I µg/L	3	0.005	0.005	0.005	0%
Endosulfan II µg/L	3	0.005	0.005	0.005	0%
Endrin µg/L	3	0.005	0.005	0.005	0%
Glyphosate µg/L	3	2.5	2.5	2.5	0%
Hardness as CaCO3 mg/L	3	370	640	473	100%
HCH, alpha µg/L	3	0.005	0.005	0.005	0%
HCH, beta µg/L	3	0.005	0.005	0.005	0%
HCH, delta µg/L	3	0.005	0.005	0.005	0%
HCH, gamma µg/L	3	0.005	0.005	0.005	0%
Heptachlor µg/L	3	0.005	0.005	0.005	0%
Heptachlor epoxide µg/L	3	0.005	0.005	0.005	0%
Lead,Dissolved µg/L	3	0.125	0.125	0.125	0%
Lead,Total µg/L	3	0.42	0.79	0.55	100%
Linuron µg/L	3	0.2	0.2	0.2	0%
Malathion µg/L	3	0.05	0.05	0.05	0%

Analyte and Unit	Count	Min	Max	Average	Percentage Detected
Methamidophos µg/L	3	0.1	0.1	0.1	0%
Methidathion µg/L	3	0.05	0.05	0.05	0%
Methiocarb µg/L	3	0.2	0.2	0.2	0%
Methomyl µg/L	3	0.035	0.035	0.035	0%
Methoxychlor µg/L	3	0.005	0.005	0.005	0%
Molybdenum,Total µg/L	3	4.1	4.5	4.23	100%
Nickel,Dissolved µg/L	3	1.6	2.1	1.87	100%
Nickel,Total µg/L	3	2.4	3.5	2.93	100%
Nitrate + Nitrite as N mg/L	3	0.29	0.72	0.57	100%
Nitrogen, Total Kjeldahl mg/L	3	0.05	1.1	0.72	67%
OrthoPhosphate as P,Dissolved mg/L	3	0.021	0.043	0.03	100%
Oxamyl µg/L	3	0.2	0.2	0.2	0%
Paraquat dichloride µg/L	3	0.25	0.25	0.25	0%
Parathion, Methyl µg/L	3	0.05	0.05	0.05	0%
Phorate µg/L	3	0.05	0.05	0.05	0%
Phosmet µg/L	3	0.1	0.1	0.1	0%
Phosphate as P mg/L	3	0.24	0.26	0.25	100%
Selenium,Total µg/L	3	0.08	0.12	0.10	100%
Simazine µg/L	3	0.12	0.47	0.28	67%
Suspended Solids,Total mg/L	4	12	37	27.5	100%
Total Organic Carbon mg/L	3	8.5	9.4	9.03	100%
Toxaphene µg/L	3	0.25	0.25	0.25	0%
Trifluralin µg/L	3	0.025	0.025	0.025	0%
Turbidity NTU	4	17	30	20.3	100%
Zinc,Dissolved µg/L	3	0.5	1	0.67	33%
Zinc,Total µg/L	3	2.6	4	3.17	100%
Oxygen, Dissolved mg/L	3	5.12	7	5.8	100%
pH none	3	7.28	7.49	7.4	100%
SpecificConductivity µS/cm	3	1211	1910	1493	100%
Temperature °C	3	10.12	12.04	10.8	100%

Source: CVWQCB 2010

Note: For the purpose of data evaluation, non-detect data was assumed to equal half the reporting limit.

5.5 CHEMISTRY ANALYSIS METHODS

The MVCAC Monitoring Coalition will comply with the laboratory requirements of the permit as highlighted in attachments C-Monitoring and Reporting Program, I-General Monitoring Provisions, B and C.

5.6 REPORTING REQUIREMENTS

The MVCAC Monitoring Coalition will comply with the reporting requirements of the permit as highlighted in attachments C-Monitoring and Reporting Program, V-Reporting Requirements, Provisions, A, B and C.

Figure 5-1 Gustine Spray Block 39

Figure 5-2. Brack Tract

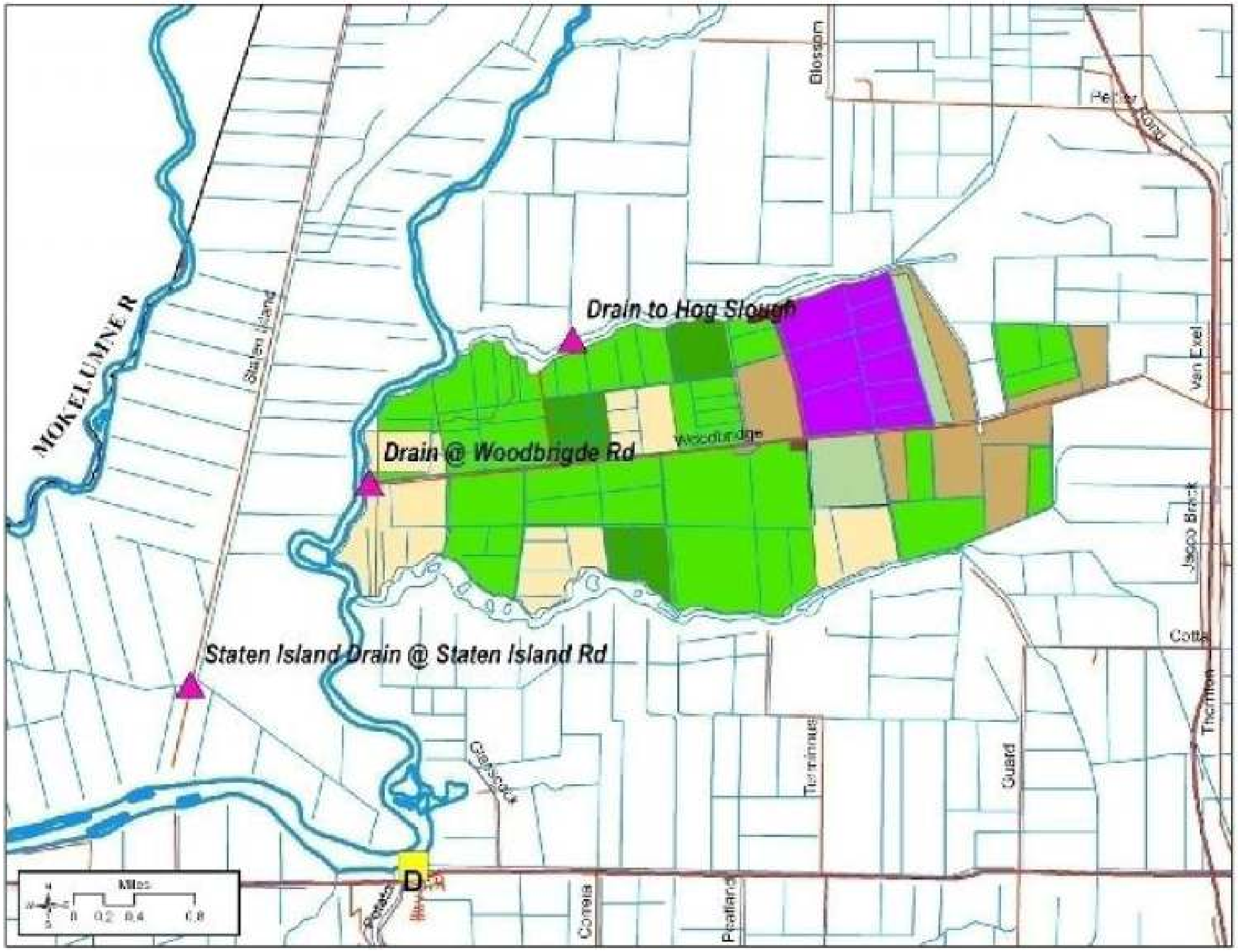

Figure 5-3 City of Colusa

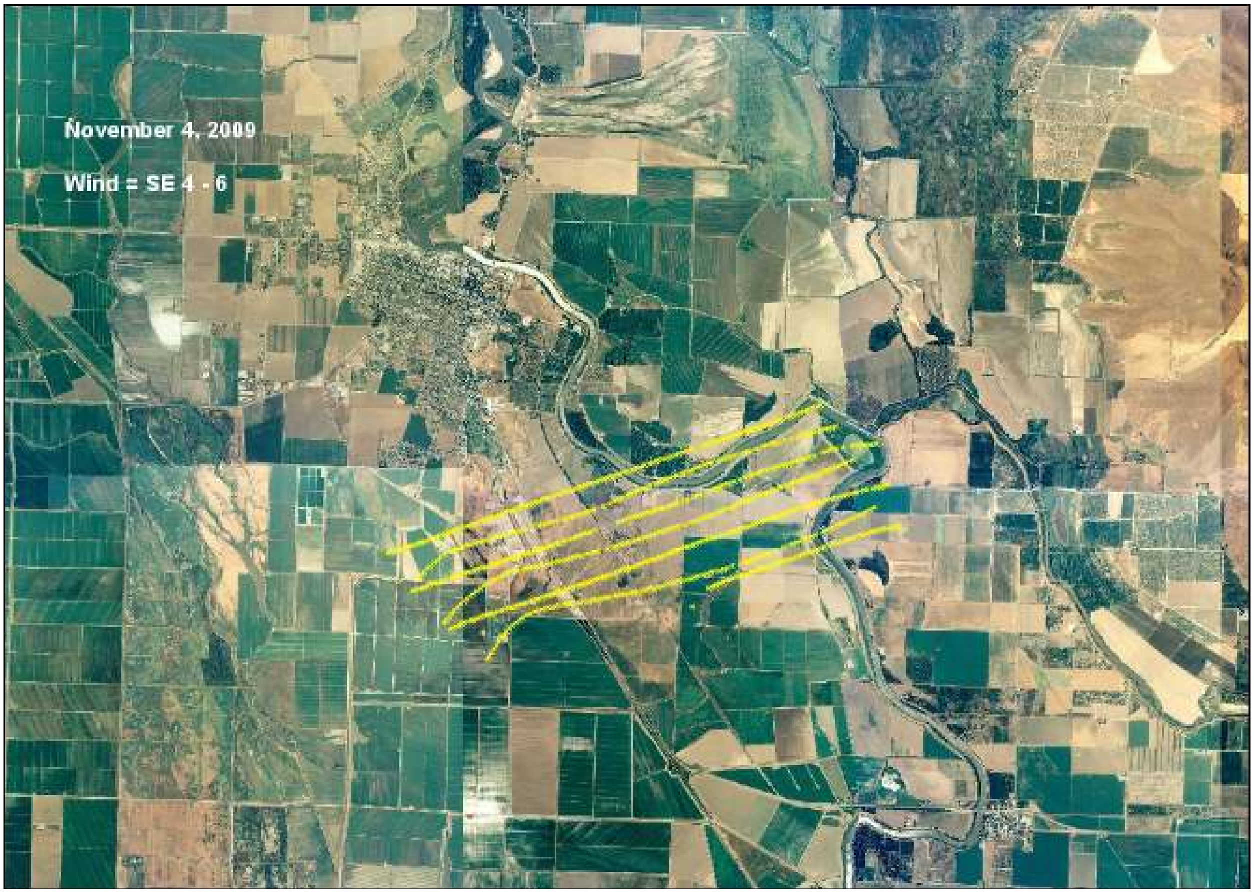

Table 5-3 Examples of Current Analytical Methods

Parameter	Laboratory	Analytical Method or Detectors	Reporting Limits (µg/L)	Detection Limits (µg/L)
Pyrethrins	Caltest Analytical Laboratory	EPA 8270 (GCMS-SIM)	0.1 to 0.5	0.004 to 0.11
Pyrethoids	USGS	GCMS		0.002 to 0.006
	USGS	GCMS-MS		0.0005 to 0.001
	CDFG	GCMS and GC-ECD		0.001 to 0.005[a]
	Caltest Analytical Laboratory	EPA 8270 (GCMS-SIM)	0.005[b]	0.004[b]
	CRG Marine Laboratories, Inc.	GCMS-NCI	0.025[a]	0.005[a]
Naled	Caltest Analytical Laboratory	U.S. EPA 614(m) or 8141A	1	0.03
	CRG Marine Laboratories, Inc.	U.S. EPA 625(m)	0.01	0.005
Temephos	Universtiy of California IR-4 Laboratory	GCMS, GCMS-MS	0.005	0.0005

Notes:

[a] Analysis of Permethrin, but detection limits are not developed for Phenothrin.

[b] Detection/reporting limits for both Permethrin and Phenothrin.

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