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Patterns of Pyrethroid Contamination and Toxicity in Agricultural and Urban Stream Segments

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Pyrethroid insectides are in widespread use in both agricultural and urban environments. In order to understand if there are systematic differences in the composition of pyrethroid mixtures found in sediment arising from runoff from these two land uses, and to compare their toxicological effects, sediment samples were collected from three creeks in and around Salinas, California. Pyrethroids were present in sediments from both agricultural and urban reaches of all three creeks. Sediment from all sampling locations in both agricultural and urban areas was toxic to *Hyalella azteca*, an amphipod commonly used for sediment testing, and, in all cases there was sufficient mass of pyrethroid present in the sediment to explain the measured toxicity. The organophosphate chlorpyrifos likely contributed to toxicity in one instance. While the compositional differences in sediment pyrethroid mixtures between the land uses were not dramatic, there was a tendency for cyfluthrin and cypermethrin to be typical of urban areas, and lambda-cyhalothrin to be found in agricultural reaches. Bifenthrin and permethrin were somewhat characteristic of urban and agricultural areas, respectively, though either land use could be a potential source.

Introduction

Pesticides are used widely in urban areas, where insects are both nuisances and, in some cases, vectors for disease. Due to the withdrawal of some of the most widely used organophosphates, pyrethroid pesticides are now used extensively in urban environments, whether applied by homeowners or professional pest controllers. Over 327,000 kg of pyrethroids were used by professional applicators for structural pest control and landscape maintenance in California in 2005 (www.cdpr.ca.gov/docs/pur/purmain.htm), and although data are not publicly reported, retail sales to homeowners can be assumed to be considerable. Recent research points to bifenthrin, cyfluthrin and cypermethrin, as the greatest cause for concern in creeks within residential areas, being the most frequent contributors to aquatic toxicity in streams in and around Sacramento, California (*1, 2*).

While a dramatic increase in commercial and home use of pyrethroids has been reported, agricultural use of pyrethroids has been relatively steady in California over the past decade, ranging from a low of 105,000 kg in 1999 up to 142,000 kg in 2005 (the most current data available). However, some industry segments, like almond and stone fruit production, have reported a reduction in organophosphate use with an increased use of pyrethroids *(3).* As a result of this widespread use, agriculture-affected water bodies may contain pyrethroid residues in the sediments, with permethrin the most commonly found (*4, 5)*. However, since permethrin is among the least toxic of the pyrethroids to aquatic life (*6),* the pyrethroids bifenthrin, lambda-cyhalothrin and esfenvalerate are more frequently found at concentrations associated with toxicity. Pyrethroids are believed to be responsible for toxicity in agricultural-affected sediment samples in about 60% of the instances when toxicity to the standard toxicity testing species, *Hyalella azteca*, is observed (*5*).

Thus, pyrethroids are widely used in both agriculture and urban areas, and both uses have resulted in sediment contamination of creeks within the watersheds. However, when both agricultural and urban areas are in close proximity to one another, it may be difficult to distinguish the sources of the pesticides. Downstream toxicity may not be traceable to a single well-defined source since both urban and agricultural subwatersheds can deliver runoff into the same waterbody, and thus contribute pyrethroids and aquatic toxicity to that water body. In order to make informed management decisions, take regulatory action, or inititate mitigation, it is necessary to be able to discriminate among the potential pyrethroid sources.

While research has been conducted on pyrethroids from agricultural and urban land uses, comparisons between the two different uses have not been made. This study explores the relative toxicological impact and compositional differences in the pyrethroid mixtures of urban and agricultural areas. If such differences exist, it may be possible to develop characteristic “fingerprints” of pyrethroids from both land uses in order to guide management actions.

Materials and Methods

Study area

Salinas, California was chosen as the study site because of the close juxtaposition of urban and agricultural land uses. Salinas is the county seat of Monterey County, and a major urban center with a population of approximately 150,000 people. In addition to residential housing, the city includes associated commercial and industrial development, much of which supports the agricultural industry. The farmland surrounding the city produces salad vegetables (e.g., lettuce, spinach) as well as many other fruits and vegetables (e.g., strawberries, broccoli, cauliflower, celery, artichokes, and wine grapes). Agricultural production is heavily dependent on irrigation, for annual rainfall is approximately 33 cm, and largely limited to November through April. The city itself is surrounded by agricultural lands, but is unique in that is has a flood control basin in the center of the city, Carr Lake Regional Park, which is also used for agriculture (http://www.ci.salinas.ca.us).

Three creeks run through the city: Gabilan Creek, Natividad Creek, and Alisal Creek, the later being renamed Reclamation Ditch at a point southeast of Salinas where the water course turns to the northwest (Figure 1). All three creeks originate in undeveloped land in hills northeast of the city, flow through agricultural lands, through the city, and then back in to agricultural lands. The three water courses join in the Carr Lake area. The combined flow from all three water courses leaves Carr Lake via the Reclamation Ditch, which flows northwest and finally empties into Tembladero Slough and ultimately into the Pacific Ocean in Monterey Bay. Flow into the creeks varies dramatically with season. During the winter, large storm events produce the greatest amount of flow through the creeks (e.g., up to about 200 cfs at US Geological Survey gage in Reclamation Ditch; http://waterdata.usgs.gov/ca/nwis). During the summer, flow rates are very low (about 3 cfs in Reclamation Ditch) and the minimal water present is return flow from irrigated agricultural fields or urban runoff from landscape irrigation.

Sampling Procedures

Background samples, intended to have little or no pesticide residue, were taken from Gabilan and Alisal Creeks upstream of any urban or agricultural development (Table I; Stations SG1 and SA1). There was no comparable background site accessible on Natividad Creek. Two to three additional sampling sites were established along each watercourse as they passed through agricultural lands, and then through the city of Salinas. When possible, particular effort was made to establish sites just upstream of transition points between agricultural and urban land uses, so that those sites would be indicative of the integrated effects of the upstream land use (e.g., agricultural) and just prior to the inputs from the downstream land use (e.g., urban). Urban portions of Natividad and Gabilan creeks consisted largely of single-family residential development, with only minor commercial influence. Urban sites along Reclamation Ditch were a mix of residences, commercial establishments, and industry.

Samples were collected on September 23, 2005, prior to the onset of the winter rains. At each site, the upper one centimeter of the surface sediment in the creek beds was skimmed off with a stainless steel scoop and transferred into solvent-cleaned glass jars. The finest-grained sediments (silts and clays) available at each site were collected since pyrethroids are strongly hydrophobic and associate with the organic fractions of the sediment. In the lab, sediment was homogenized by hand mixing, and then held at 4ºC for toxicity samples, and -20ºC for chemistry samples.

Analytical Methods

Chemical analysis of the sediment was done using the methods outlined in You et. al. (*7)*. Briefly, the sediment sample was sonicated with 50 ml of a 50:50 mixture of acetone and methylene chloride. Three extractions were done, with the extracts combined and solvent exchanged to hexane. Clean-up was performed using Florisil (Thermo Fisher Scientific, Waltham, MA), deactivated with distilled water, and elution from the column with 30% diethyl ether in hexane. Florisil extracts were solvent exchanged to hexane, reduced to 1 ml, 25 mg of primary/secondary amine (PSA) was added, and the samples shaken for 2 min. Following centrifugation, the supernatant was analyzed on an Agilent 6890 series gas chromatograph with an Agilent 7683 autosampler and an electron capture detector (Agilent Techologies, Palo Alto, CA). Two columns from Agilent, a HP-5MS, and a DB-608 were used. The seven pyrethroids quantified were: bifenthrin, lambda-cyhalothrin, esfenvalerate, deltamethrin, permethrin, cyfluthrin, and cypermethrin. Analytes also included one organophosphate, chlorpyrifos, and 21 organochlorines, including: alpha-, beta-, delta-, and gamma-BHC, heptachlor, heptachlor epoxide, alpha- and gamma-chlordane, alpha- and beta-endosulfane, endosulfan sulfate, p,p'-DDE, p,p'-DDD, p,p'-DDT, aldrin, dieldrin, endrin, endrin aldehyde, endrin ketone, and methoxychlor.

Grain size was determined using wet sieving, and total organic carbon was measured using a CE-440 Elemental Analyzer from Exeter Analytical (Chelmsford, MA), following acid vapor treatment to remove inorganic carbon.

Toxicity Testing

Ten-day toxicity tests were performed using 7-10 day old freshwater amphipods, *H. azteca,* according to standard U.S. Environmental Protection Agency protocols *(8).* Using 8 replicates for each sediment sample, about 50-75 mL of sediment, and about 250 mL of overlying water were added to 400 ml glass beakers. Tests were conducted at 23ºC, with a 16 h light: 8 h dark cycle, with feeding of 1 ml of yeast/cerophyll/trout chow per beaker per day. Fresh water was delivered with an automatic water delivery system that provided two volume additions (500 ml) daily using Milli-Q purified water, made moderately hard by added salts. Water samples for pH, conductivity, alkalinity, hardness, and ammonia were taken at the beginning and end of the test; dissolved oxygen and temperature were monitored regularly. Mortality of amphipods was determined by sieving sediment on a 425 µm screen, and determining the proportion of the initial 10 amphipods per beaker that survived the 10-d exposure.

Toxicity data was analyzed using ToxCalc 5.0 software (Tidepool Scientific Software, McKinleyville, CA). Each batch of test sediments tested included a control sediment from San Pablo Dam Reservoir (Orinda, CA), and survival in test sediments was statistically compared to the control using a t-test with arcsine transformation. Control survival ranged from 86-95%.

The concentrations of each pyrethroid in the sediments were used to calculate toxic units (TU) with respect to *H. azteca* as:

$$\text{TU} = \frac{\text{Actual concentration of pyrethroid in sediment}}{\text{Known 10-d LC50 for } \textit{H. azteca}}$$

Since pyrethroids are strongly hydrophobic, both the actual concentration and the LC50 were organic carbon (oc) normalized. The reported 10-d sediment LC50 values were as follows: cypermethrin = 0.38 µg/g oc, lambda-cyhalothrin = 0.45 µg/g oc, bifenthrin = 0.52 µg/g oc, deltamethrin = 0.79 µg/g oc, cyfluthrin = 1.08 µg/g oc, esfenvalerate = 1.54 µg/g oc, permethrin = 10.83 µg/g oc (*9, 10*). Pyrethroid TUs were assumed to be additive due to the common mode of action of compounds within the class.

Results

The sediment samples consisted of fine-grained material ranging from 20-85% fines (silts and clays combined) with a median of 41% fines. The percent total organic carbon of the sediment samples ranged from 0.6 – 4.4% with a median of 2.0%.

All sediments were tested for acute toxicity to *H. azteca*, and only minimal mortality was seen in the designated background sites, prior to the creeks entering agricultural lands (Table I: SA1 and SG1). SA1 had only 4% mortality; SG1 had 14% mortality. While the later value was statistically different (probability < 0.05) from the concurrent control sample with 5% mortality, the mortality rate in a later control test was comparable to the SG1 sample, and the 14% mortality seen at SG1 is not considered to be a meaningful difference.

The remaining 11 other sediment samples collected in the study were significantly toxic, with mortality rates ranging from 31-100% (Figure 2). The highest mortality was seen in two urban sites; the mixed use urban site of SR2 (100% mortality) and the residential area of SN3 (96%). Substantial toxicity was seen in agricultural sites as well, with 90% mortality at SN1, 84% mortality at SA2, and 84% mortality at SG2. All three of these sites were in agricultural reaches of their respective creeks, prior to the creeks entering any urban development. There was little overall difference in the toxicity of agricultural and urban reaches, with a median mortality of 68% among the urban sites and 75% among the agricultural sites.

The two background sites contained no detectable pyrethroids (Table II). However, pyrethroids were present at every other site, whether in areas of agricultural or urban land use. Permethrin was the dominant pyrethroid, and generally typified the agricultural reaches of the creeks. However, it was also found in some urban areas (e.g. SR2, SN2, SN3). It can not be conclusively determined from the existing data whether the permethrin residues in urban areas represent input from the surrounding urban landscape, or transport from more upstream agricultural areas. At only one site (SA2) was the permethrin concentration above the estimated 10-d sediment LC50 for *H. azteca*. At several sites concentrations were about one-third that threshold.

Bifenthrin was present at most sites, and its concentration reached at least half the *H. azteca* LC50 at five sites (SR1, SR5, SN2, SN3, SG3). On Natividad and Gabilan Creeks, the compound was clearly associated with urban land uses, with no measurable bifenthrin in sediments from agricultural regions, but then increasing to over 10 ng/g in urban areas. In Reclamation Ditch the data suggest both urban and agricultural bifenthrin sources.

Among the other pyrethroids, lambda-cyhalothrin tended to be associated with agricultural reaches, and attained concentrations at least half the LC50 at three sites (SA2, SR1, SR2). Cypermethrin and cyfluthrin attained their highest concentrations in urban reaches. Esfenvalerate concentrations were far below the LC50, and the compound was not clearly associated with one particular land use.

Sediment concentration data for the non-pyrethroid analytes are not shown, but concentrations were generally not toxicologically significant at least with respect to explaining *H. azteca* mortality results. Chlorpyrifos was nearly always below 20 ng/g, which would represent about one-third of a TU given the median organic carbon content in the samples (2.0%) and the reported chlorpyrifos LC50 to *H. azteca* (2.97 µg/g oc; (*11)*). The sole exception was SR5 where chlorpyrifos reached 68 ng/g, or 1.6 TU given the organic carbon content at this site (1.4%). The organochlorine pesticides or their degradation products were frequently detected but well below acutely toxic concentrations to *H. azteca*. The most commonly detected were DDE (maximum 254 ng/g), DDD (max. 234 ng/g), DDT (max. 152 ng/g), dieldrin (max. 40 ng/g), endrin (max. 14.9 ng/g), alpha-chlordane (max. 8.5 ng/g) and gamma-chlordane (max. 7.0 ng/g). These concentrations were all below 0.1 TU given the LC50 estimates of Weston et al., (*4*).

The pyrethroid concentrations alone showed a strong relationship to *H. azteca* mortality as observed in the sediment toxicity tests (Figure 3). Not only did mortality show a significant increase concurrently with increasing pyrethroid TUs, but the overall pattern suggested 50% mortality occurred at about one TU (0.6-1.4 depending on sample), precisely the relationship that would be expected if pyrethroids were the dominant contributor to toxicity. Assuming additive toxicity among the pyrethroids such that the compound-specific TUs could be added to derive a total pyrethroid TU, every site, excluding the two background locations, contained at least 0.5 TU. Six of the eleven sites reached or exceeded one TU. Even without the additivity assumption, a strong pyrethroid contribution to toxicity is still suggested with eight of the eleven sites reaching at least 0.5 TU and three reaching one TU.

There is also limited evidence from toxicity identification evaluation (TIE) procedures for a contributing role of pyrethroids. Sample SR2, which contained potentially toxic concentrations of lambda-cyhalothrin and cypermethrin, was tested with addition of an esterase enzyme to the overlying water (*5*). The enzyme is intended to cleave the ester bond present in pyrethroids, substantially reducing the toxicity. Without esterase, the SR2 sediment caused near complete mortality; with esterase 38% of the *H. azteca* survived (*12*), supporting the suspected role of pyrethroids in explaining the toxicity. Results from TIE manipulation of a second sample containing lambda-cyhalothrin at probable toxic concentrations are less conclusive. Sediment SN1 was tested in a dilution series with addition of piperonyl butoxide (PBO) to the overlying water, a procedure which makes pyrethroids more toxic. Without PBO in the overlying water the LC50 of SN1 sediment was 29.8% (expressed as percent original sediment when diluted with control sediment; 95% confidence interval of 23.3-38.2%) (*11*). With PBO, the LC50 was reduced to 19.8% (16.2-24.3%). While the PBO did increase the toxicity (decreasing the LC50) as expected if lambda-cyhalothrin were the toxicant, the decrease was not as dramatic as usually seen with PBO, and the LC50 confidence intervals did slightly overlap. Thus, the results from the SN1 sample were inconclusive and the presence of another unidentified toxicant in the sample remains a possibility.

Discussion

It is clear that pyrethroids from both agricultural and urban uses are reaching the creeks of Salinas, and that they are usually present in the fine sediment in these creeks at concentrations acutely toxic to *H. azteca*, a species widely used for sediment toxicity assessment. This observation is consistent with prior studies in agricultural areas of California (*4, 5, 13, 14*) and work in urban creeks of the Sacramento, California and San Francisco Bay areas (*1, 2*). Toxicity testing with *H. azteca* of both agricultural and urban reaches of Salinas creeks commonly showed acute mortality, and there is evidence from both toxic unit analysis and TIE procedures that pyrethroids were the major contributor to this toxicity. The organophosphate chlorpyrifos was also likely a contributor at one agricultural site. Although this compound no longer has appreciable use in urban environments, it is still widely used in agriculture.

This study indicates that the differences between an agricultural pyrethroid ‘fingerprint’ and an urban one are not dramatic, but yet some distinctions could be made. Cyfluthrin and cypermethrin were characteristic of urban-affected stream reaches. Bifenthrin was also commonly found and attained highest concentrations in sediments located in urban areas, though it has agricultural sources and uses as well. On the other hand, lambda-cyhalothrin was distinctly found in agriculture-affected samples. Permethrin was characteristic of sediments found in areas with both land uses.

California is unique in that commercial use of pesticides requires reporting of that use to the California Department of Pesticide Regulation, including the compound applied and the amount used. For the most part, the pesticide-related land use distinctions made on the basis of the Salinas creek data are supported by reported use data from California as a whole, and specifically from Monterey County in which Salinas is located (Table III). The usage data as well as the environmental monitoring both support the primarily urban sources of cyfluthrin, the agricultural sources of lambda-cyhalothrin, and the dual sources of permethrin and bifenthrin. The only significant difference between the Salinas findings and pesticide use data is cypermethrin, for which dominant urban use is suggested by the creek sediment data and from statewide use statistics, but in Monterey County use is primarily agricultural.

The use data (Table III) also suggests that some other pyrethroids are distinctly urban or agricultural, though those distinctions could not be made with the Salinas creek data set. The presence of deltamethrin would be a clear marker of urban sources, since its agricultural use is negligible. Similarly esfenvalerate and fenpropathrin are likely to be from agricultural sources because of very limited non-agricultural use. It should, however, be recognized that Table III excludes retail sales, as that data are not tracked by California agencies with the level of detail available for commercial pesticide applications. For example, esfenvalerate can be found in some retail products sold for home and garden use. Finally, it should be recognized that these distinctions apply only to pyrethroid use in California. There are likely to be regional differences in crops produced and pesticides applied which prevent broad national generalizations. A pyrethroid that may have only non-agricultural uses in one area of the country could be a significant agricultural insecticide in another, and thus the distinctions made here would have to be reassessed in other locations.

The very fact that there were differences in pyrethroid composition among the sampling sites suggests that the sediments on which the pyrethroids are adsorbed may be transported fairly limited distances. Water-soluble pesticides can travel considerable distances (*15*), but being particle-associated, pyrethroid dispersal may be more limited. Our most downstream site, SR5, located approximately 4 km downstream of Salinas contained only esfenvalerate and bifenthrin, with no evidence of the lambda-cyhalothrin, permethrin, cypermethrin and cyfluthrin known to be present in more upstream locations. This conclusion may be a consequence of the timing of sampling. Sediments were collected in September, near the end of the dry season when flow is very low and limited to irrigation runoff. Major winter storm events, typically beginning in December in the Salinas area, may be important in promoting sediment transport over greater distances, and blurring the land use distinctions evident in dry season sampling.

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Figures and Artwork

Figure 1

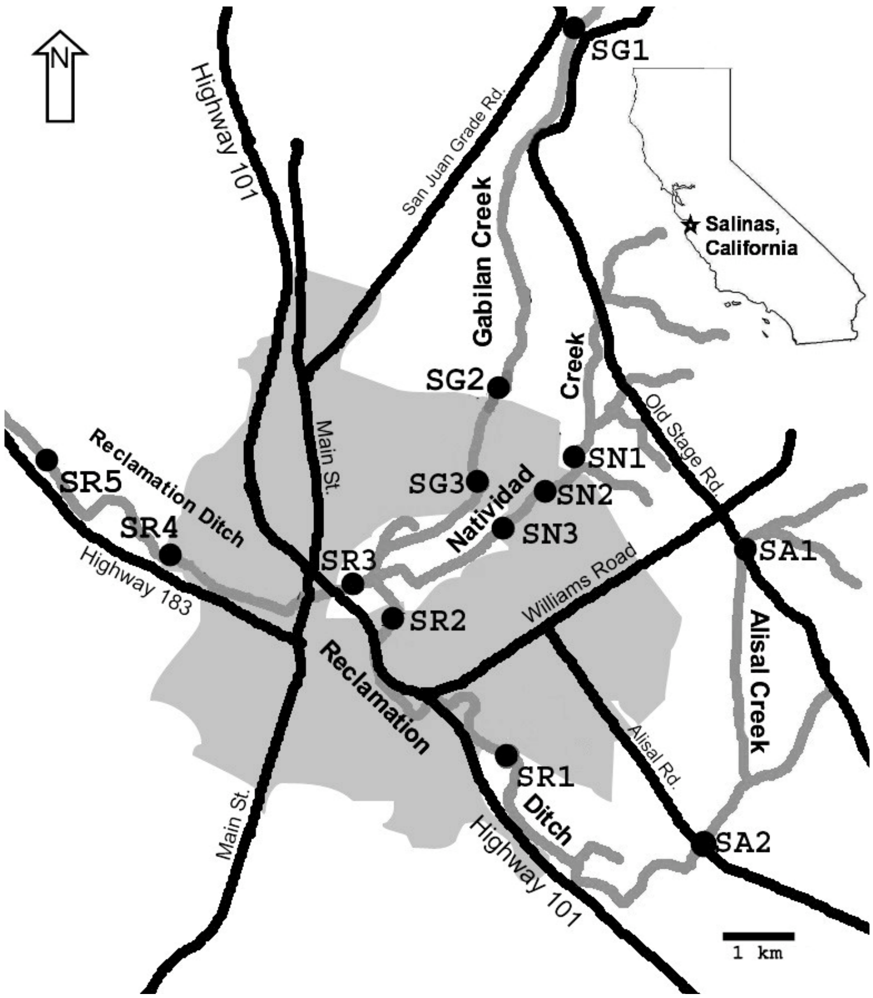

Figure 2

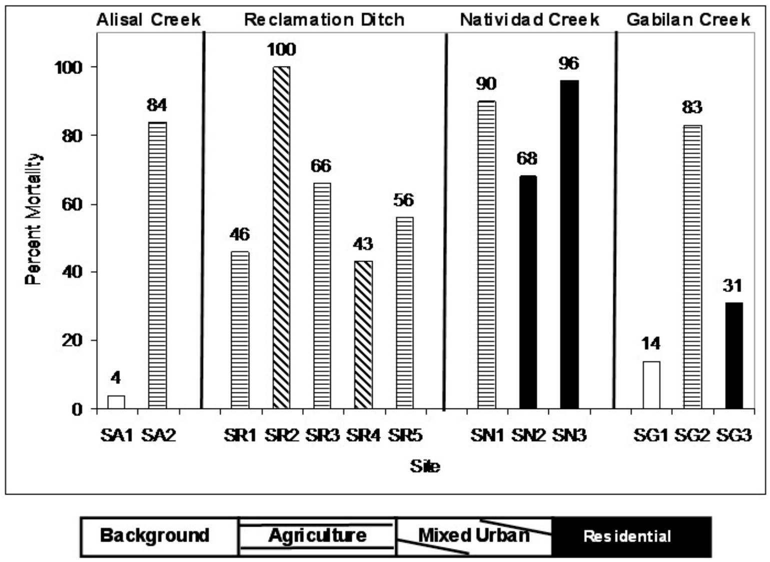
Alisal Creek
Reclamation Ditch
Natividad Creek
Gabilan Creek
Percent Mortality
0
20
40
60
80
100
4
84
46
100
66
43
56
90
68
96
14
83
31
SA1 SA2
SR1 SR2 SR3 SR4 SR5
SN1 SN2 SN3
SG1 SG2 SG3
Site
Background
Agriculture
Mixed Urban
Residential

Figure 3

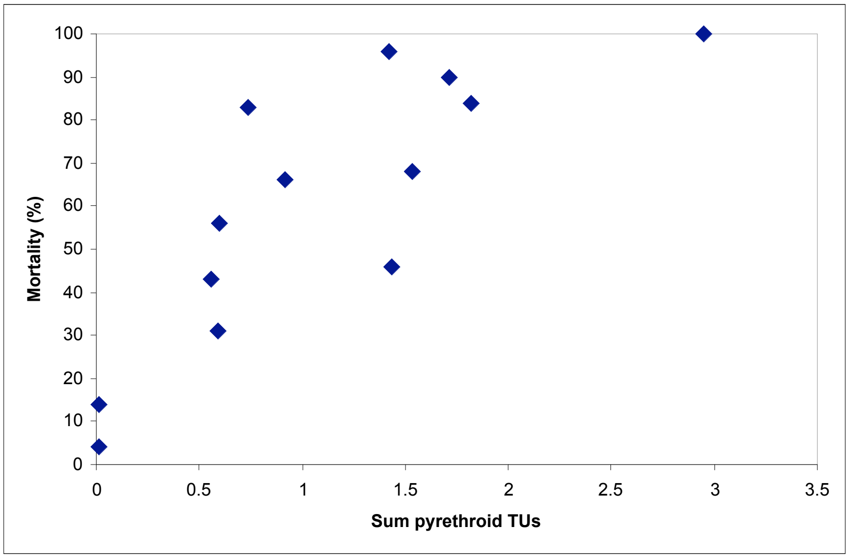
100
90
80
70
60
50
40
30
20
10
0
Mortality (%)
0
0.5
1
1.5
2
2.5
3
3.5
Sum pyrethroid TUs

Figure Caption List

Figure1: Map of Salinas (a) illustrating the creeks sampled, Alisal Creek (SA1, SA2) and Reclamation Ditch (SR1, SR2, SR3, SR4, SR5), Gabilan Creek (SG1, SG2, SG3), and Natividad Creek (SN1, SN2, SN3). Flow is generally from the east to the west. The urban areas are shaded gray. The white agricultural area in the center of the city represents Carr Lake.

Figure 2: Percent mortality of Hyalella azteca when exposed to sediment from the sampling sites. Shading indicates the classification of each site into background, agricultural, mixed urban (residential/commercial/industrial), or residential.

Figure 3: Graph of the percent mortality of Hyalella azteca at each site in Salinas, CA in relation to the sum of pyrethroid toxic units (TU).

Table I: Locations and descriptions of sampling sites along the three water courses in and around Salinas

Site name	N Latitude W Longitude	Site description	Surrounding land use
Alisal Creek/Reclamation Ditch			
SA1	36.69238 121.56915	Alisal Creek @ Old Stage Rd.	Point where creek transitions from undeveloped land to agricultural land
SA2	36.64567 121.57698	Alisal Creek @ Alisal Rd.	Agriculture
SR1	36.65858 121.61379	Reclamation Ditch @ Moffett St.	Agricultural area, just prior to creek entering commercial district
SR2	36.67978 121.63735	Reclamation Ditch @ Cesar Chavez Park	Mixed commercial and residential
SR3	36.68507 121.64772	Reclamation Ditch @ Sherwood Dr.	Edge of agricultural Carr Lake, just prior to creek entering commercial district
SR4	36.68426 121.66735	Reclamation Ditch @ Victor St. and Victor Way	Commercial district, just prior to creek entering agricultural lands
SR5	36.70475 121.70525	Reclamation Ditch @ San Jon Rd.	Agriculture
Natividad Creek			
SN1	36.70202 121.60262	Natividad Creek @ Boronda Rd.	Agriculture just prior to creek entering residential area
SN2	36.69887 121.61067	Natividad Creek @ Freedom Pkwy.	Residential
SN3	36.69020 121.62151	Natividad Creek @ Gee St.	Residential
Gabilan Creek			
SG1	36.78040 121.58541	Gabilan Creek @ Old Stage Rd.	Undeveloped land
SG2	36.71553 121.61643	Gabilan Creek @ Boronda Rd.	Agriculture just prior to creek entering residential area
SG3	36.70030 121.62196	Gabilan Creek @ Independence Blvd. and Lexington Dr.	Residential

Table II: Pyrethroid concentrations (ng/g, dry weight basis) in the sediments at the sampling sites, with sites shaded based upon surrounding land use. ND indicates not detected (<1 ng/g). Deltamethrin was among the analytes but was never detected at any site. The number of Hyalella azteca toxic units (TU) each concentration value represents, given the sediment organic carbon content, is shown in parentheses. Bifenthrin = Bif, Cyfluthrin = Cyf, Cypermethrin = Cyp, Esfenvalerate = Esf, Lambda-cyhalothrin= Lam, Permethrin = Per

Background	Agricultural	Mixed urban	Residential

Site and land-use	**Total organic carbon (%)**	**Bif**	**Cyf**	**Cyp**	**Esf**	**Lam**	**Per**
Alisal Creek/Reclamation Ditch							
SA1	3.57	ND	ND	ND	ND	ND	ND
SA2	0.56	ND	ND	ND	ND	1.6 (0.6)	72.0 (1.2)
SR1	2.51	7.4 (0.6)	ND	2.1 (0.2)	4.3 (0.1)	5.5 (0.5)	14.1 (0.1)
SR2	1.84	4.0 (0.4)	3.5 (0.2)	7.0 (1.0)	3.4 (0.1)	6.8 (0.8)	82.5 (0.4)
SR3	1.99	3.4 (0.3)	ND	ND	1.6 (0.1)	2.0 (0.2)	67.8 (0.3)
SR4	2.00	1.2 (0.1)	1.1 (0.1)	2.7 (0.4)	ND	ND	8.1 (<0.1)
SR5	1.39	4.0 (0.6)	ND	ND	1.0 (0.1)	ND	ND
Natividad Creek							
SN1	0.93	ND	ND	ND	ND	6.8 (1.6)	9.0 (0.1)
SN2	2.99	10.5 (0.7)	3.7 (0.1)	5.1 (0.5)	1.4 (<0.1)	3.0 (0.2)	11.3 (<0.1)
SN3	2.15	8.8 (0.8)	ND	4.6 (0.6)	1.0 (<0.1)	ND	9.3 (<0.1)
Gabilan Creek							
SG1	4.40	ND	ND	ND	ND	ND	ND
SG2	1.87	ND	ND	2.0 (0.3)	ND	1.0 (0.1)	68.8 (0.3)
SG3	4.02	10.7 (0.5)	ND	1.0 (0.1)	ND	ND	5.4 (<0.1)

Table III. Relative agricultural and non-agricultural commercial use of pyrethroids in California as a whole and in Monterey County in which Salinas is located (2005 data; www.cdpr.ca.gov/docs/pur/purmain.htm). Non-agricultural use consists largely of applications by professional pest control firms, and figures do not include retail sales to homeowners for which comparable data are not available. The table also shows whether the compound was characteristic of urban or agricultural stream segments in the current study.

Pyrethroid	Statewide agricultural use (kg)	Statewide non-agricultural use (kg)	Monterey County agricultural use (kg) and primary crop	Monterey County non-agricultural use (kg)	Finding in current Salinas study
Bifenthrin	9,439	18,748	297 Strawberries	175	Largely urban but some agricultural
Cyfluthrin	7,810	14,526	11 Lettuce	63	Urban
Cypermethrin (including S-cypermethrin	14,070	92,068	3138 Lettuce	140	Urban
Deltamethrin	38	6,238	0	19	Not detected
Esfenvalerate	14,780	118	1555 Artichokes, lettuce, broccoli	0	Undetermin ed
Fenpropathrin	17,940	3	2295 Grapes, strawberries	0	Not measured
Lambda-cyhalothrin	10,296	6,298	1390 Lettuce	2	Agricultural
Permethrin	67,796	183,110	9900 Lettuce, spinach, celery	519	Both urban and agric.