Monitoring Program for Pathogen-Transmitting and Nuisance Adult Diptera Associated with the Stormwater BMP Retrofit Pilot Program in Caltrans District 7 and District 11

FINAL REPORT

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Executive Summary

A monitoring program was carried out to determine the abundance of pathogen-vectoring and nuisance flies at 33 sites of the Caltrans Stormwater BMP Retrofit Program in Los Angeles (Caltrans District 7) and San Diego (Caltrans District 11) counties before and during stormwater device operation. The monitoring program consisted of two components: (1) a background monitoring program carried out during the second half of 1998, before the BMPs were operational, and (2) a post-construction monitoring program carried out as and after construction was completed at the majority of sites. Post-construction monitoring began in January 1999 and terminated on the last week of June 2000. Adult host-seeking mosquitoes (i.e., female mosquitoes potentially biting humans), gravid mosquitoes (i.e., female mosquitoes ready to lay eggs), and non-biting midges were collected using two types of traps: (1) carbon dioxide-baited, UV light traps and (2) gravid traps.

There were no significant differences in the abundance of host-seeking mosquitoes and midges at stormwater BMP sites in July - December 1998 versus July - December 1999; however, several sites showed increased gravid mosquito activity during 1999. This comparison of pre- and post-construction insect activity is for a period of comparatively little precipitation and, consequently, most stormwater BMPs should not have contained standing water during much of the annual period of greatest mosquito activity in 1999. Also, any differences that might have occurred due to vector production from the sites would have been lessened because of the control efforts focused on the immature mosquitoes. Increased host-seeking and gravid mosquito activity was observed during 2000 at several sites, particularly enhanced gravid mosquito activity at 79% of sites in District 11.

Mosquito abundance at “control” locations was significantly lower than at paired stormwater BMP sites, particularly media filters, for 50-75% of comparisons. The number of host-seeking or gravid mosquitoes collected at sites that were designated as “controls” was never significantly greater than the abundance of mosquitoes at paired stormwater BMP sites (i) during July through December 1999, (ii) during a shorter, but comparatively wetter, period from May through early July 1999, and (iii) during spring 2000.

Activity of mosquito populations was however generally low and did not differ consistently for a particular stormwater BMP design in comparisons across all sites. Averaged across sites, host-seeking activity was < 2 individuals per trap night and gravid activity was < 15 individuals per trap night. Gravid mosquitoes may provide a better measure of vector activity than do host-seeking mosquitoes because overall gravid mosquito activity was 10 to 13-fold greater than host-seeking activity at most of the trapping sites. Stormwater BMPs containing standing water, such as CDS units, MCTTs, and wet basins, will require continuous vector monitoring. Mosquito activity at the wet basin increased over time and was probably associated with increased coverage by emergent vegetation. Gravid mosquito activity increased markedly following the

installation of CDS units. Design features that permit standing water in stormwater BMPs which otherwise would not hold water for > 72 hours (i.e., cisterns and sumps at bioswales and biostrips) will also produce mosquitoes and elevate mosquito abundance above the natural background levels.

Adult midge activity at stormwater BMP sites did not increase significantly above the background levels that were present prior to operation of the stormwater BMP retrofit devices. This observation suggests that none of the stormwater devices was producing significant numbers of chironomid midges.

The adult monitoring program coincided with a program to monitor the presence of immature mosquito life stages in standing water at the BMP sites. The larval surveys and coordination of control efforts are being carried out under the direction of the California Department of Health Services. The presence of mosquito larvae provides unequivocal evidence of vector production at a particular site and results from larval surveys will aid in further interpretation of the results presented here.

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Overview:
In 1997, the California Department of Transportation (Caltrans) initiated a program to evaluate the cost effectiveness and water quality benefits of nine designs for processing stormwater discharge at 33 sites in southern California. Thirty-nine structural Best Management Practices (BMPs) were to be retrofitted to freeways, interchanges, park and rides and maintenance stations in Los Angeles (26 BMPs at 21 sites in Caltrans District 7) and San Diego (13 BMPs at 12 sites in Caltrans District 11) counties. Some of the stormwater devices have the potential to produce pestiferous insects and vectors of pathogens causing human disease.

The purpose of the monitoring program described here was to determine the abundance of adult host-seeking mosquitoes (i.e., female mosquitoes potentially biting humans), gravid mosquitoes (i.e., female mosquitoes ready to lay eggs), and non-biting midges at Caltrans Stormwater BMP retrofit locations in Los Angeles (Caltrans District 7) and San Diego (Caltrans District 11) counties before and during stormwater device operation. The monitoring program consisted of two components: (1) a background monitoring program carried out during the second half of 1998, before the BMPs were operational, and (2) a post-construction monitoring program carried out after construction was completed at the majority of sites, beginning in January 1999 and terminating on the last week of June 2000. This monitoring coincides and supplements a program to monitor the presence of immature mosquito life stages in standing water at the BMP sites, which is being carried out under the direction of the California Department of Health Services.

This report (1) summarizes the results for the post-construction monitoring program, (2) compares the abundance of mosquitoes and midges before and after operation of the stormwater BMPs and (3) compares mosquito and midge abundance at operational BMP sites to sites without stormwater BMPs. The data collected during the background monitoring program have been summarized previously (Walton 1999).

Rationale:
Mosquito abatement is an important concern in southern California because the climate is amenable to mosquitoes and the pathogens that they can transmit for a large portion of the year. Biting flies such as mosquitoes are important vectors of pathogens that cause diseases in humans and domesticated animals. The diseases have a variety of causative agents (e.g., viruses, bacteria, protistans). Fifteen of the twenty-two (22) arboviruses in California are known to be transmitted by biting flies to humans and other mammals (Reisen 1995); eight (8) of the viruses have been shown to cause febrile and central nervous system illnesses in humans (Reeves 1990). The rapid increase in the human population and the addition of new sources of standing water into a historically dry region creates the potential for disease transmission and nuisance biting by mosquitoes.

Each year, encephalitis virus transmission is detected in sentinel bird populations which are used as an early warning system of virus activity within urban and rural settings of the region (Reisen 1995, Kramer et al. 1996). Ongoing monitoring of wild bird populations

in Orange County has indicated that the St. Louis encephalitis virus has been present every year since monitoring began in 1987 (Bennett et al. 1996, Cummings et al. 1998). Mosquitoes that utilize storm drains, organically-enriched puddles and ponds, wetlands, etc., are capable of transmitting encephalitis viruses to humans and horses, as well as to birds which serve as the reservoir for the viruses. Although the last serious encephalitis outbreak among humans in southern California occurred in the mid-1980s, mosquitoes and other flies which originate from freeway and stormwater drainage systems, treatment wetlands, and from nearly any unmanaged source of standing water can become a nuisance to people. New or existing habitat that might produce large numbers of mosquitoes is a concern to the public agencies charged with vector control.

In addition to mosquitoes whose biting potentially creates discomfort and transmits disease-causing pathogens to humans, non-biting midges in the family Chironomidae can also be produced in substantial quantities from standing water. The immature stages of the midge life cycle occur in water. Even though adult midges do not blood-feed like mosquitoes, they can become a serious nuisance near wetlands, drainage channels, lakes, golf course ponds, etc., where adults are attracted to lights and subsequently alight on, or enter, human residences. Adult midges are very similar in appearance to mosquitoes and are also a concern for agencies charged with abating public nuisances.

Sampling Overview

In order to evaluate the abundance of mosquito and midge populations at stormwater BMP retrofit sites, a monitoring program was undertaken to sample the following:

(1) host-seeking adult female mosquitoes by carbon dioxide-baited traps,
(2) gravid female mosquitoes by gravid traps, and
(3) adult midge populations by light traps.

Although surveying larval mosquitoes and midges is a better approach for documenting the presence of nuisance insects and insects of concern to public health in a stormwater BMP device than is trapping adults, monitoring adult insect activity is important for several reasons. First, monitoring adult mosquito and midge populations is important at sites where larval monitoring is not feasible throughout the entire basin (e.g., wet basins) and in sites where standing water in the BMP might not be readily accessible for larval/pupal sampling (e.g., oil/water separators, multi-chambered treatment trains (MCTTs), freeway drains and associated catch basins). Second, if standing water is present, host-seeking mosquitoes that are attracted to a BMP site may create nuisance biting of humans. Adult monitoring is required to assess this potential. Last, adult monitoring was the only method available to compare insect activity before and after stormwater BMP construction because standing water, which supports immature mosquitoes and midges, was not present at the sites prior to construction.

The two trap types used for monitoring are standard designs used in adult mosquito and midge surveillance programs (Service 1993, Merritt and Cummins 1994, Reisen 1995)

and are designed to utilize behaviors that are typical of many mosquito and midge species. The adult population of mosquitoes can be separated into three groups based on behavior: (1) host-seeking, (2) gravid and (3) resting adults. Host-seeking adults are female mosquitoes that are actively seeking a blood meal which will serve as a protein source necessary for the development of eggs. In addition to a potential source of disease-causing pathogens, host-seeking individuals can be an annoyance to humans and to domesticated animals.

Gravid mosquitoes are females that contain eggs and typically are collected as they search for sites to deposit their eggs, such as standing water. Except in rare instances where females of particular species can produce one group of eggs without blood feeding, the majority of gravid females will have taken at least one blood meal. Because more than one blood meal is required for the transmission of most disease-causing pathogens known in California, gravid females provide a more reliable means of assessing the prevalence of pathogens in the mosquito population than do host-seeking females.

Resting individuals are usually a mixture of newly emerged females which have not taken a blood meal, recently blood-fed females which are digesting the blood prior to egg production, and males which do not consume blood. Resting individuals are often collected in comparatively dark and humid environs, such as on shaded, vertical walls near mulch piles (Schreiber et al. 1993). Whereas, host-seeking and gravid females of many species are collected readily by luring individuals to traps, collection of resting mosquitoes is considerably more time consuming because individuals are not easily attracted to traps.

The abundance of host-seeking females represents the potential for nuisance biting and pathogen transmission. The abundance of gravid females represents the potential for colonization of standing water and for pathogen transmission. Both components of adult mosquito populations are routinely monitored throughout California (Reisen 1995).

Sampling Site Locations

The BMP pilot sites were selected by Caltrans and its consultants so that retrofit options allowed for observations pertaining to technical feasibility, costs of retrofitting and benefits. Typical sites were selected along Caltrans' right-of-way, including interchanges, park and rides (P&R) and maintenance stations (MS). Each site for a retrofit pilot project was selected to be appropriate for the type of best management practice to be evaluated and without pre-judgment about the outcome of the associated retrofit pilot study. BMP pilot sites are identified on Exhibit A within Appendix A and Exhibits A and B within Appendix A of the "BMP Retrofit Pilot Program: Vector Control Background Monitoring Plan (Mosquitoes and Midges)" for Caltrans District 7 (Caltrans 1998a) and District 11 (Caltrans 1998b), respectively. However, because of subsequent revisions in plans, BMP designs (e.g., sites 73102 and 73103) and locations (e.g., 111104) differ from some of those listed in Caltrans (1998a, b).

Trap locations for the Vector Control Background Monitoring Program initially used the same designations listed in Caltrans (1998a, b), except for Penasquitos sites 1 (111101) and 2 (112201) in District 11. These sites were designated as San Diego sites 11 and 12, respectively (Table 1). BMP sites were assigned new designations as of 21 July 1999 by consultants coordinating the project; new identification numbers were assigned to vector monitoring sites to correspond with the water quality designations utilized by all agencies participating in the project (Table 1).

Six additional locations were added during summer 1999 to serve as "control" locations for trapping at sites not adjacent to a stormwater BMP device (Table 1). Only adult vector monitoring was carried out at the sites; therefore, they were not assigned a water quality number. Control sites were paired with a particular stormwater BMP site and were chosen (1) to be on Caltrans property and (2) to be situated close enough to the BMP site that background levels of mosquito activity were likely to be equivalent, yet, the sites were far enough apart so no to strongly influence each other. Control sites were in areas where adult mosquitoes are likely to be found, such as trees or near comparatively humid environs such as mulch piles. A description of each trapping location follows.

Altadena Maintenance Station (73211): Traps were positioned in vegetation near the entrance to the station and northeast of the BMP site.

East Regional Maintenance Station (74202): Traps were positioned in vegetation along the southern perimeter of the maintenance station, behind a clearing area for compost.

Foothill Maintenance Station (73216): Traps were positioned along a fence on the north side of the maintenance station.

Termination Park and Ride (74204): Traps were positioned in/beneath vegetation between the parking lot and the overpass along the southwestern perimeter of the Park and Ride.

Kearny Mesa Maintenance Station (112201): Traps were positioned in/beneath a tree in the northeast corner of station.

Carlsbad Maintenance Station (112207): Traps were positioned adjacent to a mulch storage area on the northeastern side of the station.

These six sites, two sites in Pacoima adjacent to standard freeway drains (73102C, 73103C), and site 112202 served as control locations. The trapping location for site 112202 was not in the immediately adjacent to the BMP. Because standing water was not found in the BMP, this device should not have produced mosquitoes and midges.

Table 1. Trapping locations for adult mosquitoes and midges at the Caltrans Stormwater BMP Retrofit Pilot Program.

Caltrans Retrofit Pilot Program District 7

WQ Site No.	Bkgrnd. Monitor /UCR No.	Site	Operational Date	BMP Type
73101	10	I-605/SR-91 Interchange	4/9/99	IB
73102	2	I-210/East of Orcas Ave.	5/19/00	CDS
	1	I-210/West of Orcas Ave.	7/98	Control (73102C)
73103	3	I-210/East of Filmore St.	5/19/00	CDS
	4	I-210/East of Van Nuys Blvd.	7/98	Control (73103C)
74101	9	I-5/I-605 Intersection	2/26/99	EDB
74102	8	I-605/SR-91 Intersection	2/22/99	EDB
74103	18	Paxton P&R	Not operational	MF
74104	20	Metro MS	Not operational	MCTT
74201	19	Alameda MS	5/17/99	Oil/Water Separator.
74202	16	Eastern Regional MS	2/15/99	MF
	25	Eastern Regional MS		Control (74202C)
74203	7	Foothill MS	3/8/99	MF
	23	Foothill MS		Control (74203C)
74204	17	Termination P&R	5/17/99	MF
	26	Termination P&R		Control (74204C)
74206	21	Via Verde P&R	5/17/99	MCTT
74208	22	Lakewood P&R	5/17/99	MCTT
73211a,b	11	Altadena MS	10/1/99	Bio. Strip + IT
	24	Altadena MS		Control (73211C)
73216	7	Foothill MS	1/22/99	DII
73217	5	Las Flores MS	1/22/99	DII
73218	6	Rosemead MS	1/22/99	DII
73222a,b	13	I-605/SR-91 Interchange	10/1/99	Bio.Strip+Swale
73223	12	Cerritos MS	10/1/99	Bio. Swale
73224	14	I-5/I-605	10/1/99	Bio. Swale
73225	15	I-605/Carson & Del Amo Ave.	10/1/99	Bio. Swale

Caltrans Retrofit Pilot Program District 11

111101	11	I-5/SR-56	1/24/99	EDB
111102	1	I-15/SR-78	1/24/99	EDB
111103	6	I-5/La Costa Ave. (w)	1/24/99	IB
111104	7	I-5/La Costa Ave (se)	10/1/99	Wet Basin
111105	2	I-5/ Manchester Ave.	10/1/99	EDB
112201	12	Kearny Mesa MS	10/1/99	MF
	14	Kearny Mesa MS		Control (112201C)
112202	8	Escondido MS	2/16/99	MF/Control for 111102
112203	9	I-5/La Costa P&R	2/16/99	MF
112204	10	SR-78/I-5 P&R	2/26/99	MF
112205	5	SR-78/Melrose Dr.	3/1/99	Bio. Swale
112206	4	I-5/Palomar Airport Rd.	10/1/99	Bio. Strip
112207a,b	3	Carlsbad MS	10/1/99	Bio. Strip + IT
	13	Carlsbad MS		Control (112207C)

MATERIALS AND METHODS

CO_2-Light Traps

In order to sample both mosquitoes and midges, carbon dioxide and ultraviolet light were combined into a single suction trap. A miniature Centers for Disease Control (CDC) light trap with single 4-watt blacklight lamp (wavelength range: 320-420 nm in the near ultraviolet) was combined with a carbon dioxide source (dry ice). The top of the trap consisted of (i) an adapter and (ii) an insulated storage container for solid carbon dioxide equipped with a manifold for delivering approximately 500 ml CO_2 min^{-1}. Each CO_2-light trap was stocked nightly with approximately 2 kg of dry ice. The carbon dioxide sublimated above the fan and motor which provided suction to draw host-seeking mosquitoes into the collection chamber. In order to standardize the trapping period, each trap was equipped with a photoswitch and gate system that was activated at dusk and deactivated after sunrise. The gate closed and prohibited egress of adult flies from the trap after sunrise. Power was supplied by either rechargeable 6 V batteries or by an array of D-cells.

Gravid Traps

A modification of the Reiter-Cummings gravid trap (Reiter 1983, 1987) was used to monitor the abundance of gravid (egg-laying) female mosquitoes. The upper component assembly (42 X 21 X 17 cm) included the motor, fan, intake and exhaust manifolds, power supply, electronics array and the collection chamber. The lower component was a heavy-duty beige plastic tray (approximately 20 X 38 X 13 cm) that served as a basin for an organic infusion and as a support for the upper component assembly. At each BMP pilot site, four liters of an organic infusion were added to the bottom of the gravid trap and then the top components of the trap were assembled and placed onto the trap's base. In order to standardize the trapping period, each trap was equipped with a photoswitch that was activated at dusk. The fan was deactivated upon collection of the trap on the following morning. Power was supplied by either rechargeable 6 V batteries or by an array of D-cells.

Each week a new infusion of oviposition medium (Reiter 1986) was set up in a large plastic trash bin. The oviposition attractant consisted of 0.5 kg hay, 5 g dried brewer's yeast, 5 g lactalbumen and 114 liters of water aged for seven days. The mixture was covered, and left to incubate for 5 days out-of-doors. In order to keep water temperatures below 40^{o}C, the infusion chambers were to be kept out of direct sunlight. Prior to use, the infusion was sieved (opening: ~0.6 cm) to remove floating debris. The coarsely filtered infusion was transferred from the infusion chamber into 20 liter Nalgene carboys for transport to the BMP sites.

Within each Caltrans district, a set of traps (one CO_2-light and one gravid trap) was run on the same night at each trapping site. Traps were run weekly at each site from April 1 until October 31; and then biweekly from November through March. This sampling frequency represents weekly samples during the peak activity for mosquitoes in southern California and biweekly samples during the late autumn when host-seeking and reproductive activities normally decline. Trapping was not carried out during rain events when mosquitoes are not active. For locations where more than one BMP device was being studied (e.g., District 7 BMP sites 73203, 73216 [Foothill MS Media Filter (MF)], 73211 [Altadena Biostrip + Infiltration Trench (IT)], 73222 [I-605/SR 91 Interchange Biostrip + Bioswale]), one set of traps was run.

Traps were placed as close to prospective sites of the BMP devices as possible so not to interfere with daily operations at Maintenance Stations (MS) and Park and Rides (P&R), and so not to be jeopardized by or interfere with construction of the BMP devices. Traps were situated in comparatively sheltered locations, often near vegetation or buildings. In addition to apprising Caltrans supervisors, superintendents and other personnel of monitoring activities, a schedule of monitoring activities and pictures of the traps were provided to regional law enforcement agencies such as County Sheriffs Departments and the California Highway Patrol.

Each trap carried a site-specific tag/label attached to the collection bag. At collection, the fine mesh bags containing mosquitoes and midges were placed into an insulated cooler, returned to the laboratory and killed by freezing. Freezing eliminated the need to use poisons (e.g., potassium cyanide) or other chemicals putatively harmful to humans (e.g., trichloroethylene) as a means of killing insects in the samples.

Mosquitoes were identified using Bohart and Washino (1978) and Meyer and Durso (1998). Midges were categorized as morphospecies and representative specimens were sent to a systematic expert for identification. Voucher specimens of all species collected during the background monitoring study are maintained at the Entomology Research Museum, University of California-Riverside.

Weather data

Daily weather data collected at five sites in Los Angeles County (Claremont, Glendale, Long Beach [El Dorado], Pomona, and Santa Monica) and at three sites in San Diego County (Escondido, Oceanside and San Diego) by the CIMIS (California Irrigation Management Information System, California Department of Water Resources) network were summarized. The Escondido weather station began operation on 1 February 1999. Daily maximum, minimum and average temperatures were examined. Seven day running averages for average daily temperature were computed for each site. Precipitation data were available for all sites except Claremont. Rainfall events > 2 mm (> 0.1 in.) were typically districtwide events; daily districtwide averages were calculated.

Analyses

Seasonal and natural variability in the number of insects collected at BMP sites was typically quite large, especially when counts were summed across several months. The relationship between the variance and mean for counts of particular insects (e.g., host-seeking mosquitoes) collected by each trap type was examined for Los Angeles or San Diego sites using Taylor's Power Law. The variance increased directly (slope typically > 1.3) with the mean number of individuals collected at each site; therefore, insect abundance was log-transformed to stabilize the variance of counts. A back-transformed geometric mean ± 95% confidence interval was calculated for each site.

Table 2. Positions of California Irrigation Management Information System (CIMIS) weather stations used in this study.

Station no.	Station name	County	Latitude	Longitude	Elevation (m)
Caltrans District 7					
78	Pomona	Los Angeles	34°03'30"N	117°48'42"W	219
82	Claremont	Los Angeles	34°07'48"N	117°41'46"W	486
99	Santa Monica	Los Angeles	34°02'28"N	118°28'34"W	102
102*	El Dorado	Los Angeles	33°47'50"N	118°05'38"W	5
133	Glendale	Los Angeles	34°11'59"N	118°13'56"W	333
Caltrans District 11					
49	Oceanside	San Diego	33°15'21"N	117°19'11"W	15
66	San Diego	San Diego	32°43'59"N	117°08'05"W	111
153†	Escondido SPV	San Diego	33°04'52"N	116°58'33"W	117

* Station taken out of service on October 20, 1999.
† Station began service on February 1, 1999.

Comparisons of the abundance of host-seeking mosquitoes, gravid mosquitoes or adult chironomid midges between the preconstruction and postconstruction surveys for approximately the same period within each year (July-December 1998 versus July- December 1999) were made. Second, comparisons were made between the wet period of 1999 (May or June through early July) versus the dry period of 1999 (July through December) for the mosquitoes. Third, comparisons among stormwater BMP designs for the total number of host-seeking or gravid mosquitoes collected during post-construction monitoring were carried out by ANOVA.

The numbers of host-seeking and gravid mosquitoes collected at each pair of "control" site versus stormwater BMP sites were compared using paired *t*-tests. Counts were log (x + 1)-transformed prior to analysis. Comparisons were made at the following District 7 sites: 73102 (I-210/East of Orcas Ave. Continuous Deflection Separator [CDS] unit), 73103 (I-210/East of Filmore Ave. CDS unit), 73211(Altadena MS Biostrip and IT), 74203 (Foothill MS Media Filter), 74204 (Termination P&R Media Filter). Site 73225 (I-605/Carson & Del Amo Ave. Bioswale) was initially designated as a control location for site 73101 (I-605/SR-91 Infiltration basin [IB]); however, because mosquito larvae were present at site 73225, this site was not considered further as a control location. For District 11, the following sites were compared: 112201 (Kearny Mesa MF), 112207 (Carlsbad MS Biostrip + IT), 112202 (Escondido MS: control) vs. 111102 (I-5/SR-56 Extended Detention Basin [EDB]) and 111103 (I-5/La Costa Ave IB) vs. 111104 (I-5/La Costa Ave. wet basin). Comparisons were made for three periods: (1) July through December 1999, (2) spring 1999 and (3) spring 2000.

RESULTS
District 7 sites: July - December 1998 vs. 1999

Host-seeking Mosquitoes

The abundance of host-seeking mosquitoes at Los Angeles sites did not differ appreciably over the period July 17 - December 17, 1998 versus July 22 - December 29, 1999 (Figure 1). Relative to collections during 1998, the average number of host-seeking mosquitoes collected at the majority of sites did not change significantly during the summer and autumn 1999. The number of host-seeking mosquitoes collected by CO_2-light traps during 1999 increased significantly at site 19 (74201); however, it is unlikely that the oil/water separator installed at the Alameda Maintenance Station (MS) caused the increased mosquito abundance. Overall, the number of mosquitoes actively searching for blood meals was low at most sites: the mean number of females per trap night was less than 1.

Gravid Mosquitoes

The abundance of gravid mosquitoes at Los Angeles sites did not differ appreciably over the period July 17 - December 17, 1998 versus July 22 - December 29, 1999 for most sites; however, an increased abundance of gravid mosquitoes was observed at 5 sites during 1999 (Figure 1). Relative to collections during 1998, the average nightly catches of gravid mosquitoes collected at sites 4 (control site for 73103, CDS unit in Pacoima), 11 (73211a,b; Altadena MS), 12 (73223, Cerritos MS), 16 (74202, Eastern Regional MS) and 22 (74208, Lakewood P&R) increased significantly during the summer and autumn 1999. The number of mosquitoes collected by gravid traps during 1999 also increased at sites 3 (73103, I-210/Filmore CDS unit), 6 (73218, Rosemead MS), 7 (74203, Foothill MS), 10 (73101, I-605/SR-91 IB), 13 (73222a,b; I-605/SR-91 Biostrip + bioswale) and 19 (74201, Alameda MS). Yet, despite a near doubling of the mean for gravid female mosquitoes at many of these sites in 1999, the 95% confidence intervals for both years overlapped considerably for these sites. Gravid mosquitoes were 4 to 10-fold more abundant than were host-seeking mosquitoes at most sites.

Adult Midges

Relative to the period July 17 - December 17, 1998, the abundance of adult midges in CO_2-light trap collections at Los Angeles sites during July 22 - December 29, 1999 did not differ appreciably, or was lower, at all sites except for site 10 (Cerritos IB, 73101, Figure 2). The increase in midge numbers at site 10 during 1999 was not significant. Midge abundance after the comparatively wetter spring of 1998 was appreciably larger than during 1999 at sites 1 (73102-control, Pacoima), 2 (73102, I-210/Orcas Ave. CDS unit), 4 (73103-control, Pacoima), 12 (73233, Cerritos MS), 13 (73222a, b; I-605/SR-91) and 14 (73224, I-605/SR-91). There is no evidence that the Retrofit Pilot Program BMP Sites that were operational during July through December 1999 produced midges in abundance greater than was observed during the pre-construction period in 1998.

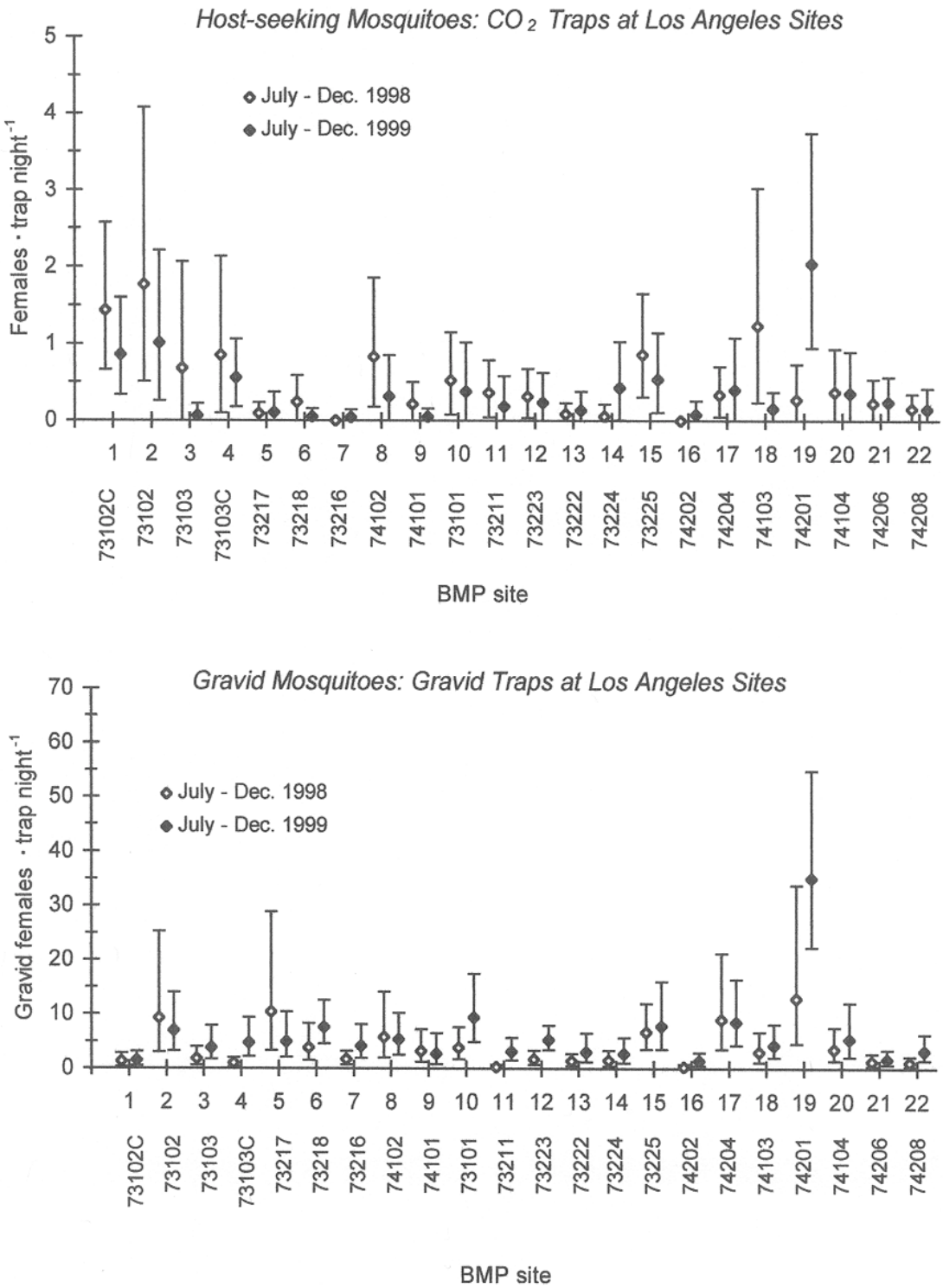

Figure 1. Host-seeking and gravid mosquitoes (± 95% CI) collected at District 7 BMP Retrofit Pilot Program Sites during July through December 1998 and 1999. The abscissa of each plot lists the BMP sites by the number assigned to them during the background monitoring program and, for the sites added in 1999, as a continuation of the series above the last number used in each Caltrans district: 22 in District 7 and 12 in District 11 (see Table 1). Water quality numbers assigned to BMP sites are listed below background monitoring program site numbers.

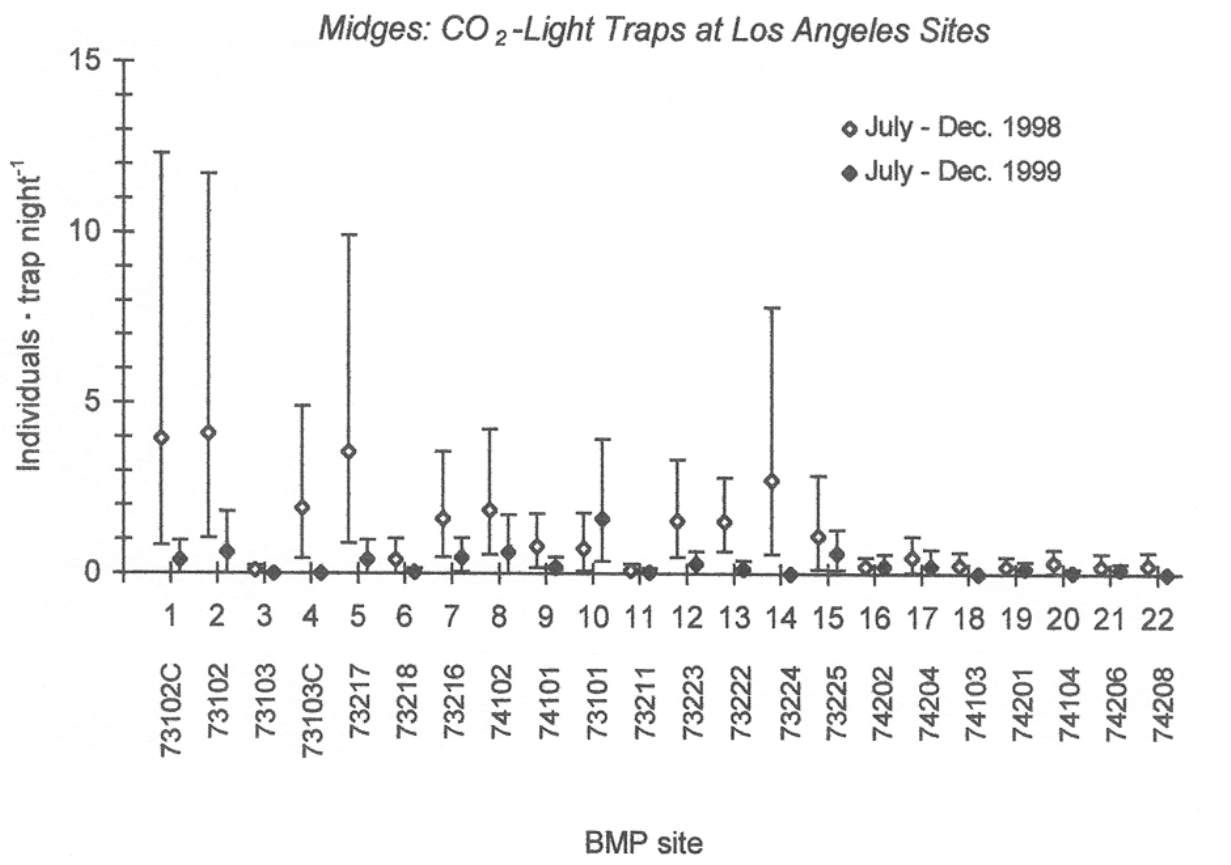

Figure 2. Adult chironomid midges (± 95% CI) collected at District 7 Retrofit Pilot Program BMP Sites during July through December 1998 and 1999. Numbering on the abscissa is explained in the legend to Figure 1.

District 11 sites: July - December 1998 vs. 1999

Host-seeking Mosquitoes

The abundance of host-seeking mosquitoes at eleven of the San Diego sites over the period July 19 - December 13, 1999 either did not differ or declined relative to the period July 30 - December 15, 1998 (Figure 3). Host-seeking mosquito abundance at site 4 (112206, I-5/Palomar Airport Rd. Biostrip) during 1999 was larger than during 1998, albeit, the increase in abundance was very small. There is no indication that host-seeking mosquito activity was significantly enhanced at the BMP stormwater devices that were operational during the second half of 1999.

Gravid Mosquitoes

The abundance of gravid mosquitoes at eleven of the San Diego sites over the period July 19 - December 13, 1999 also either did not differ or declined relative to the period July 30 - December

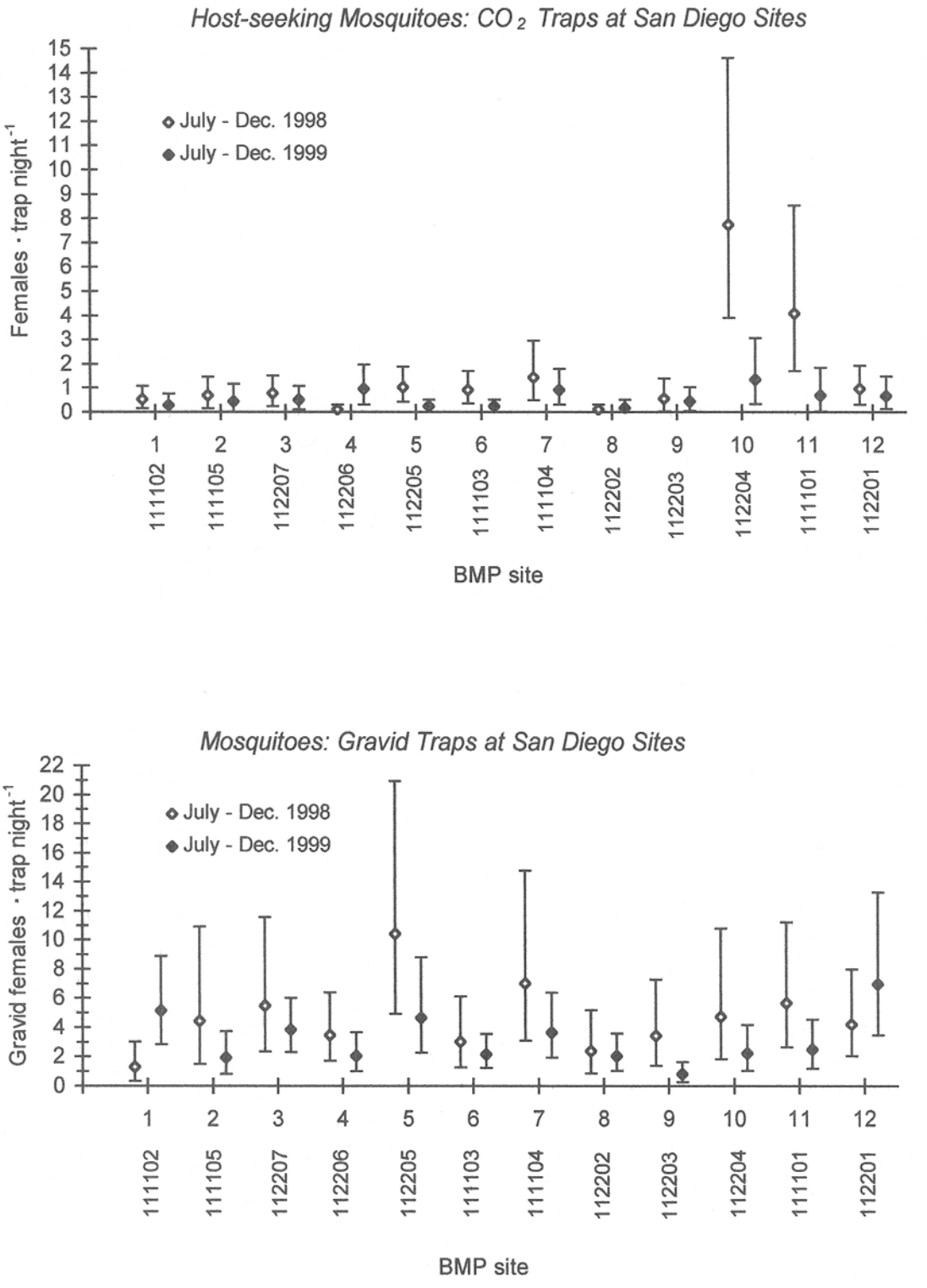

Figure 3. Host-seeking and gravid mosquitoes (± 95% CI) collected at District 11 Retrofit Pilot Program BMP Sites during July through December 1998 and 1999. Numbering on the abscissa is explained in the legend to Figure 1.

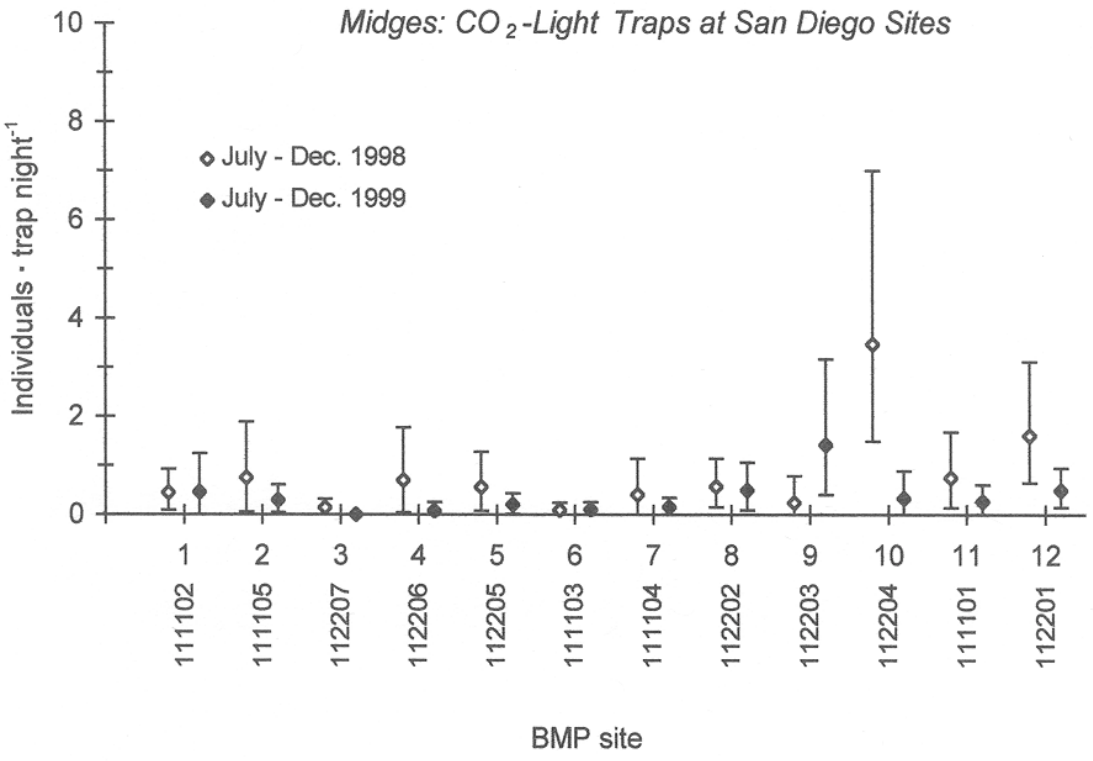

Figure 4. Adult chironomid midges (± 95% CI) collected at District 11 Stormwater BMP Retrofit Pilot Program sites during July through December 1998 and 1999. Numbering on the abscissa is explained in the legend to Figure 1.

15, 1998 (Figure 3). The mean for gravid females collected per trap night at site 1 (111102, I-15/SR-78 EDB) increased significantly from about 1.5 in 1998 to 5 in 1999. The activity of gravid mosquitoes was not significantly enhanced at the stormwater BMP devices that were operational during this period.

Adult Midges

Relative to the period July 30 - December 15, 1998, the abundance of adult midges in CO_2-light trap collections at San Diego sites during July 19 - December 13, 1999 did not differ appreciably, or was lower, at all sites except for site 9 (112203, I-5/La Costa P&R, Figure 4). The increase in midge numbers at site 9 during 1999 was not significant. Midge abundance after the comparatively wetter spring of 1998 was appreciably larger than during 1999 at sites 3 (112207a, b; Carlsbad MS Biostrip + IT), 4 (112206, I-5/Palomar Airport Rd. Biostrip), 7 (111104, I-5/LaCosta Ave. WB), and 10 (112204, SR-78/I-5 P&R, MF). There is no evidence that the stormwater units that were operational during July through December 1999 produced midges in abundance greater than was observed during the pre-construction period in 1998. The 95% confidence intervals for most sites in 1999 did not exceed 2 individuals per trap night and is indicative of the low abundance of chironomid midge adults. Even though site 9 had a larger mean abundance and showed greater variability in midge numbers than did the other sites, the upper 95% confidence interval did not exceed 4 individuals per trap night.

Trends in Precipitation and Air Temperature for the Period July 1998 through June 2000

The comparisons between years summarized above are primarily for periods during which standing water was not present at most sites because stormwater devices were not present (preconstruction monitoring) or significant rainfall events did not occur (mid-July through December 1999: postconstruction monitoring). Composite rainfall data for five weather monitoring sites in Los Angeles County and 3 weather monitoring sites in San Diego County are illustrated in Figure 5. Between July and December 1999, a 3 mm rainfall event occurred in early November in Los Angeles. The last significant storm event before the late autumn rain was during May in Los Angeles and during mid-June in San Diego (Figure 5).

Rainfall was equivalently low in Los Angeles and San Diego counties during summer 1998 and 1999 (July 1 to September 1: < 8 mm [0.31 in.]). However, the cumulative amount of precipitation between September 2 and December 31, 1998 was nearly 10-fold greater than during the same period in 1999 (Los Angeles 1998: 56.5 mm [2.23 in.], 1999: 6.9 mm [0.27 in.]; San Diego 1998: 52.5 mm [2.1 in], 1999: 7.5 mm [0.3 in]).

Rainfall during a period of natural mosquito activity (April 1 through June 30) within the post-construction monitoring study was relatively similar at Los Angeles sites during 1999 vs. 2000 (1999: 87.5 mm [3.45 in.], 2000: 77.2 mm [3.03 in.]) as compared to the San Diego sites. Precipitation during this same period at the San Diego sites during 1999 was nearly four-fold greater than during 2000 (1999: 84.2 mm [3.31 in.], 2000: 22.5 mm [0.88 in.]).

Mean air temperature during pre-construction monitoring of adult mosquitoes and midges was warmer (Los Angeles: 0.2^{o}C; San Diego: 0.4^{o}C) than during the same period (July through December) during post-construction monitoring. Monthly mean air temperature was cooler (2-3^{o}C) than normal (long-term average computed by the National Weather Service) between March and September 1999. The period January 1 through June 30, 1999 was, on average, nearly 2^{o}C (Los Angeles: 2.0^{o}C; San Diego: 1.9^{o}C) cooler than during the same period in 2000.

The seasonal distribution of rainfall and variation in air temperature can have important effects on mosquito abundance. Mosquitoes depend on standing water to complete development into adults. Air temperature will directly affect the water temperature of shallow water bodies which are preferred developmental sites for mosquitoes. Air temperature will also influence the activity patterns of host-seeking and egg-laying mosquitoes. Increased rainfall and warmer temperatures (to ca. 30^{o}C: Bailey and Gieke 1968; Mead and Conner 1987) during the period of greatest annual mosquito activity can enhance mosquito abundance by providing developmental sites and increasing the rate at which mosquitoes develop from eggs into adults, respectively.

District 7 sites: May-July 1999, July - December 1999, January - June 2000

Host-seeking Mosquitoes

A comparison of host-seeking activity for May through mid-July 1999 versus mid-July through December indicated that host-seeking mosquito activity in June and early July at sites 2 (73102, I-210/Orcas Ave. CDS unit), 4 (control for 73103, I-210/Van Nuys Blvd.), 7 (73216, Foothill MS

MF and Drain Inlet Insert [DII]), 12 (73223, Cerritos MS Bioswale), 13 (73222a,b; I-605/SR-91 Biostrip + bioswale), 14 (73224, I-5/I-605 Bioswale), and 15 (73225, I-605 Carson & Del Amo Ave. Bioswale) was higher than during the drier part of 1999 (Figure 6). Host-seeking mosquito activity at these sites also was higher than at sites 23 through 26. Increased activity at sites 2 and 4 cannot be attributed to stormwater BMP devices because devices were not installed and operational until May 2000. Increased activity at the sites along I-605 near Cerritos was correlated with the presence of larvae in sumps at the BMP sites. Although biostrips and bioswales would not typically contain standing water, standing water in the cement sumps/cisterns along the flow path for the stormwater provided favorable conditions for mosquitoes.

During January through June 2000, host-seeking mosquito activity remained low at the majority of sites (mean < 1 individual per trap night; Figure 6). Relative to the same time period during 1999, host-seeking activity increased at two Cerritos sites: the infiltration basin (73101) and at a bioswale site adjacent to the infiltration basin (73222).

The number of host-seeking mosquitoes collected during post-construction monitoring did not differ significantly among stormwater BMP devices, both within each Caltrans district and across both districts (ANOVAs, $P > 0.05$). Differences in the number of host-seeking mosquitoes among sites were strongly influenced by site-specific influences rather than by a consistent effect of a particular BMP design. Therefore, one could not predict, for example, that host-seeking mosquito abundance at sites with a particular BMP design was on average 5 individuals per trap night, whereas, host-seeking mosquito abundance at sites having another stormwater BMP design was on average 10 individuals per trap night. Seasonal changes of mosquito abundance also contributed to the variation within and among sites.

Gravid Mosquitoes

Gravid mosquito activity at the BMP sites during the wetter part of 1999 showed some concordance with the host-seeking data at four sites (2, 4, 14, and 15) and no concordance with blood feeding activity at three sites (7, 12 and 13: Figure 6). Increased gravid mosquito activity also occurred at sites 17 (Media filter: 74204) and 20 (Multi-Chambered Treatment Train [MCTT]: 74104), but a stormwater BMP was not operational at the latter site, the Metro MS. Gravid mosquito activity at "control" sites 24, 25, and 26 was lower than that observed at any of the aforementioned sites; however, gravid mosquito activity was comparatively high on one date at site 23. The chronic high levels of mosquito activity recorded at the Alameda MS (74201, site 19) were unlikely to have been related to the stormwater BMP device (oil/water separator).

During the first half of 2000, gravid mosquito activity was not enhanced appreciably to that observed during spring 1999 at 73% of the trapping sites. As compared to activity during 1999, enhanced gravid mosquito activity was observed in June at the two CDS sites (73102, site 2 and 73103, site 3), at one media filter site (73216, site 7, Foothill MS), at one drain inlet insert site (73218, site 6, Rosemead MS), at one MCTT site (74208, site 22, Lakewood P&R) and at one control site (74204C, site 26, Termination P&R).

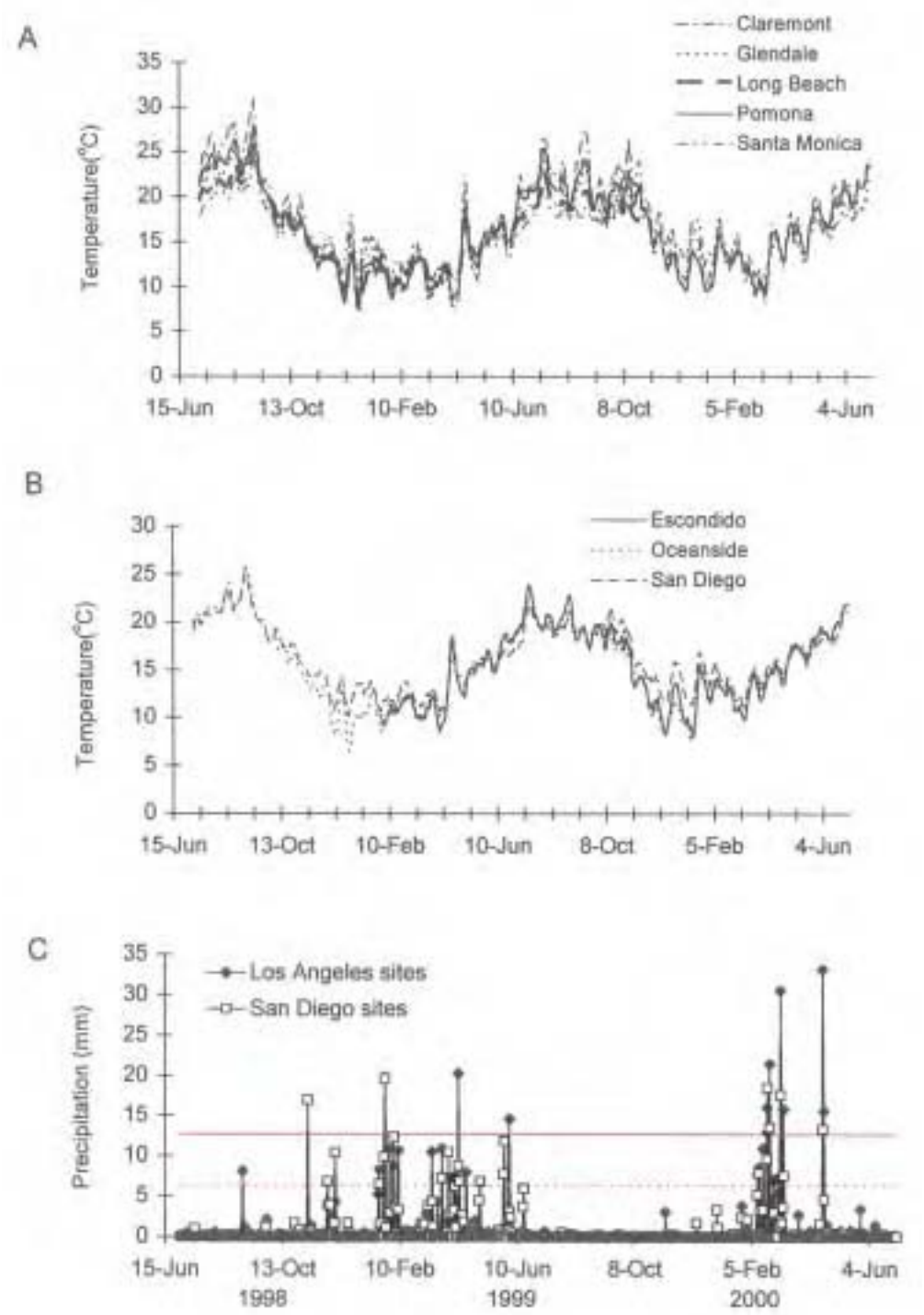

Figure 5. Composite average daily air temperature and precipitation in Los Angeles and San Diego counties from June 1998 through June 2000. (A) Seven day running averages for 5 sites in Los Angeles County. (B) Seven day running averages for 3 sites in San Diego County. (C) Average precipitation for weather station sites in Los Angeles and San Diego counties. Horizontal lines indicate 0.5 in. (solid line) and 0.25 in. (dashed line) rainfall.

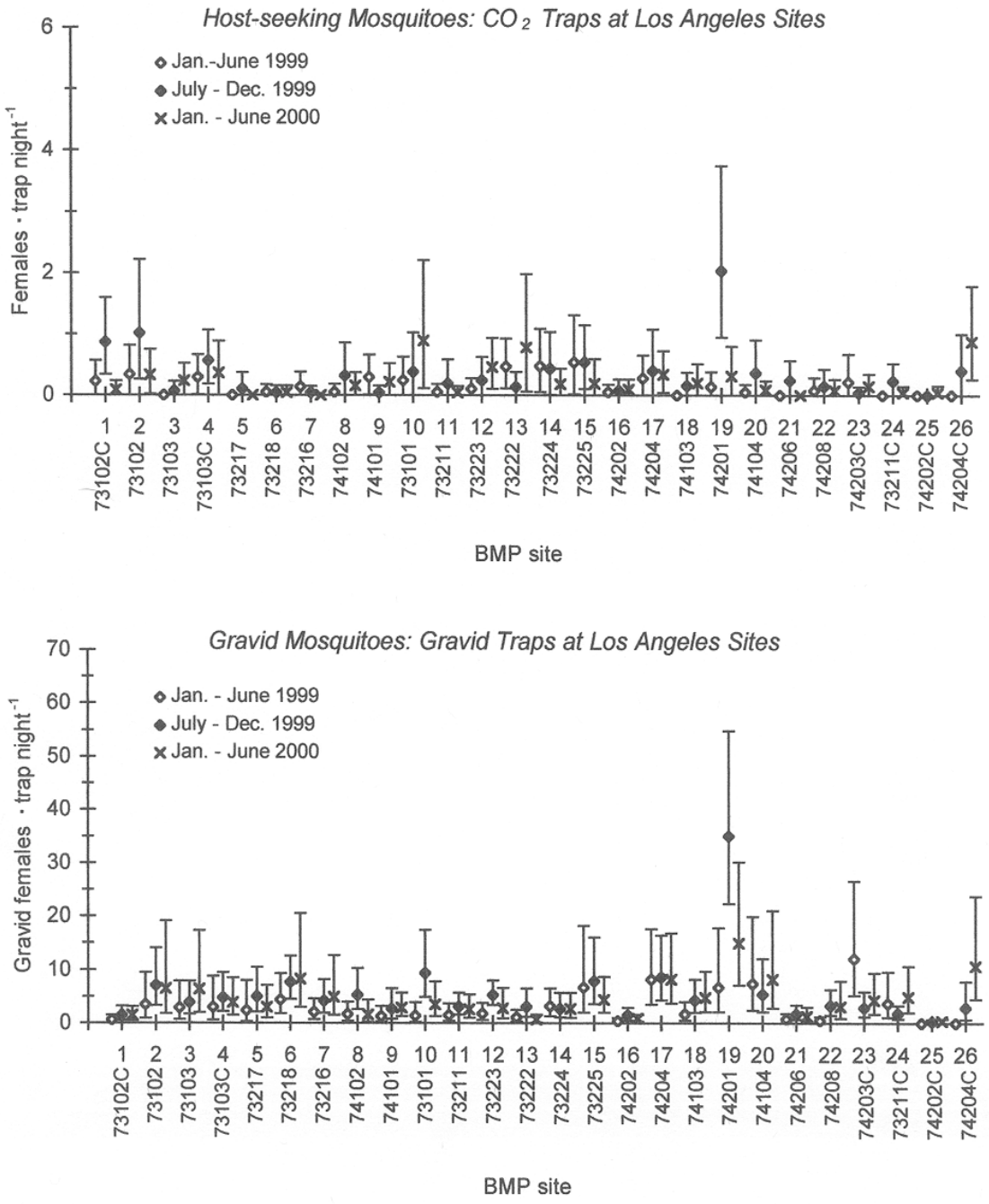

Figure 6. Host-seeking and gravid mosquitoes (± 95% CI) collected at District 7 Retrofit Pilot Program BMP Sites during 1999 and 2000. The abscissa of each plot lists the BMP sites by the number assigned to them during the background monitoring program or, for the added sites, as a continuation of the series above the last number used in each Caltrans district: 22 in District 7 and 12 in District 11. Water quality numbers assigned to BMP sites are listed below background monitoring program site numbers.

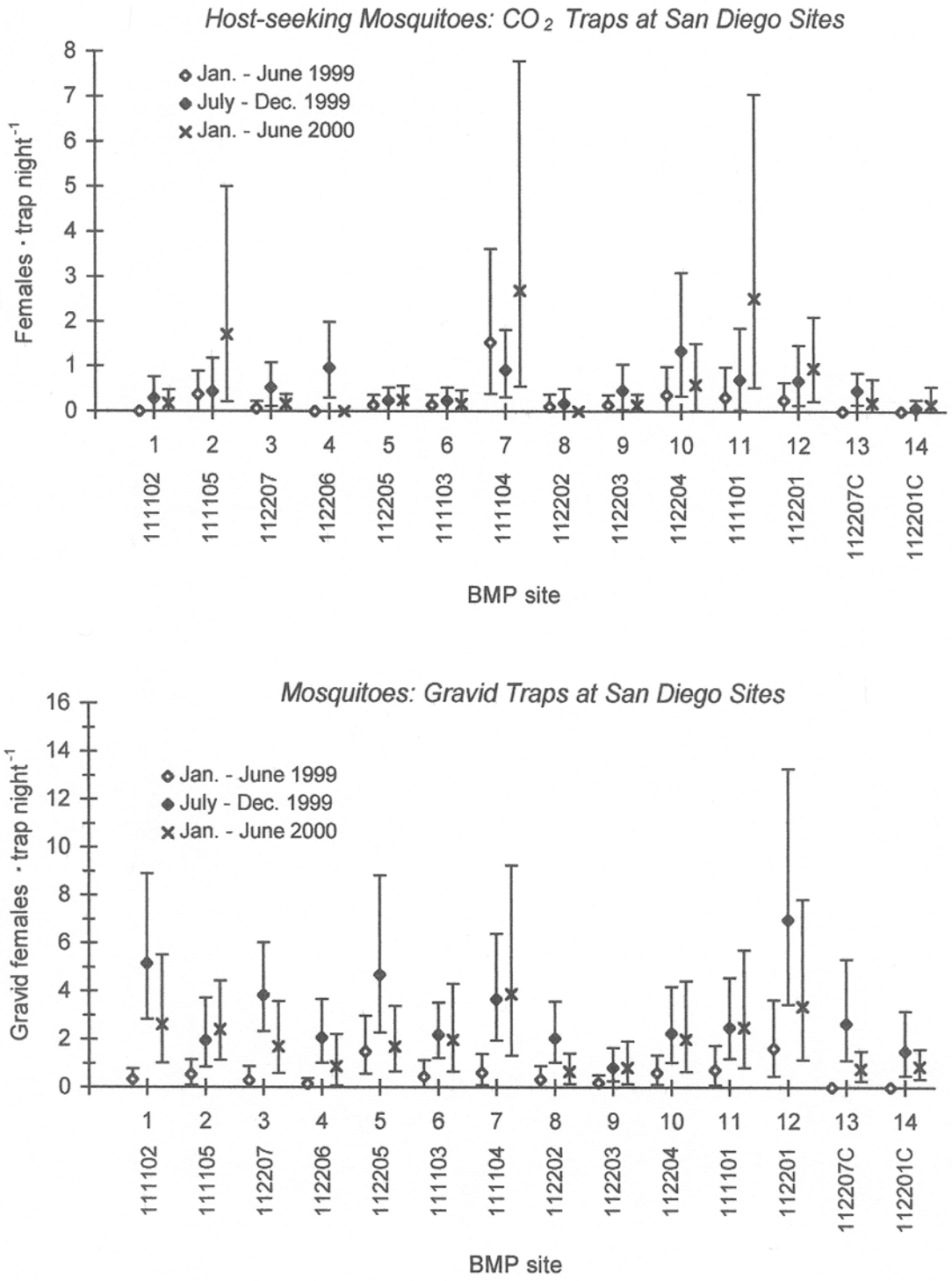

Figure 7. Host-seeking and gravid mosquitoes (± 95% CI) collected at District 11 Retrofit Pilot Program BMP Sites during 1999 and 2000. Numbering on the abscissa is explained in the legend to Figure 6.

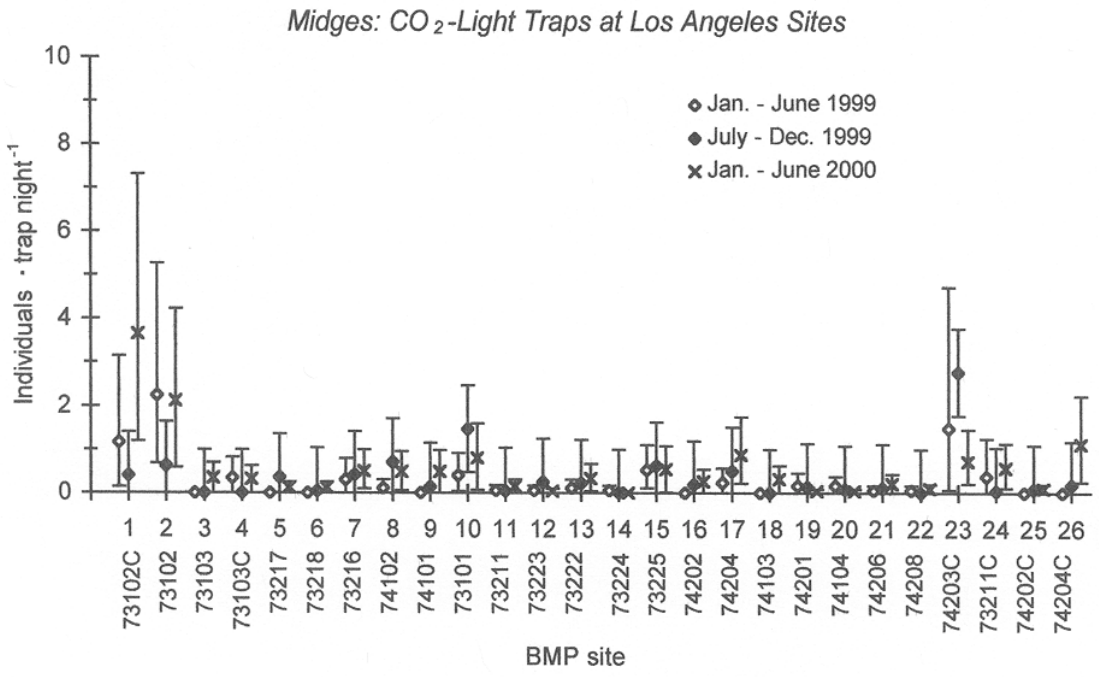

Figure 8. Adult chironomid midges (± 95% CI) collected at District 7 Retrofit Pilot Program BMP Sites during 1999 and January through June 2000. Numbering on the abscissa is explained in the legend to Figure 6.

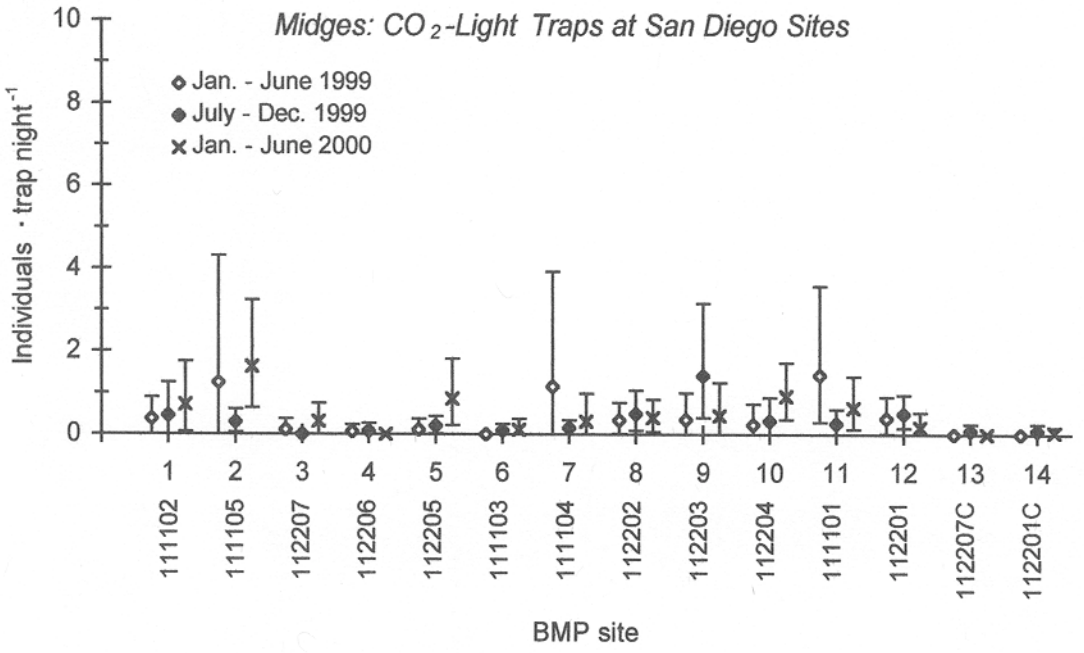

Figure 9. Adult chironomid midges (± 95% CI) collected at District 11 Retrofit Pilot Program BMP Sites during 1999 and January through June 2000. Numbering on the abscissa is explained in the legend to Figure 6.

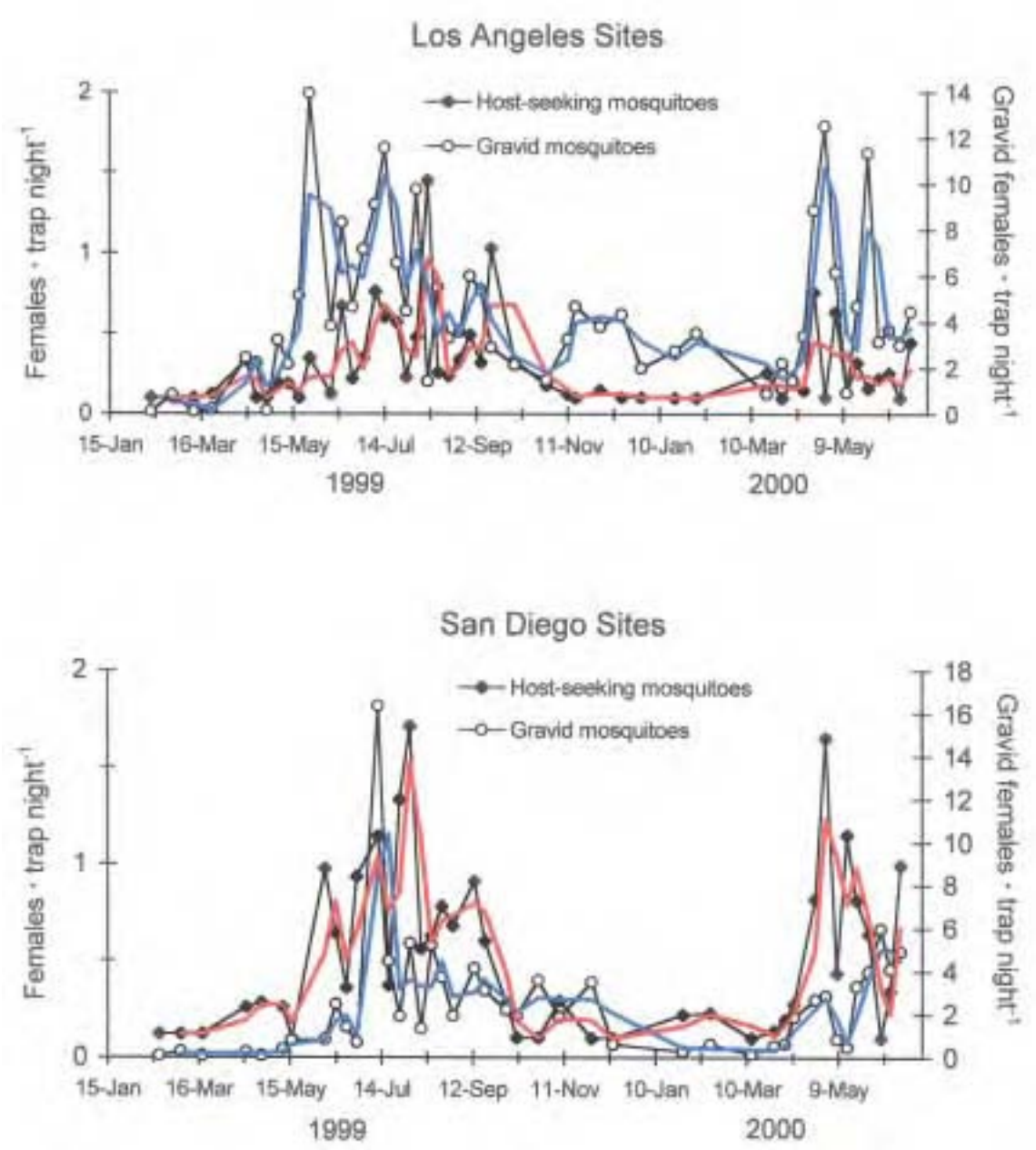

Figure 10. Seasonal trends for host-seeking and gravid mosquitoes (districtwide averages) collected at District 7 (Los Angeles Sites) and District 11 (San Diego Sites) Retrofit Pilot Program BMP Sites during 1999 and 2000. The red line is a 2-point running average for host-seeking mosquitoes. The blue line is a 2-point running average for gravid mosquitoes.

The number of gravid mosquitoes collected during post-construction monitoring, either within each Caltrans district or across both districts, did not differ significantly among stormwater BMP devices (ANOVAs, $P > 0.05$). Variation in the number of gravid mosquitoes collected within and among sites was strongly influenced by site-specific effects and seasonal changes in abundance rather than by a consistent effect of a particular BMP design.

Adult Midges

The number of midges collected by light traps remained low (mean < 5 individuals per trap night) throughout the post-construction monitoring (Figure 8). The small number of midges collected in light traps and the lack of a significant change in midge abundance suggest that the stormwater BMP devices were not producing midges in significant quantities.

District 11 sites: January-June 1999, July - December 1999, January - June 2000

Host-seeking Mosquitoes

Host-seeking activity of mosquitoes at the San Diego BMP stormwater sites during January through June 1999 was not significantly enhanced as compared to the drier part of 1999 (Figure 7). Even though host-seeking mosquito activity at site 11 (I-5/SR-56 EDB, 111101) during May and June 1999 was higher than during July through December, the mosquitoes were being produced in the adjacent saltmarsh and not in the extended detention basin. Host-seeking activity also was low at the added sites (13 and 14).

Host-seeking mosquito activity increased at 4 stormwater BMP sites during the first half of 2000. The mean and variation of the host-seeking mosquito collections during 2000 at two extended detention basins (111105, site 2; 111101, site 11), at the wet basin (111104, site 7) and at the media filter at the Kearny Mesa MS (112201, site 12) were larger than during the first half of 1999.

Gravid Mosquitoes

Gravid mosquito activity during January through June also was not significantly greater than during July though December (Figure 7). Gravid mosquito activity at sites 13 and 14 was as high, or higher, than at sites 1 - 12. Unlike the Los Angeles basin where gravid mosquito activity increased markedly in mid-May, gravid mosquito activity at the San Diego sites did not increase abruptly until mid July when the mean for the number of gravid females per trap night increased from approximately 1 to 17. Gravid mosquito activity at the San Diego sites was comparatively lower than at most of the Los Angeles sites. There is no evidence of enhanced gravid mosquito activity at the San Diego BMP stormwater sites during May and June 1999.

As compared to January through June 1999, gravid mosquito activity during January through June 2000 increased appreciably at all trapping sites except 112205 (SR-78/Melrose Dr. Bioswale, site 5), 112202 (Escondido MS MF, site 8) and 112201 (Kearny Mesa MS MF, site 12). Gravid mosquito activity increased even though rainfall during April through June 2000 was approximately 25% of that during 1999. Gravid mosquito activity increased almost two-fold near the media filter at the Kearny Mesa MS (112201); the mean for gravid collections during 2000 was not greater than the upper 95% CI for 1999. Even though gravid mosquito collections during 2000 were generally larger than during the first half of 1999, gravid mosquito activity during 2000 was either lower or not appreciably different from that during the latter half of 1999 (Figure 7).

Adult Midges

The number of midges collected by light traps remained low (mean < 2 individuals per trap night) throughout the postconstruction monitoring (Figure 9). The small number of midges collected in light traps and the lack of a significant change in midge abundance suggest that the stormwater BMP devices were not producing midges in significant quantities.

Seasonal Trends of Abundance and Species Composition

The greatest period of adult mosquito activity typically begins in early April and ends in late October. This phenology is strongly influenced by weather; host-seeking and egg-laying activities may occur before and after the aforementioned dates if the weather is warm enough to permit flight (i.e., air temperature ≥ 10-12^{o}C [50-55^{o}F]). The potential for colonization of standing water and blood-feeding by overwintering adult mosquitoes in southern California is greater than for many other regions in the U.S. because winter temperatures are rarely below 0^{o}C for extended periods. Whereas the annual pattern of mosquito activity is usually unimodal along the western coast of southern California, other patterns of activity can occur in the inland regions of southern California, where summer is hotter than along the coast, and activity patterns change as a function of latitude (Bohart and Washino 1978).

Host-seeking activity at the stormwater BMP sites increased in May (District 11) or June (District 7) 1999 and declined during late September and October (Figure 10). Host-seeking activity during 2000 increased during early April, earlier than during 1999. Gravid mosquito activity in District 7 increased earlier than in District 11. The abundance of egg-laying mosquitoes at Los Angeles stormwater BMP sites increased markedly during April in both 1999 and 2000 (Figure 10). Gravid mosquito activity increased comparatively later at the San Diego sites, in early June 1999 and mid-May 2000. The potential for colonization of standing water during the late autumn and winter 1999-2000 was greater at the Los Angeles sites than for the San Diego sites, as evidenced by the peaks of egg-laying activity observed during warm weather in November 1999 and late January 2000 (Figure 10).

Thirteen mosquito species were collected during post-construction monitoring. The diversity of the mosquito assemblage and the relative abundance of the predominant species in the gravid traps were similar to the background monitoring study during July through December 1998. The mosquito assemblage in District 11 was more diverse (12 species vs. 10 species) than that found in District 7 and reflects the diversity of habitats adjacent to the stormwater BMP sites in San Diego. Unlike 1998 when three *Culex* mosquitoes were collected by CO_2-baited traps in nearly equal relative abundance in District 11, *Cx. quinquefasciatus* represented nearly 60% of the mosquitoes collected during 1999 through 2000. Based on the total number of individuals collected at each site, three species were predominant in collections by CO_2-baited light traps (Table 3): *Culex erythrothorax* (14%), *Cx. tarsalis* (17%) and *Cx. quinquefasciatus* (56%). In the more urbanized environments of District 7, *Cx. quinquefasciatus* was 77% of the mosquitoes collected by CO_2-baited light traps. The next most abundant species were a group of mosquitoes that accounted for 4-6% of the mosquitoes in CO_2-baited light trap catches: *Cx. tarsalis* (6%), *Culiseta incidens* (6%), *Anopheles franciscanus* (4%) and the predominant vector of human malaria in southern California, *An. hermsi* (4%). Whereas, *Cx. erythrothorax* is not a significant

public health concern, *Cx. tarsalis* and *Cx. quinquefasciatus* are efficient vectors of pathogens to humans and livestock (Meyer et al. 1988).

Gravid trap collections were mostly *Cx. quinquefasciatus*. The southern house mosquito was 99.5% and 92.1% of the individuals collected in District 7 and District 11, respectively (Table 3).

Table 3. Relative abundance (proportion ± SE) of mosquitoes collected by two trap types at District 7 and District 11 BMP sites during 1999 and 2000. Comparisons are based on the relative abundance of mosquitoes at each BMP site calculated for the entire period of background monitoring. N = 26 for District 7. N = 14 for District 11.

	District 7, Los Angeles		District 11, San Diego	
Species	CO2-baited light	Gravid	CO2-baited light	Gravid
Aedes dorsalis	0 ± 0	0 ± 0	0.001 ± 0.001	0 ± 0
Ae. nigromaculis	0.002 ± 0.020	0 ± 0	0.006 ± 0.006	0 ± 0
Ae. squamiger	0.003 ± 0.024	0 ± 0	0.023 ± 0.013	0.004 ± 0.002
Ae. taeniorhynchus	0 ± 0	0 ± 0	0.063 ± 0.046	0.003 ± 0.002
Anopheles franciscanus	0.040 ± 0.061	<0.001 ± 0.005	0.005 ± 0.004	0.001 ± 0.001
An. hermsi	0.043 ± 0.068	<0.001 ± 0.007	0.015 ± 0.014	0.025 ± 0.024
Culex erythrothorax	0.005 ± 0.033	0.001 ± 0.016	0.135 ± 0.076	0.028 ± 0.015
Cx. quinquefasciatus	0.765 ± 0.102	0.995 ± 0.016	0.564 ± 0.096	0.921 ± 0.033
Cx. stigmatosoma	0 ± 0	<0.001 ± 0.003	0 ± 0	0 ± 0
Cx. tarsalis	0.064 ± 0.077	0.002 ± 0.012	0.174 ± 0.055	0.011 ± 0.004
Culiseta incidens	0.057 ± 0.006	0.001 ± 0.008	0.013 ± 0.006	0.003 ± 0.001
Cs. inornata	0.006 ± 0.029	<0.001 ± 0.003	0.032 ± 0.012	0.002 ± 0.001

Seven other species were rarely collected (< 0.2%) at the Los Angeles stormwater BMP sites. *Culex tarsalis* and *An. hermsi* were approximately 3% of the individuals collected in District 11 gravid traps. Because *Cx. quinquefasciatus* is readily attracted to the organic infusion (Reisen 1995), the predominance of the southern house mosquito in collections is not unexpected.

Paired Comparisons of Stormwater BMP Sites and "Control" Locations

District 7 sites: 1999 and 2000

Host-seeking Mosquitoes

Host-seeking mosquito abundance differed significantly between stormwater BMP sites and "control" sites for 67% (4 of 6) of the comparisons for the period between June through December 1999. However, *a priori* expectations were that mean mosquito

abundance at the paired Pacoima sites (2 vs. 1 [control], and 3 vs. 4 [control]) would not differ significantly because stormwater BMP devices were not operational. Significantly more host-seeking mosquitoes were collected at sites 2 and 4 than were collected at sites 1 and 3, respectively. Whereas the sites might function adequately as paired experimental units and controls for water quality studies, the mosquito populations at each pair of sites differed significantly. Nevertheless, the number of host-seeking mosquitoes collected each of at the four sites was typically small (< 5 individuals per trap night).

For the other 1999 comparisons, significantly fewer mosquitoes were collected at site 26 as compared to site 17 (74204, Termination P&R Media Filter; $t_{13} = 2.59$, $P = 0.01$) and site 25 versus site 16 (74202, Eastern Regional MS Media Filter; no *t*-test was run because variance = 0 for site 25). No host-seeking mosquitoes were collected at site 25. The number of host-seeking mosquitoes collected at sites 24 vs. 11 (73211, Altadena MS) and 23 vs. 7 (74203, Foothill MS) did not differ significantly during 1999.

When the same comparisons were run for spring 1999, host-seeking mosquitoes were not collected at 3 of the 4 (sites 24-26) of the added "control" locations and only 1 mosquito was collected at site 23. Even though the host-seeking populations were in low abundance, mosquitoes were collected at all stormwater BMP devices during the same period. The numbers of host-seeking mosquitoes collected at sites 1 vs. 2 did not differ significantly (Figure 6); however, significantly fewer host-seeking mosquitoes were collected at site 3 than were collected at site 4 (Figure 6).

During spring 2000 (April through June), significantly more host-seeking mosquitoes were collected at sites 17 (74204, Termination P&R Media Filter; $t_{15} = 1.86$, $P = 0.04$) and 7 (73216, Foothill MS Media Filter; no host-seeking mosquitoes were collected at the control site) than at the respective control locations. The number of host-seeking mosquitoes collected at sites 11 (73211, Altadena MS Biostrip + IT) and 16 (74202, Eastern Regional MS Media Filter) did not differ significantly from that collected at the control sites. Also, the number of host-seeking mosquitoes collected at the two pairs of Pacoima sites did not differ significantly.

Gravid Mosquitoes

Gravid mosquito abundance differed significantly between stormwater BMP sites and "control" sites for 50% (3 of 6) of the comparisons for the period between June through December 1999. Significantly fewer mosquitoes were collected at the site 26 as compared to site 17 (74204, Termination P&R Media Filter; $t_{13} = 2.59$, $P = 0.01$), site 25 versus site 16 (74202, Eastern Regional MS Media Filter; $t_{13} = 2.126$, $P < 0.03$) and site 2 versus 1 (no operational stormwater BMP device; $t_{32} = 5.22$, $P < 0.001$). The number of gravid mosquitoes collected at sites 24 vs. 11 (73211, Altadena MS Biostrip + IT), 23 vs. 7 (74203, Foothill MS Media Filter) and 3 (no operational stormwater device) vs. 4 did not differ significantly (*t*-tests, $P > 0.05$) during 1999. Again, as previously stated, *a priori* expectations were that mean abundance at the paired Pacoima sites (2 vs. 1

[control], and 3 vs. 4 [control]) would not differ significantly because stormwater devices were not operational.

When the same comparisons were run for the spring 1999, gravid mosquitoes were not collected at "control" locations 25 and 26, and significantly fewer mosquitoes were collected at site 24 ($t_4 = 2.13$, $P = 0.05$) than at the media filter. The mean abundance of gravid mosquitoes at sites 7 and 23 did not differ significantly. Therefore, mosquito abundance at "control" locations was lower for 75% of the paired site comparisons. As expected, the numbers of gravid mosquitoes collected at sites 1 vs. 2 and 4 vs. 3 did not differ significantly (*t*-tests, $P > 0.05$).

During spring 2000 (April through June), significantly more gravid mosquitoes were collected at the majority of BMP sites paired with control sites. Gravid mosquito collections were significantly larger at two of the sites containing media filters (74204, $t_7 = 2.48$, $P = 0.02$; 74202, $t_{10} = 2.07$, $P = 0.03$), a site with an infiltration trench and bioswale (73211, $t_{11} = 1.92$, $P = 0.04$), and at one of the Continuous Deflection Separator sites (site 2, 73102, $t_7 = 3.00$, $P = 0.006$). The number of host-seeking mosquitoes collected at sites 16 (74202, Media filter) and site 3 (73103, CDS) did not differ significantly from that collected at the control sites. However, the abundance of gravid mosquitoes increased at all of the Pacoima sites following the installation of the CDS units; the maximum number of gravid mosquitoes collected at the two CDS sites (250 and 100 females per trap night; Appendix B) was markedly higher than at the control locations (26 and 25 females per trap night) and catches at the CDS sites were larger than at the respective control sites from late May through June 2000.

District 11 sites: 1999 and 2000

Host-seeking Mosquitoes

Host-seeking mosquito abundance differed significantly between stormwater BMP sites and "control" sites for 50% (2 of 4) of the comparisons for the period between June through December 1999. The mean abundance of host-seeking mosquitoes at stormwater BMP sites 14 (112201C, $t_{16} = 2.77$, $P < 0.007$) and 6 (111103, $t_{26} = 3.01$, $P < 0.003$) differed significantly from sites 12 (112201, Kearny Mesa MS Media Filter) and 7 (111104, I-5/La Costa Ave. wet basin), respectively. Host-seeking mosquito abundance did not differ significantly between sites 13 vs. 3 (112207, Carlsbad MS Biostrip and IT) and 8 (Escondido MS) vs. 1 (111102, I-15/SR-78 EDB).

The same results were found for comparisons for the wetter period of 1999 (14 vs. 12; $t_3 = 2.57$, $P = 0.04$; 7 vs. 6: $t_{10} = 2.82$, $P < 0.009$) and spring 2000 (14 vs. 12; $t_9 = 2.10$, $P < 0.02$; 7 vs. 6: $t_9 = 3.01$, $P < 0.007$). The number of host-seeking mosquitoes collected at "control" sites never significantly exceeded that collected at paired stormwater BMP sites.

Gravid Mosquitoes

Gravid mosquito abundance differed significantly between stormwater BMP sites and "control" sites for 50% (2 of 4) of the comparisons for the period between June through December 1999. The mean abundance of gravid mosquitoes at stormwater BMP sites 14 (t_{16} = 4.91, $P < 0.001$) and 8 (t_{26} = 3.59, $P < 0.001$) was significantly lower than at sites 12 and 1, respectively. Gravid mosquito abundance did not differ significantly between sites 13 vs. 3 and 6 vs. 7. The same results were found comparisons for a subset of 1999 dates during the wetter period. In no instance did the mean abundance of gravid females at "control" locations significantly exceed that observed at stormwater BMP sites.

During spring 2000, significantly more gravid mosquitoes were collected at 3 of the 4 stormwater BMP sites than at their respective paired control locations (112201, Kearny Mesa MS Media Filter, t_{10} = 3.88, $P < 0.003$; 112207, t_{10} = 2.92, $P < 0.006$; 111102, I-15/SR-78 EDB, t_{10} = 3.77, $P < 0.002$). The abundance of gravid mosquitoes at the wet basin and the La Costa Ave. infiltration basin did not differ significantly.

Conclusions for Adult Dipteran Monitoring at Caltrans Retrofit Pilot Program BMP Sites

1) There were no significant differences in the abundance of host-seeking mosquitoes and midges between July - December 1998 and July - December 1999. Several sites showed increased gravid mosquito activity during 1999.

   There are several factors that need to be considered when evaluating the interannual comparisons for July through December. First, two periods of essentially no standing water are being compared. During the preconstruction period, sites did not contain water and there was very little rainfall during the postconstruction period from July - November 1999. Second, any differences that might have occurred due to vector production from the sites would have been lessened because of the control efforts focused on the immature mosquitoes. There was a high degree of concordance between increased host-seeking activity and the presence of larvae at many Los Angeles sites during early 1999. Last, BMP designs which are likely to produce/attract mosquitoes (i.e., contain standing water for > 5 days) were not fully operational during the period of greatest precipitation in 1999.

2) For one-half to three-quarters of the comparisons, mosquito abundance at "control" locations was significantly lower than at paired stormwater BMP sites, particularly media filters. The number of host-seeking or gravid mosquitoes collected at sites that were added in District 7 (sites 23-26) and District 11 (sites 13-14), and designated as "controls", was never significantly greater than the abundance of mosquitoes at paired, operational stormwater BMP sites (i) during June through December 1999, (ii) during a shorter, but comparatively wetter, period during June through early July

1999, and (iii) during spring 2000. This trend also was true for 2 stormwater BMP sites (sites 6 and 8) in District 11 which were subsequently designated as "control" locations.

Again, several factors need to be considered when evaluating these findings in relation to stormwater BMPs. First, the Pacoima sites (sites 1-4) which were expected not to differ significantly, in fact, did differ significantly for some comparisons. These differences reflect inherent differences in the abundance of mosquitoes among the sites which must be considered when intersite comparisons are being made. Second, "control" locations at comparatively small maintenance stations (i.e., site 7 in District 7) might not be far enough away from the stormwater devices, or other potentially attractive sites, to be unaffected by mosquito activity focused nearby. Female *Culex* can emigrate from developmental sites at rates of nearly 1 km per night. Third, even though a site might be designated as a "control" location, local environmental factors (i.e., adjacent offsite water sources, trees, edaphic factors, etc.) and ongoing activities at maintenance yards (e.g., piling of mulch which would be attractive to resting and gravid mosquitoes (i.e., site 13 in District 11), activities that create standing water) unrelated to the stormwater BMP devices can influence mosquito abundance. These considerations also apply to evaluation of mosquito activity at stormwater BMP devices and emphasize the importance of larval surveys as *prima facie* evidence of mosquito production.

3) Activity of mosquito populations was low. Averaged across sites, host-seeking activity was < 2 individuals per trap night and gravid activity was < 15 individuals per trap night. The same was true for midges collected by CO_2-light traps. Unlike treatment wetlands receiving wastewater where host-seeking mosquito populations can be hundreds to thousands of individuals per trap night, host-seeking mosquito populations at the stormwater BMPs were comparatively smaller. Nevertheless, BMPs containing standing water, such as CDS units, MCTTs, and wet basins, require continuous vector monitoring. Mosquito activity at the wet basin increased over time and was probably associated with increased coverage by emergent vegetation.

4) Adult midge activity at stormwater BMP sites did not increase significantly above the background levels which were present prior to operation of the stormwater BMP retrofit devices. This observation suggests that none of the stormwater devices was producing significant numbers of chironomid midges.

5) Gravid mosquitoes may provide a better measure of vector activity than do host-seeking mosquitoes because there are more gravid mosquitoes to sample. On average, gravid mosquito activity was 10 to 13-fold greater than host-seeking activity at most of the trapping sites. There was an earlier onset of gravid mosquito activity at the Los Angeles sites than at the San Diego sites. Host-seeking activity of *Culex* mosquitoes was comparable in both regions; the apparently earlier onset of host-seeking activity in San Diego during 1999 was the result of non-BMP related mosquito activity.

6) There is an indication of significantly greater adult mosquito activity at several sites during the spring, particularly at the sites near Cerritos and along the I-605 freeway. While these results re-emphasize the potential of standing water to produce insects of public health significance, the design features that caused mosquito production, at BMP stormwater devices (biostrips and bioswales) that would not have been expected to produce mosquitoes, have been corrected.

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