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Pesticides of Interest for Urban Surface Water Quality

Urban Pesticides Use Trends Annual Report 2008

Prepared for the
San Francisco Estuary Project

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PREFACE

This is a report of research performed by TDC Environmental, LLC for the San Francisco Estuary Project (SFEP). This report was prepared for SFEP to fulfill the annual reporting requirements in Task 7.1.3 of SFEP's grant agreement (Number 06-342-552-0) with the State Water Resources Control Board for Taking Action for Clean Water.

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SUMMARY

This report is intended to assist California water quality agencies—including municipalities—by summarizing and analyzing urban pesticide use trends for the pesticides of greatest interest for urban surface water quality. This annual review is prepared by the Urban Pesticide Pollution Prevention (UP3) Project with funding from the State Water Resources Control Board.

This report uses existing data to examine urban use patterns for pesticides of concern for water quality (which were identified in the UP3 Project report *Pesticides in Urban Surface Water: Annual Review of New Scientific Findings 2008*)—pyrethroids, carbaryl, malathion, polyhexamethylene biguanadine (PHMB), and fipronil. This report also documents the decline in use of the two previously most common urban insecticides—diazinon and chlorpyrifos.

This report looks exclusively at urban pesticide use. It not only considers sales and use patterns, but also explores the potential for adverse effects on urban surface waters in its analysis, with the intent of making it a more complete and useful resource than reports that simply address pesticide market availability or pesticide use patterns.

Methodology. The urban pesticide use estimates in this report are derived primarily from pesticide sales and use data from the California Department of Pesticide Regulation (DPR). Using these data, it is possible to develop gross quantitative estimates of urban pesticide use in California. Data from other sources are used to provide additional insight into California urban pesticide use patterns and to examine uncertainties inherent in the DPR data sets. This year's analysis includes California pesticide sales and use data through calendar year 2006 (the most recent data available).

Major findings:

- Use of pyrethroids, carbaryl, and PHMB in California urban areas has increased significantly since 2000. Pyrethroids are currently the most commonly applied insecticides in California urban areas. Pyrethroids, fipronil, and (to a lesser extent) carbaryl appear to have replaced diazinon and chlorpyrifos in the urban pesticide use market.
- Use of the organophosphorous insecticides diazinon and chlorpyrifos in California urban areas has decreased significantly since 2000. Most urban uses of diazinon and chlorpyrifos ended in 2005; however, existing stocks of some products can continue to be used until those stocks are exhausted. Estimated urban use of malathion also decreased over the last few years, even though regulatory changes did not severely limit allowable urban uses of malathion.
- More than 75% of California pyrethroid use occurred in urban areas in 2005-2006. More than 90% of estimated urban pyrethroid use was by professional applicators. Most California pyrethroid use was by professional applicators for structural pest control.
- Two pyrethroids—cypermethrin and bifenthrin—accounted for almost 80% of the pyrethroid-related aquatic "toxicity equivalents"[1] estimated released in California urban areas in 2005-2006.

[1] The use of aquatic "toxicity equivalents" allows comparison of a family of related substances that have significantly different toxicity to aquatic organisms. See Section 2.5 for details on how toxicity equivalents are calculated for pyrethroids.

- The most heavily used pyrethroids in California urban areas in 2005-2006 were bifenthrin, cyfluthrin (including beta-cyfluthrin), cypermethrin, deltamethrin, esfenvalerate, lambda-cyhalothrin, and permethrin. Use by professional applicators accounted for at least two-thirds of the estimated urban use of each of these pyrethroids except esfenvalerate, which was used primarily by non-professionals.
- Not all urban pyrethroid use is outdoors. Some applications are made underground; other applications are indoors.
    - A significant fraction of the pyrethroids applied by professionals for structural pest control may be injected underground, where pyrethroids are not readily transported to surface water.
    - Pyrethroids may also be used indoors, where they may ultimately be discharged to municipal wastewater treatment plants. Indoor use by professionals is estimated to represent a relatively small fraction of the quantity of pyrethroids applied by professionals for structural pest control; however, indoor use may represent a meaningful fraction of non-professional pyrethroid use.

<u>Recommendations</u>. The UP3 Project recommends that managers responsible for water quality protection consider all recommendations in Section 3.2.

The highest priority for actions to end current urban pesticide water quality problems is to make changes to outdoor, aboveground use of pyrethroids. Since most outdoor aboveground use of pyrethroids appears to be targeting ants around buildings, defining and implementing new ant control strategies that avoid broadcast applications of pesticides toxic to aquatic organisms (and any uncontainerized applications of other pesticides that are highly toxic to aquatic organisms, such as fipronil, carbaryl, or malathion) is recommended.

Other recommendations include conducting scientific studies to address priority pesticide use information needs and modifying DPR data systems to improve the state’s ability to assess urban pesticide use patterns.

1.0 INTRODUCTION

1.1 Background

The presence of pesticides in urban surface water and the environmental effect of pesticides that are found in water bodies are topics of great interest to research scientists, regulatory agencies, municipalities, and the general public. Future trends in water quality depend, in part, on trends in use of urban pesticides. This report is intended to assist California water quality agencies—including municipalities—by analyzing urban pesticide use trends. This report provides water quality agencies with the "big picture" of urban pesticide use in California, particularly regarding the use of pesticides of concern for urban surface water quality.

This is one of three reports prepared annually by the Urban Pesticide Pollution Prevention (UP3) Project.[2] The purpose of the UP3 Project is to help California Water Boards and municipalities prevent pesticide-related water quality problems.[3] The San Francisco Estuary Project (SFEP) has been awarded California water bond grant funds by the State Water Resources Control Board to implement the UP3 Project through mid-2009. TDC Environmental is providing technical support for the project.

1.2 Scope of This Report

This is the fourth annual urban pesticide sales and use trends report prepared by the UP3 Project. This report looks exclusively at urban pesticide[4] use. For purposes of this report, "urban" was broadly defined to include essentially all non-agricultural pesticide use, including applications at residences, commercial buildings, institutions, parks, golf courses, and in rights-of-way. It presents an analysis of data and reports relevant to urban pesticide use trends for pesticides that have the potential to cause adverse effects in urban surface waters. It not only considers sales and use patterns, but also explores the potential for adverse effects on urban surface waters, with the intent of making it a more complete and useful resource than reports that simply address pesticide market availability or pesticide use patterns.

As explained in the UP3 Project *Annual Review of New Scientific Findings 2008* (TDC Environmental 2008), use of pyrethroid insecticides in California urban areas is causing adverse effects in aquatic ecosystems receiving urban runoff. Section 2.5 of this report specifically examines how pyrethroids are used in urban areas to assist water quality managers and their colleagues with their response to this problem.

Based on previous analysis of pesticide sales and use (TDC Environmental 2007a) and pesticide retail shelf surveys (TDC Environmental 2005; Joshel 2003-2006; Clarke 2007-2008) the following pyrethroids are of greatest concern for urban surface water quality and therefore are included in this analysis: bifenthrin, cyfluthrin (including beta-cyfluthrin), cypermethrin, deltamethrin, esfenvalerate, lambda-cyhalothrin, permethrin, and tralomethrin. This report also includes information relevant to the other pesticides of concern for water quality identified in the UP3 Project *Annual Review of New Scientific*

[2] The other two reports are a review of California water quality agencies' urban pesticide water quality regulatory activities and a summary of recent scientific findings that are relevant to urban surface water quality management activities.

[3] In addition to statewide work, the UP3 Project does some work specifically in the San Francisco Bay Area to help implement the Diazinon and Pesticide-Related Toxicity in Bay Area Urban Creeks Water Quality Attainment Strategy and Total Maximum Daily Load (Johnson, 2005).

[4] The term "pesticide" encompasses all substances used to repel, kill, or control insect or animal pests, vegetation, fungi, virus, bacteria, or any other microorganism. Pesticides include insecticides, herbicides, fungicides, wood preservatives, and biocides (which are often referred to as "antimicrobials").

Findings 2008—carbaryl, malathion, polyhexamethylene biguanadine (PHMB), and fipronil—and information about two pesticides associated with recent (now believed to be past) urban water quality problems—the organophosphorous insecticides diazinon and chlorpyrifos. Together, the pesticides above comprise the list of pesticides that the UP3 Project has identified as being of concern for urban surface water quality. In this report, this list is called the "study list." Since all but one of the study-list pesticides are insecticides, the remainder of the report focuses primarily on insecticides.[5] Table 1 lists the study-list pesticides and their other commonly used names.

Table 1. Pesticides of Concern for Urban Surface Water Quality ("Study-List Pesticides") and Their Common Names

Name	Synonyms and Trade Names (Examples)
Pyrethroids	
Bifenthrin	Biphenthrin, Bifenthrine, Biflex, Brigade, Capture, Onyx, Talstar
Cyfluthrin	Baythroid, Tempo, Cykick, Renounce
Beta-Cyfluthrin	Tempo Ultra, Cylence
Cypermethrin	Ammo, Cynoff, Demon, Cymbush
Deltamethrin	Decamethrin, Deltadust, Deltaguard, Suspend SC
Esfenvalerate	(S)-Fenvalerate, Asana
Lambda-Cyhalothrin	Scimitar, Demand
Permethrin	Ambush, Nix, Pounce
Tralomethrin	Saga
Organophosphorous Pesticides (OPs)	
Chlorpyrifos	Dursban, Lorsban
Diazinon	Diazol
Malathion	Cythion, Carbophos, Fyfanon
Other	
Carbaryl	Sevin
Fipronil	Termidor, Maxforce FC, Frontline, Chipco Choice
PHMB	Baquacil, Revacil, Vantocil, Chlorine Free Splashes Sanitizer, Clear Comfort Sanitizer, Clorox Readymop Advanced Floor Cleaner, Free, Soft Soak Sanitizer

Source: DPR Product/Label database.

This report builds on previous related work, particularly last year's *Urban Pesticide Use Trends Annual Report* (TDC Environmental 2007a), the UP3 Project *Annual Review of New Scientific Findings 2008* (TDC Environmental 2008) and a 2003 review of the water quality implications of the shift in urban insecticide use patterns resulting from the phase out of most urban uses of diazinon and chlorpyrifos (TDC Environmental 2003). The recommendations in this report specifically address how new scientific research and pesticide use information can be used to improve the effectiveness of California water

[5] Pesticide-related surface water problems in urban areas have historically been most commonly linked to insecticides (rather than herbicides or fungicides). USGS National Water Quality Assessment data suggest that insecticides are more likely than herbicides to be linked to pesticide-related toxicity in urban surface waters (see Hoffman et al. 2000 for more information).

quality agency efforts to prevent pesticide-related toxicity in surface waters, urban runoff, and municipal wastewater discharges.

1.3 Data Sources

This report is based on a review of information relating to trends in urban use of pesticides. Information in this report was obtained from a variety of sources:

- Pesticide sales and use data collected by the California Department of Pesticide Regulation (DPR);
- Pesticide retail shelf surveys;
- Pesticide product labels;
- Pesticide use surveys conducted by universities and government agencies; and
- Interviews with agency staff and researchers.

Since this report builds on previous reports, the focus is on the most recently available information (i.e., information that became available in 2007 and early 2008).

1.4 Report Organization

This report is organized as follows:

- *Section 1* (this section) provides the background and scope of the report.
- *Section 2* provides estimates of the California use of pesticides most likely to threaten urban surface water quality and looks at trends in the use of these pesticides.
- *Section 3* gives this report's conclusions on the sales and use trends for pesticide of interest for urban surface water quality and provides recommendations for future actions based on the information in this report.
- *Section 4* lists the references cited in the body of the report.

2.0 ESTIMATED URBAN USE OF STUDY-LIST PESTICIDES

2.1 Background

The only public source of quantitative data about California pesticide use is the California Department of Pesticide Regulation (DPR). It is possible to develop gross estimates of pesticide use in California based on DPR data. The estimation process uses pesticide sales data, reported pesticide use data, and a calculation of unreported use as described below. To ensure consistency with other pesticide data, this analysis follows DPR's convention of describing pesticide use in terms of pounds of pesticide "active ingredient." Pesticides in this section are grouped by chemical families—pyrethroids, organophosphorous pesticides (OPs), and other pesticides.

2.2 Pesticide Sales

While not all pesticides sold are used (some are stored indefinitely or disposed of), over the long term, there is likely to be a correlation between pesticide sales and pesticide use. The State of California compiles annual statewide pesticide sales volumes, by amount of active ingredient, based on the payment of a fee that provides the majority of California's pesticide regulatory program funding. California pesticide sales data are based on a report that accompanies payment of a fee on the first sale of a pesticide into or within California.[6] Using information from the fee payment reports, DPR compiles pesticide sales volumes, in pounds of pesticide active ingredient, into an annual report. Data are generally released 10 to 12 months after the end of the reporting year. The most recent data available are for calendar year 2006 (DPR 2008b).[7]

These sales data are available only as annual aggregate data; no temporal distributions or regional breakdowns are publicly available. Since 2005, DPR has made public sales data for all pesticides. Prior to 2005, data were only made public for pesticides for which more than three companies ("registrants") had registered products during the calendar year for which sales were reported (these data included about 90% of the quantity of pesticide active ingredients sold[8]). In 2003 and 2004, all study-list pesticide had more than three registrants; therefore sales data were made public for all study-list pesticides.

Aside from the DPR data, sales data from specific pesticide manufacturers, distributors, and retailers are usually considered confidential and are generally unavailable to water quality agencies. Occasionally, individual manufacturers, retailers, and distributors have disclosed specific sales figures, but such disclosure is unusual. Although market data firms do occasionally sell such data, the price has proven prohibitive for water quality agencies.

Table 2 (on the next page) presents California statewide sales of study-list pesticides from 2000-2006 (the most recent data available). These data include all pesticide sales, whether for urban or agricultural use. Note that sales of pyrethroids, fipronil, and PHMB have generally increased since 2000, while sales of diazinon, malathion, and carbaryl have generally decreased.

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[6] The fee is paid by whatever entity is responsible for the first sale in California—this may be a pesticide manufacturer, distributor, or other entity. DPR collects fees from about 1,700 entities each quarter (Farnsworth 2007). The fee applies only to the first sale of a pesticide into or within California. For most pesticides, subsequent sales do not require reporting and do not entail fee payments to the state.

[7] DPR makes these data available on the Internet: http://www.cdpr.ca.gov/docs/mlassess/nopdsold.htm.

[8] All DPR sales reports provide the total quantity of California pesticide sales each year. Reports of sales data for years prior to 2005 included both total disclosed sales and the total of all pesticide sales (including undisclosed sales) (DPR 2001a, 2002a, 2003a, 2005a, 2006a).

Table 2. Total (Agricultural and Urban) Sales of Study-List Pesticides in California, 2000-2006
(Pounds of Pesticide Active Ingredient)

Pesticide	2000	2001	2002	2003	2004	2005	2006
Pyrethroids							
Bifenthrin	NR[a]	32,000	32,000	71,000	110,000	44,000	160,000
Cyfluthrin	47,000	47,000	51,000	45,000	46,000	37,000	41,000
Beta-Cyfluthrin	NR	NR	NR	4,300	16,000	5,500	5,400
Cypermethrin	50,000	50,000	65,000	82,000	78,000	91,000	85,000
Deltamethrin	8,300	3,200	4,400	4,900	3,900	4,000	4,700
Esfenvalerate	43,000	36,000	43,000	54,000	57,000	50,000	80,000
Lambda-Cyhalothrin	NR	NR	24,000	28,000	26,000	38,000	55,000
Permethrin	440,000	280,000	430,000	480,000	470,000	480,000	610,000
Tralomethrin	1,900	34,000	?[b]	3,200	4,200	1,500	2,500
OPs							
Chlorpyrifos[c]	2,400,000	2,000,000	1,700,000	2,000,000	2,300,000	2,400,000	2,500,000
Diazinon[d]	1,400,000	1,400,000	920,000	750,000	810,000	500,000	420,000
Malathion	1,100,000	1,100,000	1,000,000	1,700,000	1,600,000	1,100,000	670,000
Other							
Carbaryl	560,000	410,000	420,000	330,000	390,000	410,000	410,000
Fipronil	1,900	19,000	32,000	14,000	18,000	22,000	24,000
PHMB	27,000	NR	NR	56,000	36,000	69,000	310,000

Source: DPR Sales data reports (DPR 2001a, 2002a, 2003a, 2005a, 2006a, 2007b, 2008b) Note that data in this table reflect corrected year 2003 and 2004 reports issued in 2007. Data are rounded to reflect their estimated accuracy (assumed to be two significant figures).
[a] NR = Not Reported. Prior to 2005, sales of products with fewer than four registrants were not disclosed to the public.
[b] Reported value is known to be inaccurate due to an internal database error that was corrected starting with 2003 DPR pesticide sales data reports.
[c] Retail sales of almost all non-professional use chlorpyrifos products ended in December 2001.
[d] Retail sales of diazinon products for urban use ended in December 2004.

Uncertainty

Since DPR sales data are based on fees from pesticide sellers, researchers generally consider these data to be relatively accurate, as it is reasonable to assume that most pesticide sellers comply with state fee requirements. Errors are known to result from the following sources:

- Failure to pay required fees. A 2004 audit of Long's Drugs sales data suggested that sales data may understate actual sales, particularly for urban products (DPR 2004; Brank 2006). Based on this audit, DPR estimates that its past sales data are at least 10% below actual total pesticide sales, not including unregistered products (Brank 2005). The understatement of sales data is believed to apply primarily to non-agricultural products. DPR has estimated that prior to its 2004-2005 enforcement activities, non-agricultural pesticide retail sales may have been underestimated by an average of 20%, based on a limited number of individual audits (Brank 2006). This is an aggregate error estimate—the error in the data for the specific pesticides on the study list is not known. Relative errors in pesticide sales data are likely to differ among pesticides, since this error is based on non-compliance by particular categories of retailers (e.g., "big box" stores) and since the non-agricultural sales fractions differ among pesticides.

This error may extend beyond the non-professional sector for some pesticides. For example, as explained below, reported sales of cypermethrin and deltamethrin averaged less than 50% of the reported use of these pesticides between 1999 and 2005. This error could be explained by non-payment of fees, or it could be due to errors in reporting (see below).

Since the error associated with non-payment of fees is systematic, it is not expected to affect evaluation of past trends. Stepped-up enforcement of sales and registration requirements in 2005 and subsequent years may affect evaluation of trends that include data prior to and after 2005.

- Data errors. Prior to releasing its annual report, DPR does a quality assurance review of the data, with the intent of eliminating major data errors, such as errors in data entry or units (Owen 2006). However, neither registrants nor DPR rely on the pesticide product volumes reported by registrants for any fee or regulatory purpose, so the level of review given these numbers is not always high (fees are based on dollar sales, not quantity sales).

  Data entry errors also exist in DPR's internal database that is used to calculate the quantity of active ingredient sold. A 2006 DPR review of database values for pyrethroid products with high concentrations of active ingredient corrected several significant data entry errors. One bifenthrin product manufacturer also completed such a review and identified additional smaller data entry errors. DPR issued corrected sales reports for 2003, 2004, and 2005;[9] these corrections are reflected in this report.

  The UP3 Project has worked with DPR and registrants to review unusual data for study-list pesticides and to correct identified errors. Such cooperation has greatly improved the data. Because this has been on a case-by-case basis, it is likely that a few data errors continue to be reflected in the data used in this report.

- Year-to-year variations. Pesticide shipment scheduling practices and tax payment timing may cause sales to appear to fluctuate in a manner that does not reflect use patterns. (For instance, the spike in permethrin sales in 2000 may reflect timing of sales that would actually have occurred in 1999 or 2001, as this data point is inconsistent with the 10-year trend in permethrin sales). Sales may be higher than use in situations where purchasers are stockpiling products (e.g., situations where manufacturing is being phased out but existing product sales and/or use may continue until a later date or until existing stocks are exhausted). Evaluation of multiple years of sales data is necessary to ensure that apparent trends are meaningful. It is also important to recognize that pesticide use depends on environmental factors—such as the weather and pest populations—making year-to-year variations normal for the data set.

- Duplicate payments. Occasionally, fees are paid to DPR twice for the same container of a pesticide. This relatively unusual situation occurs when a labeled product is sold to another registrant, who then re-labels it; in this case, both would report the sale. It is unknown whether any such transfers occurred with any study-list pesticide.

[9] When DPR corrects errors in its sales reports, it posts the revised reports on the Internet.

2.3 Pesticide Use Reports

Certain pesticide applications[10] are required to be reported to the County Agricultural Commissioner who, in turn, reports the data to DPR. In general, the pesticide uses that require reporting are agricultural uses or urban applications made by professional applicators.[11] Examples of pesticide applications that require reporting—and applications that do not require reporting—are provided in Table 3.

Table 3. Overview of Pesticide Use Reporting in California

Examples of Pesticide Applications that Do Require Reporting	Examples of Pesticide Applications that Do Not Require Reporting
All applications by professional applicators	*All applications by non-professionals* (assuming application by non-professionals is legal)
All applications to agricultural crops	Incorporation of pesticides into consumer products, such as: • Wood preservatives • Biocides in soaps, cleaning products, or impregnated into solid materials (e.g., cutting boards, toys, clothing) • Biocides incorporated in products to prevent the product's degradation (e.g., in sponges and liquid products) • Insecticide-treated clothing • Biocides in paints • Biocide-generating equipment (e.g., clothes washing machines that generate silver ions)
Structural pest control (other than by a residential pesticide user), such as: • Termite, ant, and cockroach treatments • Building fumigation	Swimming pool, spa, and fountain treatments, such as: • Algaecides • Biocides (e.g., chlorine)
Landscape maintenance (other than by a residential pesticide user), such as: • Lawns • Gardens • Golf courses • Parks • Cemeteries	Cooling water system treatment with biocides
Road, rail, and utility rights of way, for purposes such as: • Weed control • Algae control	Use of biocides, such as: • Bleach use • Hospital and medical facility and equipment disinfection • Drinking water and wastewater disinfection
Mosquito control applications by mosquito abatement agencies	Pet flea treatments
Food product fumigation	Marine antifouling paint application

Source: TDC Environmental, based on review of California pesticide use reporting data, California pesticide products, and pesticide use reporting requirements in California law.

[10] The following pesticide uses must be reported: pesticide uses for the production of any agricultural commodity, except livestock; for the treatment of post-harvest agricultural commodities; for landscape maintenance in parks, golf courses, and cemeteries; for roadside and railroad rights-of-way; for poultry and fish production; any application of a restricted material; any application of a pesticide designated by DPR as having the potential to pollute ground water when used outdoors in industrial and institutional settings; and any application by a person engaged for hire in the business of pest control (e.g., a licensed pest control operator).

[11] In this report, "professional" refers to "[a]ny person engaged for hire in the business of pest control" (Title 3, California Code of Regulations, Section 6624). Professional applications can only be made by a trained person who works under the supervision of a licensed pesticide applicator or pest control operator.

DPR prepares annual summary reports on the basis of pesticide use reporting data. Required non-agricultural pesticide use reports lack the detail necessary for a complete examination of reported urban pesticide applications. Reporting requirements differ between agricultural and non-agricultural pesticide applications. Unlike agricultural pesticide use reports, which must include the specific geographic location and crop type, non-agricultural pesticide use reports identify application county (not the specific geographic location) and a broad application category like structural pest control or landscape maintenance. DPR has defined several broad reporting categories for non-agricultural pesticide use reporting. These categories are sufficiently detailed to identify categories of pesticide applications that are defined as "urban" for purposes of this analysis.[12] For non-agricultural pesticide applications, required reporting also includes (but is not limited to) the registration number of the product that was applied, the quantity applied, and the month it was applied. California pesticide use reporting data are available from an Internet database of pesticide use reports that is maintained by DPR.[13]

Table 4 (on the next page) summarizes statewide reported use of study-list pesticides in 2006 (the most recent data available). Note that the majority of pyrethroid reported use was for structural pest control. The structural pest control reporting category includes aboveground applications (e.g., spraying around a building to control ants), indoor applications, pre-construction termiticide treatments (e.g., treatment of soil prior to foundation construction), and underground injection (e.g., injection of pesticides into holes drilled into the ground to control termites).

Fipronil data are not included in Table 4 because a significant reporting problem was identified by DPR in response to questions from the UP3 Project. While exploring the question of why reported fipronil use exceeded reported sales, DPR discovered that a few professional structural pest control applicators were apparently reporting the amount of diluted product applied, rather than the amount of actual formulated product used. Because fipronil concentrate is typically diluted 150 times, this reporting error caused use to be over-reported by some 150 times. This seemingly minor error had significant consequences—nearly 30% of the entire reported use of fipronil in California in 2005 was reported under one professional applicator's license number. With the assistance of the appropriate County Agricultural Commissioner, DPR was able to confirm that this applicator was indeed reporting use of diluted material rather than the product itself (Farnsworth 2007).

DPR has notified County Agricultural Commissioners of the identified reporting errors. DPR's 2005 and 2006 reported use data for fipronil is currently being updated to reflect corrections to reports of fipronil use. Because the corrections are still in progress, fipronil reported use data are not included in this report.

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[12] For purposes of this analysis, the following categories of use from DPR's annual compilation reports were defined as urban uses: landscape maintenance, public health, regulatory pest control, rights of way, structural pest control, vertebrate control, uncultivated non-agricultural sites, and food processing plants. Some typically agricultural categories may include some applications in urban areas (*e.g.*, nurseries, greenhouses, sod/turf, fumigation), so this "urban" estimate is likely to understate actual reported use in urban areas.

[13] DPR's California Pesticide Information Portal (CalPIP) database is accessible on the Internet: http://calpip.cdpr.ca.gov/cfdocs/calpip/prod/main.cfm.

Table 4. California Study-List Pesticides Reported Use, 2006 (Pounds of Pesticide Active Ingredient)

Pesticide	Total (Agricultural and Urban)	Total (Urban Only)	Structural Pest Control	Landscape Maintenance
Pyrethroids				
Bifenthrin	110,000	88,000	85,000	2,400
Cyfluthrin	80,000	64,000	63,000	450
Beta-Cyfluthrin	16,000	16,000	11,000	1,900
Cypermethrin	190,000	190,000	190,000	1,600
Deltamethrin	8,800	8,700	8,000	140
Esfenvalerate	38,000	230	210	16
Lambda-Cyhalothrin	39,000	16,000	16,000	160
Permethrin	670,000	500,000	490,000	10,000
Tralomethrin	3	3	3	<1
OPs				
Chlorpyrifos	1,900,000	8,400	5,300	2,500
Diazinon	390,000	2,600	1,600	940
Malathion	410,000	52,000	23,000	2,200
Other				
Carbaryl	160,000	19,000	13,000	5,100
Fipronil	--[a]	--[a]	--[a]	--[a]
PHMB[b]	0[b]	0	0	0

Source: DPR's California Pesticide Information Portal (CalPIP) database (DPR 2008a). Data are rounded to reflect their estimated accuracy (assumed to be two significant figures). Totals may not add up due to rounding. Only malathion had more than 5,000 pounds of reported urban use other than structural pest control and landscaping (24,000 pounds for regulatory pest control). Less than 10% of the total volume of other study-list pesticides was reported for urban uses not listed in the table.

[a] Fipronil is not included in this table for reasons explained in the text.

[b] PHMB is only registered for uses that do not require reporting.

Uncertainty

Pesticide use reports are generally considered relatively reliable as compared to other data sources. DPR's reporting requirements and DPR's and County Agricultural Commissioners' enforcement systems are intended to ensure that most pesticide applications that require reporting are reported. Potential sources of error include:

- Non-compliance with reporting requirements. An unknown amount of non-reporting certainly occurs. Because DPR has never completed a field verification of the pesticide use reporting system, a quantitative estimate of non-reporting is not available. DPR completed an analysis comparing reported sales to reported use for a group of pesticides for which all uses are reportable (this analysis involved a small subset of all pesticides). DPR found a rather large variation in reporting among pesticides (Wilhoit 2005). In this analysis, DPR found that on average about 90% of the sales of the analyzed pesticides (for which all uses are reportable) was reported as used over a five-year period; however, since there was a large variation in results for individual pesticides, this average is very uncertain (Wilhoit 2005; Brank 2006). The error rate for individual pesticides—and for urban reportable uses (which could not be explored separately from agricultural uses with this analytical method)—may differ significantly from the aggregate underreporting suggested by this DPR analysis.

- Reporting errors. As mentioned above, professional applicators may occasionally make reporting errors, e.g., by reporting diluted product volumes rather than actual product volumes. If dilutions are high, like they are for fipronil, errors by only a small number of individuals can significantly change statewide data sets, as they did in the case of fipronil. Several other study-list pesticides may also be subject to this error, which is a possible explanation for finding that cypermethrin and deltamethrin reported use consistently significantly exceeds reported sales. Recognizing the importance of accurate pesticide use reporting, the Pest Control Operators of California, which is the professional organization for structural pest control applicators, has made its members aware of this issue (Van Steenwyk 2007). This should improve reporting accuracy for structural pest control applications starting in 2007.
- Data handling errors. Prior to releasing its annual report, DPR has always completed a quality assurance review of the data, which should eliminate data entry errors that are likely to have a significant effect on the data from the water quality perspective. After an audit of the data management system (Wilhoit et al. 2001), DPR implemented improved error handling processes and has continued efforts to improve the system; DPR believes these improvements keep errors to less than 1-2% (Wilhoit 2002; Wilhoit 2005).

2.4 Quantitative Pesticide Use Estimates

Using data from DPR, it is possible to develop gross quantitative estimates of pesticide use in California. The estimates use pesticide sales data, reported pesticide use data, and a calculation of pesticide use that does not require reporting. Assuming all pesticides sold are used within a particular year, pesticide use that does not require reporting ("unreported pesticide use") can be estimated to be approximately equal to the difference between statewide pesticide sales and statewide reported pesticide use This difference should be approximately equal to over-the-counter sales (retail sales to non-professionals). In other words, this estimation method is based on the assumption that urban use of a pesticide by non-professionals is approximately equal to over-the-counter sales of that pesticide.

Mathematically, this approach to estimating urban pesticide use can be expressed as follows:

$$\text{Urban Use} \approx \text{Reported Urban Use} + \text{Over-the-Counter (OTC) Sales}$$

$$\text{Statewide OTC Sales} \approx \text{Statewide Sales} - \text{Statewide Reported Use}$$

The main assumption behind this urban pesticide use estimation method is that all unreported pesticide use occurs in urban areas. The primary exceptions to California's pesticide use reporting requirements are home and garden use and most industrial, commercial, and institutional pesticide applications not made by professional applicators.[14] Because these activities occur primarily in urban areas—and essentially all agricultural use[15] requires reporting—the assumption that essentially all unreported uses of the study-list pesticides are urban is reasonable.

Another important assumption is that all pesticides sold are used—and used in the year they are sold. Some pesticides are stored and used in years after the year of purchase. If the market is stable, the effect of storage may not be very important. In a steady state market, use of past purchases may offset current purchases stored for future use. However, when the market changes—as it has due to phase out of previously popular diazinon and chlorpyrifos, for example—the stored products may have different active ingredients than current purchases that are stored for future use. In times of market change, the assumption that all pesticides sold are used in a given year would tend to overstate use of the active ingredient and understate use of the formerly popular active ingredient. Since some pesticides that are sold are never used, this approach generally overestimates non-professional use to an unknown degree. The unused amount cannot be quantitatively estimated. It should be assumed that estimated over the counter sales are an upper bound on annual use quantities by non-professionals.

Generally, it is reasonable to assume that pesticide use correlates with pesticide sales. Market factors may, however, cause this to not be the case for individual active ingredients. In addition to incidental storage of over-the-counter purchase noted above, professionals may also store products for future use. For example, pesticides newly introduced into the market may be sold in one calendar year, but not applied until the next year. When allowable pesticide uses are changed, sometimes users (both professional and non-professional) stockpile pesticides with the “old” label, which are generally allowed to be applied for the previously allowable use until stocks with labels allowing this use are exhausted.

Uncertainty

Errors in source data. Estimates of unreported urban use made in this manner combine uncertainties in the use reporting and sales data described above. The effect of errors in the source data is variable, depending on the pesticide. For example, there are two pesticides for which reported use has exceeded reported sales for at least five years (see below). If a pesticide has agricultural uses, any underreporting of those uses would cause unreported urban use to be overestimated. Agricultural underreporting has the most potential to affect unreported urban use estimates for study-list pesticides with significant agricultural use (carbaryl, chlorpyrifos, diazinon, malathion, cyfluthrin, esfenvalerate, and lambda-cyhalothrin).

Since the primary identified errors in pesticide sales and reported use data are systematic, they affect quantitative estimates more than they affect trends. These uncertainties must be kept in mind while reviewing this section, as errors for individual pesticides are unknown and may differ significantly from these average estimates.

In light of the uncertainties detailed above, this report focuses on general trends and conclusions that can be supported by the available data. To reflect the uncertainties in the quantitative estimates in this section, this report utilizes significant figures when presenting estimates. Sales data and use data from DPR and estimates based on calculations are rounded to provide the appropriate number of significant figures.

[14] Pesticides incorporated into consumer products (e.g., treated wood, pet collars, insecticidal clothing) are often unreported, or reported as applied at the product manufacturing site rather than at the site where the products are used. Use of biocides to treat drinking water and wastewater are also usually not reported.
[15] Except livestock treatment.

Statewide Urban Pesticide Use Estimates—All Pesticides

Data from DPR indicate that at least half of all California pesticide use occurs in urban areas. In 2006, DPR reports indicate that about 740 million pounds of pesticide active ingredient were sold (DPR 2008b) and 190 million pounds of pesticide active ingredients were reported to have been used in manners requiring reporting (DPR 2008a). Assuming that on average, an amount equivalent to pesticide sales is used each year, about 70% of California pesticide use in 2006 did not require reporting.[16] For 2006, the sum of estimated unreported pesticide use (about 500 million pounds [see equations above]) and reported urban use (about 20 million pounds) is between 500 and 600 million pounds—this is between 70 and 80% of total use. Given the uncertainties in the data sources, this urban pesticide use estimate is not exact; nevertheless, it indicates that at least half of California pesticide use occurs in urban areas.

Reported urban pesticide use, however, comprises only a small fraction of all reported pesticide use (most reported pesticide use is associated with agriculture). According to DPR, 20 million pounds of pesticide active ingredient were applied for reported urban uses in 2006 (DPR 2008a). This represented about 10% of all reported pesticide use in 2006.

Statewide Urban Pesticide Use Estimates—Study-List Pesticides

Use patterns for study-list pesticides differ from the statewide averages for all pesticides. Most use of most of these pesticides is in urban areas—and most of that use is by professionals. Table 5 (on the next page) provides an overview of the use patterns of study-list pesticides including statewide sales, reported use, estimated unreported use, and the fraction of use that is unreported.

Table 5 and subsequent tables present data as two-year averages for the years 2005 and 2006. Two-year averages are used in this analysis to average out data variations due to year-to-year variations (see Section 2.2 above).

For several pesticides, specific factors should be considered when reviewing Table 5 and subsequent tables:

- Organophosphorous Insecticides (Diazinon, Chlorpyrifos, and Malathion). For diazinon and chlorpyrifos, the difference between sales and reported use cannot represent unreported urban use (which is assumed to equal over-the-counter sales), because legal over-the-counter sales of chlorpyrifos products for almost all non-reportable urban uses (except containerized baits) ended in December 2001 and legal over-the-counter sales of diazinon products for urban use ended in December 2004. Although over-the-counter sales of malathion remain legal, retail shelf surveys show only a limited retail presence that is not consistent with the relatively large unreported use estimate. The values for OPs could possibly reflect under-reporting of the agricultural uses of these pesticides, which have lost popularity since the U.S. EPA released risk information about them in the last few years.

[16] Note that most use of biocides like chlorine (sales of more than 70 million pounds in 2005) and sodium hypochlorite (sales of 141 million pounds in 2005) do not require reporting. These two biocides are used in large quantities to treat drinking water and wastewater. Sodium hypochlorite is also sold over the counter in bleach, which is registered as a pesticide.

Table 5. California Study-List Pesticides Sales, Reported Use and Estimated Unreported Use, 2005-2006 (Pounds of Pesticide Active Ingredient, 2-Year Average)

Pesticide	Sales	Reported Use	Estimated Unreported Use[a]	Estimated % of Use That Is Unreported
Pyrethroids				
Bifenthrin	100,000	89,000	10,000	10%
Cyfluthrin	39,000	65,000	Limited[b]	Small
Beta-Cyfluthrin	5,500	11,000	Limited	Small
Cypermethrin	88,000	200,000	Limited	Small
Deltamethrin	4,400	11,000	Limited	Small
Esfenvalerate	65,000	36,000	30,000	50%
Lambda-Cyhalothrin	46,000	38,000	9,000	20%
Permethrin	550,000	610,000	Limited	Small
Tralomethrin	2,000	23	2,000	Almost 100%
OPs				
Chlorpyrifos	2,400,000	2,000,000	Limited[c]	Small[c]
Diazinon	460,000	390,000	Limited[c]	Small[c]
Malathion	880,000	420,000	500,000	50%
Other				
Carbaryl	410,000	170,000	200,000	50%
Fipronil	23,000	--[d]	--[d]	--[d]
PHMB	190,000	0[e]	200,000	100%
All Pesticides	***680,000,000***	***190,000,000***	***500,000,000***	***70%***

Source: DPR sales data (DPR 2007b and 2008b), pesticide use reports (DPR 2007a and 2008a), and mathematical calculations.

[a] Total estimated use values have only one significant figure to reflect uncertainty in these estimates. Totals may not add up due to rounding.

[b] When reported use exceeds sales, unreported use is assumed to be relatively limited.

[c] Essentially all registered uses required reporting. It is not known why sales exceed reported use.

[d] Fipronil reported use data are not included in this table for reasons explained in the text.

[e] PHMB is only registered for urban uses that do not require reporting.

- Cyfluthrin, Beta-Cyfluthrin, Cypermethrin, Deltamethrin, and Permethrin. For all of these pesticides, statewide reported use exceeded statewide reported sales; therefore, unreported use was assumed to be small. Annual variations in sales data can cause these data anomalies to occur; however, cypermethrin and deltamethrin are notable in that reported sales averaged less than 50% of reported use between 1999 and 2006. Since all were found in a few products in 2005 and 2006 retail shelf surveys (TDC Environmental 2005, Joshel 2006) the unreported use was almost certainly not zero. These data can be interpreted to suggest that retail sales for non-professional uses were probably not a significant part of the overall use of these pesticides.
- Carbaryl and Permethrin. Unreported use estimates for these pesticides rely on the differences between rather large sales and reported use values. Errors in sales and/or reported use values that are small relative to these individual totals could be large relative to the unreported use estimate. For these two pesticides,

errors within the uncertainty of the sales and reported use data could significantly change the unreported use estimate.

Total estimated statewide urban pesticide use is the sum of urban reported use (see Table 4 above) and estimated unreported use (all of which is assumed to be urban, as explained above). Table 6 presents an estimate of the total urban use of study pesticides in California in 2005-2006. These data should be interpreted with the understanding that the margin of error in the estimates is likely to be more than 10% (as explained in the discussions of uncertainties in Sections 2.2 and 2.3).

Table 6. California Study-List Pesticides Estimated Urban Use, 2005-2006 (Pounds of Pesticide Active Ingredient, 2-Year Average)

Pesticide	Reported Urban Use	Estimated Unreported Use[a]	Total Estimated Urban Use[b]
Pyrethroids			
Bifenthrin	66,000	10,000	80,000
Cyfluthrin	48,000	Limited	50,000
Beta-Cyfluthrin	11,000	Limited	10,000
Cypermethrin	200,000	Limited	200,000
Deltamethrin	11,000	Limited	10,000
Esfenvalerate	250	30,000	30,000
Lambda-Cyhalothrin	15,000	9,000	20,000
Permethrin	450,000	Limited	500,000
Tralomethrin	23	2,000	2,000
OPs			
Chlorpyrifos	42,000	Limited[c]	40,000[c]
Diazinon	7,300	Limited[c]	7,000[c]
Malathion	56,000	500,000	500,000[b]
Other			
Carbaryl	16,000	200,000	300,000
Fipronil	--[d]	--[d]	20,000[d]
PHMB	0[e]	200,000	200,000

Source: TDC Environmental calculations based on data in Tables 3 and 4 and DPR's California Pesticide Information Portal (CalPIP) database (DPR 2008a).
[a] Unreported use values reflect only one significant figure to reflect uncertainty in these values.
[b] Total estimated use values reflect one significant figure to reflect uncertainty in these values. Totals may not appear to add up due to rounding.
[c] Essentially all registered uses required reporting. Sales to the public are almost completely prohibited. Use of chlorpyrifos baits and stock on hand of old products by non-professionals is assumed to be relatively small.
[d] Fipronil reported use data are not included in this table for reasons explained in the text. Since all allowable uses are urban, total urban use was assumed to equal sales.
[e] PHMB is only registered for urban uses that do not require reporting.

In Table 7 (on the next page), pesticide sales and reported agricultural pesticide use data are used to estimate the fraction of the total statewide use of each study-list pesticide that occurs in agricultural and in urban areas. Note that most study-list pyrethroids and malathion are used primarily in urban areas—and all fipronil and PHMB.

Table 7. California Study-List Pesticides Agricultural and Estimated Urban Usage Percentages, 2005-2006 (Pounds of Pesticide Active Ingredient, 2-Year Average)

Pesticide	Sales	Reported Agricultural Use	% of Use that is Agricultural	% of Use that is Urban
Pyrethroids				
Bifenthrin	100,000	23,000	20%	80%
Cyfluthrin	39,000	17,000	40%	60%
Beta-Cyfluthrin	5,500	900	20%	80%
Cypermethrin	88,000	4,000	<5%	Almost 100%
Deltamethrin	4,400	63	<2%	Almost 100%
Esfenvalerate	65,000	35,000	50%	50%
Lambda-Cyhalothrin	46,000	23,000	50%	50%
Permethrin	550,000	160,000	30%	70%
Tralomethrin	2,000	<1	0%	Almost 100%
OPs				
Chlorpyrifos	2,400,000	1,900,000	Almost 100%[a]	<1%
Diazinon	460,000	390,000	Almost 100%[a]	<1%
Malathion	880,000	360,000	40%	60%
Other				
Carbaryl	410,000	160,000	40%	60%
Fipronil[b]	23,000	0	0%	100%
PHMB[b]	190,000	0	0%	100%

Source: DPR sales data (DPR 2007b and 2008b), pesticide use reports (DPR 2007a and 2008a), and mathematical calculations.

[a] Since unreported urban use is essentially zero for chlorpyrifos and diazinon, this estimate is based on the agricultural reported use in this table and the urban reported use in Table 6.

[b] Neither fipronil nor PHMB is registered for agricultural use in California.

2.5 Pyrethroids Urban Use

As explained in the UP3 Project *Annual Review of New Scientific Findings 2008* (TDC Environmental 2008), there is strong scientific evidence that use of pyrethroid insecticides in California urban areas is causing adverse effects in aquatic ecosystems receiving urban runoff. Ending this toxicity is a priority for California water quality agencies. Understanding how pyrethroids are used in urban areas will help agencies develop management strategies to respond to this problem. This section explores how pyrethroids are used in urban areas.

Background

All uses of pyrethroids are as insecticides (i.e., there are no pyrethroid-containing chemical products that are not registered pesticides). Pyrethroids are not formed by decomposition of other chemicals in the environment. Because pyrethroids are not very volatile and because urban uses comprise a very significant fraction of all pyrethroids use, air transport of pyrethroids from agricultural areas into urban areas is unlikely to be a significant source of pyrethroids in urban runoff. Most California urban creeks that have been studied do not receive agricultural runoff. Thus, it is reasonable to assume that the only significant source of pyrethroids in many California urban creeks is urban pesticide use.

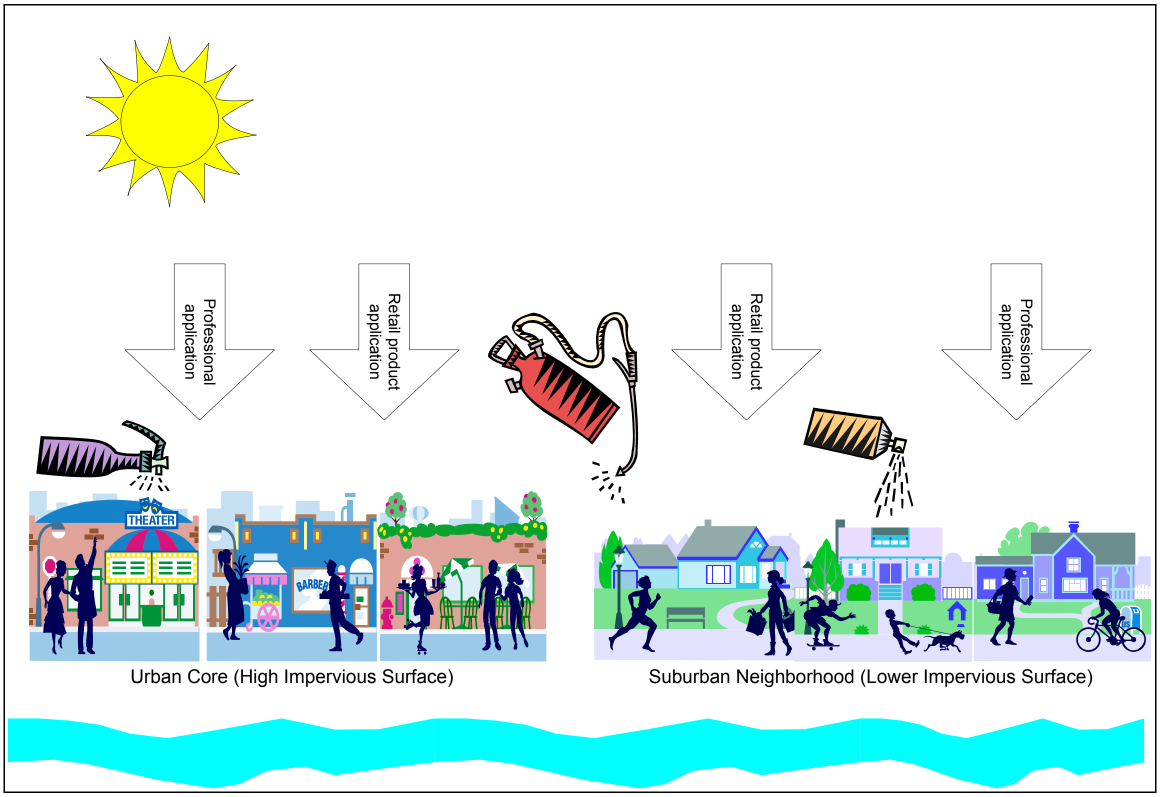
Figure 1 (below) graphically summarizes where pesticides may initially be deposited in conjunction with urban application activities. Sources of pesticides in urban environments include:

a) Application around buildings
b) Application to lawns/grassy areas/golf courses
c) Application to gardens/soil
d) Application to outdoor impervious surface (gutter, driveway, crack & crevice, sidewalk, etc.)
e) Post-application cleanup (including waste disposal)
f) Atmospheric deposition (from either urban or agricultural applications)

The initial outcomes of urban pesticide use may include the following environmental releases (some of which are not legal):

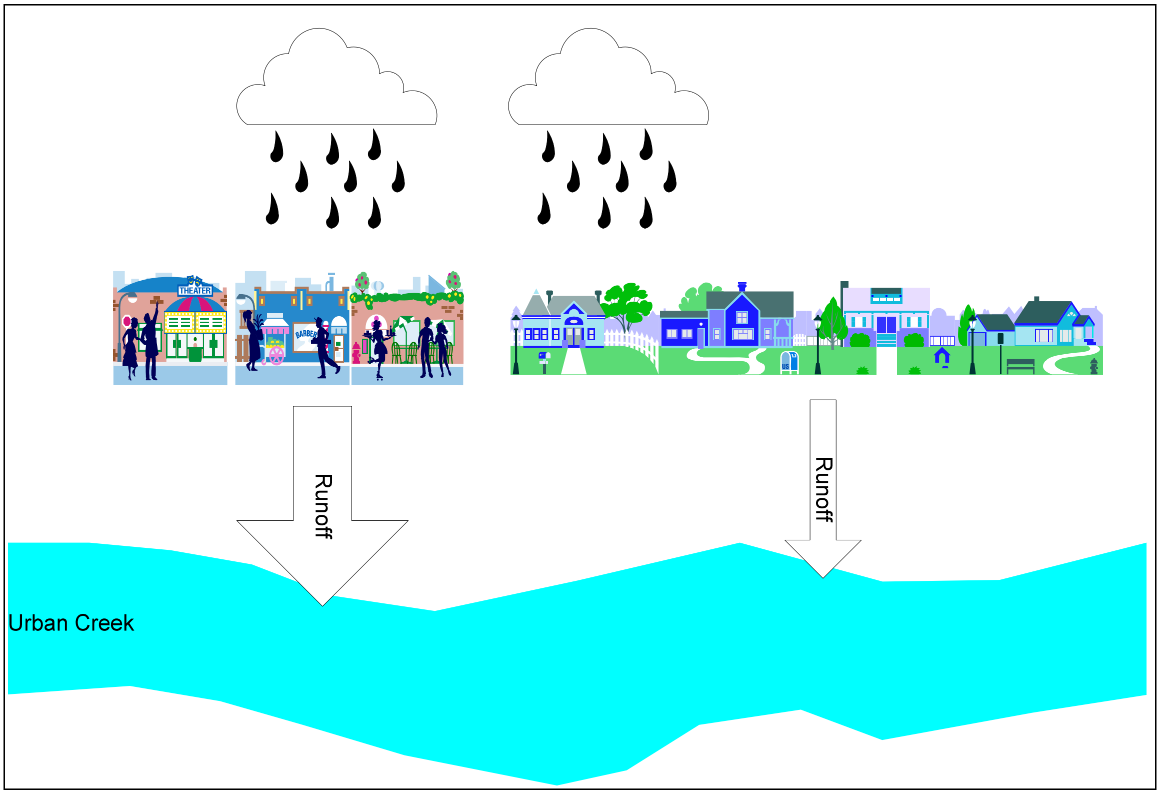
1) The pesticide is deposited on impervious surfaces
2) The pesticide is deposited on lawns/grassy areas
3) The pesticide is deposited on other pervious surfaces
4) The pesticide is discharged to a wastewater (sewer) system
5) The pesticide is discharged to a storm drain (no treatment)
6) The pesticide is placed into the garbage

Figure 1. Pesticide Applications in Urban Environments



When it rains (or when water is discharged for other reasons in urban areas), urban runoff flows through storm drains into urban creeks. Water also drains from urban areas to storm drains from a variety of miscellaneous non-rain flows—examples of such non-rain water discharges include excess irrigation runoff; wash water from cleaning outdoor surfaces (like buildings, driveways, and walkways); water from emptying swimming pools, spas, and fountains; vehicle wash water; and water released while flushing drinking water systems. Figure 2 illustrates these transport pathways.

Figure 2. Pesticide Transport to Urban Creeks



The primary locations from which pesticides are transported to urban creeks are:

a) Impervious surfaces
b) Lawns/grass
c) Other pervious surfaces (e.g., soil)
d) Material illegally dumped into storm drains

Pesticides present in outdoor urban environments have several possible fates:

1) Wash to storm drain/creek
2) Remain on land
3) Degrade prior to transport (degradates may need consideration)
4) Evaporate into air
5) Uptake by organisms

In almost all of California, stormwater does not receive any type of treatment before it is discharged.[17] Urban runoff carries pollutants from urban surfaces into storm drains and

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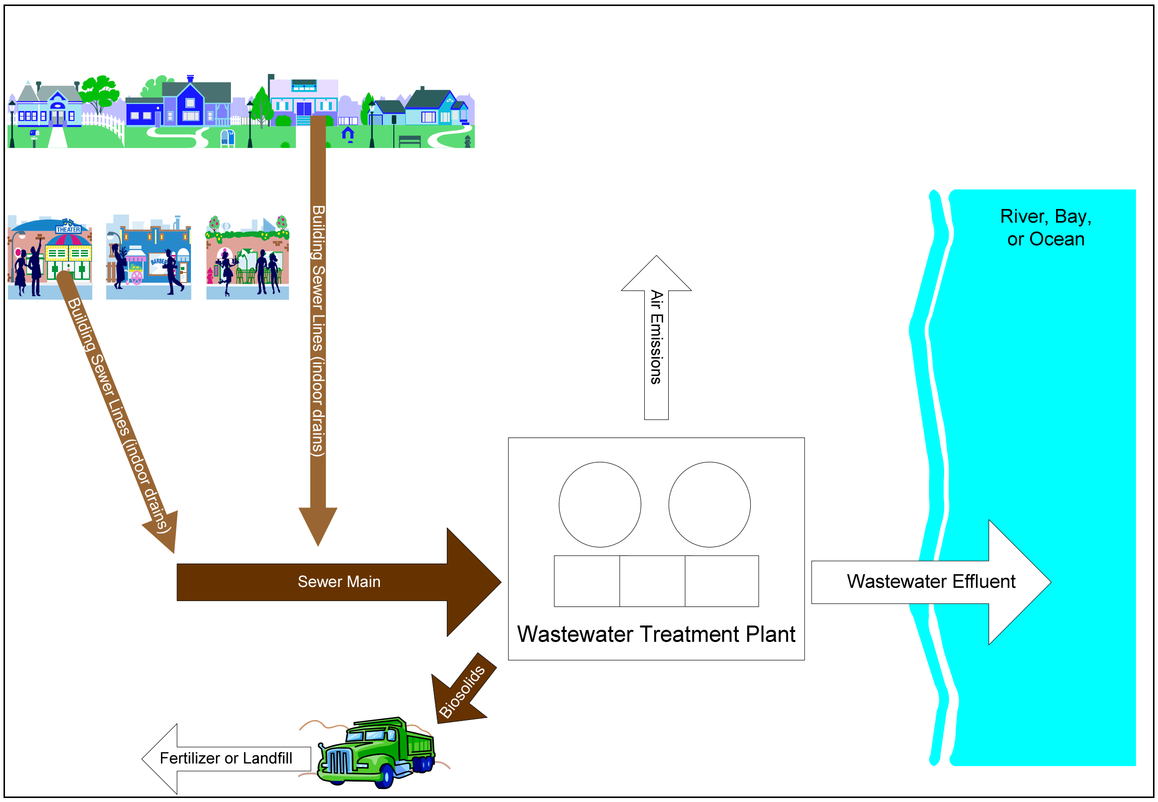
[17] A few areas, like most of the city of San Francisco, have combined sewer systems that flow to municipal wastewater treatment plants. Innovative stormwater treatment projects and requirements to treat runoff from new development and redevelopment sites provide treatment for a very small—but steadily increasing--fraction of California's urban runoff.

creeks. These pollutants may be dissolved in the water or attached to fine particles that flow with the water through the storm drain system (given pyrethroids' low solubility, the latter is the most likely pathway for pyrethroid transport). Only a small fraction of the total quantity of pesticides that are applied outdoors washes off. On the basis of limited data, washoff fractions from pesticide applications to impervious surfaces appear to be significantly higher than washoff fractions from "pervious" surfaces like lawns and landscaped areas (see TDC Environmental 2003 for more information).

Pyrethroids may also be discharged to municipal wastewater treatment plants. Figure 3 shows the primary pathways for pyrethroids transport into and out of municipal wastewater treatment plants.

Figure 3. Pesticide Transport Into and Out of Municipal Wastewater Treatment Plants



Pyrethroids may enter municipal wastewater systems in conjunction with the following activities:

a) Treating indoor drains, manholes, or sewer lines
b) Washing pesticide-containing fabric
c) Post-application cleanup (including down-the-drain disposal of solutions)
d) Washing off pet flea or human lice and scabies treatments
e) Urban runoff (includes rain inflow and systems where some or all runoff is deliberately routed to a municipal wastewater treatment plant)
f) Other miscellaneous sources (e.g., washing items used to clean pesticide-treated surfaces, carpet cleaning water, human waste, industrial wastewater, etc.)

Pyrethroids that flow to municipal wastewater treatment plants may be:

1) Discharged in the wastewater treatment plant's effluent
2) Transferred to biosolids (sludge)

3) Degraded
4) Emitted into air

In California, most wastewater treatment plants discharge to rivers, bays, or the ocean; only a few discharge to urban creeks. None of the urban creeks where pyrethroid-related sediment toxicity has been found receives wastewater treatment plant discharges upstream of or in the area where toxicity test samples were collected (for example see Amweg et al. 2006; Weston et al. 2005). Because there is not an identified link between wastewater discharges and currently identified toxicity, this analysis focuses on outdoor pyrethroids use.

Pyrethroid Application Timing and Relationship to Runoff

As detailed in the 2007 UP3 Project *Urban Pesticide Use Trends Annual Report* (TDC Environmental, 2007a), urban pyrethroids applications occur at all times of the year. Professional applications of study-list pyrethroids for landscape maintenance peak in the summer and are lower during the winter. In contrast, professional structural pest control application rates are relatively more consistent throughout the year. Non-professional application timing can only be evaluated based on anecdotal information (from product manufacturers and retailers), which suggests that non-professional applications are more common in summer and less common in winter.

In California's Mediterranean climate, application timing is not directly connected to runoff, because rain—the primary mechanism to transport pesticides from outdoor urban surfaces into surface water—rarely occurs outside of the winter months. In non-rainy months, other water flows like irrigation overflow and cleaning water can transport pollutants to urban creeks. Non-rain flows typically have relatively low flow rates and volumes, which makes them relatively inefficient at washing pollutants off of outdoor urban surfaces (some of which are never contacted by such flows); consequently, they provide relatively limited particle transport as compared to stormwater runoff flows. While there are many examples of water quality problems associated with dry weather flows, urban runoff during storm events has been a focus of regulatory programs because storm events are normally associated with higher pollutant concentrations and loads. This pattern has not been fully investigated for pesticides, but available data show that creek samples obtained during storms are more likely to contain environmentally meaningful quantities of pesticides than creek samples collected during dry weather, which suggests that pesticide transport from outdoor urban surfaces is consistent with the pattern for other pollutants (Riverside County 2007; Scanlin and Feng 1997; Ruby 2005; California Regional Water Quality Control Board, San Francisco Bay Region 2007; AQUA-Science 2007).

Permethrin Equivalents

The pyrethroids are a family of pesticides with similar mechanisms of toxicity. They are believed to have additive effects on aquatic organisms (Weston et al. 2004). To understand the environmental importance of the pyrethroids, it is necessary to look at them as a group. Simply adding up the total quantity of pyrethroids is not sufficient, because the aquatic toxicity of pyrethroids differs among the individual pesticides—some are more than twenty times more toxic than others. Toxicity differences among pyrethroids must be taken into account to understand the potential for pyrethroids to cause aquatic toxicity. To address their toxicity, pyrethroids can be summed on the basis of "*permethrin equivalents*," which are calculated based on the toxicity of each pyrethroid, as explained below. (To ensure that the reader recognizes where this convention—rather than pounds of active ingredient—is used, the phrase "*permethrin equivalents*" is italicized throughout this report.)

Toxicity to the sediment-dwelling organism *Hyalella azteca* is an important environmental endpoint (Weston et al. 2004; Amweg et al. 2005). Comparing toxicity to *Hyalella azteca* of various pyrethroids is a convenient method of expressing their toxicity differences. Table 8 (on the next page) summarizes the average concentration of each pyrethroid that is lethal to 50% of *Hyalella azteca* test organisms placed in sediment for a 10-day test period (10-day LC50). The table also shows the relative toxicity of the pyrethroids, expressed as the ratio of the toxicity of each pyrethroid to the toxicity of permethrin. The number of "*permethrin equivalents*" is calculated by multiplying the quantity of a pyrethroid by the "Ratio to Permethrin LC50" listed in Table 8.

Table 8. Toxicity of Pyrethroids to *Hyalella azteca*

Pyrethroid	Average sediment 10-Day LC50 (µg/g organic carbon)	Ratio to Permethrin LC50
Bifenthrin	0.52	21
Cyfluthrin	1.08	10
Beta-Cyfluthrin	[1.08][a]	[10][a]
Cypermethrin	0.38	29
Deltamethrin	0.79	14
Esfenvalerate	1.54	7.03
Lambda-Cyhalothrin	0.45	24
Permethrin	10.83	1.00
Tralomethrin	[10.83][b]	[1][b]

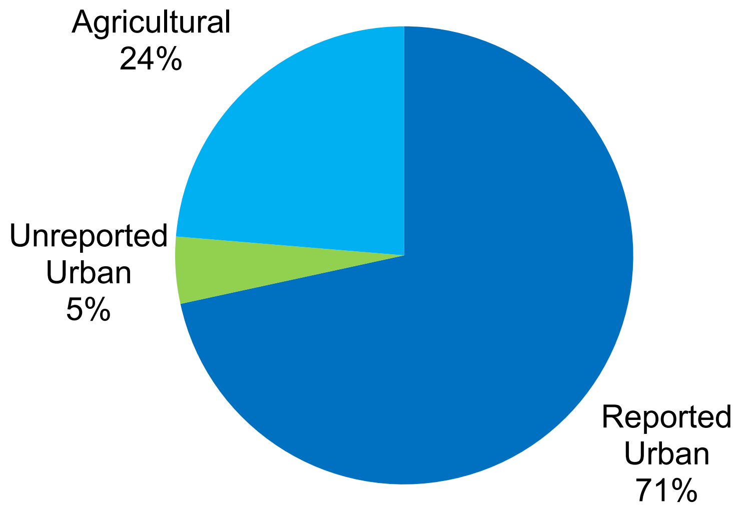
Source: Maund et al. 2002 (cypermethrin); Amweg et al. 2005 (all others).
[a] No data available. Because it is a subset of cyfluthrin isomers, beta-cyfluthrin was assumed to have the same toxicity as cyfluthrin.
[b] No data available. Based on relative toxicity to other aquatic species, tralomethrin was assumed to have the same toxicity as permethrin.

California Pyrethroid Use

Figures 4 and 5 (on the next page) provide an overview of the use of study-list pyrethroids in California. These two figures are based on DPR pesticide sales data, DPR pesticide use reports, and mathematical calculations (see Table 5). Figure 4 is based on the total quantity of study-list pyrethroids applied, without consideration of the toxicity of the individual pyrethroids. In these and subsequent figures, "reported urban" indicates pyrethroid applications by professional applicators and "unreported urban" indicates estimated non-professional urban use. By comparing Figure 4 to Figure 5 (which expresses the data in terms of toxicity using the *permethrin equivalents* listed in Table 8), it is apparent that the study-list pyrethroids applied for agricultural uses are, in aggregate, less toxic to aquatic life (as represented by *Hyalella azteca*) than those applied by professionals for urban use.

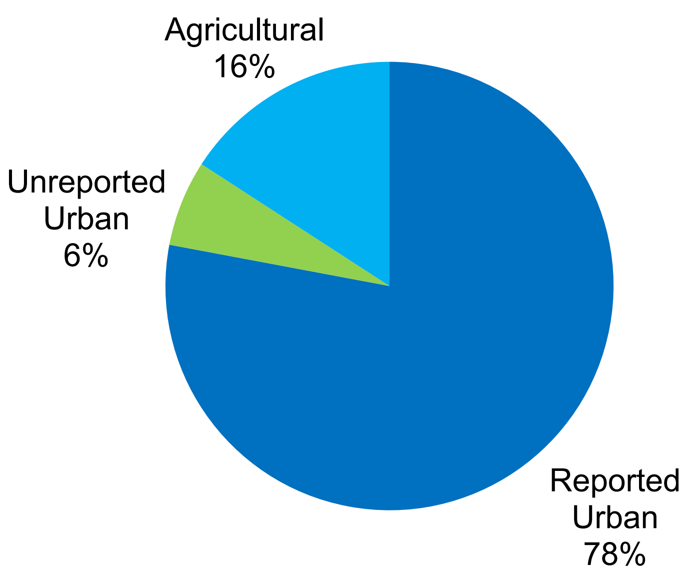
Table 9 (on page 24) provides an overview of estimated urban pyrethroids use. Most urban use of study-list pyrethroids is for structural pest control (exceptions are esfenvalerate and tralomethrin). It is important to remember that some pyrethroids applied for structural pest control are applied by underground injection—and therefore relatively unimportant for urban surface water quality (this topic is explored further later in this section). Because it is possible that these data may be affected by reporting errors similar to that identified for fipronil, without further pesticide-specific analysis, conclusions are best limited to qualitative statements (i.e., "relatively large fraction" and "relatively small fraction") rather than quantitative estimates.

Figure 4. California Study-List Pyrethroids Estimated Use, 2005-2006
(Pounds of Pesticide Active Ingredient, 2-Year Average)



Source: DPR pesticide sales data (DPR 2007b, 2008b), DPR pesticide use reports (DPR 2007a, 2008a), and mathematical calculations (see Table 5).

Figure 5. California Study-List Pyrethroids Estimated Use, 2005-2006
(Expressed in Terms of Toxicity Using *Permethrin Equivalents*, 2-Year Average)



Source: DPR pesticide sales data (DPR 2007b, 2008b), DPR pesticide use reports (DPR 2007a, 2008a), and mathematical calculations (see Table 5). Conversion to *permethrin equivalents* based on values in Table 8.

Table 9. California Study-List Pyrethroids Urban Use Overview, 2005-2006 (2-Year Average)

Pesticide	Estimated Urban Use[a] (lb a.i.)[b]	Reported Structural Pest Control Use[c]		Other Reported Urban Use		Estimated Fraction of Use That Is Unreported
		(lb a.i.)	Fraction	(lb a.i.)	Fraction	
Pyrethroids						
Bifenthrin	80,000	63,000	Most	3,500	Small	<One-fifth
Cyfluthrin	50,000	47,000	Most	720	Small	Small
Beta-Cyfluthrin	10,000	8,100	Majority	2,400	About one-quarter	Small
Cypermethrin	200,000	190,000	Most	1,600	Small	Small
Deltamethrin	10,000	11,000	Most	530	Small	Small
Esfenvalerate	30,000	230	Small	19	Small	Most
Lambda-Cyhalothrin	20,000	15,000	Majority	170	Small	About one-third
Permethrin	450,000	440,000	Most	12,000	Small	Small
Tralomethrin	2,000	21	Small	2	Small	Most

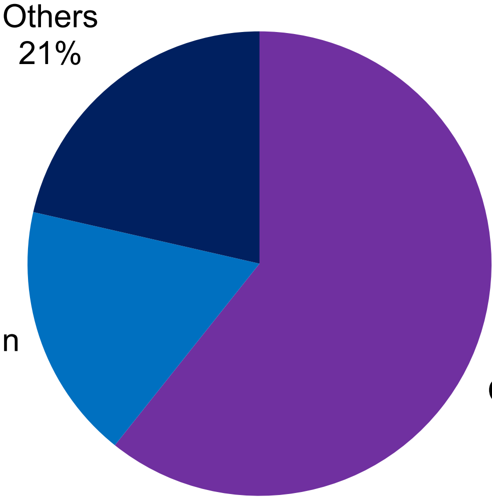
Source: DPR pesticide sales data (DPR 2007b, 2008b), DPR pesticide use reports (DPR 2007a, 2008a), and mathematical calculations (see Table 6).
[a] Total estimated use values reflect one significant figure to reflect uncertainty in these values. Totals may not add up due to rounding.
[b] Pounds of pesticide active ingredient.
[c] Reported use values have two significant figures to reflect uncertainty in these values. “Small” means <10%. “Majority” means >50%. “Most’” means ≥80%.

Figure 6 (on the next page), shows that two pyrethroids—cypermethrin and bifenthrin—account for almost 80% of the pyrethroid-related toxicity (expressed in *permethrin equivalents*) that was used in California urban areas in 2005-2006. Urban pyrethroid use estimates are generally consistent with environmental monitoring data, which show that three pyrethroids—cypermethrin, cyfluthrin (including beta-cyfluthrin) and bifenthrin—most commonly contribute to toxicity in urban creeks (Amweg et al. 2006; Weston et al. 2005). While these urban pyrethroid use estimates are generally consistent with environmental monitoring data, they do not completely correlate with environmental data because pyrethroid use quantities alone do not determine the relative contribution of individual pyrethroids to aquatic toxicity. Other factors—such as application location, transport processes, and environmental degradation rates—are also involved in determining the environmental concentrations of pyrethroids.

Underground Applications

The pesticide reporting form used in California for structural pest control applications does not provide a way to distinguish among applications above ground (e.g., around buildings to control ants, pre-construction soil treatments at building sites), indoors (e.g., baseboard sprays and flea foggers), and those made by underground injection (e.g., to control termites). Because applications by underground injection are unlikely to contribute significantly to aquatic toxicity—and applications indoors would affect sewer discharges rather than urban runoff—it would be preferable to be able to distinguish among outdoor, indoor, and underground applications.

Figure 6. Study-List Pyrethroids Estimated Use in California Urban Areas, 2005-2006
(Expressed in Terms of Toxicity Using *Permethrin Equivalents*, 2-Year Average)



Source: DPR pesticide sales data (DPR 2007b, 2008b), DPR pesticide use reports (DPR 2007a, 2008a), and mathematical calculations (see Table 6). Conversion to *permethrin equivalents* based on values in Table 8.

Pesticide application reports require applicators to identify the specific pesticide product that was applied. Assuming that professionals use products according to their label directions, it is possible to identify potential application types (outdoor, indoor, underground) based on a review of the labels for the applied products. Copies of product labels are available on the Internet in the U.S. EPA's Pesticide Product Label System (PPLS) (U.S. EPA 2008). PPLS labels may differ slightly from labels for products sold in California; however, differences are not common since California cannot control pesticide labels directly (all special California labels must be approved by U.S. EPA). Differences are expected to be unusual for urban uses of pyrethroid products because DPR does not normally examine urban uses in detail during its registration process.

The PPLS labels for study-list pyrethroid products that account for more than 98% of the reported use of each active ingredient for structural pest control in the California in 2006 were reviewed to determine whether allowable uses included aboveground outdoor uses, indoor uses, and/or underground injection applications. Where multiple labels were in the database, the label applicable in 2006 was selected. All products were found to allow application above ground outdoors for structural pest control. Nearly all products (except granular formulations) allowed indoor applications. Only a portion of the products were labeled for underground injection—these included some bifenthrin and cypermethrin products and all permethrin products. No cyfluthrin, beta-cyfluthrin, deltamethrin, esfenvalerate, lambda-cyhalothrin, or tralomethrin product labels allowed underground injection structural pest control applications.

As shown in Table 10 (on the next page), more than 85% of bifenthrin and cypermethrin, and all permethrin reported applied for structural pest control applications in California in 2005-2006 were from products where labels allow underground injection. Overall, about 85% of the total quantity (76% when expressed in terms of toxicity using *permethrin* *equivalents*) of study-list pyrethroids that were applied were of products where labels allow underground injection. While it is unlikely that all of this was applied underground, this analysis method identifies the minimum (0%) and the maximum (85%) fraction of the reported structural pest control pyrethroids use that could have been applied underground. The actual fraction of underground applications is likely to be between these two extremes.

Table 10. California Study-List Pyrethroids Structural Pest Control Use, 2005-2006 (2-Year Average)

Pesticide	Reported Structural Pest Control Use (Pounds of Pesticide Active Ingredient)	Portion of Estimated Urban Use Represented by Reported Structural Pest Control Use[a]	Portion of Structural Pest Control Use that Could Have Been Applied Underground
Pyrethroids			
Bifenthrin	63,000	Most	0% - 86%
Cyfluthrin	47,000	Most	0%
Beta-Cyfluthrin	8,100	Majority	0%
Cypermethrin	190,000	Most	0% - 86%
Deltamethrin	11,000	Most	0%
Esfenvalerate	230	Small	0%
Lambda-Cyhalothrin	15,000	Majority	0%
Permethrin	440,000	Most	0% - 100%
Tralomethrin	21	Small	0%

Source: Pesticide product labels in PPLS (U.S. EPA 2008), DPR pesticide use reports (DPR 2007a, 2008a), and mathematical calculations based on these data and values in Table 6.
[a] Reported use portion described qualitatively to reflect uncertainty in these values (see Table 9). “Small” means <10%. “Majority” means >50%. “Most’” means >80%.

Some unreported pyrethroids use may involve applications by “trenching,” which is the typical non-professional method for applying termite-control pesticides. This method, if properly implemented, would cause most of the pesticide to be applied below the ground surface and thus not be subject to runoff. The fraction of unreported applications of pyrethroids made in this manner is not known, but is anticipated to be relatively small, as pesticide applications to control termites by residents (rather than by professionals) appear to be rare based on surveys of consumer pesticide use (Wilen 2001; Wilen 2002; Flint 2003).

Indoor Applications

Professional structural pest control applications can be made indoors. As mentioned above, the labels for nearly all study-list pyrethroid products that were reported to have been applied for structural pest control (except granules, only a few percent of reported use) allow indoor application. Neither reporting nor labels provide a means to estimate quantitatively the fraction applied indoors. Consumer surveys can, however, provide a qualitative indication of the extent of indoor applications. Recognizing the need for this type of information (and other information about residential pesticide use), DPR funded three sets of surveys (described below) that provide California-specific qualitative information about indoor pesticide use. Available surveys cover residents, but not businesses, and thus may not fully reflect application patterns.

In 2002-2003, the University of California Integrated Pest Management program (U.C. IPM) completed detailed telephone surveys of residents in the San Francisco Bay Area and the Central Valley (Sacramento and Stockton areas) (Flint 2003). These surveys, which were designed to collect representative samples of residents in each region, included a question about how professional pest control operators hired by the resident applied pesticides. Only 4% of San Francisco Bay Area respondents who hired professional pest control applicators said that the professional applied pesticides indoors. For the surveyed Central Valley regions, indoor applications by professionals were reported by fewer than 6% of respondents who hired professionals.

In 2000 and 2001, U.C. IPM conducted similar surveys in Southern California (in the San Diego Creek and Delhi Channel areas of Orange County and in the Chollas Creek watershed of San Diego County) (Wilen 2001; Wilen 2002). These surveys also found that indoor pesticide applications by professionals were relatively uncommon, but perhaps slightly more common than in Northern California. In these surveys, fewer than 2% of respondents reported hiring a professional pest control company to apply pesticides indoors; however, 10-16% said that a building manager handled pest control, including any indoor applications that might be needed.

Based on these survey data, it is reasonable to assume that indoor applications by professionals occur, but that these applications represent a relatively small fraction of the total quantity of pyrethroids applied for structural pest control. This small quantity falls in the range of the error of the estimates. Omitting consideration of indoor applications of study-list pyrethroids by professional structural pest control applicators should have little effect on interpretation of data on pesticide use quantities with regard to outdoor applications.

For unreported applications, the surveys do not provide a clear basis for estimating the fraction of pyrethroids use that occurs indoors. Although the Northern California surveys did not address indoor self-applications, the Southern California surveys did ask residents if they applied pesticides indoors. About 60% of respondents to these surveys reported indoor pesticide applications by household members (in contrast, only about 25% to 45% reported outdoor pesticide applications by household members). More than half of these applications were aerosol sprays, which generally contain very small quantities of pesticide active ingredients. However, formulations that may have more substantial quantities of pyrethroid active ingredients (ready-to-use pump sprays, other liquids, concentrates, and powders) were used indoors by more than 20% of respondents in the Delhi Channel area of Orange County and the Chollas Creek watershed of San Diego County (the only regions where this question was asked).

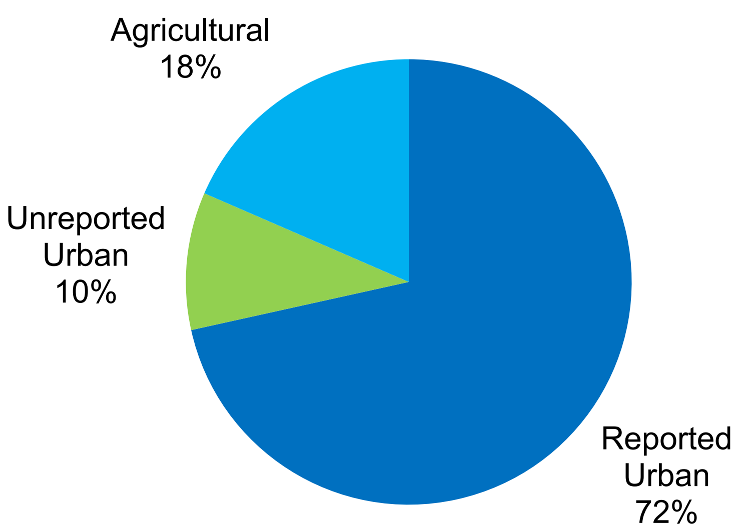
Bifenthrin Urban Use

Of the study-list pyrethroids, the one most commonly associated with toxicity to aquatic organisms in urban creek sediments is bifenthrin (Amweg et al. 2006; Weston et al. 2005). This section summarizes data on California bifenthrin use in 2005-2006. Unless otherwise noted, all data in this section are two-year averages for 2005 and 2006.

Like the estimates above, the bifenthrin use estimates in this section rely on the assumption that urban use of a pesticide by non-professionals is approximately equal to over-the-counter sales of that pesticide (see Section 2.4). In this report, non-professional urban pesticide use estimates are based on the assumption that the difference between statewide pesticide sales and statewide reported pesticide use is approximately equal to over-the-counter sales. For bifenthrin, data provided by one pesticide manufacturer allows this assumption to be tested. In 2005, Scotts Miracle-Gro was the only manufacturer of bifenthrin products for non-professionals (however, in 2006, other manufacturers also sold products for non-professionals). Scotts provided its actual sales data for its bifenthrin products in 2005 and 2006 to the UP3 Project (Scotts Miracle-Gro 2006, Scotts Miracle-Gro 2008).[18] Scotts' bifenthrin sales of 11,600 pounds (2005-2006 average) are relatively close to the bifenthrin non-reported use estimate of 12,500 pounds (2005-2006 average[19]). The difference between actual sales and the estimate is well within the uncertainty of the estimate (see discussion of uncertainties in Sections 2.2, 2.3, and 2.4) and is reasonable in light of the entry of other manufacturers into the bifenthrin non-professional product market in 2006.

As shown in Figure 7, about 80% of California bifenthrin use in 2005-2006 was in urban areas. Figure 8 (on the next page), which focuses only on urban bifenthrin use, shows that almost 90% of urban bifenthrin use in 2005-2006 was by professional applicators. In Figures 7 and 8, "reported urban" indicates pyrethroid applications by professional applicators and "unreported urban" indicates estimated non-professional urban use.

Figure 7. Total California Bifenthrin Use 2005-2006
(Pounds of Pesticide Active Ingredient, 2-Year Average)

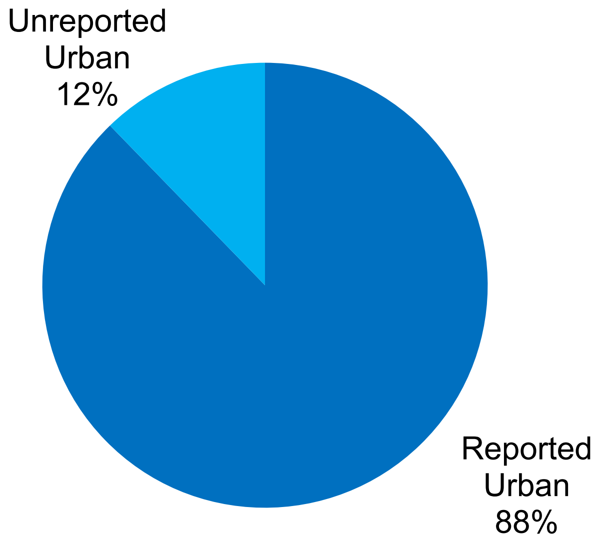


Source: DPR pesticide sales data (DPR 2007b, 2008b), DPR pesticide use reports (DPR 2007a, 2008b), and mathematical calculations. Note: Data accuracy warrants only one significant figure. Additional digits provided to simplify category tracking between figures.

[18] Scotts Miracle-Gro (SMG) requested that the following statement be included in this report (Moses 2007): "The facts in the report represent Scotts Miracle-Gro's most accurate assessment of sales information for all SMG Products in CA containing Bifenthrin. SMG is not responsible for any loss or liability that results from use of this information. With that in mind, SMG anticipates that the use of this information in proper context, without distortion. SMG does not endorse any scientific, toxicological, environmental, or other conclusion derived from the plain facts presented unless expressly stated and agreed to by the appropriate SMG representative. SMG is providing the information to the UP3 Project in good faith and with a continued interest in partnership and cooperation."

[19] This value is rounded to 10,000 pounds elsewhere in this report to reflect only one significant figure, which is consistent with the uncertainty in the estimate.

Figure 8. Urban Bifenthrin Use in California 2005-2006
(Pounds of Pesticide Active Ingredient, 2-Year Average)



Source: DPR pesticide sales data (DPR 2007b, 2008b), DPR pesticide use reports (DPR 2007a, 2008a), and mathematical calculations. Note: Data accuracy warrants only one significant figure. Additional digits provided to simplify category tracking between figures.

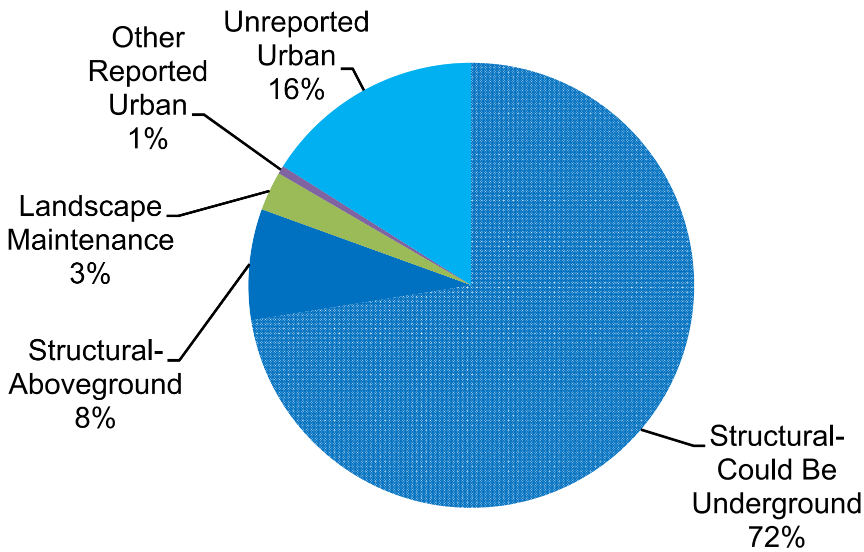
Figure 9 (on the next page) provides a breakdown of urban bifenthrin use in 2005-2006. The largest single category, comprising about 80% of urban bifenthrin use, was applications by professionals for structural pest control. A large fraction of these applications (between 80 and 90% of the total quantity applied by professionals for structural pest control) were of products for which the label allows underground injection applications. With currently available data (see the discussion of underground applications above), it is not possible to determine how much of this bifenthrin was applied underground (where it would not be subject to runoff). Similarly, it is not possible to estimate quantitatively the amount of this bifenthrin applied indoors; however, as noted above, it is reasonable to assume that this quantity is relatively small.

The "unreported urban" category may include outdoor structural, outdoor landscaping, or indoor applications of bifenthrin by non-professionals. A portion of this category may have been applied below the ground surface to control termites; however, as mentioned above, survey data suggest this use is infrequent.

Three categories—landscape maintenance, other reported urban, and unreported urban—include applications to outdoor pervious (soil, lawn, or landscaped) surfaces. These data suggest that less than 20% of urban bifenthrin use involved applications specifically to lawns, landscaping, and other pervious outdoor surfaces. Because structural pest control applications may also involve treatment of pervious outdoor surfaces near buildings, the fraction of pyrethroids applied to outdoor pervious surfaces cannot be estimated with available data.

Of the categories in Figure 9, only structural and "unreported urban" are likely to involve intentional applications to impervious surfaces (as well as to pervious surfaces). The fraction of these applications that occurred on impervious surfaces cannot be estimated with available data.

Figure 9. Urban Bifenthrin Use in California 2005 2006 – by Category (Pounds of Pesticide Active Ingredient, 2-Year Average)



Source: DPR pesticide sales data (DPR 2007b, 2008b), DPR pesticide use reports (DPR 2007a, 2008a), U.S. EPA PPLS (U.S. EPA 2008), and mathematical calculations. Note: Data accuracy warrants only one significant figure. Additional digits provided to simplify category tracking between figures.

2.6 Trends

Table 11 (on the next page) shows the trends in estimated California urban use (both reported and unreported) of study-list pesticides from 2000-2006. This reflects the most recent available data (2006) and most of the time period during which the market was transitioning in response to U.S. EPA's year 2000 announcements of the termination of most urban uses of diazinon and chlorpyrifos. Until several years of data are available to reflect the period after the final end of sales of diazinon urban use products (December 2004) and chlorpyrifos termiticide products (December 2005), the effect of the transition may not be fully understood.

To evaluate the effect of the transition, it is necessary to look at the trend between 2000 (the year of the phase-out announcements) and 2006 (the most recent year for which data are available). The data in Table 11 show the following trends between 2000 and 2006:

- Use of pyrethroids, carbaryl, and PHMB increased. Estimated use of bifenthrin and beta-cyfluthrin, increased significantly (use at least quadrupled). Estimated use of permethrin and cypermethrin increased; however, it is not yet clear if this apparent increase is significant or just a reflection of ordinary fluctuations in use. Estimated use of several other pyrethroids (cyfluthrin, esfenvalerate, and lambda-cyhalothrin) increased by more than one-third during this time period. (Due to database problems, the trend for tralomethrin cannot be evaluated).
- Use of diazinon and chlorpyrifos decreased significantly. These reductions reflect implementation of the outcomes of agreements associated with the U.S. EPA reregistration process, which eliminated most urban uses of diazinon and chlorpyrifos.
- Estimated malathion use declined over the last few years. The reason for the change in malathion use cannot be determined on the basis of available data.

Table 11. Study-List Pesticides Estimated Urban Use 2000-2006[a]
(Pounds of Pesticide Active Ingredient)

Pesticide	2000	2001	2002	2003	2004-2005 (2-Year Average)	2005-2006 (2-Year Average)
Pyrethroids						
Bifenthrin	*10,000*[a]	20,000	30,000	50,000	60,000	80,000
Cyfluthrin	40,000[b]	30,000	40,000	30,000	30,000	50,000
Beta-Cyfluthrin	*>0*	*1,000*	*3,000*	4,000	10,000	10,000
Cypermethrin	100,000	200,000	200,000	200,000	200,000	200,000
Deltamethrin	10,000	20,000	10,000	20,000	10,000	10,000
Esfenvalerate	10,000	10,000	10,000	20,000	20,000	30,000
Lambda-Cyhalothrin	*10,000*	*10,000*	10,000	10,000	10,000	20,000
Permethrin	300,000	200,000	300,000	300,000	400,000	450,000
Tralomethrin	>500[c]	>400[c]	>700[c]	3,000	3,000	2,000
OPs						
Chlorpyrifos	800,000	?[d]	100,000	100,000	100,000	40,000
Diazinon	900,000	900,000	?[d]	?[d]	?[d]	8,000
Malathion	600,000	700,000	600,000	1,000,000	900,000	500,000
Other						
Carbaryl	200,000	100,000	200,000	100,000	200,000	300,000
Fipronil[e]	2,000	20,000	30,000	10,000	20,000	20,000
PHMB[e]	30,000	*>0*	*>0*	60,000	50,000	200,000

Source: TDC Environmental calculations based on DPR sales (DPR 2001a, 2002a, 2003a, 2005a, 2006a, 2007b, 2008b) and reported use data (DPR 2001b, 2002b, 2003b, 2005b, 2007a, 2008a).
[a] Values in italics do not include any estimate of unreported use, as sales data were not available (sales of products with fewer than four registrants were not disclosed to the public until 2005).
[b] More than half of the shaded estimates was estimated unreported use.
[c] Values reflect reported urban use only; unreported use could not be estimated because tralomethrin sales data from DPR for 2000-2002 likely reflect an error in an internal DPR database that was corrected starting with 2003 data.
[d] Estimates made according to the methodology described in the text are very unlikely to represent actual chlorpyrifos urban use in 2001 and diazinon urban use for 2002-2004 as they are based primarily on estimated retail sales, which were phasing out. Retail sales are assumed to be zero after 2001 for chlorpyrifos (when they were essentially prohibited) and 2005 for diazinon. See Section 2.4.
[e] Since all allowable uses are urban, total urban use was assumed to equal sales.
Notes: Uncertainties are discussed in Section 2.4. Values reflect one significant figure.

These data suggest that pyrethroids—and perhaps carbaryl and fipronil—are replacing diazinon and chlorpyrifos in the urban pesticide use market. These changes are consistent with urban runoff and urban creek monitoring data, which show increased presence of pyrethroids and declining concentrations of diazinon and chlorpyrifos (TDC Environmental 2008). Quantitatively estimating how this shift affects urban runoff is not simple, as some of the previous uses of diazinon and chlorpyrifos and the new uses of these products are not outdoor surface applications.

The total quantity of pyrethroids estimated used in California urban areas in 2005-2006 (about 850,000 pounds) is lower than the total quantity of diazinon and chlorpyrifos estimated used in 2000 (about 1.8 million pounds). However, a comparison based only on the amount used will not provide a complete and correct assessment of the potential surface water quality impact of pesticide use. In general, pyrethroids are significantly more toxic to the most sensitive aquatic species than diazinon and chlorpyrifos (see TDC Environmental 2003). Consequently, much lower concentrations—and much lower use rates—can adversely affect surface water quality.

3.0 CONCLUSIONS AND RECOMMENDATIONS

This section summarizes the information above into key conclusions and provides recommendations based on this analysis of urban pesticide use data for study-list pesticides. The conclusions and recommendations below are intended to be viewed together with the conclusions and recommendations of the other two UP3 Project annual reports: the review of California water quality agencies' urban pesticide water quality regulatory activities (TDC Environmental 2007b) and the review of the latest scientific findings relevant to pesticides and urban surface water quality (TDC Environmental 2008). The recommendations below are not directed only at California water quality agencies—U.S. EPA, DPR, and others need to play a significant (if not leading) role in their implementation.

3.1 Conclusions

Conclusion 1: *Urban use of pyrethroids, carbaryl, PHMB, and fipronil increased from 2000 to 2006. Pyrethroids are currently the most commonly applied insecticides in California urban areas. Pyrethroids, fipronil, and (to a lesser extent) carbaryl have replaced diazinon and chlorpyrifos in the urban pesticide use market.* Specific changes in the urban insecticide market include:

- Use of pyrethroids for structural pest control increased in 2005-2006, likely reflecting the final transition away from chlorpyrifos and diazinon.
- Bifenthrin sales doubled between 2003 and 2006. Most of this increase appears to be due to increased professional use of bifenthrin for structural pest control.
- Carbaryl use for structural pest control increased—almost doubling between 2005 and 2006. Carbaryl use for structural pest control is relatively small compared to pyrethroids use.
- Estimated urban use of bifenthrin, cyfluthrin, esfenvalerate and lambda-cyhalothrin increased more than 30% between 2004-2005 and 2005-2006. For bifenthrin and cyfluthrin, increased reported use in structural pest control accounted for almost the entire increase. For esfenvalerate and lambda-cyhalothrin, increased estimated unreported use accounted for the increase.

Estimating how the urban pesticide market shift affects water quality is not simple, as the primary aquatic toxicity endpoints are different and some of the previous uses of diazinon and chlorpyrifos and the new uses of substitute products involve underground applications and containerized baits, neither of which are likely to be important for surface water quality. Although the total quantity of pyrethroids estimated used in California urban areas in 2005-2006 (two-year average of about 850,000 pounds) is lower than the total quantity of diazinon and chlorpyrifos estimated used in 2000 (about 1.8 million pounds), pyrethroids have greater potential to cause aquatic toxicity, as pyrethroids are significantly more toxic to aquatic species than diazinon and chlorpyrifos.

Conclusion 2: *Urban use of organophosphorous insecticides decreased significantly from 2000 to 2006.* Phase out of most urban uses of diazinon and chlorpyrifos in response to U.S. EPA agreements with manufacturers is evident in DPR pesticide sales and pesticide use reporting data. Remaining urban use in 2005-2006 was estimated to be <1% of total California use of these insecticides. Estimated urban use of malathion also decreased over the last few years, even though regulatory changes did not severely limit allowable urban uses of malathion. The reason for the change in malathion use cannot be determined on the basis of available data.

<u>Conclusion 3</u>: *Urban use of pyrethroids that could be transported to surface water falls into several categories: professional structural pest control applications, other outdoor professional applications, and non-professional (primarily residential) applications.* Both professionals and non-professionals apply pyrethroids outdoors. Professionals apply pyrethroids to control pests in and around structures ("structural pest control") and in vegetated areas, such as lawns, landscaping, and rights-of-way. Of the various outdoor pyrethroid application categories, professional structural pest control applications likely comprise most of the quantity of pyrethroids applied to outdoor impervious surfaces.

<u>Conclusion 4</u>: *Two pyrethroids—cypermethrin and bifenthrin—accounted for almost 80% of the pyrethroid-related aquatic "toxicity equivalents" estimated released in California urban areas in 2005-2006.* These two pyrethroids are among those that have most often been linked (as significant contributors) to pyrethroid-related toxicity to sediment dwelling organisms in Northern California urban creeks.

<u>Conclusion 5</u>: *The most heavily used pyrethroids in California urban areas in 2005-2006 were bifenthrin, cyfluthrin (including beta-cyfluthrin), cypermethrin, deltamethrin, esfenvalerate, lambda-cyhalothrin, and permethrin.* Professional applicators accounted for at least two-thirds of the estimated urban use of each of these pyrethroids except esfenvalerate, which was used primarily by non-professionals.

<u>Conclusion 6</u>: *A significant fraction of the pyrethroids reported applied by professionals for structural pest control may be injected underground, where they cannot be transported readily to surface water.* As much as 85% of the study-list pyrethroids applied by professionals for structural pest control in 2005-2006 could have been applied underground. The actual fraction of underground applications is likely less than 85%, but greater than zero. Based on consumer surveys, it is unlikely that a meaningful fraction of unreported (non-professional) pyrethroid use involves underground applications.

<u>Conclusion 7</u>: *Indoor applications are unlikely to comprise a significant fraction of professional structural pest control use of study-list pyrethroids, but may comprise a meaningful fraction of pyrethroid use by non-professionals*. Omitting consideration of indoor use of study-list pyrethroids by professional structural pest control applicators should not significantly affect interpretation of pesticide use data.

<u>Conclusion 8</u>: *In 2006, at least half of all California pesticide use was in urban areas.* Although only about 10% of reported pesticide use is urban, about 70% of all pesticide use is not reported. Essentially all pesticide uses that do not require reporting are urban in nature. The sum of urban reported pesticide use and estimated unreported pesticide use was between 70% and 80% of pesticide sales in California in 2006.

<u>Conclusion 9</u>: *Most use of most study-list pyrethroids is by professionals.* Use patterns of study-list pyrethroids differ from the statewide averages for all pesticides. Most California pyrethroid use is by professional applicators for structural pest control. More than 90% of estimated urban pyrethroid use is by professional applicators.

<u>Conclusion 10</u>. *Most use of most study-list pesticide is in urban areas.* Of the study-list pesticides, only diazinon, chlorpyrifos, and the pyrethroids lambda-cyhalothrin and esfenvalerate were used equally or more in agricultural areas than in urban areas in 2005-2006. About 70% of the total California use of study-list pyrethroids occurred in California urban areas in 2005-2006.

<u>Conclusion 11</u>. *Urban pyrethroids applications occur at all times of the year*. Previous detailed analysis (TDC Environmental 2007a) showed that landscaping applications by professionals peaked in the summer, but professional structural pest control applications

did not vary significantly by season. Although applications occur year-round, runoff is most likely to occur when it rains. In California's Mediterranean climate, rain occurs almost exclusively in the winter months.

3.2 Recommendations

Management

Recommendation 1: *Target outdoor, aboveground use of pyrethroids in pesticide toxicity reduction programs.* Any outdoor use of pyrethroids that is subject to storm water (or other water) runoff could contribute to the pyrethroid-related toxicity that has been identified in Northern California urban creeks. Applications that involve treatment of impervious surfaces are the highest priority, because pesticides are washed off impervious surfaces more efficiently than they are washed off of pervious surfaces (TDC Environmental 2003).

Recommendation 2: *Seek to change the way Argentine ants are kept out of buildings in California.* Argentine ant control around buildings is the most common urban insecticide application in California (Wilen 2001; Wilen 2002, Flint 2003). Surfaces around buildings are often impervious, from which meaningful fractions of pesticides can wash off when it rains (or when non-rainwater discharges occur). Spraying insecticides on and around buildings to control Argentine ants has historically been among the most problematic pesticide uses for water quality. Shifting Argentine ant control methods away from perimeter sprays and to IPM-based methods that minimize insecticide releases to surface waters (e.g., use of containerized baits and barriers like caulking) may be an important element in ending recurring surface water quality problems from urban insecticide use. Consideration should also be given to identifying building methods, materials, and landscaping practices that can reduce Argentine ant problems inside buildings.

Recommendation 3: *Avoid recommending against or terminating use of a particular pesticide without promoting or requiring a less environmentally problematic substitute.* History continues to show that simply substituting one group of pesticides for the previous one has unintended—and often undesirable—environmental consequences.

Recommendation 4: *Recognize that widespread use of any pesticide active ingredient in an urban watershed has the potential to have significant adverse cumulative impacts on surface waters receiving runoff and wastewater treatment plant discharges*. Adverse effects of pesticides on water quality involve a combination of pesticide toxicity and the quantity of pesticide used in manners that lead to releases to surface water bodies. Cumulative impacts are a possible consequence when a large number of pesticide applications occur in a watershed. Developing and implementing pest control and pesticide application methods that provide effective pest control while minimizing pesticide runoff (e.g., mechanical controls, containerized baits, restriction of urban outdoor pesticide applications to spot treatments) would reduce the potential for pest control to create water quality problems.

Outreach and Education

The highest priorities for outreach and education are Recommendations 1 through 4 above. The additional recommendations below focus on potential hazards of specific pesticides to aquatic life. The University of California report *Tracking Non-Residential Pesticide Use in Urban Areas of California* (Wilen et al. 2005) contains an excellent set of recommendations addressing all priorities for outreach and education to urban pesticide users (particularly non-residential users) for reducing water quality impacts.[20]

<u>*Recommendation 5*</u>: *Continue to discourage use of outdoor broadcast pesticide applications in general, and uncontainerized uses of pyrethroids, carbaryl, fipronil, and malathion as replacements for urban uses of diazinon and chlorpyrifos.* Instead, encourage IPM-based insect control methods that minimize pesticide releases to surface waters (e.g., use of containerized baits and barriers like caulking). Because containerized baits are unlikely to release significant quantities of pesticide active ingredients into runoff, it is not necessary to avoid fipronil in containerized baits (however, aboveground outdoor application of uncontainerized fipronil products should be avoided).

<u>*Recommendation 6*</u>: *Continue to exercise discretion with recommendation of alternative insecticides for urban outdoor applications.* Instead, as explained in Recommendation 5, encourage IPM-based insect control methods that minimize pesticide releases to surface waters. When uncontained pesticides are needed to manage a pest problem, spot treatments pose the least risk for water quality, because with spot treatments the total quantity of active ingredient that is released to the environment is relatively small.

<u>**Research**</u>

<u>*Recommendation 7*</u>: *Obtain additional information about the linkage between pyrethroid use and the presence of pyrethroids in surface waters (including sediments) in urban areas.* Such information will allow toxicity reduction programs to more effectively target the causes of toxicity in surface water sediments. Both monitoring and modeling will likely be needed to determine whether any one specific pyrethroid use pattern (e.g., around buildings or on lawns) is the most significant contributor to pyrethroid levels in creek sediments.

<u>*Recommendation 8*</u>: *Examine urban use patterns of carbaryl, fipronil, malathion, and PHMB in greater detail.* Careful examination of the urban use of study-list pesticides other than pyrethroids would provide water quality agencies with improved ability to develop strategies from preventing water quality problems from these pesticides.

<u>*Recommendation 9*</u>: *Explore inconsistencies in DPR sales and reported use data for cypermethrin and other study-list pyrethroids*. For several study-list pyrethroids, sales quantities reported to DPR are less than reported use quantities. These discrepancies prevent more detailed analysis of urban use patterns. Of particular interest is cypermethrin (for which reported use has exceeded sales since 1999) because of its large estimated urban use, high toxicity to aquatic organisms, and documented contribution to toxicity to sediment-dwelling organisms in urban creeks. DPR operational changes that increased enforcement of DPR fees on pesticide sales should improve the quality of sales data for 2006 and future years, which will assist with the exploration of the data inconsistencies (if these inconsistencies remain).

<u>*Recommendation 10*</u>: *Conduct research to support selection and development of effective methods to keep Argentine ants out of buildings without spraying a band of insecticide on and around buildings.* Implementation of Recommendation 2 would be facilitated by identification and development of effective Argentine ant management strategies that do not rely on traditional perimeter sprays. These strategies should be developed with the participation of Argentine ant researchers and statewide leaders from the pest control operator industry. The focus should be on methods that minimize

[20] Available on the Internet: http://www.up3project.org/documents/dpr_ucipm_non-residential_pesticide_use.pdf or http://www.ipm.ucdavis.edu/PDF/PUBS/ucdavisrep.pdf.

insecticide releases to surface waters. It would be helpful if the research identified building methods, materials, and landscaping practices that can reduce Argentine ant problems inside buildings. DPR's pest management alliance program is a potential source of support for the needed research (if the program is amended to allow funding of research projects). The DPR pest management alliance program is well-positioned to support adoption of effective management methods as they are developed.

Recommendation 11. *Examine regulatory, procedural, and contractual requirements that are linked to urban insecticide applications to determine whether alternative compliance approaches are possible or whether runoff protection measures can be integrated into compliance programs*. Regulations, contracts, and other forces can cause insecticides to be used in urban areas even in the absence of a pest problem—and without flexibility in selecting the pest management approach. For example, Federal home financing requirements are linked to pre-construction termiticide treatments, which often involve treating soil (which is exposed until the foundation is poured) with relatively high concentrations of pyrethroids. Agricultural pest protection requirements have caused nurseries to commonly mix insecticides into planting mixes; which has been linked to relatively high concentrations of pyrethroids in runoff from nurseries implementing this practice (Budd et al. 2007). Research to demonstrate the efficacy of alternative procedures may be necessary before existing requirements can be changed.

Regulatory

Recommendation 12: Modify California pesticide use reporting processes and forms to differentiate among key categories of pesticide applications. Differentiation among outdoor pesticide applications around structures, pre-construction termiticide soil treatments, underground injection applications, and indoor pesticide applications to control pests in structures is a priority. To estimate the amount of pesticides subject to runoff in urban areas, it is necessary to separate aboveground and underground/indoor pesticide applications.

Recommendation 13: Field-verify California pesticide use reporting data. While DPR's pesticide use reporting system can provide valuable information for managing pesticide related water quality problems, available information suggests that the error rate for reported data could be much greater than 10% for individual pesticide active ingredients. An audit that included field verification of reporting would be able to determine the level of error in the data. Auditing urban uses would be particularly helpful, given that this analysis identifies structural pest control applications as a significant urban use of pyrethroids, which have been linked to adverse effects in aquatic ecosystems.

Recommendation 14: Ask Agricultural Commissioners to work with professional applicators to minimize reporting errors. For some pesticides, simple administrative errors by a small number of professional applicators (e.g., reporting the quantity of diluted solution rather than the quantity of pesticide product used) have the potential to create significant errors in statewide data sets. A voluntary education program could prevent such errors in the future. Initially targeting correct reporting of liquid formulations appears warranted based on errors identified in fipronil reporting.

Recommendation 15: Enforce requirements to report pesticide sales quantities accurately. Errors in data reported to DPR have, on occasion, created significant inaccuracies in DPR's pesticide sales data reports.

Recommendation 16: *Explore potential approaches to obtain pesticide sales and use data by region and in a more timely manner.* Currently, pesticide sales data are available only on a statewide basis. The data set cannot be broken down by county, city, or watershed. While agricultural pesticide use reports include application location, urban reports only specify the county of application. Data are usually not available to the public until late in the year after applications are reported (i.e., data from applications reported in January-December 2006 were not made public until November 2007). Water quality managers could more effectively design water quality protection programs if they had access to regional or local pesticide sales and use data in a timely manner; however, creating systems that would generate such data would involve new approaches, new participants, and the time and energy of many organizations.

Recommendation 17: Explore the potential to create one or more leading indicators that can be used to estimate urban pesticide use trends. Available data allow examination of past use patterns, but do not provide a suitable basis for predicting future use patterns and trends.

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