

Survey of Pesticide Contamination in Sediments at Prospective SCH Sites

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Executive Summary

Occurrence of organochlorine and some current-use pesticides was surveyed in areas around the Salton Sea that may be potentially used for the construction of species conservation habitats (SCHs). About 60 sediment cores, both air-exposed and submerged, from areas adjacent to the Alamo River and New River mouths, were collected and analyzed for pesticides in three depth increments, i.e., 0-5, 5-15, and 5-30 cm. A limited number of water samples were also taken from the Alamo River and New River and analyzed for the same pesticides. The following general observations were made:

- DDE was the predominant organochlorine pesticide present in the sediment.
- The total DDE levels were generally below the consensus probable effect level (PEL) given by McDonalds et al. (2000) at 31.3 ng g^{-1} , and exceedances were mostly associated with the dry subsurface sediment samples at the Alamo River-Red Hill site and the New River east playa site (about 25% exceedances rate).
- The levels of organochlorine insecticides were higher in the Alamo River-Red Hill area and in the east playa of New River. The Alamo River-Davis Road area and New River mid playa had lower levels. The New River far west playa had the lowest levels

of pesticides. Therefore, legacy pesticides appear to accumulate near the river mouths.

- Levels of organochlorine pesticides were higher in the air-exposed sediments than in the submerged sediments, which may be due to more extensive degradation in the submerged areas (under reduced conditions).
- In the air-exposed sediment cores, levels of DDTs (including DDE and other metabolites) were always higher in the subsurface layers than in the surface layer (0-5 cm). This may be caused by the deposition and burial of sediment with higher levels of DDTs during a time when the use of DDT was heavy (i.e., before 1970s). Therefore, if the sediment bed is disturbed during the construction of SCHs, it is likely that DDT residues may be redistributed to the surface to some degree. This needs to be considered for SCH site selection and construction.
- Analysis of the small number of water samples showed absence of organochlorine pesticides in the Alamo River and New River water; only Chlorpyrifos was occasionally detected. However, the number of samples was too small to allow for a concrete conclusion as to whether or not the influent from the Alamo River and New River would contribute significant amounts of pesticides to the SCHs, if the water was used to flood the SCH ponds.

1. Introduction and Background

The Salton Sea is the terminal destination for nutrients, pesticides, trace elements, and salts in agricultural drainage water flowing into the Sea via the New, Alamo and Whitewater rivers (de Vlaming et al., 2004; Phillips et al., 2007). The levels of pesticides and trace elements in the water entering the Salton Sea have frequently been found to be toxic to aquatic organisms (de Vlaming et al., 2004; Phillips et al., 2007). Several studies have examined pesticide concentrations in the drainage water, suspended sediment and bed sediment in the Salton Sea as well as in the three rivers near their outlets (e.g., Vogl and Henry, 2002; LeBlanc et al., 2004; Sapozhnikova et al., 2004; LeBlanc and Kuivila, 2008; Orlando et al., 2008; Miles et al., 2009). Most studies to date have focused on surveying pesticides in the water flowing into the Sea, and relatively few studies also considered pesticides in the bed sediment within the Sea (Leblanc et al., 2004; LeBlanc and Kuivila, 2008; Mile et al., 2009). The studies generally show that concentrations of current-use pesticides in sediments and water correlate well with their seasonal usage in the adjacent agricultural areas (LeBlanc and Kuivila, 2008; Orlando et al., 2008). The detections of select current-use and legacy pesticides in two previous studies are summarized in Table 1. The legacy organochlorine pesticides were generally not found in the dissolved form in water samples collected from the rivers, but DDT derivatives such as p,p'-DDE were often detected on the suspended sediment from the river water samples as well as the bed sediments from the rivers or within the Sea (LeBlanc et al., 2004; Sapozhnikova et al., 2004). The overwhelming majority of the total

DDT was due to DDE (LeBlanc et al., 2003; Sapozhnikova et al., 2004). When detected, the level of p,p'-DDE was consistently below 100 ng g⁻¹ (dry wt). In addition, LeBlanc et al. (2004) showed that more pesticides on the suspended sediment were detected near the shoreline or at the mouth of the inflowing rivers, while few pesticides were detected on the suspended sediment or in the bed sediment from the offshore sites (1.5 - 3.5 km from river mouth). Lack of detection of pesticides on the suspended sediment from the off-shore locations was attributed to dilution and/or matrix interference caused by algal materials (LeBlanc et al., 2004). In Sapozhnikova et al. (2004), sediment samples were taken from the middle of the Sea, and the level of DDE was <30.6 ng g⁻¹, while very few other organochlorine insecticides were found.

In 2006, Miles et al. (2009) carried out an ecosystem monitoring study of 4 newly constructed saline habitat ponds (SHPs) covering 50 hectares at the southeastern shoreline of the Sea. These SHPs were explored as an alternative to the restoration of lost wetlands. The test site was located north of Morton Bay, next to the Alamo River outlet. Blended water from the Salton Sea and Alamo River was used to flood the SHPs. Water, sediment and biological samples were collected and analyzed for various chemical constituents, including legacy organochlorine pesticides, from the sites in the four SHPs as well as reference sites outside of the test area. The results showed that only DDT derivatives were found in the sediments from the SHPs, and when detected, the levels (<20 ng g⁻¹) were statistically lower than those from reference sites.

2. Objectives

The objective of this investigation was to provide a snapshot of the occurrence and levels of historical and current-use pesticides in the bed sediments at sites that may be used for constructing species conservation habitats (SCHs) in the near future. For this purpose, the sample sites were clustered next to the mouths of Alamo River and New River, and included both submerged areas and dry playa areas along the shoreline. A unique emphasis was placed on examination of the vertical distribution of pesticides in the bed sediment, as the construction of SCHs may lead to disturbance of the bed sediment to some degree in selected areas. This goal differed from previous studies in which only sediment from the surface (2-10 cm) was collected for evaluation. In addition, compared to previous sediment survey studies on the Salton Sea, the sampling scheme in this study was also much more comprehensive. This information is expected to provide a preliminary assessment on the baseline pesticide concentrations in areas that may be used for housing SCHs.

3. Methods

3.1 Sample Collection

Five sampling trips were made to collect sediment and water samples at the south end of the Salton Sea in May and June 2010. It must be noted that the sampling scheme was designed primarily for the characterization of selenium. In total, sediment cores were collected at 92 sites near the Alamo and New Rivers and within the proposed footprint of the SCHs. Of these samples, about 2/3 were used for pesticide analysis due to time and resource constraints. Sediment samples were collected with a shovel or

auger, and spatulas from the exposed sediments in the playa areas. A sediment core sampler from Aquatic Research Instruments (Hope, ID) was used to collect samples from the submerged areas. The submerged samples were collected by wading or from an air boat provided by California Department of Fish and Game. Grab water samples from the Salton Sea, Alamo River, and New River were collected in amber glass bottles by dipping.

Sediment samples were divided into three depth intervals, 0-5 cm, 5-15 cm, and 15-30 cm, and placed in polyethylene freezer bags. Selected sediment cores were split in the middle to create split samples. It must be noted that due to potentially localized distribution of pesticides, these split samples may not be considered as true duplicate samples, especially for the strongly hydrophobic organochlorine pesticides. Duplicate water samples were taken on each sampling trip. All samples were placed on ice for transport back to the laboratory and stored in a 4 °C cold room before analysis.

3.2 Analysis of Water Samples

Water samples were stored at 4 °C and extracted within 48 h from collection. Each water sample (1000 ml) was passed through a 0.7- μ m Whatman GF/B filter (Fisher Scientific, West Chester, PA) to remove particles. Filtered water samples were analyzed using a modified version of EPA method 3510 for liquid-liquid extraction (USEPA, 1996a,b). Briefly, after filtration, water samples were transferred to a 2-L separatory funnel and extracted with 70 mL of methylene chloride. The methylene chloride fraction was passed through a Whatman No. 41 filter (Whatman, Maidstone, UK) filled with 20 g

of anhydrous Na_2SO_4 to remove the residue water. The remaining aqueous phase was extracted with fresh methylene chloride for two additional times. The solvent phase for the same samples was combined and concentrated to dryness. The sample was reconstituted to 1.0 ml with hexane. Pesticide residues in the GF/B filters were extracted by ultrasound-assisted extraction (ultrasound bath IS30H, Fisher Scientific, Pittsburgh, PA) with 40 mL methylene chloride: acetone (1:1, v/v). The solvent fraction was filtered through a Whatman No. 41 paper (Whatman, Maidstone, UK) filled with 20 g of anhydrous Na_2SO_4 . The extraction procedure was repeated two more times. The solvent phase for the same sample was combined and concentrated until dryness and was reconstituted to 1.0 ml with hexane. The analyses gave the concentrations in the dissolved phase and on the suspended particles.

3.3 Analysis of Sediments

Pesticides in the sediment was determined using modified versions of EPA method 3550 for extraction, method 3620 for Florisil cleanup, and method 3660B for removing sulfur interference (USEPA, 1996b, 2007). Briefly, 5.0 g (dry wt) aliquot of sediment was mixed with anhydrous sodium sulfate in a beaker until the sample was dry. Next, 70 mL of methylene chloride-acetone (1:1, v/v) was added to each beaker and the mixture was sonicated for 15 min. After 15 min, the extract was decanted and filtered through a Whatman No. 41 filter paper (Whatman, Maidstone, UK) filled with 20 g of anhydrous Na_2SO_4 . The extraction was repeated two more times and the extracts were combined. The solvent phase was evaporated using a vacuumed rotary evaporator

at 40 °C. The sample was reconstituted to 1.0 ml with hexane. Activated copper was added to remove sulfur. A Florisil column was used for the sample cleanup. After the cleanup, the sample was concentrated and then diluted to 1.0 ml with hexane.

Prior to extraction, all samples were spiked with decachloridebiphenyl as the recovery surrogate and the recoveries between 70-130% were accepted for the concentration correction. Quantification was confirmed by the internal standard method, quantifying against ¹³C-*cis*-permethrin that was added to the sample.

The sample extracts were analyzed on a Varian 3800 gas chromatograph coupled with a Varian 1200 triple-quadrupole mass spectrometer in the electron impact mode. A DB-5MS column (30 m × 0.25 mm × 0.25 μm) (J&W Scientific, Folsom, CA) was used for the separation. The column temperature was programmed at 80 °C, held 1 min, increased to 160 °C at 4.2 °C min⁻¹ and held for 5 min. Helium was used as a carrier gas at a constant flow rate of 1ml min⁻¹. The injector, transfer line and ion source temperatures were set at 260 °C, 300 °C and 170 °C, respectively.

3.4 QA/QC Practices

In addition to precautions used in sample collection, transport, and storage, QA/QC was achieved by using a surrogate (to confirm recovery) and a stable isotope labeled internal standard (¹³C-permethrin) in all samples. The surrogate recoveries were always >70% for sediment samples. The use of an isotope-labeled internal standard for calibration was expected to minimize variations due to instrument instability and/or

matrix interference. Matrix spikes were prepared using one of the Salton Sea sediments with no detectable pesticide residues. Five replicate samples were spiked with each pesticide at 10 ng g⁻¹ and analyzed using the same methods as given above. Evaluation of the 5 matrix spikes showed that the mean recoveries for all pesticides ranged from 79 to 111% (Table 2). The matrix spikes were further used to estimate the method detection limits for individual pesticides. The MDLs ranged from 0.23 (p,p'-DDD) to 1.95 (cypermethrin) ng g⁻¹, depending on the type of pesticides. Method reproducibility was also evaluated from the variation of results obtained from the matrix spikes (Table 2). The standard deviations (%) ranged from 3.67% (p,p'-DDD) to 29.27% (cypermethrin), with the average at 11.19%.

All water samples were analyzed in duplicates. In addition, one transport and one field blanks were used. No pesticide was detected in any of the blanks.

In the final GC-MS/MS analysis, a laboratory solvent blank was included in the sequence for every 15-20 samples. No pesticide was ever detected in the solvent blanks.

4. Results and Discussion

4.1 Bed Sediments

Organochlorine Pesticides

The detailed concentrations of pesticides in sediment samples are provided in the Excel file. The reported data include values below MDLs if the peaks were distinct and clearly identifiable. This is justifiable because instrument sensitivity and matrix

interference vary over time or across samples. The summary and statistically processed results are given in Tables 3-6, and depicted in Figures 2-8. The total concentrations of pesticides detected in the sediment ranged from 0.2 to 120 ng g⁻¹ (Tables 3-6).

DDT and derivatives (detected in 100% of sediment samples) and chlordane (*cis* and *trans* isomers, detected in 77% of the sediment samples) were the most frequently found organochlorine pesticides in the sediment samples (Tables 3-6). Other organochlorine pesticides, such as dieldrin, endosulfan and heptachlor were detected in some sediment samples at concentrations lower than 10 ng g⁻¹ (Tables 3-6). In general, concentrations of DDT and its metabolites represented more than 80% of the total concentration of organochlorine pesticides detected in the Salton Sea sediments. The most abundant metabolite of DDT was p,p'-DDE, which comprised 75-100% of the Σ DDT in most sediment samples. The relative contribution of DDE to the total pesticides detected was the highest in the air-exposed sediments from the Alamo River area (85.8-87.0%), which was followed by the submerged Alamo River sediments (51.1-69.9%) and air-exposed sediments from the New River area (53.5-66.9%) (Tables 5 and 6). The relative concentration of DDE was the lowest in the submerged sediments from the New River sites (22.4-30.0%) (Table 6).

Sediment samples from Alamo River-Red Hill (near to the Alamo river) and New River east playas contained higher concentrations (10-110 ng g⁻¹) of organochlorine pesticides than sediments from Alamo River-Davis Road (north to the Alamo river), the New river far west and mid playas (< 10 ng g⁻¹) (Figures 3-9). Sediment samples from

Alamo River-Red Hill and New River east playas were closer to their river mouths than sediments from Alamo River-Davis Road, or the far west and mid playas of the New River. Thus, the preliminary results of this study suggest that levels of organochlorine pesticides in the bed sediment decreased with distance from the river mouth. This observation is in agreement with LeBlanc et al. (2004).

In general, the concentrations of organochlorine pesticides were higher in the 5 – 30 cm depth interval than in the 0 – 5 cm depth interval. Taking into account that the majority of organochlorine pesticides including DDT were banned in the U.S. in 1970s, the sediment at the 5-30 cm depths may be from sediment deposition during the time when the use of organochlorine pesticides was still prevalent. In contrast, the sediment depth interval of 0 to 5 cm corresponds to the most recent sediment deposition.

The total DDE concentrations in the sediment samples were analyzed using the consensus probable effect level (PEL) (31.3 ng g^{-1}) cited in MacDonald et al. (2000) for DDE in freshwater sediments. Total DDE concentrations exceeded the PEL threshold in about 27% air-exposed samples from the Alamo-Red Hill area, and in about 25% air-exposed samples from the Alamo-Davis Road (north Alamo River) area. Much lower exceedance rates were observed for air-exposed sediments from the New River sites. Of the three New River areas, only the New River East playa showed about 10% exceedance, while only one exceedance was found for 55 samples analyzed for the New River middle and fast west playas. With the exception of one sample, nearly all 55 submerged sediment samples showed total DDE levels lower than the PEL threshold. It

was also noted that the majority of exceedances were in subsurface sediment samples, suggesting that the relatively elevated levels of DDE were likely from historical use and deposition.

The average pesticide concentrations in sediments under air-exposed conditions were observed to be higher than those under submerged conditions in all sampling sites except the New River far west playa (Figures 7 and 8). In general, the submerged sediments were cleaner than the corresponding air-exposed ones. The high pesticide concentrations in the submerged sediments at site 15[#] and 22[#] may be due to the nearby agricultural fields.

Current-use Pesticides

In general, total pyrethroid insecticide concentrations in the Salton Sea sediment were lower than 15 ng g⁻¹. Bifenthrin (detected in 91% of the samples, with the highest concentration of 26 ng g⁻¹) was the most commonly detected pyrethroid and also found at the highest concentrations. Detection of other pyrethroids such as fenpropathrin, lambda-cyhalothrin and permethrin was limited to sites near to the Alamo River and New River east playas at concentrations lower than 2 ng g⁻¹. The levels of pyrethroids suggested potential toxicity to sensitive invertebrates at some sites. Amweg et al. (2005) measured the sediment toxicity of six pyrethroids and the average 10-d median lethal concentration (LC50) of bifenthrin to *Hyalella azteca* (a benthic invertebrate) was found to be 4.5 ng/g dry weight. Some of the air-exposed sediments contained bifenthrin at levels higher than the LC50 threshold (Table 5). However, the levels of bifenthrin in the

submerged sediments were all below the LC50 value (Table 6). To a great degree pyrethroids behave like organochlorine insecticides due to their very high hydrophobicity. Bifenthrin has also been found in sediments at numerous sites including both urban and agricultural impacted streams.

The organophosphate insecticide chlorpyrifos was also detected in the Alamo River and New River east playas in concentrations at below 2 ng g^{-1} . Chlorpyrifos was moderately hydrophobic and it is not known for accumulation in the bed sediment.

4.2. Water

Chlorpyrifos, one of more water soluble compounds examined, was the most frequently detected compound in water and also occurred at the highest concentrations (80 ng L^{-1}) (Table 7). Most organochlorine pesticides were not detected or measured at concentrations lower than 1.5 ng L^{-1} . Permethrin was the most commonly detected pyrethroid in water while fenpropathrin was detected at the highest concentrations (Table 7). However, the number of water samples collected was likely too small to estimate the potential input of pesticides via influents from the Alamo River and New River to the potential SCHs.

5. Conclusions

Based on the overall pesticide data, some preliminary conclusions may be made in the context of site selection for SCH construction:

- DDE is the predominant organochlorine pesticide present in the sediment of the Salton Sea. Chlordane and bifenthrin were also found but at lower levels. Other pesticides were infrequently detected.
- The total DDE levels were generally below the consensus probable effect level (PEL) given by McDonalds et al. (2000) at 31.3 ng g^{-1} , and exceedances were mostly associated with subsurface, air-exposed sediment samples at the Alamo River-Red Hill site and the New River east playa site.
- The levels of organochlorine insecticides were higher in the Alamo River-Red Hill area and in the east playa of New River. The Alamo River-Davis Road area and New River mid playa had lower levels. The New River far west playa had the lowest levels of pesticides. Therefore, legacy pesticides appear to accumulate near the river mouths. Based on the pesticide data alone, the New River far east playa appears to be the cleanest site, followed by the New River mid playa and the Alamo River-Davis Road sites.
- Levels of organochlorine pesticides were higher in the air-exposed sediments than in the submerged sediments. This may be due to more extensive degradation in the submerged areas (under reduced conditions). Therefore, based on pesticide information alone, it appears that including submerged areas for SCHs would be more desirable.

- In the air-exposed sediment cores from both Alamo River and New River areas, levels of DDTs (including DDE and other metabolites) were always higher in the subsurface layers than in the surface layer (0-5 cm). This may be caused by the deposition and burial of sediment with higher levels of DDTs during a time when the use of DDT was heavy (i.e., before 1970s). Therefore, if the sediment bed is disturbed during the construction of SCHs, it is likely that DDT residues may be redistributed to the surface to some degree. This needs to be considered for SCH site selection and construction.
- The number of water samples was too small to allow for a concrete conclusion as to whether or not the influent from the Alamo River and New River are contributing significant amounts of pesticides to Salton Sea.

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Table 1. Pesticide concentrations in bed sediments of the Salton Sea from two previous studies

Pesticide	Concentration (ng g ⁻¹ dry wt)
Bifenthrin	7.5 ^a
Carbaryl	0.8 ^a
Carbofuran	1.9 - 2.3 ^a
Chlorothalonil	0.5 - 8.9 ^b
Chlorpyrifos	10.2 - 27.7 ^a
Dachtal	3.7 - 7.9 ^a ; 1.2 - 6.0 ^b
Diazinon	1.9 - 4.9 ^a ; 0.5 - 5.4 ^b
Dieldrin	0.5 - 12.3 ^b
Diethylatyl-ethyl	1.9 ^a
Dimethoate	1.3 - 2.3 ^b
Disulfoton	29.6 ^b
Dursban	4.0 - 9.5 ^b
Endrin	Nd
EPTC (eptam)	2.3 - 4.0 ^a
HCB	0.7 - 1.8 ^b
Heptachlor	0.3 - 4.5 ^b
lambda-Cyhalothrin	11.2 ^a
Lindane	0.7 - 8.3 ^b
Malathion	0.8 - 7.2 ^b
o,p'-DDD	0.6 - 6.7 ^b
o,p'-DDT	1.5 - 4 ^b
p,p'-DDD	93.9 ^a ; 0.7 - 2.8 ^b
p,p'-DDE	nd - 31.5 ^a ; nd - 30.6 ^b
p,p'-DDT	nd
Permethrin	7.9 - 8.5 ^a
Prometryn	4.2 ^a
ΣDDT ^c	6.8 - 40.2 ^b
Total DDD	2.6 - 6.7 ^b
Total DDE ^d	6.2 - 30.6 ^b
Total DDT	1.5 - 1.9 ^b
Trifluralin	0.5 - 1.9 ^a ; 1.2 - 5.5 ^b

^aLeblanc et al. 2004

^bSapozhnikova et al. 2004

^cΣDDT = total DDE+ total DDD+ total DDT

^dTotal DDE = op-DDE +pp-DDE

Table 2. Pesticide recoveries and method detection limits (MDLS) (ng g^{-1}) as determined from matrix spikes containing individual pesticides at 10 ng g^{-1} each ($n = 5$)

Compound	Mean Recovery (%)	Minimum (%)	Maximum (%)	STD (%)	MDL (ng/g)
Alachlor	92.03	82.69	103.59	9.83	0.64
Bifenthrin	85.72	79.65	94.39	11.08	0.48
Chlorothalonil	79.41	66.86	91.08	9.35	0.66
Chlorpyrifos	109.19	99.82	125.36	6.03	0.77
<i>cis</i> -chlordane	111.40	93.07	132.74	9.37	1.20
Cyfluthrin	88.88	67.24	120.62	13.21	1.48
cypermethrin	88.83	61.22	116.78	5.20	1.95
decachlorobiphenil	91.92	82.72	97.70	14.37	0.58
deltamethrin	97.23	81.41	111.83	10.79	0.93
Dieldrin	98.91	87.91	116.86	10.88	0.98
endosulfan-sulfate	104.32	87.42	124.14	10.67	1.30
esfanvalerate	97.24	87.21	101.30	13.20	0.44
fenpropathrin	89.96	80.75	101.58	12.31	0.72
Heptachor	91.51	85.37	97.85	3.67	0.41
lambda-cyhalothrin	91.21	82.03	99.79	4.62	0.57
Lindane	87.71	77.20	101.09	16.59	0.65
<i>o,p</i> -DDD	87.79	78.38	101.53	12.92	0.70
<i>o,p</i> -DDE	93.93	87.27	99.61	7.48	0.37
<i>o,p</i> -DDT	85.39	82.16	91.03	10.66	0.30
Permethrin	89.37	75.22	100.15	8.37	0.77
<i>p,p'</i> -DDD	84.82	81.38	89.12	11.53	0.23
<i>p,p'</i> -DDE	92.00	82.43	106.83	22.25	0.75
<i>p,p'</i> -DDT	81.81	69.82	95.64	29.27	0.79
<i>trans</i> -chlordane	96.65	84.08	113.21	8.46	0.96
α -endosulfan	89.93	78.68	102.39	6.04	0.73
β -endosulfan	97.20	84.39	114.95	12.70	0.90

Table 3. Averaged pesticide concentrations detected (ng/g) in air-exposed sediment samples from Salton Sea Basin at different depths

Depth (cm)	Alamo River (n = 20)			New River (n = 28)		
	0-5	5-15	15-30	0-5	5-15	15-30
<u>Organochlorine pesticides (OCPs)</u>						
Lindane	ND	0.08 (ND-1.52)	ND	ND	ND	ND
Chlordane	0.23 (ND-1.13)	0.18(ND-1.04)	0.63(ND-7.70)	0.66(ND-8.82)	0.80(ND-10.18)	0.61(ND-5.46)
Dieldrin	0.03(ND-0.31)	ND	0.05(ND-0.61)	0.04(ND-0.52)	0.03(0-0.12)	0.04(ND-0.96)
Σ DDE ^a	12.09(ND-34.40)	20.55(ND-38.26)	25.46(ND-102.6)	2.59(ND-23.71)	4.84(0-41.16)	10.92(ND-47.83)
Σ DDT ^b	12.83(ND-35.52)	21.43(ND-39.52)	26.67(ND-108.75)	2.85(ND-24.31)	5.13(0.40-43.06)	11.78(ND-55.64)
<u>Current-use pesticides (CUPs)</u>						
Chlorpyrifos	ND	0.03(ND-0.47)	0.02(ND-0.14)	0.02(ND-0.37)	0.01(ND-0.24)	0.01(ND-0.25)
Bifenthrin	0.39(ND-1.78)	1.56(ND-3.53)	3.48(ND-18.36)	1.11(ND-7.63)	1.62()	3.64(ND-26.22)
Permethrin	0.14(ND-2.23)	0.10(ND-1.05)	0.04(ND-0.37)	0.04(ND-1.05)	ND	ND
Σ Pyrethroids ^c	0.53(ND-2.63)	1.73(ND-3.93)	3.75(ND-18.36)	1.15(ND-7.63)	1.67(ND-9.25)	3.66(ND-26.22)
Σ CUPs ^d	0.70(ND-2.63)	1.93(ND-3.93)	3.84(ND-18.36)	2.06(ND-7.53)	2.49(ND-9.25)	399
Σ Pesticides ^e	11.83(ND-38.16)	23.61(0.37-69.02)	31.19(ND-120.15)	5.71(ND-6.40)	8.47(ND-48.60)	16.45(ND-83.64)

^a Σ DDE: total concentrations of *o,p'*-DDE and *p,p'*-DDE.

^b Σ DDT: total concentrations of *o,p'*-DDE, *p,p'*-DDE, *o,p'*-DDD, *p,p'*-DDD, *o,p'*-DDT, and *p,p'*-DDT.

^c Σ pyrethroids: total concentrations of all detected pyrethroids, including bifenthrin, fenpropathrin, lambda-cyhalothrin, permethrin, cyfluthrin, cypermethrin, esfenvalerate and deltamethrin.

^d Σ CUPs: total concentrations of all detected current-use pesticides.

^e Σ pesticides: total concentrations of all detected pesticides.

Table 4. Averaged pesticide concentrations detected (ng/g) in submerged sediment samples from the Salton Sea Basin at different depths

Depth (cm)	Alamo River (n=9)			New River (n=6)		
	0-5	5-15	15-30	0-5	5-15	15-30
<u>Legacy organochlorines (OCPs)</u>						
Lindane	0.01(ND-0.06)	0.05(ND-0.45)	0.04(ND-0.21)	ND	ND	ND
Chlordane	0.84(ND-2.15)	0.61(ND-1.59)	1.03(ND-2.79)	0.71(0.31-1.14)	0.53(0.03-1.03)	0.50(0.16-1.16)
Dieldrin	0.04(ND-0.33)	0.04(ND-0.19)	0.06(ND-0.33)	0.02(0-0.07)	ND	ND
Σ DDE ^a	4.52(0.11-21.33)	10.56(ND-28.61)	10.79(ND-33.02)	0.69(0.13-2.07)	0.70(0.09-2.23)	0.74(0.13-2.25)
Σ DDT ^c	5.50(0.71-22.71)	12.04(ND-31.61)	12.54(ND-36.56)	1.37(0.53-3.40)	1.05(0.23-2.90)	1.16(0.46-2.92)
<u>Current-use pesticides (CUPs)</u>						
Chlorpyrifos	ND	ND	ND	ND	ND	ND
Bifenthrin	0.32(ND-1.03)	0.58(ND-1.90)	0.38(ND-0.83)	0.14(0.10-0.18)	0.11(0.10-0.14)	0.18(0.10-0.48)
Permethrin	ND	1.49(ND-6.12)	3.15(ND-17.56)	ND	0.06(ND-0.23)	ND
Σ Pyrethroids ^d	0.34(ND-1.84)	2.07(ND-6.68)	3.54(ND-18.12)	0.14(0.10-0.18)	0.17(0.07-0.36)	0.18(0.10-0.48)
Σ CUPs ^e	0.52(ND-1.84)	2.45(ND-7.50)	4.07(0.27-20.25)	0.45(0.10-0.18)	0.75(0.30-1.32)	0.97(0.09-2.71)
Σ Pesticides ^f	6.89(ND-26.06)	15.11(ND-36.10)	17.65(0.71-58.36)	3.09(0.83-5.01)	2.32(0.70-4.88)	2.64(0.81-6.80)

^a Σ DDE: total concentrations of *o,p'*-DDE, *p,p'*-DDE.

^b Σ DDT: total concentrations of *o,p'*-DDE, *p,p'*-DDE, *o,p'*-DDD, *p,p'*-DDD, *o,p'*-DDT and *p,p'*-DDT.

^c Σ pyrethroids: total concentrations of all detected pyrethroids, including bifenthrin, fenpropathrin, lambda-cyhalothrin, permethrin, cyfluthrin, cypermethrin, esfenvalerate and deltamethrin.

^d Σ CUPs: total concentrations of all detected current-use pesticides.

^e Σ Pesticides: total concentrations of all detected pesticides.

Table 5. Concentration profiles of primary pesticides in the air-exposed sediment samples

	Alamo River (n =19)			New River (n =30)		
	0-5 cm	5-15 cm	15-30 cm	0-5 cm	5-15 cm	15-30 cm
<u>DDE^a</u>						
Range (µg/kg)	ND-34.40	ND-61.51	0-102.60	0-23.71	0.28-41.16	0-47.83
APT (%) ^c	85.8	87.0	81.6	53.46	66.90	65.12
DF (%) ^d	94.7	95.2	94.1	93.33	100	96.00
<u>Chlordane^b</u>						
Range (ng/g)	0-2.15	0-1.04	0-7.70	0-8.82	0-3.94	0-5.46
APT (%)	3.42	0.73	2.03	4.81	3.76	3.28
DF (%)	47.37	33.33	35.29	40.00	35.48	36.00
<u>Bifenthrin</u>						
Range (ng/g)	0-1.78	0-3.53	0-18.36	0-7.63	0-9.25	0-26.22
APT (%)	2.92	6.20	11.16	16.2	13.42	24.12
DF (%)	73.68	90.48	88.24	63.33	70.97	72.00

^a DDE: total concentrations of *o,p'*-DDE and *p,p'*-DDE.

^b Chlordane: total concentrations of *cis-* and *tran-* chlordane.

^c APT: Average percentage of the total pesticide amount.

^d DF: detection frequency.

Table 6. Concentration profiles of main pesticide contaminants in submerged sediment samples

	Alamo River (n = 9)			New River (n = 6)		
	0-5 cm	5-15 cm	15-30 cm	0-5 cm	5-15 cm	15-30 cm
<u>DDE^a</u>						
Range (ng/g)	0.19-21.33	0.12-28.61	0.12-33.02	0.13-2.07	0.09-2.23	0.13-2.25
APT (%) ^c	56.1	69.9	61.2	22.42	29.97	27.96
DF (%) ^d	100	100	100	100	100	100
<u>Chlordane^b</u>						
Range (ng/g)	0-2.15	0-1.59	0-2.79	0.31-1.14	0.03-1.03	0.16-1.16
APT (%)	16.89	4.05	5.84	23.08	22.63	19.05
DF (%)	77.9	66.7	77.8	100	100	100
<u>Bifenthrin</u>						
Range (ng/g)	0-1.03	0-1.90	0-0.83	0.01-0.18	0.07-0.14	0.07-0.48
APT (%)	4.94	3.85	2.18	4.61	9.53	6.94
DF (%)	88.89	88.89	88.89	100	100	100

^a DDE: total concentrations of *o,p'*-DDE and *p,p'*-DDE.

^b Chlordane: total concentrations of *cis-* and *tran-* chlordane.

^c APT: Average percentage of the total pesticide amount.

^d DF: detection frequency.

Table 7. Pesticide concentrations (ng L⁻¹) in water of the Alamo River and New River

	AR-1 ^a	AR-1'	AR-2	AR-2'	NR-1	NR-1'	NR-2	NR-2'
Organochlorines								
Lindane	ND	ND	ND	ND	ND	ND	UD	UD
Heptachlor	ND	ND	ND	ND	ND	ND	ND	ND
Chlordane	ND	ND	UD	ND	ND	ND	0.17	0.17
<i>o,p</i> -DDE	ND	ND	UD	ND	ND	ND	ND	ND
Endosulfan	ND	ND	ND	ND	ND	ND	ND	ND
Dieldrin	ND	ND	ND	ND	ND	ND	ND	ND
<i>p,p</i> -DDE	0.15	ND	UD	ND	ND	ND	ND	ND
<i>o,p</i> -DDD	ND	ND	UD	ND	ND	ND	ND	ND
<i>p,p</i> -DDD + <i>o,p</i> -DDT	ND	ND	ND	ND	ND	ND	ND	ND
<i>p,p</i> -DDT	ND	ND	ND	ND	ND	ND	ND	ND
Endosulfan sulfate	ND	ND	ND	ND	ND	ND	ND	ND
ΣDDE	0.15	ND	UD	ND	ND	ND	ND	ND
ΣDDT	0.15	ND	UD	ND	ND	ND	ND	ND
Current-use pesticides								
Chlorothalonil	ND	0.11	ND	ND	ND	ND	ND	ND
Alachlor	ND	ND	ND	ND	ND	ND	1.32	ND
Chlorpyrifos	80.23	13.68	0.44	0.83	UD	UD	0.34	0.25
Bifenthrin	UD	UD	UD	UD	UD	UD	UD	ND
Fenpropathrin	ND	ND	ND	1.19	11.55	ND	ND	ND
lambda-Cyhalothrin	ND	ND	ND	ND	ND	ND	ND	ND
Permethrin	6.85	ND	ND	ND	7.50	0.16	ND	3.30
Cyfluthrin	ND	ND	ND	ND	ND	ND	ND	ND
Cypermethrin	ND	ND	ND	ND	ND	ND	ND	ND
Esfenvalerate	ND	ND	ND	ND	ND	ND	ND	ND
Deltamethrin	ND	ND	ND	ND	ND	ND	ND	ND
Total CUPs	87.08	13.79	0.44	2.03	19.05	0.16	1.66	3.55
Total Pesticides	87.23	13.79	0.44	2.03	19.05	0.16	1.84	3.72

^aAR-1 and AR1', duplicate samples taken from Alamo River on the May 12th 2010 trip; NR-1 and NR-1': Duplicate samples taken from New River on the May 12th 2010 trip; AR-2 and AR2', duplicate samples taken from Alamo River on the June 15th 2010 trip; NR-2 and NR-2': Duplicate samples taken from New River on the June 15th 2010 trip.

Figure 1. Map of sediment sampling stations. Symbol \diamond denotes air-exposed sediment samples; Symbol \blacktriangle denotes submerged sediment samples.

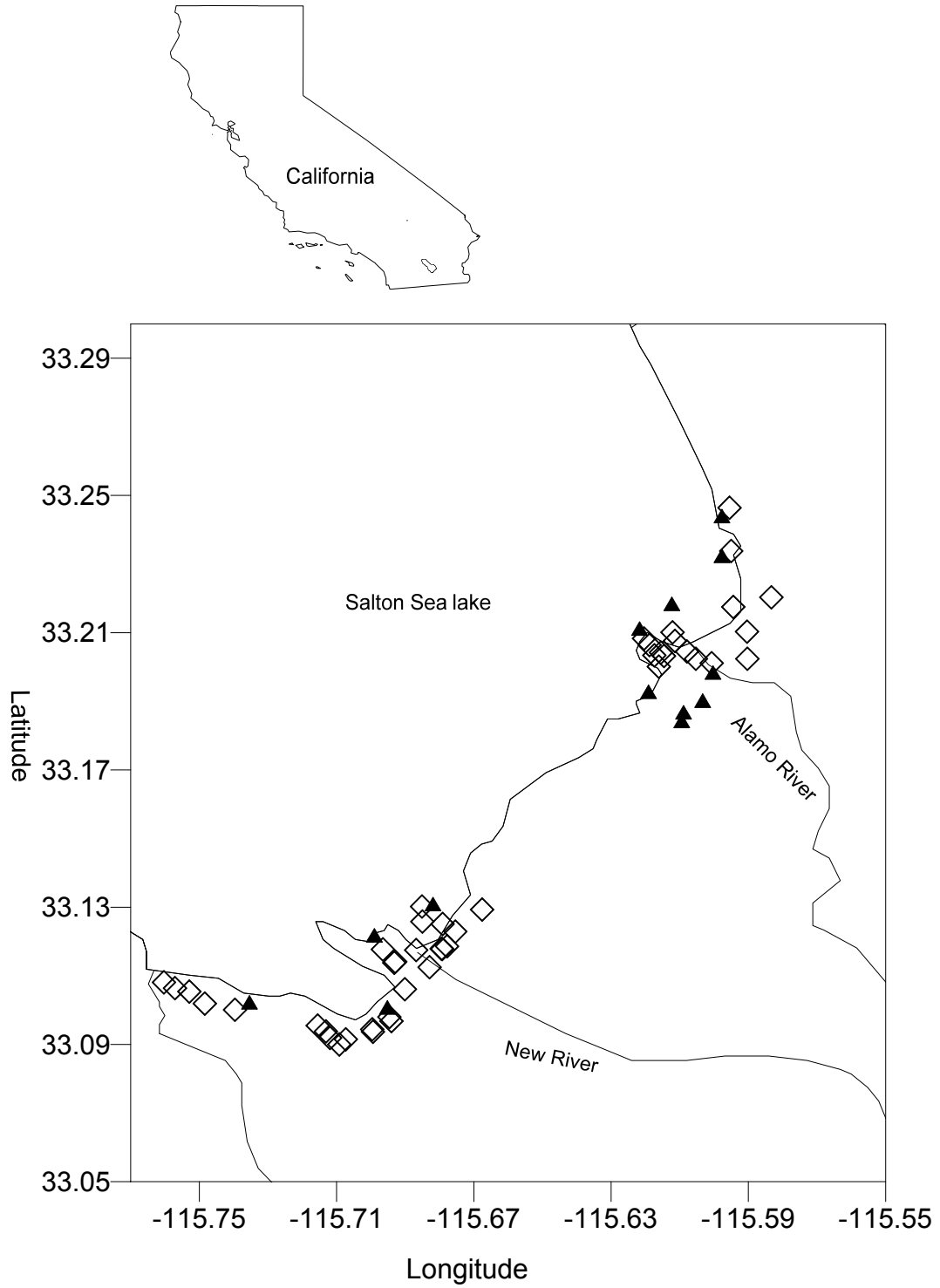


Figure 2. Concentrations range of organochlorine pesticides at Alamo River –Red Hill

(near Alamo River)

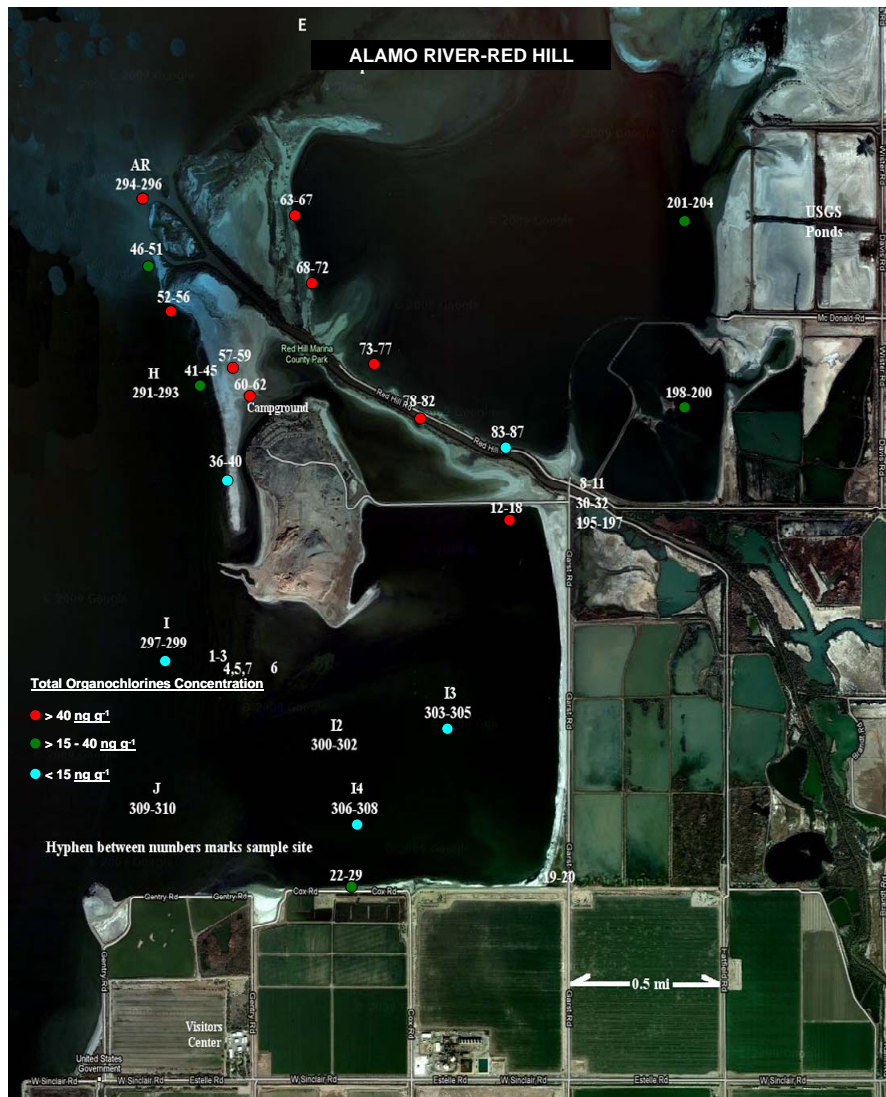


Figure 4. Concentration ranges of organochlorine pesticides at different sites in the east
 playa of the New River.

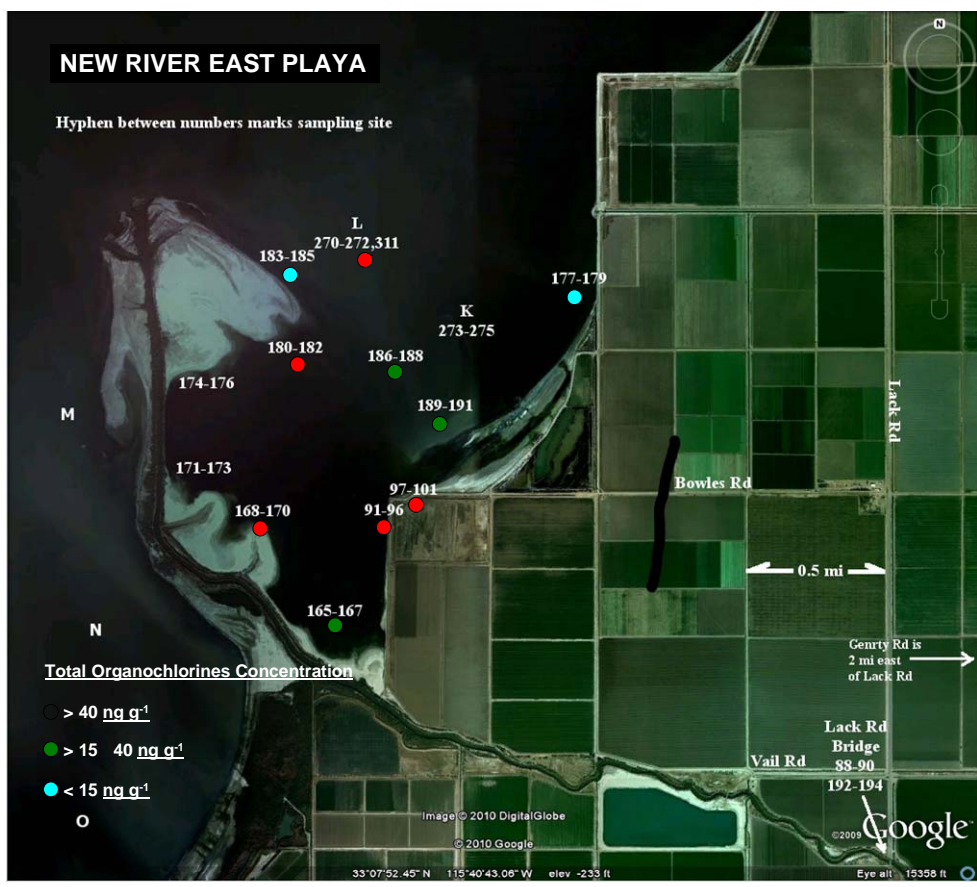


Figure 5. Concentration ranges of organochlorine pesticides at different sites in the far west playa of the New River

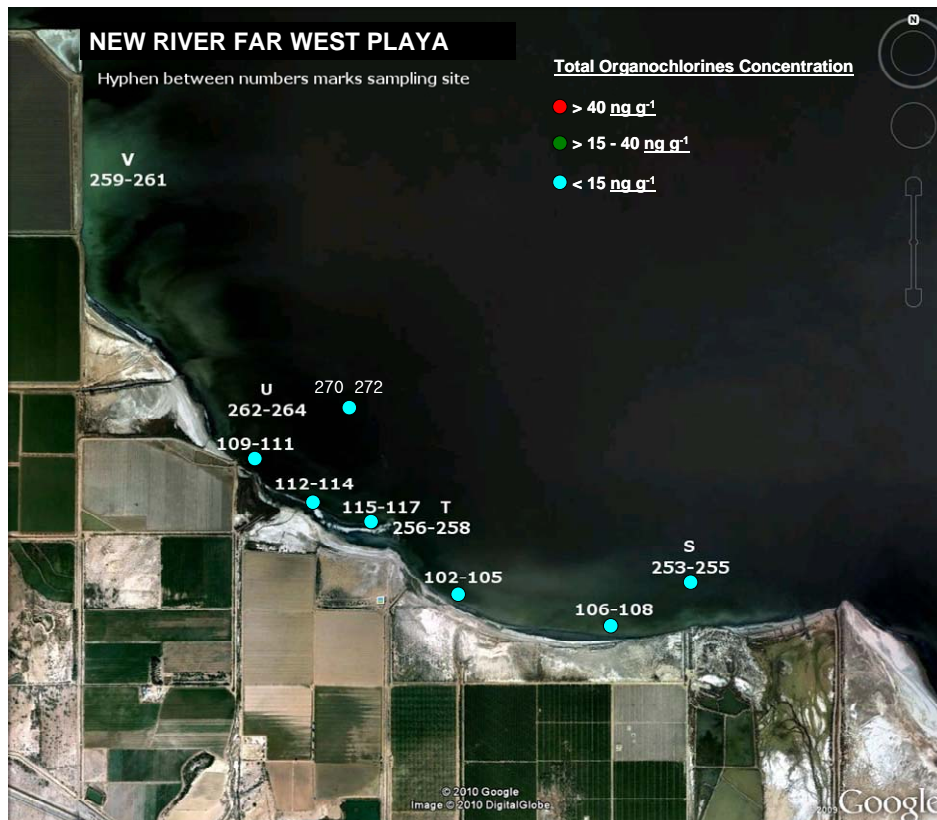


Figure 6. Concentration ranges of organochlorine pesticides at different sites in the mid playa of the New River

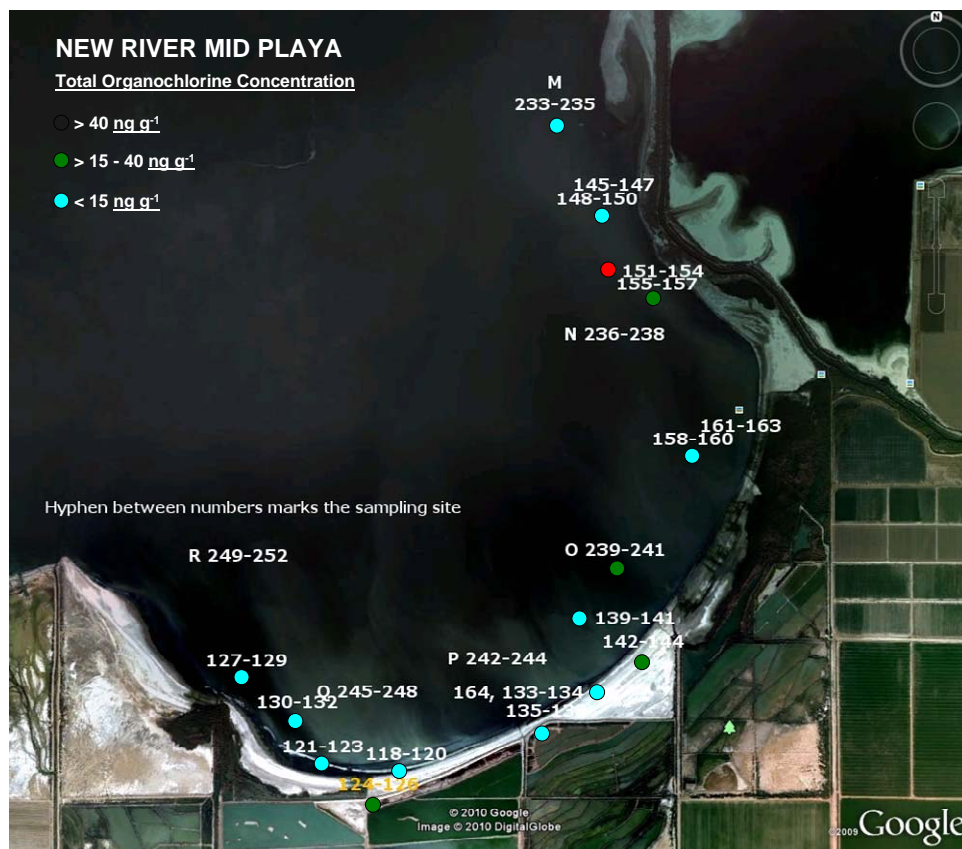


Figure 7. Distribution of Σ DDT (sum of *o,p'*-DDE, *p,p'*-DDE, *o,p'*-DDD, *p,p'*-DDD, *o,p'*-DDT, and *p,p'*-DDT) residues in sediment around Alamo River at depth of (A) 0-5 cm (surface sediment), (B) 5-15 cm (subsurface sediment), and (C) 15-30 cm (bottom sediment). The black dots denote the sampling sites.

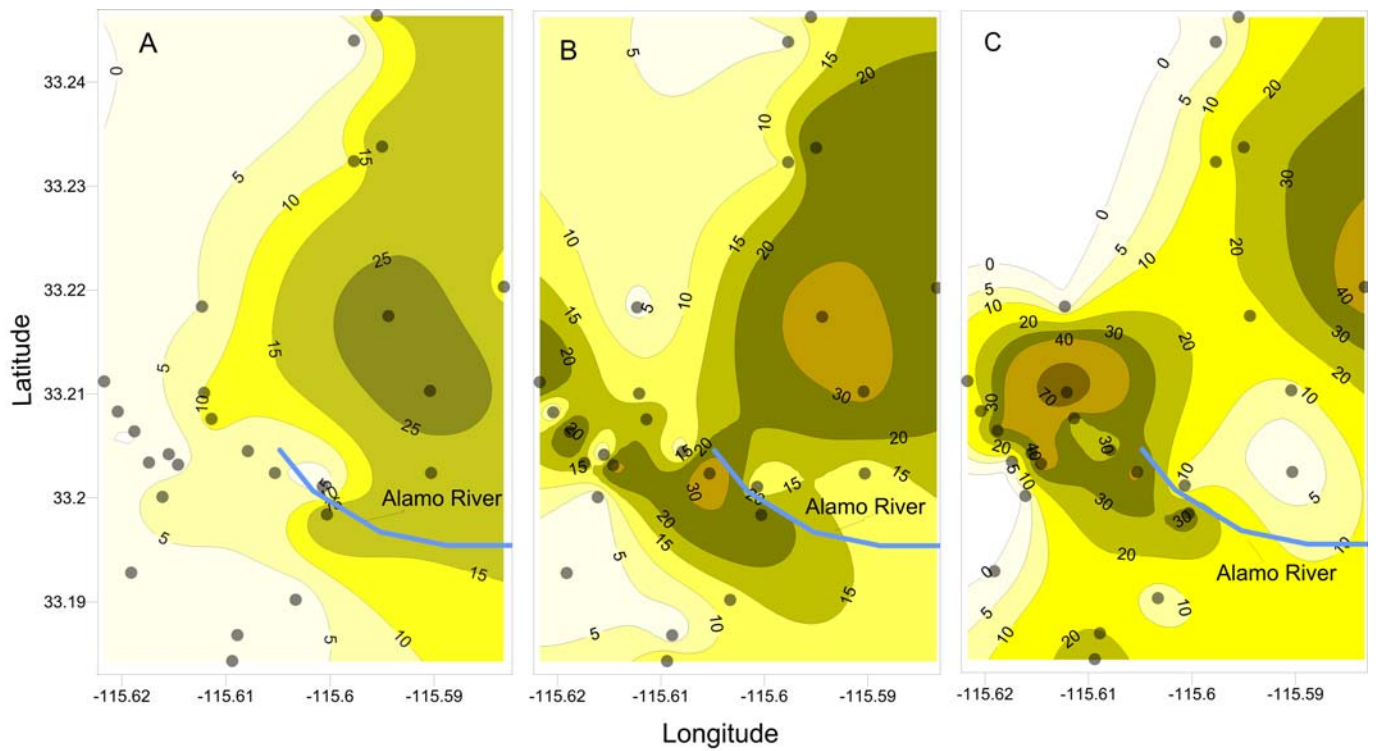


Figure 8. Distribution of Σ DDT (sum of *o,p'*-DDE, *p,p'*-DDE, *o,p'*-DDD, *p,p'*-DDD, *o,p'*-DDT, and *p,p'*-DDT) residues in sediment around New River at depth of (A) 0-5 cm (surface sediment), (B) 5-15 cm (subsurface sediment), and (C) 15-30 cm (bottom sediment). The black dots denote the sampling sites.

