SWAMP
Surface Water Ambient Monitoring Program

TOXICITY IN CALIFORNIA WATERS: CENTRAL VALLEY REGION

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ACKNOWLEDGEMENTS

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EXECUTIVE SUMMARY E

Toxicity testing has been used to assess effluent and surface water quality in California since the mid-1980s. When combined with chemical analyses and other water quality measures, results of toxicity tests provide information regarding the capacity of water bodies to support aquatic life beneficial uses. This report summarizes the findings of monitoring conducted by the Surface Water Ambient Monitoring Program (SWAMP) and associated programs between 2001 and 2010.

As in Anderson et al. (2011), the majority of data presented in this report were obtained from monitoring studies designed to increase understanding of potential biological impacts from human activities. As such, site locations were generally targeted in lower watershed areas, such as tributary confluences or upstream and downstream of potential pollutant sources. Only a minority of sites was chosen probabilistically (i.e., at random). Therefore, these data only characterize the sites monitored and cannot be used to make assumptions about unmonitored areas.

Water and sediment toxicity were common in the Central Valley Region between 2001 and 2010. Water toxicity was more frequently seen than sediment toxicity, but high toxicity was seen more often in sediment than in water. Moderate toxicity was observed most frequently with *Ceriodaphnia dubia* and most rarely with *Pimephales promelas*. However, *P. promelas* also had the smallest percentage of sites that were non-toxic, indicating that toxicity to fish in the Central Valley was wide spread but of low magnitude.

In the SWAMP and California Environmental Data Exchange Network (CEDEN) databases, water toxicity information was largely limited to data from sites in agricultural areas while sediment toxicity data were collected in both agricultural and urban areas. Differences in water toxicity do not appear to be related to differences in land use characteristics among sites tested with each class of freshwater organism, whereas urban sediments showed significantly lower survival than sediments from all other types of sites ($P < 0.05$) when tested with *Hyalella azteca*.

Correlation analyses and toxicity identification evaluations (TIEs) were used to determine causes of water and sediment toxicity statewide, and the results of these analyses showed that the majority of toxicity was caused by insecticides. Water toxicity to *C. dubia* has been caused primarily by a combination of organophosphate and pyrethroid pesticides. Non-polar organic compounds, potentially herbicides, have been shown to be the primary cause of algal toxicity. The majority of sediment TIEs and chemical analyses of toxic sediments have identified pyrethroid pesticides as causes of toxicity to *H. azteca*.

As discussed in Anderson et al. (2011), the principal approach to determine whether observations of toxicity in laboratory toxicity tests are indicative of ecological impacts in receiving waters has been to conduct field bioassessments of macroinvertebrate communities. These studies have included "triad" assessments of chemistry, toxicity and macroinvertebrate communities, the core components of SWAMP. One recommendation for future SWAMP monitoring is to conduct further investigations on the linkages between surface water toxicity and receiving system impacts on biological communities.

SECTION 1 INTRODUCTION

The California State Water Resources Control Board published a statewide summary of surface water toxicity monitoring data from the Surface Water Ambient Monitoring Program (SWAMP) in 2011 (Anderson et al., 2011; http://www.waterboards.ca.gov/water_issues/programs/swamp/reports.shtml). This report reviewed statewide trends in water and sediment toxicity collected as part of routine SWAMP monitoring activities in the nine California water quality control board regions, as well as data from associated programs reported to the CEDEN database. The report also provided information on likely causes and ecological impacts associated with toxicity and management initiatives that are addressing key contaminants of concern. The current report summarizes a subset of the statewide database that is relevant to the Central Valley Region (Region 5). Source programs, test counts and sample date ranges are outlined in Table 1.

Table 1
Source programs, water and sediment toxicity test counts and test dates for Central Valley regional toxicity data included in this report.

Toxicity Test Type	Program	Test Count	Sample Date Range
Water Column	Irrigated Lands Regulatory Program	3178	3/26/03 – 11/28/07
	SWAMP San Joaquin River (SJR) Trends	838	1/28/03 – 03/29/07
	Other SWAMP	15	1/3/03 – 3/15/03
Sediment	Irrigated Lands Regulatory Program	335	5/28/02 – 9/25/07
	Statewide Urban Pyrethroid Monitoring	12	11/14/06 – 11/21/06
	Stream Pollution Trends (SPoT)	31	4/28/08 – 8/20/08
	SWAMP Sediment Tox	61	10/9/01 – 9/19/05
	Other SWAMP	23	9/24/04 – 11/7/04

The Central Valley Region comprises 22,500 square miles and includes the Sacramento River and San Joaquin River watersheds and Delta as well as the Tulare Basin. The valley floor is an immensely productive agricultural area, whose output provides eight percent of the value of all agricultural production in the USA. The largest urban areas include Sacramento, Fresno, Bakersfield, Stockton and Modesto. Watersheds in this region are therefore influenced by a mix of land uses and the major rivers are impacted by both urban and agricultural runoff. The majority of the toxicity data produced in the

Central Valley has been performed under SWAMP and the Irrigated Lands Program (ILP) and has addressed the potential for water and sediment toxicity arising from agricultural land uses. Recent research has expanded the consideration of the toxicity of urban runoff, particularly in regard to contamination of urban waterways by pyrethroid pesticides (Amweg et al., 2006; Weston et al., 2005; Weston et al., 2009). Another area of inquiry that has moved to the fore during the past decade concerns the decline of populations of pelagic fish in the Sacramento – San Joaquin Delta, and the ecological stressors in the Delta region have come under increasing scrutiny, including the potential effects of contaminants in urban and agricultural runoff (Sommer et al., 2007).

SECTION 2
SCOPE AND METHODOLOGY

This study examined all toxicity data included in the SWAMP and CEDEN databases from toxicity tests whose controls showed acceptable performance according to the Measurement Quality Objectives of the 2008 SWAMP Quality Assurance Project Plan (QAPrP). The attached maps (Figures 5-14) show locations of sites sampled for toxicity by SWAMP and partner programs and the intensity of toxicity observed in the water and sediment samples collected at those sites. Sites are color-coded using the categorization process described in Anderson et al. (2011), which combines the results of all toxicity tests performed on samples collected at a site to quantify the magnitude and frequency of toxicity observed there. At sites where both water and sediment toxicity data were collected, two toxicity categories were calculated to separately summarize the degree of toxicity in water and in sediment. Toxicity test results reported in the Central Valley included freshwater exposures of the cladoceran *Ceriodaphnia dubia*, the fathead minnow *Pimephales promelas* and the alga *Pseudokirchneriella subcapitata* (formerly known as *Selenastrum capricornutum*). Freshwater sediment samples were tested using the amphipod *Hyalella azteca*. Only survival endpoints and algal growth are considered in the measures of toxicity reported here; therefore all sites identified as toxic showed a significant decrease in test animal survival or algal growth in one or more samples. Some *P. subcapitata* algal growth inhibition tests recorded in the SWAMP/CEDEN databases were performed on water samples that exceeded the upper conductivity limit for optimal growth of this species (1500 uS/cm). These tests were excluded from the data set unless an appropriate high conductivity control was performed, in which case the sample was compared to the appropriate control and included in the study.

In order to summarize the magnitude of toxicity at each site, the data went through a number of steps:

1. Standardize the statistical analyses: When data were submitted to the SWAMP/CEDEN databases, reporting laboratories evaluated the potential toxicity of samples using a variety of statistical protocols. In order to standardize the analysis of the entire data set, all control – sample comparisons were re-analyzed using the proposed EPA Test of Significant Toxicity (Anderson et al., 2011; Denton et al., 2011; U.S. EPA, 2010).

2. Calculate the High Toxicity Threshold: The High Toxicity Threshold is determined for each species' endpoint from the entire dataset summarized in the Statewide Report (Anderson et al., 2011). This threshold is the average of two numbers, both expressed as a percentage of the control performance. The first number is the data point for the 99th percentile of Percent Minimum Significant Difference (PMSD), representing the lower end of test sensitivity across the distribution of PMSDs in the Statewide Report. The second value is the data point for the 75th percentile of

Organism Performance Distribution of all toxic samples, representing an organism's response on the more toxic end of the distribution. This average serves as a reasonable threshold for highly toxic samples.

3. Determine the Toxicity Category for each site: The magnitude and frequency of toxicity of each sample collection site was categorized (Table 2) according to Anderson et al. (2011) and Bay et al. (2007) as "non-toxic", "some toxicity", "moderately toxic", or "highly toxic". Throughout this document the terms some, moderately and highly will be italicized when in reference to these categories.

Separate categories were created for sediment and for water toxicity, as well as for toxicity to individual freshwater species.

Effluent toxicity data were collected in the Central Valley Region during 2001 to 2010, but were not included in the SWAMP and CEDEN databases, and were not examined in this study due to the difficulty of obtaining electronic replicate-level data in a timely fashion.

Table 2
Data conditions used to determine toxicity categories for any given sample collection site.

Category	Conditions for Categorization
Non-toxic	No sample is ever toxic to any test species
Some Toxicity	At least one sample is toxic to one or more species, and all of the species' responses fall above their species-specific High Toxicity Threshold
Moderate Toxicity	At least one sample is toxic to one or more species and at least one of the species' responses falls below their species-specific High Toxicity Threshold
High Toxicity	At least one sample is toxic to one or more species and the mean response of the most sensitive species falls below its respective High Toxicity Threshold

SECTION 3
REGIONAL TOXICITY

Water and sediment toxicity were common in the Central Valley Region between 2001 and 2010 (Table 3; Figure 1). Water toxicity tests included exposures of fish, invertebrates and algae, while sediment toxicity tests were performed using the amphipod *H. azteca*. Water toxicity was more common than sediment toxicity, but *high* toxicity was seen more often in sediment than in water. Thirty-three percent (33%) of sampling sites showed *some* water toxicity, with 17% of sites showing *moderate* water toxicity, but less than 1% of sites showing *high* water toxicity. Thirty-eight percent (38%) of sites showed *some* sediment toxicity, with 26% of sites showing *moderate* sediment toxicity, and 16% showing *high* toxicity.

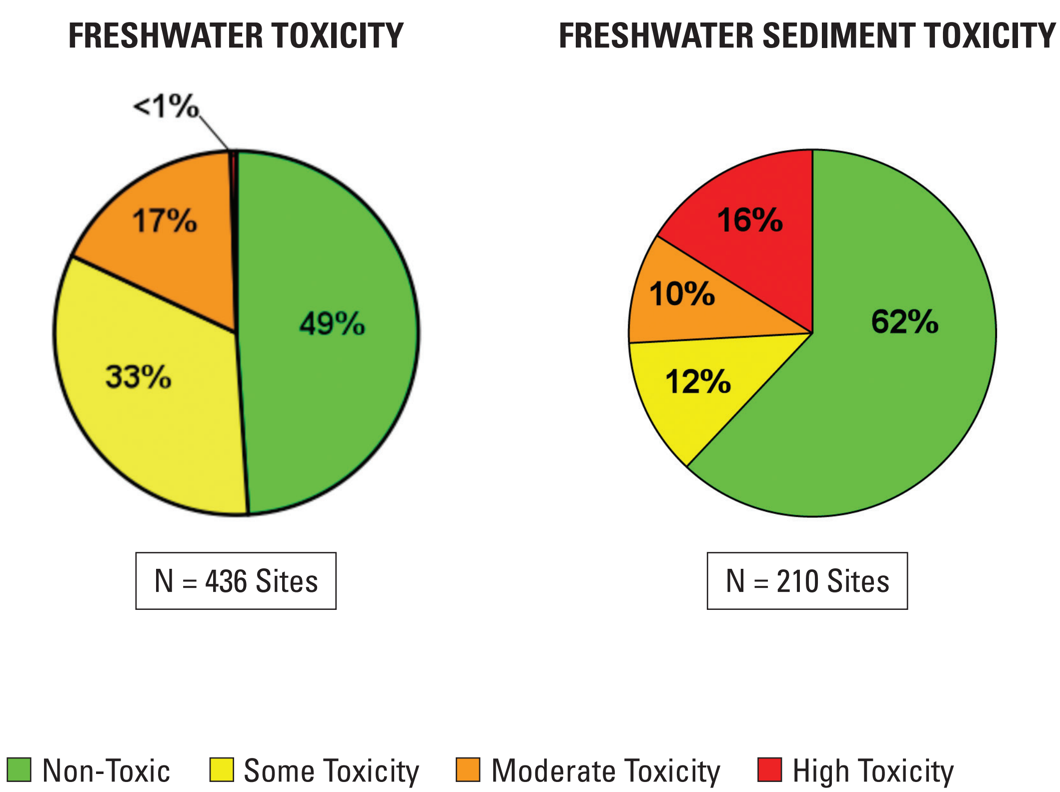


Figure 1. Magnitude of toxicity in water and sediment samples in the Central Valley of California.

Table 3
Species-specific maximum levels of toxicity observed at sites tested with *C. dubia*, *P. promelas* and *P. subcapitata* water toxicity tests and *H. azteca* sediment toxicity tests.

Toxicity Test Type Species	Program Number of Sites	Maximum Toxicity Level Observed			
		Non-Toxic	Some Toxicity	Moderately Toxic	Highly Toxic
C. dubia	147	75	29	42	1
P. promelas	162	62	91	9	0
P. subcapitata	127	76	24	25	2
H. azteca	210	130	26	20	34

TOXICITY BY SPECIES

The fathead minnow *P. promelas*, the cladoceran *C. dubia*, and the alga *P. subcapitata* were used to test the toxicity of water samples to examine the potential for ecological responses to contaminants across a range of trophic levels. Water toxicity is summarized by individual species in Figure 2.

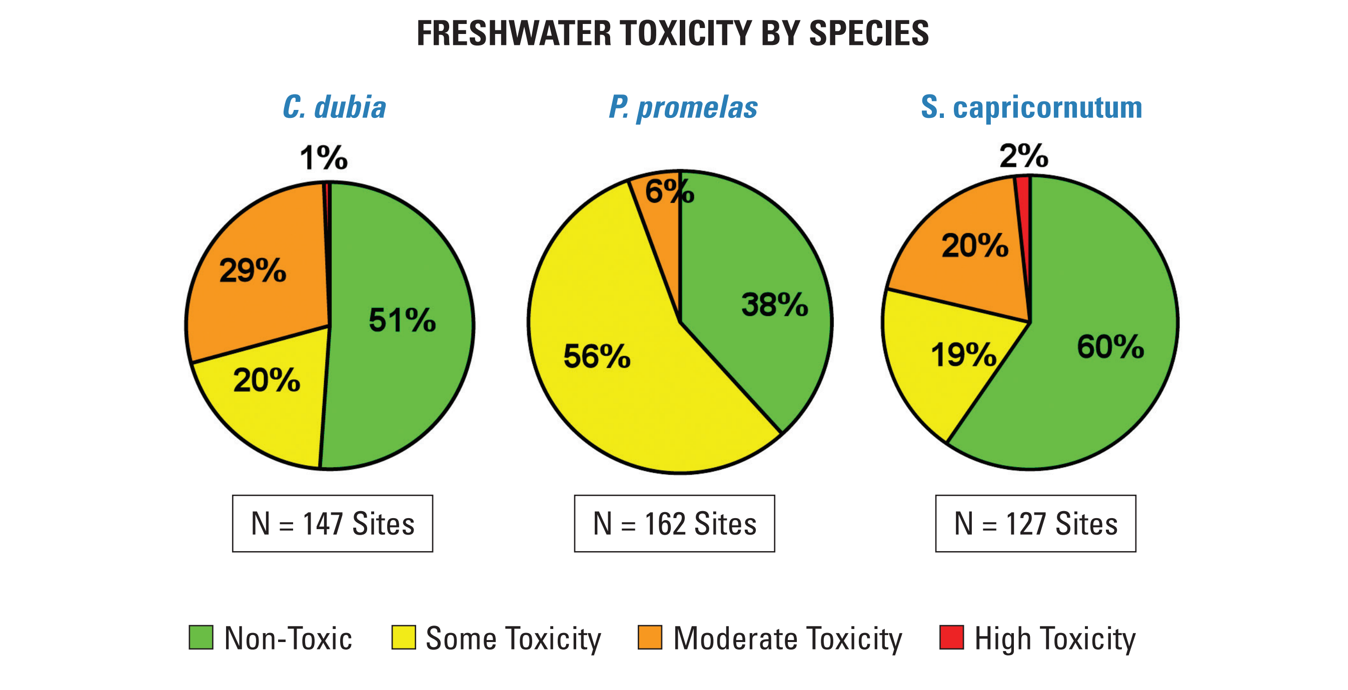


Figure 2. Magnitude of toxicity to individual freshwater species in water samples from the Central Valley Region of California.

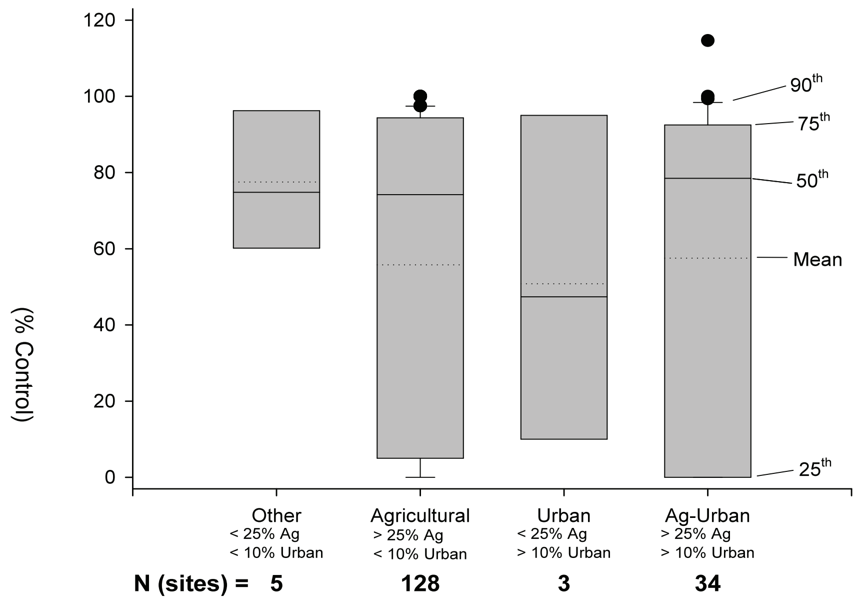
SECTION 4
RELATIONSHIPS BETWEEN LAND USE AND TOXICITY

Land use was quantified as described in Anderson et al. (2011), around stream, canal and ditch sites at which samples were collected for testing in water column or sediment toxicity tests. Using ArcGIS, polygons were drawn to circumscribe the area within one kilometer of each site that was upstream of the site, in the same catchment, and within 500 meters of a waterway draining to the site. Land use was categorized according to the National Land Cover Database. All "developed" land types in the land cover database were collectively categorized as "urban". "Cultivated crops" and "hay/pasture" were categorized together as "agricultural". All other land types were categorized as "other" for the purpose of this analysis. Percentages of each land use type were quantified in the buffers surrounding the sample collection sites. Urban land category represents sites with nearby upstream land use of greater than 10% urban and less than 25% agricultural areas. Agricultural land category represents sites with nearby upstream land use of greater than 25% agricultural and less than 10% urban areas.

In the SWAMP/CEDEN databases, water toxicity information from the Central Valley was largely limited to data from sites in agricultural areas, while sediment toxicity data were collected in both urban and agricultural areas (Figure 4). Neither type of toxicity data was collected at a large number of less-developed sites. Comparisons of Central Valley toxicity with land use therefore had limited statistical power (Figure 3). Among the sets of sites that were sampled for testing with the three classes of organisms, the average percentages of urban land in 1 kilometer upstream buffers ranged from 8.9% (fish) to 9.8% (invertebrate), and average percentages of agricultural land ranged from 78.9% (invertebrate) to 80.2% (fish).

In *H. azteca* sediment tests, urban sediments showed significantly lower survival than sediments from all other types of sites (Figure 3: Wilcoxon Rank Sum Test, $P < 0.05$), and although there was a larger number of sites in agricultural areas, sites from urban areas exhibited a higher magnitude of toxicity (Figure 4). Sediments showed widespread *high* toxicity in the vicinity of urban areas such as Sacramento, Yuba City, Redding, and Antioch, and sediment toxicity in the Central Valley was clearly elevated in urban areas compared to the surrounding agricultural land (Figures 6 - 14, sediment toxicity maps). Greater *H. azteca* sediment toxicity in urban areas has been reported previously by Weston et al. (2005), some of whose data was incorporated into the data set analyzed in the current report. Although it was not possible to use the Central Valley's regional data set to examine associations between toxicity and agriculture, these associations are well established (Anderson et al. 2011; de Vlaming et al., 2000; Holmes et al., 2005; Weston et al., 2004).

3-A. WATER TOXICITY: ALL SPECIES COMBINED



3-B. SEDIMENT TOXICITY: *H. AZTECA* 10-DAY SURVIVAL

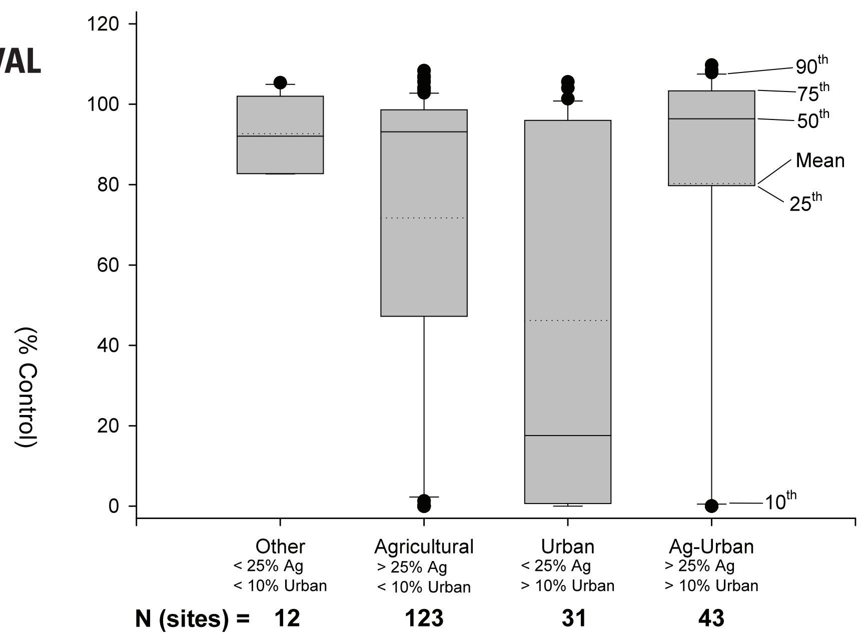
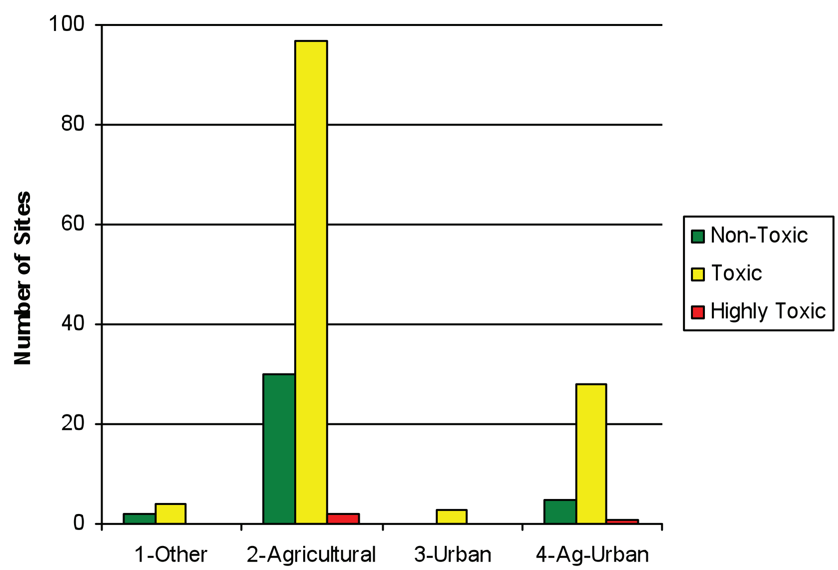


Figure 3. Toxicity distribution for samples collected from sites in urban, agricultural, agricultural-urban and less developed areas. (A) Water column toxicity; data are for the most sensitive test species at each site. (B) Sediment toxicity. Lower values represent lower levels of survival and indicate higher toxicity. Solid lines, from top to bottom, represent the 90th, 75th, 50th (median), 25th and 10th percentiles of the distribution. Dotted lines are the mean result. * = Significantly lower than other categories (one-tailed Wilcoxon Rank Sum Tests).

4-A. WATER TOXICITY: ALL SPECIES COMBINED



4-B. SEDIMENT TOXICITY: *H. AZTECA*

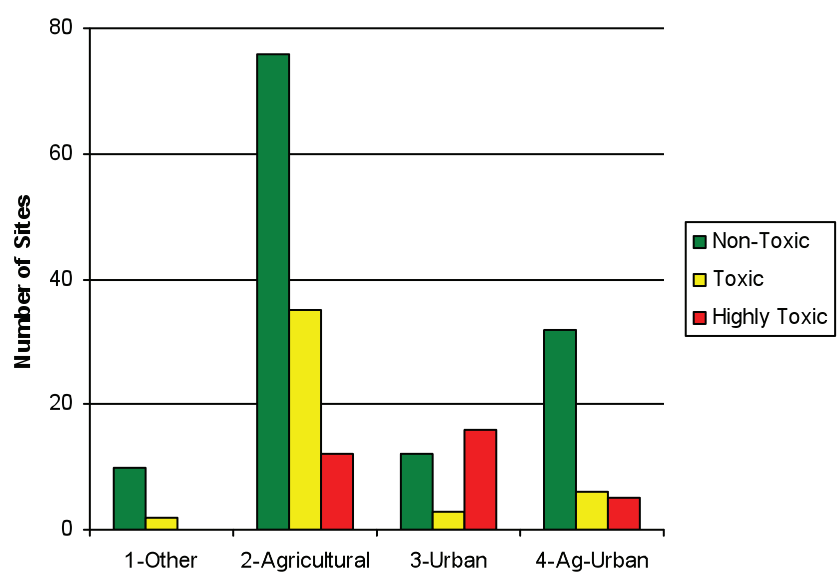


Figure 4. Numbers of sites where water and sediment were classified as nontoxic, toxic, or highly toxic, using the coding system outlined in Table 2. (A) Water column toxicity; (B) Sediment toxicity. "Some Toxicity" and "Moderate Toxicity" categories are combined here.

SECTION 5
GEOGRAPHICAL PATTERNS IN TOXICITY

High water toxicity was rarely seen in samples collected in the Central Valley between 2001 and 2010. *Moderate* toxicity was observed most frequently with *C. dubia* (29%), less frequently with *P. subcapitata* (20%) and most rarely with *P. promelas* (6%). However, *P. promelas* also showed the lowest percentage of sites with no toxicity (38%), indicating that toxicity to fish in the Central Valley was widespread, though of low magnitude. Differences in water toxicity do not appear to be related to differences in land use characteristics among the sites tested with each class of organism.

NORTHERN CENTRAL VALLEY REGION

(Figures 5 - 6)

This area has not been extensively sampled for water or sediment toxicity. Site 508SUP038 on the outskirts of Redding showed *high* sediment toxicity in the only sample collected at the site.

SACRAMENTO RIVER WATERSHED: CHICO - LINCOLN

(Figures 7 - 8)

Some to *moderate* water toxicity was widespread throughout the agricultural and urban-agricultural areas in the upper Sacramento River watershed, including the Colusa Basin, the area surrounding the Sutter Buttes, and the eastern valley floor between Chico and Lincoln.

In contrast, sediments sampled throughout the agricultural lands of this region were by and large non-toxic, with the exception of moderate toxicity found at one site on Spring Creek and at another site in an unnamed drain on Walker Creek in the Colusa Basin (520XXCS15 and 520XXCS12). Sediments downstream of the city of Chico showed *some* to no toxicity, while downstream of Yuba City, Gilsizer Slough showed *high* toxicity at multiple sites. In agricultural reaches of Gilsizer Slough further downstream from Yuba City, toxicity was less intense.

DELTA AND LOWER SACRAMENTO AND SAN JOAQUIN WATERSHEDS: SACRAMENTO - STOCKTON

(Figures 9 - 10)

Agricultural sites in the lower Sacramento River watershed showed a wide range of levels of water toxicity. The most *highly* toxic water samples were found at the Winters Canal at Road 86A (511XXSS06) and the Sacramento Slough near Karnak (520XSSLNK) which showed *high* algal toxicity.

Sediment toxicity was absent from agricultural areas in the lower Sacramento River watershed, but was *high* in the Sacramento metropolitan area. *High* sediment toxicity was found at the majority of the sites examined in residential areas of the Pleasant Grove Creek watershed in Roseville. The results of the Roseville sediment toxicity study are discussed in detail by Weston et al. (2005). On the southern outskirts of the Sacramento metropolitan area, high sediment toxicity was found in Elk Grove Creek (519SUP057), Morrison Creek (519SUP051) and Carson Creek (532SUP011). Sediments were not sampled in the cities of Vacaville, Davis, Woodland or Dixon.

In the lower San Joaquin River watershed, *some* to *moderate* water toxicity was pervasive at agricultural and urban-agricultural sites. *Moderate* toxicity to algae and invertebrates was observed in the Terminous Tract and Potato Slough area of the Delta. In the city of Antioch and the agricultural area around Tracy, toxicity to every test species was observed. The agricultural areas east of Stockton showed *moderate* toxicity to invertebrates and sites southeast of the city showed *moderate* toxicity to both invertebrates and algae. Further east, in Lone Tree Creek at Brennan Road (535XLTABR), intense toxicity to both fish and invertebrates was observed in February, 2006.

As in the lower Sacramento River watershed, sediment toxicity in the lower San Joaquin River watershed was less pervasive than water toxicity, but was *high* in some locations. In and around the city of Antioch sediment toxicity was *high*, and *moderate* toxicity was found throughout the area between Stockton and Antioch. On the northern edge of Stockton, Mosher Slough at Davis Road (531SUP026) was found to be *highly* toxic. Sediments were non-toxic in most of the remaining agricultural areas of the lower San Joaquin River watershed, with the exception of *some* toxicity found in some waterways east of Stockton. The urban areas of Manteca, Lathrop, Lodi and Galt were not sampled.

SOUTHERN SAN JOAQUIN RIVER WATERSHED AND TULARE BASIN

(Figures 11 - 14)

As in the rest of the Central Valley, *some* to *moderate* water toxicity was found throughout the agricultural lands of the southern San Joaquin River watershed and the Tulare Basin. *High* v water toxicity was found in Island Field Drain at Catrina Road (541XSSJ04).

Sediment toxicity was more widespread in this region than in other areas of the Central Valley. *High* sediment toxicity was found in the western valley waterways near the coast range, including Hospital Creek (541XSED12), Ingram Creek (541STC040), the Grayson Road Drain (541STC030), and all five sites on Del Puerto Creek east of Highway 33. *High* sediment toxicity was also found in the Hatch Drain (535XHDATR) and west of Visalia and Porterville in Packwood Creek and an unnamed ditch. *Moderate* sediment toxicity was found at downstream sites on Orestimba Creek and nearby drains, as well as in small waterways scattered throughout the southern Central Valley. Samples were not collected in the agricultural area south of Bakersfield. In the center of the Modesto urban area, the sediment was non-toxic. Other urban areas throughout the San Joaquin watershed and the Tulare Basin were not sampled, including Modesto, Fresno, Bakersfield, Tracy, Merced, Visalia, and Porterville.

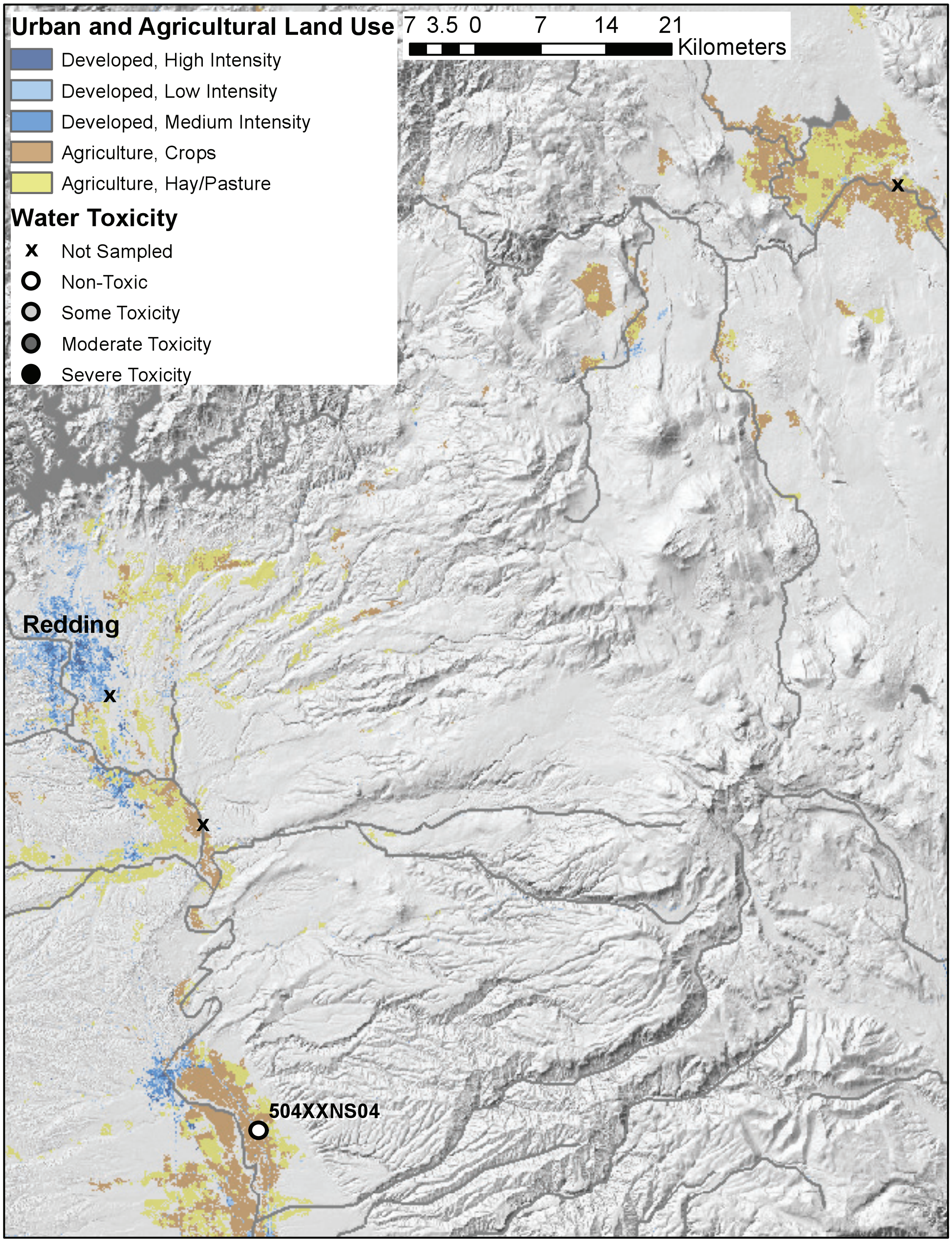


Figure 5. Magnitude of water column toxicity at sites in the northern Central Valley Region of California based on the most sensitive species (test endpoint) in water samples collected at each site.

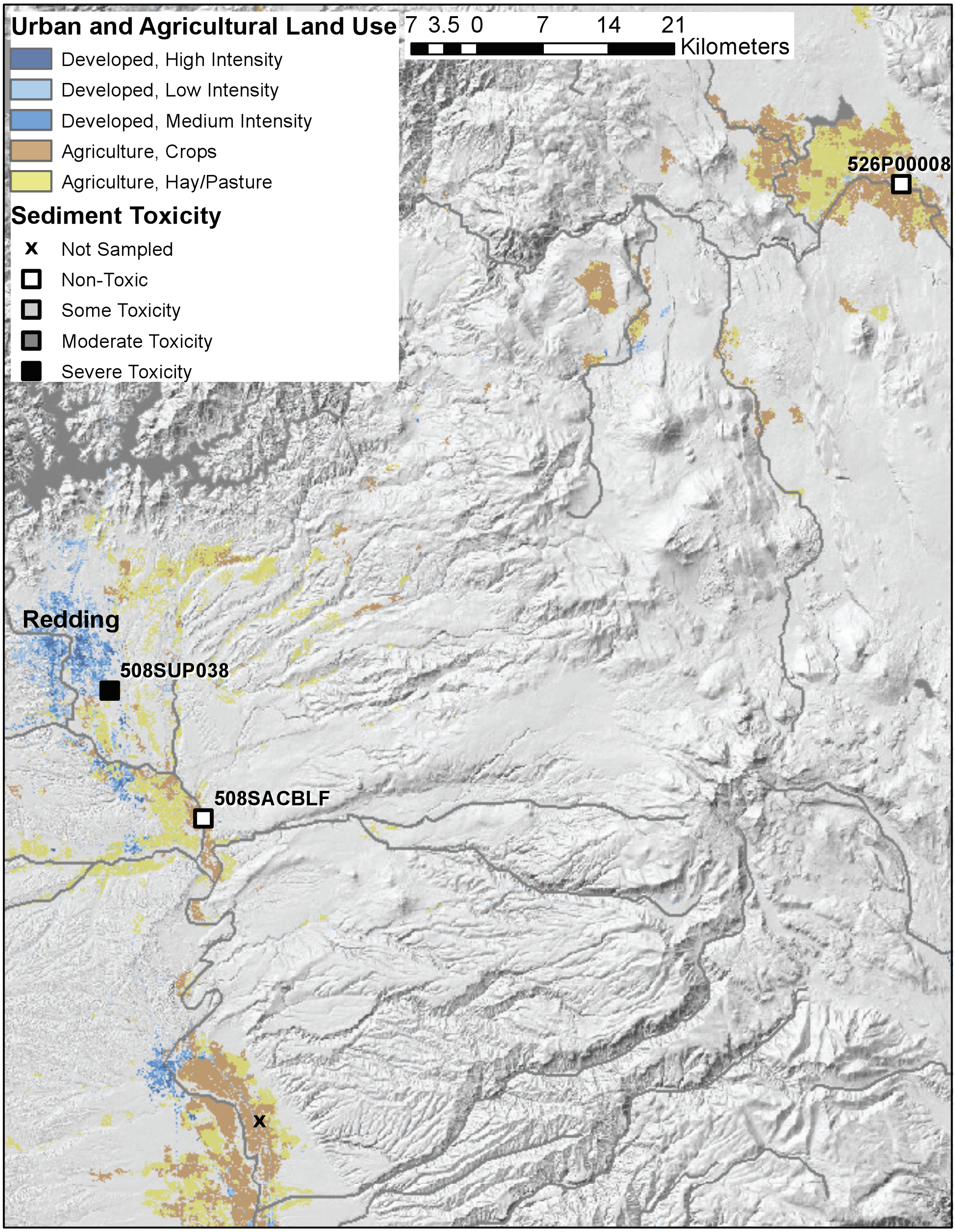


Figure 6. Magnitude of sediment toxicity at sites in the northern Central Valley Region of California based on the 10-d survival of *H. azteca* in sediment samples collected at each site.

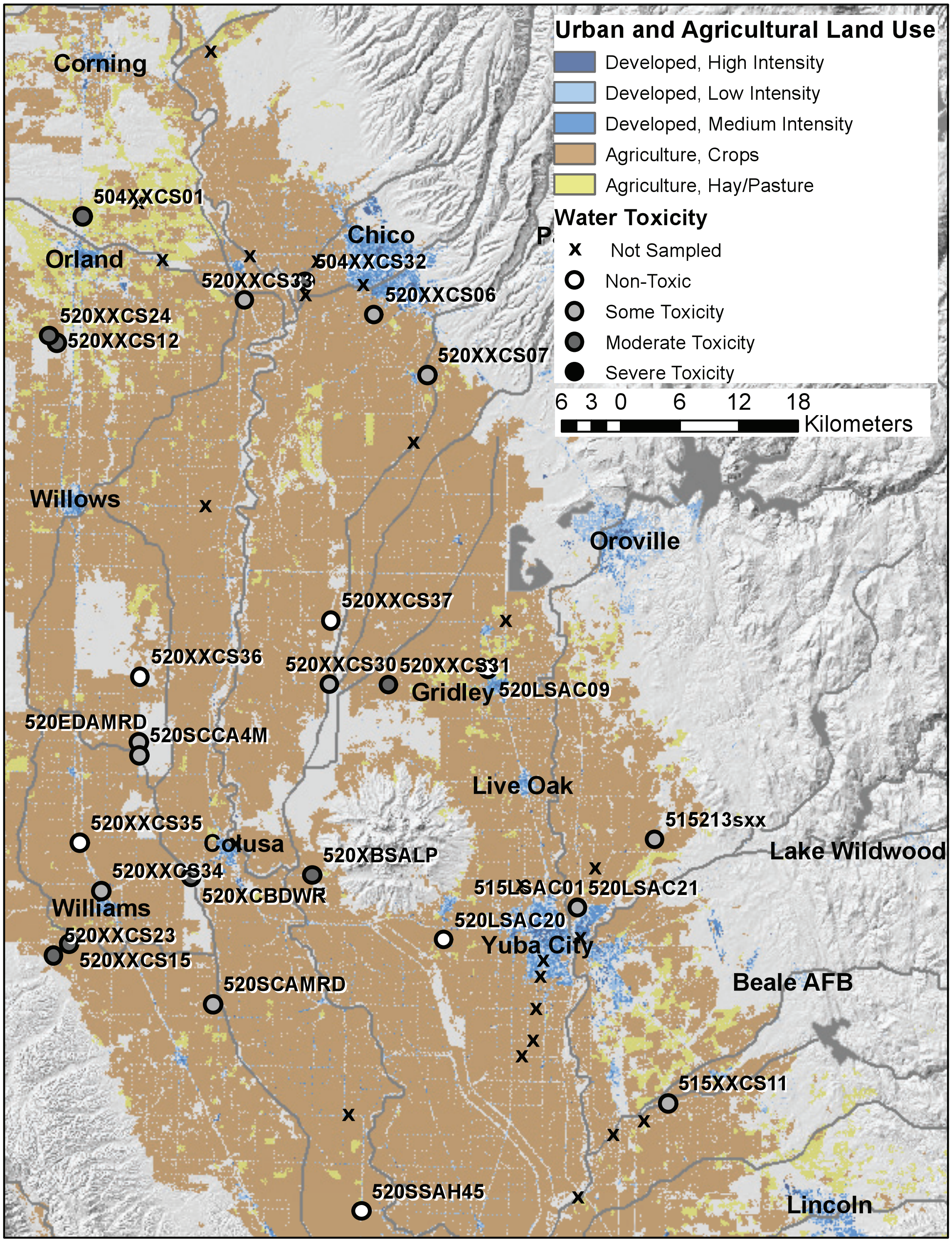


Figure 7. Magnitude of water column toxicity at sites in the upper Sacramento River watershed in the Central Valley Region of California based on the most sensitive species (test endpoint) in water samples collected at each site.

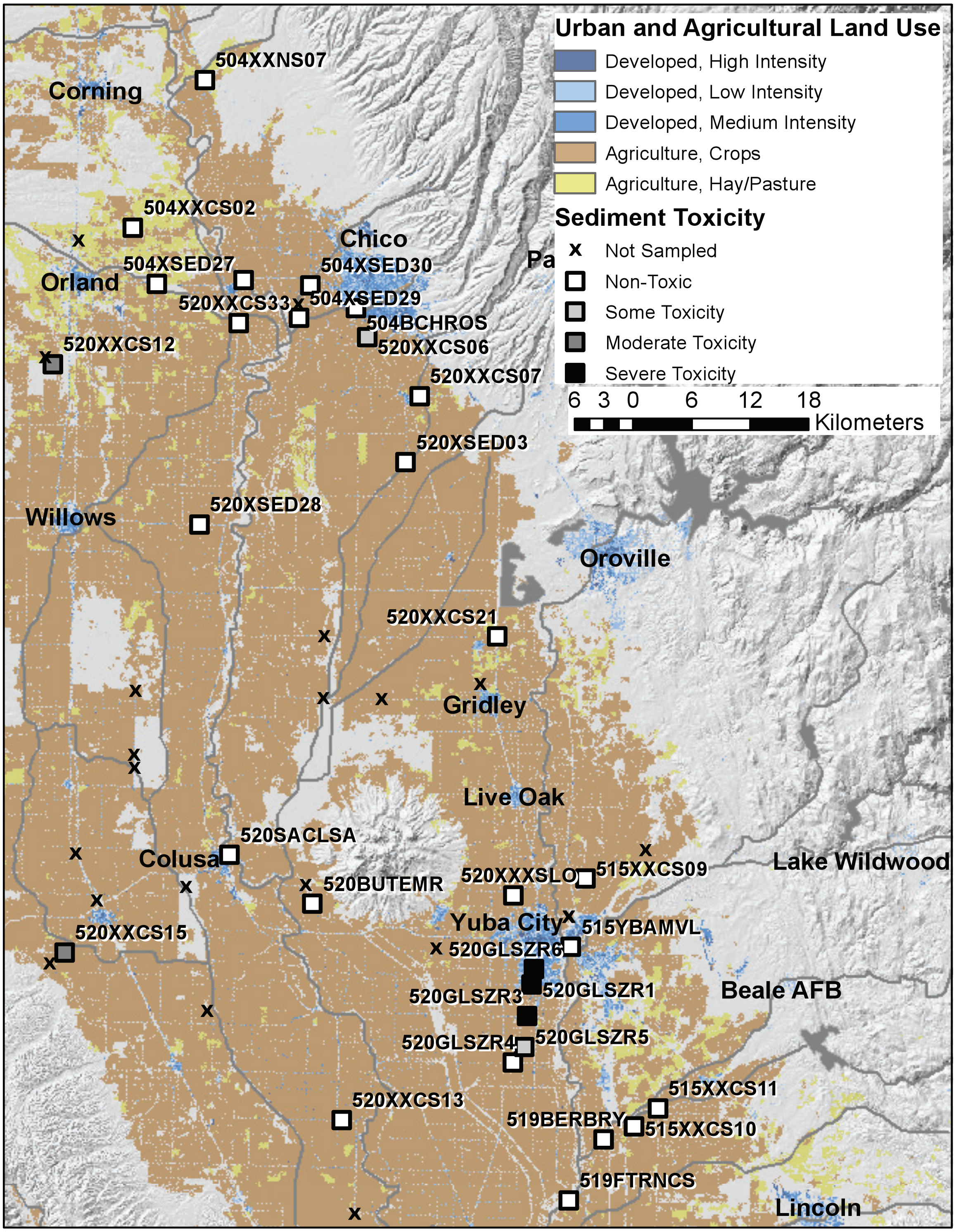


Figure 8. Magnitude of sediment toxicity at sites in the upper Sacramento River watershed in the Central Valley Region of California based on the 10-d survival of *H. azteca* in sediment samples collected at each site.

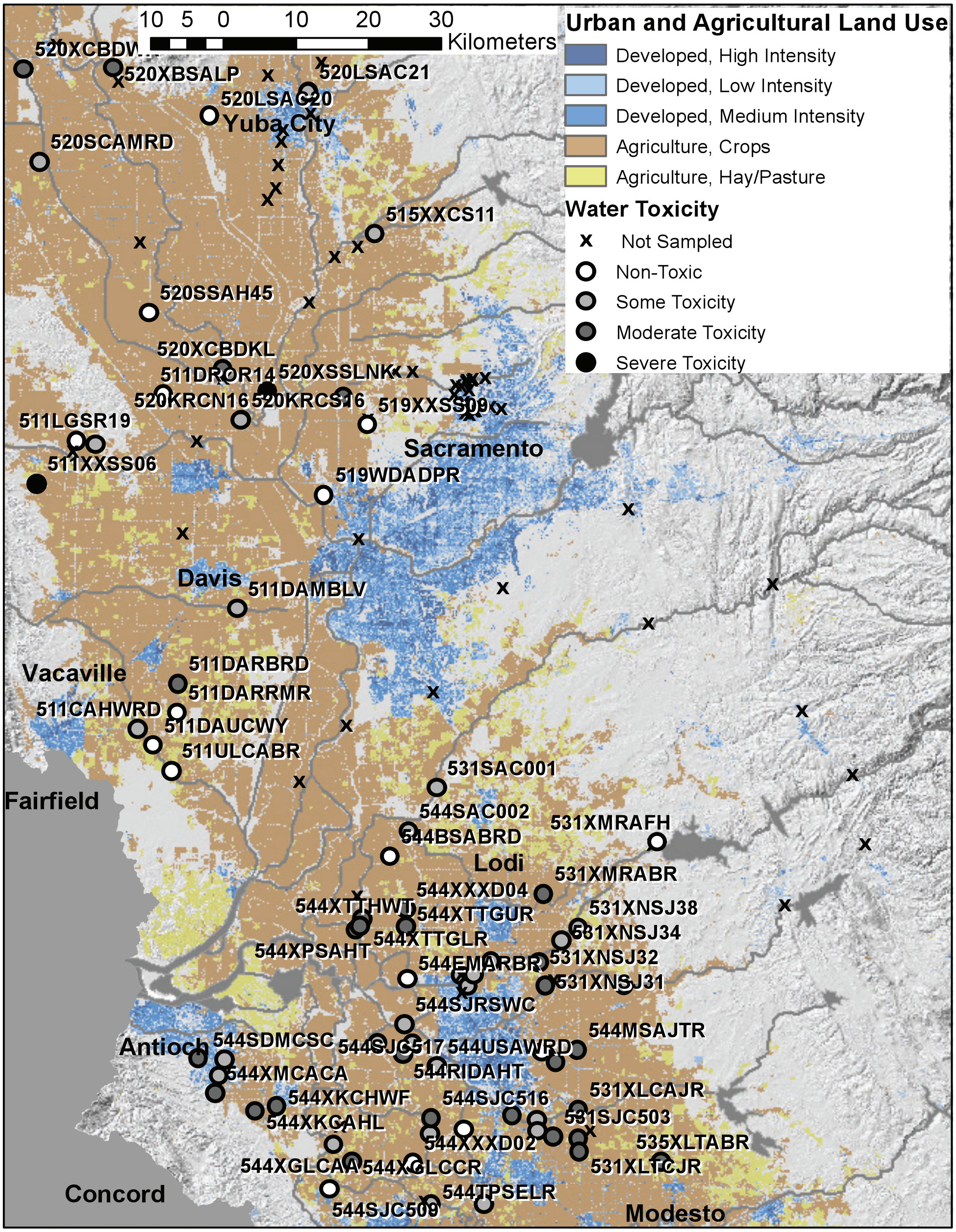


Figure 9. Magnitude of water column toxicity at sites in the lower Sacramento and San Joaquin River watersheds and Delta in the Central Valley Region of California, based on the most sensitive species (test endpoint) in water samples collected at each site.

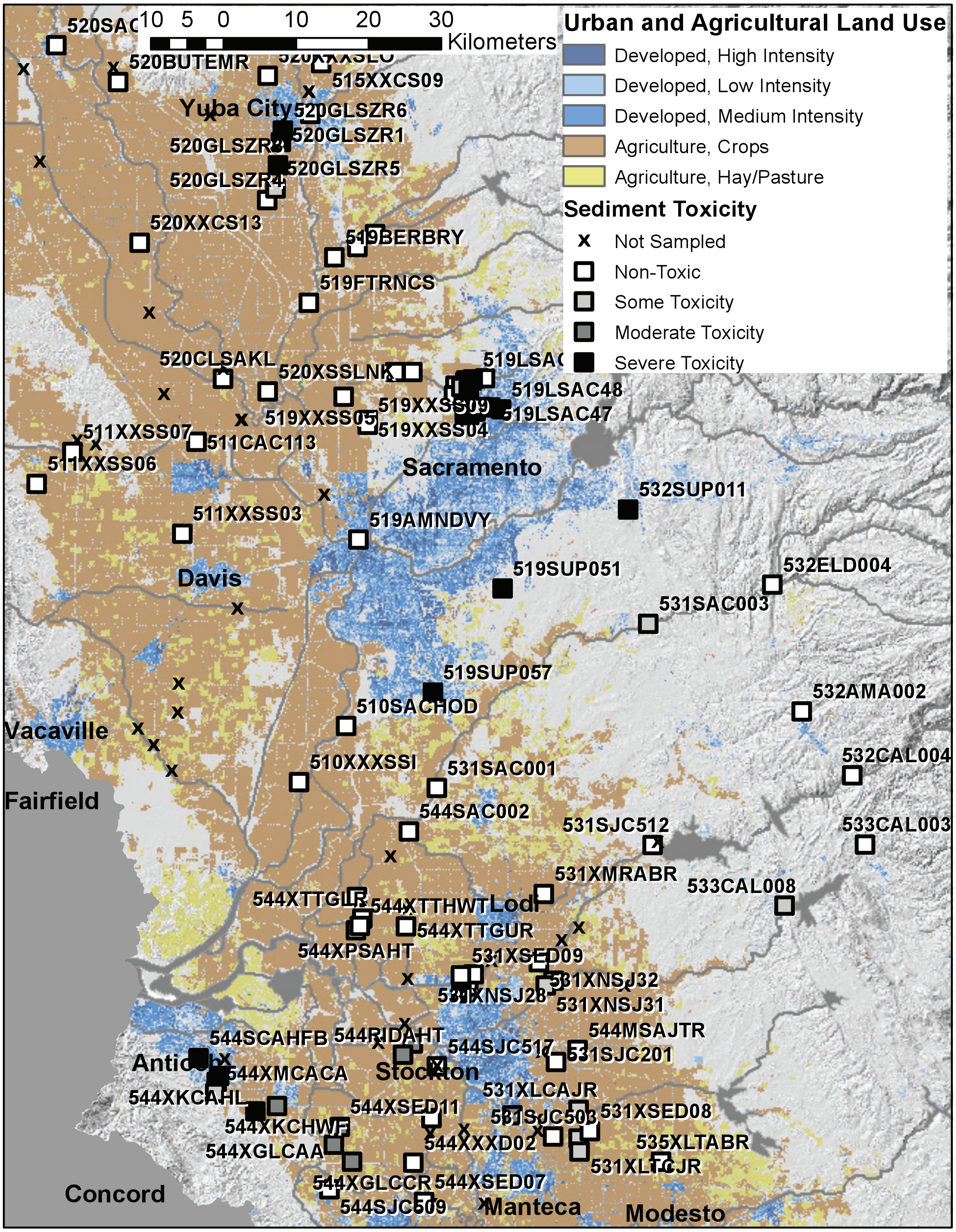


Figure 10. Magnitude of sediment toxicity at sites in the lower Sacramento and San Joaquin River watersheds and Delta in the Central Valley Region of California, based on the 10-d survival of *H. azteca* in sediment samples collected at each site.

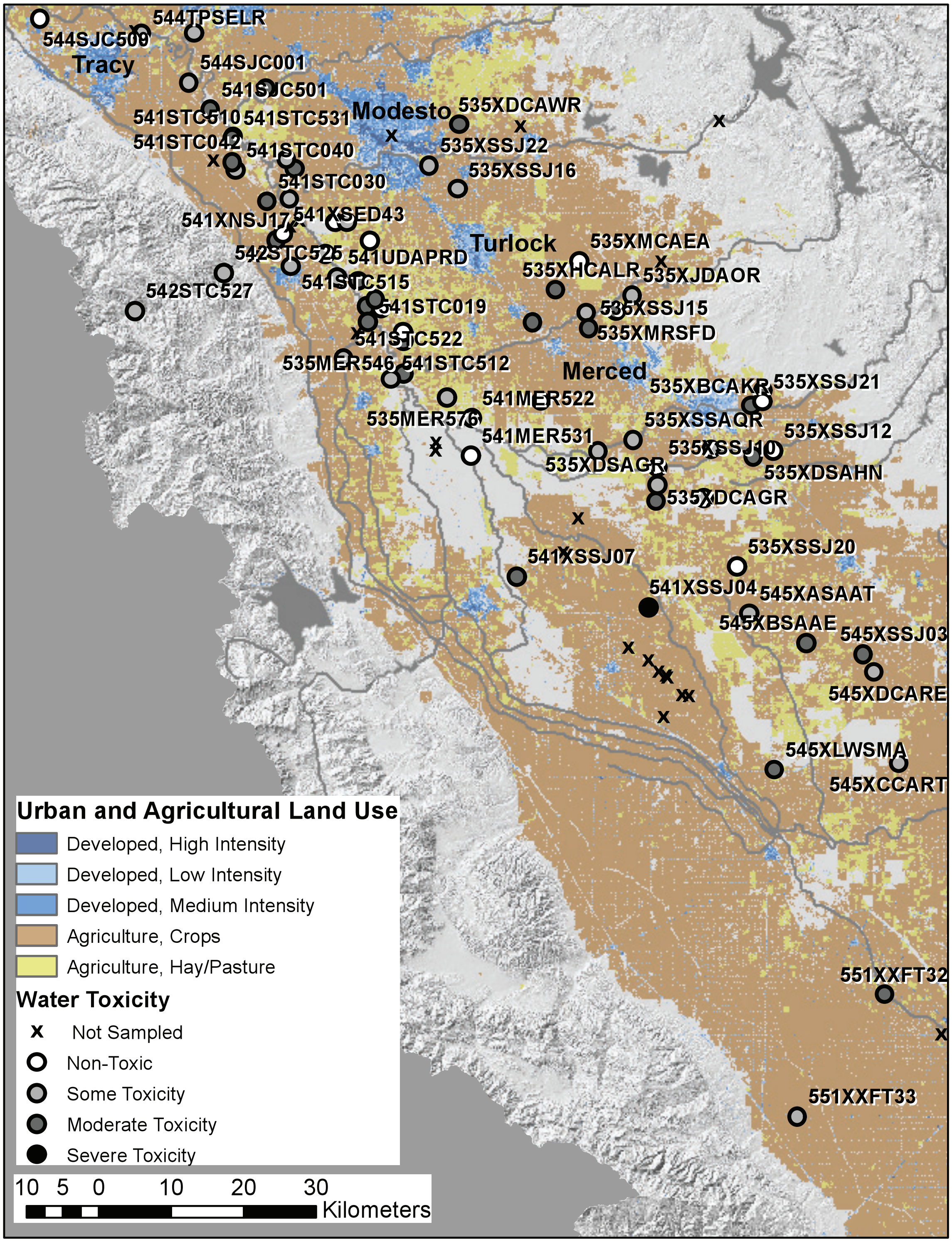


Figure 11. Magnitude of water column toxicity at sites in the Modesto - Merced area of the San Joaquin River watershed in the Central Valley Region of California, based on the most sensitive species (test endpoint) in water samples collected at each site.

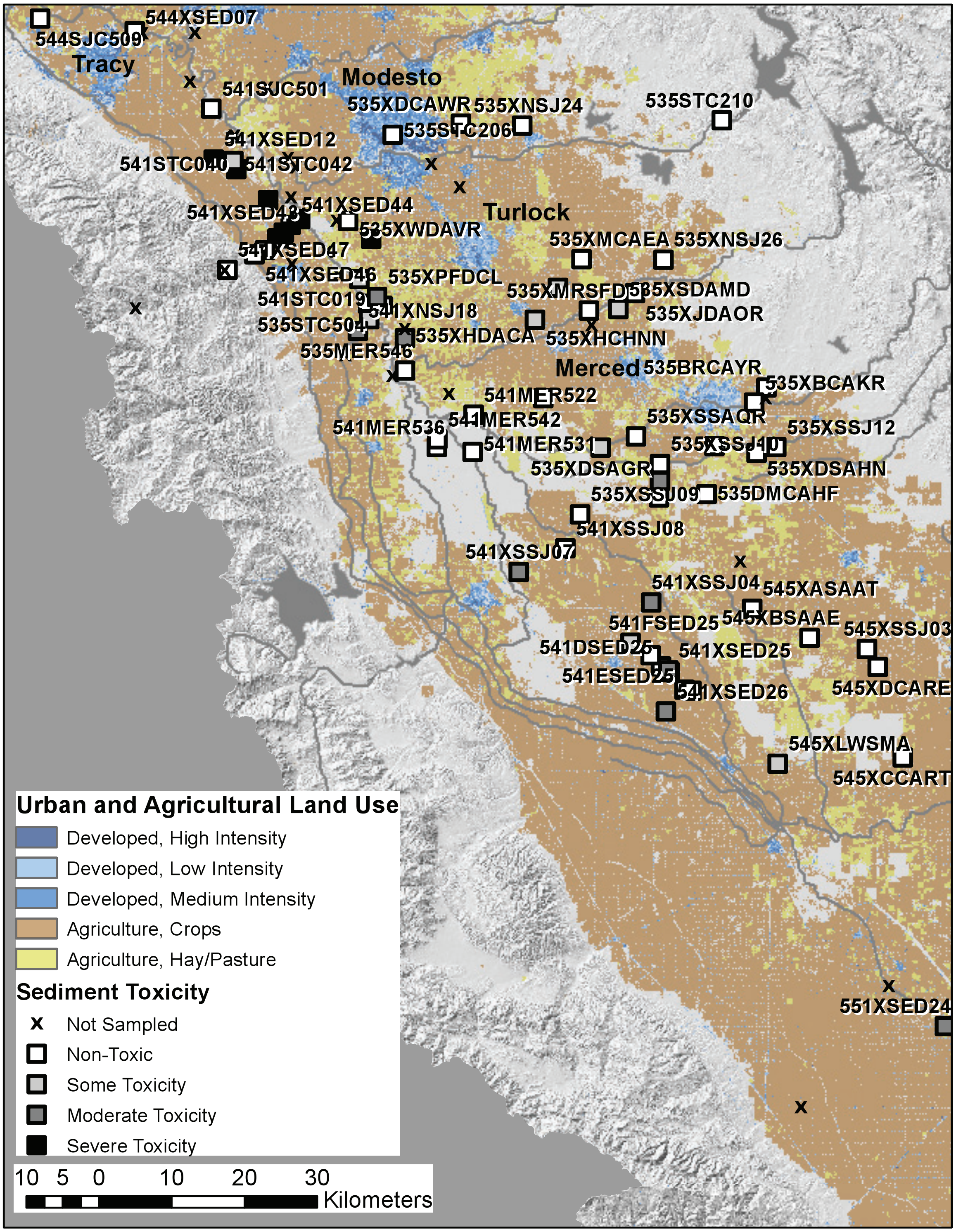


Figure 12. Magnitude of sediment toxicity at sites in the Modesto - Merced area of the San Joaquin River watershed in the Central Valley Region of California, based on the 10-d survival of *H. azteca* in sediment samples collected at each site.

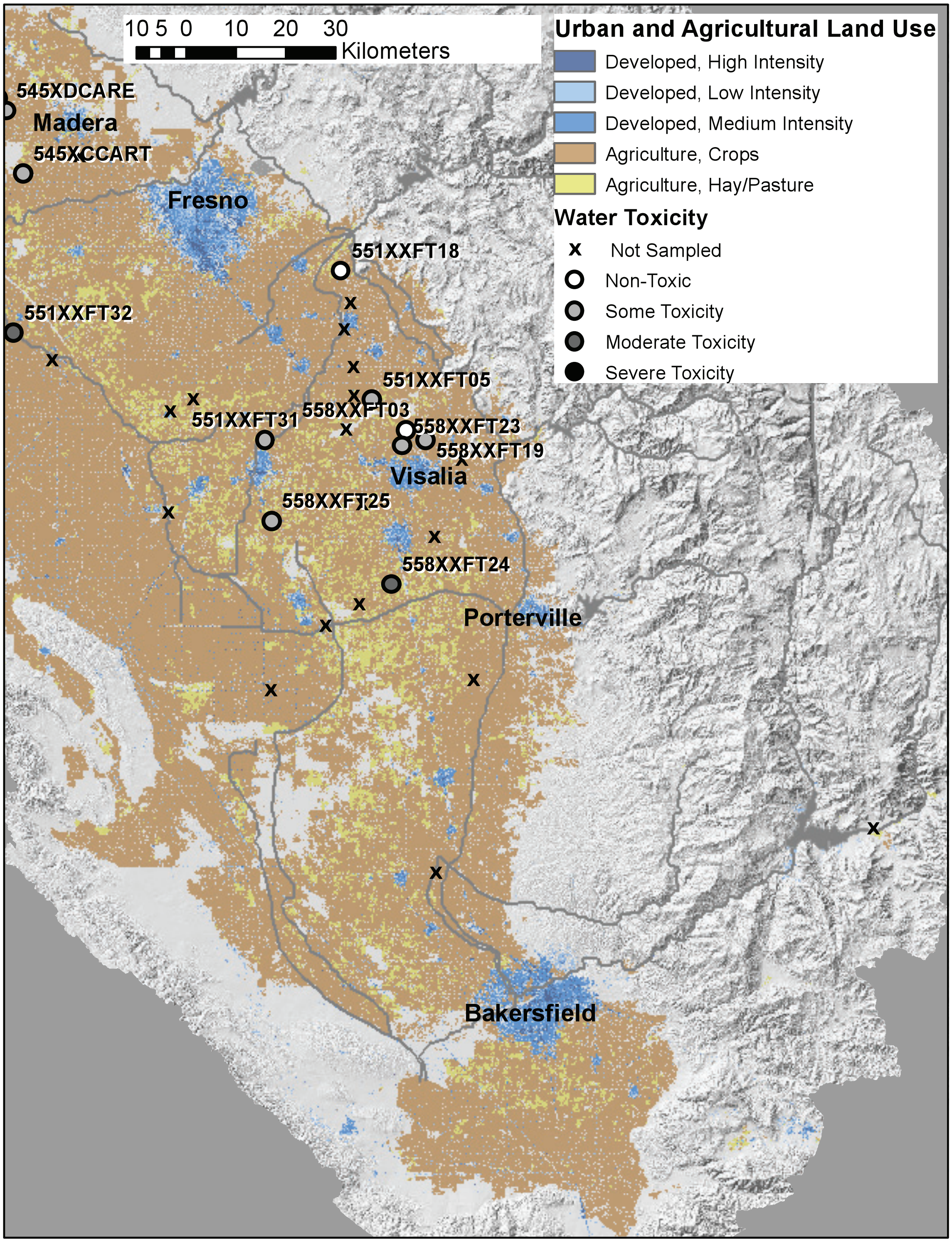


Figure 13. Magnitude of water column toxicity at sites in the Fresno - Bakersfield area of the Central Valley Region of California, based on the most sensitive species (test endpoint) in water samples collected at each site.

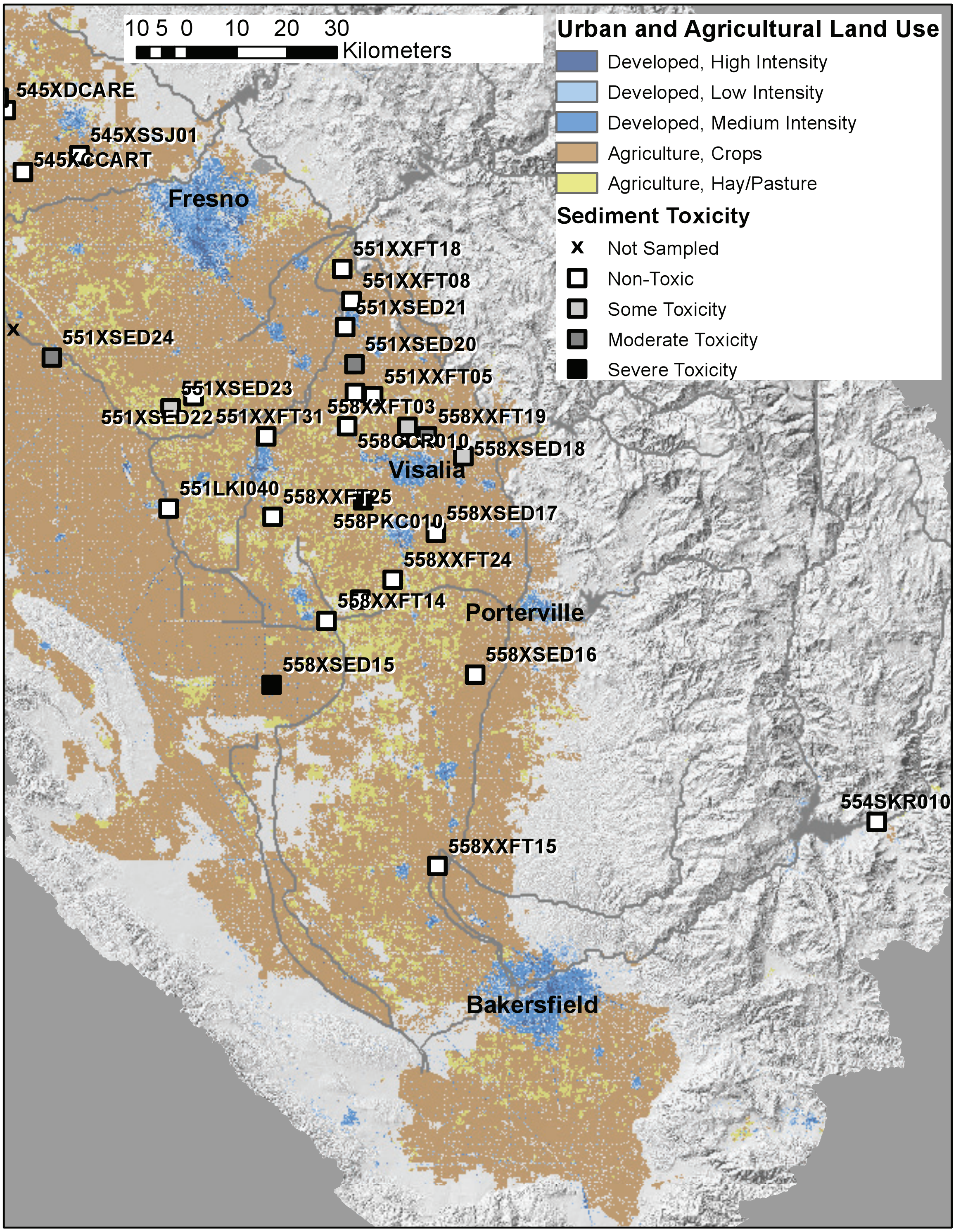


Figure 14. Magnitude of sediment toxicity at sites in the Fresno - Bakersfield area of the Central Valley Region of California, based on the 10-d survival of *H. azteca* in sediment samples collected at each site.

SECTION 6 CAUSES OF TOXICITY

WATER

Correlation analyses and toxicity identification evaluations (TIEs) were used to determine causes of water and sediment toxicity statewide (Anderson et al., 2011). The results of these analyses showed that the majority of toxicity was caused by insecticides. TIE studies and pesticide detections in toxic water samples from the Central Valley also have demonstrated that water toxicity to *C. dubia* is caused primarily by a combination of organophosphate and pyrethroid pesticides (Aquascience, 2007; Aquatic Ecosystems Analysis Laboratory, 2005; Bacey et al. 2005; de Vlaming et al. 2000; Holmes et al., 2005). Recent water column TIEs with *H. azteca* have identified pyrethroids as the major chemical class of concern in urban runoff, and have found that toxicity of agricultural runoff was caused by mixtures of organophosphates and pyrethroids (Weston and Lydy, 2010a; Weston and Lydy, 2010b). Aerial vector control spraying of pyrethrins for mosquito control in the Sacramento area was not found to cause water column toxicity (Weston et al., 2006).

Toxicity to fish was not *high* between 2001 and 2010, and few water samples reached a level of fish mortality sufficient to initiate the TIE process. *Moderate* to *high* algae toxicity was fairly common, but algal TIEs are not yet well-developed or widely used, and causes of algal toxicity remain unclear. Three algae TIEs performed during sampling of Central Valley agricultural waterways identified non-polar organic compounds, potentially herbicides, as the cause of algal toxicity (Aquatic Ecosystems Analysis Laboratory, 2005). In addition, TIEs conducted on six samples from the Sacramento/San Joaquin Delta suggested toxicity to algae were caused by the herbicide diuron (AquaScience, 2002).

SEDIMENT

Sediment TIEs using *H. azteca* have been conducted in most regions of California where toxicity has been observed. The majority of sediment TIEs and chemical analyses of toxic sediments have identified pyrethroid pesticides as causes of toxicity. Other studies have shown sediment toxicity is due to the organophosphate pesticide chlorpyrifos, or to mixtures of chlorpyrifos and pyrethroids. The majority of these studies have been conducted in the Central Valley and on the Central Coast. A study of statewide sediment toxicity in urban creeks found that the Central Valley was one of the regions where sediment toxicity was most intense, and pyrethroid pesticides were detected in every sediment sample (Holmes et al., 2008). Sediment toxicity due to pyrethroids has been found to be widespread in both urban and agricultural waterways in the Central Valley. Urban pyrethroid sediment toxicity has been identified in the Sacramento area, in runoff from a residential area of Roseville and in Elk Grove (Amweg et al., 2006; Weston et al., 2005; Weston et al., 2009). Other urban areas in the Central Valley are not well studied.

In addition to urban creek TIEs, a TIE was conducted on sediment from the Westley Wasteway Creek, an agricultural drainage creek on the west side of the San Joaquin River watershed (Anderson et al., 2008). Results showed that sediment toxicity in this creek was caused by a number of pyrethroids, primarily cyhalothrin and bifenthrin. In addition to this study, a number of sediment TIEs were conducted as part of regional SWAMP monitoring of agricultural creeks in the Central Valley. These include Ingram Creek, Hospital Creek, Del Puerto Creek, and Orestimba Creek. Results of these TIEs also showed pyrethroids were the likely cause of sediment toxicity (MPSL-SWAMP-CVRWQCB unpublished data). The primary pyrethroids responsible were bifenthrin and cyhalothrin. Agricultural sediment toxicity in the Central Valley has been found in a number of other streams, drains, canals, sloughs and tailwater ponds. Frequently detected analytes have included chlorpyrifos, permethrin, bifenthrin, esfenvalerate and lambda-cyhalothrin (Aquatic Ecosystems Analysis Laboratory, 2005; Weston et al., 2004; Weston et al., 2008).

SECTION 7
ECOLOGICAL IMPACTS ASSOCIATED WITH TOXIC WATERS

Field bioassessments provide information on the ecological health of streams and rivers, and bioassessments of macroinvertebrate communities have been used extensively throughout California. When combined with chemistry, toxicity, and TIE information, these studies indicate linkages between laboratory toxicity and ecosystem impacts.

Throughout California, toxicity testing and bioassessments have revealed similar geographical patterns of impaired waterways, with more severely impaired waterways occurring in areas of the most intense agricultural and urban land uses (Anderson et al., 2011; Ode et al., 2011). Benthic community impairment can have multiple causes in addition to contaminated water and sediment, and this impairment can be expected to be found more frequently than toxic conditions (Hall et al., 2007; Hall et al., 2009; Ode et al., 2011). This is evident in the streams of the Central Valley, where the condition of benthic communities at all sites except for those at the extreme northern end of the valley floor were classified as “degraded” or “very degraded”, but the severity of water and sediment toxicity was observed to vary widely between sites and sub-regions (Anderson et al., 2011; Ode et al., 2011, this document). When benthic community impairment is detected, it is often difficult to use bioassessment to parse the effects of multiple stressors, even when used in concert with chemical analysis and quantification of habitat parameters (Bacey and Spurlock, 2007). Examination of toxicity can show potential limitations placed on community composition by polluted water and sediment , and can therefore play an essential role in stressor identification when a waterbody is determined to be ecologically impaired.

Most bioassessment and toxicity monitoring efforts in the Central Valley have not been coordinated, but some waterways have been independently evaluated using both toxicity and bioassessment. Mazor et al. (2010) found impaired benthic communities in the agricultural waterways of Jack Slough and Wadsworth Canal, and in the urban Pleasant Grove Creek and Morrison Creek. Toxicity has not been examined in Wadsworth Canal. Jack Slough has shown water toxicity at two agricultural sites: one close to Marysville and one further upstream. Severe sediment toxicity has been found in Pleasant Grove Creek and Morrison Creek (Weston et al., 2005; this document). It is likely that the toxicity observed in these waterways plays a role in their ecological impairment, especially where severe toxicity has been found. More generally, given the widespread severe urban sediment toxicity in the Central Valley, it is likely that pesticide toxicity plays a role in the impairment of urban benthic communities throughout the region. When Bacey and Spurlock (2007) examined invertebrate communities in urban and agricultural streams near Elk Grove and Stockton, they found communities dominated by pollution-tolerant taxa, and detected pesticides at all sites. Toxicity testing and TIEs of samples from these sites and other waterways with impaired benthic communities could help to determine if water or sediment contamination is a significant stressor at a given site, and identify specific chemical stressors.

SECTION 8
MONITORING RECOMMENDATIONS

An examination of toxicity monitoring sites with data recorded in the SWAMP/CEDEN databases shows that toxicity seen in the region can be attributed to organophosphate and pyrethroid pesticides. Water toxicity, although of relatively low magnitude, was pervasive across the region and affected all test species. Sediment toxicity was of higher magnitude and occurred mainly in the few urban-dominated land use areas selected for sampling. However, sampling in the Central Valley is limited by incomplete coverage of urbanized waterways and other areas within the boundaries of the Delta. Based on these results, we offer the following recommendations:

URBAN TOXICITY

Sediment testing has occurred in only a few Central Valley cities, and the toxicity of the water column in urban waterways in the Central Valley is largely unexamined. The need for more comprehensive sampling of urban areas is clear, given that the urban sites examined so far have shown widespread high sediment toxicity. The cities of the Highway 99 corridor through the southern Central Valley, Sacramento and the I-80 corridor, and the I-5 corridor would all be fruitful targets for the exploration of urban aquatic toxicity, as this region remains largely unexamined.

SACRAMENTO - SAN JOAQUIN DELTA AND PELAGIC ORGANISM DECLINE

Recent declines in populations of pelagic fish in the Delta, including the endemic delta smelt (*Hypomesus transpacificus*), have led to an effort to identify the causes of these declines. Sommer et al. (2007) included contaminants in their conceptual model of possible agents contributing to a reduction in the capacity of the Delta to sustain fish populations. Water that enters the Sacramento - San Joaquin Delta is influenced by contamination from dense agricultural and urban land uses throughout the Central Valley. This contamination can affect fish populations by acting on all trophic levels of the Delta food web, and toxicity testing using a variety of taxa can help elucidate these effects.

In a review of pesticide inputs to the Delta, Kuivila and Hladik (2008) point to the need for more comprehensive monitoring in the sloughs and drains inside the Delta itself. Werner et al. (2010) present results of *H. azteca* toxicity tests examining ambient Delta water. Samples were collected mid-channel in major waterways, and the average incidence of toxic samples over all sites was 5.6%, with sites on the Sacramento River showing greater toxicity than sites in other areas. Toxicity testing recorded in the SWAMP/CEDEN databases found potential ecological degradation at multiple trophic levels within the Delta in the Terminous Tract and Potato Slough, showing moderate toxicity to both algae and invertebrates (see Geographical Patterns section above). Given that these were the only sites sampled within the Delta, toxicity monitoring at more Delta sites will be necessary to obtain an accurate picture of the effects of within-Delta inputs on the Delta ecosystem.

Expanded toxicity monitoring within the tidally-influenced Delta would rely on the use of salinity-tolerant species, including the amphipod *H. azteca*, the alga *Thalassiosira pseudonana*, the sheepshead minnow *Cyprinodon variegatus*, the topsmelt *Atherinops affinis* and the endangered delta smelt *H. transpacificus*, which can be obtained in limited quantities from the UC Davis Fish Conservation and Culture Laboratory in Byron, CA.

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