SWAMP
Surface Water Ambient Monitoring Program

TOXICITY IN CALIFORNIA WATERS: COLORADO RIVER BASIN REGION

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August 2012

California Water Boards

www.waterboards.ca.gov/swamp

ACKNOWLEDGEMENTS

The authors thank Jeff Geraci of the Colorado River Basin Regional Board. We are grateful for the services provided by the field crews, laboratory and data management staff who participated in this project. Funding was provided by the Surface Water Ambient Monitoring Program.

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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 2002 and 2008.

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.

Five freshwater sites showed *some* degree of water column toxicity (28%), and five sites showed *some* degree of sediment toxicity (38%, figure 1). Toxicity in the Salton Sea was more common, with 83% of the sites were toxic to both *Atherinops affinis* in the water column and *Hyalella azteca* in sediment (Figure 2). A higher percentage of the Salton Sea sites were *highly* toxic to both water column and sediment organisms compared to the freshwater sites.

Because of the minimal number of sites that were used in the land use analysis, it was difficult to determine trends based on the toxicity results. Nonetheless, the survival of test organisms in freshwater samples from sites with >10% urban use and <25% agricultural use was found to be significantly lower than survival at sites in other categories (Wilcoxon Rank Sum Test, P = 0.0138, Figure 4a). The highest magnitude of toxicity in fresh water column samples and sediment toxicity samples occurred at sites with the largest urban influence (Figures 4a and 4b). The lowest magnitude responses were observed in samples from sites with a combination of agricultural and urban influence and from less-developed sites. Although there was a significant difference between the urban dominated group and the “other” group, samples size were quite low and any conclusions based on these relationships should be viewed with caution.

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 California Environmental Data Exchange Network (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 Colorado River Region (Region 7). 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 Colorado River Basin regional toxicity data included in this report.

Toxicity Test Type	Program	Test Count	Sample Date Range
Water Column	SWAMP	150	5/6/02 – 10/29/08
Sediment	Stream Pollution Trends (SPoT)	3	10/28/08 – 10/29/08
	Other SWAMP	85	5/6/02 – 4/22/08

The Colorado River Basin Region is the most arid of the nine California Water Quality Control Board regions and comprises 20,000 square miles. The region includes the Colorado River watershed and the Salton Sea Transboundary watershed which contains the Salton Sea. Water from the Colorado River irrigates more than 700,000 acres of productive farmland in the Imperial, Coachella, Bard, and Palo Verde Valleys. The river also provides drinking water to several million people in California's southern coastal cities. The Salton Sea is California's largest lake and is significant for its sport fishing, and other recreational uses. The Salton Sea also provides significant resting and foraging habitat for birds migrating along the Pacific Flyway. It is a saline lake in a closed basin that is approximately 35 miles long and 9 to 15 miles wide, with approximately 360 square miles of water surface area and 105 miles of shoreline. The Salton Sea is also a federally and state designated repository to receive and store agricultural, surface, and subsurface drainage waters from the Imperial and Coachella Valleys. Water imported from the Colorado River has created an irrigated agricultural ecosystem in the watershed; wildlife and aquatic species are dependent on habitat created by the discharge of agricultural return flows. With few major urban areas in the region, watersheds are primarily influenced by agricultural runoff. The majority of the toxicity data produced in the region has been performed under SWAMP, and has addressed the potential for water and sediment toxicity arising from agricultural land uses. Particular interest has been paid to the effects in the New River and Alamo River, and the Salton Sea (de Vlaming et al., 2004; Phillips 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 5-12) 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 Colorado River Region included freshwater exposures of the cladoceran *Ceriodaphnia dubia* and the fathead minnow *Pimephales promelas*, with the amphipod *Hyalella azteca* used to examine freshwater samples above the conductivity range optimal for *C. dubia* health, and the topsmelt (*Atherinops affinis*) used to test hypersaline water samples from the Salton Sea. Freshwater and Salton Sea sediment samples were tested using *H. azteca*. Only survival endpoints are considered in the measures of toxicity reported here; therefore all sites identified as toxic showed a significant decrease in test animal survival in one or more samples.

Several steps were followed to determine the toxicity of individual samples, and to categorize the toxicity of individual sites:

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). Individual samples were categorized as not toxic, toxic or highly toxic (see 2 below).

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 the Percent Minimum Significant Difference (PMSD) 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 at 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 species.

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 respective 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

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

Species	Test Type	Number of Sites	Maximum Toxicity Level Observed			
			Non-Toxic	Some Toxicity	Moderately Toxic	Highly Toxic
H. azteca	Sediment	18	10	5	1	2
C. dubia	Water Column	15	13	0	1	1
P. promelas		6	4	1	0	1
H. azteca		5	3	0	1	1
A. affinis		6	1	1	4	0

Table 4
List of sites, sampling periods, and number samples tested for each species and matrix. Highlighted cells indicate a particular species was not used in testing with a site.

Site	Sampling Period	Water Column				Sediment
		C. dubia	*H. azteca*	*P. promelas*	*A. affinis*	*H. azteca*
713CRNVBD	2002-2008	11		2		
714PLH216	2002	2				1
715CPVDRN	2004	1				
715CPVLG1	2002-2008	8		3		6
715CPVOD2	2002-2008	7		3		6
715CRIDG1	2002-2008	11		3		5
715CRIDU1	2002-2003	3				2
715CRPDDM	2002	2				1
715CRSQLK	2002	2				
715CRTLI1	2002	2				1
715TF0091	2002	2				
719CVSC52	2005-2006	2				
719CVSCOT	2002-2008	9		2		9
723ARGRB1	2002-2008	1	6			10
723ARINTL	2002-2008	2	8			5
723NRBDRY	2002-2008		11			10
723NROTWM	2002-2008		9			10
723NRRCD3	2002					1
725SCSLGH	2002		2			
728SSDNW1	2002-2006				3	1
728SSDNW2	2005-2006				3	1
728SSGS02	2002-2008				9	7
728SSGS03	2002				2	
728SSGS07	2002-2007				9	6
728SSGS09	2002-2007				9	6

SECTION 3
REGIONAL TOXICITY

Eighteen freshwater sites were tested for water toxicity with *C. dubia* and/or *H. azteca*. A subset of these sites was tested with fathead minnow larvae, *P. promelas*. Six sites were tested for hypersaline water toxicity in the Salton Sea with topsmelt larvae, *A. affinis*. Twelve freshwater sites and five sites in the Salton Sea were also tested for sediment toxicity with *H. azteca* (Tables 3 and 4).

Five freshwater sites showed *some* degree of water column toxicity (28%), and five sites showed *some* degree of sediment toxicity (38%, figure 1). Toxicity in the Salton Sea was more common, with 83% of the sites were toxic to both *A. affinis* in the water column and *H. azteca* in sediment (Figure 2). A higher percentage of the Salton Sea sites were *highly* toxic to both water column and sediment organisms compared to the freshwater sites.

WATER COLUMN TOXICITY BY SPECIES

In freshwater toxicity testing, *C. dubia*, *P. promelas*, and *H. azteca* showed toxicity at two sites each. Water from the Coachella Valley Storm Channel (719CVSC52) was toxic to both *C. dubia* and *P. promelas* in October, 2005. *Ceriodaphnia dubia* was used in testing at the greatest number of sites, so the percentage of toxic sites was lowest for this species. Freshwater toxicity was detected at sites in the Imperial and Coachella Valleys, with the exception of one instance of toxicity to *P. promelas* in the Colorado River. Many of the sites tested using only *C. dubia* were located on the Colorado River and not in the more toxic agricultural valleys, and this likely accounted for the lower percentage of sites toxic to *C. dubia*.

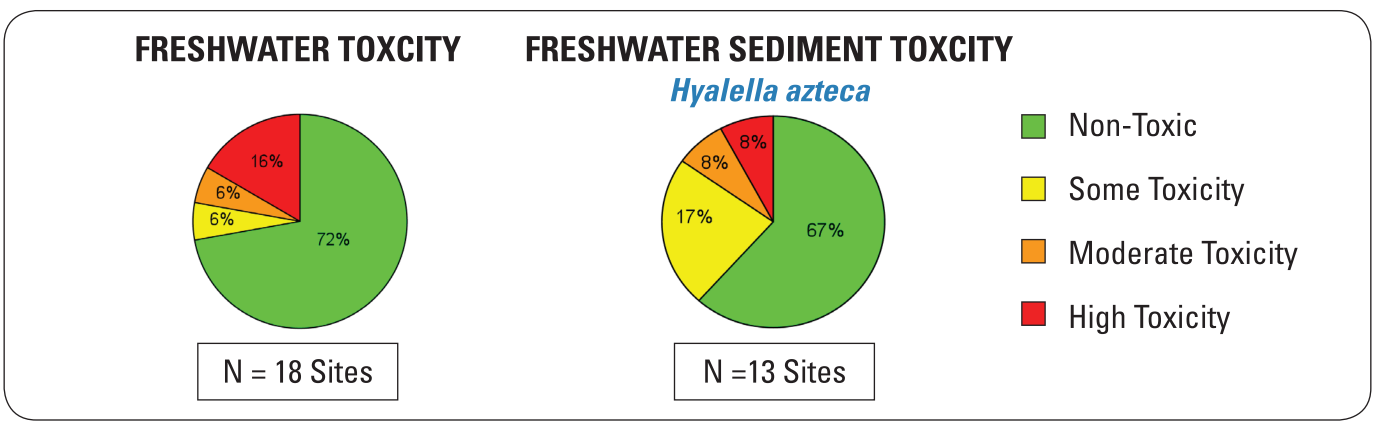


Figure 1. Magnitude of toxicity in freshwater samples in the Colorado River Region of California.

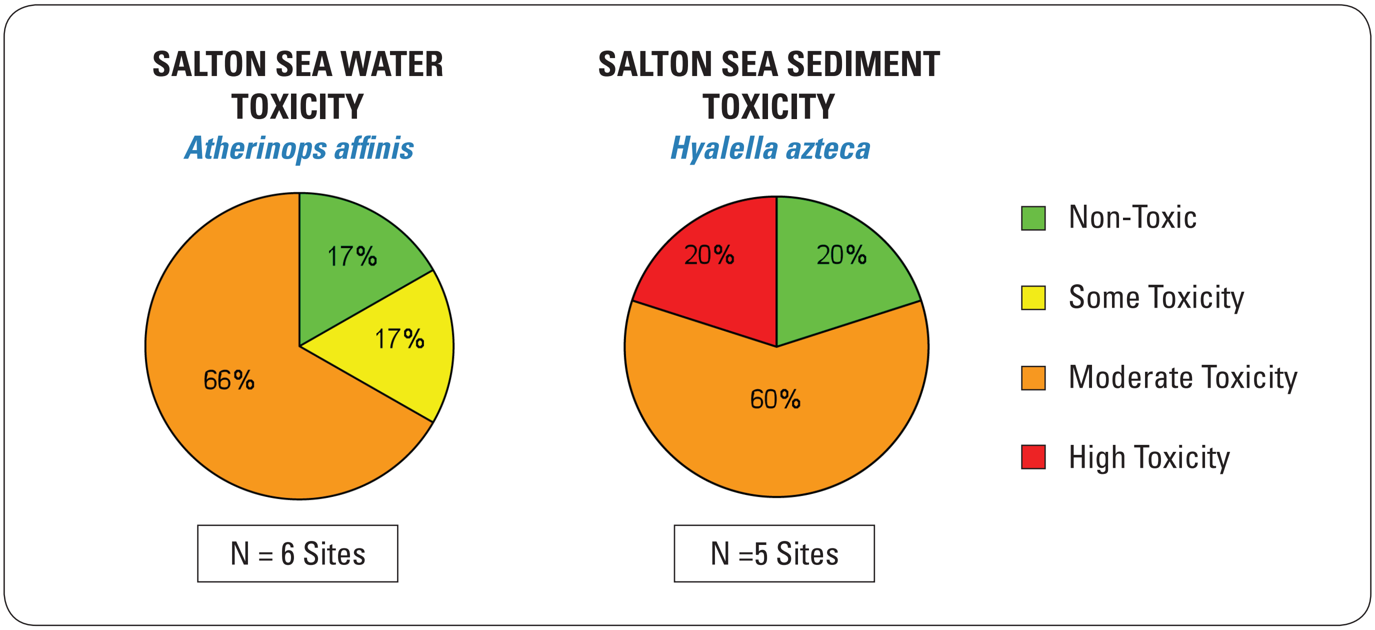


Figure 2. Magnitude of toxicity in Salton Sea samples in the Colorado River Region of California.

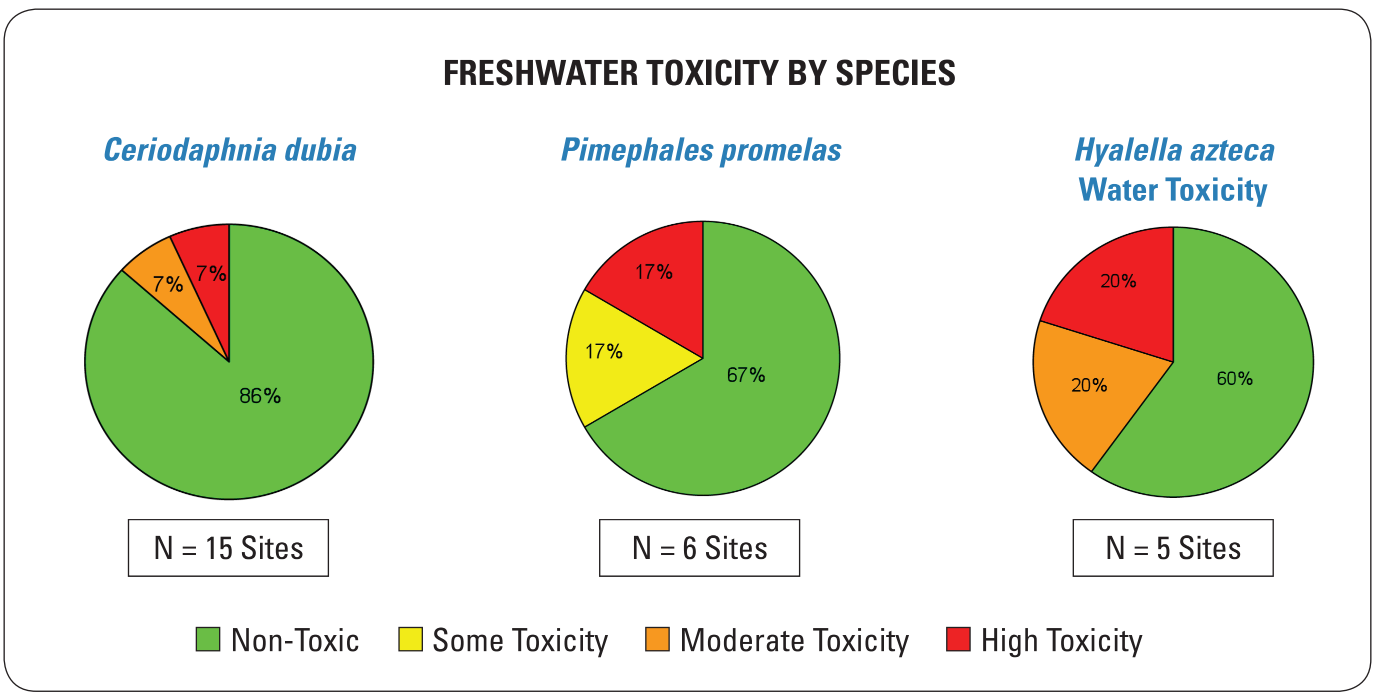


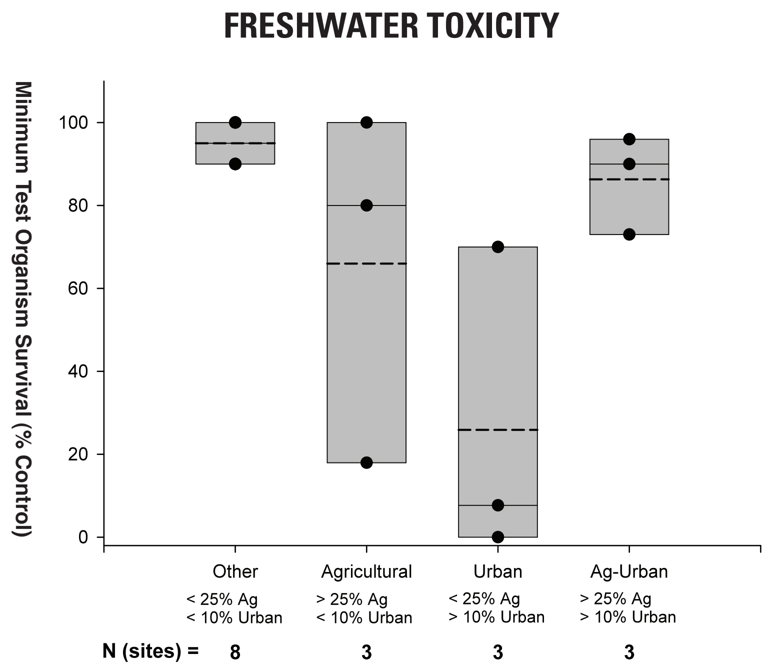
Figure 3. Magnitude of toxicity to individual species in freshwater samples from the Colorado River Region of California.

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 Colorado River region, water and sediment toxicity were examined at sites with upstream inputs influenced by a range of agricultural, urban, and less developed land uses. Land use percentages were determined for 18 sites with freshwater toxicity data, and 12 sites with freshwater sediment toxicity data. Salton Sea sites were not used in the analysis. Sites were sorted individually into four different land use categories based on the percentages (see Figure 4). One freshwater toxicity site (the Alamo River Outlet, 723ARGRB1) was excluded from the analysis. This site near the shore of the Salton Sea had high toxicity, was downstream of the Imperial Valley agricultural area, and was surrounded by agricultural runoff water, but was actually greater than one kilometer from agricultural areas. Categorizing this site as a less developed area would have skewed the analysis.

Because of the minimal number of sites that were used in the land use analysis, it was difficult to determine trends based on the toxicity results. Nonetheless, the survival of test organisms in freshwater samples from sites with >10% urban use and <25% agricultural use was found to be significantly lower than survival at sites in other categories (Wilcoxon Rank Sum Test, $P = 0.0138$, Figure 4a). The highest magnitude of toxicity in fresh water column samples and sediment toxicity samples occurred at sites with the largest urban influence (Figures 4a and 4b). The lowest magnitude responses were observed in samples from sites with a combination of agricultural and urban influence and from less-developed sites. Although there was a significant difference between the urban dominated group and the "other" group, samples size were quite low and any conclusions based on these relationships should be viewed with caution.



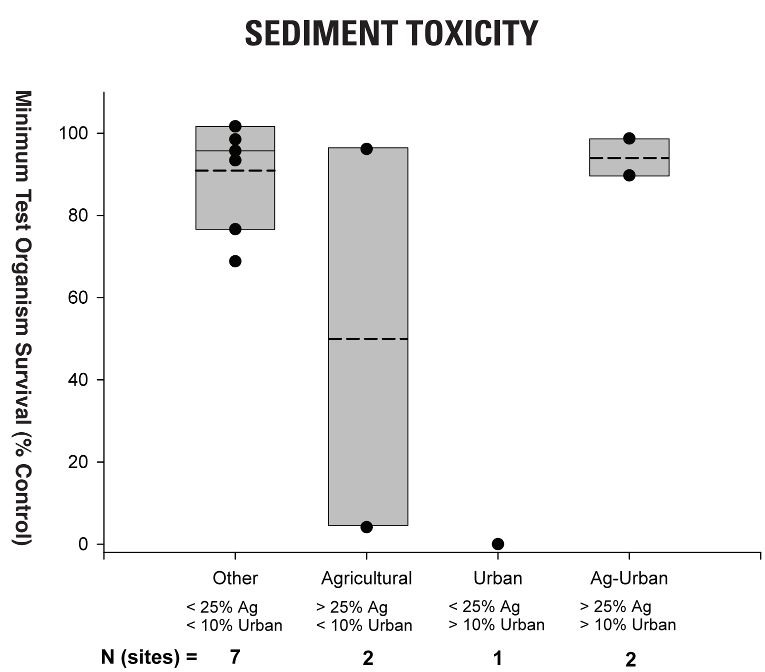


Figure 4. Toxicity distribution for water samples (a) and sediment samples (b) collected from sites in urban, agricultural, agricultural-urban and less developed areas. Lower values represent lower levels of survival, and indicate higher toxicity. Data are for the most sensitive test species at each site. Solid lines, from top to bottom, represent the 75th, 50th (median), and 25th percentiles of the distribution. Dotted lines are the mean result. * = Survival significantly lower than at "other" land use sites (one-tailed Wilcoxon Rank Sum Tests).

SECTION 5 GEOGRAPHICAL PATTERNS IN TOXICITY

Between 2002 and 2008, 25 sites were tested for toxicity in the Colorado River region. Thirteen of these sites were sampled only one to three times during one to two years, but the remaining 12 sites were sampled once or twice per year for the entire period. Nineteen sites were located in strictly freshwater areas, and six sites were located in the Salton Sea.

IMPERIAL VALLEY AND COACHELLA VALLEY (FIGURES 5 AND 6)

High water column toxicity was observed at five of the seven sites tested in this geographical area. *High* sediment toxicity was observed at two of the six sites tested. The New River at the U.S.-Mexico Border (723NRBDRY) was sampled once or twice per year between 2002 and 2008 and exhibited the most consistent *high* toxicity in both the water column and sediment until the spring of 2007. The New River is one of two main tributaries to the Salton Sea. The current river channel was formed when floods destroyed irrigation diversions on the Colorado River in 1905 and the river ran unchecked into the Salton Sink. The river currently originates approximately 25 km south of the City of Mexicali and conveys agricultural runoff from the Mexicali and Imperial Valleys as well as urban runoff, consisting of untreated and partially treated municipal and industrial wastes from Mexicali (Gruenberb, 1998; de Vlaming et al., 2004). Average survival of water column and sediment organisms between 2002 and 2006, was 0% and 13%, respectively. Between 2007 and 2008 the averages had risen to 95% and 76%, respectively. The possible reasons for this change in toxicity are discussed below. *High* toxicity was also observed in water and sediment samples from the New River Outlet to the Salton Sea (723NROTWM), but much fewer samples were toxic compared to the border station.

The other main tributary to the Salton Sea is the Alamo River. Compared to the New River, fewer toxic water and sediment samples were observed at the two Alamo River stations (723ARINTL and 723ARGRB1). No toxicity has been observed at 723ARINTL, but *some* toxicity was observed at 723ARGRB1. The latter station was classified as *highly* toxic because complete mortality to *C. dubia* was observed on one occasion. Since that time, water from the site has been nontoxic to *H. azteca*. Four of ten sediment samples were *moderately* toxic.

Some toxicity was observed in the Coachella Valley in the Storm Channel at Avenue 52 (719CVSC52). Three of four water samples from 2005 and 2006 were *highly* toxic to *P. promelas* and *C. dubia*. Bifenthrin and diazinon were detected during one event each, but not in sufficient concentrations to explain the observed toxicity. The Coachella Valley Stormwater Outlet to Salton Sea (719CVSCOT) has been tested frequently between 2002 and 2008, but had only had one *moderately* toxic sediment sample (2004).

SALTON SEA (FIGURES 5 AND 6)

Mostly *moderate* water column toxicity to *A. affinis* was observed throughout the Salton Sea, with the exception of Salton Sea USGS Site 3 (728SSGS03), where toxicity was less intense, and Salton Sea Drain Northwest 1 (728SSDNW1), which was found to be nontoxic. *High* toxicity was observed in four samples from four different sites (728SSDNW1, 728SSGS02, 728SSGS07, and 728SSGS09). Most sediments throughout the Salton Sea showed *moderate* toxicity to *H. azteca*. However, as with the water column samples, four samples from the same four sites were *highly* toxic. These four samples were not collected at the same time as the water samples. Sediments from Salton Sea Drain Northwest 1 (728SSDNW1) were nontoxic.

COLORADO RIVER SITES (FIGURES 7 TO 12)

Eleven sites were sampled along the Colorado River on the California-Arizona border. All of the sites were tested for water toxicity to *C. dubia* and three sites were tested for water toxicity to *P. promelas*. Only one station exhibited mild toxicity to the fathead minnows in 2005. Sediment samples were collected from seven sites and all were non-toxic.

SECTION 6
CAUSES OF TOXICITY

Correlation analyses and Toxicity Identification Evaluations (TIEs) were used to determine causes of water and sediment toxicity statewide (Anderson et al., 2011a). The results of these analyses showed that the majority of toxicity was caused by pesticides.

FRESHWATER

Toxicity monitoring in the Colorado River Basin Region prior to the SWAMP data set covered in this report demonstrated extensive water toxicity to *C. dubia* and the mysid shrimp *Neomysis mercedis* (de Vlaming et al., 2004). Toxicity identification evaluations (TIEs) and correlations with chemical concentrations determined that water toxicity at stations in the New and Alamo Rivers was primarily caused by organophosphate pesticides. These samples were collected between 1993 and 2002. Elevated concentrations of chlorpyrifos, diazinon, malathion, and the carbamate carbofuran were the primary causes of toxicity (de Vlaming et al., 2004). Another study conducted between 2001 and 2002 detected elevated concentrations of organophosphate pesticides in water from the rivers and receiving waters in the Salton Sea (LeBlanc and Kuivila, 2008).

In toxicity testing of freshwater samples collected during 2006 - 2007, one toxicity identification evaluation and one investigation of ammonia toxicity were performed. A sample collected in the New River at the international boundary (723NRBDRY) on 2 May 2006 caused 100% mortality to *H. azteca*. The severity of toxicity was found to be approximately six toxic units. Surfactants or volatile compounds were the primary agents of toxicity, and non-polar organic compounds may have played a role in the toxicity. A sample collected in the Coachella Valley storm channel (719CVSC52) contained 12 mg/L of ammonia as nitrogen, and caused significant reductions in *P. promelas* survival and biomass. TIE pH shift treatments showed that this toxicity was the result of high ammonia in the sample (Werner et al., 2007).

More recently, toxicity has been attributed to the increasing use of pyrethroid pesticides. A study at 723NRBDRY determined that elevated concentrations of cypermethrin were the primary cause of toxicity to *H. azteca* in water exposures (Phillips et al., 2007). Prior to this study, LeBlanc and Kuivila (2008) did not detect pyrethroids in water or sediment samples. Although pyrethroids were implicated as a cause of toxicity, the current data set demonstrates a recent reduction of pyrethroids in both water and sediment samples in the New River and a corresponding reduction in water and sediment toxicity. Diazinon continues to be detected in almost all of the water samples collected, but at concentrations well below the toxicity threshold for *H. azteca*.

FRESHWATER 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 the cause 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.

Sediment toxicity at sites other than the New River was *moderate* and sporadic. *High* toxicity was only observed at the New River sites. In the current data set pyrethroids in samples from these sites were detected in approximately 89% of the sediments collected up until 2006, but only about 13% of samples collected between 2007 and 2008. Prior to 2007, elevated concentrations of pyrethroids above the toxicity threshold of *H. azteca* track with observations of severe toxicity, indicating pyrethroids contributed to toxicity. Some pyrethroid detections between 2007 and 2008 were associated with *moderate* toxicity.

Sediments from three Colorado River Region sites are collected as part of SWAMP's Stream Pollution Trends (SPoT) monitoring program. These sites are sampled yearly for toxicity and chemistry. Between 2008 and 2010, concentrations of pyrethroids in the New River (723NROTWM) were high enough to cause the observed toxicity. SPoT recently began conducting toxicity tests at two temperatures for a subset of sites to help diagnose toxicity caused to pyrethroids. Although the 2011 sample from 723NROTWM was not toxic at the standard temperature of 23 °C, significant toxicity was observed when the sample was tested at 15 °C, indicating pyrethroids were contributing to toxicity. SPoT is designed to track long-term trends, continuing monitoring in the New River and other sites in the Colorado River Region will detect whether apparent reductions in the number of samples with pyrethroid detections are part of a larger trend in the Colorado River Region. This will be combined with analysis of changes in land-use and pesticide use patterns.

SALTON SEA

A range of toxicity responses have been observed in water and sediment samples from the Salton Sea sites. There has been no pattern of toxicity either spatially or temporally in either matrix. There have also been no investigations of Salton Sea toxicity through TIEs, and an examination of the water and sediment chemistry did not yield any obvious causes of toxicity.

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.

FRESHWATER HABITATS

A comprehensive series of studies linking water and sediment toxicity with impacts on resident macroinvertebrates in California was conducted in the Salinas River. In these studies, diazinon and chlorpyrifos from agriculture runoff caused water and sediment toxicity, and also were associated with reductions in population densities of resident pesticide-sensitive benthic invertebrates such as the amphipod *H. azteca* and mayflies of the genus Procloeon. (Anderson et al., 2003a; Anderson et al., 2003b; Phillips et al., 2004). The influence of habitat quality on macroinvertebrates was also assessed and it was concluded that habitat was a less important factor than pesticides (Anderson et al., 2003b).

While no similar series of studies has been conducted in the Colorado River Basin region, the findings of the Salinas River studies are likely to be broadly applicable wherever benthic communities are exposed to toxic water and sediment. Throughout California, toxicity testing and bioassessment 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 beyond contaminants (Hall et al., 2007; Hall et al., 2009; Ode et al., 2011).

Most bioassessment and toxicity monitoring efforts in the Colorado River region have not been coordinated, but some waterways have been independently evaluated using both toxicity and bioassessment. Bioassessment monitoring a several SWAMP stations was conducted in 2003, but the results were not compared to toxicity results (Sibbald, 2003).

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 pesticides. Based on these results, we offer the following recommendations:

- Coordinate SWAMP with other monitoring programs (e.g., stormwater and other NPDES monitoring). Linkage between SPoT measures with bioassessments conducted as proposed in the Basin Plan would help strengthen the in situ ecological context of toxicity and chemical monitoring data.
- Consider the importance of emerging contaminants of concern in future water and sediment monitoring (e.g., algal toxins, additional pesticides such as fipronil).
- Data from SWAMP regional and SPoT testing programs should be useful in detecting changes in toxicity patterns over larger spatial and temporal scales, as there is a need for consistency in monitoring to capture emerging trends.
- Investigate causes of toxicity in water and sediment samples from the Salton Sea.

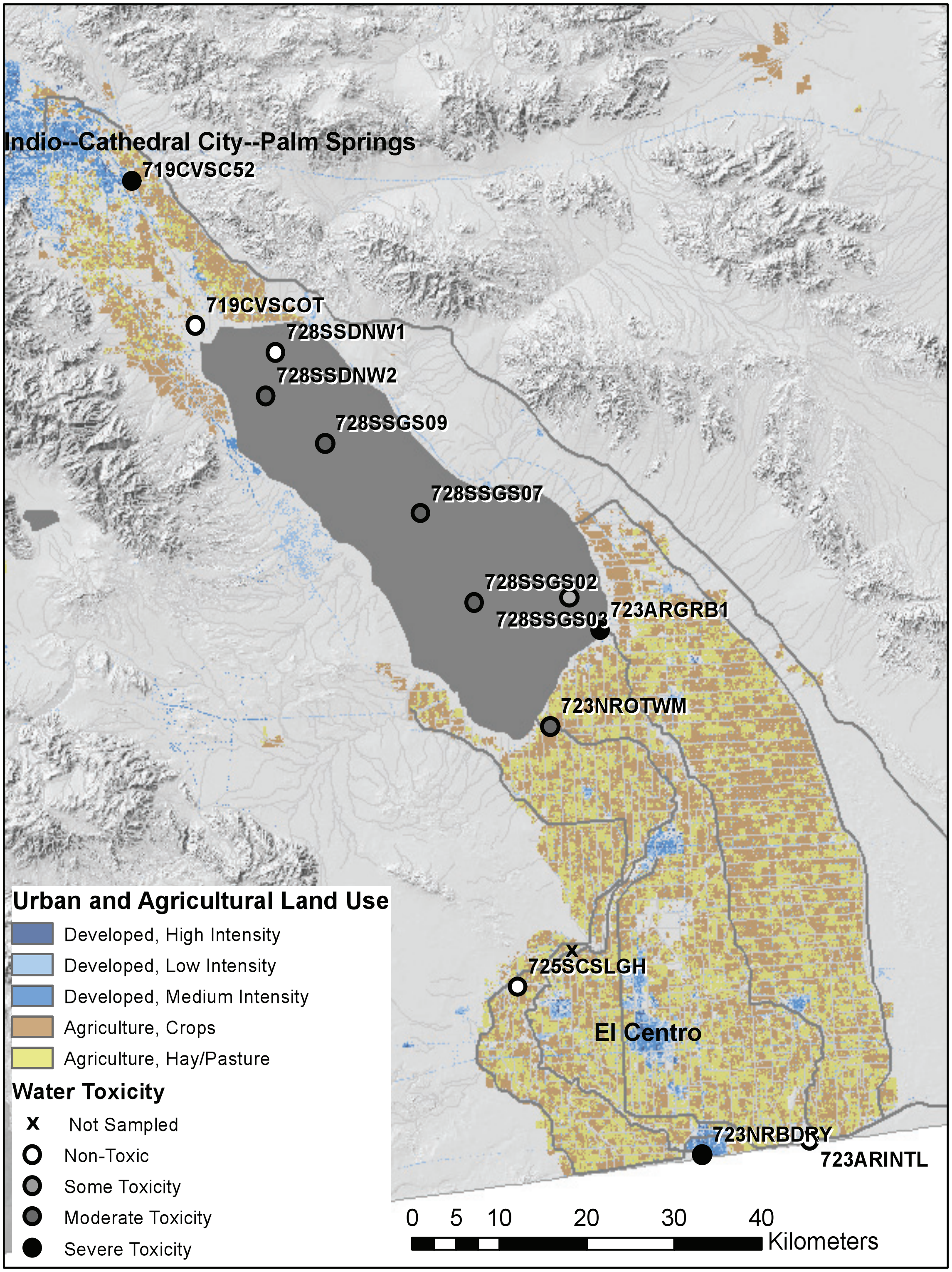


Figure 5. Magnitude of water toxicity in the Salton Sea and at freshwater sites in the Coachella and Imperial Valleys of the Colorado River Region of California based on the most sensitive species (test endpoint) in water samples collected at each site.

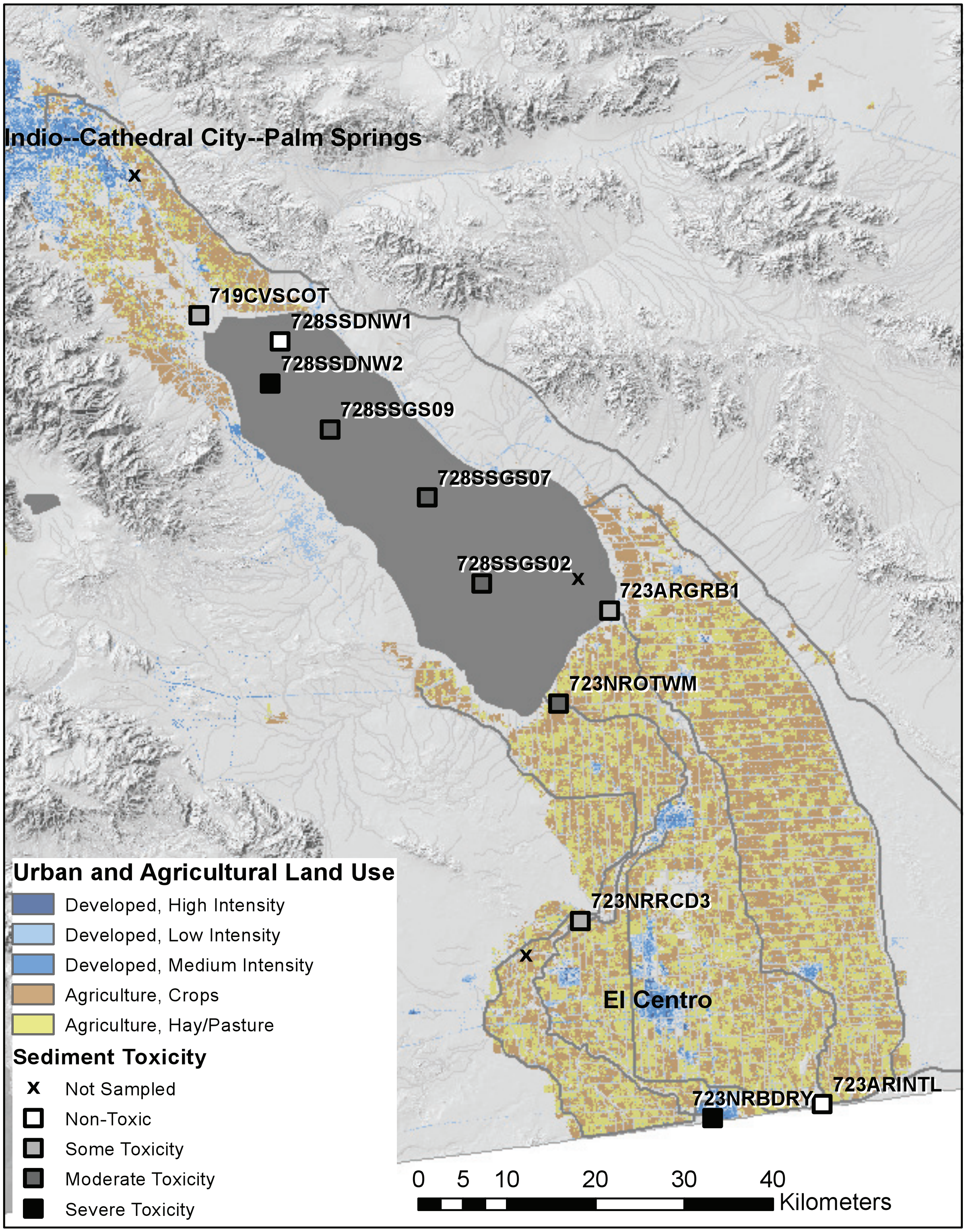


Figure 6. Magnitude of toxicity in freshwater sediments and Salton Sea sediments at sites in the Coachella and Imperial Valleys of the Colorado River Region of California based on the most sensitive species (test endpoint) in water samples collected at each site.

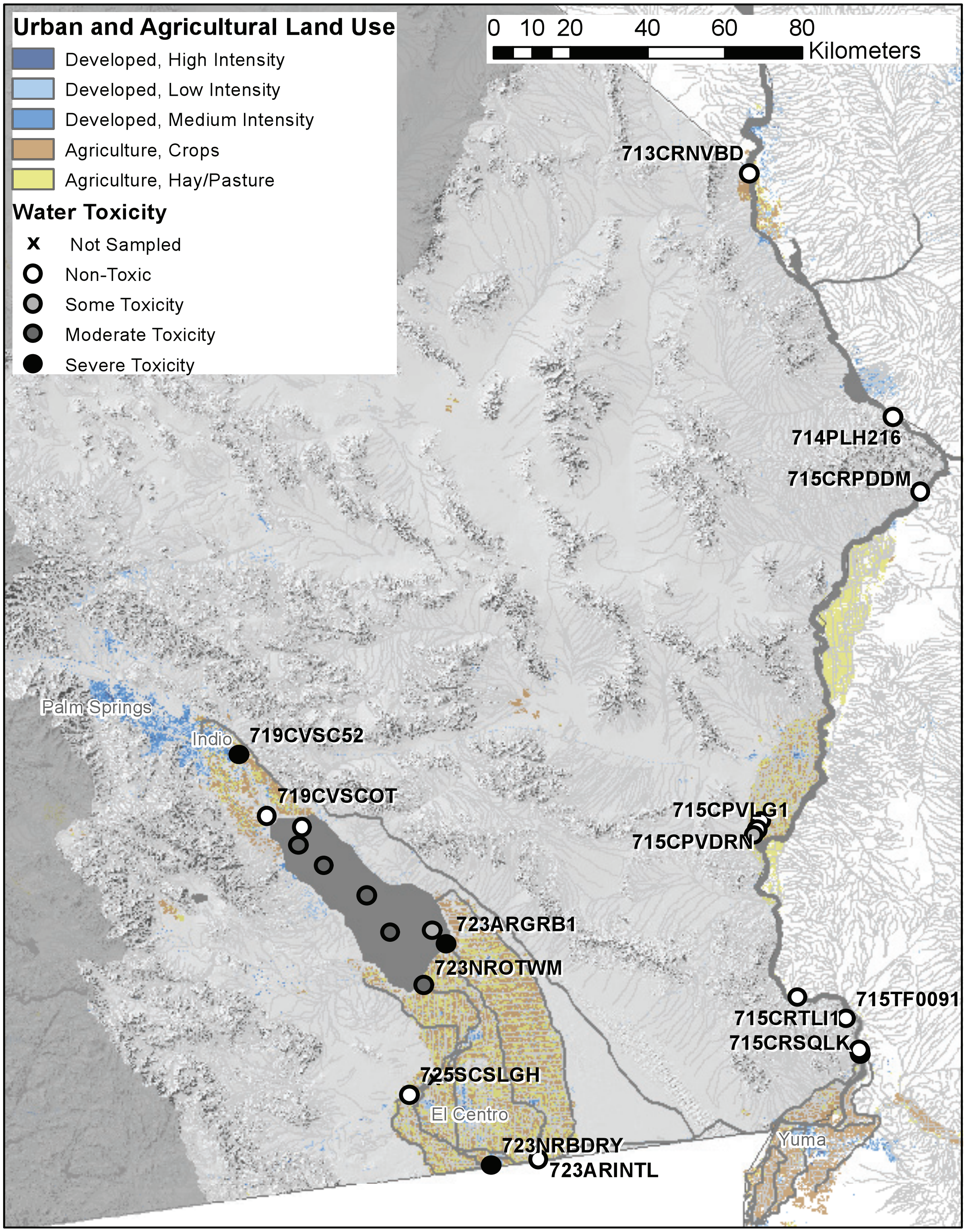


Figure 7. Magnitude of water toxicity in the Salton Sea and at freshwater sites in the Colorado River Region of California based on the most sensitive species (test endpoint) in water samples collected at each site.

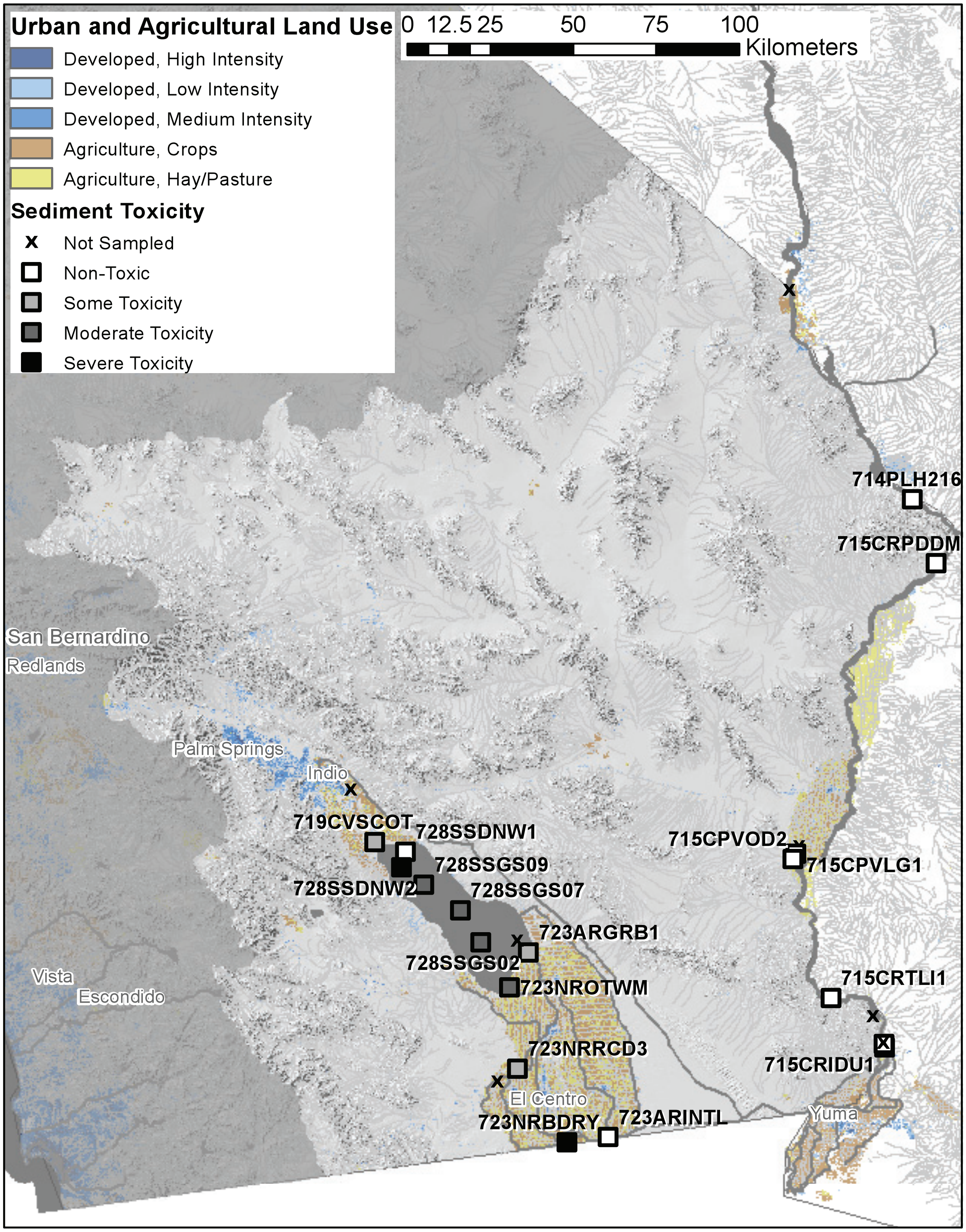


Figure 8. Magnitude of toxicity in freshwater sediments and Salton Sea sediments at sites in the Colorado River Region of California based on the most sensitive species (test endpoint) in water samples collected at each site.

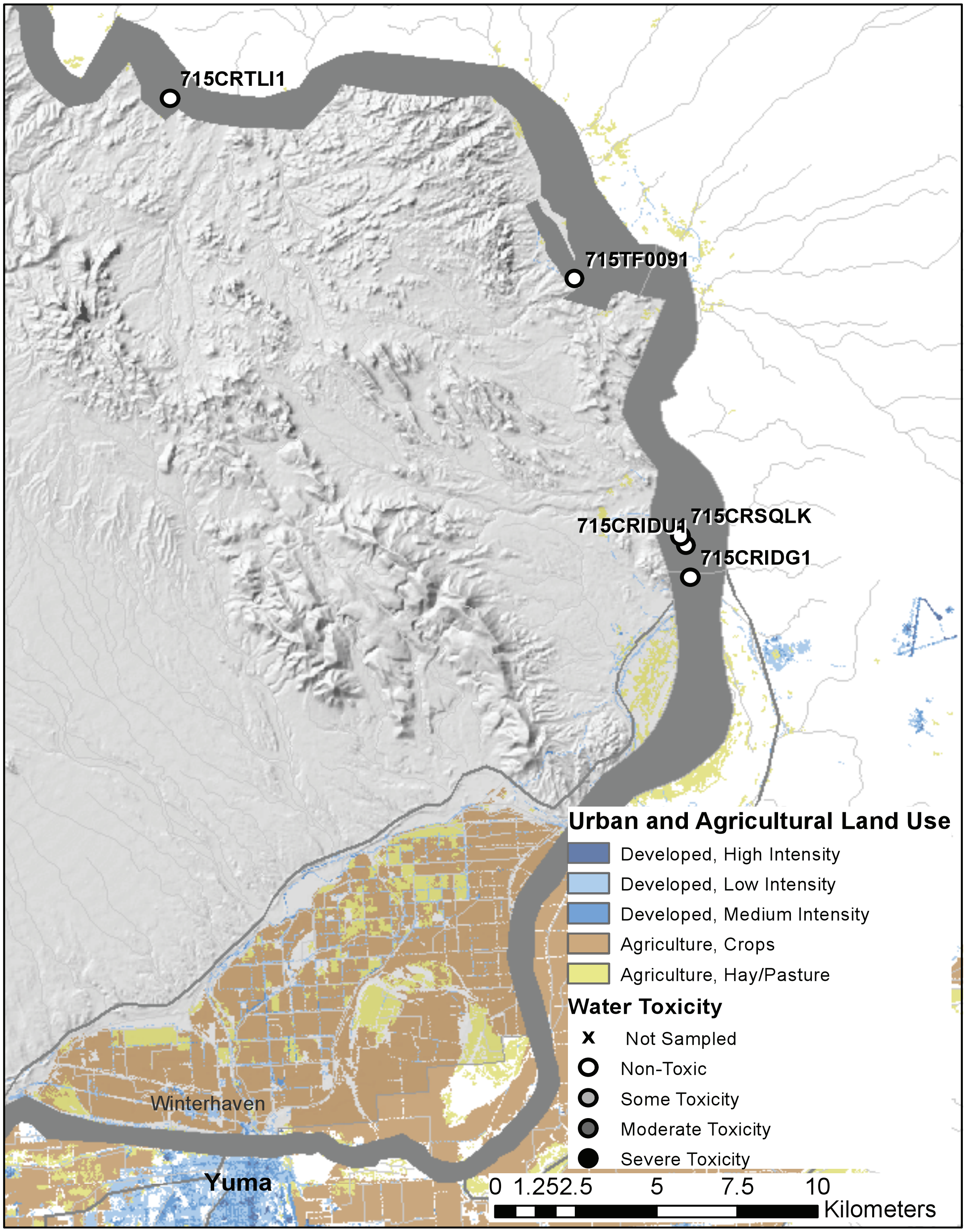


Figure 9. Magnitude water toxicity at freshwater sites in the Colorado River along the California-Arizona border, based on the most sensitive species (test endpoint) in water samples collected at each site.

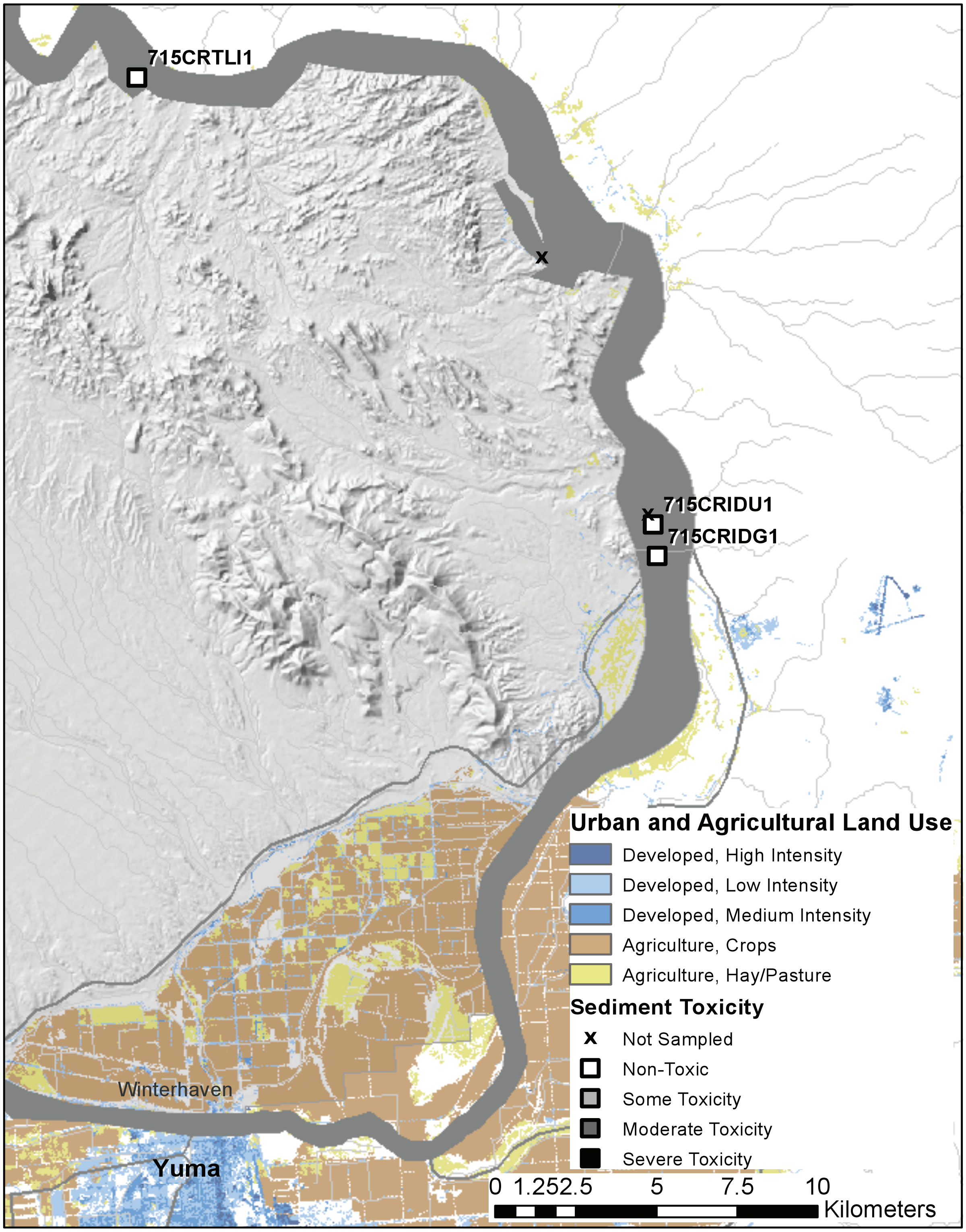


Figure 10. Magnitude of toxicity in freshwater sediments in the Colorado River along the California-Arizona border, based on the most sensitive species (test endpoint) in water samples collected at each site.

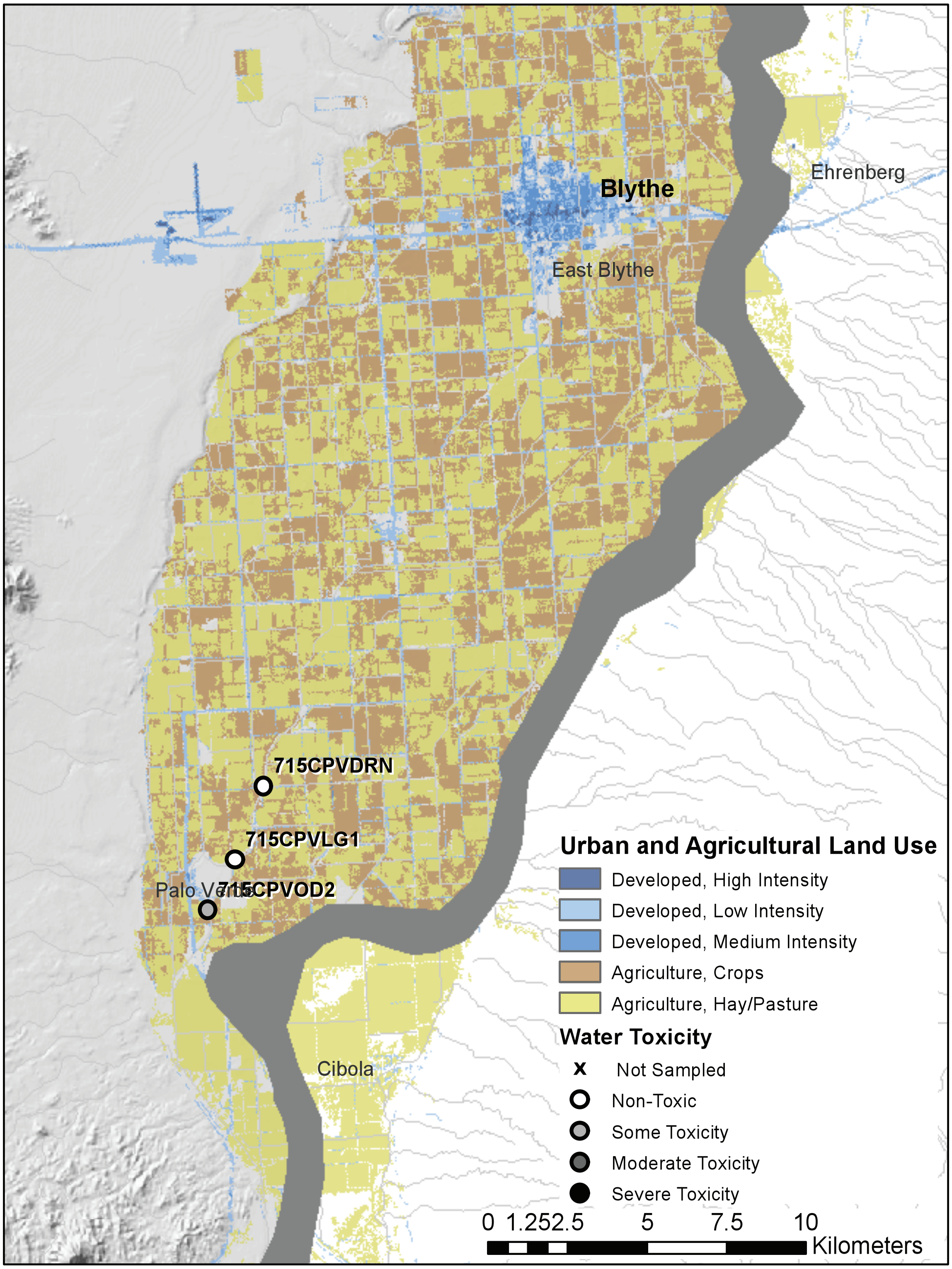


Figure 11. Magnitude of water toxicity at freshwater sites in the Palo Verde agricultural area along the California-Arizona border, based on the most sensitive species (test endpoint) in water samples collected at each site.

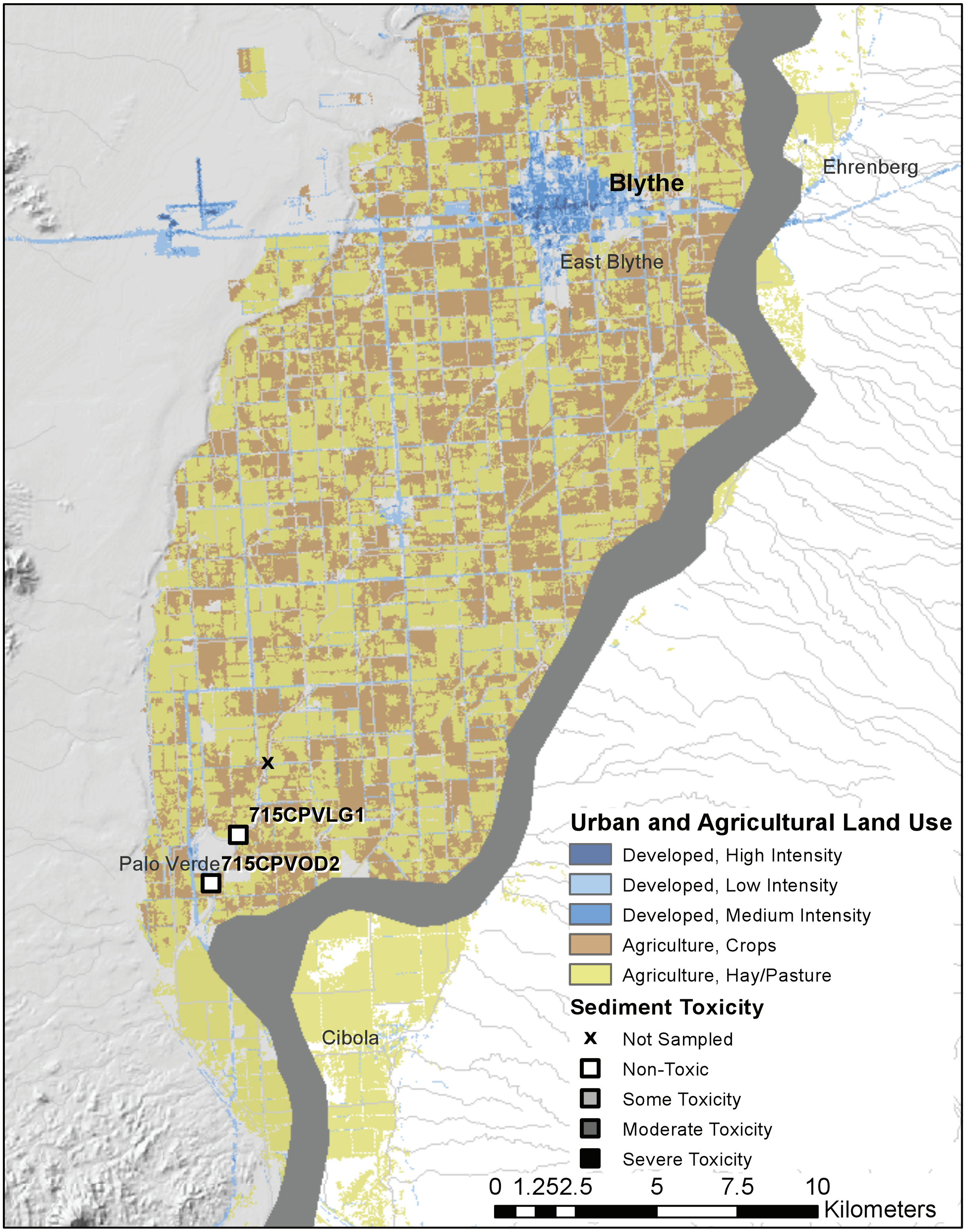


Figure 12. Magnitude of toxicity in freshwater sediments in the Palo Verde agricultural area along the California-Arizona border, based on the most sensitive species (test endpoint) in water samples collected at each site.

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