In cooperation with the Sacramento Regional County Sanitation District

Dissolved Pesticide Concentrations in the Lower Sacramento River and Its Source Waters, California, 2016

Open-File Report 2018–1153

U.S. Department of the Interior
U.S. Geological Survey

Cover images: Fall scenes of the Sacramento River, 2016.
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U.S. Geological Survey
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Conversion Factors

International System of Units to U.S. customary units

Multiply	By	To obtain
	Length	
millimeter (mm)	0.03937	inch (in.)
micrometer (µm)	25,400.0	inch (in.)
meter (m)	3.281	foot (ft)
	Area	
square kilometer (km^2)	0.3861	square mile (mi^2)
	Volume	
microliter (µL)	29,573.5	ounce, fluid (fl. oz)
milliliter (mL)	29.5735	ounce, fluid (fl. oz)
liter (L)	33.81402	ounce, fluid (fl. oz)
cubic meter (m^3)	35.31467	cubic feet (ft^3)
	Flow rate	
milliliter per minute (mL/min)	0.033814	ounce, fluid per minute (fl. oz/min)
	Mass	
milligram (mg)	28,349.5	ounce, avoirdupois (oz)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as

$$°F = (1.8 \times °C) + 32.$$

Datums

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

Altitude, as used in this report, refers to distance above the vertical datum.

Supplemental Information

Specific conductance is given in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Concentrations of chemical constituents in water are given in either milligrams per liter (mg/L) or micrograms per liter (µg/L), or nanograms per liter (ng/L).

Abbreviations

3,4-DCA	3,4-Dichloroaniline
DCM	dichloromethane
DCPMU	N-3,4-dichlorophenyl-N-methyl-urea
EtOAc	ethyl acetate
GC/MS	gas chromatography with mass spectrometry
LC/MS/MS	liquid chromatography with tandem mass spectrometry
OCRL	Organic Chemistry Research Laboratory
Regional San	Sacramento Regional County Sanitation District
SPE	solid phase extraction
USGS	U.S. Geological Survey

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Abstract

As part of a collaborative study designed to better understand water-quality conditions in the Sacramento River, surface-water samples were collected from the lower Sacramento River and five of its tributaries and then analyzed by the U.S. Geological Survey for a suite of 162 current-use pesticides and pesticide degradates. Samples were collected in May and October 2016 at 16 sites on the Sacramento River and its tributaries. Samples were analyzed for pesticide concentrations by using gas chromatography with mass spectrometry and liquid chromatography with tandem mass spectrometry laboratory methods.

A total of 27 pesticides and pesticide degradates were detected in the water samples collected during the study (12 herbicides, 9 insecticides, 5 fungicides, and 1 synergist). Two herbicides were detected in the suspended sediments filtered from the water samples. Pesticides were detected in 100 percent of the water samples, and mixtures of two or more pesticides were detected at all sites and in all but four samples. The pesticides detected most frequently in the May and October sampling periods were the herbicides hexazinone (detected in 88 percent of the water samples), and diuron (84 percent), and the fungicide azoxystrobin (84 percent). Pesticide concentrations ranged from below the method detection limits to 576 nanograms per liter (clomazone). All pesticides were detected at concentration levels lower than the U.S. Environmental Protection Agency's aquatic life benchmarks (U.S. Environmental Protection Agency, 2017).

During the May sampling period, the fungicides boscalid and azoxystrobin (both 94 percent); the herbicides clomazone, diuron, and hexazinone (all 94 percent); thiobencarb (88 percent); and metolachlor (81 percent) were the most frequently detected compounds. During the October sampling period, the herbicides hexazinone (81 percent) and diuron (75 percent) and the herbicide degradates 3,4-dichloroaniline (75 percent) and N-3,4-dichlorophenyl-N-methyl-urea (50 percent), along with the fungicide azoxystrobin (75 percent) and the insecticide methoxyfenozide (63 percent), were the most frequently detected compounds.

Introduction

The Sacramento River is the largest in California with an average annual discharge of over 760 million cubic meters. It supplies nearly two-thirds of the annual freshwater to the Sacramento–San Joaquin Delta (hereinafter Delta; California Department of Water Resources, 1993, 1994). The Sacramento River and the Delta are areas of critical habitat for numerous species of concern, including Chinook salmon (Sommer and Mejia, 2013), which are present in the Sacramento River year-round. The recent simultaneous decline in abundance of several pelagic fish species in the Delta has become known as the pelagic organism decline (POD; Sommer and others, 2007). These species and many others rely, in part, on the river's primary producers to support their food chain. Important changes in the pelagic food web have been documented in the Delta during the last two decades, indicating a decline in primary productivity. Physical processes, including water residence times and turbidity, nutrient availability, including anthropogenic loading from effluent (Dugdale and others, 2012; Parker and others, 2012); the presence of contaminants, and predation from invasive clams (Winder and Jassby, 2011; Cloern and Jassby, 2012; Kimmerer, and others, 2012) have all been examined as potential mechanisms affecting primary production. Dissolved anthropogenic contaminants such as current-use pesticides could also have a negative effect on primary producers.

Pesticides, including herbicides, insecticides, and fungicides associated with agricultural and urban runoff, have been detected in the Delta throughout the year and the types and concentrations of these pesticides vary based largely on their use in the Sacramento River watershed (Dileanis and others, 2002; Kratzer and others, 2002; Orlando and Kuivila, 2005; Weston and Lydy, 2010; Orlando and others, 2013; Orlando and others, 2014). Previous studies have shown that environmental levels of herbicides can inhibit phytoplankton growth (Peterson and others, 1994; Ricart and others, 2009). The herbicide diuron, when combined with other herbicides, has been shown to have additive toxic effects (Magnusson and others, 2010), and in mixtures with its degradates, diuron has been shown to act synergistically to inhibit phytoplankton growth (Gatidou and Thomaidis, 2007).

In addition to herbicides, many insecticides from urban and agricultural sources enter the Sacramento River and either dissolve in the water column or sorb onto particulate matter. Pyrethroids, which are replacing organophosphate insecticides on the market, target invertebrates and could pose a threat to non-target benthic species. Pyrethroids are hydrophobic (Laskowski, 2002), tend to be detected in suspended and bed sediments (Hladik and others, 2009), and are known to be highly toxic to aquatic organisms (Hill, 1989).

To better understand the water-quality conditions in the Sacramento River, the Sacramento Regional County Sanitation District (Regional San) investigated the occurrence of a variety of constituents, including nutrients and pesticides in the Sacramento River. As part of this investigation, the U.S. Geological Survey (USGS) characterized the occurrence and concentrations of current-use pesticides and pesticide degradates in the lower Sacramento River and its source waters during the spring and fall of 2016. Surface-water samples for pesticide analysis were collected over 5-day periods in May and October 2016 at 16 sites on the Sacramento River and its tributaries (table 1). These sites include pesticide input from catchments representative of various land uses in the lower Sacramento River watershed (fig. 1). Sampled locations can be classified as either "indicator" sites, at locations targeting specific environmental influences (such as agricultural runoff), or as sites considered representative "integrators," characterized by more complex environmental inputs (Gilliom and others, 1995; Domagalski and others, 1998; Panshin and others, 1998). The indicator sites in this study included three agricultural drains and two larger rivers, the Feather and American, all of which are tributary to the Sacramento River. The larger tributaries are integrators of their own watersheds and receive much of their water from areas upstream of agricultural and urban inputs; however, because only one node was sampled on each of these tributaries, they are classified as indicator sites with respect to the Sacramento River.

Purpose and Scope

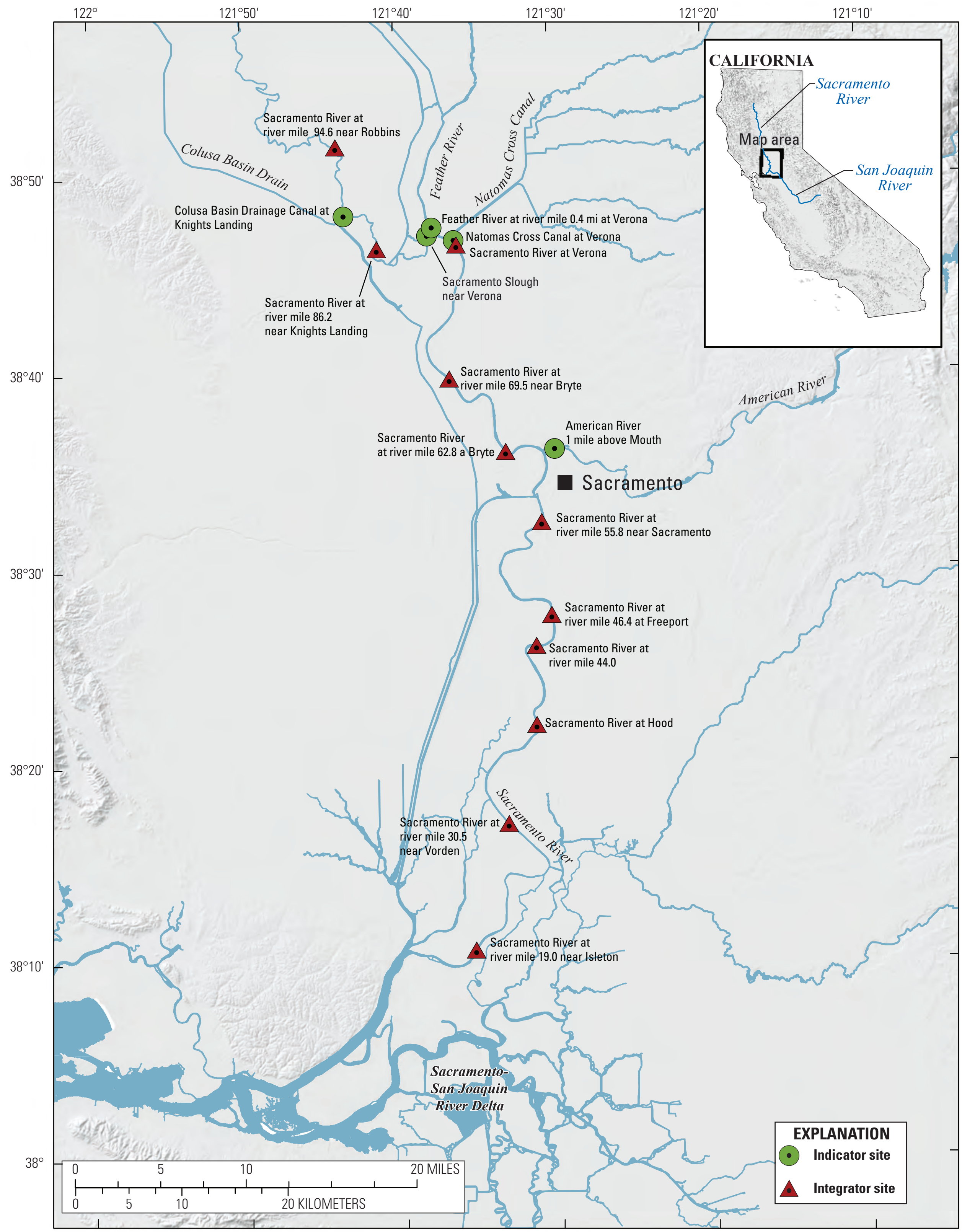
This report describes the methods and procedures used in measuring dissolved pesticide concentrations in filtered water samples and associated suspended sediments collected from 16 sites in May and October 2016. Results are presented for a suite of 162 current-use pesticides and pesticide degradates in surface water.

Table 1. Surface-water sampling sites in the Sacramento River watershed, California.

[NWIS, National Water Information System; USGS, U.S. Geological Survey]

USGS station name	USGS NWIS station number	Latitude[1]	Longtitude[1]	Site type
SACRAMENTO R A R MILE 94.6 NR ROBBINS CA	385137121440101	38.86027	–121.73368	Integrator
COLUSA BASIN DRAINAGE CANAL A KNIGHTS LANDING CA	384804121432401	38.80108	–121.72325	Indicator
SACRAMENTO R A R MILE 86.2 NR KNIGHTS LANDING CA	384623121411401	38.77300	–121.68728	Integrator
SACRAMENTO SLOUGH NR VERONA CA	384649121381101	38.78018	–121.63746	Indicator
FEATHER R A R MILE 0.4 MI A VERONA CA	384726121373901	38.79058	–121.62765	Indicator
NATOMAS CROSS CANAL A VERONA CA	384649121361501	38.78028	–121.60412	Indicator
SACRAMENTO R A VERONA CA	11425500	38.77435	–121.59829	Integrator
SACRAMENTO R A R MILE 69.5 NR BRYTE CA	383944121363901	38.66222	–121.61072	Integrator
SACRAMENTO R A R MILE 62.8 A BRYTE CA	383600121330301	38.60008	–121.55092	Integrator
AMERICAN R 1 MI AB MOUTH CA	383609121293200	38.60240	–121.49329	Indicator
SACRAMENTO R A R MILE 55.8 NR SACRAMENTO CA	383225121304601	38.54040	–121.51288	Integrator
SACRAMENTO R A R MILE 46.4 A FREEPORT CA	382740121301201	38.46112	–121.50347	Integrator
SACRAMENTO R A R MILE 44.0 CA	382605121310401	38.43463	–121.51884	Integrator
SACRAMENTO R A HOOD CA	382205121311300	38.36797	–121.52134	Integrator
SACRAMENTO R A R MILE 30.5 NR VORDEN CA	381703121331101	38.28423	–121.55307	Integrator
SACRAMENTO R A R MILE 19.0 NR ISLETON CA	381038121352501	38.17715	–121.59023	Integrator

[1]All locations reference the North American Datum of 1983.



Base modified from U.S. Geological Survey and other Federal and State digital data, various scales; Albers Equal Area Conic projection, standard parallels are 29°30′ N. and 45°30′ N.; North American Datum of 1983

Figure 1. Locations of indicator and integrator sampling sites in the lower Sacramento River watershed, California.

Study Area

The Sacramento River watershed spans nearly 70,000 square kilometers (km^2) in central northern California and extends from the Delta to the Oregon border (California Department of Water Resources, 1993). The Sacramento River flows southward down the northern half of the Central Valley known as the Sacramento Valley. Land cover is largely forest in the mountainous upper headwaters of the basin, whereas agriculture dominates land use in the valley (approximately 5,128 km^2, U.S. Geological Survey, 2014). Major crops by area include rice, alfalfa, almonds, peaches, prunes, and walnuts. Because of the intense levels of cultivation, irrigated and urban water use, and population (roughly 2 million people, U.S. Census Bureau, 2011), the Sacramento River and its tributaries flowing through the valley are subject to inputs from agricultural and urban runoff, discharge from storm drains, and wastewater treatment-plant effluents at many locations; thus, there is increased risk for elevated pesticide concentrations in the valley's surface waters (Domagalski and Dileanis, 2000).

Procedures and Methods

Basic water-quality parameters (water temperature, specific conductance, pH, and dissolved oxygen concentration) were measured at the time of sample collection (table 2). Water samples were transported to the USGS Organic Chemistry Research Laboratory (OCRL) in Sacramento, California, and analyzed for a suite of 162 current-use pesticides using two methods: (1) gas chromatography with mass spectrometry (GC/MS) and (2) liquid chromatography with tandem mass spectrometry (LC/MS/MS). Extensive quality-control (QC) sampling was also performed for each method, including field blanks, field replicates, and laboratory matrix-spike and matrix-spike-replicate samples.

Sample Collection

Surface-water samples were collected by Regional San staff from the lower Sacramento River and its tributaries at 16 sites (table 1) in May and October 2016. Samples were collected in accordance with the Surface Water Ambient Monitoring program (SWAMP; California State Water Resources Control Board, 2014) protocols, with samples collected mid-channel at 0.5-meter (m) depth using a peristaltic pump from the Regional San's research vessel. Environmental and quality-control grab samples were collected in 1-liter baked amber bottles from all sites over a 5-day period. Following collection, samples were placed on ice and transported to the USGS OCRL for extraction and analysis.

Pesticide Extraction and Analysis

Extraction and analysis were performed in the laboratory within 24 hours of sample collection. Water samples were filtered through pre-weighed, baked 0.7-micrometer (µm) glass-fiber filters (Grade GF/F, Whatman, Piscataway, New Jersey) to remove suspended material. The filter papers containing the suspended sediments were dried at room temperature overnight (in the dark), then stored in a freezer at –20 degrees Celsius (°C) until extraction.

Sample Extraction

The full extraction procedure and instrumental analysis by LC/MS/MS is described in Hladik and Calhoun (2012). Filtered water samples were spiked with the recovery surrogate standards monuron (Chem Service, West Chester, Pennsylvania) and imidacloprid-d_4 (Cambridge Isotope Laboratories, Andover, Massachusetts). Each sample was then passed through an Oasis Hydrophilic Lipophilic Balance (HLB) solid-phase extraction (SPE; 6 milliliters [mL], 500 milligrams [mg]; Waters, Milford, Massachusetts) cartridge that had been cleaned with one column volume of dichloromethane (DCM), followed by one column volume of acetone and two column volumes of deionized water. During this process, the water samples were pumped through the SPE cartridge at a flow rate of 10 milliliters per minute (mL/min); the cartridge was then dried under nitrogen gas until the SPE sorbent was dry. The analytes were eluted with 10 mL of 50:50 DCM:acetone, and the eluent was then evaporated to less than 0.5 mL using a gentle stream of dry nitrogen gas, solvent-exchanged into acetonitrile, and further evaporated to 0.2 mL. The internal standard (20 microliters [uL] of a 5-nanogram per microliter [ng/µL] solution of $^{13}C_3$-caffeine; Cambridge Isotope Laboratories) was then added to the sample. Lastly, the sample extracts were stored in a freezer at –20 °C until analysis (up to 30 days).

Table 2. Water-quality parameters measured in samples collected at surface-water sites in the Sacramento River watershed, California, May and October 2016.

[Numbers in brackets are U.S. Geological Survey (USGS) National Water Information System (NWIS) parameter codes. **Abbreviations**: hhmm, hours:minutes; mg/L, milligrams per liter; mm/dd/yyyy, month/day/year; °C, degrees Celsius; µS/cm at 25 °C, microsiemens per centimeter at 25 degrees Celsius]

USGS station name	Sample date (mm/dd/yyyy)	Sample time (hhmm)	Water temperature (°C) [00010]	Specific conductance (µS/cm at 25 °C) [00095]	pH [00400]	Dissolved oxygen (mg/L) [00300]
SACRAMENTO R A R MILE 94.6 NR ROBBINS CA	05/09/2016	1550	19.9	166	7.1	9.2
COLUSA BASIN DRAINAGE CANAL A KNIGHTS LANDING CA	05/09/2016	1410	18.8	172	7.4	9.1
SACRAMENTO R A R MILE 86.2 NR KNIGHTS LANDING CA	05/09/2016	1154	19.2	214	7.3	9.0
SACRAMENTO SLOUGH NR VERONA CA	05/10/2016	1102	21.9	343	7.2	5.6
FEATHER R A R MILE 0.4 MI A VERONA CA	05/10/2016	1301	20.0	86.3	7.3	9.1
NATOMAS CROSS CANAL A VERONA CA	05/10/2016	1450	21.9	147	6.5	7.6
SACRAMENTO R A VERONA CA	05/10/2016	1555	20.8	161	6.7	8.6
SACRAMENTO R A R MILE 69.5 NR BRYTE CA	05/11/2016	1646	21.6	172	7.1	8.7
SACRAMENTO R A R MILE 62.8 A BRYTE CA	05/11/2016	1505	21.8	164	7.1	8.6
AMERICAN R 1 MI AB MOUTH CA	05/11/2016	0940	15.2	60.0	7.1	9.8
SACRAMENTO R A R MILE 55.8 NR SACRAMENTO CA	05/11/2016	1155	19.6	136	7.3	8.7
SACRAMENTO R A R MILE 46.4 A FREEPORT CA	05/12/2016	1416	20.8	134	7.1	8.8
SACRAMENTO R A R MILE 44.0 CA	05/12/2016	1212	20.3	147	7.1	8.8
SACRAMENTO R A HOOD CA	05/12/2016	0910	19.1	152	7.1	8.5
SACRAMENTO R A R MILE 30.5 NR VORDEN CA	05/13/2016	1158	20.4	144	7.2	8.5
SACRAMENTO R A R MILE 19.0 NR ISLETON CA	05/13/2016	0900	19.1	144	7.4	8.5
SACRAMENTO R A R MILE 94.6 NR ROBBINS CA	10/24/2016	1132	15.3	136	7.4	9.7
COLUSA BASIN DRAINAGE CANAL A KNIGHTS LANDING CA	10/24/2016	1400	16.3	449	7.4	8.4
SACRAMENTO R A R MILE 86.2 NR KNIGHTS LANDING CA	10/24/2016	1525	15.2	136	7.4	9.7
SACRAMENTO SLOUGH NR VERONA CA	10/25/2016	1311	16.8	430	7.2	5.8
FEATHER R A R MILE 0.4 MI A VERONA CA	10/25/2016	1140	15.5	91.0	7.2	9.6
NATOMAS CROSS CANAL A VERONA CA	10/25/2016	1504	16.5	254	6.9	4.8
SACRAMENTO R A VERONA CA	10/25/2016	1606	15.6	149	7.3	9.3
SACRAMENTO R A R MILE 69.5 NR BRYTE CA	10/26/2016	1606	16.0	143	7.4	9.2
SACRAMENTO R A R MILE 62.8 A BRYTE CA	10/26/2016	1431	16.0	138	7.4	9.2
AMERICAN R 1 MI AB MOUTH CA	10/26/2016	0933	17.0	65.0	7.0	8.6
SACRAMENTO R A R MILE 55.8 NR SACRAMENTO CA	10/26/2016	1145	15.9	130	7.3	9.1
SACRAMENTO R A R MILE 46.4 A FREEPORT CA	10/27/2016	1607	16.2	138	7.3	9.2
SACRAMENTO R A R MILE 44.0 CA	10/27/2016	1410	16.4	161	7.0	9.0
SACRAMENTO R A HOOD CA	10/27/2016	1055	16.3	145	7.0	8.9
SACRAMENTO R A R MILE 30.5 NR VORDEN CA	10/28/2016	1245	16.5	162	7.0	8.6
SACRAMENTO R A R MILE 19.0 NR ISLETON CA	10/28/2016	0940	16.5	147	7.0	8.4

The full extraction procedure and instrumental analysis by GC/MS is described in (Hladik and others, 2008, 2009; Hladik and McWayne, 2012). Filtered-water samples were spiked with the recovery surrogate standard $^{13}C_3$-atrazine (Cambridge Isotope Laboratories). Each sample was passed through an Oasis HLB SPE (6 mL, 500 mg; Waters, Milford, Massachusetts) cartridge that had been cleaned with two column volumes of ethyl acetate (EtOAc), followed by two column volumes of methanol and two column volumes of deionized water. During this process, the water samples were pumped through the SPE cartridge at a flow rate of 10 mL/min, and the cartridge was then dried under nitrogen gas until the SPE sorbent was dry. After extraction, sodium sulfate was added to the sample bottle to remove any residual water, then the bottle was rinsed three times with approximately 2 mL of DCM into a collection tube. The bottle rinse was concentrated to 1 mL under a gentle stream of nitrogen gas. The SPE cartridge was dried under nitrogen gas until the SPE sorbent was dry, then the analytes were eluted with 12 mL of EtOAc into the concentrator tube containing its bottle rinse. The combined bottle rinse and eluent mixture was evaporated to less than 0.2 mL using a gentle stream of dry nitrogen gas. The internal standard (20 µL of a 10-ng/µL solution of the deuterated polycyclic aromatic hydrocarbon compounds acenaphthene-d_{10} and pyrene-d_{10}) was then added to the sample. The sample extracts were stored in a freezer at –20 °C until analysis (up to 30 days).

Filter papers were cut up and placed in an Erlenmeyer flask, spiked with the recovery surrogate standards d_{14}-trifluralin, $^{13}C_{12}$-*p,p'*-DDE, and $^{13}C_6$-permethrin (Cambridge Isotopes) and extracted twice with 50 mL of DCM in a sonicator (Branson 5200, Danbury, Connecticut) for 15 minutes. The extract was filtered through sodium sulfate, reduced using a Zymark Turbovap II evaporator (Hopkinton, Maryland) to 0.5 mL, solvent exchanged into EtOAc, and further evaporated to less than 0.2 mL using a gentle stream of dry nitrogen gas. The internal standard (20 µL of a 10-ng/µL solution of the deuterated polycyclic aromatic hydrocarbon compounds acenaphthene-d_{10} and pyrene-d_{10}) was then added to the sample. The sample extracts were stored in a freezer at –20 °C until analysis (up to 30 days).

Analytical Methods

Water extracts were analyzed by LC/MS/MS on an Agilent (Palo Alto, California) 1100 HPLC system coupled to a 6430 tandem MS system with a Zorbax Eclipse XDB-C18 column (2.1 by 150 by 3.5 millimeters [mm]). The column flow rate was 0.6 mL/min, and the column temperature was 30 °C. Data were collected in the multiple-reaction-monitoring mode. Additional details about the instrument method can be found in Hladik and Calhoun (2012).

Water and filter extracts were analyzed by GC/MS on an Agilent 7890A gas chromatograph with an Agilent 5975C Inert XL electron ionization (EI) mass-selective detector system using a DB-5MS analytical column (30 meters [m] by 0.25 mm by 0.25 µm) for separation with helium as the carrier gas. Data were collected in the selected ion-monitoring mode. Additional details of the GC/MS method can be found in Hladik and others (2008, 2009).

Method Detection Limits

Method detection limits (MDLs) for pesticide concentrations in surface water were validated in previous work (Hladik and others, 2008; Hladik and Calhoun, 2012) by using the procedure described in 40 CFR 136, Appendix B (U.S. Environmental Protection Agency, 1992). Method detection limits for pesticides in suspended sediments filtered from surface water were validated in previous studies by Hladik and others (2009) and Hladik and McWayne (2012). Method detection limits for pesticide concentrations measured in surface water are listed in table 3. Analytes can sometimes be identified at concentrations less than the MDLs with lower confidence in the numerical value; therefore, concentrations of compounds detected below the MDLs are reported as estimates.

Table 3. Method detection limits for dissolved pesticides in surface water and on suspended sediments measured by the U.S. Geological Survey Organic Chemistry Research Laboratory.

[GC/MS, gas chromatography with mass spectrometry; LC/MS/MS, liquid chromatography with tandem mass spectrometry; ng/L, nanograms per liter; NWIS, National Water Information System]

Compound	NWIS parameter code	Chemical class	Pesticide type	Method detection limit (ng/L)	Analytical method
Acetamiprid	68302	Neonicotinoid	Insecticide	3.3	LC/MS/MS
Acibenzolar-*S*-methyl	51849	Unclassified	Fungicide	3.0	GC/MS
Alachlor	65064	Chloroacetanilide	Herbicide	1.7	GC/MS
Allethrin	66586	Pyrethroid	Insecticide	1.0	GC/MS
Atrazine	65065	Triazine	Herbicide	2.3	GC/MS
Azinphos-methyl	65066	Organophosphorus	Insecticide	9.4	GC/MS
Azinphos-methyl oxon	68211	Organophosphorus	Degradate	9.4	GC/MS
Azoxystrobin	66589	Strobin	Fungicide	3.1	GC/MS
Benefin (Benfluralin)	51643	2,6-Dinitroaniline	Herbicide	2.0	GC/MS
Bifenthrin	65067	Pyrethroid	Insecticide	0.7	GC/MS
Boscalid	67550	Anilide	Fungicide	2.8	GC/MS
Bromoconazole	68315	Azole	Fungicide	3.2	GC/MS
Butralin	68545	2,6-Dinitroaniline	Herbicide	2.6	GC/MS
Butylate	65068	Thiocarbamate	Herbicide	1.8	GC/MS
Captan	68322	Thiophthalimide	Fungicide	10.2	GC/MS
Carbaryl	65069	N-Methyl carbamate	Insecticide	6.5	GC/MS
Carbendazim	68548	Benzimidazole	Fungicide	4.2	LC/MS/MS
Carbofuran	65070	N-Methyl carbamate	Insecticide	3.1	GC/MS
Carboxin	52765	Anilide	Fungicide	4.5	LC/MS/MS
Chlorantraniliprole	51856	Anthranilic diamide	Insecticide	4.0	LC/MS/MS
Chlorothalonil	65071	Substituted benzene	Fungicide	4.1	GC/MS
Chlorpyrifos	65072	Organophosphorus	Insecticide	2.1	GC/MS
Chlorpyrifos oxon	68216	Organophosphorus	Insecticide	5.0	GC/MS
Clomazone	67562	Unclassified	Herbicide	2.5	GC/MS
Clothianidin	68221	Neonicotinoid	Insecticide	3.9	LC/MS/MS
Coumaphos	51836	Organophosphorus	Insecticide	3.1	GC/MS
Cyantraniliprole	51862	Anthranilic diamide	Insecticide	4.2	LC/MS/MS
Cyazofamid	51853	Azole	Fungicide	4.1	LC/MS/MS
Cycloate	65073	Thiocarbamate	Herbicide	1.1	GC/MS
Cyfluthrin	65074	Pyrethroid	Insecticide	1.0	GC/MS
Cyhalofop-butyl	68360	Aryloxyphenoxy propionic acid	Herbicide	1.9	GC/MS
Cyhalothrin (all isomers)	68354	Pyrethroid	Insecticide	0.5	GC/MS
Cymoxanil	51861	Unclassified	Fungicide	3.9	LC/MS/MS
Cypermethrin	65075	Pyrethroid	Insecticide	1.0	GC/MS
Cyproconazole	66593	Azole	Fungicide	4.7	GC/MS
Cyprodinil	67574	Pyrimidine	Fungicide	7.4	GC/MS
DCPA	65076	Alkyl phthalate	Herbicide	2.0	GC/MS
DCPMU	68231	Urea	Degradate	3.5	LC/MS/MS
DCPU	68226	Urea	Degradate	3.4	LC/MS/MS
Deltamethrin	65077	Pyrethroid	Insecticide	0.6	GC/MS

Table 3. Method detection limits for dissolved pesticides in surface water and on suspended sediments measured by the U.S. Geological Survey Organic Chemistry Research Laboratory.—Continued

[GC/MS, gas chromatography with mass spectrometry; LC/MS/MS, liquid chromatography with tandem mass spectrometry; ng/L, nanograms per liter; NWIS, National Water Information System]

Compound	NWIS parameter code	Chemical class	Pesticide type	Method detection limit (ng/L)	Analytical method
Desthio-prothioconazole	51865	Unclassified	Degradate	3.0	LC/MS/MS
Diazinon	65078	Organophosphorus	Insecticide	0.9	GC/MS
Diazoxon	68236	Organophosphorus	Degradate	5.0	GC/MS
3,4-Dichloroaniline	66584	Amine	Degradate	3.2	LC/MS/MS
3,5-Dichloroaniline	67536	Unclassified	Degradate	7.6	GC/MS
Difenoconazole	67582	Azole	Fungicide	10.5	GC/MS
Dimethomorph	68373	Morpholine	Fungicide	6.0	GC/MS
Dinotefuran	68379	Neonicotinoid	Insecticide	4.5	LC/MS/MS
Dithiopyr	51837	Pyridinecarboxylic acid	Herbicide	1.6	GC/MS
Diuron	66598	Urea	Herbicide	3.2	LC/MS/MS
EPTC	65080	Thiocarbamate	Herbicide	1.5	GC/MS
Esfenvalerate	65081	Pyrethroid	Insecticide	0.5	GC/MS
Ethaboxam	51855	Unclassified	Fungicide	3.8	LC/MS/MS
Ethalfluralin	65082	2,6-Dinitroaniline	Herbicide	3.0	GC/MS
Etofenprox	67604	Pyrethroid ether	Insecticide	2.2	GC/MS
Famoxadone	67609	Oxazolidinedione	Fungicide	2.5	GC/MS
Fenamidone	51848	Imidazole	Fungicide	5.1	GC/MS
Fenarimol	67613	Pyrimidine	Fungicide	6.5	GC/MS
Fenbuconazole	67618	Azole	Fungicide	5.2	GC/MS
Fenhexamid	67622	Anilide	Fungicide	7.6	GC/MS
Fenpropathrin	65083	Pyrethroid	Insecticide	0.6	GC/MS
Fenpyroximate	51838	Pyrazole	Insecticide	5.2	GC/MS
Fenthion	51839	Organophosphorus	Insecticide	5.5	GC/MS
Fipronil	66604	Pyrazole	Insecticide	2.9	GC/MS
Fipronil desulfinyl	68891	Unclassified	Degradate	1.6	GC/MS
Fipronil desulfinyl amide	66609	Unclassified	Degradate	3.2	GC/MS
Fipronil sulfide	66610	Unclassified	Degradate	1.8	GC/MS
Fipronil sulfone	66613	Unclassified	Degradate	3.5	GC/MS
Flonicamid	51858	Unclassified	Insecticide	3.4	LC/MS/MS
Fluazinam	67636	2,6-Dinitroaniline	Fungicide	4.4	GC/MS
Fludioxonil	67640	Unclassified	Fungicide	7.3	GC/MS
Flufenacet	51840	Anilide	Herbicide	4.7	GC/MS
Flumetralin	51841	2,6-Dinitroaniline	Plant growth regulator	5.8	GC/MS
Fluopicolide	51852	Benzamide pyridine	Fungicide	3.9	GC/MS
Fluopyram	52761	Amide	Fungicide	3.8	GC/MS
Fluoxastrobin	67645	Strobin	Fungicide	9.5	GC/MS
Flupyradifurone	52764	Butenolide	Insecticide	3.0	LC/MS/MS
Fluridone	51864	Unclassified	Herbicide	3.7	LC/MS/MS
Flusilazole	67649	Azole	Fungicide	4.5	GC/MS
Flutolanil	51842	Anilide	Fungicide	4.4	GC/MS
Flutriafol	67653	Azole	Fungicide	4.2	GC/MS

Table 3. Method detection limits for dissolved pesticides in surface water and on suspended sediments measured by the U.S. Geological Survey Organic Chemistry Research Laboratory.—Continued

[GC/MS, gas chromatography with mass spectrometry; LC/MS/MS, liquid chromatography with tandem mass spectrometry; ng/L, nanograms per liter; NWIS, National Water Information System]

Compound	NWIS parameter code	Chemical class	Pesticide type	Method detection limit (ng/L)	Analytical method
Fluxapyroxad	51851	Anilide, Pyrazole	Fungicide	4.8	GC/MS
Hexazinone	65085	Triazinone	Herbicide	8.4	GC/MS
Imazalil	67662	Azole	Fungicide	10.5	GC/MS
Imidacloprid	68426	Neonicotinoid	Insecticide	3.8	LC/MS/MS
Indoxacarb	68627	Unclassified	Insecticide	4.9	GC/MS
Ipconazole	52762	Triazole	Fungicide	7.8	GC/MS
Iprodione	66617	Dicarboximide	Fungicide	4.4	GC/MS
Kresoxim-methyl	67670	Strobin	Fungicide	4.0	GC/MS
Malaoxon	68240	Organophosphorus	Degradate	5.0	GC/MS
Malathion	65087	Organophosphorus	Insecticide	3.7	GC/MS
Mandipropamid	51854	Amide	Fungicide	3.3	LC/MS/MS
Metalaxyl	68437	Xylylalanine	Fungicide	5.1	GC/MS
Metconazole	66620	Azole	Fungicide	5.2	GC/MS
Methidathion	65088	Organophosphorus	Insecticide	7.2	GC/MS
Methoprene	66623	Juvenile hormone mimic	Insect growth regulator	6.4	GC/MS
Methoxyfenozide	68647	Diacylhydrazine	Insecticide	2.7	LC/MS/MS
Methyl parathion	65089	Organophosphorus	Insecticide	3.4	GC/MS
Metolachlor	65090	Chloroacetanilide	Herbicide	1.5	GC/MS
Molinate	65091	Thiocarbamate	Herbicide	3.2	GC/MS
Myclobutanil	66632	Azole	Fungicide	6.0	GC/MS
Napropamide	65092	Amide	Herbicide	8.2	GC/MS
Novaluron	68655	Benzoylurea	Herbicide	2.9	GC/MS
Oryzalin	68663	2,6-Dinitroaniline	Herbicide	5.0	LC/MS/MS
Oxathiapiprolin	52766	Pyrazole	Fungicide	3.2	LC/MS/MS
Oxadiazon	51843	Unclassified	Herbicide	2.1	GC/MS
Oxyfluorfen	65093	Diphenyl ether	Herbicide	3.1	GC/MS
p,p’-DDD	65094	Organochlorine	Degradate	4.1	GC/MS
p,p’-DDE	65095	Organochlorine	Degradate	3.6	GC/MS
p,p’-DDT	65096	Organochlorine	Insecticide	4.0	GC/MS
Paclobutrazol	51846	Azole	Plant growth regulator	6.2	GC/MS
Pebulate	65097	Thiocarbamate	Herbicide	2.3	GC/MS
Pendimethalin	65098	2,6-Dinitroaniline	Herbicide	2.3	GC/MS
Penoxsulam	51863	Triazolopyrimidine	Herbicide	3.5	LC/MS/MS
Pentachloroanisole	66637	Organochlorine	Degradate	4.7	GC/MS
Pentachloronitrobenzene	66639	Substituted benzene	Fungicide	3.1	GC/MS
Penthiopyrad	52769	Pyrazole	Fungicide	3.2	LC/MS/MS
Permethrin	65099	Pyrethroid	Insecticide	0.6	GC/MS
Phenothrin	65100	Pyrethroid	Insecticide	1.0	GC/MS
Phosmet	65101	Organophosphorus	Insecticide	4.4	GC/MS
Picoxystrobin	51850	Strobin	Fungicide	4.2	GC/MS
Piperonyl butoxide	65102	Unclassified	Synergist	2.3	GC/MS

Table 3. Method detection limits for dissolved pesticides in surface water and on suspended sediments measured by the U.S. Geological Survey Organic Chemistry Research Laboratory.—Continued

[GC/MS, gas chromatography with mass spectrometry; LC/MS/MS, liquid chromatography with tandem mass spectrometry; ng/L, nanograms per liter; NWIS, National Water Information System]

Compound	NWIS parameter code	Chemical class	Pesticide type	Method detection limit (ng/L)	Analytical method
Prodiamine	51844	2,6-Dinitroaniline	Herbicide	5.2	GC/MS
Prometon	67702	Triazine	Herbicide	2.5	GC/MS
Prometryn	65103	Triazine	Herbicide	1.8	GC/MS
Propanil	66641	Anilide	Herbicide	10.1	GC/MS
Propargite	68677	Unclassified	Insecticide	6.1	GC/MS
Propiconazole	66643	Azole	Fungicide	5.0	GC/MS
Propyzamide	67706	Amide	Herbicide	5.0	GC/MS
Pyraclostrobin	66646	Strobin	Fungicide	2.9	GC/MS
Pyridaben	68682	Unclassified	Insecticide	5.4	GC/MS
Pyrimethanil	67717	Pyrimidine	Fungicide	4.1	GC/MS
Quinoxyfen	51847	Quinoline	Fungicide	3.3	GC/MS
Resmethrin	65104	Pyrethroid	Insecticide	1.0	GC/MS
Sedaxane	52648	Anilide, Pyrazole	Fungicide	5.2	GC/MS
Simazine	65105	Triazine	Herbicide	5.0	GC/MS
Sulfoxaflor	52767	Sulfoximine	Insecticide	4.4	LC/MS/MS
tau-Fluvalinate	65106	Pyrethroid	Insecticide	0.7	GC/MS
Tebuconazole	66649	Azole	Fungicide	3.7	GC/MS
Tebufenozide	68692	Moulting hormone agonist	Insecticide	3.0	LC/MS/MS
Tebupirimfos	68693	Organophosphorus	Insecticide	1.9	GC/MS
Tebupirimfos oxon	68694	Organophosphorus	Degradate	2.8	GC/MS
Tefluthrin	67731	Pyrethroid	Insecticide	4.2	GC/MS
Tetraconazole	66654	Azole	Fungicide	5.6	GC/MS
Tetradifon	51651	Unclassified	Insecticide	3.8	GC/MS
Tetramethrin	66657	Pyrethroid	Insecticide	0.5	GC/MS
Thiabendazole	67161	Benzimidazole	Fungicide	3.6	LC/MS/MS
Thiacloprid	68485	Neonicotinoid	Insecticide	3.2	LC/MS/MS
Thiamethoxam	68245	Neonicotinoid	Insecticide	3.4	LC/MS/MS
Thiazopyr	51845	Pyridinecarboxylic acid	Herbicide	4.1	GC/MS
Thiobencarb	65107	Thiocarbamate	Herbicide	1.9	GC/MS
Tolfenpyrad	51866	Pyrazole	Insecticide	2.9	LC/MS/MS
Triadimefon	67741	Azole	Fungicide	8.9	GC/MS
Triadimenol	67746	Azole	Fungicide	8.0	GC/MS
Triallate	68710	Thiocarbamate	Herbicide	2.4	GC/MS
Tribufos	68711	Organophosphorus	Defoliant	3.1	GC/MS
Tricyclazole	52768	Azole	Fungicide	4.1	LC/MS/MS
Trifloxystrobin	66660	Strobin	Fungicide	4.7	GC/MS
Triflumizole	67753	Azole	Fungicide	6.1	GC/MS
Trifluralin	65108	2,6-Dinitroaniline	Herbicide	2.1	GC/MS
Triticonazole	67758	Azole	Fungicide	6.9	GC/MS
Zoxamide	67768	Amide	Fungicide	3.5	GC/MS

Quality-Control Methods and Results

Pesticide concentrations in water samples were validated against a comprehensive set of performance-based quality-control samples, including field replicates, field blanks, matrix spikes, and matrix-spike replicates in accordance with the laboratory’s Quality Assurance Project Plan (James Orlando, U.S. Geological Survey Organic Chemistry Research Laboratory, written commun., 2016) for California pesticide studies. Quality control samples were analyzed using the GC/MS and LC/MS/MS methods described earlier.

Four field blanks consisting of organic-free OCRL facility water, that was provided to the field sampling crew, were collected to demonstrate the cleanliness of field procedures. Two field blanks were collected at one site during each sampling period and analyzed by GC/MS and LC/MS/MS. No pesticides were detected in any of the blanks.

Four sequential field-replicate sample pairs were collected to test the reproducibility of results. Replicate pairs were collected at one site in each sampling period and analyzed by GC/MS and LC/MS/MS. There were 12 detections of pesticides in the sample pairs, and the relative standard deviation between the replicate and the complementary environmental sample was less than the control limit of 25 percent in all cases. The correlation of pesticide detections between the environmental and replicate samples was 100 percent.

Four laboratory matrix spikes, each paired with a matrix-spike-replicate, were analyzed to assess pesticide recovery, degradation, sorption, and interferences caused by the sampling matrix. Matrix spike and matrix-spike-replicate pairs were analyzed in samples collected at one site in each sampling period and analyzed by GC/MS and LC/MS/MS. All samples met the data-quality objective of 70–130 percent recovery of the matrix-spike compounds. The relative standard deviation between the matrix-spike samples and their complementary replicates was less than the 25-percent control limit in all cases.

Results

A variety of pesticide types, concentrations, and mixtures were detected in the water samples collected from the lower Sacramento River and five of its tributaries during this study. A total of 27 pesticides and pesticide degradates were detected in the water samples: 12 herbicides, 9 insecticides, 5 fungicides, and 1 synergist (fig. 2; table 4). Estimated concentration values (less than the individual compound MDL) are included in all the detection frequency and concentration data (table 5). At least one pesticide was detected in each water sample collected in May and October 2016. Mixtures of 2 or more pesticides were detected at 15 sites in May and 13 sites in October. Most of the pesticides detected in this study were herbicides (63 percent), whereas fungicides and insecticides represented 22 percent and 14 percent of the total detections, respectively. The compounds detected most frequently in the May and October sampling periods were the herbicides hexazinone (detected in 88 percent of the samples), diuron (84 percent), and the fungicide azoxystrobin (84 percent; table 5). Two pesticide compounds (clomazone and thiobencarb) were detected in three suspended-sediment samples filtered from the water samples collected from the three agricultural drainage sites (table 6). Concentrations of pesticides in suspended sediments are provided in nanograms per liter (ng/L) to facilitate the approximation of a whole-water pesticide concentration by summing the dissolved- and suspended-sediment concentrations of pesticides (table 6).

During this study, many of the pesticides and pesticide degradates detected at relatively high concentrations were those associated with use on rice crops (azoxystrobin, clomazone, and thiobencarb). Many of these elevated concentrations were detected in samples from the agricultural drainage sites (Colusa Basin Drainage Canal, Sacramento Slough, and Natomas Cross Canal) and also downstream in the Sacramento River at lower concentrations. These agricultural drainage indicator sites had average pesticide concentrations greater than those in the larger tributaries. The American River indicator site had the fewest total pesticide detections in this study and aside from the herbicide hexazinone, no pesticides were detected during the May sampling event, and none of the rice herbicides were detected here during either sampling event. Pesticide concentrations were relatively low at the Feather River and American River indicator sites during both sampling events.

During the May sampling event, the fungicides boscalid and azoxystrobin (both with 94 percent detection frequency); the herbicides clomazone, diuron, and hexazinone (all 94 percent); thiobencarb (88 percent); and metolachlor (81 percent) were the most frequently detected pesticides in the water samples (fig. 3; table 5). Pesticide concentrations ranged from below the MDLs to 576 ng/L (clomazone, fig. 4). The herbicide clomazone was frequently detected at concentrations above 100 ng/L. Average pesticide concentrations and the average number of pesticide detections at the agricultural drainage indicator sites were 77 and 41 percent greater than those in the Sacramento River integrator sites, respectively. Two pesticides (clomazone and thiobencarb) were detected in three suspended sediment samples (table 6) filtered from water samples with both relatively high dissolved pesticide concentrations (greater than 300 ng/L) and relatively large amounts of suspended sediments (greater than 0.030 gram). All pesticides were detected at concentrations lower than the U.S. Environmental Protection Agency’s aquatic life benchmarks (U.S. Environmental Protection Agency, 2017).

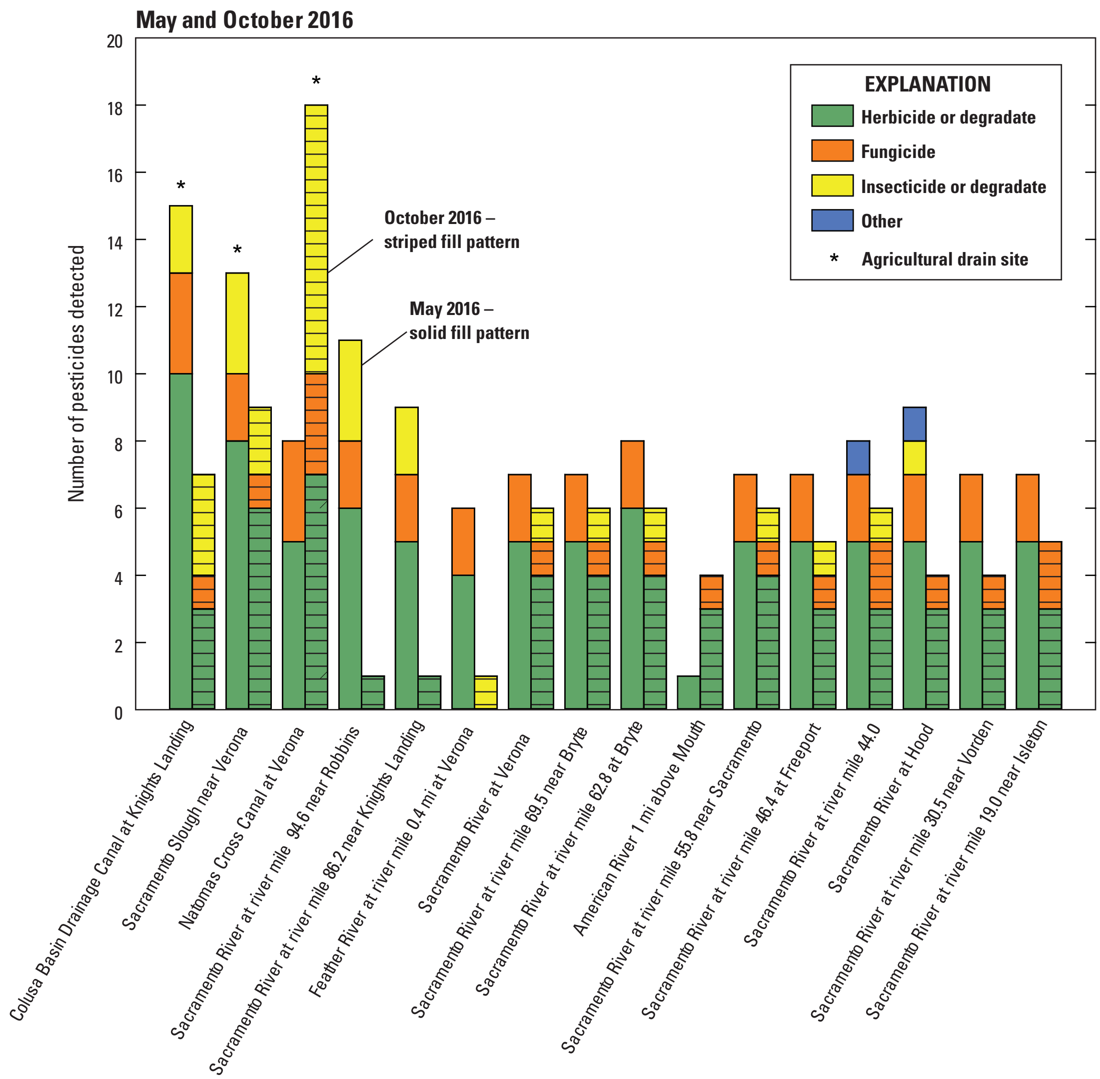


Figure 2. Number of pesticides detected at sites in the Sacramento River watershed, California, during May and October 2016.

Table 4. Pesticide concentrations in surface-water samples collected in the Sacramento River watershed, California, May and October 2016.

[Numbers in brackets are U.S. Geological Survey (USGS) National Water Information System (NWIS) parameter codes. Concentrations are in nanograms per liter (ng/L). Results in parentheses ( ) are below method detection limits and are estimates. The following compounds were analyzed but were not detected in any samples: 3,5-dichloroaniline, acetamiprid, acibenzolar-methyl, alachlor, allethrin, atrazine, azinphos methyl, azinphos methyl oxon, benfluralin, bifenthrin, bromuconazole, butralin, butylate, captan, carbaryl, carbofuran, carboxin, chlorothalonil, chlorpyrifos, chlorpyrifos oxon, clothianidin, coumaphos, cyantraniliprole, cyazofamid, cycloate, cyfluthrin, cyhalofop-butyl, cyhalothrin, cymoxanil, cypermethrin, cyproconazole, cyprodinil, DCPA, deltamethrin, desthioprothioconazole, diazinon, diazinon oxon, difenconazole, dimethomorph, dinotefuran, EPTC, esfenvalerate, ethaboxam, ethalfluralin, etofenprox, famoxadone, fenamidone, fenarimol, fenbuconazole, fenhexamide, fenpropathrin, fenpyroximate, fenthion, fipronil desulfinyl amide, flonicamid, fluazinam, fludioxinil, flufenacet, flumetralin, fluopicolide, fluopyram, fluoxastrobin, flusilazole, flutolanil, flutriafol, imazalil, indoxacarb, ipconazole, iprodione, kresoxim-methyl, malathion, malathion oxon, mandipropamid, metalaxyl, metconazole, methidathion, methoprene, methyl parathion, molinate, myclobutanil, napropamide, novaluron, oryzalin, oxydiazon, oxyfluorfen, p,p'-DDE, p,p'-DDT, paclobutrazol, pentachloroaniline, pentachloroanisole, pebulate, pendimethalin, penthiopyrad, permethrin, phenothrin, phosmet, picoxystrobin, prodiamine, prometon, prometryn, propanil, propargite, propiconazole, propyzamide, pyraclostrobin, pyridaben, pyrimethanil, quinoxyfen, resmethrin, sedaxane, sulfoxaflor, tau-fluvalinate, tebuconazole, tebufenozide, tebupirimfos, tebupirimfos oxon, tefluthrin, tetraconazole, tetradifon, tetramethrin, thiabendazole, thiacloprid, thiamethoxam, thiazopyr, tolfenpyrad, triadimefon, triadimenol, triallate, tribufos, tricyclazole, trifloxystrobin, triflumizole, trifluralin, triticonazole, and zoxamide. **Abbreviations**: hhmm, hours:minutes; mm/dd/yyyy, month/day/year; —, not detected]

USGS station name	Sample date (mm/dd/yyyy)	Sample time (hhmm)	3,4-Dichloro-aniline [66584]	Azoxys-trobin [66589]	Boscalid [67550]	Carben-dazim [68548]	Chlorantra-niliprole [51856]	Clomazone [67562]	DCPMU [68231]
		May 2016							
SACRAMENTO R A R MILE 94.6 NR ROBBINS CA	05/09/2016	1550	—	6.7	7.7	—	4.0	70.1	—
COLUSA BASIN DRAINAGE CANAL A KNIGHTS LANDING CA	05/09/2016	1410	19.1	140.0	29.5	—	8.9	538.0	7.4
SACRAMENTO R A R MILE 86.2 NR KNIGHTS LANDING CA	05/09/2016	1154	—	43.8	22.4	—	6.2	129.1	—
SACRAMENTO SLOUGH NR VERONA CA	05/10/2016	1102	8.1	85.1	13.6	—	4.0	576.3	4.1
FEATHER R A R MILE 0.4 MI A VERONA CA	05/10/2016	1301	—	9.1	9.1	—	—	79.6	—
NATOMAS CROSS CANAL A VERONA CA	05/10/2016	1450	—	23.2	5.1	8.6	—	301.0	6.9
SACRAMENTO R A VERONA CA	05/10/2016	1555	—	37.2	5.2	—	—	134.8	—
SACRAMENTO R A R MILE 69.5 NR BRYTE CA	05/11/2016	1646	—	49.4	7.1	—	—	162.2	—
SACRAMENTO R A R MILE 62.8 A BRYTE CA	05/11/2016	1505	5.3	45.3	6.5	—	—	143.4	—
AMERICAN R 1 MI AB MOUTH CA	05/11/2016	0940	—	—	—	—	—	—	—
SACRAMENTO R A R MILE 55.8 NR SACRAMENTO CA	05/11/2016	1155	—	38.7	5.5	—	—	105.0	—
SACRAMENTO R A R MILE 46.4 A FREEPORT CA	05/12/2016	1416	—	32.6	5.3	—	—	111.3	—
SACRAMENTO R A R MILE 44.0 CA	05/12/2016	1212	—	32.6	4.9	—	—	110.3	—
SACRAMENTO R A HOOD CA	05/12/2016	0910	—	29.6	4.9	—	—	103.3	—
SACRAMENTO R A R MILE 30.5 NR VORDEN CA	05/13/2016	1158	—	30.4	5.1	—	—	116.8	—
SACRAMENTO R A R MILE 19.0 NR ISLETON CA	05/13/2016	0900	—	31.4	5.6	—	—	104.2	—
		October 2016							
SACRAMENTO R A R MILE 94.6 NR ROBBINS CA	10/24/2016	1132	—	—	—	—	—	—	—
COLUSA BASIN DRAINAGE CANAL A KNIGHTS LANDING CA	10/24/2016	1400	11.4	66.2	—	—	5.4	—	(2.7)
SACRAMENTO R A R MILE 86.2 NR KNIGHTS LANDING CA	10/24/2016	1525	—	—	—	—	—	—	—
SACRAMENTO SLOUGH NR VERONA CA	10/25/2016	1311	24.0	58.7	—	—	(3.4)	—	48.8
FEATHER R A R MILE 0.4 MI A VERONA CA	10/25/2016	1140	—	—	—	—	—	—	—
NATOMAS CROSS CANAL A VERONA CA	10/25/2016	1504	9.3	14.6	—	14.2	(3.3)	—	3.8

Table 4. Pesticide concentrations in surface-water samples collected in the Sacramento River watershed, California, May and October 2016.—Continued

[Numbers in brackets are U.S. Geological Survey (USGS) National Water Information System (NWIS) parameter codes. Concentrations are in nanograms per liter (ng/L). Results in parentheses ( ) are below method detection limits and are estimates. The following compounds were analyzed but were not detected in any samples: 3,5-dichloroaniline, acetamiprid, acibenzolar-methyl, alachlor, allethrin, atrazine, azinphos methyl, azinphos methyl oxon, benfluralin, bifenthrin, bromuconazole, butralin, butylate, captan, carbaryl, carbofuran, carboxin, chlorothalonil, chlorpyrifos, chlorpyrifos oxon, clothianidin, coumaphos, cyantraniliprole, cyazofamid, cycloate, cyfluthrin, cyhalofop-butyl, cyhalothrin, cymoxanil, cypermethrin, cyproconazole, cyprodinil, DCPA, deltamethrin, desthioprothioconazole, diazinon, diazinon oxon, difenconazole, dimethomorph, dinotefuran, EPTC, esfenvalerate, ethaboxam, ethalfluralin, etofenprox, famoxadone, fenamidone, fenarimol, fenbuconazole, fenhexamide, fenpropathrin, fenpyroximate, fenthion, fipronil desulfinyl amide, flonicamid, fluazinam, fludioxinil, flufenacet, flumetralin, fluopicolide, fluopyram, fluoxastrobin, flusilazole, flutolanil, flutriafol, imazalil, indoxacarb, ipconazole, iprodione, kresoxim-methyl, malathion, malathion oxon, mandipropamid, metalaxyl, metconazole, methidathion, methoprene, methyl parathion, molinate, myclobutanil, napropamide, novaluron, oryzalin, oxydiazon, oxyfluorfen, p,p'-DDE, p,p'-DDT, paclobutrazol, pentachloroaniline, pentachloroanisole, pebulate, pendimethalin, penthiopyrad, permethrin, phenothrin, phosmet, picoxystrobin, prodiamine, prometon, prometryn, propanil, propargite, propiconazole, propyzamide, pyraclostrobin, pyridaben, pyrimethanil, quinoxyfen, resmethrin, sedaxane, sulfoxaflor, tau-fluvalinate, tebuconazole, tebufenozide, tebupirimfos, tebupirimfos oxon, tefluthrin, tetraconazole, tetradifon, tetramethrin, thiabendazole, thiacloprid, thiamethoxam, thiazopyr, tolfenpyrad, triadimefon, triadimenol, triallate, tribufos, tricyclazole, trifloxystrobin, triflumizole, trifluralin, triticonazole, and zoxamide. **Abbreviations**: hhmm, hours:minutes; mm/dd/yyyy, month/day/year; —, not detected]

USGS station name	Sample date (mm/dd/yyyy)	Sample time (hhmm)	3,4-Dichloro-aniline [66584]	Azoxys-trobin [66589]	Boscalid [67550]	Carben-dazim [68548]	Chlorantra-niliprole [51856]	Clomazone [67562]	DCPMU [68231]
October 2016—Continued									
SACRAMENTO R A VERONA CA	10/25/2016	1606	4.3	3.8	—	—	—	—	4.3
SACRAMENTO R A R MILE 69.5 NR BRYTE CA	10/26/2016	1606	4.8	5.2	—	—	—	—	4.0
SACRAMENTO R A R MILE 62.8 A BRYTE CA	10/26/2016	1431	5.5	5.3	—	—	—	—	3.7
AMERICAN R 1 MI AB MOUTH CA	10/26/2016	0933	—	—	—	6.9	—	—	5.1
SACRAMENTO R A R MILE 55.8 NR SACRAMENTO CA	10/26/2016	1145	4.3	(2.3)	—	—	—	—	4.0
SACRAMENTO R A R MILE 46.4 A FREEPORT CA	10/27/2016	1607	4.4	4.1	—	—	—	—	—
SACRAMENTO R A R MILE 44.0 CA	10/27/2016	1410	4.9	4.4	—	7.7	—	—	—
SACRAMENTO R A HOOD CA	10/27/2016	1055	3.9	(2.6)	—	—	—	—	—
SACRAMENTO R A R MILE 30.5 NR VORDEN CA	10/28/2016	1245	7.5	5.5	—	—	—	—	—
SACRAMENTO R A R MILE 19.0 NR ISLETON CA	10/28/2016	0940	5.0	(2.3)	—	4.9	—	—	—

USGS station name	Sample date (mm/dd/yyyy)	Sample time (hhmm)	DCPU [68226]	Dithiopyr [51837]	Diuron [66598]	Fipronil [66604]	Fipronil desulfinyl [68891]	Fipronil sulfide [66610]	Fipronil sulfone [66613]
May 2016—Continued									
SACRAMENTO R A R MILE 94.6 NR ROBBINS CA	05/09/2016	1550	—	—	3.4	—	—	—	—
COLUSA BASIN DRAINAGE CANAL A KNIGHTS LANDING CA	05/09/2016	1410	(3.2)	—	24.2	—	—	—	—
SACRAMENTO R A R MILE 86.2 NR KNIGHTS LANDING CA	05/09/2016	1154	—	—	4.8	—	—	—	—
SACRAMENTO SLOUGH NR VERONA CA	05/10/2016	1102	(2.4)	—	14.3	—	—	—	—
FEATHER R A R MILE 0.4 MI A VERONA CA	05/10/2016	1301	—	—	6.7	—	—	—	—
NATOMAS CROSS CANAL A VERONA CA	05/10/2016	1450	—	—	26.4	—	—	—	—
SACRAMENTO R A VERONA CA	05/10/2016	1555	—	—	8.6	—	—	—	—
SACRAMENTO R A R MILE 69.5 NR BRYTE CA	05/11/2016	1646	—	—	11.4	—	—	—	—
SACRAMENTO R A R MILE 62.8 A BRYTE CA	05/11/2016	1505	—	—	3.6	—	—	—	—

Table 4. Pesticide concentrations in surface-water samples collected in the Sacramento River watershed, California, May and October 2016.—Continued

[Numbers in brackets are U.S. Geological Survey (USGS) National Water Information System (NWIS) parameter codes. Concentrations are in nanograms per liter (ng/L). Results in parentheses ( ) are below method detection limits and are estimates. The following compounds were analyzed but were not detected in any samples: 3,5-dichloroaniline, acetamiprid, acibenzolar-methyl, alachlor, allethrin, atrazine, azinphos methyl, azinphos methyl oxon, benfluralin, bifenthrin, bromuconazole, butralin, butylate, captan, carbaryl, carbofuran, carboxin, chlorothalonil, chlorpyrifos, chlorpyrifos oxon, clothianidin, coumaphos, cyantraniliprole, cyazofamid, cycloate, cyfluthrin, cyhalofop-butyl, cyhalothrin, cymoxanil, cypermethrin, cyproconazole, cyprodinil, DCPA, deltamethrin, desthioprothioconazole, diazinon, diazinon oxon, difenconazole, dimethomorph, dinotefuran, EPTC, esfenvalerate, ethaboxam, ethalfluralin, etofenprox, famoxadone, fenamidone, fenarimol, fenbuconazole, fenhexamide, fenpropathrin, fenpyroximate, fenthion, fipronil desulfinyl amide, flonicamid, fluazinam, fludioxinil, flufenacet, flumetralin, fluopicolide, fluopyram, fluoxastrobin, flusilazole, flutolanil, flutriafol, imazalil, indoxacarb, ipconazole, iprodione, kresoxim-methyl, malathion, malathion oxon, mandipropamid, metalaxyl, metconazole, methidathion, methoprene, methyl parathion, molinate, myclobutanil, napropamide, novaluron, oryzalin, oxydiazon, oxyfluorfen, p,p'-DDE, p,p'-DDT, paclobutrazol, pentachloroaniline, pentachloroanisole, pebulate, pendimethalin, penthiopyrad, permethrin, phenothrin, phosmet, picoxystrobin, prodiamine, prometon, prometryn, propanil, propargite, propiconazole, propyzamide, pyraclostrobin, pyridaben, pyrimethanil, quinoxyfen, resmethrin, sedaxane, sulfoxaflor, tau-fluvalinate, tebuconazole, tebufenozide, tebupirimfos, tebupirimfos oxon, tefluthrin, tetraconazole, tetradifon, tetramethrin, thiabendazole, thiacloprid, thiamethoxam, thiazopyr, tolfenpyrad, triadimefon, triadimenol, triallate, tribufos, tricyclazole, trifloxystrobin, triflumizole, trifluralin, triticonazole, and zoxamide. **Abbreviations**: hhmm, hours:minutes; mm/dd/yyyy, month/day/year; —, not detected]

USGS station name	Sample date (mm/dd/yyyy)	Sample time (hhmm)	DCPU [68226]	Dithiopyr [51837]	Diuron [66598]	Fipronil [66604]	Fipronil desulfinyl [68891]	Fipronil sulfide [66610]	Fipronil sulfone [66613]
May 2016—Continued									
AMERICAN R 1 MI AB MOUTH CA	05/11/2016	0940	—	—	—	—	—	—	—
SACRAMENTO R A R MILE 55.8 NR SACRAMENTO CA	05/11/2016	1155	—	—	5.4	—	—	—	—
SACRAMENTO R A R MILE 46.4 A FREEPORT CA	05/12/2016	1416	—	—	3.7	—	—	—	—
SACRAMENTO R A R MILE 44.0 CA	05/12/2016	1212	—	—	4.4	—	—	—	—
SACRAMENTO R A HOOD CA	05/12/2016	0910	—	—	6.0	—	—	—	—
SACRAMENTO R A R MILE 30.5 NR VORDEN CA	05/13/2016	1158	—	—	5.0	—	—	—	—
SACRAMENTO R A R MILE 19.0 NR ISLETON CA	05/13/2016	0900	—	—	3.3	—	—	—	—
October 2016—Continued									
SACRAMENTO R A R MILE 94.6 NR ROBBINS CA	10/24/2016	1132	—	—	—	—	—	—	—
COLUSA BASIN DRAINAGE CANAL A KNIGHTS LANDING CA	10/24/2016	1400	—	—	—	—	—	—	—
SACRAMENTO R A R MILE 86.2 NR KNIGHTS LANDING CA	10/24/2016	1525	—	—	—	—	—	—	—
SACRAMENTO SLOUGH NR VERONA CA	10/25/2016	1311	6.5	—	326.0	—	—	—	—
FEATHER R A R MILE 0.4 MI A VERONA CA	10/25/2016	1140	—	—	—	—	—	—	—
NATOMAS CROSS CANAL A VERONA CA	10/25/2016	1504	6.3	26.2	17.0	3.6	8.8	3.0	8.8
SACRAMENTO R A VERONA CA	10/25/2016	1606	—	—	40.7	—	—	—	—
SACRAMENTO R A R MILE 69.5 NR BRYTE CA	10/26/2016	1606	—	—	12.2	—	—	—	—
SACRAMENTO R A R MILE 62.8 A BRYTE CA	10/26/2016	1431	—	—	10.6	—	—	—	—
AMERICAN R 1 MI AB MOUTH CA	10/26/2016	0933	9.3	—	25.2	—	—	—	—
SACRAMENTO R A R MILE 55.8 NR SACRAMENTO CA	10/26/2016	1145	—	—	23.7	—	—	—	—
SACRAMENTO R A R MILE 46.4 A FREEPORT CA	10/27/2016	1607	—	—	11.2	—	—	—	—
SACRAMENTO R A R MILE 44.0 CA	10/27/2016	1410	—	—	15.4	—	—	—	—
SACRAMENTO R A HOOD CA	10/27/2016	1055	—	—	13.2	—	—	—	—
SACRAMENTO R A R MILE 30.5 NR VORDEN CA	10/28/2016	1245	—	—	12.1	—	—	—	—
SACRAMENTO R A R MILE 19.0 NR ISLETON CA	10/28/2016	0940	—	—	14.1	—	—	—	—

Table 4. Pesticide concentrations in surface-water samples collected in the Sacramento River watershed, California, May and October 2016.—Continued

[Numbers in brackets are U.S. Geological Survey (USGS) National Water Information System (NWIS) parameter codes. Concentrations are in nanograms per liter (ng/L). Results in parentheses ( ) are below method detection limits and are estimates. The following compounds were analyzed but were not detected in any samples: 3,5-dichloroaniline, acetamiprid, acibenzolar-methyl, alachlor, allethrin, atrazine, azinphos methyl, azinphos methyl oxon, benfluralin, bifenthrin, bromuconazole, butralin, butylate, captan, carbaryl, carbofuran, carboxin, chlorothalonil, chlorpyrifos, chlorpyrifos oxon, clothianidin, coumaphos, cyantraniliprole, cyazofamid, cycloate, cyfluthrin, cyhalofop-butyl, cyhalothrin, cymoxanil, cypermethrin, cyproconazole, cyprodinil, DCPA, deltamethrin, desthioprothioconazole, diazinon, diazinon oxon, difenconazole, dimethomorph, dinotefuran, EPTC, esfenvalerate, ethaboxam, ethalfluralin, etofenprox, famoxadone, fenamidone, fenarimol, fenbuconazole, fenhexamide, fenpropathrin, fenpyroximate, fenthion, fipronil desulfinyl amide, flonicamid, fluazinam, fludioxinil, flufenacet, flumetralin, fluopicolide, fluopyram, fluoxastrobin, flusilazole, flutolanil, flutriafol, imazalil, indoxacarb, ipconazole, iprodione, kresoxim-methyl, malathion, malathion oxon, mandipropamid, metalaxyl, metconazole, methidathion, methoprene, methyl parathion, molinate, myclobutanil, napropamide, novaluron, oryzalin, oxydiazon, oxyfluorfen, p,p'-DDE, p,p'-DDT, paclobutrazol, pentachloroaniline, pentachloroanisole, pebulate, pendimethalin, penthiopyrad, permethrin, phenothrin, phosmet, picoxystrobin, prodiamine, prometon, prometryn, propanil, propargite, propiconazole, propyzamide, pyraclostrobin, pyridaben, pyrimethanil, quinoxyfen, resmethrin, sedaxane, sulfoxaflor, tau-fluvalinate, tebuconazole, tebufenozide, tebupirimfos, tebupirimfos oxon, tefluthrin, tetraconazole, tetradifon, tetramethrin, thiabendazole, thiacloprid, thiamethoxam, thiazopyr, tolfenpyrad, triadimefon, triadimenol, triallate, tribufos, tricyclazole, trifloxystrobin, triflumizole, trifluralin, triticonazole, and zoxamide. **Abbreviations**: hhmm, hours:minutes; mm/dd/yyyy, month/day/year; —, not detected]

USGS station name	Sample date (mm/dd/yyyy)	Sample time (hhmm)	Flupyradi-furone [52764]	Fluridone [51864]	Fluxa-pyroxad [51851]	Hexa-zinone [65085]	Imidaclo-prid [68426]	Methoxy-fenozide [68647]	Meto-lachlor [65090]
May 2016—Continued									
SACRAMENTO R A R MILE 94.6 NR ROBBINS CA	05/09/2016	1550	—	—	—	15.3	(2.6)	6.7	12.8
COLUSA BASIN DRAINAGE CANAL A KNIGHTS LANDING CA	05/09/2016	1410	—	—	13.6	16.5	—	8.0	78.3
SACRAMENTO R A R MILE 86.2 NR KNIGHTS LANDING CA	05/09/2016	1154	—	—	—	15.3	—	5.7	27.2
SACRAMENTO SLOUGH NR VERONA CA	05/10/2016	1102	—	—	—	10.0	(3.4)	4.8	64.4
FEATHER R A R MILE 0.4 MI A VERONA CA	05/10/2016	1301	—	—	—	(7.9)	—	—	—
NATOMAS CROSS CANAL A VERONA CA	05/10/2016	1450	—	—	—	—	—	—	—
SACRAMENTO R A VERONA CA	05/10/2016	1555	—	—	—	10.4	—	—	15.2
SACRAMENTO R A R MILE 69.5 NR BRYTE CA	05/11/2016	1646	—	—	—	14.7	—	—	15.2
SACRAMENTO R A R MILE 62.8 A BRYTE CA	05/11/2016	1505	—	—	—	17.3	—	—	16.2
AMERICAN R 1 MI AB MOUTH CA	05/11/2016	0940	—	—	—	29.1	—	—	—
SACRAMENTO R A R MILE 55.8 NR SACRAMENTO CA	05/11/2016	1155	—	—	—	15.0	—	—	11.3
SACRAMENTO R A R MILE 46.4 A FREEPORT CA	05/12/2016	1416	—	—	—	16.1	—	—	10.7
SACRAMENTO R A R MILE 44.0 CA	05/12/2016	1212	—	—	—	16.1	—	—	11.2
SACRAMENTO R A HOOD CA	05/12/2016	0910	—	—	—	15.3	(2.7)	—	11.3
SACRAMENTO R A R MILE 30.5 NR VORDEN CA	05/13/2016	1158	—	—	—	18.1	—	—	11.4
SACRAMENTO R A R MILE 19.0 NR ISLETON CA	05/13/2016	0900	—	—	—	14.4	—	—	12.1
October 2016—Continued									
SACRAMENTO R A R MILE 94.6 NR ROBBINS CA	10/24/2016	1132	—	—	—	29.5	—	—	—
COLUSA BASIN DRAINAGE CANAL A KNIGHTS LANDING CA	10/24/2016	1400	4.7	—	—	33.7	—	52.0	—
SACRAMENTO R A R MILE 86.2 NR KNIGHTS LANDING CA	10/24/2016	1525	—	—	—	27.8	—	—	—
SACRAMENTO SLOUGH NR VERONA CA	10/25/2016	1311	—	—	—	13.2	—	41.7	—
FEATHER R A R MILE 0.4 MI A VERONA CA	10/25/2016	1140	—	—	—	—	—	5.8	—
NATOMAS CROSS CANAL A VERONA CA	10/25/2016	1504	—	(3.4)	—	—	6.1	7.4	—

Table 4. Pesticide concentrations in surface-water samples collected in the Sacramento River watershed, California, May and October 2016.—Continued

[Numbers in brackets are U.S. Geological Survey (USGS) National Water Information System (NWIS) parameter codes. Concentrations are in nanograms per liter (ng/L). Results in parentheses ( ) are below method detection limits and are estimates. The following compounds were analyzed but were not detected in any samples: 3,5-dichloroaniline, acetamiprid, acibenzolar-methyl, alachlor, allethrin, atrazine, azinphos methyl, azinphos methyl oxon, benfluralin, bifenthrin, bromuconazole, butralin, butylate, captan, carbaryl, carbofuran, carboxin, chlorothalonil, chlorpyrifos, chlorpyrifos oxon, clothianidin, coumaphos, cyantraniliprole, cyazofamid, cycloate, cyfluthrin, cyhalofop-butyl, cyhalothrin, cymoxanil, cypermethrin, cyproconazole, cyprodinil, DCPA, deltamethrin, desthioprothioconazole, diazinon, diazinon oxon, difenconazole, dimethomorph, dinotefuran, EPTC, esfenvalerate, ethaboxam, ethalfluralin, etofenprox, famoxadone, fenamidone, fenarimol, fenbuconazole, fenhexamide, fenpropathrin, fenpyroximate, fenthion, fipronil desulfinyl amide, flonicamid, fluazinam, fludioxinil, flufenacet, flumetralin, fluopicolide, fluopyram, fluoxastrobin, flusilazole, flutolanil, flutriafol, imazalil, indoxacarb, ipconazole, iprodione, kresoxim-methyl, malathion, malathion oxon, mandipropamid, metalaxyl, metconazole, methidathion, methoprene, methyl parathion, molinate, myclobutanil, napropamide, novaluron, oryzalin, oxydiazon, oxyfluorfen, p,p’-DDE, p,p’-DDT, paclobutrazol, pentachloroaniline, pentachloroanisole, pebulate, pendimethalin, penthiopyrad, permethrin, phenothrin, phosmet, picoxystrobin, prodiamine, prometon, prometryn, propanil, propargite, propiconazole, propyzamide, pyraclostrobin, pyridaben, pyrimethanil, quinoxyfen, resmethrin, sedaxane, sulfoxaflor, tau-fluvalinate, tebuconazole, tebufenozide, tebupirimfos, tebupirimfos oxon, tefluthrin, tetraconazole, tetradifon, tetramethrin, thiabendazole, thiacloprid, thiamethoxam, thiazopyr, tolfenpyrad, triadimefon, triadimenol, triallate, tribufos, tricyclazole, trifloxystrobin, triflumizole, trifluralin, triticonazole, and zoxamide. **Abbreviations**: hhmm, hours:minutes; mm/dd/yyyy, month/day/year; —, not detected]

USGS station name	Sample date (mm/dd/yyyy)	Sample time (hhmm)	Flupyradi-furone [52764]	Fluridone [51864]	Fluxa-pyroxad [51851]	Hexa-zinone [65085]	Imidaclo-prid [68426]	Methoxy-fenozide [68647]	Meto-lachlor [65090]
October 2016—Continued									
SACRAMENTO R A VERONA CA	10/25/2016	1606	—	—	—	17.6	—	4.7	—
SACRAMENTO R A R MILE 69.5 NR BRYTE CA	10/26/2016	1606	—	—	—	28.7	—	4.1	—
SACRAMENTO R A R MILE 62.8 A BRYTE CA	10/26/2016	1431	—	—	—	19.8	—	3.3	—
AMERICAN R 1 MI AB MOUTH CA	10/26/2016	0933	—	—	—	—	—	—	—
SACRAMENTO R A R MILE 55.8 NR SACRAMENTO CA	10/26/2016	1145	—	—	—	19.2	—	3.7	—
SACRAMENTO R A R MILE 46.4 A FREEPORT CA	10/27/2016	1607	—	—	—	15.4	—	3.5	—
SACRAMENTO R A R MILE 44.0 CA	10/27/2016	1410	—	—	—	14.7	—	3.6	—
SACRAMENTO R A HOOD CA	10/27/2016	1055	—	—	—	17.3	—	—	—
SACRAMENTO R A R MILE 30.5 NR VORDEN CA	10/28/2016	1245	—	—	—	19.1	—	—	—
SACRAMENTO R A R MILE 19.0 NR ISLETON CA	10/28/2016	0940	—	—	—	17.5	—	—	—

USGS station name	Sample date (mm/dd/yyyy)	Sample time (hhmm)	Oxathiapip-rolin [52766]	p,p′-DDD [65094]	Piperonyl butoxide [65102]	Penoxsulam [51863]	Simazine [65105]	Thiobencarb [65107]
May 2016—Continued								
SACRAMENTO R A R MILE 94.6 NR ROBBINS CA	05/09/2016	1550	—	—	—	—	6.6	9.2
COLUSA BASIN DRAINAGE CANAL A KNIGHTS LANDING CA	05/09/2016	1410	—	—	—	5.3	5.1	319.0
SACRAMENTO R A R MILE 86.2 NR KNIGHTS LANDING CA	05/09/2016	1154	—	—	—	—	—	93.6
SACRAMENTO SLOUGH NR VERONA CA	05/10/2016	1102	—	—	—	—	7.2	—
FEATHER R A R MILE 0.4 MI A VERONA CA	05/10/2016	1301	—	—	—	—	—	9.8
NATOMAS CROSS CANAL A VERONA CA	05/10/2016	1450	—	—	—	—	(4.3)	158.9
SACRAMENTO R A VERONA CA	05/10/2016	1555	—	—	—	—	—	35.9
SACRAMENTO R A R MILE 69.5 NR BRYTE CA	05/11/2016	1646	—	—	—	—	—	54.4
SACRAMENTO R A R MILE 62.8 A BRYTE CA	05/11/2016	1505	—	—	—	—	—	46.7

Table 4. Pesticide concentrations in surface-water samples collected in the Sacramento River watershed, California, May and October 2016.—Continued

[Numbers in brackets are U.S. Geological Survey (USGS) National Water Information System (NWIS) parameter codes. Concentrations are in nanograms per liter (ng/L). Results in parentheses ( ) are below method detection limits and are estimates. The following compounds were analyzed but were not detected in any samples: 3,5-dichloroaniline, acetamiprid, acibenzolar-methyl, alachlor, allethrin, atrazine, azinphos methyl, azinphos methyl oxon, benfluralin, bifenthrin, bromuconazole, butralin, butylate, captan, carbaryl, carbofuran, carboxin, chlorothalonil, chlorpyrifos, chlorpyrifos oxon, clothianidin, coumaphos, cyantraniliprole, cyazofamid, cycloate, cyfluthrin, cyhalofop-butyl, cyhalothrin, cymoxanil, cypermethrin, cyproconazole, cyprodinil, DCPA, deltamethrin, desthioprothioconazole, diazinon, diazinon oxon, difenconazole, dimethomorph, dinotefuran, EPTC, esfenvalerate, ethaboxam, ethalfluralin, etofenprox, famoxadone, fenamidone, fenarimol, fenbuconazole, fenhexamide, fenpropathrin, fenpyroximate, fenthion, fipronil desulfinyl amide, flonicamid, fluazinam, fludioxinil, flufenacet, flumetralin, fluopicolide, fluopyram, fluoxastrobin, flusilazole, flutolanil, flutriafol, imazalil, indoxacarb, ipconazole, iprodione, kresoxim-methyl, malathion, malathion oxon, mandipropamid, metalaxyl, metconazole, methidathion, methoprene, methyl parathion, molinate, myclobutanil, napropamide, novaluron, oryzalin, oxydiazon, oxyfluorfen, p,p’-DDE, p,p’-DDT, paclobutrazol, pentachloroaniline, pentachloroanisole, pebulate, pendimethalin, penthiopyrad, permethrin, phenothrin, phosmet, picoxystrobin, prodiamine, prometon, prometryn, propanil, propargite, propiconazole, propyzamide, pyraclostrobin, pyridaben, pyrimethanil, quinoxyfen, resmethrin, sedaxane, sulfoxaflor, tau-fluvalinate, tebuconazole, tebufenozide, tebupirimfos, tebupirimfos oxon, tefluthrin, tetraconazole, tetradifon, tetramethrin, thiabendazole, thiacloprid, thiamethoxam, thiazopyr, tolfenpyrad, triadimefon, triadimenol, triallate, tribufos, tricyclazole, trifloxystrobin, triflumizole, trifluralin, triticonazole, and zoxamide. **Abbreviations**: hhmm, hours:minutes; mm/dd/yyyy, month/day/year; —, not detected]

USGS station name	Sample date (mm/dd/yyyy)	Sample time (hhmm)	Oxathiapiprolin [52766]	p,p′-DDD [65094]	Piperonyl butoxide [65102]	Penoxsulam [51863]	Simazine [65105]	Thiobencarb [65107]
		May 2016—Continued						
AMERICAN R 1 MI AB MOUTH CA	05/11/2016	0940	—	—	—	—	—	—
SACRAMENTO R A R MILE 55.8 NR SACRAMENTO CA	05/11/2016	1155	—	—	—	—	—	31.8
SACRAMENTO R A R MILE 46.4 A FREEPORT CA	05/12/2016	1416	—	—	—	—	—	33.7
SACRAMENTO R A R MILE 44.0 CA	05/12/2016	1212	—	—	5.0	—	—	34.6
SACRAMENTO R A HOOD CA	05/12/2016	0910	—	—	6.7	—	—	28.8
SACRAMENTO R A R MILE 30.5 NR VORDEN CA	05/13/2016	1158	—	—	—	—	—	34.3
SACRAMENTO R A R MILE 19.0 NR ISLETON CA	05/13/2016	0900	—	—	—	—	—	31.0
		October 2016—Continued						
SACRAMENTO R A R MILE 94.6 NR ROBBINS CA	10/24/2016	1132	—	—	—	—	—	—
COLUSA BASIN DRAINAGE CANAL A KNIGHTS LANDING CA	10/24/2016	1400	—	—	—	—	—	—
SACRAMENTO R A R MILE 86.2 NR KNIGHTS LANDING CA	10/24/2016	1525	—	—	—	—	—	—
SACRAMENTO SLOUGH NR VERONA CA	10/25/2016	1311	—	—	—	4.8	—	—
FEATHER R A R MILE 0.4 MI A VERONA CA	10/25/2016	1140	—	—	—	—	—	—
NATOMAS CROSS CANAL A VERONA CA	10/25/2016	1504	27.0	4.5	—	5.8	—	—
SACRAMENTO R A VERONA CA	10/25/2016	1606	—	—	—	—	—	—
SACRAMENTO R A R MILE 69.5 NR BRYTE CA	10/26/2016	1606	—	—	—	—	—	—
SACRAMENTO R A R MILE 62.8 A BRYTE CA	10/26/2016	1431	—	—	—	—	—	—
AMERICAN R 1 MI AB MOUTH CA	10/26/2016	0933	—	—	—	—	—	—
SACRAMENTO R A R MILE 55.8 NR SACRAMENTO CA	10/26/2016	1145	—	—	—	—	—	—
SACRAMENTO R A R MILE 46.4 A FREEPORT CA	10/27/2016	1607	—	—	—	—	—	—
SACRAMENTO R A R MILE 44.0 CA	10/27/2016	1410	—	—	—	—	—	—
SACRAMENTO R A HOOD CA	10/27/2016	1055	—	—	—	—	—	—
SACRAMENTO R A R MILE 30.5 NR VORDEN CA	10/28/2016	1245	—	—	—	—	—	—
SACRAMENTO R A R MILE 19.0 NR ISLETON CA	10/28/2016	0940	—	—	—	—	—	—

Table 5. Detection frequencies and maximum concentrations for selected pesticides in surface-water samples collected at sites in the Sacramento River watershed, California, May and October 2016.

[Detection frequencies and highest measured concentrations of pesticides from 16 water-sampling sites in May and October 2016. Overall detection frequency combines both sampling events. Results in parentheses ( ) are below method detection limits and are estimates. **Abbreviations:** EPA OPP, U.S. Environmental Protection Agency Office of Pesticide Programs; ng/l, nanograms per liter; µg/l, microgram per liter; —, not detected]

Compound	May 2016 detection frequency (in percent)	May 2016 highest concentration detected (ng/l)	October 2016 detection frequency (in percent)	October 2016 highest concentration detected (ng/l)	Overall 2016 detection frequency (in percent)
3,4-dichloroaniline	19	19.1	75	24.0	47
Azoxystrobin	94	140.0	75	66.2	84
Boscalid	94	29.5	0	—	47
Carbendazim	6	8.6	25	14.2	16
Chlorantraniliprole	25	8.9	19	5.4	22
Clomazone	94	576.3	0	—	47
DCPMU	19	7.4	50	48.8	34
DCPU	13	(3.2)	19	9.3	16
Dithiopyr	0	—	6	26.2	3
Diuron	94	26.4	75	326.0	84
Fipronil	0	—	6	3.6	3
Fipronil desulfinyl	0	—	6	8.8	3
Fipronil sulfide	0	—	6	3.0	3
Fipronil sulfone	0	—	6	8.8	3
Flupyradifurone	0	—	6	4.7	3
Fluridone	0	—	6	(3.4)	3
Fluxapyroxad	6	13.6	0	—	3
Hexazinone	94	29.1	81	33.7	88
Imidacloprid	19	(3.4)	6	6.1	13
Methoxyfenozide	25	8.0	63	52.0	44
Metolachlor	81	78.3	0	—	41
Oxathiapiprolin	0	—	6	27.0	3
p,p’-DDD	0	—	6	4.5	3
Piperonyl butoxide	13	6.7	0	—	6
Penoxsulam	6	5.3	13	5.8	9
Simazine	25	7.2	0	—	13
Thiobencarb	88	319.0	0	—	44

Table 6. Pesticide concentrations in suspended sediment filtered from surface-water samples collected at sites in the Sacramento River watershed, California, May and October 2016.

[Numbers in brackets are U.S. Geological Survey (USGS) National Water Information System (NWIS) parameter codes. The following compounds were analyzed but were not detected in any samples: 3,4-dichloroaniline, 3,5-dichloroaniline, acibenzolar-methyl, alachlor, allethrin, atrazine, azinphos methyl, azinphos methyl oxon, azoxystrobin, benfluralin, bifenthrin, boscalid, bromuconazole, butralin, butylate, captan, carbaryl, carbofuran, chlorothalonil, chlorpyrifos, chlorpyrifos oxon, coumaphos, cycloate, cyfluthrin, cyhalofop-butyl, cyhalothrin, cypermethrin, cyproconazole, cyprodinil, DCPA, deltamethrin, diazinon, diazinon oxon, difenconazole, dimethomorph, dithiopyr, EPTC, esfenvalerate, ethalfluralin, etofenprox, famoxadone, fenamidone, fenarimol, fenbuconazole, fenhexamide, fenpropathrin, fenpyroximate, fenthion, fipronil, fipronil desulfinyl amide, fipronil desulfinyl, fiprinil sulfide, fiprinil sulfone, fluazinam, fludioxinil, flufenacet, flumetralin, fluopicolide, fluopyram, fluoxastrobin, flusilazole, flutolanil, flutriafol, fluxapyroxad, hexazinone, imazalil, indoxacarb, ipconazole, iprodione, kresoxim-methyl, malathion, malathion oxon, metalaxyl, metconazole, methidathion, methoprene, methyl parathion, metolachlor, molinate, myclobutanil, napropamide, novaluron, oxydiazon, oxyfluorfen, p,p'-DDD, p,p'-DDE, p,p'-DDT, paclobutrazol, pentachloroanisole, pentachloronitrobenzene, pebulate, pendimethalin, permethrin, phenothrin, phosmet, picoxystrobin, piperonyl butoxide, prodiamine, prometon, prometryn, propanil, propargite, propiconazole, propyzamide, pyraclostrobin, pyridaben, pyrimethanil, quinoxyfen, resmethrin, sedaxane, simazine, tau-fluvalinate, tebuconazole, tebupirimfos, tebupirimfos oxon, tefluthrin, tetraconazole, tetradifon, tetramethrin, thiazopyr, triadimefon, triadimenol, triallate, tribufos, trifloxystrobin, triflumizole, trifluralin, triticonazole, and zoxamide. **Abbreviations**: hhmm, hours:minutes; mm/dd/yyyy, month/day/year; ng/L, nanogram per liter; —, not detected]

USGS station name	USGS station number	Sample date (mm/dd/yyyy)	Sample time (hhmm)	Sediment weight (gram)	Clomazone [67562] (ng/L)	Thiobencarb [65107] (ng/L)
COLUSA BASIN DRAINAGE CANAL A KNIGHTS LANDING CA	384804121432401	05/09/2016	1410	0.067	5.4	5.4
SACRAMENTO SLOUGH NR VERONA CA	384649121381101	05/10/2016	1102	0.036	7.1	—
NATOMAS CROSS CANAL A VERONA CA	384649121361501	05/10/2016	1450	0.018	3.4	—

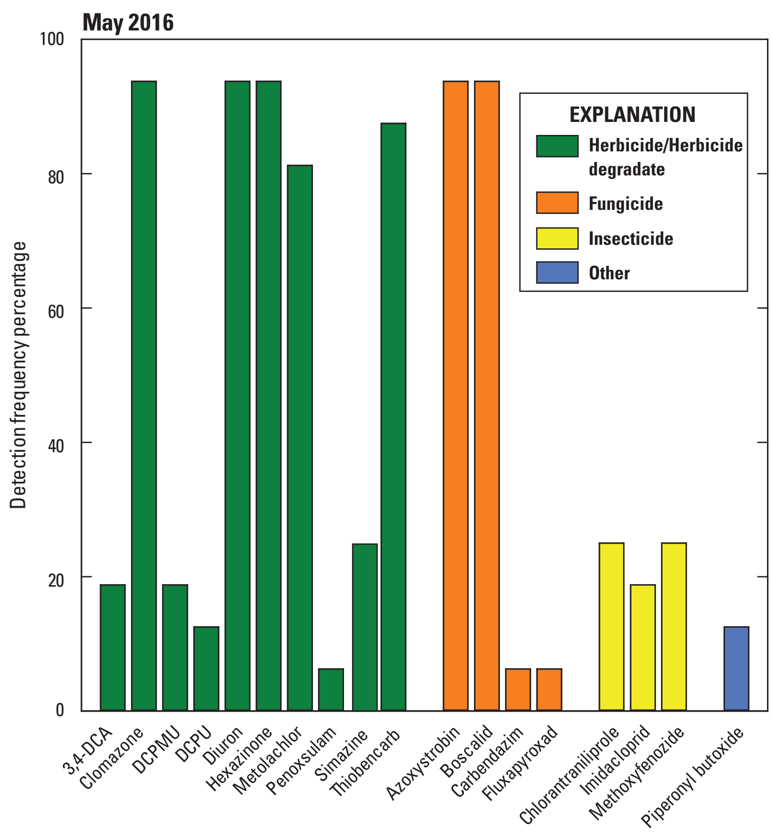


Figure 3. Pesticide detection frequencies in 16 samples from sites in the Sacramento River watershed, California, during May 2016.

During the October sampling event, the herbicides hexazinone (81 percent detection frequency), diuron (75 percent), and the herbicide degradates N-3,4-dichlorophenyl-N-methyl-urea (DCPMU; 50 percent); and 3,4-dichloroaniline (3,4-DCA; 75 percent); along with the fungicide azoxystrobin (75 percent); and the insecticide methoxyfenozide (63 percent), were the most frequently detected pesticides in water samples (fig. 5; table 5). Pesticide concentrations ranged from below the MDLs to 326 ng/L (diuron), and maximum concentrations were all below 70 ng/L, except for one detection of diuron (fig. 6; table 5). Average pesticide concentrations and the average number of pesticide detections at the agricultural drainage indicator sites were over 80 percent greater than in the Sacramento River integrator sites. All pesticides were detected at concentration levels lower than the U.S. Environmental Protection Agency's aquatic life benchmarks (U.S. Environmental Protection Agency, 2017). No pesticides were detected in the suspended sediments filtered from the water samples collected during the October sampling event.

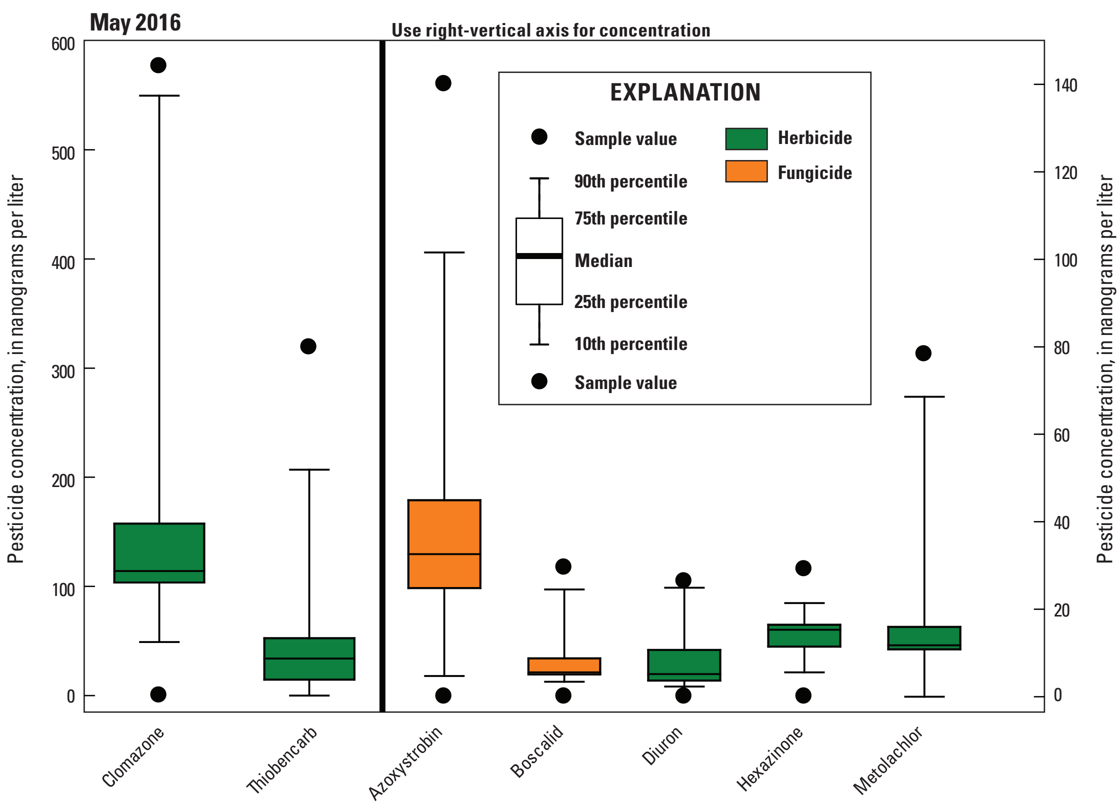


Figure 4. Frequency distribution of concentrations of the most frequently detected pesticides at sites in the Sacramento River watershed, California, during May 2016.

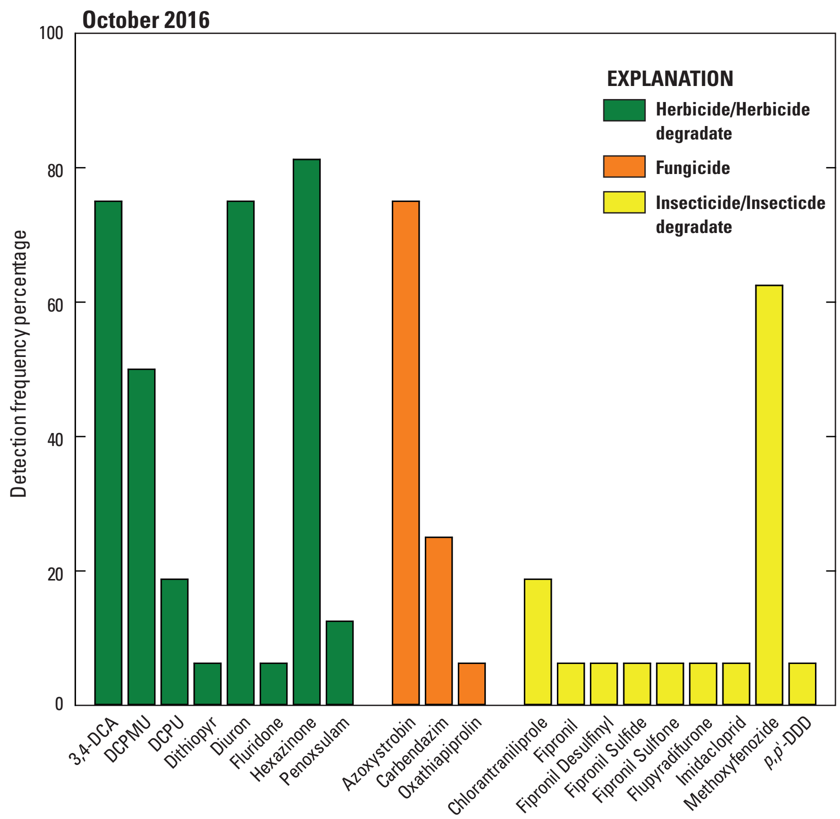


Figure 5. Pesticide detection frequencies in 16 samples from sites in the Sacramento River watershed, California, during October 2016.

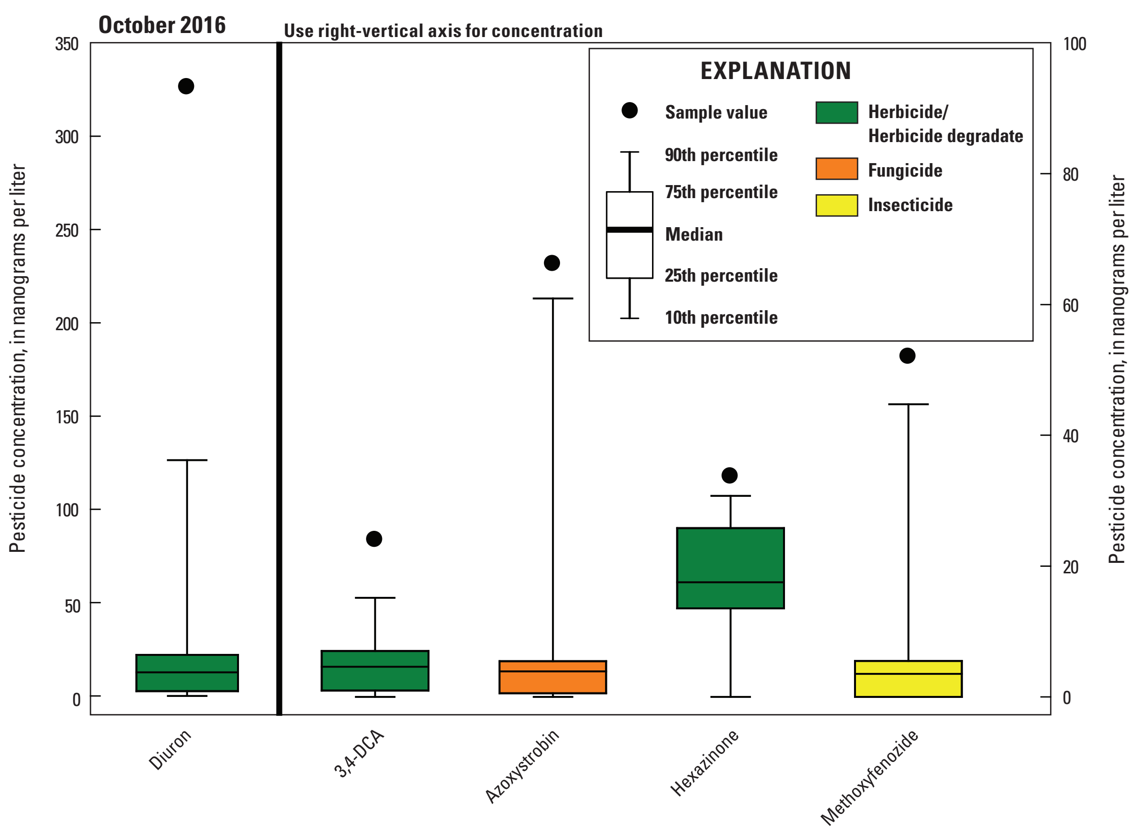


Figure 6. Frequency distribution of concentrations of the most frequently detected pesticides at sites in the Sacramento River watershed, California, during October 2016.

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