# Organochlorine Pesticides and Polychlorinated Biphenyls (PCB) Concentrations in Muscle Tissue of Fish Collected from the San Joaquin River and Sacramento River Watersheds and Delta During 2005


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# Executive Summary

Data collected in the 1970s thorough 2003 document that fish collected from some Central Valley and Sacramento/San Joaquin River Delta Estuary water bodies were contaminated with organochlorine (OC) pesticides and polychlorinated biphenyls (PCBs) at concentrations of concern for human health. Consequently, fish consumption advisories related to these organic contaminants were issued by the California Office of Environmental Health Hazard Assessment (OEHHA) for some of these Central Valley and Delta Estuary water bodies. Also as a result of OC pesticide or PCB fish contamination 11 Central Valley and Delta Estuary water bodies were placed by the Central Valley Regional Water Quality Control Board (CVRWQCB) on the Clean Water Act (CWA) §303d list as impaired. The primary intent of this project was to analyze OCs and PCBs in fish collected during 2005 from the Sacramento River watershed, San Joaquin River watershed, and Delta Estuary. Objectives of this project include (1) Provide data to assist the CVRWQCB assess contamination in fish collected from Central Valley and Delta water bodies (i.e., assist in decisions on CWA §303d listing, delisting, or continuing listing); (2) provide data to assist OEHHA determine whether fish from Central Valley and Delta Estuary waterways are safe for human consumption; (3) provide data for temporal trend analysis of fish OC/PCB contamination; (4) conduct a literature review on [a] temporal trends in OC pesticide and PCB fish contamination as well as methods for analyzing such trends, [b] OC and PCB fish contamination in Central Valley and Delta compared to that in other aquatic systems in the US and worldwide, and [c] determinants of OC and PCB bioaccumulation; and (6) offer recommendations to the SWRCB regarding monitoring fish OC pesticide and PCB contamination.

To predict whether fish are safe for human consumption fish tissue residues of OCs and PCBs were compared to 1999 OEHHA's screening values and to 2006 OEHHA-proposed screening values plus guidance tissue levels. Based on the 2005 data, I recommend 13 303(d) delistings (nine of 11 water bodies) for PCB, Group A pesticide, or DDT fish contamination (Table 47). I recommend that additional data be gathered in two of the 303(d) listed water bodies.

The 2005 data reveal that DDT fish contamination is neither extensive nor extreme in the San Joaquin River watershed and Delta. In only nine (Table 27) of 92 composites from six of 28 sites the ∑DDTs exceeded the 1999 OEHHA screening value. DDT levels in none of the 92 composites exceeded the 2006 OEHHA-proposed screening value. The lower Tuolumne River is not currently CWA 303(d) listed for DDT fish contamination. The ∑DDTs in two composites of Sacramento sucker (unpopular for human consumption) from the Tuolumne River exceeded the OEHHA 1999 screening value. DDTs in composites of carp and channel catfish collected from the Tuolumne in 2005 were considerably below the screening value. These two composites are adequate (SWRCB policy) for 303(d) listing of the Tuolumne if the 1999 OEHHA screening value remains in place, but not if the OEHHA 2006-proposed screening value is adopted. According to 2006 OEHHA recommendations, DDT concentrations in all 92 composites from fish collected in the San Joaquin River watershed and Delta during 2005 were such that 12 or more fish meals per month could be consumed.

Only two of 46 composites of fish collected in the Sacramento River watershed (18 sites) exceeded the 1999 OEHHA DDT screening value; DDT concentration in both composites was near the 1999 screening value and considerably below the 2006 0EHHA-recommended screening value. The 2005 data are insufficient to 303(d) list either site. The 2005 data document that DDT fish contamination is not a serious issue in the Sacramento River watershed.

Dieldrin concentration in only nine (Table 19) of 92 composites of fish from seven of 28 sites collected in the San Joaquin River watershed and Delta during 2005 exceeded the 1999 OEHHA screening value. Dieldrin in none of the 92 composites was above the 2006 OEHHA-proposed screening value. ∑Chlordanes in none, including those from the 303(d) listed water bodies, of the 92 composites exceeded the 1999 OEHHA screening value and were considerably below the 2006 OEHHA-proposed screening value. The 2005 data document that dieldrin and chlordane fish contamination is neither extensive nor extreme in the San Joaquin River watershed and Delta. In concert with OEHHA 2006 recommendations, dieldrin concentrations in all 92 composites from all sites sampled in the San Joaquin River watershed and Delta during 2005 were such that 12 or more fish meals per month could be consumed.

Dieldrin and chlordanes were not detected or below reporting level in 63 and 83%, respectively, of 46 composites of fish collected in the Sacramento River watershed. Only four composites (Table 41) from three of 17 sites exceeded the 1999 OEHHA dieldrin screening value. The three water bodies are not 303(d) listed for Group A pesticide contamination. Dieldrin in none of the 46 composites exceeded the 2006 OEHHA-proposed screening value. The ∑chlordanes in none of the 46 composites of fish sampled in the Sacramento River watershed exceeded the 1999 OEHHA screening value. Data are insufficient for listing any of the three sites at which dieldrin exceeded screening value. Clearly, Group A pesticide fish contamination in the Sacramento River watershed is neither extensive nor extreme. According to OEHHA 2006 recommendations, dieldrin concentrations in all 92 composites from all sites sampled in the Sacramento River watershed during 2005 were such that 12 or more fish meals per month could be consumed.

The ∑PCB congeners in 83% of 92 composites of fish collected in the San Joaquin River watershed and Delta were less than reporting level. Thus, PCB fish contamination is neither extensive nor extreme. In only seven composites (Table 10) from six of 28 sites the ∑PCBs exceeded the OEHHA screening value. None of the six water bodies are currently CWA 303(d) listed. All exceedances of the screening value were in older, fatty Sacramento sucker (unpopular for human consumption) that do not reflect current PCB exposure levels. With the exception of Sacramento sucker at six sites, PCB concentrations in all other species of fish caught at sites in the San Joaquin River watershed and Delta were such that 12 or more fish meals per month could be consumed (OEHHA, 2006).

PCBs were not detected or below reporting level in 76% of 46 composites from fish collected in the Sacramento River watershed. PCB fish contamination was neither extensive nor extreme. ∑PCBs in six composites (Table 34) from five of 17 sites exceeded the OEHHA screening level. None of the five water bodies are 303(d) listed. Data are insufficient (SWRCB policy) for 303(d) listing of the five water bodies. With the exception of six composites, PCB concentrations in all other species of fish caught at all sites in the Sacramento River watershed were such that 12 or more fish meals per month could be consumed.

Table 48 summarizes the highest OC pesticide and PCB concentrations in fish collected from four large river systems in the United States. Because whole fish were analyzed in these studies, it is impossible to compare these results to the 2005 fillet data from the California Central Valley and Delta. My prediction, however, is that OC pesticide contamination of fish in the San Joaquin River watershed and parts of the Delta was higher during the 1990s than in any of four river systems listed in Table 48.

My literature review revealed that there are many (Table 49) determinants of OC pesticide and PCB bioaccumulation in fish. Decline rates in OC pesticide and PCB contamination of fish collected in the Central Valley and Delta waterways are equivalent to those observed in other US water bodies (Table 50).

This report contains 33 recommendations that pertain mostly to (1) establishment of an ongoing and long-term persistent organic pollutants (POP) monitoring and assessment program at the State Water Resources Control Board that is effectively and consistently funded, (2) components of such a POP program, and (3) proposals for follow-up on results of this 2005 project.

# Introduction

The production of fish that are safe for human and wildlife consumption beneficial uses of aquatic resources in the Central Valley and Sacramento/San Joaquin River Delta Estuary. Concentrations of mercury and other contaminants in fish collected in the Central Valley and Delta Estuary were at levels of concern for human and wildlife health. Data on fish organic chemical contamination are not as extensive as for mercury, but relatively recent publications (Larry Walker Associates, 2001, 2002, 2003; Lee and Jones-Lee, 2002; Greenfield et al., 2004; Davis et al., 2008) summarized data documenting that organochlorine (OC) pesticide and/or polychlorinated biphenyls (PCBs) concentrations in fish collected in some Central Valley and Delta Estuary waterways exceeded thresholds for human health. Consequently, fish consumption advisories related to these organic contaminants were issued by the California Office of Environmental Health Hazard Assessment (OEHHA) for some of these Central Valley and Delta Estuary water bodies. Also as a result of excess OC pesticide or PCB contamination of fish tissue 11 Central Valley and Delta Estuary water bodies have been placed on the Clean Water Act (CWA) §303d list of impaired water bodies by the Central Valley Regional Water Quality Control Board (CVRWQCB).

Several large fish sampling projects have been undertaken recently (1998-2005) in the Central Valley and Delta Estuary with the focus on mercury contamination. Fish sampling was funded by CalFed, CVRWQCB, and the State Water Resources Control Board (SWRCB) Surface Water Ambient Monitoring Program (SWAMP). These samples have been analyzed for mercury. Some of the fish (1998-2003) also have been analyzed for OCs and PCBs. With funding from the Sacramento River Watershed Program (SRWP), Larry Walker Associates selected fish collected during 2005 in the Sacramento River watershed for analysis of OCs and PCBs. Analyses of the SRWP samples and those selected for this project were conducted at the California Department of Fish and Game Water Pollution Control Laboratory (DFG WPCL).

The primary intent of this project was to select and analyze for the bioaccumulative and biomagnified OCs and PCBs archived fish collected during 2005 in the Sacramento River watershed, San Joaquin River watershed and Delta Estuary. Objectives of this project include (1) Provide additional data to assist the CVRWQCB assess contamination in fish collected from Central Valley and Delta water bodies (i.e., assist in decisions on CWA §303d listing, delisting, or continuing listing—see Table 1); (2) Provide data to assist OEHHA in determining whether fish from Central Valley and Delta Estuary waterways are safe for human consumption; (3) Provide data that will contribute to the analysis of fish OD/PCB contamination temporal trends (i.e., for determining or predicting when it will be safe to eat fish for these water bodies and in deliberations regarding remediation); (4) Provide data that will contribute to assessment of the spatial distribution and extent of fish OC/PCB contamination in Central Valley and Delta Estuary waterways; (5) Provide data that will contribute to assessments of whether contamination levels are safe for wildlife; and (6) Provide data for assessing whether 'bridging' among fish species is possible (i.e., Can level of contamination in several species be predicted from contamination in key species?).

# Materials and Methods

## Selection of Sampling Sites

As stated above, all fish samples analyzed for OCs and PCBs in this project were originally sampled for mercury contamination projects. The rationale for selecting those sites is summarized in a QAPP prepared by Larry Walker Associates (Larry Walker Associates, 2006). Sites sampled for this and the SRWP projects are listed in Table 1. Fish from a subset of those sites will be selected for OC and PCB analyses for the current project. The criteria for selecting sites for fish analysis were: (1) They are on waterways appearing on the CWA §303d list of impaired (consequent to OC or PCB fish contamination) water bodies in the Central Valley (Table 2); (2) They were recommended by OEHHA; (3) They are sites with historical data on fish contamination and, thus, will contribute to the analysis of fish contamination temporal trends; (4) They will expand spatial coverage and, thus, contribute to assessment of the spatial distribution and extent of fish contamination in Central Valley and Delta Estuary waterways; and/or (5) They are sites where a large number of fish species were collected and, thus, provide data for assessing whether 'bridging' among fish species is possible.

## Fish Sampling, Sample Transport, and Sample Storage Procedures

DFG's Moss Landing Marine Laboratory (MLML) was responsible for all fish sampling. Fish sampling, sample transport, and sample storage procedures are described in the QAPP for this project (de Vlaming, 2006—see Attachment A) and the SRWP QAPP (Larry Walker Associates, 2006). Sample custody and documentation procedures also are thoroughly described in those QAPPs.

## Selection of Species to be Analyzed

A range of species was collected at the different sites. Largemouth bass was the key species for investigation of mercury contamination. For the current project white catfish and Sacramento suckers are the favored species for analyses because they are fatty bottom fish that tend to accumulate the contaminants of concern to a much greater extent than less fatty pelagic fish. The SRWP analyzed a large number of Sacramento suckers collected in the Sacramento River watershed during 2005. Thus, the Sacramento sucker data from the San Joaquin watershed and Delta can be directly compared to those collected in the Sacramento River watershed. This will aid in gaining an overall picture of contamination in the Central Valley and in assessing spatial variation in this region. While bottom dwelling fatty white catfish, channel catfish, and Sacramento suckers tend to bioaccumulate the contaminants of interest to a much greater extent than less fatty pelagic fish, the ability to generally predict (i.e., bridge among species) contaminant burdens in pelagic fish based on data collected from the more fatty fish would be very valuable. At some sites sampled during 2005 for the mercury projects several species of fish were collected. At the sites where several species were collected composites were prepared for all species where an adequate number of fish and tissue were available. Results of these analyses should provide preliminary data for predicting whether 'bridging' among fish species is possible (i.e., Can level of contamination in several species be predicted from contamination in key species?).

**Sample Handling and Custody**
Handling and storage of fish samples was as described in the DFG MLML SOP (Attachment A: SOP MPSL 104). The field coordinator was responsible for ensuring that each field sampling team adheres to proper custody and documentation procedures. A master sample logbook of field data sheets was maintained for all samples collected during each sampling event. A chain-of-custody (COC) form was completed after sample collection, archive storage, and prior to sample release.

**Compositing of Fish Samples**
All samples to be analyzed for OCs and PCBs were composited from three to five fish (see OEHHA, 2005). Compositing of samples was performed at the DFG MPSL. Preparation of the filets from which the samples were taken and the compositing procedures are described in the QAPP for this project (de Vlaming, 2006—Attachment A) and in the SRWP QAPP (Larry Walker Associates, 2006). At sites where a sufficient number of a species of interest were collected 'duplicate' composites were prepared for analysis. For some analyses (e.g., temporal and spatial variation) conducted, it is important to have an estimate of variability of contamination in species of interest at the sites. Therefore, the average of fish size (standard length) in the different composites were made as equivalent as possible. While OEHHA recommends that composite samples should be consistent with the '75 percent rule' (the smallest fish contributing to the composite should have a standard length no less that 75 percent of the largest fish), our interest in variability in contaminant residues in fish of equivalent average size took precedent over the '75 percent rule'. In a high percentage of the composite samples we selected for analysis the '75 percent rule' did apply, but not in all.

Seventy composite samples from fish collected in 2005 were analyzed for OCs and PCBs. All samples were composites of tissues from three to five fish. These composites consisted of 32 from white catfish, 20 from Sacramento suckers, five from channel catfish, three from large mouth bass, three from red-ear sunfish, four from carp, two from bluegill, and one each from striped bass, crappie, Sacramento perch, and Sacramento pike minnow. Fifteen and one composite samples from fish collected in 2000 and 2002, respectively, were analyzed for PCBs and OCs. All samples are composites from four to five fish. These composites consist of ten from white catfish, four from Sacramento suckers, and one each from carp and channel catfish.

**Fish Tissue Contamination Criteria**
To predict whether fish are safe for human consumption tissue residues of OCs and PCBs were compared to OEHHA's screening levels (Broadberg and Pollock, 1999) and proposed screening levels plus guidance tissue levels (OEHHA, 2006). To predict whether OCs and PCBs may be impacting wildlife tissue residues are compared to adverse effect concentrations reported in the science literature. Several statistical procedures (e.g., analysis of variance, t-tests, 95% confidence limits, and regression analysis) were used to assess spatial and temporal variation in fish contamination.

Table 3 summarizes OEHHA existing and proposed OC and PCB screening values; for chlordane, total DDT, dieldrin, toxaphene, and PCBs these screening values are 30, 100, 2, 30, and 20 µg/Kg wet weight and 200, 560, 16, 220, and 20 µg/Kg wet weight, respectively. OEHHA guidance tissue levels (GTLs) for the OCs and PCBs are illustrated in Table 4. GTLs vary with the number of fish meals consumed per month. For example, OEHHA suggests that if tissue residues of DDTs are 560 to 830 ppb no more than approximately eight fish meals per month should be consumed. If, however, fish tissue residues of DDTs are less that 560 ppb approximately 12 fish meals per month are acceptable.

**Analytical Procedures**
All fish composite analyses were conducted at the DFG WPCL and the Marine Pollution Studies Laboratory. Analytical procedures, detection and reporting levels, and QA measures are described in the QAPP for this project (de Vlaming, 2006—Attachment A) and the SRWP QAPP (Larry Walker Associates, 2006). Tables 5 and 6 provide a list of analytes measured in this project. All methods followed original SWAMP and DFG WPCL Standard Operating Procedures. The SOPs for organic constituents were written by DFG WPCL.

Tissue samples were analyzed at the DFG WPCL for OC pesticides and PCBs using dual column (DB5 and DB17) gas chromatography equipped with dual electron capture detectors (GC-ECD) and/or GC-MS, or high performance liquid chromatography-mass spectrometry (HPLC-MS). All positive results are confirmed using mass spectrometry. Reporting limits for the OC and PCB compounds in tissue range from 0.3 to 3 ng/g and 0.2 ng/g, respectively (Tables 7 and 8). Each sample run analysis included a set of certified analytical standards along with appropriate method blanks, fortified samples and duplicates. Any deviations were reported to the DFG WPCL QAO and to the project manager within 24 hours. The DFG WPCL QAO was responsible for documenting such deviations and issuing corrective actions, if appropriate. Any deviations and corrective actions will be noted in this report.

DFG WPCL conducts quality control through several activities and methodologies. These methods of quality control allow identification of possible contamination problem(s), matrix interference and the ability to duplicate/repeat results and produce accurate data. If control limits are exceeded the WPCL QAO reviews with appropriate laboratory staff to ascertain the possible cause of the exceedance. A review of SOPs was conducted and any deficiencies identified, documented, and corrected. In the event of deviation from QA specification verbal notification of the corrective actions is given to the project manager within 24 hours; a written report of the corrective action(s) is provided to the PI and project manager via email within 48 hours.

**Reporting Analytical Data**
In this report concentrations of OCs and PCBs are expressed as ng/g wet weight. PCB concentrations are the sum of congeners. DDT concentrations are the sum of DDD o, p'; DDD p, p'; DDE o, p'; DDE p, p'; DDMU p, p'; DDT o, p'; DDT p, p'. Chlordane is the sum of alpha-chlordene, gamma chlordane, cis-chlordane, trans-chlordane, cis-norachlor, oxychlordane, and trans-nonchlor. In calculation of contaminant means non-detects are

valued at zero, DNQ measurements (between detection level and reporting level) are valued at the DNQ estimation (as recommended by the SWAMP QA team).

# Results

## Data Quality

Several QA/QC procedures were performed during the analysis of fish tissue composites. Included were method detection limit determination, accuracy and precision assessment, method performance analysis, contamination assessment, recovery of target analytes assessment, and dual-column conformation. Outcomes of these QA/QC procedures were within limits identified in the project QAPP (de Vlaming, 2006—Attachment A) so the data presented herein are reported without qualifications and reliable.

Tissue concentrations of PCBs, chlordanes, dieldrin, and DDTs in all composites analyzed for this project and/or discussed herein are summarized in Appendix C tables C1, C2, C3, and C4, respectively.

### San Joaquin River Watershed and Delta

## Fish Tissue PCB Residues

*Frequency of contamination, spatial distribution, and comparison to OEHHA screening value*—Of the 92 fish (collected during 2005) tissue composite samples PCBs were below the reporting level (DNQ—detected but not quantified or non-detect) in 83%. In nine composite samples (10%) PCB concentrations ranged from 9 to 17 ng/g wet weight (Table 9). PCB concentrations in seven composites (8%) were at, or above, 20 ng/g (OEHHA 1999 screening level) with a range of 20 to 46 ng/g (Table 10). The highest levels of fish tissue PCB contamination were seen in the Tuolumne River, Mokelumne River, San Joaquin River and Delta sites downstream of these two tributaries. Other than this, no discernable spatial pattern of PCB contamination is recognizable. Northern Delta waterways are CWA 303(d) listed for PCB fish contamination. The composite of Sacramento suckers collected from Prospect Slough (northern Delta) contained 20 ng/g PCBs (almost certainly related to high composite lipid content); concentrations of PCBs in composites from white catfish and striped bass collected at this site were 12 and 10 ng/g and 11 ng/g, respectively (Table 9). Moreover, PCBs were below reporting level in nine composites of eight other species collected from Prospect Slough (Table 11). Thus, in all species analyzed in 2005, other than Sacramento sucker, PCB levels in the north Delta are such that up to 12 meals per month could be consumed (OEHHA, 2006—Table 4 in this report). On a weight-of-evidence basis these 2005 data do not support 303(d) listing of the north Delta, but are insufficient, according to the SWRCB policy document (SWRCB, 2004), for delisting the north Delta. Nine composites from eight species were available from Prospect Slough; five composites from five species were available from other sites in the northern Delta. The upper 95% confidence limit of the mean and geometric mean PCB concentration in composites from Prospect Slough and in all (14) composites from the northern Delta do not overlap the OEHHA screening value. From my perspective these data should be sufficient to delist the northern Delta. None of the other waterways in Table 10 are on the CWA 303(d) list for PCB contamination.

When Greenfield et al. (2004) analyzed data from fish collected during 1997 through 2001 there were eight of 15 composites from the San Joaquin River and Delta where PCB concentrations were higher than the 20 ng/g OEHHA screening value. The data from 2005-collected fish connote that PCB contamination has declined. The PCB concentration (86 ng/g) in a composite of channel catfish collected from the Merced River during 1998 was higher than the OEHHA screening value (Greenfield et al., 2004). PCB concentrations derived from Sacramento suckers caught in the Merced River during 2005 suggest a decline in PCB contamination in this river.

While PCB concentration in a composite of Sacramento sucker collected from the San Joaquin River @ Vernalis slightly exceeded (27 ng/g) the OEHHA screening value, PCBs in 22 composites of fish collected from the lower San Joaquin River were below the screening value. Therefore, the 2005 data do not support listing of the lower San Joaquin River. Moreover, current data suggest that it is only the older, fatty Sacramento sucker that exceed the OEHHA screening value.

In contrast to PCB concentrations in a composite of Sacramento sucker (Table 10) caught from the Tuolumne in 2005, levels in channel catfish and carp from that site were below reporting level. Because there were two Sacramento sucker composites with PCB concentrations exceeding the OEHHA screening level there are sufficient data for 303(d) listing of this river according to SWRCB policy (SWRCB, 2004). I would recommend more data be collected before such an action is considered since old, fatty Sacramento sucker (that do not reflect current PCB exposure levels) was the only species to manifest PCB levels in excess of the screening level. I recommend multiple composites from five to seven species other than Sacramento sucker from the Tuolumne River be analyzed for PCBs.

The highest composite PCB concentration in a Sacramento sucker (from Potato Slough) composite was 46 ng/g (Table 10). In all other species collected in the San Joaquin River watershed and Delta PCB levels were such that up to 12 fish meals per month could be consumed (OEHHA, 2006—Table 4 in this report). If Sacramento sucker is consumed, no more than eight meals per month should be consumed of fish caught from Prospect Slough, the lower Mokelumne River (Lodi Lake) and the San Joaquin River around Vernalis; no more than four meals of fish caught at Big Break, Potato Slough and from the lower Tuolumne River (OEHHA, 2006—Table 4 this report). The level of contamination in the Sacramento sucker should not be extrapolated to other species at these sites. Because there was only one composite exceeding the screening level from Big Break (west Delta), Potato Slough (east Delta), and the Mokelumne River, data are insufficient for 303(d) listing (SWRC, 2004). Additional data should be gathered from Potato Slough in eastern Delta, Big Break in the western Delta, Prospect Slough in the north Delta, Tuolumne River; Mokelumne River and lower San Joaquin River. The focus should be on species favored by fishermen. Almost certainly data from other species will reveal that Sacramento sucker is the only species with PCB levels exceeding the screening value.

The mean and geometric mean (with lower and upper 95% confidence limits) PCB concentrations in white catfish (32 composites) collected in the San Joaquin River watershed and Delta are 5, 4-6 and 4, 3-5 ng/g, respectively; median concentration is 3.5 ng/g. Coefficient of variation for the means is 86 and 60%, respectively, indicating that the PCB data are a better fit to a log-normal distribution. The mean and geometric mean (with lower and upper 95% confidence limits) PCB concentrations in Sacramento sucker (16 composites) collected in the San Joaquin River watershed and Delta are 18, 10-26 and 11, 6-21 ng/g, respectively; median concentration is 15.5 ng/g. Coefficient of variation for the means is 78 and 51%, respectively, indicating again that the PCB data are a better fit to a log-normal distribution. The upper 95% confidence limit for the Sacramento sucker, but not white catfish and the geometric mean overlaps the PCB OEHHA screening value. Table 12 is a summary of mean PCB levels, along with lower and upper 95% confidence limits, for the San Joaquin River and areas of the Delta. While sample sizes are generally small, the values in this table provide an indication of statistically significant differences when comparing groups of sites, species, and to OEHHA screening values. Non-transformed and log-transformed data suggest that white catfish from the east Delta were somewhat more contaminated than the same species from the San Joaquin River, as well as the south and west Delta (Table 12). Data presented in Table 12 also show that the PCB upper 95% confidence limit (both actual and log-transformed) for white catfish collected from the San Joaquin River, west, and south Delta do not overlap the OEHHA PCB screening value (20 ng/g). While the Sacramento sucker sample size was low this species was more PCB-contaminated than white catfish. The relatively high Sacramento sucker means for the east and entire Delta were driven by a single composite (46 ng/g) of Sacramento sucker caught at Potato Slough. Analyses in this report reveal that PCB (as well as OC pesticides) concentrations in larger, fatty Sacramento sucker do not equate to current high exposure levels at a sampling station. Statistical comparisons were also performed by calculating the t statistic, as did Greenfield et al. (2004). The formula utilized was:

$$t = (\mu - X)/sd/\sqrt{n})$$

Where $\mu$=screening value; X=mean PCB concentration for the water body; sd=standard deviation; and n=number of sample composites. The results of this operation coincided with application of the 95% confidence interval. That is, for the San Joaquin River and the east and west regions of the Delta mean PCB concentrations in white catfish were significantly less than the OEHHA screening value.

PCB contamination of fish in the San Joaquin River watershed and Delta is not extensive and low (below OEHHA screening levels). The only fish with PCB concentrations greater than the screening level were old, fatty Sacramento sucker. This species is not ideal for prediction of current PCB contamination at sites (see section below on the relationship between tissue PCB concentrations and lipid content).

*PCB levels among species*—Table 13 summarizes the relationship among PCB contamination, fish species, length, and composite lipid content. Frequently Sacramento suckers were the largest fish collected at the sites, but not in all cases. Comparing PCB contamination in white catfish and Sacramento sucker collected from the entire Delta and the San Joaquin River, both actual and log-transformed data indicate that Sacramento sucker were significantly more PCB-contaminated than white catfish (Table 13).

Although there was not significant difference in size of fish in Sacramento sucker and channel catfish composites, a higher percentage of Sacramento sucker contained detectable PCB concentrations. Furthermore, the carp analyzed for PCBs were significantly larger than Sacramento sucker, yet a higher percentage of Sacramento suckers contained detectable PCB levels. Sacramento sucker tissues samples were considerably fattier than all other species analyzed. Lipid content in Sacramento sucker fillets is a primary determinant of hydrophobic chemical contamination and this species is not optimal for assessing current exposure levels at sampling sites (see below). These data suggest that large Sacramento suckers may be the preferable indicators of PCB contamination. Further, this species is not popular for human consumption.

Composites from nine different species collected from Prospect Slough, seven different species collected from the San Joaquin River at Crows Landing and from the San Joaquin at Vernalis were analyzed for PCBs (Table 11). Composites from three species (Sacramento sucker, channel catfish, carp) were available from the Merced and Tuolumne Rivers. Composites from three species also were available for the Calaveras River (white catfish, bluegill, red-ear sunfish), Paradise Cut (white catfish, bluegill, red-ear sunfish), and Frank's Tract (white catfish, bluegill, Sacramento perch). Composites from two species were available for the Stanislaus River (Sacramento sucker, channel catfish), Cosumnes River (Sacramento sucker, channel catfish), Salt Slough (channel catfish, carp) Big Break (Sacramento sucker, white catfish), San Joaquin River @ Laird Park (white catfish and red-ear sunfish), Mokelumne River (Sacramento sucker, rainbow trout)., Whiskey Slough (white catfish, bluegill), Middle River @ Hwy 4 (white catfish and bluegill), Old River @ Tracy Blvd (white catfish and bluegill), Clifton Court Forebay (white catfish and bluegill), Smith Canal (white catfish, red-ear sunfish) Lost Slough (Sacramento sucker, bluegill). Other than the two composites of white catfish from Prospect Slough the only measurable tissue PCBs at this site were observed in Sacramento suckers (Table 11). This is not particularly surprising given that Sacramento suckers were frequently the largest (and probably oldest) fish collected at the sites. However, fish size is not the only parameter affecting PCB contamination. The average lengths of carp in composites from the San Joaquin at Vernalis and from Prospect Slough (505 and 517 mm, respectively) were greater than those of the Sacramento suckers (463 and 434, respectively) from the two sites yet PCBs were lower than the reporting level in the carp composites. These differences are almost certainly related to relatively higher lipid content in Sacramento sucker tissues. Percent lipid in Sacramento sucker and carp composites from fish collected at Vernalis was 4.62 and 1.14%, respectively, and at Prospect Slough was 4.84 and 0.70%, respectively.

Sacramento sucker were the only species collected at the Crow's Landing, Vernalis, Tuolumne River, and Merced River sites with measurable PCB levels (Table 11). PCBs were below reporting level in the three species taken at the Paradise Cut and Frank's Tract sties. In composites of channel catfish and Sacramento sucker from the Stanislaus and Cosumnes Rivers and in composites of channel catfish and carp from Salt Slough PCBs were below reporting level. PCBs were below reporting level in both species from the Lost Slough, Clifton Court Forebay, Middle River, and San Joaquin River @ Laird Park sites. PCB concentrations in two composites of Sacramento sucker collected from the Mokelumne River @ Lodi Lake were 13 and 23 ng/g, but below reporting level in a composite of rainbow trout. In a composite of Sacramento sucker caught at Big Break the ∑PCBs was 33, but less than the reporting level in a composite of rainbow trout. PCB concentrations in two composites of white catfish from Smith Canal were 12 and 16 ng/g while below reporting level in a composite of red-ear sunfish.

*Hatchery fish*—Rainbow trout composites from the Moccasin Creek and San Joaquin River hatcheries were analyzed for PCBs. Concentration in both composites was below reporting level. Chinook salmon composites from Merced River and Mokelumne hatcheries also were analyzed; concentrations of PCBs in these composites were 9 and 10 ng/g, respectively.

*Relationships among tissue PCB concentration, tissue lipid content and composite mean fish length*

Sacramento sucker

In this project, 16 composites of Sacramento suckers collected from the San Joaquin River watershed and Delta were analyzed for PCBs. Non-transformed and log-transformed PCB tissue concentration data fit a normal distribution; the non-transformed concentration data were a better fit than the log-transformed data. Log-transformed composite % lipid, but not non-transformed, data fit a normal distribution. Neither non-transformed nor log-transformed mean fish length data fit a normal distribution. The failure of the mean length data to fit a normal distribution may be consequent to the variation in fish sizes constituting the composites and the tendency to select the largest fish collected. In all cases the small sample size possibly confounded assessment of normal distribution.

Results of regression analyses are summarized in Table 14. A statistically significant relationship between composite % lipid and PCB concentration was detected. Percent lipid in composites appears to account for up to 76% of the variation in tissue PCB concentration (Table 14). A statistically significant relationship also was noted between mean length of fish in composites and PCB concentration, but could account for less (approximately 52%--Table 14) of the variability in levels. Length/age of Sacramento sucker appears to be a determinant of tissue lipid levels, but could account for less than 45% of the variability in this parameter. In a multiple regression with log composite % lipid and log composite mean fish length as the independent variables and log PCB concentration as the dependent variable the $R^2$ was 0.81 ($P<0.00001$). Addition of length as a predictor of PCB concentration only slightly increased the $R^2$ (from 0.76) compared to the regression with log % lipid alone; further, length was not a statistically significant predictor of PCB concentration in the multiple regression. Wet weight PCB concentrations (non-transformed and log-transformed) were regressed on lipid-normalized PCB concentrations; results disclosed that lipid-normalized values were significant predictors of wet weight PCB concentrations, providing further support for lipid being a determinant (not simply current exposure level) degree of Sacramento sucker PCB contamination (Table 14). Sites were ranked based on the lipid content of composite(s) and on level of PCB concentration; a rank correlation analysis was then performed. The $R^2$ for this analysis was 0.81 ($P<0.00001$) and the slope was 0.93. These results provide robust evidence that lipid content of Sacramento sucker is a better predictor of PCB contamination than exposure level at a site. Moreover, there is no reason to believe that PCB exposure levels at sites would be dictated by lipid content of Sacramento sucker. Further, these findings call for a re-evaluation of assumptions regarding PCB/OC pesticide fish contamination. A similar link was not, however, detected in white catfish collected at sites in the San Joaquin River watershed and Delta, so the situation with Sacramento sucker should not be extrapolated to other species without confirming data. If lipid content is the only determinant of Sacramento sucker tissue PCB concentrations, a regression of lipid-normalized PCB concentration on percent lipid should not yield a statistically significant $R^2$ (Herbert and Keenlyyside, 1995). While the $R^2$ of log-transformed data was only 0.34 there was a statistically significant relationship (Table 14). This finding suggests that lipid content is co-varying with another or other PCB concentration determinants (see Discussion section on determinants of POP concentrations).

Geometric wet weight and lipid-normalized mean (with lower and upper 95% confidence limits) PCB concentrations in Sacramento sucker are 11, 6-12 and 407, 284-583 ng/g respectively. Coefficients of variation for these means are 51 and 11%, respectively, disclosing that lipid-normalization reduces variability in the PCB data.

Tables 15 and 16 summarize regression coefficients ($R^2$) and rank (sites ranked by level of contamination) correlation coefficients (Rho), respectively, from analyses of wet weight and lipid-normalized PCB/OC pesticide concentrations in Sacramento sucker collected in the San Joaquin River watershed and Delta. Note that in both analyses statistically significant associations were observed between contaminant wet weight concentrations, but not with lipid-normalized concentrations. The fact that positive statistically significant associations among the three contaminants *implies* that sites that are the most are contaminated by all three of the contaminants (PCBs, DDTs, and dieldrin). Moreover, the implication is that there is a ranking of sites by total PCB/OC pesticide contamination; that is, the most contaminated sites are contaminated by PCBs, DDTs, and dieldrin. Why should Sacramento sucker tissue PCB concentration at a site predict DDT and dieldrin tissue concentrations unless there is parallel contamination of PCBs, DDTs, and dieldrin at the sites sampled? Such a situation does not seem likely. I propose an alternative interpretation that is supported by data in Tables 15 and 16. My hypothesis is that exposure levels of PCBs, DDTs, and dieldrin are not necessarily the highest at sites with the most contaminated Sacramento sucker. I propose that factors, conditions, and the fish at sites differ and those with the most contaminated Sacramento sucker have conditions most favorable to bioaccumulation and biomagnification. Body lipid and a host of other physical, chemical, ecological, and physiological factors that affect bioaccumulation (see Discussion section on determinants of tissue and body concentrations of persistent organic pollutants—POPs). The data in Tables 15 and 16 provide impelling evidence that, in the San Joaquin River watershed and Delta, lipid content of Sacramento sucker was a more significant determinant of PCB/OC concentration in fish than site exposure level. Five of the Sacramento sucker composites that exceeded the OEHHA dieldrin (55% of exceedances) screening value also exceeded the PCB (83% of exceedances) and DDT (55% of exceedances) screening levels providing further evidence that these old, fatty Sacramento sucker are not providing an assessment of current PCB/OC pesticide exposure levels. That is, contaminant concentrations in these old, fatty Sacramento sucker are consequent to historic exposure throughout their lives. It is inappropriate to use Sacramento sucker contaminant levels to predict current exposure levels or contaminant levels in shorter-lived, less fatty fish at a site.

White catfish

PCBs were measured in 32 composites of white catfish captured in the San Joaquin River watershed and Delta. Neither non-transformed nor log-transformed tissue PCB concentration, tissue lipid content, and composite mean fish data were normally distributed. Most likely, this is related to the fact that these three parameters (especially composite lipid content and PCB concentration) were less variable in white catfish than in Sacramento sucker (see above).

Table 17 summarizes the results of regression analyses with white catfish data. In contrast to results with Sacramento sucker, no significant relationships were seen among composite tissue lipid content, composite mean fish length, and tissue PCB levels. The slopes of the regressions of PCB concentration on average length of fish in composite were negative, with the value of the log:log plot being -0.38. Fish length may be a weak (accounting for no more than 22% of the variability), but significant, predictor of muscle lipid content (Table 17). There was no covariance of contaminant concentrations in white catfish associated with sites as detected in the Sacramento sucker data. This result is almost certainly related to the lower and lesser variation in lipid levels in white catfish compared to Sacramento sucker. Moreover, lipid levels in white catfish composites do not appear to be a major determinant of tissue PCB concentrations in white catfish. Therefore, white catfish are probably more accurate assessors of current PCB/OC pesticide exposure levels than Sacramento sucker.

Channel catfish and carp

Tissue PCBs were analyzed in nine and seven composites of channel catfish and carp, respectively. Channel catfish composite lipid content ranged from 0.37 to 1.08% with a mean of 0.74%; tissue PCB concentrations were below reporting level in all composites, estimates ranging from 2 to 6 ng/g. So, there was no apparent relationship between composite lipid content and PCB concentration. Carp composite lipid content ranged from 0.40 to 1.65% while PCB concentrations were below reporting level in all composites, with estimates ranging from 2 to 12 ng/g. Regression analysis disclosed a significant association between log percent lipid and log estimated PCB concentration ($R^2$=0.73, P=0.01). Note that PCB concentrations were higher and more variable in the two species, Sacramento sucker and carp, with higher lipid content.

The lack of statistically significant relationships in many of these regression analyses should be interpreted with caution. Several factors could affect the outcome of these analyses, including overall relatively low levels of PCB contamination in the San Joaquin River watershed and Delta, and fish were collected from multiple sites that potentially varied in level of PCB contamination. Furthermore, lipid content in white catfish was relatively low and not that variable. For ideal regressions to assess the role of lipid in determining contaminant concentrations there would be sufficient samples at each site to complete adequate analyses (i.e., decreasing the exposure level variable).

*Same species 'duplicates'*—Two 'duplicate' composites of white catfish were analyzed at 13 sites. In ten of the 'duplicate' composites both were below reporting level. In the other three 'duplicate' composites the difference was 1 (average length of fish in composite 258 and 258 mm), 2 (average length 255 and 253 mm), and 3 ng/g (average length 263 and 272 mm). Although limited, these data indicate relatively good consistency of composites within this species in individuals of equivalent size. The consistency is likely due to a large extent to the over all low PCB tissue levels in the San Joaquin River watershed and Delta. Percent lipid in the 'duplicate' white catfish composites was relatively equivalent. Two separate composites of Sacramento suckers were analyzed at six sites. PCBs in both composites were below reporting level at four of these sites. In the two other paired composites the differences were 6 (average lengths of fish in composites were 456 and 466 mm) and 10 ng/g (average lengths were 455 and 458 mm). Differences in tissue lipid content could not account for the 6 ng/g difference, but may have been a factor in the 10 ng/g difference. Although there were fewer paired composite 'duplicates' for Sacramento suckers, consistency appears less than with white catfish. This almost certainly due to the difference in lipid levels in the Sacramento from different sites.

*Temporal trends*—Assessing temporal trends is difficult when the same sites and same species are not sampled yearly as well as when the number of samples analyzed in inadequate for robust statistical analyses. Spatial and temporal variation in OC pesticide and PCB fish contamination are realities. Thus, sampling numerous (same) sites, the same species per site, and 'replicate' composites per site on a yearly or every other year basis is essential for accurate temporal trend analysis as well as for predicting future changes in fish contamination. While fish sampling for OC/PCB contamination in the Sacramento River watershed has been more extensive than in the San Joaquin River watershed and Delta, all of the above problems plague temporal trend analyses of fish contamination in Central Valley waterways. Clearly there was and is no consistent strategy or plan for addressing this issue.

The analysis of Greenfield et al. (2004) revealed that OC pesticide and PCB contamination of fish in Central Valley declined rapidly in the 1970s to the mid-1980s, but the rate of decrease slowed in the 1990s such that statistical differences could not be detected among years. Inability to detect statistically significant decreases almost certainly relates to the small number of sites, samples, and duplicates. Given that the rapid decline in the 1970s and early-1980s has been documented, my focus is on the period between 1990 and 2005. Thus, I examined the SFEI database for fillet composites of Sacramento sucker, white catfish, channel catfish, and carp collected in that period. For the San Joaquin River watershed and east, south, and west Delta only 18 composites of these species were available for this 15 year period, 16 of white catfish plus one each of channel catfish and carp. All these composites were from fish collected in 1998 except one of Sacramento sucker (from Stanislaus River) and one of white catfish (from Salt

Slough) taken in 1990. The ∑PCBs in the 1990 composite of Sacramento sucker collected from the Stanislaus River was reported as 330 ng/g whereas in 'duplicate' composites of Sacramento sucker and in a composite of channel catfish caught at this site in 2005 PCBs were below the reporting level, documenting a considerable decline in PCB contamination in this river. The ∑PCBs in a composite of channel catfish collected at this site during 2005 was below the reporting level. These findings document a major decline in PCB fish contamination in this river. PCB levels in composites of white catfish collected from Salt Slough during 1990 and 1998 were below the reporting level and 17 ng/g, respectively. Concentration in two composites of channel catfish captured at this site during 2005 were both below reporting level, suggesting a decline to below reporting level of PCB fish contamination at this location (especially given that channel catfish tend to be fattier and more contaminated than white catfish). The ∑PCBs in a composite of channel catfish collected from the Merced River in 1998 was 86 ng/g. PCBs were below the reporting level in 'duplicate' composites of Sacramento sucker collected in the Merced River during 2005. These data suggest a large decline to below reporting level in PCB fish contamination in this river since 1998, however, a caveat is that the lipid content in the 1998 catfish composite was 5.50% whereas 2.29 and 1.61% in the 2005 Sacramento sucker composites. At issue is whether it is only exposure level that determines tissue levels of PCBs/OC pesticides or do other factors such as age, lipid content, trophic position, plus other factors contribute significantly or to a greater extent compared to exposure level. Herein, I provide evidence that in some species (e.g., Sacramento sucker) that current exposure level (contaminant levels in food items) is not always the primary determinant of PCB/OC pesticide tissue concentrations.

As with white catfish collected in the San Joaquin watershed and Delta during 2005, PCB concentrations (non-transformed nor log-transformed) in composites of fish taken during 1998 were not significantly related to composite percent lipid ($R^2$=0.14 and 0.01, respectively). Mean PCB concentrations in composites of white catfish collected from the San Joaquin River watershed and Delta during 1998 (n=14) and 2005 (n=32) were compared in a t-test. Means for 1998 and 2005 were 32 (coefficient of variation=91%) and 5 ng/g (CV=86%), respectively, and significantly different (P<0.002). PCB geometric means for 1998 and 2005 were 21 (CV=14%) and 4 (CV=60%), respectively, and highly significantly different (P=0.0005). CVs for the geometric means were lower indicating that the PCB concentrations are more log-normal distributed. PCB medians for 1998 and 2005 were 18.5 and 3.5 ng/g, respectively. The decrease in PCB mean and geometric mean concentration between 1998 and 2005 was 85 and 83% respectively; decline of median concentration was 81%. If decline was relatively constant between 1998 and 2005 the rate would be approximately 12% year. With this rate of decline the average PCB concentration in white catfish in the San Joaquin River watershed and Delta should be 1 ng/g or less during 2008. Summarized below are concentrations (ng/g) of PCBs in composites of white catfish collected during 1998 and 2005 at the same sites.

| | 1998 | 2005 |
|---|---|---|
| SJR @ Veranlis | 16, 39 | <RL |
| Smith Canal | 105 | 17, 16 |
| Middle River | 10 | <RL, <RL |

| | | |
|---|---|---|
| Old River | 27 | <RL, <RL |
| Paradise Cut | 17 | <RL, <RL |

While white catfish, channel catfish, carp, and all other species analyzed indicate that PCB concentrations at most locations in the San Joaquin River watershed and south, east, and west portions of the Delta are near, or below reporting level and approaching zero, PCB concentration in composites of Sacramento sucker collected from Big Break, the Mokelumne River, the San Joaquin River @ Vernalis, Potato Slough, and the Tuolumne River during 2005 ranged from 20 to 46 ng/g. Due to several considerations (not just exposure levels) spatial differences in rates of PCB decline are likely (see Discussion section on determinants of contaminant concentrations). There are insufficient data to estimate rates of decline in Sacramento sucker, channel catfish, and carp at these five sites. Future investigations into PCB fish contamination should focus on or include these five locations. As stated above, however, Sacramento sucker and possibly carp, from the San Joaquin River watershed and Delta do not reflect current PCB exposure levels (i.e., concentration of PCBs in food items). Further, it is only Sacramento sucker (not popular for consumption) that manifest PCB concentrations of concern for human health.

**Fish Tissue Chlordane Residues**

Of the 92 fish tissue composite samples chlordane was below the reporting level (DNQ—detected but not quantified) in 83%; chlordane was not detected in one composite sample. In 17% of composites, from 11 sites, chlordane concentrations ranged from 1 to 25 ng/g wet weight. The 11 sites were:

Merced River @ Hatfield Park: Sacramento sucker composite, 1 ng/g
Tuolumne River @ Shiloh Road: Sacramento sucker composites, 14.& 12 ng/g
Mokelumne River @ Lodi Lake: Sacramento sucker composites, 3 & 2 ng/g
San Joaquin River @ Crows Landing: Sacramento sucker composite, 7 ng/g
San Joaquin River @ Laird Park: White catfish composites, 6 & 3 ng/g
San Joaquin River @ Vernalis: Sacramento sucker, carp, and channel catfish composites, 12, 3, & 1 ng/g, respectively
San Joaquin River @ Hwy 99: Carp, 2 ng/g
Potato Slough: Sacramento sucker composite, 25 ng/g
Big Break: Sacramento sucker composite, 8 ng/g
Clifton Court Forebay: Bluegill, 2 ng/g
Prospect Slough: Sacramento sucker composite, 8 ng/g

Note that 10 of the 16 composites with measurable chlordane residues were from Sacramento suckers. The highest chlordane concentrations in Sacramento sucker were in fish from Potato Slough and the Tuolumne; lipid content in these two composites were the highest (12.17%) and second highest (4.84%) of the 16 Sacramento sucker composites analyzed in this project. Chlordane concentrations in all 16 composites were below the OEHHA screening level of 30 ng/g and considerably below the OEHHA 2006 proposed screening level of 200 ng/g. At all sites where fish were collected and with all species chlordane tissue concentrations are such that 12 or more fish meals a month can be consumed (OEHHA, 2006—Table 4 in this document).

The San Joaquin River, lower Merced River, lower Tuolumne River, lower Stanislaus River and the eastern and western Delta are currently on the CWA 303(d) list for Group A pesticides. Greenfield et al. (2004) also reported that chlordane fish tissue concentrations were below the OEHHA screening value in fish collected 1997 through 2001 from all these 303(d)-listed waterways. In the current study multiple composites from multiple species collected from the lower San Joaquin River were considerably below the OEHHA screening value. ∑Chlordanes in two composites from Sacramento sucker and one composite from channel catfish caught in the Stanislaus River were below reporting level. ∑Chlordanes in two composites from Sacramento sucker, one composite from carp, and one composite from channel catfish taken in the Merced River were below reporting level. In two composites from Sacramento sucker, one composite from carp, and one composite from channel catfish collected in the Tuolumne River chlordanes were below reporting level. ∑Chlordanes in one composite from Sacramento sucker, one composite from bluegill, one composite from red-ear sunfish, and four composites from white catfish collected in the east Delta were below reporting level; another composite of Sacramento sucker caught in the east Delta contained chlordanes below the OEHHA screening value. In five composites from white catfish, one composite from red-ear sunfish, and one composite from bluegill collected in the west Delta chlordanes were below reporting level; a composite of Sacramento sucker caught in the west Delta contained chlordanes below the OEHHA screening value. The 2005 data clearly illustrate that chlordane contamination of fish in the San Joaquin is neither extensive nor problematic in regard to human health concerns; combined with the 2005 dieldrin data these chlordane results do not support the Group A pesticide 303(d) listing of the Merced River, Tuolumne River, Stanislaus River, San Joaquin River, east Delta, and west Delta. According to SWRCB policy (SWRCB, 2004), however, these data are insufficient for delisting these water bodies because of too few samples (27 of 28) below the screening level. From my perspective monitoring funds could be utilized much more profitably on more pressing water quality issues.

*Hatchery fish*—Rainbow trout composites from the San Joaquin Hatchery and Moccasin Creek Hatchery were analyzed for chlordanes. Composites of Chinook salmon from the Merced and Mokelumne hatcheries also were analyzed for chlordanes. In all composites chlordanes were below reporting level.

*Temporal trends*—Assessing temporal trends is difficult when the same sites and same species are not sampled yearly as well as when the number of samples analyzed in inadequate for robust statistical analyses. Spatial and temporal variation in OC pesticide and PCB fish contamination are realities. Thus, sampling numerous (same) sites, the same species per site, and 'replicate' composites per site on a yearly or every other year basis is essential for accurate temporal trend analysis as well as for predicting future changes in fish contamination. While fish sampling for OC/PCB contamination in the Sacramento River watershed has been more extensive than in the San Joaquin River watershed and Delta, all of the above problems plague temporal trend analyses of fish contamination in Central Valley waterways. Clearly there was and is no consistent strategy or plan for addressing this issue.

The analysis of Greenfield et al. (2004) revealed that OC pesticide and PCB contamination of fish in Central Valley declined rapidly in the 1970s to the mid-1980s, but the rate of decrease slowed in the 1990s such that statistical differences could not be detected. Inability to detect statistically significant decreases very possibly relates to the small number of sites, samples, and duplicates. Given that the rapid decline in the 1970s and early-1980s has been documented, my focus is on the period between 1990 and 2005. Thus, I examined the SFEI database for fillet composites of Sacramento sucker, white catfish, channel catfish, and carp collected in that period. For the San Joaquin River watershed and east, south, and west portions of the Delta only 18 composites of these species were available for this 15 year period, 16 of white catfish plus one each of channel catfish and carp. All these composites were from fish collected in 1998 except one of Sacramento sucker (from Stanislaus River) and one of white catfish (from Salt Slough) taken in 1990. Chlordane concentration in the 1990 composite of Sacramento sucker collected from the Stanislaus River was 172 ng/g whereas in 'duplicate' composites of Sacramento sucker and in a composite of channel catfish caught in 2005 ∑chlordanes were below reporting level, signifying considerable decline in contamination in this river. Chlordane concentrations in composites of white catfish collected from Salt Slough during 1990 and 1998 were less than reporting level and 1 ng/g, respectively. Levels in two composites of channel catfish captured at this site in 2005 were both below reporting level, suggesting that chlordane contamination at this location remains low to non-existent. The ∑chlordanes in a composite of channel catfish collected from the Merced River in 1998 was 23 ng/g. Chlordanes were below reporting level and 1 ng/g in two composites of Sacramento sucker caught in the Merced River during 2005. Chlordane was below reporting level in 83 % of 92 composites from fish collected from the San Joaquin River watershed and south, east, and west portions of the Delta in 2005. In all but one of 14 composites in which chlordane was detected concentrations were 6 ng/g or less. The mean concentration and geometric mean of chlordane in composites from white catfish (n=14) collected during 1998 was 8 (coefficient of variation=90%) and 5 ng/g (CV=60%), respectively. CVs for these means indicated that chlordane concentrations are log-normally distributed. Summarized below are chlordane concentrations (ng/g) in composites of white catfish collected during 1998 and 2005 at the same sites.

| | 1998 | 2005 |
|---|---|---|
| SJR @ Veranlis | 12, 16 | <RL |
| Smith Canal | 5 | <RL |
| Middle River | 1 | <RL |
| Old River | 13 | <RL |
| Paradise Cut | 5 | <RL |

Even though chlordane fish tissue concentrations were low in 1998, they continued to decline through 2005. This decline is emphasized given that most of the composites in which chlordanes were detected (all except one composite 6 ng/g or less) in 2005 were from Sacramento sucker (10), channel catfish (1), and carp (1); these species tend to be fattier and more contaminated than white catfish. Thus, chlordane does not appear to be a prominent issue in the San Joaquin River watershed and east, south, and west portions of the Delta since fish contamination is less than or near reporting level.

**Fish Tissue Dieldrin Residues**

*Frequency of contamination, spatial distribution, and comparison to OEHHA screening value*—Dieldrin was below the reporting level (DNQ—detected but not quantified) in 38% of the 92 composite samples; in one composite sample dieldrin was not detected. In 36, 16 (Table 18), and 10% (Table 19) of the composites dieldrin concentrations were reporting level to 1.0, 1.1 to 1.9, and 2.0 ng/g (the OEHHA screening level) or above, respectively. Dieldrin concentrations in fish tissue composites were above the OEHHA 1999 screening value at seven sites (Table 19). Tables 18 and 19 illustrate that dieldrin contamination was greatest in upper San Joaquin River tributaries (Salt Slough, Merced River, and Tuolumne River), the main-stem San Joaquin River, and extends into the Delta. By far the highest dieldrin concentration (13.9 ng/g) observed in the 2005 samples was in a composite of Sacramento suckers collected from Potato Slough; dieldrin level in the other eight composites listed in Table 19 was 4 ng/g or less. Lipid content in the Potato Slough composite was 2.5 to 12X higher than in the other 15 Sacramento composites analyzed from the San Joaquin River watershed and Delta.

Dieldrin concentration of Sacramento sucker and carp collected from Prospect Slough (north Delta) were higher than 2 ng/g, but levels in eight composites of seven other species (Table 20) were less than 2 ng/g. While these data appear sufficient (SWRCB, 2004) for CWA 303(d) listing of the north Delta, I recommend that additional data be collected because the Sacramento sucker, not popular for consumption, composite had high lipid content and dieldrin concentration in the carp composite (2.1 ng/g) was near the screening value. Dieldrin concentration in a composite of channel catfish from Salt Slough was 2.5 ng/g whereas in a composite of carp from this site the level was 1.35 ng/g. A second composite with concentration greater than the screening value would be needed to 303(d) list Salt Slough. The lower Merced, Tuolumne, and Stanislaus Rivers, as well as the lower San Joaquin River, east, and west Delta are on the CWA 303(d) list for Group A pesticide contamination. With the exception of the nine composites listed in Table 18, dieldrin levels in all other composites from the San Joaquin River watershed and Delta were less than 2 ng/g (38% of 92 composites below reporting level). Dieldrin in all 92 composites was below the 2006 OEHHA proposed screening value of 16 ng/g.

Dieldrin concentrations were less than 2 ng/g in 19 composites from fish collected in the lower San Joaquin River, but grater than 2 ng/g in three composites. Consequently, these data are insufficient for delisting the lower San Joaquin River based on the SWRCB policy document (SWRCB, 2004). However, the upper 95% confidence limit of the mean and geometric mean dieldrin concentration in the 22 composites from fish collected in the lower San Joaquin River do not overlap the OEHHA 1999 screening value. Thus, combined with the chlordane data, I contend that the weight of evidence is sufficient for delisting the lower San Joaquin River for Group A pesticide fish contamination.

While dieldrin concentration in a composite of Sacramento sucker caught from the Tuolumne River was 2.5 ng/g, levels in a second Sacramento sucker composite, a carp composite, and a channel catfish composite from fish collected at this site were below reporting level. Although it is apparent that it is only older, very fatty Sacramento sucker from the Tuolumne River that manifest dieldrin levels above the OEHHA screening value, the 2005 data are not adequate for delisting (SWRCB, 2004) this river (another 24 composites or individual fish samples below the screening level would be needed). Dieldrin concentrations in two composites of Sacramento sucker, one composite of channel catfish, and one composite of carp collected from the Merced River were all less than reporting level. Dieldrin levels in three (two Sacramento sucker and one channel catfish) composites from fish collected in the Stanislaus River were non-detect and below reporting level. While it is very clear that dieldrin contamination is not currently a problem in the Merced and Stanislaus Rivers, it appears that the 2005 data are insufficient (SWRCB, 2004) to 303(d) delist these water bodies. Another 25 composites or individual fish samples (from each river) below the 1999 screening level would be required to meet the SWRCB policy. Monitoring funds almost certainly could be spent more productively on more pressing water quality issues. On a weight of evidence basis, I recommend that the Merced, Tuolumne, and Stanislaus Rivers be delisted for Group A pesticide fish contamination. If the 2006 OEHHA recommended screening level of 16 ng/g is adopted by the CVRWQCB, delisting of these water bodies should definitely occur.

While dieldrin concentration was higher than 2 ng/g in the fat-laden composite of Sacramento sucker collected at Potato Slough, levels in eight composites from fish caught in the east and eight composites from fish collected in the west Delta were all less than the OEHHA screening value. Nonetheless, the 2005 data appear to be inadequate (SWRCB, 2004) to 303(d) delist these two portions of the Delta. This is unfortunate given that the weight-of-evidence reveals that dieldrin and chlordane are not contaminating consumable fish such that there is a risk to human health. It is only older, fatty Sacramento sucker, carp, and channel catfish that manifest dieldrin concentrations that exceed the screening level. Twenty composites or individual fish samples from the east and west Delta (total of 40) with dieldrin concentrations below the screening value will be needed for delisting (SWRCB, 2004). The upper 95% confidence limits for the mean and geometric dieldrin concentrations in nine and eight composites of fish collected in the eastern and western Delta, respectively, do not overlap the 1999 OEHHA screening value. Based on this weight of evidence I recommend 303(d) delisting of both regions of the Delta. As stated above, the CVRWQCB monitoring budget could most likely be spent more effectively on other water quality issues. Should the 2006 OEHHA-recommended screening level of 16 ng/g is approved by the CVRWQCB, delisting of these water bodies is definitely in order.

Composites with dieldrin concentrations greater than 2 ng/g all came from fatty, older fish and do not provide conclusive evidence that dieldrin contamination is currently high at the seven sites listed in Table 18 (see Discussion section on determinants of POP concentrations in fish). Furthermore, Sacramento sucker is not a popular fish for consumption. According to the OEHHA 2006 draft report, all locations in the San Joaquin River watershed and Delta where fish were sampled, dieldrin concentrations are such that 12 or more fish meals per month could be consumed.

The mean and geometric mean (with lower and upper 95% confidence limits) dieldrin concentrations in composites (n=16) of Sacramento sucker collected during 2005 in the San Joaquin River watershed and Delta are 2.2, 0.4-4.0 ng/g and 1.4, 0.8-2.5 ng/g, respectively; median concentration is 1.0 ng/g. Coefficients of variation (CV) for these means are 150 and 70%, respectively. The high variability in the dieldrin data and relatively high means are driven by one outlier (Potato Slough Sacramento sucker composite—13.9 ng/g). Without that value the means would be 1.4 and 1.2, respectively. CVs document that the dieldrin data are a better fit to a log-normal distribution. The mean and geometric mean (± 95% confidence limits) dieldrin concentrations in composites (n=32) of white catfish collected during 2005 in the San Joaquin River watershed and Delta are both 0.6±0.1 ng/g; median concentration is 0.55 ng/g. Coefficients of variation (CV) for these means are 55 and 38%, respectively. Again, CVs document that the dieldrin data are a better fit to a log-normal distribution. The Sacramento sucker (without the Potato Slough composite) and white catfish average data indicate overall low levels of dieldrin contamination in the San Joaquin River watershed and Delta with minimal threats to human health from fish consumption.

Table 21 is a summary of mean dieldrin levels, along with lower and upper 95% confidence limits for the San Joaquin River and areas of the Delta. Results of both log-transformed and non-transformed data are included in the table. While sample sizes are generally small, the values in this table provide an indication of statistically significant differences when comparing groups of sites, species, and to OEHHA screening values. Both non-transformed and log-transformed data suggest that white catfish from the San Joaquin River were slightly, but significantly more dieldrin-contaminated than the same species captured in the east, south, and west Delta (Table 21). The dieldrin upper 95% confidence limit (both actual and log-transformed) for white catfish collected from the San Joaquin River, east, south, west and entire Delta do not overlap the OEHHA 2ng/g screening value (Table 21); t-test results yielded the same outcome. The same does not hold for Sacramento suckers, but only six composites were available for the entire Delta and San Joaquin River combined. The relatively high means for the east and entire Delta are consequent to one composite from Potato Slough (13.9 ng/g). Dieldrin concentration in another composite from the east Delta was 0.4 ng/g.

While the average length of Sacramento suckers in the Potato Slough composite (481 mm) was somewhat higher than the composites from Vernalis (463 mm), the Tuolumne River (466 mm), Big Break (458 mm), and Crow's Landing (421 mm), it is unlikely that fish size is the primary reason for the elevated dieldrin contamination of the Potato Slough Sacramento suckers. Moreover, lipid content (12.2%) in the Potato Slough composite was much greater than in those from fish collected at the other four sites (all less than 5% lipid0. Furthermore, the average length of carp in the composites from Prospect Slough (517 mm) and from Vernalis (505 mm) were greater than the mean length of the Potato Slough Sacramento suckers, yet the carp were characterized by much lower dieldrin tissue contamination. Lipid content in the carp composites (0.7 and 1.14%, respectively) was much lower than in the Potato Slough Sacramento sucker composite.

*Dieldrin levels among species*—Table 22 summarizes the relationship among dieldrin contamination, fish species, length, and composite lipid content. The species (carp, Sacramento suckers, and channel catfish) with the highest dieldrin tissue concentrations were also the largest fish analyzed. Comparing dieldrin contamination in white catfish and Sacramento suckers from the San Joaquin River and the entire Delta, both non-transformed and log-transformed data denote that Sacramento suckers were significantly more dieldrin-contaminated than white catfish (Table 22).

Composites from nine different species collected from Prospect Slough, seven different species collected from the San Joaquin River at Crows Landing and from the San Joaquin at Vernalis were analyzed for dieldrin (Table 20). Composites from three species (Sacramento sucker, channel catfish, carp) were available from the Merced and Tuolumne Rivers. Composites from three species also were available for the Calaveras River (white catfish, bluegill, red-ear sunfish), Paradise Cut (white catfish, bluegill, red-ear sunfish), and Frank's Tract (white catfish, bluegill, Sacramento perch). Composites from two species were available for the Stanislaus River (Sacramento sucker, channel catfish), Cosumnes River (Sacramento sucker, channel catfish), Salt Slough (channel catfish, carp) Big Break (Sacramento sucker, white catfish), San Joaquin River @ Laird Park (white catfish and red-ear sunfish), Mokelumne River (Sacramento sucker, rainbow trout)., Whiskey Slough (white catfish, bluegill), Middle River @ Hwy 4 (white catfish and bluegill), Old River @ Tracy Blvd (white catfish and bluegill), Clifton Court Forebay (white catfish and bluegill), Smith Canal (white catfish and red-ear sunfish) and Lost Slough (Sacramento sucker, bluegill). At all sites listed in Table 19 where Sacramento sucker were collected the highest dieldrin concentrations were in this species.

At the Crow's Landing site on the San Joaquin River dieldrin concentrations in composites of Sacramento suckers>blue gill>carp>channel catfish>large mouth bass>white catfish (Table 20). The average length of bluegills in the composite was less than the average for carp, channel catfish, large mouth bass and white catfish while dieldrin contamination was higher. It is not clear why bluegills had a higher dieldrin level contamination than these other species. The average length of fish in the red-ear sunfish (another centrarchid species) composite was higher than in the bluegill composite, yet dieldrin in the former was less than the reporting level. While lipid content of composites accounts , to a large extent, for differences among species, it does not 'explain' the relatively high bluegill dieldrin contamination (ranking relative to lipid content: Sacremento sucker>carp>channel catfish>white catfish>large mouth bass>red-ear sunfish>bluegill).

At the Vernalis site dieldrin concentrations in composites of Sacramento suckers>carp>bluegill>large mouth bass=channel catfish>white catfish>red-ear sunfish (Table 20). The average length of bluegills in the composite was less than the average length for channel catfish, large mouth bass and white catfish while dieldrin contamination was higher. The average length of fish in the red-ear sunfish composite was higher than in the bluegill composite, yet dieldrin concentration in the former was less. This occurrence is equivalent to that seen in fish collected at the San Joaquin River at Crow's Landing site. Lipid content in composites of carp and bluegill were equivalent, so it is not that unexpected that bluegill dieldrin contamination was relatively high. To a large extent lipid content of composites accounted for differences in dieldrin contamination among species (ranking relative to lipid content: Sacramento sucker>bluegill=carp>large mouth bass>white catfish>red-ear sunfish).

At the Prospect Slough site dieldrin concentrations in composites of Sacramento suckers>carp>Sacramento perch=white catfish>large mouth bass=striped bass=hitch>crappie=Sacramento pike minnow (Table 20). The average length of fish in the Sacramento perch was the lowest of all species, yet dieldrin concentration was greater than in composites of large mouth bass, crappie, hitch and striped bass. Lipid content of composites could not account for differences in level of dieldrin contamination among species (ranking relative to lipid content: Sacramento sucker>striped bass>white catfish=Sacramento perch>large mouth bass>carp>Sacramento pike minnow>crappie=hitch). Also of note is that the two white catfish composites from this site were of equivalent average length, but the dieldrin concentrations differed considerably. As indicated above, multiple composites of a species at each site are needed to obtain an accurate assessment of dieldrin contamination.

In samples from the Stanislaus and Cosumnes Rivers the average length of fish in channel catfish composites was higher or equivalent to those in Sacramento sucker composites, yet dieldrin was less than the reporting level in the channel catfish composites. The tendency toward higher dieldrin contamination in Sacramento sucker almost certainly relates to higher tissue lipid content compared to other species (see section on role of lipid in determining tissue contaminant concentration). Large Sacramento suckers and carp may be preferable species for assessing worst-case dieldrin contamination, but not good indicators of current exposure levels. The average length and lipid content of fish in the two Sacramento sucker composites from the Stanislaus River were very different, but dieldrin contamination was equivalent. The highest average length (482 mm) in a Sacramento sucker composite was from the Stanislaus River site, yet the dieldrin concentration in this composite was next to lowest observed in Sacramento sucker composites from the six sites listed in Table 19. The highest average length (305 mm) in a white catfish composite was from the Big Break site, yet dieldrin was below reporting level. Lipid content in three of the four other composites listed in this table was lower than in the Big Break composite. Clearly, factors, including tissue lipid content, other than species and size affect fish dieldrin contamination.

Dieldrin concentrations in two composites (% lipid=4.19%; mean length=456 mm and % lipid=4.37%; mean length=467 mm) of Sacramento sucker collected from the Tuolumne River were 1.25 and 2.5 ng/g, respectively. In composites of channel catfish (% lipid=0.465%; mean length=418 mm) and carp (% lipid=0.62%; mean length=545 mm) from this site dieldrin levels were 0.8 and 0.9 ng/g, respectively (Table 19). Dieldrin concentrations paralleled lipid content more than fish length in the three species collected at this site. Dieldrin concentrations in two composites (% lipid=2.29%; mean length=375 mm and % lipid=1.61%; mean length=386 mm) of Sacramento sucker collected from the Merced River were 1.4 and 0.8 ng/g, respectively (Table 19). In composites of channel catfish (% lipid=0.37%; mean length=381 mm) and carp (% lipid=0.44%; mean length=508 mm) from this site dieldrin levels were 0.9 and 0.5 ng/g, respectively. While dieldrin concentration was highest in the Sacramento sucker composite with the highest lipid content, levels in the other three composites did not parallel lipid or mean length of fish.

Dieldrin levels in two composites (% lipid=0.43%; mean length=275 mm and % lipid=0.66%; mean length=278 mm) of white catfish from Paradise Cut were 0.4 and 0.6 ng/g, respectively (Table 19). In composites of bluegill (% lipid=0.57%; mean length=165 mm) and red-ear sunfish (% lipid=0.54%; mean length=222 mm) from this site dieldrin concentrations were 0.7 and 0.6 ng/g, respectively. At such low levels of lipid and dieldrin contamination patterns are difficult to discern. Very similar results were obtained from composites of the same three species caught in the Calaveras River. Dieldrin concentrations in two composites (% lipid=1.62%; mean length=343 mm and % lipid=1.00%; mean length=337 mm) of white catfish from Frank's Tract were 0.8 and 0.6 ng/g, respectively (Table 19). Dieldrin levels in bluegill (% lipid=0.41%; mean length=157 mm) and Sacramento perch (% lipid=0.60%; mean length=173 mm) from this site were 0.85 ng/g and below reporting level, respectively. No clear relationship between composite lipid content or mean fish length and dieldrin concentration could be distinguished in the three species collected at Frank's Tract.

Dieldrin concentrations in two composites (% lipid=0.76%; mean length=434 mm and % lipid=0.76%; mean length=271 mm) of channel catfish from Salt Slough were 1.4 and 2.5 ng/g, respectively. In a composite of carp (% lipid=0.40%; mean length=446 mm) from this site dieldrin level was 1.35 ng/g. At this site dieldrin concentration in these two species appears to be much more related to lipid content than to fish length. In a composite of channel catfish (% lipid=0.78%; mean length=456 mm) collected from the Cosumnes River dieldrin concentration was 0.45 ng/g. Dieldrin concentrations in two composites (% lipid=1.09%; mean length=385 mm and % lipid=1.02%; mean length=393 mm) of Sacramento sucker from this site were 0.3 and 0.6 ng/g, respectively. While contamination at this site was low, fish length does not appear to have been the primary determinant of fillet dieldrin concentrations.

In a composite of Sacramento sucker (% lipid=4.02%; mean length=458 mm) caught at Big Break dieldrin concentration was 2.1 ng/g. Dieldrin level in a composite of white catfish (% lipid=0.73%; mean length=305 mm) from this site was 0.4 ng/g. Dieldrin concentrations in Sacramento sucker (% lipid=2.22%; mean length=455 mm; % lipid=2.66%; mean length=458 mm) taken from the Mokelumne River (Lodi Lake) were 0.5 and 0.6 ng/g, respectively. In a composite of rainbow trout (% lipid=1.20%; mean length=330 mm) from this site dieldrin was below the reporting level. Dieldrin level in a composite of Sacramento sucker (% lipid=1.27%; mean length=450 mm) captured at Lost Slough was 0.4 ng/g, whereas in a composite of bluegill (% lipid=0.57%; mean length=143 mm) from this site dieldrin concentration was 0.5 ng/g. While average length of bluegill a in composite was much smaller and less fatty the level of dieldrin contamination was equivalent to that in the Sacramento sucker.

Dieldrin concentrations in two composites of white catfish (% lipid=1.11%; mean length=335 mm; (% lipid=1.07%; mean length=330 mm) collected from Whiskey Slough were 0.9 and 0.6 ng/g, respectively. In a composite (% lipid=0.53%; mean length=115 mm) of bluegill from this site dieldrin was below reporting level. Dieldrin concentration in two composites of white catfish (% lipid=0.54%; mean length=272 mm; (% lipid=0.58%; mean length=263 mm) captured at Middle River was 0.6 ng/g in both, while in a composite of bluegill (% lipid=0.38%; mean length=170 mm) from this site the dieldrin was below reporting level. Dieldrin concentration in two composites of white catfish (% lipid=0.32%; mean length=258 mm; % lipid=0.43%; mean length=258 mm) collected from Smith Canal was 0.5 ng/g in both, but below reporting level in a composite of red-ear sunfish (% lipid=0.325%; mean length=188 mm) from the site. In composites of white catfish (% lipid=0.73%; mean length=229 mm and % lipid=0.525; mean length=228 mm) caught from the San Joaquin River @ Laird Park dieldrin levels were 1.3 and 0.9 ng/g, respectively; dieldrin was below reporting level in a composite of red-ear sunfish (% lipid=0.42%; mean length=272 mm) from this site. At these four sites (Whiskey Slough, Middle River, Smith Canal, and the San Joaquin River @ Laird Park) dieldrin contamination of fish was low, yet was higher in the fattier white catfish than the centrarchids (bluegill and red-ear sunfish).

While Sacramento sucker were always the most contaminated the order (highest to lowest) of tissue contamination level by species differed at the three sites where multiple species were collected:

Crow's Landing:
Sacramento sucker>blue gill>carp>channel catfish>large mouth bass>white catfish

Vernalis:
Sacramento sucker>arp>bluegill>large mouth bass=channel catfish>white catfish>red-ear sunfish

Prospect Slough:
Sacramento sucker>carp>Sacramento perch=white catfish>large mouth bass=striped bass=hitch>crappie=Sacramento pike minnow

The discussion above suggests that average fish length constituting composites usually does not completely account for differences in the order of species contamination level. The role of fish size (average length of fish contributing to composite) in determining level of contaminant and differences among species was further explored. Sacramento suckers were most often the most contaminated, as well as largest and fattiest, fish collected at a site. Therefore, at the three sites where multiple species were collected, contaminant and length ratios were calculated (species X/Sacramento sucker). From these ratios, sizes of other species collected at the site were size-adjusted to be equivalent to Sacramento suckers at the site. Table 23 summarizes actual and size-adjusted contaminant ratios at the three sites. The order of species contamination ratios is not the same at the different sites. Of particular note is that both the actual nor the size-adjusted (standardized to Sacramento suckers) contaminant level in a species can be very different among sites. These data complement the hypothesis that factors other than species and fish size affect level of dieldrin tissue contamination. Furthermore, determinants of fish dieldrin contaminant appear to vary from site to site. Thus, it appears that we cannot effectively predict level of contamination in other species from dieldrin concentrations in the most contaminated species.

*Hatchery fish*—Dieldrin concentration in composites from the San Joaquin River and Moccasin Creek hatcheries were below reporting level and a non-detect. In composites of Chinook salmon from the Merced and Mokelumne River hatcheries dieldrin levels were 1.3 and 0.9 ng/g, respectively.

*Relationships among tissue dieldrin concentration, tissue lipid content and composite mean fish length*

Sacramento sucker

In this project, 16 composites of Sacramento suckers collected from the San Joaquin River watershed and Delta were analyzed for dieldrin. Neither non-transformed nor log-transformed dieldrin tissue concentration data fit a normal distribution. Log-transformed composite % lipid, but not non-transformed, data fit a normal distribution. Neither non-transformed nor log-transformed mean fish length data fit a normal distribution. The failure of the mean length data to fit a normal distribution may be consequent to the variation in fish sizes constituting the composites and the tendency to select the largest fish collected. In all cases the small sample size possibly confounded assessment of normal distribution.

Results of regression analyses are summarized in Table 24. A statistically significant relationship between composite % lipid and dieldrin concentration, as observed with PCB data, was detected. Percent lipid in composites appears to account for up to 93% of the variation in tissue dieldrin concentration (Table 24). Contrary to what was seen with PCB data, a statistically significant relationship was not detected between mean length of fish in composites and dieldrin concentration. Length/age of Sacramento sucker may be a determinant of tissue lipid levels, but could account for less than 45% of the variability in this parameter (Table 24). In a multiple regression with log composite % lipid and log composite mean fish length as the independent variables and log dieldrin concentration as the dependent variable the $R^2$ was 0.86 ($P<0.00001$). Addition of length as a predictor of dieldrin concentration only slightly increased the $R^2$ (from 0.81) compared to the regression with log % lipid alone; further, length was not a statistically significant predictor of dieldrin concentration in the multiple regression. Wet weight dieldrin concentrations (non-transformed and log-transformed) were regressed on lipid-normalized dieldrin concentrations; results disclosed that non-transformed, but not log-transformed, lipid-normalized values were significant predictors of wet weight dieldrin concentrations, providing further support for lipid being a contributing determinant (not simply exposure level) of fish dieldrin contamination (Table 24). Sites were ranked based on the lipid content of composite(s) and on level of dieldrin concentration; a rank correlation analysis was then performed. The $R^2$ for this analysis was 0.78 ($P<0.00001$) and the slope 0.91. These results provide robust evidence that lipid content of

Sacramento sucker is a superior predictor of dieldrin contamination than exposure level at a site. Moreover, there is no reason to believe that dieldrin exposure levels at sites would be dictated by lipid content of Sacramento sucker. Further, these findings call for a re-evaluation of assumptions regarding PCB/OC pesticide fish contamination. A similar link was not, however, detected in white catfish collected at sites in the San Joaquin River watershed and Delta, so the situation with Sacramento sucker should not be extrapolated to other species without confirming data. If lipid content is the only determinant of tissue dieldrin concentrations, a regression of lipid-normalized dieldrin concentration on composite percent lipid should not yield a statistically significant $R^2$ (Herbert and Keenleyside, 1995). While the $R^2$ of non-transformed data was only 0.36 there was a statistically significant relationship (Table 24). This finding suggests that lipid content is co-varying with another or other dieldrin concentration determinants (see Discussion section on determinants of POP concentrations).

Geometric wet weight and lipid-normalized mean ($\pm$95% confidence interval) dieldrin concentrations in Sacramento sucker are 1.5, 0.8-2.5 and 41, 29-57 ng/g. Coefficients of variation for these means are 70 and 17%, respectively, revealing that lipid-normalization considerably reduces variability in the dieldrin data.

Tables 15 and 16 summarize regression coefficients ($R^2$) and rank (sites ranked by level of contamination) correlation coefficients (Rho), respectively, from analyses of wet weight and lipid-normalized PCB/OC pesticide concentrations in Sacramento sucker collected in the San Joaquin River watershed and Delta. Note that in both analyses statistically significant associations were observed between contaminant wet weight concentrations, but not with lipid-normalized concentrations. The fact that positive statistically significant associations among the three contaminants *implies* that sites that are the most are contaminated by all three of the contaminants. Moreover, the implication is that there is a ranking of sites by total PCB/OC pesticide contamination; that is, the most contaminated sites are contaminated by PCBs, DDTs, and dieldrin. Why should Sacramento sucker tissue PCB concentration at a site predict DDT and dieldrin tissue concentrations unless there is parallel contamination of PCBs, DDTs, and dieldrin at the sites sampled? Such a situation does not seem likely. I propose an alternative interpretation that is supported by data in Tables 15 and 16. My hypothesis is that exposure levels of PCBs, DDTs, and dieldrin are not necessarily the highest at sites with the most contaminated Sacramento sucker. I propose that factors, conditions, and the fish at sites differ and those with the most contaminated Sacramento sucker have conditions most favorable to bioaccumulation and biomagnification. Body lipid and a host of other physical, chemical, ecological, and physiological factors that affect bioaccumulation (see Discussion section on determinants of tissue and body concentrations of persistent organic pollutants—POPs). The data in Tables 15 and 16 provide impelling evidence that, in the San Joaquin River watershed and Delta, lipid content of Sacramento sucker was a more significant determinant of PCB/OC concentration in fish than site exposure level. Five of the Sacramento sucker composites that exceeded the OEHHA dieldrin (55% of exceedances) screening value also exceeded the PCB (83% of exceedances) and DDT (55% of exceedances) screening levels providing further evidence that these old, fatty Sacramento sucker are not providing an assessment of current PCB/OC pesticide exposure levels. That is, contaminant concentrations in these old, fatty Sacramento sucker are consequent to historic exposure throughout their lives. It is inappropriate to use Sacramento sucker contaminant levels to predict current exposure levels or contaminant levels in shorter-lived, less fatty fish at a site.

White catfish

Dieldrin was measured in 32 composites of white catfish captured in the San Joaquin River watershed and Delta. Neither non-transformed nor log-transformed tissue dieldrin concentration, tissue lipid content, and composite mean fish data were normally distributed. Most likely, this is related to the fact that these three parameters (especially composite lipid content and dieldrin concentration) were less variable in white catfish than in Sacramento sucker.

Table 25 summarizes the results of regression analyses with white catfish data. In contrast to results with Sacramento sucker, no significant relationship was seen between tissue lipid content and tissue dieldrin levels. . Neither was a significant relationship between composite mean fish length and tissue dieldrin levels. The slopes of the regressions of dieldrin concentration on length were negative, with the value of the log:log plot being -0.49. Fish length may be a weak (accounting for no more than 22% of the variability), but statistically significant, predictor of muscle lipid content (Table 25). There was no covariance of contaminant concentrations in white catfish associated with sites as detected in the Sacramento sucker data. This result is almost certainly related to the lower and lesser variation in lipid levels in white catfish compared to Sacramento sucker. Moreover, lipid levels in white catfish composites do not appear to be a major determinant of tissue dieldrin concentrations in white catfish. Therefore, white catfish are probably more accurate assessors of current PCB/OC pesticide exposure levels than Sacramento sucker.

Channel catfish and carp

Tissue dieldrin was analyzed in nine and seven composites of channel catfish and carp, respectively. Channel catfish composite lipid content ranged from 0.37 to 1.08% with a mean of 0.74%; tissue dieldrin concentrations ranged from non-detect to 2.5 ng/g with a mean of 1.1 ng/g. There was no apparent relationship between composite lipid content and dieldrin concentration. In fact, dieldrin was not detected in the composite with the highest lipid content. Carp composite lipid content ranged from 0.40 to 1.65% while dieldrin concentrations ranged from 0.2 to 2.5 ng/g. In contrast to PCB data in these carp, there was no apparent relationship (low $R^2$, not statistically significant) between composite lipid content and dieldrin concentration.

The lack of statistically significant relationships in many of these regression analyses should be interpreted with caution. Several factors could affect the outcome of these analyses, including overall relatively low levels of dieldrin contamination and fish were collected from multiple sites that potentially varied in level of dieldrin contamination. Furthermore, lipid content in white catfish was relatively low and not that variable. For ideal regression there would be sufficient samples at each site to complete adequate analyses (i.e., decreasing the exposure level variable).

*Same species 'duplicates'*—Two separate composites of white catfish were analyzed at 13 sites. At four sites both 'duplicate' composites were below the dieldrin reporting level. The same concentration of dieldrin occurred in both 'duplicates' at two sites. At six sites the concentration of dieldrin in the 'duplicate' composites differed by 0.2 (average fish length in composites 343 and 337 mm), 0.2 (average lengths 275 and 278 mm), 0.2 (average lengths 330 and 335 mm), 0.4 (average lengths 229 and 241 mm with the smaller more contaminated), 0.6 (average lengths 253 and 255 mm), and 0.9 ng/g (average lengths 230 and 230 mm). In all but one case of 'duplicate' composites, the higher dieldrin concentration was in the composite with the higher lipid content. At three sites one of the 'duplicate' composites was below the reporting level whereas in the other dieldrin concentration was 0.5 or 0.6 ng/g.

Two separate composites of Sacramento suckers were analyzed at six sites. Composites of Sacramento suckers from the Stanislaus River contained 0.6 (average length=338 mm) and 0.7 ng/g (average length=482 mm); contamination in the two composites was equivalent even though there was no over lap in fish size in the two composites. Further, lipid content in the composite constituted from the larger fish was 0.79% higher than in the other composite. In fish collected from the Tuolumne and Merced Rivers composite sample dieldrin concentrations were 1.2 (average length=456 mm) and 2.5 ng/g (average length=467 mm) and 0.8 (average length=320 mm) and 1.4 ng/g (average length=386 mm), respectively. In both cases dieldrin concentration was higher in the 'replicate' composite with the higher lipid content. Dieldrin levels in 'duplicate' composites from the Mokelumne and Cosumnes Rivers were 0.5 (average length=455 mm) and 0.6 ng/g (average length=458 mm) and below reporting level (average length=385) and 0.6 ng/g (average length=393 mm), respectively. Differences in composite lipid content could not account for differences in dieldrin concentrations. Dieldrin concentrations in 'duplicate' Sacramento sucker composites from the same site appear even more variable than in white catfish. Therefore, more composites per species at sites is recommended to accurately assess level of dieldrin contamination.

*Temporal trends*—Assessing temporal trends is difficult when the same sites and same species are not sampled yearly as well as when the number of samples analyzed in inadequate for robust statistical analyses. Spatial and temporal variation in OC pesticide and PCB fish contamination are realities. Thus, sampling numerous (same) sites, the same species per site, and 'replicate' composites per site on a yearly basis is essential for accurate temporal trend analysis as well as for predicting future changes in fish contamination. While fish sampling for OC/PCB contamination in the Sacramento River watershed has been more extensive than in the San Joaquin River watershed and Delta, all of the above problems plague temporal trend analyses of fish contamination in Central Valley waterways. Clearly there was and is no consistent strategy or plan for addressing this issue.

The analysis of Greenfield et al. (2004) revealed that OC pesticide and PCB contamination of fish in Central Valley declined rapidly in the 1970s to the mid-1980s, but the rate of decrease slowed in the 1990s such that statistical differences could not be detected. Inability to detect statistically significant decreases very possibly relates to the small number of sites, samples, and duplicates. Given that the rapid decline in the 1970s and early-1980s has been documented, my focus is on the period between 1990 and 2005. Thus, I examined the SFEI database for fillet composites of Sacramento sucker, white catfish, channel catfish, and carp collected in that period. For the San Joaquin River watershed and east, south, and west portions of the Delta only 18 composites of these species were found for this 15 year period, 16 of white catfish plus one each of channel catfish and carp. All these composites were from fish collected in 1998 except one of Sacramento sucker (from Stanislaus River) and one of white catfish (from Salt Slough) taken in 1990.

Temporal patterns of dieldrin fish contamination are confounded by alteration of reporting level. The reporting limit for dieldrin has changed over the years primarily due to the extracts final volume (personal communication, Kathleen Regalado from Dave Crane's laboratory). In 1990 the extract's final volume was 10 mls and dieldrin's reporting limit was 5 ng/g. In 1998 the laboratory initiated accelerated solvent extraction and GPC to extract and cleanup samples. GPC removed most of the lipid from tissue extracts. Extract final volume changed from 10 to 2 mls. Extracts were cleaned up such that a 1 ml final volume was possible with a 0.5 ng/g reporting limit.

Dieldrin concentration in the 1990 composite of Sacramento sucker collected from the Stanislaus River was 24 ng/g whereas in 'duplicate' composites of Sacramento sucker caught in 2005 at this site levels were 0.6 and 0.7 ng/g., documenting a considerable decrease in dieldrin fish contamination in this river. Dieldrin levels in composites of white catfish collected from Salt Slough during 1990 and 1998 were below reporting level (but detection and reporting levels were higher) and 3 ng/g, respectively. Concentrations in two composites of channel catfish caught at this site during 2005 were 1.6 and 2.5 ng/g, suggesting dieldrin contamination of fish at Salt Slough has declined compared to 1998, especially since channel catfish tend to be fattier and more OC-contaminated than white catfish. The highest dieldrin concentrations in composites of white catfish collected from the San Joaquin River watershed and Delta in 1998 were 38 and 13 ng/g, higher than any (highest=1.9 ng/g) of the 2005 white catfish 92 composites. Comparison of dieldrin mean concentrations in white catfish collected in 1998 and 2005 is inappropriate because detection and reporting levels are currently lower than in 1998. Nonetheless, available data suggest that dieldrin fish contamination decreased considerably between 1998 and 2005. Dieldrin concentrations ranged from 2.1 to 3.4 ng/g in Sacramento sucker or channel catfish composites collected from Salt Slough, the Tuolumne River, the San Joaquin River @ Crow's Landing and Veranlis), and Big Break (east Delta). Rates of dieldrin decline likely vary spatially and could not be estimated for any of these sites (for Sacramento sucker, channel catfish, or carp) consequent of insufficient data.

**Fish Tissue DDT Residues**

*Frequency of contamination, spatial distribution, and comparison to OEHHA screening value*—Tissue concentrations were non-detects or below reporting level, reporting level to 25, 26 to 50, 51 to 99, and 100 ng/g (OEHHA screening level) or above in 8, 57, 16, 9 (Table 26), and 10% (Table 27) of the 92 composites, respectively. DDT concentrations were above 100 ng/g in composites from six sites, the Tuolumne River at Shiloh, the San Joaquin River at Crow's Landing, the San Joaquin River at Laird Park, the San Joaquin River at Vernalis, Potato Slough, and Prospect Slough (Table 27). Tissue DTT residues were 51 to 99 ng/g in composites from five sites, the Merced River, the San Joaquin River at Crow's Landing, the San Joaquin River at Vernalis, Big Break, and Discovery Bay (Table 26). The highest levels of DDT contamination were found in Sacramento sucker composites from Potato Slough, the Tuolumne River, and the San Joaquin River at Vernalis (Table 27). With the possible exception of increasing DDT contamination from Crow's Landing to Vernalis, no clear spatial pattern of fish DDT contamination could be discerned along the main stem San Joaquin River. White catfish were collected at all five San Joaquin River sites with Laird Park samples being the most DDT-contaminated; equivalent DDT concentrations occurred in composites from the other four sites. Only two composites of Sacramento sucker were available from the lower San Joaquin River. DDT in the Sacramento sucker composite from fish collected at Vernalis was more than double that of the Crow's Landing composite. DDT fish tissue concentrations from none of the sites in Table 27 were above the OEHHA 2006-proposed 560 ng/g screening level. Moreover, DDT concentrations in all 92 composites from fish collected during 2005 from the San Joaquin River watershed and Delta were such that 12 or more fish meals per month could be consumed (OEHHA, 2006—Table 4 in this report).

The lower Tuolumne River is not currently CWA 303(d) listed for DDT contamination. In data gathered during 1997 through 2001 largemouth bass DDT tissue concentrations in fish from the lower Tuolumne River were greater than 100 ng/g (Greenfield et al., 2004). The ∑DDTs in two composites of Sacramento sucker caught in the Tuolumne River during 2005 were 269 and 339 ng/g. However, DDTs in composites of carp and channel catfish collected from the Tuolumne in 2005 were 13 and 21 ng/g, respectively, a considerable divergence compared to the Sacramento sucker. These two composites are adequate (SWRCB, 2004) for 303(d) listing of the Tuolumne if the OEHHA screening level remains at 100 ng/g, but not if the 2006-proposted screening level is adopted by the CVRWQCB. Lipid content in the Sacramento sucker composites was 7 to 9X higher than in the composites from the other two species; the large difference in lipid content is almost certainly a determining factor in level of DDT contamination. Therefore, I recommend that additional data from multiple species with 'duplicate' composites per species be gathered prior to any listing actions.

In channel catfish data collected from the Merced River during 1997 through 2001 DDT concentration was greater than the OEHHA screening value of 100 ng/g (Greenfield et al., 2004). In two 'duplicate' composites of Sacramento sucker collected from the Merced River during 2005 DDT concentrations in both were less than 60 ng/g. DDTs in composites of carp and channel catfish taken from this river during 2005 were 6 and 11 ng/g, respectively. Clearly, DDT contamination in this river has subsided.

The lower San Joaquin River and eastern Delta are on the CWA 303(d) list for DDT contamination. Fish tissue DDT concentrations in five composites from three sites (Crow's Landing—Sacramento sucker, Laird Park—white catfish, and Vernalis—Sacramento sucker and carp) on the San Joaquin River were greater than 100 ng/g (Table

27). In composites of three and two other species captured at Crow's Landing and Vernalis, respectively, tissue DDT concentrations were less than 50 ng/g (Table 28). According to SWRCB policy (SWRCB, 2004) these data preclude 303(d) delisting of the lower San Joaquin River. While some samples reveal that a few species (Sacramento suckers and, sometimes, carp and white catfish) from the San Joaquin River are significantly DDT-contaminated, there is no clear spatial pattern. Furthermore, consideration should be given to the fact that DDT concentrations in 18 composites from fish caught in the lower San Joaquin River (including an additional three composites from Crow's Landing, one from Laird Park and three from Vernalis (Table 28) during 2005 were below the OEHHA 100 ng/g screening value. Most fish collected from the lower San Joaquin manifest DDT contamination below the OEHHA screening value and definitely below the 2006-proposed 620 ng/g screening value. If the lower screening level is maintained additional data from the Crow's Landing, Laird Park, and Vernalis sites would be helpful for delisting considerations. If the higher screening value is adopted, there is adequate data available in this report to support delisting of the lower San Joaquin River. In data collected during 2005 mean DDT concentration in white catfish colleted in the San Joaquin River was lower, but not significantly so, than the OEHHA screening value; mean DDT concentration in Sacramento sucker from the San Joaquin River was higher than the screening value (Table 29).

A composite of Sacramento suckers collected from Potato Slough (east Delta) had the highest DDT concentration of any fish collected in 2005. Contrary-wise, two composites of white catfish collected from both the Smith Canal and Beaver Slough (eastern Delta); DDT concentrations in these composites were less than 20 ng/g. A composite of Sacramento sucker collected from Lost Slough (eastern Delta) contained 13 ng/g DDT. The DDT concentrations in white catfish collected from the east Delta during 1997 through 2001 were higher than the OEHHA screening value. Mean DDT concentration in white catfish captured in the east Delta was significantly lower than the OEHHA screening value (Table 29). To the contrary, the average DDT concentration in Sacramento sucker taken from the east Delta in 2005 was higher than the screening value. However, there were only two composites of Sacramento sucker from east Delta sites, one with a DDT concentration of 346 ng/g Potato Slough) and the other was 11 ng/g (Lost Slough); this is a considerable divergence in level of DDT contamination. Yet, these sloughs are not contiguous and there could be substantial divergence in level of DDT contamination. DDT concentration in seven composites of fish collected during 2005 at three other east Delta sites were less than 20 ng/g. With the exception of the one Potato Slough Sacramento sucker composite, DDT contamination of fish from the east Delta appears to be below the OEHHA 100 ng/g screening value. However, according to SWRCB policy (SWRCB, 2004) there is an insufficient number of samples below the 1999 OEHHA screening level (Broadberg and Pollock, 1999). However, mean and geometric mean DDT concentrations in nine composites of fish collected in the eastern Delta are below 50 ng/g and the upper 95% confidence limit does do not overlap the OEHHA 1999 screening value. Based on this weight of evidence I recommend 303(d) delisting of the eastern portion of the Delta.

Northern Delta waterways also are 303(d) listed for DDT fish contamination. DDT levels in a composite of Sacramento collected from Prospect Slough and a composite of carp from Rio Vista were above the 1999 OEHHA screening level. These two composites preclude (SWRCB, 2004) delisting of the north Delta if the 1999 OEHHA screening level remains viable, but not if the 2006-recommended screening level is adopted. However, DDT concentrations in nine composites from eight species collected from Prospect Slough were less than 40 ng/g (Table 28). Furthermore, in composites of Sacramento sucker and white catfish from the Sacramento River @ Rio Vista site DDT concentration was 92 and 29 ng/g, respectively. In composites of Sacramento sucker (composite DDT concentration=50 ng/g), large-mouth bass (4 ng/g) and coho salmon (15 ng/g) collected from the Sacramento River @ RM44 DDT levels were also below the screening value. Overall, there were 14 composites of fish collected from the north Delta with DDT concentrations below the 1999 OEHHA screening value (11 with DDTs < 40 ng/g). While some large/old, fatty fish in areas of the north Delta are DDT-contaminated to an extent potentially harmful to humans, this contamination does not extend to all species and does not translate into present-time high DDT exposure levels. Moreover, mean and geometric mean DDT concentrations in 14 composites of fish collected in the northern Delta are below 50 ng/g and the upper 95% confidence limit does do not overlap the OEHHA 1999 screening value. Consequently, I recommend 303(d) delisting this area of the Delta.

Western Delta waterways also are on the CWA 303(d) list for DDT contamination. DDT concentration in a composite of Sacramento sucker collected from Big Break (western Delta) was 66 ng/g whereas in a composite of white catfish from this site the level was 6 ng/g. Two white catfish composites were available from fish collected from both Frank's Tract and Sand Mound Slough (western Delta). DDT levels were less than 10 ng/g in all four composites. DDT concentrations in composites of bluegill and red-ear sunfish taken at Frank's Tract were below reporting level. The mean DDT concentrations in white catfish captured in the west Delta during 1998 (Greenfield et al., 2004) and in 2005 (this study) were significantly lower than the OEHHA screening value. While the 2005 data clearly show that DDT contamination of fish in the west Delta is low, there is an insufficient number of samples below the screening level to 303(d) delist (SWRCB, 2004). Nonetheless, mean and geometric mean DDT concentrations in eight composites of fish collected in the western Delta are below 12 ng/g and the upper 95% confidence limit does do not overlap the OEHHA 1999 screening value. Therefore, I recommend 303(d) delisting this area of the Delta.

Southern Delta waterways also are 303(d) for DDT fish contamination. In a composite of channel catfish collected from Discovery Bay (southern Delta) DDT concentration was 87 ng/g. However, DDT level was 14 ng/g in a composite of white catfish collected at this site. Likewise, DDT concentration was 9 ng/g in a composite of white catfish collected in Clifton Court Forebay. In two composites from white catfish collected in the Middle River DDT concentrations were 30 and 9 ng/g. Two white catfish composites were available from fish collected from Orwood Tract/Woodward Island and from the Old River (southern Delta). In all four of these composites DDT concentrations were less than 15 ng/g. There were also two composites available from white catfish collected in

Paradise Cut and Whiskey Slough; DDT levels in all four composites were less than 25 ng/g. Mean DDT concentration in white catfish collected in the south Delta during 2005 was significantly lower than the OEHHA screening value (Table 29). DDT concentrations in composites of bluegill collected from Clifton Court Forebay, Old River, and Whiskey Slough as well as red-ear sunfish caught at Paradise Cut were all below reporting level. The data summarized above indicate low levels of fish DDT contamination (not of concern for human health), yet are insufficient according to SWRCB policy to delist the southern Delta. Mean and geometric mean DDT concentrations in 13 composites of fish collected in the southern Delta are below 20 ng/g and the upper 95% confidence limit does do not overlap the OEHHA 1999 screening value. Hence, I recommend 303(d) delisting this area of the Delta.

The mean (with lower and upper 95% confidence values) and geometric mean of ∑DDT concentrations in Sacramento sucker (16 composites) collected in the San Joaquin River watershed and Delta are 97, 31-163 and 38, 17-85ng/g, respectively; median concentration is 30.5 ng/g. Coefficients of variation for the two means are 127 and 42%, respectively, disclosing DDT data are a better fit to a log-normal distribution. The mean (with lower and upper 95% confidence values) and geometric mean of ∑DDT concentrations in white catfish (32 composites) collected in the San Joaquin River watershed and Delta are 26, 12-40) and 16, 12-22) ng/g, respectively; median concentration is 14 ng/g. Coefficients of variation for the two means are 152 and 32%, respectively, disclosing DDT data are a better fit to a log-normal distribution.

Table 29 is a summary of mean DDT levels, along with lower and upper 95% confidence limits for the San Joaquin River and areas of the Delta. While sample sizes are generally small, the values in this table provide an indication of statistically significant differences when comparing groups of sites, species, and to OEHHA screening values. The log-transformed data reveal that white catfish collected in the San Joaquin River were more DDT-contaminated than specimen of the same species from the east, west, and south Delta (Table 29). The DDT upper 95% confidence limit (log-transformed data) for white catfish collected from the San Joaquin River and the entire Delta did not overlap the OEHHA screening level. The upper 95% confidence limit for Sacramento sucker taken in the entire Delta overlapped the 100 ng/g OEHHA screening value (Table 29). The high means for the east and entire Delta are consequent, for the most part, to the outlier composite (346 ng/g) of Sacramento sucker from Potato Slough. Results with a t-test coincided with application of the 95% confidence limits.

*DDT levels among species*—Composites from nine different species collected from Prospect Slough, seven different species from the San Joaquin River at Crows Landing and from the San Joaquin at Vernalis were analyzed for DDTs (Table 28). Composites from three species (Sacramento sucker, channel catfish, carp) were available from the Merced and Tuolumne Rivers. Composites from three species also were available for the Calaveras River (white catfish, bluegill, red-ear sunfish), Paradise Cut (white catfish, bluegill, red-ear sunfish), and Frank's Tract (white catfish, bluegill, Sacramento perch). Composites from two species were available for the Stanislaus River (Sacramento sucker, channel catfish), Cosumnes River (Sacramento sucker, channel catfish), Salt Slough (channel catfish, carp) Big Break (Sacramento sucker, white catfish), San Joaquin River @ Laird Park (white catfish and red-ear sunfish), Mokelumne River (Sacramento sucker, rainbow trout)., Whiskey Slough (white catfish, bluegill), Middle River @ Hwy 4 (white catfish and bluegill), Old River @ Tracy Blvd (white catfish and bluegill), Clifton Court Forebay (white catfish and bluegill), Smith Canal (white catfish and red-ear sunfish) and Lost Slough (Sacramento sucker, bluegill).

The San Joaquin River at Crow's Landing site DDT concentrations in composites of Sacramento sucker>channel catfish>large mouth bass>carp> bluegill>white catfish>red-ear sunfish (Table 28). At this site the highest DDT contamination (127 ng/g) recorded was in the Sacramento sucker composite (average length=421 mm) compared to 81 ng/g in a channel catfish composite (average length=376). Tissue lipid content in the Sacramento sucker composite (2.93%) was notably greater than in the channel catfish composite (0.77%). DDT contamination in channel catfish was greater than in large mouth bass and carp even though average length in the composite of the former (376 mm) was less than in the two latter species (394 and 475 mm, respectively). DDT contamination in large mouth bass was somewhat greater than or equivalent to that of carp notwithstanding the average fish length in the composite of the former (394 mm) was less than in the latter (475 mm). Lipid content in the channel catfish (0.77%), large mouth bass (0.51%), and carp (0.80%) composites could not account for differences in DDT concentrations. Average fish length (150 mm) and lipid content (0.41%) in the bluegill composite were less than in white catfish (236 mm) and (0.45%), yet DDT concentration in the former was higher.

At the San Joaquin River at Vernalis site DDT concentrations in composites of Sacramento suckers>carp>large mouth bass>channel catfish>bluegill>white catfish> red-ear sunfish (Table 28). The highest contamination (338 ng/g) was in a composite of Sacramento suckers. The second highest level of DDT contamination (232 ng/g) was in a carp composite; mean length (505 mm) of carp in that composite was greater than in the Sacramento sucker (average length=463 mm) composite, but lipid content in the Sacramento sucker composite (4,62%) was more than double that in the carp composite (2.14%). DDT concentration in the large mouth bass and carp composites were 83 and 78 ng/g, respectively; mean fish length and lipid content in the large mouth bass composite (369 mm and 0.83%, respectively) were somewhat higher than in the channel catfish composite (338 mm and 0.76%, respectively. As was observed in fish collected from the San Joaquin River at Crow's Landing, average fish length in the bluegill composite (148 mm) was less than in white catfish (245 mm) yet DDT concentration in the former was higher. DDT concentration in the bluegill composite (60 ng/g) was double that in the white catfish composite (29 ng/g) as was the lipid content (1.15 versus 0.48%).

Only Sacramento suckers collected from Prospect Slough were notably contaminated with DDTs (Table 28). DDT concentrations in composites of Sacramento sucker>white catfish>=Sacramento pike minnows>carp=Sacramento perch=striped bass>crappie=large mouth bass>hitch. Even though the carp and largemouth bass constituting composites were relatively large, DDT contamination was considerably less than in Sacramento sucker. It is not surprising that the Prospect Slough Sacramento sucker were the most DDT contaminated since lipid content in the composite of that species was 4.84% while in composites was less than 1%. Lipid content of striped bass (0.91%), white catfish (0.88%), Sacramento perch (0.87%), large mouth bass (0.80%), carp (0.70%), Sacramento pike minnow (0.58%), and crappie (0.35%) composites could not account for differences in DDT tissue concentrations.

DDT concentrations in two composites (% lipid=4.19%; mean length=456 mm and % lipid=4.37%; mean length=467 mm) of Sacramento sucker collected from the Tuolumne River were 339 and 269 ng/g, respectively. In composites of channel catfish (% lipid=0.465%; mean length=418 mm) and carp (% lipid=0.62%; mean length=545 mm) from this site DDT levels were 21 and 20 ng/g, respectively. DDT concentrations were clearly higher in the fattier Sacramento sucker collected at this site. DDT concentrations in two composites (% lipid=2.29%; mean length=375 mm and % lipid=1.61%; mean length=386 mm) of Sacramento sucker collected from the Merced River were 55 and 20 ng/g, respectively. In composites of channel catfish (% lipid=0.37%; mean length=381 mm) and carp (% lipid=0.44%; mean length=508 mm) from this site DDT levels were 11 and 6 ng/g, respectively. DDT concentrations were clearly higher in the fattier Sacramento sucker collected at this site.

DDT levels in two composites (% lipid=0.43%; mean length=275 mm and % lipid=0.66%; mean length=278 mm) of white catfish from Paradise Cut were 17 and 24 ng/g, respectively. In composites of bluegill (% lipid=0.57%; mean length=165 mm) and red-ear sunfish (% lipid=0.54%; mean length=222 mm) from this site DDT concentrations were 12 and 9 ng/g, respectively. At such low levels of lipid and DDT contamination patterns are difficult to discern. Very similar results were obtained from composites of the same three species caught in the Calaveras River, except DDT concentrations were somewhat lower in all species. DDT concentrations in two composites (% lipid=1.62%; mean length=343 mm and % lipid=1.00%; mean length=337 mm) of white catfish from Frank’s Tract were 9 and 6 ng/g, respectively. DDTs in bluegill (% lipid=0.41%; mean length=157 mm) and Sacramento perch (% lipid=0.60%; mean length=173 mm) from this site were below reporting level, respectively. Consequent to low level DDT contamination no clear relationship between composite lipid content or mean fish length and DDT concentration could be distinguished in the three species collected at Frank’s Tract.

DDT concentrations in two composites (% lipid=0.76%; mean length=434 mm and % lipid=0.76%; mean length=271 mm) of channel catfish from Salt Slough were 23 and 34 ng/g, respectively. In a composite of carp (% lipid=0.40%; mean length=446 mm) from this site DDT level was 13 ng/g. At this site DDT concentration in these two species appears to be more related to lipid content than to size of fish. In a composite of channel catfish (% lipid=0.78%; mean length=456 mm) collected from the Cosumnes River DDT concentration was 8 ng/g. DDT concentration in two composites (% lipid=1.09%; mean length=385 mm and % lipid=1.02%; mean length=393 mm) of Sacramento sucker from this site was 7 ng/g. Contamination at this site was too low to distinguish patterns related to fish size and lipid content.

In a composite of Sacramento sucker (% lipid=4.02%; mean length=458 mm) caught at Big Break DDT concentration was 66 ng/g; DDT level in a composite of white catfish (% lipid=0.73%; mean length=305 mm) from this site was 6 ng/g. While mean length in the two Sacramento sucker composites was large the lipid content almost certainly was key factor in the difference in DDT concentrations. DDT concentrations in two composites of Sacramento sucker (% lipid=2.22%; mean length=455 mm and % lipid=2.66%; mean length=458 mm) taken from the Mokelumne River (Lodi Lake) were 28 and 14 ng/g, respectively, while in a composite of rainbow trout (% lipid=1.20%; mean length=330 mm) from this site DDT level was 4 ng/g. DDT level in a composite of Sacramento sucker (% lipid=1.27%; mean length=450 mm) captured at Lost Slough was 13 ng/g, whereas in a composite of bluegill (% lipid=0.57%; mean length=143 mm) from this site DDT concentration was 4 ng/g. As stated at many places in this report, distinguishing the role of lipid content versus fish size in determining OC pesticide/PCB concentrations in fillets is difficult when contamination level is low.

DDT concentrations in two composites of white catfish (% lipid=1.11%; mean length=335 mm; (% lipid=1.07%; mean length=330 mm) collected from Whiskey Slough were 17 and 13 ng/g, respectively. In a composite (% lipid=0.53%; mean length=115 mm) of bluegill from this site the DDT was below reporting level. DDT concentrations in two composites of white catfish (% lipid=0.54%; mean length=272 mm; (% lipid=0.58%; mean length=263 mm) captured at Middle River were 18 and 30 ng/g, respectively, while in a composite of bluegill (% lipid=0.38%; mean length=170 mm) from this site the DDT level was 8 ng/g. DDT concentrations in two composites of white catfish (% lipid=0.32%; mean length=258 mm; % lipid=0.43%; mean length=258 mm) collected from Smith Canal were 11 and 15, respectively, but 6 ng/g in a composite of red-ear sunfish (% lipid=0.325%; mean length=188 mm) from the site. In two composites of white catfish (% lipid=0.73%; mean length=229 mm and % lipid=0.52% mean length=228 mm) caught from the San Joaquin River @ Laird Park DTT levels were 211 and 113 ng/g, respectively; DDT concentration was 18 ng/g in a composite of red-ear sunfish (% lipid=0.42%; mean length=272 mm) from this site. At all four of these sites DDT concentrations in the fattier white catfish were higher than in the centrarchids (bluegill, red-ear sunfish).

While Sacramento sucker were always the most contaminated, the order (highest to lowest) of tissue contamination level by species differed at the three sites where multiple species were collected:
Crow's Landing:
Sacramento sucker>channel catfish>large mouth bass>carp> bluegill>white catfish>red-ear sunfish
Vernalis:
Sacramento suckers>carp>large mouth bass>channel catfish>bluegill>white catfish> red-ear sunfish
Prospect Slough:
Sacramento sucker>white catfish=Sacramento pike minnow>carp=Sacramento perch= striped bass>crappie=large mouth bass>hitch.

The discussion above suggests that fish sizes constituting composites does not always completely account for differences in the order of species DDT contamination level. As with dieldrin, the role of fish size (average length of fish contributing to composite) in determining level of DDT contamination and differences among species was further explored. Sacramento sucker were most often the most contaminated, as well as largest, fish collected at a site. Therefore, at the three sites where multiple species were collected, contaminant and size ratios were calculated (species X/Sacramento sucker). From these ratios, sizes of other species collected at the site were adjusted to be equivalent to Sacramento suckers at the site. Table 30 summarizes actual and size-adjusted contaminant ratios at the three sites. The order of species contamination ratios is not the same at the sites. Of interest is that the actual and size-adjusted (standardized to Sacramento sucker) contaminant level in a species can be very different among sites. As with the dieldrin data, the DDT data suggest that there are factors other than species and fish size that affect level of DDT tissue contamination. Thus, it appears that we cannot predict level of contamination in other species from DDT concentrations in the most contaminated species. Furthermore, the patterns of DDT (Table 30) and dieldrin (Table 21) contamination ratios among species or sites were not similar.

*Hatchery fish*—DDT concentrations in composites of rainbow trout obtained from the San Joaquin River and Moccasin Creek hatcheries during 2005 were both below reporting level. DDT concentrations in composites of Chinook salmon from Merced and Mokelumne River hatcheries were 15 and 13 ng/g, respectively.

*Relationships among tissue DDT concentration, tissue lipid content and composite mean fish length*

Sacramento sucker

In this project, 16 composites of Sacramento suckers collected from the San Joaquin River watershed and Delta were analyzed for DDTs. Non-transformed did not, but log-transformed tissue DDT concentration data did, fit a normal distribution. Log-transformed composite % lipid, but not non-transformed, data fit a normal distribution. Neither non-transformed nor log-transformed composite mean fish length data fit a normal distribution. The failure of the mean length data to fit a normal distribution may be consequent to the variation in fish sizes constituting the composites and the tendency to select the largest fish collected. In all cases the small sample size possibly confounded assessment of normal distribution.

Results of regression analyses are summarized in Table 31. As with PCB and dieldrin data, a statistically significant relationship between composite % lipid and DDT concentration was detected. Percent lipid in composites appears to account for up to 79% of the variation in tissue dieldrin concentration (Table 31). A statistically significant relationship was also detected between mean length of fish in composites and DDT concentration (equivalent to what was seen with PCB, but not dieldrin data), but could account for less variation (approximately 20-30%) in tissue DDT levels than lipid content (Table 31). Older/larger fish tend to have more body lipid, so it is highly probable that tissue lipid is more of a determinant of DDT contamination. Length/age of Sacramento sucker may be a determinant of tissue lipid levels, but could account for less than 45% of the variability in this parameter (Table 31). In a multiple regression with log composite % lipid and log composite mean fish length as the independent variables and log DDT concentration as the dependent variable the $R^2$ was 0.79 ($P<0.00001$). Addition of length as a predictor of Sacramento sucker DDT did not alter the $R^2$ compared to the regression with log % lipid alone; further, length was not a statistically significant predictor of Sacramento sucker DDT concentration in the multiple regression. Wet weight DDT concentrations (non-transformed and log-transformed) were regressed on lipid-normalized DDT concentrations; results disclosed that log-transformed, but not non-transformed, lipid-normalized values were significant predictors of wet weight DDT concentrations, providing further support for lipid being a determinant (not simply exposure level) degree of fish DDT contamination (Table 31). Sites were ranked based on Sacramento sucker composite lipid content and on level of DDT concentration; a rank correlation analysis was then performed. The $R^2$ for this analysis was 0.90 ($P<0.00001$) and the slope was 0.97. These results provide robust evidence that lipid content of Sacramento sucker is a better predictor of DDT contamination than exposure level at a site. Moreover, there is little reason to believe that DDT exposure levels at sites would be dictated by lipid content of Sacramento sucker. Further, these findings call for a re-evaluation of assumptions regarding PCB/OC pesticide fish contamination. A similar link was not, however, detected in white catfish collected at sites in the San Joaquin River watershed and Delta, so the situation with Sacramento sucker should not be extrapolated to other species without confirming data. If lipid content is the only determinant of tissue DDT concentrations, a regression of lipid-normalized DDT concentrations on percent lipid should not yield a statistically significant $R^2$ (Herbert and Keenleyside, 1995). The $R^2$ of log-transformed data was 0.55 and highly statistically significant (Table 31). This finding robustly suggests that lipid content co-varied with another or other DDT concentration determinants (see Discussion section on determinants of POP concentrations).

Geometric wet weight and lipid-normalized mean (with the lower and upper 95% confidence limits) DDT concentrations in Sacramento sucker are 38, 17-85 and 1720, 996-2968 ng/g. Coefficients of variation for these means are 42 and 13.5%, respectively, revealing that lipid-normalization considerably reduces variability in the DDT data.

Tables 15 and 16 summarize regression coefficients ($R^2$) and rank (sites ranked by level of contamination) correlation coefficients (Rho), respectively, from analyses of wet weight and lipid-normalized PCB/OC pesticide concentrations in Sacramento sucker collected in the San Joaquin River watershed and Delta. Note that in both analyses statistically significant associations were observed between contaminant wet weight concentrations, but not with lipid-normalized concentrations. The fact that positive statistically significant associations among the three contaminants *implies* that sites that are the most are contaminated by all three of the contaminants. Moreover, the implication is that there is a ranking of sites by total PCB/OC pesticide contamination; that is, the most contaminated sites are contaminated by PCBs, DDTs, and dieldrin. Why should Sacramento sucker tissue PCB concentration at a site predict DDT and dieldrin tissue concentrations unless there is parallel contamination of PCBs, DDTs, and dieldrin at the sites sampled? Such a situation does not seem likely. I proposed another interpretation that is supported by data in Tables 15 and 16. My hypothesis is that exposure levels of PCBs, DDTs, and dieldrin are not necessarily the highest at sites with the most contaminated Sacramento sucker. I propose that factors, conditions, and the fish at sites differ and those with the most contaminated Sacramento sucker have conditions most favorable to bioaccumulation and biomagnification. Body lipid and a host of other physical, chemical, ecological, and physiological factors that affect bioaccumulation (see Discussion section on determinants of tissue and body concentrations of persistent organic pollutants—POPs). The data in Tables 15 and 16 provide impelling evidence that, in the San Joaquin River watershed and Delta, lipid content of Sacramento sucker was a more significant determinant of PCB/OC concentration in fish than site exposure level. Five of the Sacramento sucker composites that exceeded the OEHHA dieldrin (55% of exceedances) screening value also exceeded the PCB (83% of exceedances) and DDT (55% of exceedances) screening levels providing further evidence that these old, fatty Sacramento sucker are not providing an assessment of current PCB/OC pesticide exposure levels. That is, contaminant concentrations in these old, fatty Sacramento sucker are consequent to historic exposure throughout their lives. It is inappropriate to use Sacramento sucker contaminant levels to predict current exposure levels or contaminant levels in shorter-lived, less fatty fish at a site.

White catfish

DDT was measured in 32 composites of white catfish captured in the San Joaquin River watershed and Delta. Log-transformed, but not non-transformed, tissue DDT concentration data fit a normal distribution. Neither non-transformed nor log-transformed tissue lipid content nor composite mean fish length data were normally distributed. Most likely, this is related to the fact that composite tissue lipid content and mean length of fish in composites were less variable in white catfish than in Sacramento sucker. Other considerations that could relate to failure to detect a normal distribution i Table 32 summarizes the results of regression analyses with white catfish data. In contrast to results with Sacramento sucker, but as with PCB and dieldrin data, no significant relationships were seen between white catfish tissue lipid content and tissue DDT levels (slopes of regression plots were negative). Regression analysis indicated a statistically significant relationship between mean length of fish constituting the composite and composite DDT concentration, but with no more than 32% of the variability in DDT concentrations attributable to length of fish constituting composites (Table 32). However, the slopes of these regressions were negative (non-transformed data -0.50; log-transformed -3.79). A small percentage (22) of the variation white catfish composite lipid content could have consequent to length of fish constituting the composite (Table 32). There was no covariance of contaminant concentrations in white catfish associated with sites as detected in the Sacramento sucker data. This result is almost certainly related to the lower and lesser variation in lipid levels in white catfish compared to Sacramento sucker. Moreover, lipid levels in white catfish composites do not appear to be a major determinant of tissue DDT concentrations in white catfish. Therefore, white catfish are probably more accurate assessors of current PCB/OC pesticide exposure levels than Sacramento sucker.

Channel catfish and carp

Tissue DDT was analyzed in nine and seven composites of channel catfish and carp, respectively. Channel catfish composite lipid content ranged from 0.37 to 1.08% with a mean of 0.82%; tissue DDT concentrations ranged from 8 to 87 ng/g with a mean of 41 ng/g. There was no apparent relationship (low and statistically insignificant $R^2$) between composite log lipid content and log DDT concentration. Carp composite lipid content ranged from 0.40 to 1.65% while DDT concentrations ranged from 8 to 232 ng/g. In contrast to PCB data in these carp, there was no apparent relationship (low and statistically insignificant $R^2$) between composite log lipid content and log DDT concentration.

The lack of statistically significant relationships in many of these regression analyses should be interpreted with caution. Several factors could affect the outcome of these analyses, including overall relatively low levels of DDT contamination and fish were collected from multiple sites that potentially varied in level of DDT contamination. Furthermore, lipid content in white catfish was relatively low and not that variable. For ideal regression analysis there would be sufficient samples at each site to complete adequate analyses (i.e., decreasing the exposure level variable).

*Same species 'duplicate' composites*—Two separate composites of white catfish were analyzed at 13 sites. The largest difference in the 'duplicate' composites was seen in fish collected from the San Joaquin River at Laird Park. In one composite (average length=229 mm) DDT concentration was 211 ng/g whereas in the other (average length=241 mm) the level was 113 ng/g. Moreover, the composite with the higher average fish length contained about half the DDT residues compared to the composite with the lower average fish length. The smaller fish had a greater tissue lipid content (0.73 versus 0.52%), possibly accounting for the higher DDT contamination. In the other 12 'duplicate' white catfish composites DDT concentrations were equivalent. The largest difference in composite average length was 19 mm with a 5 ng/g difference in 'duplicate' DDT concentration (fish collected from Sand Mound Slough). The composite composed of larger fish also had higher lipid content. The greatest difference in 'replicate' DDT residues was 12 ng/g with a 9 mm difference in composite fish average length (fish collected from the Middle River); lipid content in the two composites was equivalent (0.58 and 0.54%).

'Duplicate' composites of Sacramento suckers were available at six sites. In fish collected from the Tuolumne River one composite (average length=456 mm) had a DDT concentration of 339 ng/g whereas the level in the 'duplicate' composite (average length=467 mm) was 269 ng/g. This is a notable difference in DDT residues given that the fish were of equivalent size. Further, the smaller average length, more DDT contaminated composite had a lower lipid content (4.19 versus 4.37%). Likewise, in Sacramento suckers collected from the Merced River one composite (average length=375 mm) contained DDT residues of 55 ng/g while the 'duplicate' (average length=386 mm) concentration was 20 ng/g. However, the composite with lower mean length had notably higher lipid content (2.29 versus 1.61%). In 'duplicate' composites from the Stanislaus

River the difference in DDT concentration was only 1 (14 versus 13) even though there was no overlap in fish lengths in the two composites (average lengths of 482 and 338 mm). The composite with lower mean fish length had higher lipid content (1.89 versus 1.10%). In 'duplicate' Sacramento sucker composites from the Cosumnes River DDT concentrations were low (<10 ng/g) and identical. DDT concentrations in 'replicate' composites of Sacramento sucker taken in the Mokelumne River were 28 and 14 ng/g. Average fish length in the composites was equivalent (458 and 455 mm), but lipid content was higher (2.66 versus 2.22%) in the composite with the higher DDT concentration. These data suggest that multiple Sacramento sucker composites would provide a more accurate estimate of DDT contamination in areas where high contamination is predicted.

*Temporal trends*—Assessing temporal trends is difficult when the same sites and same species are not sampled yearly as well as when the number of samples analyzed is inadequate for robust statistical analyses. Spatial and temporal variation in OC pesticide and PCB fish contamination are realities. Thus, sampling numerous (same) sites, the same species per site, and 'replicate' composites per site on a yearly basis is essential for accurate temporal trend analysis as well as for predicting future changes in fish contamination. While fish sampling for OC/PCB contamination in the Sacramento River watershed has been more extensive than in the San Joaquin River watershed and Delta, all of the above problems plague temporal trend analyses of fish contamination in Central Valley waterways. Clearly there was and is no consistent strategy or plan for addressing this issue.

The analysis of Greenfield et al. (2004) documented that OC pesticide and PCB contamination of fish in Central Valley declined rapidly in the 1970s to the mid-1980s, but the rate of decrease slowed in the 1990s such that statistical differences could not be detected. Inability to detect statistically significant decreases very possibly relates to the small number of sites, samples, and duplicates. Given that the rapid decline in the 1970s and early-1980s has been documented, my focus is on the period between 1990 and 2005. Thus, I examined the SFEI database for fillet composites of Sacramento sucker, white catfish, channel catfish, and carp collected in that period. For the San Joaquin River watershed and Delta only 18 composites of these species were found, 16 of white catfish plus one each of channel catfish and carp. All these composites were from fish collected in 1998 except one of Sacramento sucker (from Stanislaus River) and one of white catfish (from Salt Slough) taken in 1990. The ∑DDTs in the 1990 composite of Sacramento sucker collected from the Stanislaus River was reported as 4127 ng/g whereas in 'duplicate' composites of Sacramento sucker caught in 2005 at this site DDTs were 13 and 3 ng/g. The ∑DDTs in a composite of channel catfish collected at this site in 2005 was 24 ng/g. These findings document (if the 1990 value was accurate) a major decline in DDT fish contamination in this river. DDT levels in composites of white catfish collected from Salt Slough during 1990 and 1998 were 296 and 57 ng/g, respectively. Concentration in two composites of channel catfish captured at this site during 2005 were both 34 ng/g, suggesting a continuing decline in DDT fish contamination at this location (especially given that channel catfish tend to be fattier and typically more contaminated than white catfish). The ∑DDTs in a composite of channel catfish collected from the

Merced River in 1998 was 524 ng/g. DDT levels were 49 and 20 ng/g in two composites of Sacramento sucker collected in the Merced River during 2005. These data suggest a large decline in DDT contamination of fish at this site since 1988; however, a caveat is that lipid content in the 1998 catfish composite was 5.50% whereas 2.29 and 1.61% in the 2005 Sacramento sucker composites. The point is that higher levels of DDT contamination may have been discovered if fattier fish were present, collected, and analyzed in 2005.

As with white catfish collected in the San Joaquin watershed and Delta during 2005 DDT concentrations (non-transformed nor log-transformed) in composites of fish taken during 1998 were not significantly related to composite percent lipid ($R^2$=0.16 and 0.09, respectively). DDT concentrations in composites of white catfish collected from the San Joaquin River watershed and Delta during 1998 (n=14) and 2005 (n=32) were compared in a t-test. Means for 1998 and 2005 were 186 (coefficient of variation=72%) and 29 ng/g (CV=150%), respectively, and significantly different ($P<0.001$). DDT geometric means for 1998 and 2005 were117 (CV=2%) and 17 (CV=15%), respectively, and highly significantly different ($P<0.00001$). CVs for the geometric means were lower indicating that the DDT concentrations are more log-normal distributed. DDT medians for 1998 and 2005 were 157 and 14 ng/g, respectively. The decrease in DDT mean and geometric mean concentration between 1998 and 2005 was 84 and 88% respectively; decline of median concentration was 90%. If decline was relatively constant between 1998 and 2005 the rate would be approximately 12-13% per year. At these rates of decline, average DDT residues in white catfish in the San Joaquin River watershed and Delta would not fall below 5 ng/g until approximately 2025. Summarized below are concentrations (ng/g) of DDTs in composites of white catfish collected during 1998 and 2005 at the same sites.

| | 1998 | 2005 |
|---|---|---|
| SJR @ Veranlis | 291, 389 | 29 |
| Smith Canal | 43 | 11, 13 |
| Middle River | 55 | 18, 30 |
| Old River | 255 | 10, 11 |
| Paradise Cut | 157 | 17, 24 |

Declines at these sites ranged from 45 to 92%. These, combined with other data summarized above, document significant decreases in DDT fish contamination in the San Joaquin River watershed and south, east, and west portions of the Delta. While white catfish may very well be effective indicators of current PCB/OC pesticide contamination, a caveat is that they are not usually worst-case indicators of OC/PCB contamination. Specifically, there were locations in the watershed and Delta that manifested relatively high levels of contamination. That is, DDT concentrations in composites of Sacramento sucker collected during 2005 from the San Joaquin River at Vernalis and Crow's Landing were 338 and 127 ng/g, respectively. DDT level in a composite sample of Sacramento sucker caught in Potato Slough in 2005 was 346 ng/g. In 'replicate' composites of Sacramento sucker collected from the Tuolumne River during 2005 DDT concentrations were 269 and 339 ng/g. DDT concentrations in 'duplicate' composites of white catfish taken from the San Joaquin River @ Laird Park during 2005 were 113 and 211 ng/g.

Given that there has been a significant decrease in DDT white catfish contamination at many sites in the San Joaquin River watershed and Delta these five sites definitely deserve attention in future investigations of DDT fish contamination. However, other sites in the San Joaquin River watershed and Delta would likely have manifested higher levels of DDT contamination if Sacramento sucker, channel catfish, or carp were present and collected. Due to several considerations (not only exposure levels) spatial (site) differences in rates of DDT decline are certainly possible, and there are insufficient data to estimate rates of DDT decline in Sacramento sucker, channel catfish, and carp. I argue that old, fatty Sacramento sucker are not accurate predictors of current PCB/OC pesticide exposure levels (i.e., concentrations in food items), but rather reflects exposure throughout their lifetime.

## Sacramento River Watershed

### Fish Tissue PCB Residues

*Frequency of contamination, spatial distribution, and comparison to OEHHA screening level*—Forty-six composites from fish collected in the Sacramento River watershed during 2005 were analyzed for PCBs. PCBs were not detected or below reporting level (DNQ—detected, but not quantified) in 11 and 65%, respectively, of the composites. Composite PCB concentrations were 12 to 19 ng/g and greater than 20 ng/g (OEHHA screening value) in 11 (Table 33) and 13% (Table 34), respectively. The highest PCB concentration (102 ng/g) observed was in a composite of channel catfish collected from the Sacramento River at Colusa (Table 34). The high PCB contamination at the Colusa site is enigmatic. Other sites where PCB concentrations were greater than 20 were the Sacramento River (at Veteran's Bridge), the American River (at Discovery Park), Clear Creek and Sacramento Slough (at Karnak). Clear Creek, Sacramento Slough, the lower American River, and the Sacramento River are not CWA 303(d) listed for PCB contamination. PCB levels in the composite of Sacramento sucker from Clear Creek and the composite of channel catfish from Sacramento Slough were 27 and 21 ng/g, respectively. If other species of human consumable fish at these sites were at these levels the OEHHA recommended number of fish meals per month would be eight or less (OEHHA, 2006—Table 4 in this report). However, PCB concentrations in a composite of rainbow trout from Clear Creek and a second composite of channel catfish from Sacramento Slough were below the reporting level and 13 ng/g, respectively. Because there was only one composite that exceeded the screening value from these two sites, data are insufficient (SWRCB, 2004) for 303(d) listings. PCB concentrations in the composite of Sacramento sucker from the American River @ Discovery Park and the composite of channel catfish from the Sacramento River @ Veteran's Bridge were 44 and 53 ng/g, respectively. If other species of human consumable fish at these sites were at these levels the OEHHA recommended number of fish meals per month would be four or less (OEHHA, 2006—Table 4 of this report). However, PCB concentrations in a composite of white catfish and three composites of large-mouth bass from the American River @ Discovery Park were all below reporting level. The composite of Sacramento sucker from the Discovery Park site was characterized by very high lipid content, the highest of any of the 17 Sacramento sucker composites in the 2005 dataset from the Sacramento River watershed; clearly the lipid was the determinant of the relatively high PCB concentration. Furthermore, the single composite exceedance of the screening level is insufficient to 303(d) list the lower American River. Composites of channel catfish (53 ng/g) and carp (26 ng.g) collected at the Veteran's Bridge site exceeded the OEHHA screening level, while a composite of Sacramento sucker (6 ng/g) from the site did not. PCB concentrations in these three composites exactly paralleled lipid content. The two exceedances of the screening level are adequate to 303(d) list this portion of the Sacramento River. However, I recommend that consideration be given (perhaps revising the SWRCB listing and delisting policy?) to the role of fish age and lipid in assessing PCB and OC pesticide contamination. Further, I recommend that consideration also be yielded to the fact that PCB levels in composites of fish from neither the nearest upstream (Grimes) nor downstream (RM 44) sites exceeded the screening level. Additional data also could clarify PCB contamination at the Veteran's Bridge site; multiple composites from five to six species are recommended.

PCB concentration in a composite of channel catfish from the Sacramento River @ Colusa was 102 ng/g. If other species of human consumable fish at these sites were at these levels the OEHHA recommended number of fish meals per month would be one or less (OEHHA, 2006—Table 4 in this report). However, PCB concentration in a composite of Sacramento sucker from this site was below the reporting level. The large divergence in PCB contamination in channel catfish (lipid content of composite=4.44%) and Sacramento sucker (lipid content of composite=0.93%) from the Colusa site is disconcerting. Such results evoke concerns regarding predicting level of contamination at a site from a single composite from one species and disregarding the role of lipid, as well as other factors (other than exposure level), in determining OC/PCB contamination. Since there was only one composite with an exceedances of the OEHHA screening value, 303(d) listing of the Colusa region of the river is not in order. The most PCB-contaminated fish at the five sites in Table 34 were large/old and fatty. These fish do not provide an indication of current exposure levels at these sites, but rater exposure throughout their lives.

The only waterway in the Sacramento River watershed listed for PCB contamination is Natomas East Main Drain. No fish were collected from this drain in the 2005 mercury projects. This site should be targeted in the next round of OC/PCB sampling.

In fish captured from Sacramento Slough and the Sacramento River (Rio Vista and RM 44) composite concentrations ranged from 12 to 19 ng/g (Table 31). The CVRWCB has proposed CWA 303(d) listing of the northern Delta for PCB contamination. While PCB concentration in a composite (with high lipid content) of Sacramento sucker caught in Prospect Slough was 20 ng/g (Table 10), tissue PCB contamination in Sacramento sucker collected from the Sacramento River at RM 44 and in Sacramento sucker, carp, and white catfish taken from the Sacramento River at Rio Vista was below 20 ng/g (Table 33). PCBs in composites of seven of nine species collected from Prospect Slough were below reporting level; concentrations in two composites of white catfish from this site were 10 and 12 ng/g (Table 11). From a weight-of-evidence perspective these 2005 data do not support a 303(d) listing of the northern portion of the Delta.

Mean and geometric mean (with lower and upper 95% confidence limits) PCB concentrations in composites of Sacramento sucker (17 composites) collected in the Sacramento River watershed are 9, 6-15 and 5, 2-10 ng/g, respectively (Table 35); median concentration is 6 ng/g. Coefficient of variation (CV) for the means is 119 and 85%, respectively, indicating that the PCB data are a better fit to a log-normal distribution. Mean and geometric mean ( with lower and upper 95% confidence limits) PCB concentrations in composites of Sacramento sucker plus channel catfish plus carp (26 composites) collected in the Sacramento River watershed are 15, 7-24 and 7, 4-13 ng/g, respectively (Table 35); median concentration is 7 ng/g. Coefficient of variation (CV) for the means is 142 and 64%, respectively, indicating again that the PCB data are a better fit to a log-normal distribution. The upper 95% confidence limit for the Sacramento sucker mean PCB concentration does not, but the upper limit for Sacramento sucker plus channel catfish plus carp does, overlap the OEHHA PCB screening value. Neither of the two geometric means upper 95% CI overlaps the screening value. The two most contaminated composites were from Sacramento River channel catfish (Colusa and Veteran's Bridge sites). Mean PCB concentrations in composites of Sacramento sucker and in Sacramento sucker plus channel catfish plus carp collected in the main stem Sacramento River were 7 and 20 ng/g, respectively; median concentrations were 6 and 6.5 ng/g, respectively. The upper 95% confidence limit for the Sacramento sucker mean PCB concentration did not, but the upper limit for Sacramento sucker plus channel catfish plus carp did, overlap the OEHHA PCB screening value.

Overall, data collected during 2005 disclose that PCB fish contamination in the Sacramento River watershed and north Delta is low and at concentrations such that 20 or more fish meals per month can be consumed (OEHHA, 2006). ∑PCBs exceeded screening value at seven sites; exceedances were only in composites of older, fatty fish that represent worst-case, but do not reflect current exposure levels.

*PCB levels among species*—PCB contamination in composites of channel catfish collected from the Sacramento River at Colusa and Veteran's Bridge was greater than 50 ng/g (Table 34). Notably, however, PCB level in a composite of channel catfish collected from the Sacramento River at Grimes (between the Colusa and Veteran's Bridge sites) was only 9 ng/g. Average length of fish and lipid content in the composite of channel catfish taken at Grimes was, by far, the highest (621 mm and 7.13%) in this project. No immediate explanation is available for this puzzling spatial pattern of PCB contamination. The composite from fish caught at Colusa and the Veteran's Bridge sites did have relatively high lipid content—4.44 and 2.37%, respectively. While the composite of channel catfish (mean length=470 mm; lipid content=4.44%) from the Sacramento River at Colusa had the highest PCB concentration (102 ng/g) seen in the Sacramento River watershed, the level in a composite of Sacramento sucker (mean length=403 mm; lipid content=0.93%) collected at this site was below reporting level. The large divergence in PCB contamination in channel catfish (lipid content of composite=4.44%) and Sacramento sucker (lipid content of composite=0.93%) from the Colusa site is disconcerting. Such results evoke concerns regarding predicting level of contamination at a site from a single composite from one species and disregarding the role of lipid, as well as other factors (other than exposure level), that determine OC/PCB contamination. Composites from three species were available at the Sacramento River Veteran's Bridge site. PCB concentration in composites of channel catfish (mean length=526 mm; lipid content=2.37%), carp (mean length=573 mm; lipid content=1.55%), and Sacramento sucker (mean length=409 mm; lipid content=1.01%) were 53, 26 ng/g, and below reporting level, respectively. Note that PCB concentrations relate more to lipid content than to mean length in these composites.

PCB concentration in the composite of rainbow trout (mean length=375 mm; lipid content=2.00%) collected from Clear Creek was less than the reporting limit (DNQ—detected, but not quantified) whereas the level in the composite of Sacramento sucker (mean length=447 mm; lipid content=3.03%) captured at this site was 27 ng/g. Two composites of channel catfish taken at Sacramento Slough were available; PCB concentration in one was 21 ng/g (mean length=294 mm; lipid content=1.73%) while 13 ng/g (mean length=390 mm; lipid content=1.25%) in the other. These data suggest that composite lipid can better account for tissue PCB concentration than fish length. Further, this finding denotes the need for multiple composites from several species at a site to gain an accurate assessment of fish contamination.

PCB concentration in the composite from Sacramento sucker (mean length=461 mm; lipid content=4.44%) captured at Discovery Park on the American River was 44 ng/g, whereas in the composite from white catfish (mean length=270 mm; lipid content=0.37%) taken at this site was below reporting level. PCB levels in three composites (lipid content in all less than 0.40%) of largemoth bass from the Discovery Park site were all below reporting level. These data indicate that reliance on data from a single species could lead to inaccurate assessments and also that tissue lipid content is a likely determinant of PCB contamination. In a composite of Sacramento sucker (mean length=511 mm; lipid content=0.83%) collected from the American River at Nimbus Dam PCB level was below the reporting level, illustrating a considerable difference in PCB contamination at this site compared to the not very distant Discovery Park site; yet urban Sacramento lies between the two sites. Again, however, the lipid content of the Sacramento sucker composites from the two sites was considerably different (4.44% versus 0.83%) and consistent with the difference in PCB contamination.

PCB levels in composites of Sacramento sucker (mean length=477 mm; lipid content=2.79%) and coho salmon (mean length=828 mm; lipid content=3.78%) taken from the Sacramento River at RM 44 were 15 ng/g and below reporting level, respectively. This difference is not surprising given the difference in habits (benthic versus pelagic, migratory). PCBs also were below reporting level in a composite of large-mouth bass caught at this site. There were composites from three species at the Sacramento River Rio Vista site. PCB levels in composites of Sacramento sucker (mean length=476 mm; lipid content=3.00%), carp (mean length=573 mm; lipid content=0.98%), and white catfish (mean length=337 mm; lipid content=1.00%) were relatively equivalent at 19, 13, and 12 ng/g, respectively. Note that composite lipid content is a more likely determinant of PCB contamination than fish length. These results are in contrast to what was observed in composites of the three species collected at the Veteran's Bridge site. At that site, carp were much more PCB-contaminated compared to

Sacramento sucker. At the Rio Vista site, Sacramento sucker was the most PCB-contaminated of the three species regardless of the fact they were not the largest fish. At both sites, however, composite lipid content could account for the relative levels of PCB contamination. Again, these results caution against reliance on a single composite from one species to assess contamination.

Composites from 17 Sacramento suckers, five channel catfish, and four carp collected in the Sacramento River watershed were analyzed for PCBs; two (American River @ Discovery Park and Clear Creek), three (Sacramento River @ Colusa, Sacramento River @ Veteran's Bridge, and Sacramento Slough @ Karnak), and one (Sacramento River @ Veteran's Bridge), respectively, of these composites had PCB concentrations greater than 20 ng/g (OEHHA screening value). These data suggest that, percentage-wise, channel catfish were the best 'detectors' of PCB contamination in the Sacramento River watershed. This finding most likely relates to the fact that tissue lipid content in channel catfish was higher than in any other species collected (Table 35). The mean PCB concentration in composites of Sacramento sucker collected from the main stem Sacramento River (n=8) and from the entire Sacramento River watershed (n=17) was 7 and 9 ng/g, respectively (Table 34). The upper 95% confidence limit on neither of these means overlapped 20 ng/g.

*Hatchery fish*—Composites of rainbow trout from three hatcheries (American River, Darrah Springs, and Mount Shasta) and of coho salmon from three hatcheries (Feather River, Coleman, and Nimbus) were analyzed for PCBs. PCB concentration in all hatchery trout composites was less than reporting level. Composites were also available from rainbow trout captured from Clear Creek, the Sacramento River at Bend Bridge, and the Yuba River at Marysville; PCB concentration in all these composites was below the reporting level. PCB concentration in composites of coho from the Feather River and Nimbus hatcheries also was below reporting level, as well as in a composite of coho collected from the Sacramento River at RM 44. PCB concentration in the composite of Coleman hatchery salmon was 17 ng/g; the notably higher lipid content in this composite (6.80 versus 1.79, 3.14, and 4.78% in the other three coho composites) almost certainly accounts for much of the differences in PCB concentrations.

*Relationships among tissue PCB concentration, tissue lipid content and composite mean fish length*—Table 36 summarizes composite mean lipid content and mean fish length in composites of fish species collected in the Sacramento River watershed. Lipid content in channel catfish composites was higher than any other species even though the size of fish constituting composites was not the highest.

Log-transformed, but not non-transformed, tissue PCB concentrations in composites (n=17) of Sacramento sucker collected in the Sacramento River watershed fit a normal distribution. For Sacramento sucker composite lipid and composite mean fish length, neither non-transformed nor log-transformed fit a normal distribution. In composites (n=16) of Sacramento sucker collected in the San Joaquin watershed and Delta both non-transformed and log-transformed tissue PCB concentration data fit a normal distribution. Furthermore, in composites of Sacramento sucker collected in the San Joaquin watershed and Delta log-transformed composite percent lipid fit a normal distribution. There are several possible reasons that the Sacramento River watershed Sacramento sucker data did not fit a normal distribution including (1) fish caught in the San Joaquin River watershed and Delta had significantly higher composite lipid content compared to the fish from the Sacramento River watershed, (2) compositing could obscure a normal distribution, (3) the tendency to select the largest fish available, (4) fish come from different sites that may differ in PCB contamination, and (5) many sites sampled in this project appear to have low PCB contamination.

Percent lipid in Sacramento sucker composites was significantly related to PCB concentration, potentially accounting for up to 83% of the variability in tissue contamination (Table 37). A similar situation was observed with Sacramento sucker caught in the San Joaquin River watershed and Delta (Table 13). However, a stronger relationship was seen in log-transformed data in that data set, but the reverse was noted in the Sacramento River watershed data. Slopes and intercepts of both non-transformed and log-transformed regressions of PCB concentrations on percent lipid were significantly different in the San Joaquin River watershed/Delta compared to the Sacramento River watershed datasets. Length of fish constituting composites from the Sacramento River watershed had no statistically significant relationship to level of PCB contamination (Table 37). This too is in contrast to Sacramento sucker collected from the San Joaquin River watershed/Delta where length was a weak, but statistically significant predictor of PCB concentrations. Fish length was not a statistically significant predictor of tissue lipid content in Sacramento sucker from the Sacramento River watershed, but was in fish from the San Joaquin River watershed/Delta (Table 37). The differences in the Sacramento sucker from the San Joaquin River watershed/Delta and the Sacramento River watershed provide a robust indication that determinants (not simply dissimilar exposure levels) of PCB contamination are divergent. Wet weight PCB concentrations (non-transformed and log-transformed) were regressed on lipid-normalized PCB concentrations; results disclosed that lipid-normalized values were significant predictors of wet weight PCB concentrations, providing further support for lipid being a determinant (not simply exposure level) degree of fish PCB contamination (Table 37). Sites were ranked based on the lipid content of composite(s) and on level of PCB concentration; a rank correlation analysis was then performed. The $R^2$ for this analysis was 0.58 (P=0.0004) and the slope was 0.78. These results provide evidence that lipid content of Sacramento sucker is likely a determinant of PCB contamination. Moreover, it is not simply exposure level at a location that determines level of contamination. There is little reason to believe that PCB exposure levels at sites would be dictated by lipid content of Sacramento sucker. If lipid content is the only determinant of tissue PCB concentrations, a regression of lipid-normalized PCB concentrations on percent lipid should not yield a statistically significant $R^2$ (Herbert and Keenleyside, 1995). The $R^2$ values were rather low, yet statistically significant (Table 37). This finding suggests that lipid content co-varied with another or other PCB concentration determinants (see Discussion section on determinants of POP concentrations).

The geometric mean (with the lower and upper 95% confidence limits) wet weight and lipid-normalized PCB concentrations for Sacramento sucker collected in the Sacramento

River watershed are 5, 2-10 and 185, 58-590 ng/g, respectively. Coefficient of variation on these means is 85 and 44%, respectively, revealing that lipid-normalization reduces variability in the PCB data. The geometric mean (with lower and upper 95% confidence limits) wet weight and lipid-normalized PCB concentrations for Sacramento sucker+channel catfish+carp collected in the Sacramento River watershed are 7, 4-13 and 204, 72-575 ng/g, respectively. Coefficient of variation on these means is 64 and 48%, respectively, again revealing that lipid-normalization reduces variability in the PCB data.

Tables 38 and 39 summarize regression coefficients ($R^2$) and rank (sites ranked by level of contamination) correlation coefficients (Rho), respectively, from analyses of wet weight versus lipid-normalized PCB/OC pesticide concentrations in Sacramento sucker collected in the Sacramento River watershed. Note that in both analyses statistically significant associations were observed between contaminant wet weight and lipid-normalized concentrations. In all cases, however, the degree of association between contamination is less and the P value higher in lipid-normalized concentrations. The fact that positive statistically significant associations among the three contaminants *implies* that the most contaminated sites are by PCBs, DDTs, and dieldrin. Moreover, the implication is that there is a ranking of sites by total PCB/OC pesticide contamination. Why should Sacramento sucker tissue PCB concentration at a site predict DDT and dieldrin tissue concentrations unless there is parallel contamination of PCBs, DDTs, and dieldrin at the sites sampled? Such a situation does not seem likely. I propose another interpretation that is supported by data in Tables 38 and 39. My hypothesis is that exposure levels of PCBs, DDTs, and dieldrin are not necessarily the highest at sites with the most contaminated Sacramento sucker. I propose that factors, conditions, and the fish at sites differ and those with the most contaminated Sacramento sucker have conditions most favorable to bioaccumulation and biomagnification. In addition to exposure level, body lipid and a host of other physical, chemical, ecological, and physiological factors that affect bioaccumulation (see Discussion section on determinants of tissue and body concentrations of persistent organic pollutants—POPs). The data in Tables 38 and 39 provide impelling evidence that, in the Sacramento River watershed, lipid content of Sacramento sucker was a more significant determinant of PCB/OC concentration in fish than current site exposure level.

The channel catfish composite (fish from Grimes site) with the highest lipid content (7.14%) was characterized by the lowest PCB concentration. In the other four channel catfish composites PCB concentration varied in direct parallel with composite lipid content. In rainbow trout composites (n=6) PCB concentrations were all less than the reporting level so no relationship with lipid content (range=1.42 to 3.00%) was seen.

*Same species' duplicate' composites*—Enough fish were collected at four Sacramento River watershed sites such that 'duplicate' composites could be constituted. Comparing such 'duplicate' composites yields some indication regarding variability of contamination in a species of interest. If concentrations are divergent in 'replicate' composites, a single composite is not sufficient for providing an accurate assessment of contamination. 'Duplicate' composites of Sacramento sucker were available for the Feather River at Gridley and the Yuba River at Marysville, of channel catfish for Sacramento Slough at

Karnak, and of red-ear sunfish for the Bear River at Rio Oso. PCBs in 'duplicate' composites of Sacramento sucker collected at Gridley were a non-detect (mean length=327 mm; lipid content=0.61%) and below reporting level (mean length=483 mm; lipid content=1.56%). For the Sacramento sucker caught at the Marysville site, PCB levels in 'duplicate' composites were both below reporting level (mean length=448; lipid content=0.73% and 288 mm; lipid content=1.27%). PCB concentrations in 'duplicate' composites of channel catfish captured from Sacramento Slough were 13 ng/g (mean length=390 mm; lipid content=1.25%) and 21 ng/g (mean length=293 mm; lipid content=1.73%). Note that the composite with the largest fish had a lower lipid content and a lower PCB concentration. For the red-ear sunfish collected from the Bear River, PCB levels were a non-detect (mean length=187 mm; lipid content=0.40%) and less than reporting level (mean length=171 mm; lipid content=0.38%). Sacramento sucker and red-ear sunfish 'replicates' were relatively consistent in view of differences in fish size constituting the composites. In contrast, 'duplicate' composites of channel catfish were divergent and not what expected given the differences in fish lengths constituting the composites, but more consistent with lipid content of 'duplicate' composites. PCBs in three composites of large-mouth bass from the American River at Discovery Park were all below the reporting level. PCB contamination in Sacramento sucker, red-ear sunfish, and large mouth bass was too low to distinguish effects of lipid and mean fish length in composites.

*Temporal trends*—Assessing temporal trends is difficult when the same sites and same species are not sampled yearly as well as when the number of samples analyzed is inadequate for robust statistical analyses. Spatial and temporal variation in OC pesticide and PCB fish contamination are realities. Thus, sampling numerous (same) sites, the same species per site, and 'replicate' composites per site on a yearly basis is essential for accurate temporal trend analysis as well as for predicting future changes in fish contamination. While fish sampling for OC/PCB contamination in the Sacramento River watershed has been more extensive than in the San Joaquin River watershed and Delta, all of the above problems plague temporal trend analyses in Central Valley waterways. Clearly there was and is no consistent strategy or plan for addressing this issue.
The analysis of Greenfield et al. (2004) revealed that OC pesticide and PCB contamination of fish in Central Valley declined rapidly in the 1970s to the mid-1980s, but the rate of decrease slowed in the 1990s such that statistical differences among years could not be detected. Inability to detect statistically significant decreases among years almost certainly relates to the small number of sites, samples, and duplicates. Given that the rapid decline in the 1970s and early-1980s has been documented, my focus is on the period between 1990 and 2005. Thus, I examined the SFEI database for fillet composites of Sacramento sucker, white catfish, channel catfish, and carp collected in that period. For the entire Sacramento River watershed there were a total of 46 composites analyzed for OC pesticides and PCBs for the period of 1990 through 2004. There were 22, 16, 3, and five composites of white catfish, Sacramento sucker, channel catfish, and carp, respectively. The number of composites by year was:

| | | | |
|---|---|---|---|
| 1990 | 2 | 1992 | 1 |
| 1993 | 2 | 1997 | 6 |
| 1998 | 4 | 1999 | 10 |

| | | | |
|---|---|---|---|
| 2000 | 12 | 2001 | 6 |
| 2003 | 3 | | |

There are too few composites of the same species, especially from the same sites, over this 14 year period to perform even a simple statistical analysis. Some of the clearest temporal trends in PCB fish contamination can be seen in sites (Colusa Basin Drain, Sacramento River @ RM 44, and lower American River) that have been sampled several times since 1990.
There are seven composites from fish collected at CBD for the 1990 to 2005 period.

Colusa Basin Drain

| Year | Species | PCB Concentration |
|---|---|---|
| 1998 | Carp | 4 ng/g |
| 2000 | Carp | 4 ng/g |
| 2000 | White catfish | <RL |
| 2001 | Carp | 6 ng/g |
| 2001 | Channel catfish | 9 ng/g |
| 2005 | Carp | <RL |
| 2005 | White catfish | ND |

Since 1998 PCB fish contamination at CBD has been near or below reporting level.

For the period 1990 to 2005 period there are 11 composites of fish colleted from the Sacramento River @ RM 44.

Sacramento River @ RM 44

| Year | Species | PCB Concentration |
|---|---|---|
| 1992 | White catfish | 124 ng/g |
| 1993 | White catfish | <RL |
| 1997 | White catfish | 32 ng/g |
| 1998 | White catfish | 32, 203 ng/g |
| 1999 | White catfish | 18, 24, 26 ng/g |
| 2000 | White catfish | 38 ng/g |
| 2000 | Sacramento sucker | 24 ng/g |
| 2002 | Sacramento sucker | 62 ng/g |
| 2005 | Sacramento sucker | 15 ng/g |
| 2005 | Coho salmon | <RL |
| 2005 | Large mouth bass | <RL |

For the most part, PCB concentrations at this site ranged from 15 to 40 ng/g. The high concentrations in composites from 1992, 1998, and 2002 are rather puzzling. Lipid content in the 2002 Sacramento sucker composite was very high (10.4%); this accounts for the high PCB level in this composite. The high concentration of PCBs in one of the 'duplicate' composites from 1998 is enigmatic. Lipid content in the two composites

(1.94 and 2.00%) is not a likely answer. A critical issue to address is whether this is typical of intraspecific variation in composites from a given site. The three white catfish composites from the following year (1999) were rather uniform with regards to PCB concentration, rendering the high concentration in the 1998 composite more puzzling. Throughout this report I emphasize the importance of understanding variation (within species and between species) in fish contamination at individual sites; this case supports the need for such an understanding. Lipid content in the 1992 white catfish composite was relatively high (3.70%); however, lipid content in the 1993 white catfish composite was somewhat higher (3.99%) with PCB levels below the reporting level. Lipid was not a significant predictor of tissue PCB/OC pesticide concentrations in from the San Joaquin River watershed and Delta. Only three composites of white catfish were available from the Sacramento River watershed, so we can't assess whether a similar/same situation occurs in the Sacramento River watershed. While several have attempted to simplify the analysis of contaminant temporal trends, this case is another illustration that such analyses are complex even at an individual site with a single species (see Discussion section on determinants of contaminant concentrations).

For the period 1990 to 2005 there are 12 composites of fish collected from the lower American River.

Lower American River

| Year | Species | PCB Concentration |
|---|---|---|
| 1999 | Sacramento sucker | 2, 10 ng/g |
| 2000 | Sacramento sucker | 8 ng/g |
| 2001 | Sacramento sucker | 62, 63 ng/g |
| 2002 | Sacramento sucker | 55, 288 ng/g |
| 2005 | Sacramento sucker | 44 ng/g |
| 2005 | White catfish | <RL |
| 2005 | Large mouth bass | <RL, <RL, <RL |

These data suggest that PCB Sacramento sucker contamination in the lower American River increased from 2000 to 2001 and remained relatively high through 2005. The divergence in PCB concentration in the 'duplicate' composites from 2002 is puzzling. The composite with the higher PCB concentration also had the higher lipid content (7.88 versus 5.12%), possibly accounting for some of the divergence. The issue, however, is whether such divergence is typical of PCB concentration variation within a species at the same site. Overall there is no clear trend at this site. PCB contamination in older, fatty Sacramento sucker is not indicative of tissue levels in other species, especially younger, less fatty fish. The large-mouth bass and white catfish data PCB exposure levels at this site are currently very low.

Since 1990 white catfish were collected from the Sacramento River watershed and north Delta at multiple sites in 1997, 1998, 1999, 2000, and 2005. Unfortunately, sampling was not at the same sites in those years and spatial variability of bioaccumulation, biomagnification, exposure level, and fish contaminant level is a reality. White catfish samples from the Sacramento River @ RM44 were available in four of the five years. Composites from the north Delta and from the lower American River were available for three of the years, and the Sacramento River @ Veteran's Bridge and Sacramento Slough for two of the years. The number of white catfish composites per year ranged from two (1998) to seven (2000). ANOVA, ANCOVA, and/or regression analysis could possibly be applied to these white catfish data in way of temporal trend analysis. A visual inspection of the data, however, reveals considerable spatial (within year) variation such that application of such methods is superfluous. For example, the mean PCB concentration for 1997, 1999, and 2000 ranged from 17 (1997) to 28 ng/g (2000), all with large standard deviations. Only two 1998 white catfish composites, both from the Sacramento River @ RM44, were analyzed with concentrations of 34 (typical of the other three years) and 203 ng/g. The high concentration in the one composite is puzzling since all other contaminant concentration in that composite were highly equivalent to those in the other composite from the site. Again, the issue is whether this divergence is typical of intraspecific variation of PCB concentration at a site in a given year. Overall, the white catfish data suggest little change in PCB fish contamination in the Sacramento River watershed from 1997 through 2000. The mean for 2005 (only three composites) was 6 ng/g, indicating a decline from 2000. The caveat, of course, is that the coverage of the watershed was very limited and the sample size small in all years. Looking at individual sites, PCB concentrations in white catfish composites from the north Delta in 1997 (Hill Slough), 1999 (Cache Slough), and 2000 (Cache Slough) were below reporting level, 16, and 9 ng/g, respectively. PCB levels in white catfish composites from the lower American River in 1998 and 2000 were 57 and 41 ng/g, respectively. PCB concentrations in white catfish composites from the Sacramento River @ Veteran's Bridge in 1997 and 2000 were 11 and 40 ng/g, respectively. These limited data signify no clear temporal trend in PCB contamination of white catfish in the Sacramento River watershed and north Delta between 1997 and 2000.

Since 1990 Sacramento sucker were collected at multiple sites in the Sacramento River watershed during 1999, 2000, 2001, 2002, and 2005. Unfortunately sampling was not at the same sites in those five years. Sacramento sucker samples were available from the lower American River in all five sampling years and from the Sacramento River @ RM 44 in three (2000, 2002, and 2005). The number of composites per year ranged from three (2002) to 17 (2005); there were four to five composites available for 1999, 2000, and 2001. ANOVA, ANCOVA, and/or regression analysis could possibly be applied to these white catfish data in way of temporal trend analysis. A visual inspection of the data, however, reveals considerable spatial (within year) variation such that application of such methods is superfluous. For example, mean PCB concentrations in composites of Sacramento sucker collected in 1999, 2000, 2001, and 2002 were 10, 11, 40, and 135 ng/g, respectively. However, variation in all four groups was very high such that 95% confidence intervals overlapped. The PCB means indicated a trend toward increasing concentration in the Sacramento watershed, but actually means were a reflection of the sites selected in the different years. Further, in 2002 only three composites were analyzed and two of those were 'duplicates' from the American River @ Discovery Park. PCB concentrations in the 'duplicates' were 55 and 288 ng/g. This divergence is enigmatic since concentrations of DDT, dieldrin, and chlordane were not so divergent and paralleled differences in lipid content in the composites. As stated above, the issue with this divergence is whether it is typical of variation of PCB concentration within a species at a site. Data collected in 2005 do not support an increase in PCB contamination of fish in the Sacramento watershed from 1999 through 2002. Mean concentration in composites (n=17) of Sacramento sucker collected in the Sacramento River watershed during 2005 was 9 ng/g. While the 2005 mean is significantly lower than the 2002 mean interpretation is difficult because of the small number (3) of composites analyzed in 2002 and the notable divergence of PCB concentration in 'duplicate' composites from the same site. Two and three composites of Sacramento sucker collected from the Feather River were available for 2001 and 2005, respectively. PCB concentrations in the 2001 composites were 12 and 25 ng/g and in the 2005 composites were a non-detect and two below reporting level.

Outside of urban areas PCB white catfish and Sacramento sucker contamination appears to be below or approaching the reporting level while in and below urban areas PCB contamination continues to be somewhat of an issue. While these two species probably are effective indicators of current PCB exposure levels, they are not optimal indicators of 'worst-case' contamination in the Sacramento River watershed. For example, PCB concentrations in three composites of channel catfish collected during 2005 from the Sacramento River @ Colusa and Veteran's Bridge and Sacramento Slough @ Karnak were 102 53, and 21 ng/g, respectively. PCB level in a composite of carp caught in the Sacramento River @ Veteran's Bridge was 26 ng/g. The 2005 data show that, in the Sacramento River watershed, channel catfish and carp are more PCB/OC pesticide contaminated than Sacramento sucker and white catfish.

*Comparison of PCB fish contamination in the Sacramento River watershed to the San Joaquin River watershed and Delta*—The percentage of tissue composites from fish collected in the Sacramento River watershed with PCBs below detection or less than the reporting level was 11 and 65%, respectively; PCBs were less that reporting level in 83% of the composites of fish taken in the San Joaquin River watershed and Delta. PCB concentrations were 10 to 19 ng/g in 11 and 10% of composites from fish collected n the Sacramento River watershed and in the San Joaquin River watershed plus Delta, respectively. PCB levels were greater than 20 ng/g in 13 and 8% of composites from fish caught in the Sacramento River watershed and in the San Joaquin River watershed plus Delta, respectively. Moreover, PCB contamination of fish appeared relatively equivalent in these Central Valley waterways. At two sites in the Sacramento River watershed (Sacramento River at Colusa and at the Veteran's Bridge) PCB contamination was higher in any composites from fish collected during 2005 in the San Joaquin River watershed and Delta. These high levels of contamination were in channel catfish. In fact, three of four composites from catfish collected in the Sacramento River watershed manifested PCB concentrations greater than 20 ng/g. This may give the impression that PCB fish contamination in the Sacramento River watershed is greater than in the San Joaquin River watershed and Delta. In contrast, the most heavily PCB-contaminated fish collected in the San Joaquin River watershed and Delta were Sacramento sucker (Table 10). Mean PCB concentration in composites from Sacramento sucker caught during 2005 in the main stem Sacramento River and the entire Sacramento watershed were 7 and 9 ng/g, respectively. In contrast, average PCB concentrations in composites from Sacramento sucker collected in the main stem San Joaquin River, entire Delta, and the San Joaquin

River watershed and Delta were 19, 28, and 18 ng/g (Table 12), respectively. PCB geometric means for Sacramento sucker from the San Joaquin River watershed/Delta and the Sacramento River watershed were 11 and 5 ng/g, respectively; these means are significantly different (P<0.01). Coefficients of variation for these geometric means were also different (51 versus 85%, respectively). Lipid-normalized PCB geometric means for Sacramento sucker from the San Joaquin River watershed/Delta and the Sacramento River watershed were 407 and 185 ng/g, respectively; these means are significantly different (P<0.0001). Coefficients of variation for these geometric means were also different (11 versus 44%, respectively). These data do not support the hypothesis of greater PCB contamination in the Sacramento River watershed. Of note is that composites of Sacramento sucker had the highest lipid content of all species captured in the San Joaquin River watershed and Delta during 2005 (statistically higher than Sacramento sucker from the Sacramento River watershed). In contrast, composites of channel catfish had the highest lipid content of all species collected in the Sacramento River watershed during 2005 (Table 36). This phenomenon cannot be accounted for in terms of differences in season of fish collection.

**Fish Tissue Chlordane Residues**

*Frequency of contamination, spatial distribution, and comparison to OEHHA screening level*—Chlordane was analyzed in 46 composites from fish collected in the Sacramento River watershed during 2005. Chlordane was not detected or below the reporting level in 28 and 55%, respectively of the composites. Only 17% of the composites contained measurable levels of chlordane. The 1999 OEHHA screening value for chlordane is 30 ng/g (Table 3). The highest chlordane concentration observed (7 ng/g) was in a composite from Sacramento sucker collected from the American River at Discovery Park; chlordane in a composite of white catfish and three composites of large-mouth bass caught at this site was below reporting level. All other sites where chlordane was detected were on the Sacramento River (at Colusa, Veteran's Bridge, and Rio Vista) with concentrations ranging from 3 to 4 ng/g. Moreover, no fish composite chlordane contamination was near the OEHHA 30 ng/g screening value. Composites of channel catfish and carp taken at the Veterans's Bridge site both manifested chlordane concentrations of 3 ng/g. Chlordane concentrations in composites of carp and Sacramento sucker collected from the Sacramento River at Rio Vista also were 3 ng/g; chlordane in a composite of white catfish captured at this site was below reporting level. In 2006 OEHHA proposed a ∑chlordanes screening value of 200 ng/g. The 2005 data reveal that chlordane fish contamination throughout the Sacramento River watershed is low (<8 ng/g). Concentrations at all sites sampled in 2005 were such that 12 or more fish meals could be consumed per month (OEHHA, 2006—Table 4 in this report).

Colusa Basin Drain (CBD) and the lower Feather River are on the CWA 303(d) list for Group A pesticide contamination. Chlordane was not detected in composites of carp and white catfish caught during 2005 at CBD. Chlordane was below reporting level in composites of carp, large-mouth bass, Sacramento pikeminnow, and Sacramento sucker (three composites) captured at Gridley and at Nicolaus. Chlordane was not detected in two composites of Sacramento sucker collected from the Feather River in 2001.

Chlordane was below detection level or 1 ng/g in four composites (carp, channel catfish, and white catfish) collected from CBD in 2000 and 2001. While it is clear that levels of chlordanes are below or near detection level at these two sites and pose no risk to human health, the SWRCB policy (SWRCB, 2004) indicates that 28 samples, with no more than one above reporting level, are required for 303(d) delisting. Data presented herein reveal no significant dieldrin fish contamination at these sites. Therefore, Group A pesticides are not a problem at these sites so monitoring funds could likely be spent more productively on more pressing water quality issue.

*Same species 'duplicate' composites*—At four Sacramento River watershed sites 'duplicate' composites could be constituted. 'Duplicate' composites of Sacramento sucker were available for the Feather River at Gridley and the Yuba River at Marysville, of channel catfish for Sacramento Slough at Karnak, and of red-ear sunfish for the Bear River at Rio Oso. Chlordane in 'duplicate' composites of Sacramento sucker collected at Gridley was a non-detect (mean length=327 mm) and below reporting level (mean length=483 mm). For the Sacramento sucker caught at the Marysville site, chlordane was not detected in either 'duplicate' composite (mean length=448 and 288 mm). Chlordane in both 'duplicate' composites of channel catfish captured from Sacramento Slough was below reporting level (mean length=390 and 293 mm). For the red-ear sunfish collected from the Bear River, chlordane was below reporting level in both composites (mean length=187 and 171 mm). The ∑chlordanes in three composites of large-mouth bass collected from the American River at Discovery Park were below reporting level, 0.5, and 0.6 ng/g. At these low concentrations it is difficult to evaluate variability among composites.

*Hatchery fish*—Composites of rainbow trout from three hatcheries (American River, Darrah Springs, and Mount Shasta) and of coho salmon from three hatcheries (Coleman, Feather River, and Nimbus were analyzed for chlordane. This OC was not detected in any rainbow trout composite. Composites were available from rainbow trout caught from Clear Creek, the Sacramento River at Bend Bridge, and the Yuba River at Marysville; chlordane concentrations in all these composites were non-detect or below reporting level. Chlordanes in all hatchery coho composites, except from Coleman (3 ng/g) were below reporting level as well as in a composite of coho salmon from the Sacramento River at RM 44.

*Temporal trends*—Assessing temporal trends is difficult when the same sites and same species are not sampled yearly as well as when the number of samples analyzed is inadequate for robust statistical analyses. Spatial and temporal variation in OC pesticide and PCB fish contamination are realities. Thus, sampling numerous (same) sites, the same species per site, and 'replicate' composites per site on a yearly basis is essential for accurate temporal trend analysis as well as for predicting future changes in fish contamination. While fish sampling for OC/PCB contamination in the Sacramento River watershed has been more extensive than in the San Joaquin River watershed and Delta, all of the above problems plague temporal trend analyses in Central Valley waterways. Clearly there was and is no consistent strategy or plan for addressing this issue.

The analysis of Greenfield et al. (2004) revealed that OC pesticide and PCB contamination of fish in Central Valley declined rapidly in the 1970s to the mid-1980s, but the rate of decrease slowed in the 1990s such that statistical differences among years could not be detected. Inability to detect statistically significant decreases among years almost certainly relates to the small number of sites, samples, and duplicates. Given that the rapid decline in the 1970s and early-1980s has been documented, my focus is on the period between 1990 and 2005. Thus, I examined the SFEI database for fillet composites of Sacramento sucker, white catfish, channel catfish, and carp collected in that period. For the entire Sacramento River watershed there were a total of 46 composites analyzed for chlordanes during the period of 1990 through 2004. There were 22, 16, 3, and five composites of white catfish, Sacramento sucker, channel catfish, and carp, respectively. The number of composites by year was:

| | | | |
|---|---|---|---|
| 1990 | 2 | 1992 | 1 |
| 1993 | 2 | 1997 | 6 |
| 1998 | 4 | 1999 | 10 |
| 2000 | 12 | 2001 | 6 |
| 2003 | 3 | | |

There are too few composites of the same species, especially from the same sites, over this 14 year period to perform even a simple statistical analysis. Some of the clearest temporal trends in chlordane fish contamination can be seen in sites (Colusa Basin Drain, Sacramento River @ RM 44, and lower American River) that have been sampled multiple times since 1990.

There are seven composites from fish collected at CBD for the 1990 to 2005 period.

Colusa Basin Drain

| Year | Species | ∑Chlordanes |
|---|---|---|
| 1998 | Carp | 2 ng/g |
| 2000 | Carp | ND |
| 2000 | White catfish | ND |
| 2001 | Carp | 1 ng/g |
| 2001 | Channel catfish | 1 ng/g |
| 2005 | Carp | ND |
| 2005 | White catfish | ND |

Since 1998 chlordane fish contamination at CBD has been near or below reporting level.

For the 15 year period there are 14 composites of fish collected at the Sacramento River RM44 site.

Sacramento River @ RM 44

| Year | Species | ∑Chlordanes |
|---|---|---|
| 1992 | White catfish | 13 ng/g |
| 1993 | White catfish | 9.5 ng/g |

| | | |
|---|---|---|
| 1997 | White catfish | 9 ng/g |
| 1998 | White catfish | 15, 16 ng/g |
| 1999 | White catfish | 2, 3, 3 ng/g |
| 2000 | White catfish | 2 ng/g |
| 2000 | Sacramento sucker | 2 ng/g |
| 2002 | Sacramento sucker | 23 ng/g |
| 2005 | Sacramento sucker | <RL |
| 2005 | Largemouth bass | 2 ng/g |
| 2005 | Coho salmon | ND |

Except for one year's composite chlordane concentration has been near or below reporting level since 1999 at the RM44 site. Lipid content in the 2002 Sacramento sucker composite was very high (10.4%); this is a likely contributor to the relatively high chlordane level in this composite. With the exception of this composite, chlordane fish contamination at this site has been 3 ng/g or less since 1999.
\
For the 1990 to 2005 period there are 12 composites of fish caught in the lower American River.

Lower American River

| Year | Species | ∑Chlordanes |
|---|---|---|
| 1997 | White catfish | 8 ng/g |
| 1999 | Sacramento sucker | 1, 2 ng/g |
| 2000 | Sacramento sucker | <RL |
| 2001 | Sacramento sucker | 4, 18 ng/g |
| 2002 | Sacramento sucker | 14, 20 ng/g |
| 2005 | Sacramento sucker | <RL |
| 2005 | White catfish | <RL |
| 2005 | Largemouth bass | <RL, <RL, <RL |

While fish chlordane contamination in the lower American River appears to be near or below the reporting level since 1999, the high concentrations in the two composites from 2002 and one from 2001 are puzzling given that chlordanes in all other composites were near or below reporting level. The relatively high chlordane levels in the 2002 Sacramento sucker composites is likely related, at least in part, to the high lipid content in the composites (7.88 and 5.12%). Lipid content was also relatively high in the 2001 Sacramento sucker composites (3.28 and 6.20%); the composite with higher chlordane level also had the higher lipid content. In the 1999, 2000, and 2005 composites lipid content of composites was 0.95 and 1.11%; 1.31%; and 4.44%, respectively. 2005 data from this site disclose that chlordane contamination of fish in the lower American River is below or reporting level.

Since 1990 white catfish were collected from the Sacramento River watershed and north Delta at multiple sites in 1997, 1998, 1999, 2000 and 2005. Unfortunately, sampling was not at the same sites in those years. White catfish samples from the Sacramento River @ RM44 were available in all four of the five years. Composites from the north Delta and from the lower American River were available for three of the years and from the

Sacramento River @ Veteran's Bridge and Sacramento Slough for two of the years. The number of white catfish composites per year ranged from two (1998) to seven (2000). ANOVA, ANCOVA, and/or regression analysis could possibly be applied to these white catfish data in way of temporal trend analysis. A visual inspection of the data, however, reveals that application of such methods is superfluous. For example, white catfish composite mean chlordane concentrations for 1997, 1999, 2000, and 2005 were 6, 2, 2, and 6 ng/g, respectively. Only two 1998 white catfish composites, both from the Sacramento River @ RM44, were analyzed with concentrations of 15 and 16 ng/g. The somewhat elevated concentrations at this site in 1998 is puzzling given that chlordane concentrations in three composites from that site in 1999 were 3, 2, and 3 ng/g. Lipid content in 1998 and 1999 composites was equivalent. Looking at individual sites, the ∑chlordanes in white catfish composites from the north Delta in 1997 (Hill Slough), 1999 (Cache Slough), and 2000 (Cache Slough) were 6.5, 2, and 1 ng/g, respectively. Levels in white catfish composites from the lower American River in 1998 and 2000 were 8 and 3 ng/g, respectively. Chlordanes in white catfish composites from the Sacramento River @ Veteran's Bridge in 1997 and 2000 were 3 and 2 ng/g, respectively. Chlordane contamination of white catfish in the Sacramento River watershed is below or near reporting level.

Since 1990 Sacramento sucker were collected at multiple sites in the Sacramento River watershed during 1999, 2000, 2001, 2002, and 2005. Unfortunately sampling was not at the same sites in those five years. Sacramento sucker samples were available from the lower American River in all five sampling years and from the Sacramento River @ RM 44 in three (2000, 2002, and 2005). The number of composites per year ranged from three (2002) to 17 (2005); there were four to five composites available for 1999, 2000, and 2001. ANOVA, ANCOVA, and/or regression analysis could possibly be applied to these white catfish data in way of temporal trend analysis. A visual inspection of the data, however, reveals that application of such methods is superfluous. For example, mean chlordane concentrations in composites of Sacramento sucker collected in the Sacramento River watershed during 1999, 2000, 2001, and 2002 were 1, 1, 6, and 19 ng/g, respectively. While these mean values seem to suggest increasing chlordane fish contamination in the Sacramento River watershed in 2002, it is unlikely that the mean was indicative of the Sacramento River watershed or of a temporal trend. Moreover, mean lipid content in the composites form 2002 was double or more than in earlier years. Further, 2005 data do not support the hypothesis of increasing chlordane fish contamination. In only two of 17 composites of Sacramento sucker collected from the Sacramento River watershed during 2005 were chlordane concentrations above reporting level. The highest chlordane concentration (7 ng/g) was in a composite of Sacramento sucker caught in the American River @ Discovery Park.

Overall, but especially the 2005, data document that chlordane fish contamination in the Sacramento River watershed is below or near reporting level.

**Fish Tissue Dieldrin Residues**

*Frequency of contamination, spatial distribution, and comparison to OEHHA screening level*—Forty-six composites from fish caught in the Sacramento River watershed during

2005 were analyzed for dieldrin. Dieldrin was not detected or below the reporting level (DNQ—detected, but not quantified) in 22 and 41%, respectively, of the composites. Dieldrin concentration was at or above the reporting level to 0.9 ng/g, 1.0 to 1.9 ng/g, and at or above 2 ng/g (OEHHA screening value) in 17, 13 (Table 40) and 6% (Table 41), respectively, of the composites. All dieldrin concentrations at or higher than 2 ng/g were in channel catfish composites (Table 41). These channel catfish were collected from the Sacramento River (at Colusa and Grimes) and Sacramento Slough (at Karnak). It is unclear why contamination is clustered in this area of the Sacramento River watershed. Neither the Sacramento River nor Sacramento Slough is CWA 303(d) listed for Group A pesticide contamination. Dieldrin concentration in two composites of channel catfish collected from Sacramento Slough during 2005 slightly exceeded the OEHHA 1999 screening value. These data are ample for listing this water body only if the 1999 screening value is maintained. In the Sacramento River watershed only older, fatty channel catfish manifested dieldrin concentrations slightly above the OEHHA 1999 screening value. Should the 1999 screening value be preserved, I recommend several (at least two) composites of four to seven species from Sacramento Slough be analyzed for dieldrin. Dieldrin level in a composite from Sacramento sucker collected at the Colusa site was below reporting level. Because dieldrin level in only one composite (per site) exceeded the 1999 OEHHA screening level at the Colusa and Grimes sites, data are insufficient for CWA 303(d) listing. The 2005 data from the Sacramento River and watershed clearly document that dieldrin fish contamination is neither wide-spread nor high level. However, only if the 1999 OEHHA screening level is maintained, to clarify whether dieldrin fish contamination is at a level of concern, I recommend that several (at least two) composites of four to seven species from the Grimes and Colusa sites be analyzed for dieldrin. If the OEHHA 2006-recommended screening level is approved by the CVRWQB, listing of this segment of the river is not an issue.

Table 40 summarizes the sites and species with dieldrin concentrations ranging from 1.0 to 1.9 ng/g. Whether the reduced (compared to upstream sites at Colusa and Grimes) dieldrin composite concentrations at the lower Sacramento River sites listed in Table 40 are consequent to dilution is an unknown. In 2006 OEHHA proposed a dieldrin screening value of 16 ng/g. The 2005 data reveal that dieldrin fish contamination throughout the Sacramento River watershed is low (<4 ng/g). Concentrations at all sites sampled in 2005 were such that 12 or more fish meals could be consumed per month (OEHHA, 2006—Table 4 in this report).

The lower Feather River and CBD are CWA 303(d) listed for Group A pesticide contamination. Dieldrin levels in composites of Sacramento sucker, large-mouth bass, Sacramento pikeminnow and carp collected from the Feather River at Nicolaus were all below reporting level. Dieldrin was not detected and below reporting level in 'duplicate' composites of Sacramento sucker caught in the Feather River at Gridley. The concentration of dieldrin in a composite (mean length=421 mm; lipid content=0.73%) from carp taken at CBD was 1.1 ng/g, whereas the OC pesticide was not detected in a white catfish composite (mean length=192 mm; lipid content=0.58%) collected at this location. These and the chlordane data clearly document that there is no Group A pesticide fish contamination at either of these sites. Nonetheless, the SWRCB policy document (SWRCB, 2004) indicates that 28 samples, with no more than one exceedance, are required for 303(d) delisting a water body. Monitoring funds could likely be spent more productively on more pressing water quality issue.

The CVRWQCB proposed that the northern Delta be listed for Group A pesticide contamination. While dieldrin concentrations in composites from Sacramento sucker and carp collected from Prospect Slough (north Delta) during 2005 were greater than the OEHHA screening value (Table 19). However, dieldrin concentrations in seven composites from seven species caught in Prospect Slough were 1.4 ng/g or less (Table 20). Furthermore, concentrations in composites from Sacramento sucker and largemouth bass caught in the Sacramento River at RM44 and at Rio Vista during 2005 were less than the screening value (Table 40). In the event that the 1999 OEHHA screening value of 2 ng/g is maintained the two composites exceeding this screening value are sufficient (SWRCB, 2004) for 303(d) listing of the northern portion of the Delta. However, there were ten 2005 composites from the north Delta below the screening level. Further, the composite of Sacramento sucker from Prospect Slough contained high lipid (second highest of 33 composites from Sacramento sucker collected from Central Valley waterways and Delta). Prior to 303(d) listing actions, it would be prudent to analyze additional composites from Prospect Slough fish.

Mean and geometric mean ( with 95% lower and upper confidence limits) dieldrin concentrations in composites of Sacramento sucker (17 composites) collected in the Sacramento River watershed are 0.4, 0.15-0.65 and 0.3, 0.1-0.5 ng/g, respectively; median concentration is 0.2 ng/g (Table 42). Coefficient of variation (CV) for the means is 130 and 115%, respectively. Mean and geometric mean (with 95% lower and upper confidence limits) dieldrin concentrations in composites of Sacramento sucker plus channel catfish plus carp (26 composites) collected in the Sacramento River watershed were 0.9, 0.5-1.3 and 0.7, 0.4-1.0 ng/g, respectively; median concentration is 0.4 ng/g Table 42). Coefficient of variation (CV) for the means is 115 and 91%, respectively. The upper 95% confidence limit for none of these means overlap the OEHHA 2ng/g screening value. Mean dieldrin concentrations in Sacramento sucker composites from the main stem Sacramento River and from the entire Sacramento River watershed were 0.45 and 0.4 ng/g, respectively (Table 42). Mean dieldrin concentrations in Sacramento sucker+channel catfish+carp composites from the main stem Sacramento River and from the entire Sacramento River watershed were 1.0 and 0.9 ng/g, respectively (Table 42). Overall, dieldrin fish contamination in the Sacramento River watershed and northern Delta was neither extensive nor at a level of concern for human health. The minor exception was four channel catfish composites from three sites; in all four composites dieldrin concentration was <4.0 ng/g. In combination with the chlordane data, these 2005 results denote that Group A pesticide contamination of fish is not a serious issue in the Sacramento River watershed and northern Delta.

*Dieldrin levels among species*—Dieldrin concentration in composites from channel collected from the Sacramento River at Colusa and at Grimes, as well from Sacramento Slough, was at or above 2.0 ng/g (Table 39). While the composite of channel catfish (mean length=470 mm; lipid content=4.44%) caught at Colusa had a dieldrin

concentration of 2.0 ng/g, the level in a composite of Sacramento sucker (mean length=403 mm; lipid content=0.93%) collected at the site was below reporting level. This finding is not that surprising given the considerable difference in lipid content of the composites. No fish species other than channel catfish were collected at the Grimes or Sacramento Slough locations. Composites from three species were available at the Sacramento River Veteran's Bridge site. Dieldrin concentration in composites of channel catfish (mean length=526 mm; lipid content= 2.37%), carp (mean length=573 mm; lipid content=1.55%), and Sacramento sucker (mean length=409 mm; lipid content=1.01%) was 1.5, 1.0, and below reporting level, respectively. The differences in composite lipid content mirrored the differences in dieldrin contamination. Also, there were composites from three species at the Sacramento River Rio Vista site. Composite dieldrin concentration of Sacramento sucker (mean length=476 mm; lipid content=3.00%), carp (mean length=573 mm; lipid content=0.98% ), and white catfish (mean length=337 mm; lipid content=1.00%) was 1.7, 0.9, 0.7 ng/g, respectively. Again, the differences in dieldrin concentrations were consistent with lipid content of the composites. These results are in contrast to what was observed in composites of fish collected at Veteran's Bridge. At that site, carp were more dieldrin-contaminated compared to Sacramento sucker. At the Rio Vista site the Sacramento sucker were the most dieldrin-contaminated. These results caution against reliance on a single composite from one species to assess contamination. Dieldrin level in the composite from Sacramento sucker (mean length=461 mm; lipid content=4.44%) captured at Discovery Park on the American River was 1.6 ng/g, but not detected in the composite of white catfish (mean length=270 mm; lipid content=0.37%). Dieldrin concentrations in three composites of large-mouth bass from the Discovery Park site were below reporting level, 0.5, and 0.6 ng/g; lipid content in all three composites was less than 0.4%. In carp (mean length=421 mm; lipid content=0.73%) and white catfish (mean length=192 mm; lipid content=0.58%) collected from CBD composite dieldrin concentration was 1.1 and 0.7, respectively. Dieldrin concentration in composites of Sacramento sucker (mean length=477 mm; lipid content=2.70%), coho salmon (mean length=828 mm; lipid content=3.78%), and largemouth bass (lipid content=0.38%) collected from the Sacramento River at RM 44 was 1.0, 0.8 ng/g, and below reporting level, respectively. Dieldrin was not detected in composites of Sacramento sucker (two composites) or rainbow trout caught in the Yuba River at Marysville. Dieldrin was below reporting level in composites of Sacramento sucker and red-ear sunfish (two composites) taken from the Bear River at Rio Oso. In composites of Sacramento sucker, carp, large mouth bass, and Sacramento pike minnow collected from the Feather River at Nicolaus.
Composites from 17 Sacramento sucker, five channel catfish, and four carp collected in the Sacramento River watershed were analyzed for dieldrin; none, four (Sacramento River at Colusa and Grimes plus two from Sacramento Slough), and none, respectively, of these composites had dieldrin concentrations greater than the OEHHA screening value. Dieldrin concentration was 1.0 to 1.9 ng/g in three (Sacramento River at RM 44 and Rio Vista; American River at Discovery Park), two (CBD and Sacramento River at Veteran's Bridge), and one (Sacramento River at Veterans Bridge) of these composites from Sacramento sucker, carp, and channel catfish, respectively. These data signify that, percentage-wise, channel catfish are effective 'detectors' of dieldrin contamination in the Sacramento River watershed. The mean dieldrin concentration in composites from

Sacramento sucker collected from the main stem Sacramento River (n=8) and from the entire Sacramento River watershed (n=17) was 0.45 and 0.40 ng/g, respectively. The upper 95% confidence limit for neither of these means overlapped the OEHHA screening value. This is not that unexpected given that channel catfish had the highest lipid content of all species from the Sacramento River watershed (Table 35).

*Hatchery fish*—Composites of rainbow trout from three hatcheries (American River, Darrah Springs, and Mount Shasta) and of coho salmon from three hatcheries (Coleman, Feather River, and Nimbus) were analyzed for dieldrin. In hatchery trout composites dieldrin was not detected or less than reporting level. Composites were also available from rainbow trout caught at Clear Creek, the Sacramento River at Bend Bridge, and the Yuba River at Marysville. Dieldrin was not detected or below the reporting level in all these composites. Dieldrin was below the reporting level in the coho composites from the Feather River hatchery. In coho composites from the Coleman, Nimbus hatchery and the Sacramento River at RM 44 dieldrin levels were 1.0, 0.5, and 0.8 ng/g, respectively.

*Relationships among tissue dieldrin concentration, tissue lipid content and composite mean fish length*—Table 36 summarizes composite mean lipid content and mean fish length in composites of fish species collected in the Sacramento River watershed. Lipid content in channel catfish composites was higher than any other species even though the size of fish constituting composites was not the highest.

Neither log-transformed nor non-transformed tissue dieldrin concentrations in composites (n=17) of Sacramento sucker collected in the Sacramento River watershed fit a normal distribution. This likely relates to the fact that only three composites contained reportable concentrations, with six non-detects and eight below the reporting level. For Sacramento sucker composite lipid and composite mean fish length, neither non-transformed nor log-transformed fit a normal distribution. In composites (n=16) of Sacramento sucker collected in the San Joaquin watershed and Delta neither non-transformed nor log-transformed tissue dieldrin concentration data fit a normal distribution. Furthermore, in composites of Sacramento sucker collected in the San Joaquin watershed and Delta log-transformed composite percent lipid fit a normal distribution. There are several possible reasons that the Sacramento River watershed Sacramento sucker data did not fit a normal distribution including (1) fish caught in the San Joaquin River watershed and Delta had significantly higher composite lipid content compared to the fish from the Sacramento River watershed, (2) compositing could obscure a normal distribution, (3) the tendency to select the largest fish available, (4) fish come from different sites that may differ in dieldrin contamination, and (5) many sites sampled in this project appear to have low dieldrin contamination.

Percent lipid in Sacramento sucker composites was significantly related to dieldrin concentration, potentially accounting for up to 72% of the variability in tissue contamination (Table 43). A similar situation, but with higher $R^2$ values, was observed with Sacramento sucker caught in the San Joaquin River watershed and Delta (Table 22). Both slope and intercept of the regression of non-transformed dieldrin concentration on percent lipid were significantly different in San Joaquin River watershed/Delta compared to Sacramento River watershed data; with log-transformed data, however, the only significant difference was in intercept. Length of fish constituting composites from the Sacramento River watershed had no statistically significant relationship to level of dieldrin contamination. This too is in contrast to Sacramento sucker collected from the San Joaquin River watershed/Delta where length was a weak, but statistically significant predictor of dieldrin concentrations (Table 43). Fish length was not a statistically significant predictor of tissue lipid content in Sacramento sucker from the Sacramento River watershed, but was in fish from the San Joaquin River watershed/Delta (Table 43 & 24). Wet weight dieldrin concentrations (non-transformed and log-transformed) were regressed on lipid-normalized dieldrin concentrations; results disclosed that lipid-normalized values were significant predictors of wet weight dieldrin concentrations, providing further support for lipid being a determinant (not simply exposure level) of degree of fish dieldrin contamination (Table 43). However, if exposure level and lipid content are the only determinants of tissue dieldrin concentrations, a regression of lipid-normalized dieldrin concentrations on percent lipid should not yield a statistically significant $R^2$ (Herbert and Keenleyside, 1995). The $R^2$ values were rather low, but statistically significant (Table 43). This finding suggests that lipid content co-varied with another or other dieldrin concentration determinants (see Discussion section on determinants of POP concentrations). The geometric mean (with lower and upper 95% confidence limits) wet weight and lipid-normalized dieldrin concentrations for Sacramento sucker collected in the Sacramento River watershed are 0.3, 0.1-0.6 and 10, 3-18 ng/g, respectively. Coefficient of variation on these means is 115 and 78%, respectively, revealing that lipid-normalization reduces variability in the dieldrin data. The geometric mean ($\pm$95% confidence interval) wet weight and lipid-normalized dieldrin concentrations for Sacramento sucker+channel catfish+carp collected in the Sacramento River watershed are 0.7, 0.4-1.0 and 68, 18-257 ng/g, respectively. Coefficient of variation on these means is 91 and 78%, respectively, again revealing that lipid-normalization reduces variability in the dieldrin data.

Tables 38 and 39 summarize regression coefficients ($R^2$) and rank (sites ranked by level of contamination) correlation coefficients (Rho), respectively, from analyses of wet weight and lipid-normalized PCB/OC pesticide concentrations in Sacramento sucker collected in the Sacramento River watershed. Note that in both analyses statistically significant associations were observed between contaminant wet weight and lipid-normalized concentrations. In all cases, however, the degree of association between contamination is less and the P value higher in lipid-normalized concentrations. The fact that positive statistically significant associations among the three contaminants *implies* that the most contaminated sites are contaminated by PCBs, DDTs, and dieldrin. Moreover, the implication is that there is a ranking of sites by total PCB/OC pesticide contamination. Why should Sacramento sucker tissue PCB concentration at a site predict DDT and dieldrin tissue concentrations unless there is parallel contamination of PCBs, DDTs, and dieldrin at the sites sampled? Such a situation does not seem likely. I propose another interpretation that is supported by data in Tables 38 and 39. My hypothesis is that exposure levels of PCBs, DDTs, and dieldrin are not necessarily the highest at sites with the most contaminated Sacramento sucker. I propose that factors, conditions, and the fish at sites differ and those with the most contaminated Sacramento sucker have conditions most favorable to bioaccumulation and biomagnification. In addition to exposure level, body lipid and a host of other physical, chemical, ecological, and physiological factors that affect bioaccumulation (see Discussion section on determinants of tissue and body concentrations of persistent organic pollutants—POPs). The data in Tables 36 and 37 provide impelling evidence that, in the Sacramento River watershed, lipid content of Sacramento sucker was a more significant determinant of PCB/OC concentration in fish than current site exposure level.

The channel catfish composite (fish from Grimes site) with the highest lipid content (7.14%) was characterized by the highest dieldrin concentration (3.1 ng/g). In the other four channel catfish composites dieldrin concentration did not vary in parallel with composite lipid content. For example, the channel catfish composite (fish from Sacramento Slough) with the second highest dieldrin level (3.1 ng/g) had the lowest lipid content (1.25%). The carp composite (fish from CBD) with the lowest lipid content (1.71%) had the highest dieldrin concentration (1.1 ng/g). In the other three composites dieldrin concentration did not vary in parallel with lipid content. In rainbow trout composites (n=6) dieldrin concentrations were all less than the reporting level or non-detects so no relationship with lipid content (range=1.42 to 3.00%) could be seen.

*Same species 'duplicate' composites*—A sufficient number of fish was caught at four Sacramento River watershed sites such that 'duplicate' composites could be constituted. 'Duplicate' composites of Sacramento sucker were available for the Feather River at Gridley and the Yuba River at Marysville, of channel catfish for Sacramento Slough at Karnak, and of red-ear sunfish for the Bear River at Rio Oso. Dieldrin in 'duplicate' composites of Sacramento sucker from the Gridley site was a non-detect (mean length=327 mm; lipid content=0.61% ) and below reporting level (mean length=483 mm; lipid content=1.56%). For Sacramento sucker (mean length=448; lipid content=0.73% and 288 mm; lipid content=1.27%) caught at the Marysville site, dieldrin was not detected in 'duplicate' composites. Dieldrin concentration in 'duplicate' composites of channel catfish captured from Sacramento Slough was 3.1 (mean length=390 mm; lipid content=1.25%) and 2.4 ng/g (mean length=293 mm; lipid content=1.73%). In this case the composite with the largest fish rather than the highest lipid content was more dieldrin contaminated. For red-ear sunfish collected from the Bear River, dieldrin was a non-detect (mean length=187 mm; lipid content=0.40%) and less than reporting level (mean length=171 mm; lipid content=0.38%).
With the exception of a few channel catfish, dieldrin fillet concentrations were too low to assess the role of lipid and fish length as determinants of contamination.

*Temporal trends*—Assessing temporal trends is difficult when the same sites and same species are not sampled yearly as well as when the number of samples analyzed is inadequate for robust statistical analyses. Spatial and temporal variation in OC pesticide and PCB fish contamination are realities. Thus, sampling numerous (same) sites, the same species per site, and 'replicate' composites per site on a yearly basis is essential for accurate temporal trend analysis as well as for predicting future changes in fish contamination. While fish sampling for OC/PCB contamination in the Sacramento River watershed has been more extensive than in the San Joaquin River watershed and Delta, all of the above problems plague temporal trend analyses in Central Valley waterways. Clearly there was and is no consistent strategy or plan for addressing this issue.

The analysis of Greenfield et al. (2004) revealed that OC pesticide and PCB contamination of fish in Central Valley declined rapidly in the 1970s to the mid-1980s, but the rate of decrease slowed in the 1990s such that statistical differences among years could not be detected. Inability to detect statistically significant decreases among years almost certainly relates to the small number of sites, samples, and duplicates. Given that the rapid decline in the 1970s and early-1980s has been documented, my focus is on the period between 1990 and 2005. Thus, I examined the SFEI database for fillet composites of Sacramento sucker, white catfish, channel catfish, and carp collected in that period. For the entire Sacramento River watershed there were a total of 46 composites analyzed for dieldrin during the period of 1990 through 2002. There were 22, 16, 3, and five composites of white catfish, Sacramento sucker, channel catfish, and carp, respectively. The number of composites by year was:

| | | | |
|---|---|---|---|
| 1990 | 2 | 1992 | 1 |
| 1993 | 2 | 1997 | 6 |
| 1998 | 4 | 1999 | 10 |
| 2000 | 12 | 2001 | 6 |
| 2003 | 3 | | |

Obviously there are too few composites over this 15 year period for any type of statistical analyses. Some of the clearest temporal trends in dieldrin fish contamination can be seen at sites (Colusa Basin Drain, Sacramento river @ RM44, and the lower American River) that have been sampled multiple times since 1990.

Temporal patterns of dieldrin fish contamination are confounded by alteration of reporting level. The reporting limit for dieldrin has changed over the years primarily due to the extracts final volume (personal communication, Kathleen Regalado from Dave Crane's laboratory). In 1990 the extract's final volume was 10 mls and dieldrin's reporting limit was 5 ng/g. In 1998 the laboratory initiated accelerated solvent extraction and GPC to extract and cleanup samples. GPC removed most of the lipid from tissue extracts. Extract final volume changed from 10 to 2 mls. Extracts were cleaned up such that a 1 ml final volume was possible with a 0.5 ng/g reporting limit.

For the 1990 to 2005 period only seven composite of fish collected from Colusa Basin Drain are available.

Colusa Basin Drain

| Year | Species | Dieldrin |
|---|---|---|
| 1998 | Carp | 20 ng/g |
| 2000 | Carp | 3.9 ng/g |
| 2000 | White catfish | ND |
| 2001 | Carp | 2 ng/g |
| 2001 | Channel catfish | 2 ng/g |

| | | |
|---|---|---|
| 2005 | Carp | 1.1 |
| 2005 | White catfish | 1.0 |

At this site there appears to have been a large decline (95%) in carp dieldrin from 1998 to 2005, the primary decrease (80.5%) occurring between 1998 and 2000.

Since 1990 white catfish were collected from the Sacramento River watershed and north Delta at multiple sites in 1997, 1998, 1999, 2000 and 2005. Unfortunately, sampling was not at the same sites in those years. White catfish samples from the Sacramento River @ RM44 were available in four of the five years. Composites from the north Delta and from the lower American River were available for three of the years and from the Sacramento River @ Veteran's Bridge and Sacramento Slough for two of the years. Of the 19 composites analyzed for dieldrin in the years of 1997, 1998, 1999, and 2000 concentration was above detection limit (which was too high) in only five composites. The highest dieldrin concentration recorded in a white catfish (collected from Sacramento Slough) composite from 2000 was 2.55 ng/g (dieldrin <RL in the remaining six composites) and in the same species (from CBD) during 2005 was 1.0 ng/g.

Since 1990 Sacramento sucker were collected at multiple sites in the Sacramento River watershed during 1999, 2000, 2001, 2002, and 2005. Unfortunately sampling was not at the same sites in those five years. Sacramento sucker samples were available from the lower American River in all five sampling years and from the Sacramento River @ RM 44 in three (2000, 2002, and 2005). The number of composites per year ranged from three (2002) to 17 (2005); there were four to five composites available for 1999, 2000, and 2001. Dieldrin levels in all Sacramento sucker composites from 1999, 2000, and 2001 were below reporting level (which was too high). With a lower detection limit, the mean concentration in three composites of Sacramento sucker (two from the American River @ Discovery and one from the Sacramento River @ RM44) collected during 2002 was 2.1 ng/g. It is unlikely that this mean is indicative of the level of dieldrin fish contamination in the Sacramento River watershed in 2002. Data collected in 2005 support this hypothesis. The mean dieldrin concentration in 17 composites (6 non-detects and 8<RL) of Sacramento sucker caught during 2005 was 0.4 ng/g; the highest concentration of dieldrin in a Sacramento sucker composite from 2005 was 1.7ng/g. Note, however, that dieldrin concentration in four of five channel catfish composites from sites in the Sacramento River watershed ranged from 2.0 to 3.7 ng/g; mean concentration in the five composites was 2.5 ng/g.

Overall, but especially the 2005 data, suggest that dieldrin white catfish and Sacramento sucker contamination in the Sacramento River watershed is below or near reporting level. However, channel catfish caught in the watershed have higher levels of dieldrin contamination.

*Comparison of the San Joaquin River watershed and Delta with the Sacramento River watershed*—A slightly higher percentage of composites from the San Joaquin River watershed and Delta (10%) were characterized by dieldrin concentrations greater than the OEHHA screening value compared to the Sacramento River watershed (6%). Also, a greater percentage of composites from the San Joaquin River watershed and Delta (16%)

manifested dieldrin concentrations between 1.0 to 1.9 ng/g compared to the Sacramento River watershed composites (13%). Composites with dieldrin levels less than the reporting level (DNQ—detected but not quantified) or below detection also were more frequent in the Sacramento River watershed (63%) than in the San Joaquin River watershed and Delta (38%). Dieldrin geometric means for Sacramento sucker from the San Joaquin River watershed/Delta and the Sacramento River watershed were 1.4 and 0.3 ng/g, respectively; these means are significantly different (P<0.01). Coefficients of variation for these geometric means were also different (70 versus 115%, respectively). Lipid-normalized dieldrin geometric means for Sacramento sucker from the San Joaquin River watershed/Delta and the Sacramento River watershed were 41 and 10 ng/g, respectively; these means are significantly different (P<0.0001). Coefficients of variation for these geometric means were also different (17 versus 78%, respectively). Mean dieldrin concentration in composites of Sacramento suckers from the main stem Sacramento River (n=8) and entire Sacramento River watershed (n=17) were 0.45 and 0.40 ng/g, respectively (Table 42). Mean dieldrin concentrations for Sacramento sucker plus channel catfish and carp taken in the main stem Sacramento River and entire Sacramento River watershed were somewhat higher at 1.0 and 0.9 ng/g, respectively. In composites of Sacramento sucker collected from the main stem San Joaquin River and from the entire Delta, mean dieldrin levels were 2.8 and 5.1 (Table 21), respectively. The upper 95% confidence limit for the main stem Sacramento River and for the entire Sacramento watershed (for Sacramento sucker alone and SS+CC+C) did not overlap the means for the main stem San Joaquin River or the entire Delta, signifying a significant difference in levels of dieldrin contamination. These findings are not particularly surprising given the intensity of agriculture and pesticide use in the San Joaquin River watershed and Delta.

**Fish Tissue DDT Residues**

*Frequency of contamination, spatial distribution, and comparison to OEHHA screening level*—DDTs were analyzed in 46 composites of fish caught in the Sacramento River watershed during 2005. DDTs were below the reporting leveling in 22% of the composites. DDT concentrations were at the reporting level to 24, 25 to 49, 50 to 92 ng/g, and at or above 100 ng/g (OEHHA screening value) in 50, 11, 13 (Table 44), and 4%, respectively, of the composites. The Veteran's Bridge (channel catfish composite: 109 ng/g) and Rio Vista (carp composite: 149 ng/g) sites on the Sacramento River were the only locations where composite DDT concentration was greater than 100 ng/g. DDT levels in composites of carp and Sacramento sucker collected at the Veteran's Bridge sites were less than in the channel catfish composite, at 59 and 20 ng/g, respectively. Because there was only one composite exceeding the screening level there are insufficient (SWRCB, 2004) data for 303(d) listing Veteran's Bridge site or the lower Sacramento River.

DDT concentration in a composite of Sacramento sucker collected from Prospect Slough (northern Delta) was 213 ng/g (Table 2). Possibly the DDT contamination at the Rio Vista site is related to the contamination in the upstream Prospect Slough area. That significant DDT contamination was not seen at the Sacramento River RM 44 site (between the Veteran's Bridge and Rio Vista sites) is enigmatic. Perhaps it is because no carp or channel catfish were caught at the RM 44 site, only Sacramento sucker (composite DDT concentration=50 ng/g), large-mouth bass (4 ng/g) and coho salmon (15 ng/g). Currently there are no waterways, or portions thereof, in the Sacramento River watershed, including the lower Sacramento River, CWA 303(d) listed for DDT contamination. The northern Delta is CWA 303(d) listed for DDT fish contamination. The 2005 Sacramento sucker and carp data from the Prospect Slough (Table 27) and Rio Vista sites, respectively, provide adequate data for 303(d) listing of the north Delta if the 1999 OEHHA screening level remains viable, but not if the 2006-recommended screening level is adopted. Furthermore, in composites of Sacramento sucker and white catfish from the Rio Vista site DDT concentration was 92 and 29 ng/g, respectively. DDT concentrations in nine composites from eight species collected from Prospect Slough were less than 40 ng/g (Table 28). Overall, there were 14 composites of fish collected from the north Delta with DDT concentrations below the 1999 OEHHA screening value (11 with DDTs < 40 ng/g). While some large/old, fatty fish in areas of the north Delta are DDT-contaminated to an extent potentially harmful to humans, this contamination does not extend to all species and does not translate into present-time high DDT exposure levels. However, mean and geometric mean DDT concentrations in seven composites of fish collected in the eastern Delta are below 50 ng/g and the upper 95% confidence limit does do not overlap the OEHHA 1999 screening value. Based on this weight of evidence I recommend 303(d) delisting of the eastern portion of the Delta.

Table 44 summarizes sites and species where DDT contamination ranged from 50 to 99 ng/g. The Sacramento River Colusa, Veteran's Bridge, and Rio Vista sites, as well as CBD and Sacramento Slough, are included in that table. OEHHA (2006) proposed a DDT screening value of 560 ng/g. In all 46 composites from the Sacramento River watershed and north Delta, including the Veteran's Bridge and Rio Vista sites, analyzed for DDT concentrations were such that 12 or more fish meals per month could be consumed (OEHHA, 2006—Table 4 in this report).

Mean and geometric mean (with lower and upper 95% confidence limits) DDT concentrations in composites of Sacramento sucker (17 composites) collected in the Sacramento River watershed are 15, 4-26 and 6, 3-13 ng/g, respectively (Table 43); median concentration is 7 ng/g. Coefficient of variation (CV) for the means is 153 and 73%, respectively, indicating that DDT data better fit a log-normal distribution. Mean and geometric mean (with lower and upper 95% confidence limits) DDT concentrations in composites of Sacramento sucker plus channel catfish plus carp (26 composites) collected in the Sacramento River watershed were 35, 19-51 and 14, 7-27 ng/g, respectively (Table 45); median concentration is 15 ng/g. Coefficient of variation (CV) for the means is 114 and 60%, respectively, again indicating that the DDT better fit a log-normal distribution. The upper 95% confidence limit for none of these means overlap the OEHHA screening value.

DDT composite means for Sacramento sucker and for Sacramento sucker+channel catfish+carp collected during 2005 from the main stem Sacramento River and the entire Sacramento River watershed are presented in Table 45. As suspected from the above analyses, the upper 95% confidence limit for none of these means overlap the 100 ng/g OEHHA screening value. DDT means for carp (74 ng/g; lower and upper confidence limits=29, 119; n=4) and channel catfish (70 ng/g; lower and upper CLs=48, 91; n=5) caught in the Sacramento watershed were higher than for Sacramento sucker.

*DDT levels among species*—Composites from three species were available at the Sacramento River Veteran's Bridge site. DDT concentration in composites of channel catfish (mean length=526 mm; lipid content=2.37%), carp (mean length=484 mm; lipid content=1.55%), and Sacramento sucker (mean length=409 mm; lipid content=1.01% ) were 109, 59, and 20 ng/g, respectively. So, there was species variation in level of DDT contamination at this site; this variation appears to be related to size/age and lipid content of fish constituting composites. Also, there were composites from three species at the Sacramento River Rio Vista site. DDT levels in these composites of Sacramento sucker (mean length=476 mm; lipid content=3.00%), carp (mean length=573 mm; lipid content=0.98%), and white catfish (mean length=337 mm; lipid content=1.00%) were 92, 149, and 29 ng/g, respectively. DDT concentration in these composites paralleled mean length of fish in composite more than composite lipid content.

While the composite of channel catfish (mean length=470 mm; lipid content=4.4%) from the Sacramento River at Colusa had a DDT level of 88 ng/g, the concentration in a composite of Sacramento sucker (mean length=403 mm; lipid content=0.93%) collected at this site was 10 ng/g. The difference in DDT concentration in these two composites is not surprising given the large difference in lipid content. DDT levels in composites of Sacramento sucker (mean length=477 mm; lipid content=2.70%) and coho salmon (mean length=828 mm; lipid content=3.78%) collected from the Sacramento River at RM 44 were 50 and 15 ng/g, respectively; although lipid content in both composites was relatively high, the higher contamination in the benthic species is not unusual. DDTs in a composite of large-mouth bass from this site was 4 ng/g; the low level of DDT in this composite is almost certainly related to low lipid content (0.385%). DDT concentrations in carp (mean length=421 mm; lipid content=0.73%) and white catfish (mean length=192 mm; lipid content=0.58%) caught at CBD were 66 and 44 ng/g, respectively; the differences possibly related to lipid and size/age.

Composites of Sacramento sucker (mean length=382 mm; lipid content=1.62%), carp (mean length=504 mm; lipid content=1.27%), Sacramento pike-minnow (mean length=287 mm; lipid content=0.57%) and large-mouth bass (mean length=339 mm; lipid content=0.280) from the Feather River at Nicolaus manifested DDT concentrations of 8, 24, 10 ng/g, and 2, respectively. DDT concentration in these composites did not parallel mean length of fish in composites or lipid content, probably related to the low level of contamination at this site. DDT levels in 'duplicate' composites of Sacramento sucker caught in the Yuba River at Marysville were 5 ng/g (mean length=448 mm; lipid content=0.73%) and below reporting level (mean length=228 mm; lipid content=1.27%), while at 11 ng/g in a composite of rainbow trout (mean length=260 mm; lipid content=0.42%) from the site. That the pelagic, smaller, and less fatty rainbow trout at this location were more DDT-contaminated than the larger, benthic Sacramento sucker is surprising.

In composites of Sacramento sucker (mean length=461 mm; lipid content=4.44%) and white catfish (mean length=270 mm; lipid content=0.37%) taken from the American River at Discovery Park DDT concentration was 29 and 9 ng/g, respectively. In three composites of large-mouth bass collected at this site DDT concentrations were below reporting level, 4, and 5 ng/g; lipid content in all three composites was less than 0.4%. Clearly, the lipid content in the Sacramento sucker composite was a factor in the higher DDT concentration compared to the other species. Overall these results with multiple species per site caution against reliance on a single composite from one species to assess contamination.

Seventeen, five, and four composites from Sacramento sucker, channel catfish, and carp, respectively, collected in the Sacramento River watershed were analyzed for DDT; none, one (Sacramento River at Veteran's Bridge), and one (Sacramento River at Rio Vista), respectively, manifested DDT concentrations greater than the OEHHA screening value. DDT concentration in composites of channel catfish taken from the Sacramento River at Colusa and from Sacramento Slough at Karnak was 88 and 61 ng/g, respectively (Table 43). In composites of carp caught in CBD and the Sacramento River at Veteran's Bridge DDT levels were 66 and 59 ng/g, respectively (Table 43). Only two (Sacramento River at RM 44 and at Rio Vista) of 17 Sacramento sucker composites had DDT concentrations between 50 and 99 ng/g. These findings indicate that, percentage-wise, channel catfish and carp are preferable 'detectors' of DDT contamination in the Sacramento River watershed. The mean DDT concentration in composites of Sacramento suckers collected in the main stem Sacramento River (n=8) and in the entire Sacramento River watershed (n=17) was 23 and 15 ng/g, respectively (Table 43). The upper 95% confidence limit for neither mean overlapped the OEHHA screening level. The mean DDT concentrations in composites of carp (n=4) and channel catfish (n=5) caught in the Sacramento River watershed were 74 and 70 ng/g, respectively. The upper 95% confidence limit on the carp, but not channel catfish, mean overlapped the OEHHA screening value. It is not unusual that the channel catfish tended to have relatively high DDT levels given that their tissue composites had the highest lipid content of all species collected in the Sacramento River watershed (Table 34). That carp composites manifested the highest mean DDT concentrations is rather perplexing considering that their tissue composites had relatively low lipid content (Table 34). Discounting coho salmon mean length of fish in composites was higher in carp than any other species collected in the Sacramento River watershed.

*Hatchery fish*—Rainbow trout composites from three hatcheries (American River, Darrah Springs, and Mount Shasta) and coho salmon composites from three hatcheries (Coleman, Feather River, and Nimbus) were analyzed for DDTs. Concentrations in all hatchery trout (mean lengths=300, 346, and 443 mm; lipid content=0.65, 1.58, and 1.69%) composites were below reporting level. Composites were also available from rainbow trout caught from the Yuba River at Marysville (mean length=260 mm; lipid content=0.42%), Clear Creek (mean length=375 mm; lipid content=2.00%), and the Sacramento River at Bend Bridge (mean length=365 mm; lipid content=0.97%); DDT level in these composites was 11, 4, and below the reporting level, respectively. DDT concentrations in these three composites did not have a clear relationship with mean fish length or lipid content. Composites of coho salmon from the Feather River hatchery (mean length=849 mm; lipid content=0.79%), the Nimbus hatchery (mean length=850 mm; lipid content=2.14%), the Coleman hatchery (mean length=898; lipid content 6.80%) and the Sacramento River at RM 44 (mean length=828 mm; lipid content=3.78%) contained DDT levels of 8, 12, 20, and 15 ng/g, respectively. DDT concentrations in these composites varied more in parallel with lipid content than mean fish length even though DDT contamination was low in the four composites. Overall, DDT contamination of hatchery and wild caught trout and coho was low.

*Relationships among tissue DDT concentration, tissue lipid content and composite mean fish length*—As was observed with Sacramento sucker (16 composites) collected in the San Joaquin River watershed and delta, log-transformed, but not non-transformed, tissue DDT concentrations in composites (n=17) of Sacramento sucker collected in the Sacramento River watershed fit a normal distribution. For Sacramento sucker composite lipid content and mean fish length, neither non-transformed nor log-transformed fit a normal distribution. Contrariwise, in composites of Sacramento sucker collected in the San Joaquin watershed and Delta log-transformed composite percent lipid fit a normal distribution. There are several possible reasons that the Sacramento River watershed Sacramento sucker data did not fit a normal distribution including (1) fish caught in the San Joaquin River watershed and Delta had significantly higher composite lipid content compared to the fish from the Sacramento River watershed, (2) compositing could obscure a normal distribution, (3) the tendency to select the largest fish available, (4) fish come from different sites that may differ in DDT contamination, and (5) several sites sampled in this project appeared to have relatively low DDT contamination.

Percent lipid in Sacramento sucker composites was significantly related to DDT concentration, potentially accounting for up to 37% of the variability in tissue contamination (Table 31). A similar situation was observed with Sacramento sucker caught in the San Joaquin River watershed and Delta, but a much stronger relationship ($r^2$=0.79) was noted (Table 31). With non-transformed data the slope, but not the intercept, of the regression of DDT concentration on percent lipid was significantly different in the San Joaquin River watershed/Delta and Sacramento River watershed datasets. With log-transformed data the intercept, but not the slope, of the regression of DDT concentration on percent lipid was significantly different in the San Joaquin River watershed/Delta and Sacramento River watershed datasets. Data from Sacramento sucker collected in the Sacramento River watershed imply that log, but not non-transformed values, mean length of fish in composites is an equivalent to % lipid and a statistically significant predictor of DDT levels (Table 46). Of note is that mean length was not a significant predictor of PCB or dieldrin concentrations in Sacramento sucker collected in the Sacramento River watershed. Both non-transformed and log-transformed mean length values were weak, but statistically significant predictors of DDT concentration in Sacramento sucker caught in the San Joaquin River watershed/Delta. In a multiple regression with log composite % lipid and log composite mean fish length as the independent variables and log DDT concentration as the dependent variable from fish collected in the Sacramento River watershed the $R^2$ was 0.53 (P=0.004). Thus, mean length of fish in composites combined with % lipid in composites more effectively predicted DDT concentrations than either variable alone. Fish length was not a statistically significant predictor of tissue lipid content in Sacramento sucker from the Sacramento River watershed (Table 46). Wet weight DDT concentrations (non-transformed and log-transformed) were regressed on lipid-normalized DDT concentrations; results disclosed that lipid-normalized values were highly significant predictors of wet weight DDT concentrations, providing further support for lipid being a determinant (not simply exposure level) of degree of fish DDT contamination (Table 46). Sites were ranked based on the lipid content of composite(s) and on level of DDT concentration; a rank correlation analysis was then performed. The $R^2$ for this analysis was 0.23 (P=0.05) and the slope was 0.51. These results suggest that lipid content of Sacramento sucker is a contributing determinant of DDT contamination. Moreover, it is not simply exposure level at a location that determines level of contamination. There is little reason to believe that DDT exposure levels at sites would be dictated by lipid content of Sacramento sucker. Data from Sacramento sucker collected in the San Joaquin River watershed and Delta revealed higher and more variable composite lipid content; in those fish lipid content was a very powerful predictor of DDT contamination. If lipid content is the only determinant of tissue DDT concentrations, a regression of lipid-normalized DDT concentrations on percent lipid should not yield a statistically significant $R^2$ (Herbert and Keenleyside, 1995). The $R^2$ values were very low and not statistically significant (Table 46). This finding suggests that lipid content is a very important determinant of DDT concentrations. Data presented in this paragraph imply that factors that determine (not simply exposure level) Sacramento sucker DDT concentrations are not identical in fish from the San Joaquin River watershed and Delta compared to those from the Sacramento River watershed. The geometric mean (with lower and upper 95% confidence limits) wet weight and lipid-normalized DDT concentrations for Sacramento sucker collected in the Sacramento River watershed are 6, 3-13 and 387, 257-813, respectively. Coefficient of variation on these means is 73 and 18%, respectively, revealing that lipid-normalization reduces variability in the DDT data. The geometric mean (with lower and upper 95% confidence limits) wet weight and lipid-normalized DDT concentrations for Sacramento sucker+channel catfish+carp collected in the Sacramento River watershed are 14, 7-27 and 933, 525-1660 ng/g, respectively. Coefficient of variation on these means is 60 and 21%, respectively, again revealing that lipid-normalization reduces variability in the DDT data.

Tables 38 and 39 summarize regression coefficients ($R^2$) and rank (sites ranked by level of contamination) correlation coefficients (Rho), respectively, from analyses of wet weight and lipid-normalized PCB/OC pesticide concentrations in Sacramento sucker collected in the Sacramento River watershed. Note that in both analyses statistically significant associations were observed between contaminant wet weight and lipid-normalized concentrations. In all cases, however, the degree of association between contamination is less and the P value higher in lipid-normalized concentrations. The fact that positive statistically significant associations among the three contaminants *implies* that sites most DDT contaminated are also most contaminated by PCBs and dieldrin. Moreover, the implication is that there is a ranking of sites by total PCB/OC pesticide contamination. Why should Sacramento sucker tissue PCB concentration at a site predict DDT and dieldrin tissue concentrations unless there is parallel contamination of PCBs, DDTs, and dieldrin at the sites sampled? Such a situation does not seem likely. I propose another interpretation that is supported by data in Tables 38 and 39. My hypothesis is that exposure levels of PCBs, DDTs, and dieldrin are not necessarily the highest at sites with the most contaminated Sacramento sucker. I propose that factors, conditions, and the fish at sites differ and those with the most contaminated Sacramento sucker have conditions most favorable to bioaccumulation and biomagnification. In addition to exposure level, body lipid and a host of other physical, chemical, ecological, and physiological factors that affect bioaccumulation (see Discussion section on determinants of tissue and body concentrations of persistent organic pollutants—POPs). The data in Tables 38 and 39 provide impelling evidence that, in the San Joaquin River watershed and Delta, lipid content of Sacramento sucker was a more significant determinant of PCB/OC concentration in fish than site exposure level.

The channel catfish composite (fish from Grimes site) with the highest lipid content (7.14%) was characterized by the lowest DDT concentration (44 ng/g). In the other four channel catfish composites DDT concentration did not vary in parallel with composite lipid content. The two carp composites (fish from CBD and the Sacramento River at Rio Vista) with the lowest lipid content (0.73 and 0.98%) had the highest DDT concentrations (149 and 66 ng/g), respectively. In the other three composites dieldrin concentration did not vary in parallel with lipid content. The highest DDT concentration (11 ng/g) in trout composites (n=6) was in the Yuba River site composite characterized by the lowest lipid content.

*Comparison of concentrations in 'duplicate'* composites—At five Sacramento watershed sites 'duplicate' composites could be constituted. 'Duplicate' composites of Sacramento sucker were available for the Feather River at Gridley and the Yuba River at Marysville, of channel catfish for Sacramento Slough at Karnak, of red-ear sunfish for the Bear River and of large-mouth bass for the American River at Discovery Park. DDTs in 'duplicate' composites from Sacramento sucker collected at Gridley were below reporting level (mean length=382 mm; lipid content=1.62%) and 5 ng/g (mean length=483 mm; lipid content=1.56%). For the Sacramento sucker caught at the Marysville location, 'duplicate' composite DDT levels were below reporting level (mean length=288 mm; lipid content=1.27%) and 5 ng/g (mean length=448 mm; lipid content=0.73%), respectively. DDT concentrations in 'duplicate' composites of channel catfish captured from Sacramento Slough were 61 ng/g (mean length=390; lipid content=1.25%) and 48 ng/g (mean length=294 mm; lipid content=1.73%). DDT concentration in these two composites related more to mean length of fish than to lipid content. For the red-ear sunfish taken from the Bear River, DDTs were a non-detect (mean length=187 mm; lipid content=0.40%) and at 4 ng/g (mean length=171 mm; lipid content=0.38%), respectively. DDT levels in three composites of large-mouth bass from the American River sites were below reporting level, 4, and 6 ng/g; with these low concentrations, there was no clear relationship to mean length or lipid content. Overall, given the mean length differences in composites, DDT concentration in 'duplicates' appeared relatively consistent. DDT concentrations appeared to be more related to mean length of fish in composites rather than composite lipid content. However, DDT contamination of most species other that channel catfish and carp was very low, confounding the assessment of the role of lipid and length/age as determinants of tissue DDT concentrations.

*Temporal trends*—Assessing temporal trends is difficult when the same sites and same species are not sampled yearly as well as when the number of samples analyzed is inadequate for robust statistical analyses. Spatial and temporal variation in OC pesticide and PCB fish contamination are realities. Thus, sampling numerous (same) sites, the same species per site, and 'replicate' composites per site on a yearly basis is essential for accurate temporal trend analysis as well as for predicting future changes in fish contamination. While fish sampling for OC/PCB contamination in the Sacramento River watershed has been more extensive than in the San Joaquin River watershed and Delta, all of the above problems plague temporal trend analyses in Central Valley waterways. Clearly there was and is no consistent strategy or plan for addressing this issue.

The analysis of Greenfield et al. (2004) divulged that OC pesticide and PCB contamination of fish in Central Valley declined rapidly in the 1970s to the mid-1980s, but the rate of decrease slowed in the 1990s such that statistical differences among years could not be detected. Inability to detect statistically significant decreases among years almost certainly relates to the small number of sites, samples, and duplicates. Given that the rapid decline in the 1970s and early-1980s has been documented, my focus is on the period between 1990 and 2005. Thus, I examined the SFEI database for fillet composites of Sacramento sucker, white catfish, channel catfish, and carp collected in that period. For the entire Sacramento River watershed there were a total of 46 composites analyzed for OC pesticides and PCBs for the period of 1990 through 2004. There were 22, 16, 3, and five composites of white catfish, Sacramento sucker, channel catfish, and carp, respectively. The number of composites by year was:

| | | | |
|---|---|---|---|
| 1990 | 2 | 1992 | 1 |
| 1993 | 2 | 1997 | 6 |
| 1998 | 4 | 1999 | 10 |
| 2000 | 12 | 2001 | 6 |
| 2003 | 3 | | |

There are too few composites of the same species over the 15 year period to apply even simple statistical analyses. Some of the clearest temporal trends in DDT fish contamination can be seen at sites (Colusa Basin Drain, Sacramento River @ RM 44, and lower American River) that have been sampled several times since 1990.

Only five composites of fish collected at Colusa Basin Drain are available for the 1990 to 2004 period.

Colusa Basin Drain

| Year | Species | ∑DDTs |
|---|---|---|
| 1998 | Carp | 683 ng/g |
| 2000 | Carp | 285 ng/g |
| 2000 | White catfish | 40 ng/g |

| | | |
|---|---|---|
| 2001 | Carp | 149 ng/g |
| 2001 | Channel catfish | 81 ng/g |
| 2005 | Carp | 66 ng/g |
| 2005 | White catfish | 44 ng/g |

From 1998 to 2005 DDT carp contamination at CBD decreased 90%. Between 2000 and 2005 it appears that DDT contamination of white catfish has not declined. In a least-squares regression of log carp DDT concentrations versus year $R^2$=0.93. However, this is not statistically significant (P=0.17) because of the low sample size (4). Nonetheless, if the rate of decrease (slope of the regression) remains the same, carp muscle DDT residues will not be 5 ng/g or below for approximately 55 years. This estimate is probably not realistic given that current young cohorts that have been exposed to lower DDT concentrations will be growing into the desired sample size range in the next 8-10 years. With the nonparametric Spearman rank correlation the carp association coefficient was -1 as can be deducted from a visual inspection of the above data.

For the 1990 to 2004 period 11 composites of fish collected from the Sacramento River @ RM44 are available.

Sacramento River @ RM 44

| Year | Species | ∑DDTs |
|---|---|---|
| 1992 | White catfish | 148 ng/g |
| 1993 | White catfish | 146 ng/g |
| 1997 | White catfish | 68 ng/g |
| 1998 | White catfish | 129, 138 ng/g |
| 1999 | White catfish | 31, 44, 59 ng/g |
| 2000 | White catfish | 39 ng/g |
| 2000 | Sacramento sucker | 57 ng/g |
| 2002 | Sacramento sucker | 176 ng/g |
| 2005 | Sacramento sucker | 50 ng/g |
| 2005 | Largemouth bass | 4 ng/g |
| 2005 | Coho salmon | 15 ng/g |

Between 1992 and 2000 DDT contamination of white catfish at this site declined 74%, a rate of approximately 9% per year. Initially puzzling is the relatively high DDT level in the 1998 white catfish composites. However, lipid content in the 1998 composites was notably higher than in composites from 1997, 1999, and 2000. Furthermore, DDT levels in 1998 and 1999 composites paralleled lipid content. Lipid content in the 1997 white catfish composite was relatively equivalent in the 1999 and 2000 composites. The point is that lipid content of samples can confound temporal tend analyses and should not be ignored. Nonetheless, in a least-squares regression of log carp DDT concentrations versus year $R^2$=0.66 (P=0.048). If the rate of decrease (slope of the regression) remains the same, white catfish muscle DDT residues will not be 5 ng/g or below for approximately 35 years. This is probably a worst case estimate since current young cohorts experiencing lower DDT exposures will be growing into the desired sample size range in the next 8-10 years. DDT contamination of Sacramento sucker at this site did not appear to decline between 2000 and 2005. Lipid content in the 2002 Sacramento sucker

composite was very high (10.4%--more than 3X higher than in the 2002 and 2005 composites); this is a likely contributor to the relatively high DDT level in that composite. When Sacramento sucker DDT residues in years 2000, 2002, and 2005 are lipid-normalized they are considerably more equivalent ranging from 1126 to 1692 ng/g. Again we see that lipid cannot be ignored in temporal tend analyses.
For the 14 year period 8 composites of fish caught in the lower American River are available.

Lower American River

| Year | Species | ∑DDTs |
|---|---|---|
| 1997 | White catfish | 62 ng/g |
| 1999 | Sacramento sucker | 3, 8 ng/g |
| 2000 | Sacramento sucker | 6 ng/g |
| 2001 | Sacramento sucker | 43, 68 ng/g |
| 2002 | Sacramento sucker | 30, 55 ng/g |
| 2005 | Sacramento sucker | 29 ng/g |
| 2005 | White catfish | 9 ng/g |
| 2005 | Largemouth bass | <RL, 4, 5 ng/g |

At first look these data suggest that DDT contamination of fish at this location increased in the years 2001 through 2005 compared to 1999 and 2000. However, lipid content in Sacramento sucker composites from 2001 and 2002 were 3 to 8X higher than in 1999 and 2000 composites and 1.5 to 2X higher than in 2005 composites. In the 2001 and 2002 composites DDT concentrations paralleled lipid content. When lipid-normalized, DDT contamination of Sacramento sucker in 1999, 2002, and 2005 was equivalent. Lipid-normalized DDT concentrations in 2001 and in 2000 composites were higher and lower, respectively, than in 1999, 2002, and 2005. While many have attempted to simplify the process, analysis of temporal trends of fish contamination is complex, even at a single site with the same species, because multiple factors, not just exposure levels, affect fish tissue concentrations (see Discussion section on determinants of fish contaminant concentrations). Between 1997 and 2005 white catfish DDT contamination at this site decreased 85%, approximately 11% per year.

Since 1990 white catfish were collected from the Sacramento River watershed and north Delta at multiple sites in 1997, 1998, 1999, 2000 and 2005. Unfortunately, sampling was not at the same sites in those years. White catfish samples from the Sacramento River @ RM44 were available in four of the five years. Composites from the north Delta and from the lower American River were available for three of the years and from the Sacramento River @ Veteran's Bridge and Sacramento Slough for two of the years. The number of white catfish composites per year ranged from two (1998) to seven (2000). ANOVA, ANCOVA, and/or regression analysis could possibly be applied to these white catfish data in way of temporal trend analysis. A visual inspection of the data, however, reveals that application of such methods is superfluous. For example, mean DDT concentrations in 1997, 1999, and 2000 were 53, 42, and 52 ng/g, respectively, all with relatively high standard deviations. Only two white catfish composites, both from the Sacramento River @ RM44, collected in 1998 were available with concentrations of 129 and 138 ng/g. Concentrations in these two composites are more than double those measured in white catfish composites from all other sites in the Sacramento watershed during 1997. Only three composites of white catfish were available for the Sacramento River watershed for 2005. The range and mean of composite concentrations were 9 to 44 ng/g and 27 ng/g, respectively. Overall these data indicate little change in DDT white catfish contamination in the Sacramento River watershed from 1997 through 2000. The caveat is that watershed coverage was very limited and the sample sizes were small. From 2000 to 2005 it appears that some decrease in white catfish DDT contamination occurred. Looking at individual sites, DDT concentrations in white catfish composites from the north Delta in 1997 (Hill Slough), 1999 (Cache Slough), and 2000 (Cache Slough) were 54, 56, and 55 ng/g, respectively. DDT levels in white catfish composites from the lower American River in 1998 and 2000 were 62 and 54 ng/g, respectively. DDT concentrations in white catfish composites from the Sacramento River @ Veteran's Bridge in 1997 and 2000 were 43 and 77 ng/g, respectively. Clearly there is no clear temporal trend in DDT contamination of white catfish in the Sacramento River watershed and north Delta between 1997 and 2000.

Since 1990 Sacramento sucker were collected at multiple sites in the Sacramento River watershed during 1999, 2000, 2001, 2002, and 2005. Unfortunately sampling was not at the same sites in those five years. Sacramento sucker samples were available from the lower American River in all five sampling years and from the Sacramento River @ RM 44 in three (2000, 2002, and 2005). The number of composites per year ranged from three (2002) to 17 (2005); there were four to five composites available for 1999, 2000, and 2001. ANOVA, ANCOVA, and/or regression analysis could possibly be applied to these white catfish data in way of temporal trend analysis. A visual inspection of the data, however, denotes considerable spatial (within year) variation such that application of such methods is superfluous. For example, mean DDT concentrations in composites of Sacramento sucker collected during 1999, 2000, 2001, and 2002 were 28, 18, 39, and 87 ng/g, respectively. However, variation in all four year groups was high such that none of the means were statistically different. While the mean concentrations imply an increasing DDT fish contamination in the Sacramento River watershed they are not likely representative of the entire watershed in the respective years because of the diminutive number of sites sampled and small number of samples analyzed. DDT concentrations in three composites of Sacramento sucker collected in 2002 were 30, 55, and 176 ng/g. While concentrations in two of the composites are equivalent to those in 1999, 2000, 2001, and 2005, the level in the third composite is more than double the level in 14 Sacramento sucker composites from 1999, 2000, 2001, and 2002 as well as 17 Sacramento sucker composites from 2005. Validity of the 176 DDT value is also brought to question by the fact that no other contaminant concentrations were out of line with those in the other two composites from 2002. 2005 data do not support the hypothesis of increasing DDT Sacramento sucker contamination. Specifically, the mean DDT concentration in composites (n=17) of Sacramento sucker caught in the Sacramento River watershed during 2002 was 15 ng/g (95% confidence interval=$\pm$11). Two and three composites of Sacramento sucker collected from the Feather River were available for 2001 and 2005, respectively. DDT concentrations in the 2001 composites were 18 and

29 ng/g and in the 2005 composites were below reporting level, 5, and 8. This is 72% decline in four years, approximately 18% decrease per year.

Overall, it appears that there was no statistically significant decline of DDT Sacramento sucker contamination between 1990 and 2005, but this is probably a figment of data paucity. White catfish and Sacramento sucker may not be optimal of worst-case DDT contamination in the Sacramento River watershed. The range and mean concentrations in five composites of channel catfish collected in the watershed during 2005 were 44 to 109 ng/g and 70 ng/g, respectively. Likewise, the range and mean DDT concentrations in four composites of carp collected in the watershed during 2005 were 24 to 149 ng/g and 74.5 ng/g, respectively.

*Comparison of the San Joaquin River watershed and Delta with the Sacramento River watershed*—DDT concentrations in 13 and 4% of composites from fish caught in the San Joaquin River watershed and Delta and in the Sacramento River watershed, respectively, were above the 1999OEHHA 100 ng/g screening level. Seven composites from the San Joaquin River watershed and Delta fish manifested DDT concentrations greater than 200 ng/g while no composites from the Sacramento River watershed fish were at those levels. DDT levels were below reporting level (DNQ—detected, but not quantified) in 12.5 and 22% of composites from San Joaquin River watershed plus Delta fish and Sacramento River watershed fish, respectively. DDT geometric means for Sacramento sucker from the San Joaquin River watershed/Delta and the Sacramento River watershed were 68 and 6 ng/g, respectively; these means are significantly different ($P<0.0001$). Coefficients of variation for these geometric means were also different (42 versus 73%, respectively). Lipid-normalized DDT geometric means for Sacramento sucker from the San Joaquin River watershed/Delta and the Sacramento River watershed were 1720 and 387 ng/g, respectively; these means are significantly different ($P<0.0001$). Coefficients of variation for these geometric means were also different (13.5 versus 18%, respectively). Mean DDT concentrations in composites from Sacramento sucker taken in the main stem Sacramento River ($n=8$) and in the entire Sacramento River watershed ($n=17$) was 23 and 15 ng/g, respectively. Both means were significantly ($P<0.05$) below the 1999 OEHHA screening level. In composites from Sacramento suckers collected in the main stem San Joaquin River and in the entire Delta the mean DDT concentration was 232 and 159 ng/g, respectively (Table 27). Clearly DDT contamination of fish in the San Joaquin River watershed and Delta is greater than in the Sacramento River watershed.

## Reservoirs and Lakes in the Central Valley

### PCBs

Composites from six and ten reservoirs and lakes in the San Joaquin River and Sacramento River watersheds, respectively, were analyzed for PCBs and OCs. Sites and species were selected by OEHHA. Sites and species from the San Joaquin River watershed were:

| | |
|---|---|
| Mendota Pool | Channel catfish |
| Pardee Reservoir | Channel catfish, kokanee salmon |
| Camanche Reservoir | Channel catfish |
| New Hogan Reservoir | Channel catfish |

| | |
|---|---|
| Jenkinson Lake | Rainbow trout |
| Millerton Lake | Rainbow trout |

With the exception of the two composites from Pardee Reservoir, PCB concentrations were all below the reporting level or non-detects. PCB concentrations in the channel catfish and kokanee composites were 12 and 16 ng/g, respectively. While mean length of fish in the channel catfish (688 mm) composite was much greater than in the kokanee (211 mm) composite, lipid content of the kokanee was higher than in the catfish composite (1.79 versus 1.16%).

Sites and species from the Sacramento River watershed were:

| | |
|---|---|
| Lake Britton | Carp |
| Bullards Bar Res. | Carp |
| Shasta Lake | Rainbow trout, Chinook salmon, pumpkinseed |
| Baum Lake | Rainbow trout |
| Bucks Lake | Rainbow trout, lake trout |
| Stony Gorge Res. | Channel catfish |
| East Park Res. | Channel catfish |
| Indian Valley Res. | Channel catfish |
| Whiskeytown Res. | Sac sucker, brook trout, Sacramento pike minnow |
| Lake Almanor | Sacramento sucker, steelhead trout |

With the exception of the two composites, PCB concentrations were less than the reporting level or non-detects. PCB concentrations were 36 ng/g in a composite of Sacramento pike minnow from Whiskeytown Reservoir and 6 ng/g in a composite of Chinook salmon from Shasta Lake. PCB concentrations in composites of Sacramento sucker and brook trout collected in Whiskeytown Reservoir were below reporting level. Further, the mean length of fish in the Sacramento pike minnow composite was larger than in any other composite from reservoirs and lakes in the Sacramento River and San Joaquin River watersheds; lipid content (2.41%) of the composite was also higher than in any other from reservoirs and lakes in the Sacramento River watershed. Most likely this composite consisted of tissue from an 'old', fatty fish. I contend a conclusion that current PCB exposure levels in Whiskeytown Reservoir are high is premature without additional robust evidence (see Discussion section). At Lake Shasta, also, in composites of carp and rainbow trout PCBs were a non-detect and below reporting level, respectively.

**Chlordanes**

∑Chlordanes in 22 of the 23 composite from fish collected in reservoirs and lakes of the San Joaquin River and Sacramento River watersheds was non-detect or below the reporting level. Chlordane concentration in the composite from Sacramento pike minnow caught in Whiskeytown Reservoir was 4 ng/g, considerably below the OEHHA 30 ng/g screening level.

**Dieldrin**

In most of the composites from fish collected in reservoirs and lakes of the San Joaquin River and Sacramento River watersheds dieldrin was not detected (14) or below the reporting level (6). In composites of Sacramento pike minnow and Sacramento sucker from Wiskeytown Reservoir dieldrin concentrations were 0.6 and 0.5 ng/g. Dieldrin concentration in a composite of channel catfish collected from Stony Gorge Reservoir also was 0.5 ng/g.

**DDTs**

DDTs in 16 of the composites from fish collected in reservoirs and lakes of the San Joaquin River and Sacramento River watersheds were non-detects or below the reporting level. DDT concentration in 6 of the 7 remaining composites was less than 5 ng/g. The composite of Sacramento pike minnow from Whiskeytown Reservoir contained 28 ng DDTs/g. As with PCBs in this composite, I contend a conclusion that current DDT exposure levels in Whiskeytown Reservoir are high is premature without additional robust evidence. DDT concentrations in composites of Sacramento sucker and brook trout from this reservoir were both less than reporting level.

## Discussion

While many recommendations and conclusions are offered in this report, few are definitive. Definitive recommendations are contingent upon whether the OEHHA 2006 proposed OC pesticide screening values, guidance tissue levels (GTLs), and fish consumption guidelines (Tables 3 and 4 in this report) are officially adopted by OEHHA and approved by the CVRWQCB. Decisions regarding CWA 303(d) delisting or listing water bodies for OC pesticide contamination of fish almost certainly will be affected by such actions. In deliberating the OEHHA screening values and fish consumption guidelines the CVRWQCB should be aware that US EPA (2000) values are more conservative (Table 3). My recommendations for 303(d) delisting of 13 Central Valley and Delta water bodies are summarized in Table 47.

Analyses summarized in this report provide compelling evidence that levels of PCBs and OC pesticides in fillets of large/old, fatty fish (e.g., Sacramento sucker, carp, and channel catfish) are not indicative of current exposure (contamination) level at sampling sites. Contaminant levels in these old, fatty fish are the result of exposure throughout their lives, not current exposure levels. While high levels (> 1999 OEHHA screening values) of PCBs and OC pesticides in older, fatty fish may indicate that they should not be consumed by humans, such findings should not trigger (without convincing additional data) water body remediation actions based on the assumption of present-time high level site contamination (exposure level).

**DDTs**

The lower San Joaquin River as well as the north, east, and west Delta are CWA 303(d) listed for DDT fish contamination. The ∑DDTs was analyzed in 92 composites of fish collected at sites in the San Joaquin River watershed and Delta. DDT fish contamination is neither extensive nor particularly extreme. In nine composites from six sites in the San Joaquin River watershed and Delta ∑DDTs exceeded the 1999 OEHHA screening value (100 ng/g). The sites were Tuolumne River @ Shiloh, Potato Slough (east Delta), and

Prospect Slough (north Delta); also three sites on the lower San Joaquin River—at Crow's Landing, Laird Park, and Vernalis. All the composites, with the exception of white catfish from the Laird Park site, exceeding the screening value were constituted by older, fatty fish that do not reflect current DDT exposure levels. The five composite exceedances from fish collected in the lower San Joaquin River preclude (SWRCB, 2004) delisting of the lower San Joaquin River if the 1999 OEHHA screening value is maintained. The composite of Sacramento sucker collected at Potato Slough (east Delta) had the highest DDT (as well as PCB, dieldrin, and chlordane) concentration of any 2005 fish composite from Central Valley water bodies and Delta. That composite also had a lipid content that far exceeded that of any composite of fish collected from Central Valley water bodies and Delta during 2005 (the fish constituting that composite were probably among the oldest Sacramento sucker collected during 2005). Clearly, contaminants in that composite are not indicative of current exposure levels in Potato Slough or other areas of the east Delta. DDT concentrations in five composites of fish (including one of Sacramento sucker) collected in the east Delta were 15 ng/g or less. To gain a more accurate assessment of potential DDT fish contamination at the Potato Slough site, I recommend multiple composites (at least three) of multiple species (ideally, five to seven) be analyzed for DDTs, PCBs, and dieldrin. The mean and geometric mean DDT concentration in nine composites of fish collected in the eastern Delta are below 50 ng/g and the upper 95% confidence limit does not overlap the 1999 OEHHA screening value. Based on this weight of evidence I recommend 303(d) delisting of the eastern portion of the Delta (Table 47). While DDTs in a composite of older, fatty Sacramento sucker captured from Prospect Slough exceeded the 1999 screening value, concentrations in nine composites of eight other species were 36 ng/g or less. Mean and geometric mean DDT concentrations in 14 composites of fish collected in the northern Delta during 20005 were below 50 ng/g and the upper 95% confidence limits do not overlap the 1999 OEHHA screening value. Consequently, I recommend 303(d) delisting of this Delta area (Table 47). Mean and geometric mean DDT concentrations in 13 composites of fish collected in the southern Delta are below 20 ng/g and the upper 95% confidence limit does not overlap the 1999 screening value. Likewise, mean and geometric mean DDT concentrations in eight composites of fish collected in the western Delta are below 12 ng/g and the upper 95% confidence limit does not overlap the 1999 screening value. Therefore, I recommend 303(d) delisting of these two areas of the Delta (Table 47).

DDT level in two composites of older, fatty Sacramento sucker taken from the Tuolumne River exceeded the 1999 OEHHA screening value. This is sufficient (SWRCB, 2004) data to 303(d) list this water body. Nonetheless, I would recommend that additional data be obtained at this site including several (at least three) composites from multiple (preferably five to seven) species before listing actions are taken. DDT concentration in all 92 composites of fish collected in the San Joaquin River watershed and Delta was considerably below the 2006 OEHHA-proposed screening value (560 ng/g). If this screening value is adopted and approved by the CVRWQB, delistings and new listings should be modified. In concert with OEHHA 2006 recommendations, DDT concentrations in all fish from all sites sampled from the San Joaquin River watershed and Delta during 2005 were such that 12 or more fish meals per month could be consumed.

Forty-six composites from fish collected in the Sacramento River watershed were analyzed for DDTs. DDT fish contamination in this watershed is neither extensive nor extreme. Only two composites exceeded the 1999 OEHHA screening value (100 ng/g). The sites were both on the Sacramento River at Veteran's Bridge (channel catfish composite: 109 ng/g) and at Rio Vista (carp composite: 149 ng/g). DDTs in composites of carp and Sacramento sucker from the Veteran's Bridge site were 59 and 20, respectively. The 2005 data are insufficient (SWRCB, 2004) to 303(d) list the Veteran's Bridge site or lower Sacramento River since only one composite exceeded the screening level. CWA 303(d) listing of northern Delta waterways also has been proposed by the CVRWQCB. DDT levels in a composite of Sacramento collected from Prospect Slough and a composite of carp from Rio Vista were above the 1999 OEHHA screening level. These two composites provide adequate (SWRCB, 2004) data for 303(d) listing of the north Delta if the 1999 OEHHA screening level remains viable, but not if the 2006-recommended screening level is adopted. However, DDT concentrations in nine composites from eight species collected from Prospect Slough were less than 40 ng/g (Table 26). Furthermore, in composites of Sacramento sucker and white catfish from the Sacramento River @ Rio Vista site DDT concentration was 92 and 29 ng/g, respectively. In composites of Sacramento sucker (composite DDT concentration=50 ng/g), large-mouth bass (4 ng/g) and coho salmon (15 ng/g) collected from the Sacramento River @ RM44 DDT levels were also below the screening value. Overall, there were 14 composites of fish collected from the north Delta with DDT concentrations below the 1999 OEHHA screening value (11 with DDTs < 40 ng/g). While some large/old, fatty fish in areas of the north Delta are DDT-contaminated to an extent potentially harmful to humans, this contamination does not extend to all species and does not translate into present-time high DDT exposure levels. DDT concentration in all 46 composites of fish collected in the Sacramento River watershed was considerably below the 2006 OEHHA-proposed screening value (560 ng/g). If this screening value is adopted and approved by the CVRWQB, delistings and new listings should be modified. In concert with OEHHA 2006 recommendations, DDT concentrations in all fish from all sites sampled from the Sacramento River watershed during 2005 were such that 12 or more fish meals per month could be consumed.

**PCBs**

The ∑PCB congeners was analyzed in 92 composites of fish collected at sites in the San Joaquin River watershed and Delta. PCBs in 83% of the composites were less than reporting level. PCB fish contamination was neither extensive nor extreme. In seven composites from six of 28 sites the ∑PCBs exceeded the OEHHA screening level (20 ng/g) for human health. The six sites were the Tuolumne River @ Shiloh Road, the Mokelumne River @ Lodi Lake, the San Joaquin River @ Vernalis, Potato Slough (east Delta), Big Break (west Delta) and Prospect Slough (north Delta). None of these water bodies are currently CWA 303(d) listed. Moreover, no water bodies in the San Joaquin River watershed are 303(d) listed for PCB contamination; only the northern portion of the Delta is listed for PCB fish contamination. All exceedances of the screening value were in older, fatty Sacramento sucker that do not reflect current PCB exposure levels. Two composites of Sacramento sucker collected from the Tuolumne River exceeded the

OEHHA screening value; thus, while I do not recommend such an action, data are sufficient (SWRCB policy) for 303(d) listing. At the remaining five sites data are insufficient for 303(d) listing. The northern portion of the Delta is 303(d) listed for PCB fish contamination. PCB concentration in the composite of Sacramento sucker caught in Prospect Slough (north Delta) was 20 ng/g, exactly equal to the OEHHA screening value. However, in nine composites from eight species collected at Prospect Slough PCBs were below the screening value (seven composites below reporting level). Five composites from five species were available from other sites in the northern Delta. The upper 95% confidence limits of the mean and geometric mean concentration in composites (n=14) collected in the north Delta do not overlap the OEHHA screening value. I believe these data are sufficient to 303(d) delist this area of the Delta (Table 47). With the exception of Sacramento sucker at the six sites listed above PCB concentrations in all other species of fish caught at sites in the San Joaquin River watershed and Delta were such that 12 or more fish meals per month could be consumed.

Forty-six composites from fish collected in the Sacramento River watershed were analyzed for PCBs. PCB fish contamination was neither extensive nor extreme. PCBs were not detected or below reporting level in 76% of the 46 composites. ∑PCBs in six composites from five sites exceeded the OEHHA screening level; the sites were Clear Creek, Sacramento Slough @ Karnak, American River @ Discovery Park, and Sacramento River @ Colusa and @ Veteran's Bridge. None of these water bodies are 303(d) listed. Data are insufficient (SWRCB, 2004) for 303(d) listing of Clear Creek, Sacramento Slough, the lower American River, and the Sacramento River @ Colusa; that is, PCBs in only one fish composite from each of these sites exceeded the screening value. PCB concentrations in two composites (channel catfish and carp) of fish caught at the Veteran's Bridge site. Thus, this site could be 303(d) listed according to SWRCB policy (2004). However, these two composites were comprised of older, fatty fish that are not indicative of current PCB exposure levels. Furthermore, PCBs in composites of fish taken at the immediate upstream and downstream sites were below the screening level. Therefore, I recommend that additional data be collected at the Veteran's Bridge site prior to listing actions.

**Group A pesticides**

The lower Merced River, lower Stanislaus River, lower Tuolumne River, lower San Joaquin River, the east Delta, and the west Delta are CWA 303(d) listed for Group A pesticide fish contamination. Dieldrin concentration in nine of 92 composites of fish from seven of 28 sites collected in the San Joaquin River watershed and Delta during 2005 exceeded the 1999 OEHHA screening value (2 ng/g). The sites were Salt Slough, Tuolumne River @ Shiloh Road, San Joaquin River @ Crow's Landing, San Joaquin River @ Vernalis, Potato Slough (east Delta), Big Break (west Delta), and Prospect Slough (north Delta). ∑Chlordanes in none, including those from the 303(d) listed water bodies, of the 92 composites exceeded the 1999 OEHHA screening value (30 ng/g) and were considerably below the 2006 OEHHA-proposed screening value (200 ng/g). Chlordanes were not detected or below reporting level in 83% of the 92 composites; ten of the 16 composites in which chlordanes were detected were from Sacramento sucker. Although the 2005 data document that dieldrin and chlordane fish contamination was neither extensive nor extreme, with the 1999 OEHHA screening value as the criterion, they are insufficient for 303(d) delisting the six water bodies listed above (according to SWRCB 2004 policy document). Dieldrin concentrations were less than 2 ng/g in 19 composites from fish collected in the lower San Joaquin River, but greater than 2 ng/g in three composites. Consequently, these data are insufficient for delisting the lower San Joaquin River based on the SWRCB policy document (SWRCB, 2004). However, the upper 95% confidence limit of the mean and geometric mean dieldrin concentration in the 22 composites from fish collected in the lower San Joaquin River do not overlap the OEHHA 1999 screening value. Thus, combined with the chlordane data, I contend that the weight of evidence is sufficient for delisting the lower San Joaquin River for Group A pesticide fish contamination (Table 47). The upper 95% confidence limits for the mean and geometric dieldrin concentrations in nine and eight composites of fish collected in the eastern and western Delta, respectively, do not overlap the 1999 OEHHA screening value. Based on this weight of evidence I recommend 303(d) delisting of both regions of the Delta (Table 47). On a weight of evidence basis (see Results section), I recommend that the Merced, Tuolumne, and Stanislaus Rivers be delisted for Group A pesticide fish contamination (Table 47).

Dieldrin concentration in composites of Sacramento sucker and carp taken from Prospect Slough exceeded the 1999 OEHHA screening value. If this screening level is maintained the two composites are adequate (SWRCB, 2004) for 303(d) listing of the north Delta. The two composites that exceeded the screening level were constituted of older, fatty fish that do not reflect current exposure levels. Moreover, dieldrin and chlordanes in eight composites from seven other species collected at Prospect Slough were below the screening level (most being non-detects and below reporting level). Therefore, before listing actions are taken I recommend that additional data be gathered. Dieldrin concentration in all 92 composites of fish collected in the San Joaquin River watershed and Delta was below the 2006 OEHHA-proposed screening value (16 ng/g). If this screening value is adopted and approved by the CVRWQB, delistings and new listings should be modified. In concert with OEHHA 2006 recommendations, dieldrin concentrations in all composites from all sites sampled in the San Joaquin River watershed and Delta during 2005 were such that 12 or more fish meals per month could be consumed.

Dieldrin and chlordanes were not detected or below reporting level in 63 and 83%, respectively, of 46 composites of fish collected in the Sacramento River watershed. Only four composites (all from channel catfish) from three of 17 sites exceeded the 1999 OEHHA dieldrin screening value. The sites were Sacramento Slough @ Karnak and the Sacramento River sites at Grimes and Colusa. These water bodies are not 303(d) listed. Dieldrin in none of the 46 composites exceeded the 2006 OEHHA proposed screening value. The ∑chlordanes in none of the 46 composites of fish sampled in the Sacramento River watershed exceeded the 1999 OEHHA screening value. Data are insufficient (SWRCB, 2004) for listing any of the three sites at which dieldrin exceeded screening level. Clearly, Group A pesticide fish contamination in the Sacramento River watershed is neither extensive nor extreme. Colusa Basin Drain and the lower Feather River are 303(d) listed for Group A pesticide fish contamination. The 2005 data disclose that chlordane in two composites of fish (carp and white catfish) collected from CBD was not detected; dieldrin levels in these two composites were 1.1 ng/g and below reporting level, respectively. In five composites of fish (carp, Sacramento sucker, and large mouth bass) collected from the lower Feather River in 2005 chlordane was not detected or below reporting level; dieldrin in all five of these composites was below reporting level. The 2005 data unmistakably document that Group A pesticide contamination of fish in CBD and the lower Feather River is not a human health concern. Nonetheless, according to SWRCB policy (SWRCB, 2004) these data are inadequate (27 out of 28 samples below the screening level) for delisting CBD and the lower Feather River. Rather than achieving the 28 samples below the screening value deemed necessary in the SWRCB policy for delisting, monitoring funds could be more effectively used on more pressing water quality issues. Dieldrin concentration in all 46 composites of fish collected in the Sacramento River watershed was below the 2006 OEHHA-proposed screening value (16 ng/g). If this screening value is adopted and approved by the CVRWQB, delistings and new listings should be modified. In concert with OEHHA 2006 recommendations, dieldrin concentrations in all fish from all sites sampled from the Sacramento River watershed during 2005 were such that 12 or more fish meals per month could be consumed.

**Comparison to other California waterways and river systems in the US**
How does PCB and OC pesticide contamination of fish in waterways of the Central Valley and Delta compare to other areas of California and to other river systems in the United States?

Davis et al. (2008) reviewed the literature on PCB and OC pesticide contamination of sport fish throughout California, including data collected from 1998 through 2003. The 1998-2003 data included 252 sites where muscle fillet composites were analyzed for PCBs. At 4% of the sites median PCB concentration was greater than 270 ng/g so that OEHHA's (2006—Table 4 in this report) draft report indicates that there should be no fish consumption. PCB median concentration at 30% of the sites was such (70-270 ng/g) that no more than one fish meal per month should be consumed. PCB median concentration at 66% of the sites was at a level (20-30 ng/g) so that up to eight fish meals per month should be eaten. The 2005 data presented in this report are, in general, consistent with these findings; PCB fish contamination in Central Valley water bodies and Delta appear to be somewhat less than the statewide average, but this could be because the data herein are more current. Davis et al. estimate that it will be 50 to 100 years before PCB contamination in white croaker and shiner surfperch will be below levels of concern for human health. In the period 1978 through 1987 PCB median concentration was above the no fish consumption level at 12% of the California sites sampled. So on the State level PCB fish contamination has declined (4 versus 12%).

Recent (1998 through 2003) data (239 statewide sites) indicate that all areas of the State are below chlordane thresholds of concern for human health (Davis et al., 2008). The data presented in this report are consistent with these findings. The same dataset also indicates that dieldrin median concentration in fish composites from a majority of California's water bodies (245 statewide sites) are below thresholds of concern for human health.  Moreover, at 98% sites fish were safe for human consumption; all sites in the Central Valley and Delta were in this category.  DDT median concentration in fish composites (1998 through 2003 data) from a vast majority of California's water bodies (253 statewide sites) are below thresholds of concern for human health (Davis et al., 2008).  As with dieldrin, fish were safe for human consumption at 98% sites; all sites in the Central Valley and Delta were in this category.

Schmitt et al. (2005) analyzed whole body composites from fish collected in late 1997 and early 1998 at ten stations in the Rio Grande River basin for OC pesticides and PCBs. Residues of p,p'-DDE, the most persistent metabolite of p,p'-DDT were detected (>10 ng/g wet weight) in 43 of the 47 composites and in at least one sample from all ten stations.  The highest DDE concentrations were from sites on the lower Rio Grande (in Texas). Station DDE geometric means for carp, catfish, and large mouth bass composites ranged from 20 to 52 ng/g, 100 to 1430 ng/g, and non-detect to 380 ng/g, respectively. For stations outside the lower Rio Grande geomentric means for carp, catfish, and large mouth bass ranged from 20 to 150 ng/g, 100 to 110 ng/g, and non-detect to 50 ng/g, respectively.  Only cis- and trans-chlordanes and norachlors were detected and only in 12 (of 47) composites from four stations (three on the lower Rio Grande).  Concentrations of chlordanes were highest (140 to 220 ng/g) in channel catfish from one site on the lower Rio Grande; concentration in the remaining nine composites of carp and large mouth bass were less than 50 ng/g.  Dieldrin was detected (>10 ng/g) in only 17% of the samples from two stations (both on the lower Rio Grande.  In three composites from channel catfish collected at one site on the lower Rio Grande dieldrin levels ranged from 39 to  51 ng/g; in the remaining four composites of large mouth bass and carp dieldrin concentrations were less than 15 ng/g.  Total PCB concentration in all composites in this study was below the detection limit (50 ng/g).  Because whole fish were analyzed in this study direct comparison to the California Central Valley and Delta fillet data is impossible.  Further, OC pesticide fish contamination in the Rio Grande basin has probably declined since 1997/98.  With the possible exception of chlordane, however, fish OC pesticide contamination in most of the Rio Grande basin (except the lower segment) was probably lower than in the San Joaquin River watershed during the late 90s.

OC pesticide and PCB contamination of fish collected in the Mississippi River basin was investigated by Schmitt (2002).  Fish were collected in 1995 at 46 sites.  There were a total of 163 whole fish composites (mostly carp), usually four composites per site and ten fish per composite.  Data collected in 1995 were compared to a similar dataset obtained in 1986.  ∑DDTs in composites ranged from non-detect (<10 ng/g) to 11,000 ng/g wet weight.  DDTs were detected in 55 of the 163 composites; the geometric mean concentration was 100 ng/g or less at 41 stations (74.5%).  The range of geometric means for all sub-basins was 10 to 1000 ng/g, but in five of the eight sub-basins the range of geometric means was 10 to 100 ng/g.  The most contaminated sites were in the lower Mississippi River (LMR) and Mississippi River embayment (MSE); geometric means in these sub-basins were 150 and 1000 ng/g, respectively.  The geometric mean at one of the most contaminated LMR sites in 1995 and 1986 was 1200 and 2500 ng/g, respectively (approximately 50% decline in nine years).  The range of concentrations at this site in the early 70s, 1986, and 1995 was 10,000 to 30,000, 2000 to 6000, and all <3000. With the exception of one sub-basin (LMR) contamination of bass was considerably (approx. 60%) less than carp. Analysis of the 1995 fish tissue DDTs indicated continued weathering of residual DDT rather than input of new DDT. Dieldrin was detected (>10 ng/g) in 68 (42%) composites from 57 % of the stations. In 66% of the samples where detected, dieldrin levels were <50 ng/g. As with DDTs there was approximately a 50% reduction in fish dieldrin contamination from 1986 to 1995. Chlordanes were detected (>10 ng/g) in 51% of the 163 composites from 70% of the stations. The geometric means at 77% of the stations where chlordanes were detected were in the 38 to 50 ng/g range. Compared to 1986 chlordane contamination at stations in 1995 declined, but at some changed minimally. PCBs were detected (>50 ng/g) in only 21% of 163 composites from 35% of the 46 stations. At 12 stations the PCB geometric mean was greater than 300 ng/g. Because whole fish were analyzed in this study direct comparison to the California Central Valley and Delta fillet data is impossible. Further, OC pesticide fish contamination in the Mississippi River basin has probably declined since 1995. In 1995 OC pesticide fish contamination in the lower San Joaquin River watershed was probably equivalent or higher than in the lower Mississippi River basin.

In fish (carp, bass, and catfish) collected during 2003 Hinck et al. (2007) scrutinized the spatial trends of OC pesticide contamination in the Colorado River and its tributaries. Composites (1 to 13 fish) of whole fish from 14 stations were analyzed. While all DDTs were measured the focus was on p,p'-DDE, the most persistent metabolite. Means at all sites other than one were based on two composites, one of males and one of females. Sites differed significantly in the level of fish DDE contamination (considerable spatial variation). However, the means at each site was of only two composites (males and females); consequently we do not have a reliable measure of variation at the individual sites. In 14 of the 24 composites DDE levels were less than 50 ng/g. Mean DDE concentration at the 14 stations ranged from 2 to 2150 ng/g; at nine of the sites DDE concentration in all species composites was less than 60 ng/g. Total chlordane concentration in ten composites (of 48) from only four stations was greater than 30 ng/g; the range of concentrations was from 2 to 120 ng/g. Concentrations of dieldrin were below the detection level (0.05 ng/g) in 43 of 48 composites; concentrations in the remaining five composites ranged from 10 to 22 ng/g from fish collected at two sites. Because whole fish contamination was measured in the fish it is near certain that fish in the Colorado River are, for the most part, less PCB and OC pesticide contaminated than in Central Valley water bodies and Delta.

Fish were collected at 16 sites in the Columbia River basin from September 1997 to April 1998 to assess spatial and temporal trends in OC pesticide and PCB fish contamination (Hinck et al., 2006). Composites of whole fish were analyzed. Spatial (station to station) variability in fish contaminant concentrations for all chemicals was considerable and statistically significant. There was no summary for the ∑DDTs in this publication, but the range of composite geometric p,p';-DDE means for carp at nine stations where they could be determined was 100 to 830 ng/g (wet weight). The range of composite geometric p,p';-DDE means for bass and largescale sucker at 11 and nine stations where they could be determined was 10 to 820 ng/g and 10 to 310 ng.g, respectively.

Geometric means of five of the nine sucker composites were less than 150 ng/g. Geometric means of eight of the 11 bass composites were less than 230 ng/g. The decline in DDE carp geometric means contamination from the early 1970s to 1997 at three stations was 74, 78, and 89%; in this same period the decline in bass at two stations was 51 and 82%. Total chlordanes also were measured. Of these trans-norachlor was the most frequently detected being greater that the detection level (10 ng/g) in 15 of 64 composites from eight stations. Chlordanes were greater than 30 ng/g in 11 of the 15 composites. Concentrations of dieldrin were higher than the detection limit (10 ng/g) in 13 of 64 composites from seven stations; concentrations in these composites ranged from 10 to 29 ng/g. Concentrations of PCB congeners were above the detection level (30 ng/g) in 43 of the 64 composites from13 stations; concentration in 14 of the 43 composites from nine sites was higher than 300 ng/g. The range of composite geometric PCB means for carp at nine stations where they could be determined was 20 to 330 ng/g. The range of composite geometric PCB means for bass and largescale sucker at 11 and nine stations where they could be determined was 20 to 470 ng/g and 20 to 430 ng.g, respectively. Means of all but one of the nine sucker composites were less than 200 ng/g. Means of six of the 11 bass composites less than 100 ng/g and only three means were above 300 ng/g. Because whole fish were analyzed in this study, it is impossible to compare these results to the 2005 fillet data from the California Central Valley and Delta. PCB and OC pesticide concentrations in whole fish can be 25X that in fillets and varies from species to species. Furthermore, contamination of fish in the Columbia River system almost certainly has declined since 1997/98. My best professional judgment would be that PCB and OC pesticide contamination of fish in the Columbia River basin is currently less than in Central Valley water bodies and Delta.

Table 48 summarizes the highest OC pesticide and PCB concentrations in fish collected from four large river systems in the United States. Because whole fish were analyzed in these studies, it is impossible to compare these results to the 2005 fillet data from the California Central Valley and Delta. My prediction, however, is that OC pesticide contamination of fish in the San Joaquin River watershed and parts of the Delta was higher during the 1990s than in any of four river systems listed in Table 48.

**Factors affecting bioaccumulation**

There is more to whole fish or fillet PCB and OC pesticide concentrations than contamination (exposure) level at the site of collection. Due to the limited data collected in this project analysis of the determinants of fillet PCB and OC pesticide concentrations was impossible save for one *significant* determinant in one species plus a weak and inconsistent determinant in two species. Analyses performed on the Sacramento sucker 2005 data clearly demonstrated that composite lipid level was a significant determinant of fillet concentrations of PCBs and OC pesticides, more important than present-day exposure level (concentration of contaminant) at site of collection. Moreover, it is clear that concentration of these contaminants in Sacramento sucker is *not* indicative of current exposure (contamination) levels at sites. Concentration of these contaminants in large/old, fatty Sacramento sucker must relate to exposure throughout their lifetime, especially earlier years when exposure levels were much higher than currently. Lamoureux and Glaser (2003) report that concentration of persistent organic pollutants

(POPs) in fish is inversely proportional to elimination rate and to growth rate. Elimination rate is inversely proportional to body lipid level and to POP $K_{ow}$. The large (and undoubtedly relatively old) Sacramento sucker analyzed in the 2005 data would be slow growing and have a low elimination rate due to their high lipid content.

Lipid content in white catfish fillets is much lower and less variable than in Sacramento sucker and analyses indicated no significant relationship between lipid levels and concentrations of PCBs and OC pesticides. The number of channel catfish and carp, as well as all other species, composites analyzed was too small to assess whether lipid is a major determinant of fillet PCB and OC pesticide concentrations.

Mean length (age?) of Sacramento sucker (collected in the San Joaquin River watershed and Delta, but not in the Sacramento River watershed) constituting composites was a statistically significant predictor of PCB concentration, yet not as robust as composite lipid content. However, in a multiple regression with composite lipid content and mean length of fish constituting the composite as the independent variables and composite PCB concentration as the dependent variable mean length was not a statistically significant predictor. Mean length of white catfish (collected in the San Joaquin River watershed and Delta) constituting composites was not a statistically significant predictor of PCB levels. Mean length (age?) of Sacramento sucker (collected in the San Joaquin River watershed and Delta, but not in the Sacramento River watershed) constituting composites was a very weak, but statistically significant, predictor of DDT and dieldrin concentrations, but not as robust as composite lipid content. However, in a multiple regression with composite lipid content and mean length of fish constituting the composite as the independent variables and composite DDT or dieldrin concentration as the dependent variable mean length was not a statistically significant predictor. With white catfish from the San Joaquin River watershed and Delta there was a small, but statistically significant, inverse relationship (negative slope) between mean length of fish constituting composite and DDT, as well as dieldrin, concentration. The difference between Sacramento sucker from the San Joaquin River watershed and Delta compared to those from the Sacramento River watershed is interesting, but not necessarily unexpected given the following discussion of POP concentration determinants and spatial variation thereof. Generalization regarding determinants of POP concentration in fish fillets among sites and among species should be avoided (see following discussion).

Understanding the determinants of bioaccumulation and biomagnification of persistent organic pollutants (POPs) in food webs is critical to predicting those most at risk for high levels of contamination. Bioaccumulation involves a complex of chemical, biological, and ecological processes. Norstrom (2002) observed that, despite this knowledge, our attempts to comprehend and predict bioaccumulation frequently are done in a piecemeal fashion that can lead to considerable misunderstanding and to misleading conclusions. Fisk et al. (2003) also caution against a simplistic view of bioaccumulation and claim that many contaminant publications have ignored the influence of ecological variability. Variables that have been offered as determinants/predictors include exposure level, trophic position, lipid content of whole fish or of tissue analyzed, growth rate, age, and size/length or weight. Trophic position is important because exposure in fish is primarily in the diet. Moreover, exposure to upper trophic level aquatic organisms to POPs with a log octanol/water partition coefficient ($K_{ow}$) of approximately 5 and higher is predominately through dietary accumulation (e.g., Thomann amd Connolly, 1984; Madenjian et al., 1993; 1994, 1998; Fisk et al., 1998; Jackson et al., 1998; Norstrom, 2002). In the current study, all contaminants have a log $K_{ow}$ greater than five. Consensus has not been achieved on POP concentration determinants that are most important, primarily because they vary from species to species, in different ecosystems, and from site to site within ecosystems. Season and/or year of fish collection can be significantly correlated with POP concentrations. Season and year are not 'direct' determinants of POP concentrations, but rather reflect morphological and physiological (e.g., growth rate, reproduction cycle, lipid cycle, lipid storage locations, metabolism, elimination rates, etc.) and ecological (e.g., abundance and type of prey cycles, habitat/niche, feeding rates, trophic position, physical location, etc.) variations in fish populations. Certainly, seasonal and year-to-year differences in POP concentration could relate to exposure level, but not necessarily. Differences in POP concentrations can undoubtedly relate to location (collection site) because of exposure level differences; however, location differences (related to variation of other determinants cited above) can occur without exposure differences. An objective in this project was to identify sites/locations where fish are OC contaminated to the extent they are not safe for human consumption more that to discover bioaccumulation determinants. To gain an accurate assessment of site contamination (exposure level=current contamination concentration in food items), however, it is important to have some understanding of bioaccumulation determinants so that OC concentrations can be 'corrected' or normalized for significant determinant variables. Mackay and Fraser (2000) reviewed the literature on bioaccumulation and biomagnification models.

OC pesticides and PCBs accumulate to a greater extent in whole fish and fish tissues (e.g., Muir et al., 1990; Bentzen et al., 1996; Larsson et al., 1996; Kidd et al., 1998a, b, 2001; Fisk et al., 2001; Persson et al., 2007; Weis and Ashley, 2007) that are higher in lipid and this partitioning is positively correlated to the lipophilicity of the contaminants (e.g., Mackay, 1982). Concentrations of these contaminants in upper-trophic level organisms sometimes exceed, however, that expected from lipid content alone (e.g., Oliver and Niimi, 1988; Swackhamer and Hites, 1988). To examine the effects of food-web structure on OC concentrations in top predators, Rasmussen et al. (1990) categorized lake trout (*Salvilinus namacycush*) into three trophic classes. Using these discrete groupings they demonstrated that lake trout from lakes with the longest pelagic food chains had the highest PCB concentrations and that both the length of the food chain and fish lipid content had significant effects on the OC concentrations. Upon removing the effects of lipid using an analysis of covariance (ANCOVA) Bentzen et al. (1996) discovered that PCB concentrations in lake trout remained significantly different across trophic classes; they attributed these findings to differences in food chain length and/or OC inputs into the aquatic systems investigated. Vander Zanden and Rasmussen (1996) demonstrated that PCB concentrations in lake trout are more accurately predicted with the use of a continuous variable describing trophic positioning. The following paragraphs explore POP concentration determinants.

Regression analyses indicated that both the wet and lipid weight concentrations of DDTs and PCBs in biota from aquatic species food webs in northern Canada lakes were significantly related to trophic position (Kidd et al., 1998a). These researchers also reported that concentrations of OCs in lake trout (skin-on muscle), burbot (liver), northern pike (skin-off), round whitefish (whole body), and longnose sucker (skin off muscle) from Canadian lakes varied significantly among populations (considerable spatial variation); these differences could not be ascribed size or age of the fishes. For each species, lipid content and trophic level positioning were significantly different across populations. Lipid significantly predicted OC levels both within and among populations of lake trout. These results are inconsistent with those of Stow (1995) and Stow et al. (1997) who indicated that lipid is not a predictor of PCB concentrations in lake trout (the Stow articles are summarized below). Lake trout samples in the Stow and Kidd studies were skin-on muscle samples. Lipid-adjusted concentrations of DDTs and chlordanes in lake trout remained significantly different between lakes; these differences were attributed to variable food chain lengths. Moreover, lipid content and/or trophic positioning were significant predictors of contaminant concentrations in the top predators, lake trout and burbot. Trophic positioning was a better individual predictor for the more lipophilic contaminants. A combination of the two factors accounted for more of the variability in lake trout. Upon lipid-adjustment (ANCOVA) of OC data trophic positioning remained a significant predictor of OC concentrations. Huestis et al. (1996) contend that age also is a POP concentration (both wet weight and lipid-normalized levels) determinant in lake trout.

Regression analyses indicated that both wet and lipid weight ∑DDT concentrations in biota from an aquatic species food web in a northern Canada lake were significantly related to trophic position (Kidd et al., 1995). Biota samples, including six species of fish, were collected between June and September 1993. Fish species included lake trout (skin-on muscle), lake whitefish (whole body), broad whitefish (whole body) longnose sucker (skin-off muscle), cisco (whole body) and burbot (liver). Liver is a significant lipid storage organ in burbot. DDT concentrations were much higher in the two species (burbot and lake trout) with the highest sample lipid content. Wet weight ($r^2$=0.81) DDT concentrations were more robustly related to trophic position than to lipid-normalized ($r^2$=0.65) levels. One could argue that the coefficient of determination was lower in the lipid-normalized data because normalization decreased data variability. In any case, lipid is clearly a significant determinant of ∑DDT concentration in fish from this lake.

Kidd et al. (1998b) examined persistent organochlorines in water, sediment and biota from a remote like in the Canadian artic. While several fish species, zooplankton, and benthic biota were included in the study, the two top predators were lake trout (*Salvelinus namaycush*) and artic char (*Salvelinus alpinus*). In these two species skin-on fillets were analyzed for organochlorines. Concentrations of PCBs and p,p'-DDE in lake trout, but not char, were significantly related to sample lipid content. Concentrations of PCBs and p,p'-DDE in food web biota were also significantly related to their trophic position. The more lipophilic OCs bioaccumulated to a greater degree through this food web even after accounting for the effects of lipid. Exceptionally high concentrations of the OCs were observed in a few lake trout and were accounted for by the larger size, longer lifespans, and higher lipid contents of these individuals.

At a given site POPs tend to be highest in species with the highest lipid content, but trophic position, as indicated above, can modulate this relationship. Levels of PCBs and DDTs were examined in a pike (*Esox lucius*) population inhabiting a eutrophic lake in southern Scandinavia (Larsson et al., 1993). Fish were collected in the autumn and early spring of 1989 (collection season as a predictor apparently was not examined). Analyses were performed on individual muscle fillets (skin off). In female muscle samples contaminant levels decreased linearly with age, weight, and length. The decline was ascribed the seasonal elimination of the lipophilic pollutants in roe, which contained up to ten times higher fat levels compared to muscle and over ten times the contaminant levels. Muscle from male pike contained higher levels of the contaminants than females; the authors attributed this to the lower elimination via gonadal products. No major fat deposits other than those in germinal tissue were observed in the pike; lipid content of muscle was also relatively low (0.5 to 0.8%). In contrast to some other species pike do not use fat deposits as energy reserves. Thus, a generalized bioaccumulation model cannot be proposed for all fish species.

PCBs and DDTs in an Atlantic salmon (*Salmo salar*) population spawning in a river of southern Sweden were investigated (Larsson et al., 1996). Muscle samples (skin off) were analyzed from fish collected in July and August 1993. Fat content of the salmon varied by an order of magnitude and was the most significant correlate with OC and PCB concentrations. No relationships were recorded between fat content and gender, age, weight, length, or years at sea. When pollutant levels were lipid-normalized other variants such as age and length correlated significantly with pollutant concentrations. In contrast to pike, salmonids (especially migrating species) have high concentrations of fat in muscle tissue. Larsson and colleagues state that in fat fish such as migrating salmonids and eels that spawn once in a lifetime or infrequently, POPs accumulate in males and females to high levels throughout life. For fish that spawn several times, POP concentrations tend to decrease with age and the difference between females and males increases (decline faster in females).

Olsson et al. (2000) evaluated the importance of perch (*Perca fluviatilis*) trophic position as a determinant of PCB and OC pesticides in individual (not composites) skin-off fillets. All fish (n=241) were collected over a seven day period in October 1996 from a lake in northern Latvia. Trophic position did not predict contaminant concentrations in perch less than 20 cm in length; in fish larger than 20 cm trophic position and length were significantly related to contaminant concentrations. Lipid as a possible determinant was not probed, yet all contaminant concentrations were lipid normalized. Perch deposit lipid into intestinal mesenteries and the amount varies seasonally. I would predict that OC pesticides and PCBs would tend to partition to this mesenteric adipose tissue and whole fish contaminant levels would be considerably higher than in fillets.

McIntyre and Beauchamp (2007) investigated the food web in Lake Washington (in Seattle, Washington) to assess the dominant factors governing bioaccumulation of OCs and mercury; whole body analyses were performed They found that across the food web age and trophic position together were highly significant predictors of bioaccumulation. Trophic position was more important than age for predicting concentrations of DDTs and chlordanes whereas age was a more accurate predictor of level of PCBs. In individual fish species contaminant concentrations increased with age, size, and trophic position. Lipid concentrations were correlated with contaminant concentrations in some, but not all fishes. These researchers suggested that lipids are not involved mechanistically in POP bioaccumulation. They also concluded that feeding habitat (e.g., benthic versus pelagic) had little or no influence on contaminant levels. While indicating that bioaccumulation in some food webs may be confounded by significant contributions from factors other than age and trophic position, the authors recommend that age be considered explicitly in food web bioaccumulation studies. There are considerations that confound conclusions in this publication. A primary analysis was backwards multiple linear regression, but lipid was not included as a variable. This is puzzling given that there were statistically significant coefficients of determination ($r^2$—ranging from 0.63 to 0.72) for the natural log of lipid versus DDT, PCB, and chlordane natural log concentrations in cutthroat (*Oncorhynchus clarki*); statistically significant $r^2$s (0.79 and 0.75) were also seen for DDT and chlordane in yellow perch (*Perca flavescens*). The authors described the relationship between lipid content and contaminant concentrations as spurious based (apparently) on the fact that a statistically significant relationship was not seen between lipid and contaminant concentrations in northern pike-minnow (*Ptychocheilus oregonensis*). Neither lipid levels nor seasonal variation for these three species are show in this publication. Sample size for the pike-minnow was the lowest of the three species and no information is given as to whether they were sampled in the same season as the other two species (or in a different stage of their reproductive cycle). Of note is that fish analyzed in this study were not collected in a particular season, but rather October 2001 through July 2003. The outcome of the analyses in this study could have been considerably affected consequent to the fact that fish collection was spread over 22 months. Another puzzling aspect of this study is that statistically significant correlations were seen between lipid and fish length in pike-minnow, yellow perch, and cutthroat trout. In these same three species significant correlations were noted between fish length and DDT, PCB, and chlordane concentrations. In one fish species analyzed (prickly sculpin—*Cotttus asper*) there was no significant relationship between length or age and contaminant concentrations yet the authors did not view this as inconsistent with their conclusions (even though they had used the pike-minnow data to discount the importance of lipid). Overall this publication is definitely incomplete in discounting lipid as a determinant in PCB/OC bioaccumulation.

Determinants of the ∑DDTs in fish from Lake Malawi (tropical lake in eastern Africa) were probed by Kidd et al. (2001). Whole fish analyzed except for seven large species where skin-on fillets were used. DDTs were highest in the fattiest species and higher in the larger (and presumably older) individuals with most species. The ∑DDTs was predicted by trophic position. The slope of the regression of log ∑DDT versus trophic position was significantly higher in the pelagic than in the benthic food web, indicating that pelagic organisms accumulate POPs to a greater extent that benthic biota. DDTs were significantly related to sample lipid content; this variable accounted for more of the variance in contaminant concentrations than did trophic position. This is one of the only investigations on POP concentration determinants in fish inhabiting warm water habitats.

The interacting roles of food web structure and lipid content of samples (skin-off fillets) on PCB and DDT concentrations in lake trout collected from Ontario inland lakes and the Great Lakes were evaluated (Bentzen et al., 1996). ANCOVA suggested that both lipid content and food web position were significant determinants. PCB and DDT concentrations were each proportional to lipid content in all systems but the concentration magnitude varied due to either food chain length or contaminant exposure. These findings are inconsistent with those of Stow (1995), Stow et al. (1997), Amrhein et al. (1999), and Jackson et al. (2001). These publications are summarized below.

A Lake Superior food web was analyzed (whole body analyses, including fish species) in 1994 for organochlorine contaminants including PCBs, chlordanes, and dieldrin (Kucklick and Baker, 1998). The ∑PCBs ranged more than a factor of 20 on a wet weight basis, but less than a factor of six on a lipid-normalized basis. Lipid content of organisms accounted for 81% of the variability in wet-weight PBC concentrations. Application of path analysis and regression techniques indicated that the primary influence of trophic position on PCB levels is due to a concurrent increase in lipid content with trophic position. Other research groups have explored trophic position as a determinant of POP contamination in Great Lakes salmonids (e.g., Jackson and Schindler, 1996; Madenjian et al., 1998).

PCBs and p,p'-DDE levels within and among walleye (*Stizostenion vitreum*) populations were examined to determine how analysis methods influence data interpretation (Johnston et al., 2002). The fish were collected during 1990 through 1997 from Lakes Huron, Erie and Ontario. For fish processed in the laboratory analyses were performed on whole fish homogenates. For fish processed in the field, muscle samples were collected. From most populations the muscle samples were with skin on, but from one population the skin was removed. All data were pooled with no analysis to assess whether contaminant levels varied seasonally, year-to-year or by type of sample. Whether there was a relationship between contaminant concentration and lipid level in samples was not assessed; concentrations were not lipid-normalized. In fact, contaminants were reported as total in sample. For these reasons I believe that the conclusions advanced in this publication are seriously compromised. They offer that results were not strongly influenced by method of expressing contaminant level (burden, wet weight, lipid-normalized), but was affected by choice of covariate (body mass, body length, or age).

Burreau et al. (2006) investigated biomagnifications of PCBs in food webs of the Baltic Sea and northern Atlantic Ocean. Organisms were collected in the summer and autumn of 1998 and PCB concentrations were determined in whole body samples. In the Baltic Sea food web trophic level and body weight covaried. In the Atlantic Ocean food web, consisting of fish samples (herring and Atlantic salmon) of larger body sizes, a positive correlation was observed between PCB concentration and body weight independent of trophic position. These researchers suggest that biomagnification, in some cases, depends on body size and not on trophic position. These results with Atlantic salmon cannot be directly compared to those of Larsson et al. (1996, see below) because whole body and muscle tissues, respectively, were analyzed for PCB concentrations. However, in the Burreau et al. investigation PCB concentrations were lipid-normalized, indicating lipid as a determinant. They also conclude that there probably is a trophic position influence dependence in biomagnification manifested in the food chain from zooplankton to piscivores, but no further trophic position influence on biomagnification in fish at the highest trophic levels. In an earlier publication Burreau et al. (2004) also addressed the issue of trophic position on PCB concentrations in Baltic Sea pike (*Exox lucius*), perch (*Perca fluviatilis*) and roach (*Rutilus rutilus*). In this study muscle tissue rather than whole fish was analyzed for PCBs. As in the later study they identified trophic position and body size as determinants of PCB levels. They reported that, in pike, increased size correlated with lipid-normalized PCB concentration in males, but not in females and that mean PCB concentration in males is generally higher than in females. As in the later publication they did not assess the role of lipid as a PCB concentration determinant nor did they explore the relationship between size and lipid. Nonetheless, all PCB concentrations were lipid normalized which testifies that it is a concentration determinant.

Berglund et al. (2001) explored the role of trophic position and lipid content as determinants of PCB and p,p'-DDE concentrations in muscle samples (skin off) of Atlantic salmon from the Baltic Sea. Lipid normalized PCB and DDE concentrations were not and weakly, respectively, related to trophic position of this species. These investigators declare that lipid content of samples is a more robust predictor of contaminant concentrations than trophic positon.

Consistent with the above paragraph, lipid content of Atlantic salmon individual (not composite), skin-off fillets was a more robust predictor of PCB concentrations than carbon source (Persson et al., 2007). According to these researchers lipid remained a significant predictor of PCB levels even after lipid adjustment with the ANCOVA approach. Lipid predicted 61% of the variation in PCB concentration. The coefficient of variation for mean PCB concentration on a wet weight basis was decreased when the effect of lipids was removed and was marginally lower when values were lipid normalized. This study also revealed that lipid content and PCB concentrations (up to 3-fold differences) varied within muscle samples taken from different locations in an individual fish. The authors recommend selecting an appropriate and consistent sampling location within a species based on study objectives.

Studies of artic marine food webs provide insights regarding biological and chemical factors that influence bioaccumulation and trophic transfer of OCs in aquatic systems. Lipid content, body size, age, gender, reproduction, growth rate, habitat use, migration, biotransformation, seasonal changes in habitat conditions, feeding ecology, and trophic position have all been demonstrated to influence OC concentrations and bioaccumulation in artic marine biota (Borga et al., 2004). The relative importance of each determinant varies among OCs, location, and species. According to these authors, models developed to assess OC dynamics in aquatic food webs have included some biological variables, selection of processes incorporated in these models as well as their mathematical solutions and parameterization all introduce simplification. They claim that these shortcomings reduce biological validity of the models and may be particularly problematic in a highly seasonal environment. A study conducted by Fisk et al. (2001) confirms that trophic position is a significant determinant of POP concentrations (bioaccumulation and biomagnifications) in cold water marine environments. How applicable the findings on determinants of OC bioaccumulation in artic marine food webs fit temperate riverine aquatic systems is unknown.

Ruus et al. (2002) also provide evidence that while trophic position is an important determinant of DDT and PCB contamination in a marine food web, several other factors contribute. Leblanc (1995) argues that studies that claim trophic position and biomagnification are the primary determinants of fish POP concentrations have been misconstrued. He asserts that trophic-level differences in bioconcentration are due largely to increased lipid content and decreased chemical elimination of organisms occupying increasing trophic levels.

In a study of biota from a tidal river-marsh on the Potomac River Crimmins et al. (2002) concluded that there was not clear trend between bioaccumulation factors and trophic level. The investigation was not, however, particularly well-designed nor rigorous. Fish from four likes, two small lakes in the northeastern US and two of the Great Lakes were analyzed to determine concentrations and spatial variation of polybrominated diphenyl esters (Dodder et al., 2002). These authors concluded that neither age nor trophic position contaminant concentrations in fish from the four locations. From my perspective, this conclusion is premature because only one fish species from the two Great Lakes and one of the other lakes were analyzed; two species each from the other two lakes were analyzed. Only two to six samples of each species were analyzed. There appears to be a paucity of published investigations on the significance of trophic position as a POP concentration determinant in warm water aquatic ecosystems.

According to Lamoureux and Glaser (2003) POP body burden is inversely proportional to elimination rate and to growth rate. Elimination rate is inversely proportional to body lipid level and to POP $K_{ow}$. They predict POP concentrations in lean fish should be more sensitive to variation in lipid content than fatty fish. Using whole body samples they propose a non-linear, species- and age specific relationship between lipid content and POP body burden. They also proposed that POP will remain approximately the same with increasing whole body lipid content in fast growing fish species, but will increase with lipid content in slow growing species. They observed that in species with low fillet lipid content, lipid normalization decreases variability in POP data. According to these researchers, lipid normalization is most effective at reducing POP concentration variation when whole body lipid content is approximately 2%. Lipid normalization is less beneficial with fatty fish.

Lipid is often correlated with concentrations of lipophilic contaminants, but the assumption of a causal relationship between the two has been challenged (e.g., Borgmann and Whittle, 1991a; Miller et al., 1992; Stow, 1995; Stow et al., 1997; Jackson et al., 2001; Manchester-Neesvig et al., 2001; Davis et al., 2002; McIntyre and Beauchamp, 2007).

Robust, statistically significant, correlations are frequently identified between persistent organic pollutant (POP) concentrations in fish, especially predatory species, and whole-body or muscle sample lipid content. Based on such findings, contaminant concentrations are often adjusted (expressed on a lipid unit weight basis) for variation in tissue or whole organism lipid content. This adjustment is made based on the assumption that lipophilic contaminants accumulate in *direct* proportion to tissue or whole fish lipid content. Herbert and Keenleyside (1995) observed that such ratios correct for variation in a covariate (e.g., lipid) only when the relationship between the two variables is isometric. An isometric relationship is one in which the slope of the regression line is constant and the intercept is zero. According to these authors, departures from isometry can have unpredictable consequences interpretations of normalized (ratio) data. They recommend ANCOVA as an alternative for lipid-normalizing data. Herbert and Keenleyside indicate that a statistically significant r-squared between contaminant concentration is not sufficient evidence to convert contaminant data to a lipid base. They recommend a regression of percent lipid versus contaminant concentration/unit weight lipid. If there is low and non-statistically significant $r^2$ then expressing contaminant concentration/unit lipid is acceptable, but if there is relatively high and statistically significant $r^2$ lipid normalization is unacceptable.

Borgmann and Whittle (1991a) investigated PCB and DDE contamination in Lake Ontario lake trout (*Salvelinus namaycush*—whole body analyses). They conclude that elimination rate for PCBs and DDE (most persistent of DDT metabolites) are dependent on body mass and/or lipid content. Contaminant concentrations in this species responded to changes in levels in prey species; the authors contend that this was due primarily to growth 'dilution' and not to contaminant elimination. These investigators further offer that changes in lipid levels have only minor effects on contaminant concentrations in lake trout and that it is not appropriate to lipid normalize PCB or DDE concentrations when examining trends. I cannot concur with these interpretations given than lake trout are long-lived, slow growing, the fattiest fish, and most contaminated in the Great Lakes. Because this species has such a high lipid content it is undoubtedly difficult to detect changes in contaminant concentrations with small changes in lipid content. Dismissing lipid as a determinant of POP contamination in this species given that they are the fattiest and most contaminated fish species in the Great Lakes is illogical and not supported by the body of published research.

Spatial and temporal patterns of OC pesticide and PCB contamination (analysis of skin-on muscle samples) of lake trout from Lake Michigan and Lake Superior was investigated by Miller et al. (1992). A statistically significant difference was detected in fish collected at different sites (supporting the concept of spatial variation emphasized in this report) in Lake Michigan. In a regression of fillet PCB concentration on age of fish collected in Lake Superior there was not statistical difference between lake trout and a subspecies (siscowet). The authors use these data to conclude that lipid is not a determinant of PCB levels in lake trout based on the fact that the subspecies is fattier. I cannot concur with this conclusion for several reasons. Moreover, (1) the regression was PCB versus age rather than lipid content in the sample, (2) data provided in this publication show that there is high variability in a plot of PCB concentration versus age, (3) the regression was performed on data collected over a five year period (and we know that lipid levels and PCB contamination varies from year to year), (4) the subspecies differ in factors other than lipid content, (5) while lipid content in the subspecies tends to be higher, lipid content in this species is so high such that differences in POP concentrations among individuals is probably difficult, and (6) the $R^2$ of the regression of PCB concentration on age was lower in the fattier subspecies indicating that age is less of a determinant factor (probably because of the very high lipid levels). Furthermore, as stated in the above paragraph, dismissing lipid as a determinant of POP contamination in lake trout granted that they are the fattiest and most contaminated fish species in the Great Lakes is illogical and not supported by the body of published research. On an intraspecific basis it is probable that identification of lipid as a determinate of POP contamination in lake trout would be near impossible because of very high lipid content. Stow (1995) examined 20 years (1972 to 1992) of PCB concentration data from five species of Lake Michigan salmonid fish. The samples analyzed in this study were all skin-on fillets from individual fish (no composites). An analysis of variance indicated that year, species, collection location, length, and a length-species interaction term were all significant factors for resolving PCB concentration variability in the Lake Michigan fish. Unfortunately month of collection was not included as a predictor in the final ANOVA, so seasonal variation of PCB concentrations cannot be ruled out. The researcher concluded that lipid content of samples was not a determinant of PCB concentrations because when contaminant concentration was corrected for year, species, length, and collection location, fat content was not significantly correlated with PCB concentration. However, lipid determinations were available for only 450 (26%) of the 1755 samples analyzed for PCBs. The author also indicated that it is possible that a relationship between PCBs and lipid could have been detected if whole-body samples rather than fillets were analyzed because internal organs possibly contain high fat and PCB levels.

Stow et al. (1997) examined data collected from 1984 to 1994 for five species of Lake Michigan salmonids to explore the relationship between PCB concentration and percent lipid. When mean species lipid and PCB concentration were compared a positive strong relationship was observed ($r^2$=0.74). However, within species there was little relationship between lipid and PCB concentration (all five $r^2$s were 0.02 or less). When fish were divided into spawning and non-spawning groups, a significant relationship was detected in spawning, but not non-spawning brown trout (*Salmo trutta*), Chinook salmon (*O. tshawytscha*), coho salmon (*O. kisutch*), and rainbow trout (*O. mysiss*). Lake trout (*Salvelinus namaycush*), with the highest lipid content of all five species, exhibited no discernable PCB:lipid relationship. Again, these authors concluded that lipid is not a major intraspecific determinant of PCB concentration in these salmonids. Lamoureux and Glaser (2003) suggested that POP concentration lipid normalization is much less beneficial for fatty fish. Muscle tissue in all five salmonids analyzed in this study had very high fillet lipid content (up to 25%). Further these salmonids tend to be much more POP contaminated than other species with lower muscle and total body lipid. Thus, concluding that lipid is not an important intraspecific determinant factor of POP concentrations in these species seems incorrect.

Amrhein et al. (1999) measured total PCB concentrations in fillets (skin-on) and whole-fish samples from the same individuals (no compositing). The coho salmon and rainbow trout analyzed were collected in Lake Michigan during the fall of 1992 and 1993. The average whole-fish to fillet PCB concentration ratio was 1.70 for coho salmon and 1.47 for rainbow trout, but varied considerably among individuals, with a few fish exhibiting a higher concentration in the fillet than in the whole-fish sample (not likely to occur in a skin-off fillet). Difference between whole body and fillet PCB concentrations would have been much higher if skin-off fillets would have been analyzed. Classification and regression tree (CART) models indicated that fillet PCB concentration and fish length were the best predictors of whole-fish PCB concentration, whereas fillet and whole-fish lipid concentrations were less important predictors. Lipid normalization of PCB data decreased within individual variability, was equivocal with respect to variability among individuals, and accentuated the between-species differences. It is important to remember that salmonids store lipid in muscle and have some of the highest muscle lipid content of all fishes. Lamoureux and Glaser (2003) contend that lipid normalization is most effective at reducing POP concentration variation when whole body lipid content is approximately 2%. Lipid level in these salmonids is much higher than this. While Amrhein et al. consistently downplay lipid as a determinant there it appeared that whole-body lipid was a significant predictor of whole fish PCB concentrations, but they did not report a significance (P) value. In multiple regressions to assess whole fish PCB concentration fillet, rather than whole body, lipid was used as an independent variable along with fish length. Obviously, whole fish lipid should have been included rather than fillet lipid. In a later publication on PCBs in coho and chinook salmon (analysis of skin-on fillets) from Lake Michigan Stow and colleagues (Jackson et al., 2001) minimize lipid and maximize fish size as a determinant of contaminant concentrations. Manchester-Neesvig (a co-author on the Jackson et al. publication) et al. (2001) also reported on PCBs (muscle sample including skin and bone) in Lake Michigan coho and chinook salmon with the same conclusions—size, but not lipid level, a determinant of PCB concentration. These authors reported a negative (-1.3) slope from a regression of PCB concentration on sample lipid content. In this analysis chinook and coho were pooled, even though the former tends to be larger with higher lipid content.

Seven species of sport fish collected in San Francisco Bay were analyzed for PCBs, DDTs, chlordanes, and dieldrin residues (Davis et al., 2002). All fish were collected between May 27 and July 25, 1997. Contaminant concentrations were measured in muscle tissue composites. For three species (white croaker—*Genyonemus lineatus*; jacksmelt—*Atherinopsis californiensis*; shiner surfperch—*Cymatogaster aggregate*) fillets were skin-on whereas in the other four species the fillets were skin-off. Removal of skin from white croaker fillets reduced lipid content in the composites 27 to 49% and concentrations of OCs 33 to 40%. Lipid content in the white croaker, shiner surfperch, and jacksmelt composites were considerably higher than in the other species composites; this is not surprising given that fish skin tissue is relatively lipid-rich. Concentrations of DDTs, PCBs, and chlordanes were also much higher in these three species compared to the other four species. However, comparison of POP concentrations in skin-on and skin-off composites is not valid. This case illustrates that type of sample (e.g., whole fish or skin-on, skin-off fillets) is important and can have profound effects on results on investigations into POP concentrations as well as determinants thereof. When comparing results of investigations it is imperative to specify the type of fish sample analyzed. For example, in the analysis of temporal trends it would be inappropriate to include different types of samples or to pool different types of samples. Interspecific variation in composite lipid content was significantly correlated with all organic contaminants; intraspecific variation in contaminant concentrations was not significantly correlated with composite lipid content or with mean length of fish constituting the composite. It is very possible that the small sample size in the species with low lipid levels as well as compositing obscured a relationship between OC concentrations and lipid.

PCBs, DDTs, and chlordanes were analyzed in seven species of fish collected in San Francisco Bay in 1994, 1997, and 2000 (Greenfield et al., 2005). This publication includes data in Davis et al., 2002—above paragraph). Analysis was of muscle fillet composites. For three species (white croaker—*Genyonemus lineatus*; jacksmelt—*Atherinopsis californiensis*; shiner surfperch—*Cymatogaster aggregate*) fillets were skin-on whereas n the other four species the fillets were skin-off. Lipid content of samples was highest in the skin-on fillets. For DDT concentrations in shiner surfperch, there was a statistically significant positive effect of mean length of fish constituting the composite (partial $R^2$=0.09). When length effect was accounted for there was no significant relationship between composite lipid content and DDT concentrations. Nonetheless, length was not a robust predictor of DDT concentrations. A significant positive effect of length (partial $R^2$=0.23) and composite lipid content (partial $R^2$=0.40) on DDT concentrations was identified in white croaker. Likewise, a significant positive effect of length (partial $R^2$=0.15) and composite lipid content (partial $R^2$=0.53) on chlordane concentrations were detected in white croaker. These data indicate that the role of lipid and size as predictors of OC concentrations can vary with species and contaminant. However, Davis et al. (2002) reported that removal of skin from white croaker fillets reduced lipid content in the composites 27 to 49% and concentrations of POPs 33 to 40%. In the Greenfield et al. study lipid content in the white croaker and shiner surfperch composites were considerably higher than in the other species composites; this is not surprising given that fish skin tissue is relatively lipid-rich. Concentrations of DDTs, PCBs, and chlordanes were also much higher in the white croaker and shiner surfperch composites compared to the other species. As stated above, interspecific comparison of POP concentrations in skin-on and skin-off composites is invalid.

PCBs were analyzed in white croaker and shiner surfperch collected in San Francisco Bay in 1994, 1997, 2000, and 2003 (Davis et al., 2007). This publication is an extension of the Davis et al. (2002) and Greenfield et al. (2005) publications. Analysis was of skin-on muscle fillet composites (as in Stow, 1995; Stow et al., 1997; Amrhein et al., 1999; Jackson et al., 2001). The median PCB concentrations (ng/g wet weight) in shiner surfperch were fairly equivalent in the four sampling periods; lipid-normalized median PCB concentrations were more variable than wet weight concentrations. Median PCB concentrations (ng/g wet weight) in white croaker also were less variable that lipid-normalized medians, but variations in composite PCB concentrations were greater when expressed per unit wet weight than per unit lipid weight. That the 'lipid-normalized' data were more variable indicate that other variables outweigh lipid as determinants of bioaccumulation in these two species. Yet, it is abundantly clear from the Davis et al. (2002) and Greenfield et al. (2005) publications that POP concentrations in these two species relate to lipid content. Analysis of the role of skin-on fillets and compositing in these results would be of interest.

PCB levels were analyzed in fish collected from the Hackensack Meadowlands of New Jersey section of the Hackensack River (Weis and Ashley, 2007). Skin-off fillets from fish (white perch, brown bullhead, carp, mummichog, and Atlantic silversides) collected from October 2001 through May 2003 was analyzed. The possibility that PCB concentrations and/or lipid varied seasonally and/or year-to-year was not examined. White perch (*Morone americana*) were the most contaminated species with an average concentration around 2000 ng/g wet weight. Tissue lipid-normalized PCB levels were significantly correlated ($r^2$=0.49) with percent lipid; while this documents lipid as a determinant, the researchers did not assess whether lipid was a covariant with another determinant. That the regression resulted in a robust, statistically significant $r^2$ implies that lipid is a covariant of another/other determinants (see summary of Herbert and Keenleyside, 1995, above).

Stow and colleagues (Stow, 1995; Stow et al., 1997; Amrhein et al., 1999; Jackson et al., 2001) contend that in salmonids, including lake trout, lipid content of fillets or whole fish is not the primary intraspecific POP concentration determinant. Other investigations of intraspecific determinants of POP concentration in salmonids, including lake trout, do not support the Stow and colleagues' contention, suggesting that lipid is a robust POP concentration determinant (Rasmussen et al., 1990; Bentzen et al., 1996; Larsson et al., 1996; Vander Zanden and Rasmussen, 1996; Kidd et al., 1998a; Ryan et al., 2005; Persson et al., 2007). It is interesting to note that Stow et al. (1999) provide data that reveal PCB decline rate in lake trout, brown trout, and rainbow trout is inversely proportional to lipid content. That is, decline rate is slowest in lake trout (highest lipid content and longest life span) and highest in rainbow trout. The Stow and associates studies were conducted on Lake Michigan salmonids; while it seems rather remote, the divergence in conclusions of these researchers from those of the other investigators may relate to a different ranking of POP concentration determinants in Lake Michigan salmonids. Contrary to this hypothesis is that lipid is a significant determinant of salmonid POP concentrations in several aquatic ecosystems (studies summarized herein). Stow and collaborators position regards intraspecific determinants of POP concentrations in salmonids only. Salmonids *are* fatty fish. Because of high lipid levels distinguishing POP concentration differences among individuals maybe difficult and it is logical that larger/older fish would accumulate higher POP concentrations over their lifetime. I assert, however, that there were other confounding factors affecting the Stow and associates analyses. That is, the fish analyzed were collected over a ten year period and in different seasons (Stow, 1995; Stow et al., 1997). Both lipid content and POP concentrations *do* vary seasonally and from year-to-year. Further, the fish analyzed were from many sites in Lake Michigan. The literature is replete with studies (several summarized herein) that document highly significant spatial (among sites) variation in POP concentrations as well as in fish lipid content. Furthermore, Miller et al. (1992) and Borgmann and Whittle (1991a) documented that lake trout from different locations in Lake Michigan and Lake Ontario, respectively, manifest significantly different levels of OC pesticide and PCB contamination. Prior to rejecting lipid as an intraspecific determinant of POP levels in Lake Michigan salmonids I contend that individuals from the same year, season, and site must be analyzed for a lipid:POP relationship before pooling. Such an analysis would reduce the number of variables (including exposure level) affecting POP concentrations.

Several research groups have investigated variables that are potential determinants of POP bioaccumulation. As indicated above, complete consensus on the primary determinants has yet to be achieved. Conclusions advanced by the different research groups regarding the relative role of the variables almost certainly relate to different study designs. For example, Stow (1995) and Stow et al. (1997) analyzed skin-on fillets only from salmonid species collected in different seasons over a ten year period. No information was provided on seasonal or year to year variation of lipid levels and PCB concentrations. Skin-on muscle samples also were analyzed in the Amrheim et al. (1999), Jackson et al. (2001), and Manchester-Neesvig et al. (2001) studies. .In the Larsson et al. (1993) study fish were collected in autumn and early spring (collection season as a predictor was not examined) and skin-off fillets were analyzed. Kidd et al. (1998a) analyzed whole fish (two spices), muscle (three species with skin on and one species with skin off) or liver (one species) from a wide range of fish species from various taxonomic families. All fish were collected in summer of 1992 and 1993. Fisk et al. (2001) analyzed whole fish PCB concentrations from one species (artic cod), as well as in multiple food web organisms; all organisms analyzed were collected over a three month period in one year. Analysis was of skin-on fillet composites in the Davis et al. (2007) investigation; they examined year-to-year variation, but not seasonal variation. McIntyre and Beauchamp (2007) analyzed POPs in whole fish (four predator species from different taxonomic families) collected over a 20 months period. In the Burreau et al. (2006) study organisms were collected in the summer and autumn of 1998 and PCB concentrations were determined in whole body samples. In the Weis and Ashley (2007) study muscle tissue (skin-off) from fish collected from October 2001 through May 2003 was analyzed. Whether there was seasonal or year to year variation in tissue PCB concentrations and/or lipid content was not assessed. Fish were collected throughout the year over a 20 month period. Persson et al. (2007) analyzed muscle samples (without skin) from salmon collected during one month in 2004. Seasonal variation in skin-off muscle samples of six fish species collected during July and September 2002, July and December 2003, and April 2004 were examined by Bettinetti et al. (2006). The lack of standardization in these studies renders direct comparison of results impossible. Furthermore, various research groups studied different species that vary markedly in morphology, physiology, and ecological strategies. There is no general model for POP concentration determinants that can be applied to all fish species; this relates to the variation of determinants by species, by ecosystem, and spatially within ecosystems.

As alluded to above, season of fish collection can be a confounding factor in assessing POP concentrations as well as determinants of muscle tissue and perhaps whole body POP levels. DDT concentrations were measured in six fish species (skin-off fillets) collected in Lake Maggiore in northern Italy (Bettinetti et al., 2006). All six species manifested notable (up to 18-fold difference) seasonal variation of DDT concentrations. Greenfield et al. (2005) reported that in white croaker samples collected from San Francisco Bay during 2000 PCB and chlordane wet weight concentrations were significantly higher (3X) in fish caught in autumn compared to those collected in spring. Lipid levels in samples also were lowest in spring, a probable explanation for lower contaminant levels. Thus, season of collection may be an indirect 'determinant' of POP concentrations confounding year-to-year and long-term trend and spatial trend analysis as well as other POP concentration determinants (predictors). In the Greenfield et al. study contaminant concentrations were not normalized to lipid content of composites. Composite lipid was much higher in autumn than in spring and it does appear that lipid-normalizing would have resulted in a much lower difference between spring and autumn.

Fu and Wu (2006) assessed potential seasonal variation of PCB concentrations in fillets of mullet (*Liza macrolepis*) collected during September 2002 and May 2004 from the Er-Jen River, Taiwan. While fillet lipid content was greater in autumn compared to spring, lipid-normalized PCB concentrations were not different in the two seasons. This result is confounded because fish were not only collected in different seasons (wet and dry), but also in different years. If the equivalency of lipid-normalized PCB between spring and fall is 'real', it denotes a steady state between PCBs and lipid within fish bodies. However, several variables would have to be considered including variable exposure levels (PCB concentration in food items), variable feeding rate, inconstant degradation/elimination rate, and shifts in location/distribution of body lipid. Seasonal variation of DDT levels in barbels (*Barbus graellsi*) collected from two rivers in northeastern Spain was reported by Raldua et al. (1997). Muscle samples without skin were analyzed. Mean concentration of DDTs was 57 and 72% higher in the summer compared to spring in the two rivers. This study provides further proof that season of collection is a critical consideration when assessing level of fish POP contamination. Season variation in fillet POP concentrations (as well as lipid levels) could be related to several factors including shifts in feeding rate, alteration in food availability, shifts in composition of food items (including POP levels, that is exposure levels), differences in composition of food items, temperature changes that modify metabolic rate and elimination rate, changes in body lipid content, and shifts in body distribution of POPs. While designing studies to investigate the causes of seasonal would be challenging, the role of one variable (shifts in body distribution of POPs) could be eliminated if whole fish, rather than fillet, analyses were selected.

Lipid content in many fish species varies seasonally and likely affects the assimilation of POPs. Variation in the lipid content of prey items can affect the lipid content of predators, thus influencing their POP assimilation (Borgmann and Whittle, 1991b; Madenjian et al., 2000). Lipid concentrations (whole fish composites) were measured in seven fish species from several locations in Lake Michigan during different seasons in 1994 and 1995 (Madenjian et al., 2000). Lipid cycles differed among species. In alewife

(*Alosa pseudoharengus*) lipid levels were lowest in summer and highest in autumn (4.7X difference). In two year old coho salmon lipid content was lowest in the spring and highest in the summer (4X difference). Lipid content of bloater (*Coregonus hoyi*) did not change significantly with season. In six of the seven species lipid levels increased with size (age).

Stapleton et al. (2002) examined seasonal dynamics of PCB and toxaphene bioaccumulation within a Lake Michigan food web. PCB and toxaphene concentrations were measured in bulk zooplankton, mysid shrimp, benthic amphipods, alewife (*Alosa pseudoharengus*) and bloater chub (*Coregonus hoyi*) collected from Grand Traverse Bay, Lake Michigan between April and September of 1997 and 1998. This is an important contribution because collection was over a relatively short time span and from one location (eliminating the spatial variation confounding factor). Concentrations of PCBs in the dissolved phase (water column) were consistent over time. Nonetheless, seasonal changes in contaminant concentrations within the biota were significant. Seasonal changes were most pronounced in zooplankton, which displayed highest PCB burdens in April and decreased by as much as 75% through September, coincident changes in phytoplankton biomass, species composition, and changes in the particulate pools of PCBs in the water column. Mysids displayed a similar PCB trend as zooplankton, while PCBs in benthic amphipods were highest in late summer. PCB trends in the two primary forage fish (alewife and chub) were correlated more to shifts in lipid content and seasonal diet preferences. Alewife contaminant burdens were high in spring and fall of both years, decreasing by as much as 60% in mid-summer; these changes were reflective of variation in their lipid content associated with gamete production and spawning. These results suggest that accumulation by biota on seasonal scales is determined appreciably by growth and lipid dynamics, foraging behavior, and particulate matter PCB concentrations (highest in the spring and lowest in late summer). Although a critical component of the Stapelton et al. investigation, seasonal changes in POP burdens in aquatic food webs are rarely performed due to the costly extensive sampling and analyses required. Nonetheless, I find their publication to be one of the most important and informative discovered in my literature review.

Comparing and correlating POP concentrations among species can be difficult because of differences in lipid storage areas and tissues selected for analysis. For example, burbot (*Lota lota*) have low muscle lipid levels (around 0.3%) and store lipid in the liver; POP concentrations in muscle of this species can be 400 to 700 times lower than in liver (Kidd et al., 1995). Assessment of POP bioaccumulation determinants, as well as comparison among studies, can be confounded by the type of sample analyzed. Significant differences occur between POP concentrations in fish muscle tissue and in whole-body (e.g., Oliver and Nimi, 1988; Nimi and Oliver, 1989). POP concentrations are typically, but not always, higher in whole-body samples. For example, in salmonids muscle lipid content is high; Isosaari et al. (2004) reported only a 4% difference in Atlantic salmon fillet and whole body lipid content. PCB concentration in fillets was 20% lower than in whole body.

Fillet analysis is appropriate for human health studies. Whole fish analysis more appropriate for wildlife impacts analyses and for site contamination determinations. Whole body concentrations of POPs also are probably better indicators of biomagnifications because that would reduce interspecies variation in lipid storage tissues and concentrations of POPs. The type of fillet analyzed, skin on or off can also complicate comparison among studies. Davis et al. (2002) reported that removal of skin from white croaker fillets reduced lipid content in the composites 27 to 49% and concentrations of POPs 33 to 40%.

Identification of bioaccumulation determinants and construction of a general model has been confounded by studies on different fish species. That species diverge with respect to bioaccumulation determinants is not really unexpected granted the marked species differences in morphology, physiology, and ecology.

Also confounding assessment of fish contaminant bioaccumulation and biomagnification determinants is collection of fish species from multiple locations (as in the current study) such that exposure level and/or time could be different. However, it is not only exposure level at different sites that render multiple sampling sites a confounding factor. Many other variables can differ among sites including food abundance and type, feeding rates, trophic level of species of interest, temperature, metabolic rate, fat content, age, size, growth rate, etc. These same variables can confound identification of unacceptably contaminated (high exposure) sites and temporal trend analyses.

Analysis of composite samples can confound assessment of bioassessment determinants, identification of unacceptably contaminated (high exposure) sites, and temporal trend analyses. Composites are a mean of POP concentration, fish size/length, and lipid content; consequently they can be distorted by extremely high or low values. Using the median of composites is probably not adequate to correct the composite analysis problem. Composites from species that have low lipid content (especially in muscle tissue) could misrepresent a relationship between OC concentrations and lipid content, particularly if exposure levels are low. One or even two same species composites from a site may not portray accurately variation of POP contamination at that location. Knowledge of site variation is critical for accurate determination of site contamination as well as spatial and temporal differences in level of contamination. Composites are frequently selected because of budgetary constraints; analysis of multiple fish of a given species and multiple species at many sites is costly. As always, such shortcuts sacrifice accuracy and certainty of data obtained. My review of the literature confirms that analysis of individual fillets or individual whole fish yields data that are more variable than results from composites. Thus, whether one is prepared to deal with variable data is a decision that has to be rendered.

Table 49 summarizes proposed determinants of POP bioaccumulation in fish gleaned from my literature review.

**Temporal variation**

A review of the literature reveals that several factors confound temporal trend analyses of OC pesticides and PCBs and, particularly, predictions of future rates of decline. Confounding factors include, but are not limited to (1) differences in analytical methods and detection limits, (2) differences in samples analyzed (e.g. whole fish or muscle fillet—skin-on or skin-off), (3) paucity of data and small sample size (multiple fish or multiple composites of key species at a large number of sites), (4) pooling of data from different stations/sites (spatial variation can be considerable) and failure to sample at the same sites repeatedly through the years, (5) seasonal variation (contaminant concentrations, lipid content, physiological and ecological cycles), (6) lack of consistency in terms of fish size, age, gender, etc., (7) analysis of composites rather than individual fish, and failure to assess 'other' determinants' of contaminant concentrations (see section on determinants of bioaccumulation and biomagnification). The several biases introduced by the use of composites into statistical analyses and interpretation of fish population POP contamination is effectively described by Stow et al. 1995). Among these is a concealing of fish population contamination variance. Because composite POP concentration is a mean, reporting the median of composites at a site is not likely to provide an accurate estimate of population central tendency.

Assessing temporal trends is difficult when the same sites and same species are not sampled yearly as well as when the number of samples analyzed in inadequate for robust statistical analyses. Spatial and temporal variation in OC pesticide and PCB fish contamination are realities. Thus, sampling numerous (same) sites, the same species per site, and 'replicate' composites per site on a yearly or every other year basis is essential for accurate temporal trend analysis as well as for predicting future changes in fish contamination. While fish sampling for OC/PCB contamination in the Sacramento River watershed has been more extensive than in the San Joaquin River watershed and Delta, all of the above problems plague temporal trend analyses of fish contamination in Central Valley waterways. Clearly there was and is no consistent strategy or plan for addressing this issue. Davis (2008) observed that one of the major shortcomings of the historic database on bioaccumulation in California sport fish is the lack of long-term series and conclusive information on trends.

Contaminant concentrations in composites of white catfish collected in waterways of California's Central Valley were plotted as a function of year (1970 through 2000) by Greenfield and colleagues (2004). Area-wide declines of DDTs, chlordanes, dieldrin and PCBs were observed. Where sufficient data were available declines occurred at most individual sampling stations; most exceptions were at stations where OC pesticide and PCB fish contamination was low in the 80s and 90s. Their analysis revealed that OC pesticide and PCB contamination of fish in Central Valley declined rapidly in the 1970s to the mid-1980s, but the rate of decrease slowed in the 1990s such that statistical differences could not be detected among years. Inability to detect statistically significant decreases almost certainly relates to the small number of sites, samples, and duplicates. Given that the rapid decline in the 1970s and early-1980s has been documented, my focus is on the period 1990 through 2005. Thus, I examined the SFEI database for fillet composites of Sacramento sucker, white catfish, channel catfish, and carp collected in that period. For the San Joaquin River watershed and Delta only 18 composites (excluding those in the current study) of these species were available for this 15 year period, 16 of white catfish plus one each of channel catfish and carp. All these composites were from fish collected in 1998 except one of Sacramento sucker (from Stanislaus River) and one of white catfish (from Salt Slough) taken in 1990. For the entire Sacramento River watershed there were a total of 46 composites analyzed for OC pesticides and PCBs for the period of 1990 through 2004. There were 22, 16, three, and five composites of white catfish, Sacramento sucker, channel catfish, and carp, respectively. The number of composites by year was:

| | | | |
|---|---|---|---|
| 1990 | 2 | 1992 | 1 |
| 1993 | 2 | 1997 | 6 |
| 1998 | 4 | 1999 | 10 |
| 2000 | 12 | 2001 | 6 |
| 2003 | 3 | | |

There are too few composites of the same species, especially from the same sites, over this 14 year period to perform even a simple statistical analysis.

PCBs

Mean PCB concentrations in composites of white catfish collected from the San Joaquin River watershed and Delta during 1998 (n=14) and 2005 (n=32) were compared in a t-test. Means for 1998 and 2005 were 32 and 5 ng/g, (84% decrease) respectively, and significantly different ($P<0.002$). PCB geometric means for 1998 and 2005 were 21 and 4 ng/g (81% decrease), respectively, and highly significantly different ($P=0.0005$). The 2005 data signify that throughout most of the San Joaquin River watershed and Delta PCB exposure levels (PCB concentration in food items) are near and below the analytical reporting level (remembering that there is biomagnification up the food chain) and that a majority of fish (with the exception of some old, fatty fish) do not contain PCB concentrations of concern to human health.

Temporal analysis of PCBs in composites of fish collected in the Sacramento River watershed is difficult, not only because there are so few in years between 1990 and 2004, but also because of notable composite lipid content variation among the years. There are five composites (three carp, one white catfish, and one channel catfish) representing of fish collected from Colusa Basin Drain representing three years in the 14 year period. Since 1998 PCB fish contamination at CBD has been near or below reporting level. For the 14 year period there are 11 composites (nine white catfish and two Sacramento sucker) of fish collected from the Sacramento River @ RM44; seven of the 14 years are represented by these composites. In this dataset variation in composite lipid content among the years renders generalizations impossible. The ∑PCBs in seven of eight composites of fish collected at this site from 1998 through 2002 is above 20 ng/g (OEHHA screening value). PCB concentration in Sacramento sucker, coho salmon, and largemouth bass taken at this site during 2005 is15 ng/g and below reporting level in the other two, respectively. There are eight Sacramento sucker composites from fish collected from the lower American River representing four years of the 14 year period. These data do not provide a clear temporal trend, but the PCB concentration (44 ng/g) in a composite of Sacramento sucker collected during 2005 is lower than in five composites (range=55 to 288 ng/g)of this species taken in 2001 and 2002. The ∑PCBs in three of largemouth bass, one of Sacramento sucker, and one of white composites from fish caught at this site during 2005 is below the reporting level in all five composites. Mean concentration in composites (n=17) of Sacramento sucker collected in the Sacramento River watershed during 2005 was 9 ng/g. While the 2005 mean is significantly lower than the 2002 mean (135 ng/g) interpretation is difficult because only three composites were analyzed in 2002 and the notable divergence of PCB concentration in 'duplicate' composites from the same site. In 76% of the 46 composites of fish collected in the Sacramento River watershed during 2005 the ∑PCBs is below the detection limit or below the reporting level. In only six of 46 composites from fish collected at five sites are PCB levels above the OEHHA screening level. Although the historic data from the Sacramento River watershed do not provide any clear-cut patterns such that a rate (or rates) of decline can be derived for predicting future fish PCB contamination, data do indicate that in most species throughout the watershed concentrations are below or approaching reporting level; the exception is in large/old, fatty individuals of two to three species.

Chlordanes

Chlordane was below reporting level in 83 % of 92 composites from fish collected from the San Joaquin River watershed and Delta. There are five sites in the San Joaquin River watershed and Delta that provided white catfish composites in both 1998 and 2005. In 1998 chlordane concentrations at these sites ranged from 1 to 16 ng/g; the ∑chlordanes in all composites from 2005 was below reporting level. So, even though chlordane fish tissue concentrations were low in 1998, they continued to decline through 2005. Moreover, chlordane contamination of fish tissue is not a prominent issue in the San Joaquin River watershed and Delta.

Moving to the Sacramento River watershed, there are five composites (three carp, one white catfish, and one channel catfish) representing of fish collected from Colusa Basin Drain representing three years in the 14 year period (1990-2004). Since 1998 no composite of fish from this site has a chlordane concentration greater than 2 ng/g. Chlordane was not detected in composites of carp and white catfish collected at CBD during 2005. For the 14 year period there are 11 composites (nine white catfish and two Sacramento sucker) of fish collected from the Sacramento River @ RM44; seven of the 14 years are represented by these composites. Except for one year's composite chlordane concentration has been near or below reporting level since 1999 at the RM44 site. In the 2005 dataset composites of Sacramento sucker, coho salmon, and largemouth bass were available for this site; the ∑chlordanes concentration in these composites was below reporting level, not detected, and 2 ng/g, respectively. There are eight Sacramento sucker composites from fish collected from the lower American River representing four years of the 14 year period. Fish chlordane contamination in the lower American River appears to be near or below reporting level since 1999. The ∑chlordanes in three composites of largemouth bass, one of Sacramento sucker, and one of white catfish from fish caught at this site during 2005 is below the reporting level in all five composites. In 83% of the 46 composites of fish collected in the Sacramento River watershed during 2005 chlordanes were not detected or below the reporting level; the highest concentration observed was 7 ng/g.  As in the San Joaquin River watershed and Delta, chlordane contamination of fish tissue is not a prominent issue in the Sacramento River watershed.

Dieldrin

Temporal trend analyses for dieldrin are complicated by modification of detection and reporting levels between 1990 and 2005.  Nonetheless, the 2005 data suggest that dieldrin fish contamination decreased considerably between 1998 and 2005.  The highest dieldrin concentrations in composites of white catfish collected from the San Joaquin River watershed and Delta in 1998 were 38 and 13 ng/g, higher than any (highest=1.9 ng.g) of the 2005 white catfish 92 composites.  In 90% of the 92 composites of fish collected from the San Joaquin River watershed and Delta during 2005 dieldrin concentration was below the 1999 OEHHA screening value.

There are five composites (three carp, one white catfish, and one channel catfish) of fish collected from Colusa Basin Drain representing three years in the 14 year period (1990-2004).  A large decline (95 %) in carp dieldrin contamination occurred between 1998 and 2005.  In composites of carp and white catfish taken at this site during 2005 dieldrin levels was 1.1 and 1.0 ng/g,  respectively (below the 1999 OEHHA screening value). Dieldrin concentration was not detected or below reporting level in 63% of the 46 composites from fish caught in the Sacramento River watershed during 2005.  The mean dieldrin concentration in 17 composites (6 non-detects and 8<RL) of Sacramento sucker caught during 2005 was 0.4 ng/g; the highest concentration of dieldrin in a Sacramento sucker composite from 2005 was 1.7ng/g.  Overall, but especially the 2005 data, suggest that dieldrin white catfish and Sacramento sucker contamination in the Sacramento River watershed is below or near reporting level.  However, channel catfish caught in the watershed have higher levels (but less than 4 ng/g) of dieldrin contamination.  All 92 composites were below the 2006 OEHHA recommended screening level of 16 ng/g.

DDTs

DDT concentrations in composites of white catfish collected from the San Joaquin River watershed and Delta during 1998 and 2005 were compared in a t-test.  Means for 1998 and 2005 were 186 and 29 ng/g, respectively, and significantly different ($P<0.001$).  DDT geometric means for 1998 and 2005 were117 and 17 ng/g, respectively, and highly significantly different ($P<0.00001$).  DDT medians for 1998 and 2005 were 157 and 14 ng/g, respectively.  The decrease in DDT mean and geometric mean concentration between 1998 and 2005 was 84 and 88% respectively; decline of median concentration was 90%.  If decline was relatively constant between 1998 and 2005 the rate would be approximately 12-13% per year.  At these rates of decline, average DDT residues in white catfish in the San Joaquin River watershed and Delta would not fall below 5 ng/g until approximately 2025.  Of the 92 composites of fish collected in the San Joaquin River watershed and Delta during 2005 the ∑DDTs in 90 and 65% were below the 1999

OEHHA screening value (100 ng/g) and below 25 ng/g, respectively. All 92 composites were considerably below the 2006 OEHHA recommended DDT screening value (560 ng/g.

Turning to the Sacramento River watershed, there are five composites (three carp, one white catfish, and one channel catfish) representing of fish collected from Colusa Basin Drain representing three years in the 14 year period (1990-2004). From 1998 to 2005 DDT carp contamination at CBD decreased 90%. In a least-squares regression of log carp DDT concentrations versus year $R^2$=0.93. However, this is not statistically significant (P=0.17) because of the low sample size (4). Nonetheless, if the decrease rate (slope of the regression) remains the same, CBD carp muscle DDT residues will not be 5 ng/g or below for approximately 55 years. For the 14 year period there are 11 composites (nine white catfish and two Sacramento sucker) of fish collected from the Sacramento River @ RM44; seven of the 14 years are represented by these composites. Year-to-year variation in composite lipid content seriously confounds temporal trend analyses. Nonetheless, between 1992 and 2000 DDT contamination at this site declined 74%. In a least-squares regression of log carp DDT concentrations versus year $R^2$=0.66 (P=0.048). If the decrease rate remains the same, white catfish muscle DDT residues will not be 5 ng/g or below for approximately 35 years. There are eight Sacramento sucker composites from fish collected from the lower American River representing four years of the 14 year period (1990-2004). No composite (n=13) of fish collected from the lower American River between 1997 through 2005 contained DDTs above 68 ng/g. DDTs in six of seven composites of Sacramento sucker collected at this site 1999 through 2002 were 55 ng/g or less. Year-to-year variation in composite lipid content of these composites also baffles effective temporal trend analyses. When lipid-normalized, DDT contamination of Sacramento sucker in 1999, 2002, and 2005 was equivalent. Between 1997 and 2005 white catfish DDT contamination in this portion of the river declined 85%. The ∑DDTs in 83% of the 46 composites from fish caught in the Sacramento River watershed during 2005 was below 50 ng/g. Only 4% of the composites were above the 1999 OEHHA screening level.

### Temporal Trends in Other Aquatic Ecosystems

Schmitt et al. (2005) analyzed whole body composites from fish collected in late 1997 and early 1998 at ten stations in the Rio Grande River basin for OC pesticides and PCBs. A summary of study results can be found in above (in section titled Comparison to other California waterways and river systems in the US) of the Discussion of this report. These authors also provided information on the temporal changes in DDE residues in fish collected from the Rio Grande River basin. The DDE geometric mean of composites of carp collected from a station on the lower Rio Grande in 1981 was 440 ng/g (wet weight) and 390 ng/g in 1997; these means are not significantly different. DDE geomentric means for largemouth bass collected from this station in 1980, 1984, and 1986 range from 2090 to 2730 ng/g; the geometric mean of the composite of this species caught at this site in 1997 was 380 ng/g. The means from the 80s were all significantly higher compared to the 1997 value (an 86% reduction in DDE concentration in 11 years). The DDE geometric means of composites of carp collected from a station on the upper Rio Grande in 1972 through 1980 ranged from 40 to 110 ng/g and were not significantly different in any of the five years; DDE means of carp composites collected at this station in 1984 through 1997 ranged from 10 to 20 ng/g and were not significantly different. Thus, DDE level at this site in composites from 1984 through 1997 were significantly lower than in composites from 1972 through 1980. However, there was no further decrease in DDE in fish from this upper Rio Grande site between 1984 and 1997. An equivalent pattern was observed in composites from largemouth bass. That is, DDE levels decreased significantly from 30 to 230 ng/g during 1970-1980 to around 10 ng/g in 1984. The mean in the 1997 composites was less than 10 ng/g. These data suggest that once concentrations of DDE reduce to 10 to 20 ng/g, further reduction may require a decade or more.

PCBs, DDTs, and chlordanes were analyzed in seven species of fish collected in San Francisco Bay in 1994, 1997, and 2000 (Greenfield et al., 2005). ANOVA indicated that concentrations of PCBs, DDTs, and chlordanes varied significantly among years in white croaker, shiner surfperch, and striped bass, but not leopard shark. Of the four species only striped bass showed a decline in PCB concentration from 1994 to 2000. DDT concentration in striped bass, but not the three other species, was higher in the 1994 than in 1997 and 2000. Chlordane concentrations in white croaker and striped bass, but not the other two species, declined significantly in 2000 compared to 1994 and 1997. Interannual variations often correlated to changes in fish size and lipid content, confounding the interpretation of year-to-year differences and temporal trends. Significant changes in lipid content of white croaker and shiner surfperch occurred over the 1994 through 2000 period; interannual differences of DDT and chlordane concentrations likely related to the lipid variations. Regression analysis of contaminant concentrations as a function of year (1984 through 2000) showed a statistically significant negative relationship only for DDTs in sturgeon (not the other three species). When contaminant data were ‘lipid-corrected’, no statistically significant relationships were noted for DDTs, chlordanes, or PCBs. The authors observe that their data indicate that there has been little or no significant decline in fish contaminants in San Francisco Bay over the last three decades. These data are inconsistent with many other studies of long-term trends of OCs and PCBs summarized in this section. This possibly relates to the fact that whole fish (without compositing) were analyzed in many of the other studies. Furthermore, sample size in the Greenfield et al. study was low compared to many of the other investigations. As a continuation of the temporal trends in San Francisco Bay reported by Greenfield et al. (2005), Connor et al. (2007) add on (to the 1994 through 2000 results) white croaker, shiner surfperch, striped bass, and leopard shark data collected during 2003. In this publication, however, the ∑DDTs and ∑chlordanes are reported lipid normalized. Concentrations of DDTs in composites collected from white croaker and leopard shark during 2003 were significantly lower than in the three other (1994, 1997, 2000) sampling years. DDT levels in composites of shiner surfperch collected in 2000 and 2003 were not different from one another, but both were significantly than in composites from 1997 and 1994. No significant DDT concentration differences were detected in composites of striped bass collected during the four sampling periods. Chlordane levels in composites of striped bass as well as leopard shark collected in 2000 and 2003 were not different from one another, but both were significantly than in composites from 1997 and 1994. Chlordane concentrations in composites collected from white croaker during 2003 were significantly lower than in the three other (1994, 1997, 2000) sampling years. No significant chlordane concentration differences were detected in composites of shiner surfperch collected during the four sampling periods.

PCB contamination, including temporal trends, of fish from San Francisco Bay was probed by Davis and colleagues (2007). Skin-on fillets of shiner surfperch and white croaker collected in 1994, 1997, 2000, and 2003 were analyzed. PCB concentrations in shiner surfperch showed no clear pattern of decline over the nine year period; expressed on a wet weight basis, medians were nearly identical in 1997, 2000, and 2003. Lipid normalized PCB concentrations (probably a superior index of PCB contamination in the Bay), medians were highest in 1994 and 2003 and exhibited considerable year-to-year variation. PCB concentrations in white croaker also failed to reveal a clear pattern of decline from 1994 through 2003. On a wet weight basis, median concentrations were consistent, ranging from 190 to 220 ng/g wet weight; lipid normalized median concentrations were more variable. These results suggest that PCB contamination of San Francisco Bay fish is greater than in fish from Central Valley water bodies and Delta, but direct comparison because skin-on fillets were analyzed in that study whereas in skin-off fillets in the current study.

Total PCB temporal trends in Lake Eerie walleye (*Stizostedion vitreum*) from 1977 through 2001 were reported by Whittle et al. (2003). Analyses were of whole fish. In 1977 through 1979 mean PCB concentrations were between 2000 and 3000 ng/g wet weight. Since 1980 mean concentrations have tended to be less that 2000 ng/g, but have been highly variable. Since 1994 mean concentrations have been less than 1500 ng/g (with three years less than 1000), yet high year-to-year variation continues to be seen. Furthermore, means less than 1000 ng/g occurred in 1994 and 1999.

The Great Lakes Strategy 2002 established a long-term goal that all Great Lakes fish should be safe to eat without restriction. As an indicator of progress toward that goal, the Strategy specified that lake trout PCBs should decline 25% from 2000 to 2007. PCB concentrations in five species of Lake Michigan salmonids decreased rapidly from 1978 to the early 1980s, but remained rather constant from the mid-1980s through 2000. In skin-on fillets from Lake trout (long life span and very fatty species) PCB concentrations ranged from 1000 to 6000 ng/g wet weight in 2000. Stow et al. (2004) estimated the plausibility of achieving Strategy 2002 goal by examining a time-series of Lake Michigan lake trout PCB from 1972 to 2000. They applied two different Bayesian approaches, Bayesian model averaging (BMA) and dynamic linear models (DLM), to model the trajectory of historical data and forecast concentrations through 2007. Both approaches indicated that the probability of a 25% reduction by 2007 was negligible. The most likely lake trout PCB declines predicted by the BMA and DLM were 6.8 and 8.9%, respectively. Both the BMA and DLM provided evidence that near-term PCB declines will be small. In a classical statistical context neither the percent reduction predicted by the BMA or the most current growth parameter estimate of the DLM would be considered significantly different from zero. The authors cautioned that rate of decline will be difficult without adequate data collection. They contend that at the 2003 sampling rate, it is difficult to statistically discern further decline in PCB contamination. In an earlier analysis Stow et al. (1995) pointed out that 1000 to 2000 individual fish (*not* composites) per species would have to be analyzed to detect PCB concentration changes at reasonable total error (sum of type 1 and type 2 statistical errors) rates. They assert that compositing results in considerable information loss and that documenting the sources of individual variability is particularly useful for updating fish consumption advisories as well as documenting hotspots. They advise consideration of incorporating a suite of indicators, including species that are relatively short-lived and thus more likely to reveal current short-term PCB contamination changes.

A regression model was used to determine temporal trends and effects of sampling site, age, and weight on DDE, PCB, dieldrin, and chlordane concentrations in lake trout (*Salvelinus namaycush*) from Lake Ontario from 1977 through 1988 (Borgmann and Whittle, 1991b). Whole fish were analyzed for contaminants concentrations. DDE concentrations decreased rapidly from 1997 to 1980, but then remained relatively constant through 1988. PCB concentrations declined from 1977 to 1981, increased in 1982 and 1984, and decreased again in 1985, but did not decline further through 1988. Dieldrin concentrations decreased from 1978 through 1988, but chlordane levels remained relatively constant over the 1977 through 1988 period. PCB contamination trends closely related to alewife (principal food) population growth rate, suggesting that food web interactions play an important role in determining lake trout body burdens. All contaminant concentrations augmented with increasing age and body size, but the body size effect was less within an age class than across age classes. Lipid levels in lake trout increase dramatically with increasing age and body size. Consequently, lipid normalized contaminant concentrations within an age class decrease with increasing body size. Lipid as a determinant of PCB contamination was not pursued. The authors comment that since body size and lipid levels co-vary strongly, it is not wise to include both as independent terms in the same regression model. From my perspective, lipid cannot be dismissed as an important determinant POP contamination in this species and there are statistical procedures that allow for multiple independent variables. Lake trout are one of the fattiest, if not the most, fish species in the Great Lakes and also the most POP contaminated. Thus, it is illogical to assume that lipid is not an important determinant of contamination.

Mean PCB concentration in Lake Michigan lake trout (whole fish composites) increased from 13,000 ng/g (wet weight) in 1972 to 23,000 ng/g in 1974, then declined to 2,600 ng/g by 1986 (De Vault et al., 1996). Between 1986 and 1992 there was little change in PCB contamination, with a mean of 3,500 ng/g in 1992. DDT contamination of lake trout followed a similar trend. PCB loss rates were similar, being 10 (1977-90), 9 (1978-92), 12 (1974-1992), and 10 (1982-92)%/year in Lakes Superior, Huron, Michigan, and Ontario, respectively. DDT loss rates were 16 (1977-90), 13 (1978-92), 13 (1970-92), and 9 (1982-92)%/year in Lakes Superior, Huron, Michigan, and Ontario, respectively.

Hickey et al. (2006) investigated temporal trends of chlorinated contaminants (including PCBs, DDTs, chlordanes, and dieldrin) in a top predator (lake trout) collected in the Great Lakes from 1970 through 1998. Their analyses were based on OC concentrations in whole fish. Trends depended on contaminant and the lake. While there were notable declines in the 70s through 80s, the rate of declines decreased in the 90s. For PCBs, chlordanes, and dieldrin, mean concentrations remained equivalent from 1994 through 1998. Mean total DDT concentrations were equivalent from 1991 through 1998. The authors concluded that concentrations of these OCs are gradually approaching an irreducible level. During this asymptote phase year-to-year variation in contaminant concentration was, in several cases, large; the variation was attributed to food web dynamics. Direct comparison of the Great Lakes temporal trend data to the current study is difficult because whole fish OC concentrations were reported. Consequently, concentrations were considerably higher than in the fillet samples reported herein and 1998 means ranged (among the lakes) 392 to 1821 ng/g (wet weight), 177 to 1137 ng/g, 108 to 141 ng/g, and 28 to 50 ng/g for PCBs, DDTs, chlordanes, and dieldrin, respectively.

French et al. (2006) examined temporal trends of PCB (∑congeners) and p,p'-DDT (not ∑DDTs) contamination of chinook (1983-2003) and coho (1976) salmon from Lake Ontario. Analyses were of skin-off muscle samples. Total PCB concentrations decreased from maxima of 4217$\pm$1674 ng/g wet weight (mean$\pm$sd) in 1976-77 (coho) and 4139$\pm$1188 ng/g in 1983-84 (chinook) to minima of 324$\pm$110 ng/g (coho) and 432$\pm$101 ng/g (chinook) in 2002-03 (90-94% decrease). p,p'-DDT (DDE is the most stable DDT metabolite and highest in quantity in fish tissue) in coho decreased from a maximum of 158$\pm$86 ng/g in 1976-77 to a minimum of 5$\pm$0 in 2002-03 (97% decrease) with those in chinook decreasing from 91$\pm$47 ng/g in 1983-84 to 9$\pm$2 in 2002-03 (90% decrease). $R^2$ for regressions of contaminant concentration versus year for PCBs were 0.60 and 0.68 and for p,p'-DDT were 0.61 and 0.62 for coho and chinook, respectively; all were highly statistically significant. Examination of the temporal trend plots revealed up and down oscillations. Statistical analyses linked these concentration oscillations with salmonid stocking and nutrient abatement programs, climatic cycles, and alewife (a preferred prey of the two salmon) population dynamics. These findings further document that predictions of future temporal chances in OC fish contamination can be affected by a host of factors.

'Other' studies confirm the temporal trend of PCB and OC pesticide contamination of Great Lakes fish species rapid decline in the late 70s to the mid-80s and then low (asymptotic) decline from mid-80s through the early 2000s: Huestis et al. 1996; Stow et al. 1995; Lamon et al. 1999; Heidtke et al. 2006.

OC (DDTs, chlordanes, and PCBs) concentrations in lake trout (*Salveninus namaycush*) and burbot (*Lota lota*) from three Yukon lakes (Laberge, Kusawa, and Quiet) over a span of 11 (1992 through 2003) years (Ryan et al., 2005). OC analyses were on lake trout muscle samples and burbot liver samples. Concentrations of DDTs (27-61 ng/g), chlordanes (3-7 ng/g), and PCBs (32-49 ng/g) in lake trout collected in 2002 are more equivalent to those observed in fish tissues in the current study than in most other investigations summarized herein. Temporal and spatial differences in tissue OC concentrations among the lakes were documented. Robust evidence that contaminant concentrations were declining at different rates was afforded. The decline of ∑DDTs in

Laberge, Kusawa, and Quiet was 84, 39, and 85%, respectively. The decline of ∑chlordanes in Laberge, Kusawa, and Quiet was 84, 82, and 79%, respectively. The decline of ∑PCBs in Laberge, Kusawa, and Quiet was 75%, 62%, 69%, respectively. Lipid content and log weight accounted for a majority of the variability in OC concentratins in lake trout from from Kusawa and Laberge. No consistent temporal trends were observed in OC concentrations in burbot liver samples; in some cases there were increases, while in other cases there were declines or no changes. The differences in both temporal and spatial trends related to a variety of factors, especially the species morphological and physiological characteristics such as age, weight, and lipid content. The authors propose that biotic rather than atmospheric inputs are the primary factors affecting contaminant concentrations in lake trout and burbot in these lakes. This is an important point. That is, to estimate future OC contamination decline rates it is crucial, as asserted over ten years ago (Larsson et al., 1993), to assess species biological and ecological characteristics (rate of growth, age, size, lipid content, etc.). Moreover, temporal and spatial changes in fish OC levels cannot be easily or directly predicted from atmospheric values or geographic location because a variety of factors influence OC concentrations; temporal variation in these determinants will affect prediction of rates of decline (see section on determinants of OC concentrations).

Temporal declines of DDTs and PCBs in muscle tissue (no indication of skin on or off) of herring (*Clupea harengus*) collected in the southern Baltic Sea during the period of 1972 through 2002 was reported by Sapota (2006). In the early 70s mean DDT concentrations in herring muscle was approximately 25 ng/g wet weight. Mean DDT concentration since 1996 and since 1994 has been <5 ng/g and <2.5 ng/g, respectively. Peak mean PCB concentration in herring muscle in the early 70s was approximately 17 ng/g. By the early 90s mean PCB levels were <5ng/g and since 1999 have been less than 2 ng/g.

Temporal trends (1985 through 2002) of PCB and OC pesticide concentrations in Baltic Sea herring were also investigated by Pikkarainen and Parmante (2006). Contaminant analyses were performed on skin-off fillet composites. During the period 1985-2002 the sum of seven PCBs in two-year old female herring decreased from 9-16 to 2-6 ng/g wet weight and the sum of DDTs from 8-15 to 1-5 ng/g. In 2002 the sums of PCBs and DDTs in composites of two-year old herring ranged from 2.6 to 6.3 ng/g and 1.4 to 4.5 ng/g, respectively. Lipid normalization of contaminant concentrations did not decrease data variability, probably because contaminate concentrations were so low. The greatest declines appeared after 1997-1998 (60 to 70%). Very similar trends were seen in fish collected at five different locations in the Baltic.

Multi-year PCB monitoring data for abiotic media and biota from the Baltic Sea were compiled into a database and analyzed using the equilibrium lipid partitioning (ELP—Webster et al., 1999) approach to study temporal trends between 1987 and 2001 (Nfon and Cousins, 2006). No information was presented on whether whole fish or fillets were analyzed. The ILP approach was devised to overcome the difficulty involved in interpreting data expressed in a diversity of units in different media. In this approach contaminant levels are expressed in terms of the concentration that would exist in lipid at equilibrium with the monitored medium. Available datasets for fish species revealed a declining trend in PCB concentrations in adult herring, juvenile herring, adult cod and salmon. However, statistically significant declines were noted for PCB 28 and 180 only and in adult and juvenile herring only. Estimated clearance half-lives for fish ranged from 4.2 to 10.7 years and were highly congener specific. These authors offered some interesting observations and recommendations. They noted that despite the large effort and costs invested into PCB monitoring, it was not possible to obtain statistically significant time trends and identified several possible causes for such difficulties: (1) PCBs have long half-lives making changes in concentration over time difficult to detect, (2) pooling data from different labs which use different sampling/analytical techniques that probably increase data variability, (3) analytical techniques have improved considerably over the last 30 years thus some data in databases may be compromised, and (4) pooling data from different geographical locations likely increases variability. Worthy of contemplation for application in California is their recommendation that given the long-term decline in PCB levels in the Baltic and other regions, it would seem appropriate to divert funds from long-term monitoring of PCBs and into funding monitoring of other POPs whose concentrations are currently increasing (e.g. perfluorinated organics and brominated flame retardants).

Decline rates of OC pesticides and PCBs are summarized in Table 50. Rates range from less than 1% to 16%/year. Caution should be applied when comparing thee rates because many factors affect these estimations, including priod included in calculations, nature of sample, species, how contaminant concentration is expressed, and sampling location. In general decline rate is slower in fatty fish and in the late 1990s and 2000s.The decline rate of DDTs in white catfish collected in the San Joaquin River watershed and Delta between 1998 and 2005 is 12 to 13%/year. This estimate is consistent, albeit toward the high end, with the rates summarized in Table 50.

*Temporal Trend Models*

By the mid-1980s Great Lakes, as indicated above, OC pesticide and PCB fish contamination declines had slowed to a rate more than predicted by a first-order model, and it appeared that contaminant levels were in or approaching a non-zero steady state (Stow et al., 1995). Most analyses of PCB trends have based inferences on models that contained assumptions of no change over the period of the record, with fixed parameters based on fit to available data. These models (e.g. De Vault et al., 1996 and Stow et al., 1995) are all retrospective in that they were built *a posteriori*, looking back in time. An alternative modeling strategy for contaminants in Great Lakes food webs was advanced by Lamon et al. (1998, 1999). The model is a dynamic linear model (DLM) with parameters referred to as online estimates, referring to sequential derivation while moving forward in time and learning from new observations. The prospective or forecasting model of Lamon et al. was built sequentially moving forward in time, but can be applied retrospectively to examine trajectories of contaminants over the period of the record (as in Lamon et al., 1999).

Using data from seven species of Lake Michigan fish Stow et al. (1995) applied three models (single exponent, double exponent, and non-zero asymptote) to assess PCB contamination declines. For each of the seven species the non-zero asymptote model was better supported by the data. The long-lived, slow growing, and fatty lake trout was the most PCB contaminated with a very low decline rate. Stow et al. (1999) also developed a generalized form of the common first-order (exponential) decay model for describing declines in environmental contaminant concentrations that can be useful when declines are a function of many underlying processes. In their model the exponent on contaminant concentration remains free, allowing the order of the reaction to be determined by the data. Their mixed-order model is more flexible than models with the exponent determined *a priori*, facilitating an improved fit to observed behavior. Applying the mixed-order model, predicted median PCB concentration declines from 1998 through 2010 were 18, 46, and 57% for Lake Michigan lake, brown, and rainbow trout, respectively. The rate of decline in these three species is precisely inversely proportional to life span and lipid content; lake trout have a long life span and are very fatty. For chinook and coho salmon the mixed-order model predicted declines over the same period of 42 and 32%, respectively. The mixed-order model was a better fit for existing data than two others that were assessed. The authors conclude with a statement that 'making predictions is somewhat presumptuous', suggesting that the mixed-order model offers another tool to assist in environmental assessments. Their model, as well as those of others, for predicting fish tissue contaminant declines is data intensive. They recommend 100 fish (no composites) of each key species every year from multiple sites (even within Lake Michigan). Without a large sample size and frequent sampling data variability is simply too high for accurate forecasts with low uncertainty.

**Potential Impacts on Birds and Other Wildlife**

While the primary objective of this project was to provide information on PCB and OC pesticide contamination of fish collected in Central Valley water bodies and the Delta related to potential risks to human health, another objective was to assess whether levels of contamination are a possible hazard to fish-consuming wildlife. In the US and Canada it appears that there are no legally binding numeric OC pesticide or PCB fish contamination standards for protection of fish-consuming birds and other wildlife. Moreover, my literature review suggests that numeric guidelines for protection of fish-consuming birds and other wildlife are rare world-wide. The few wildlife protection guidelines that exist are based on whole fish analyses, as they should be. Life-cycle studies that define sub-lethal, chronic effects of OCs and PCBs are needed to develop meaningful wildlife protection guidelines; credible studies in this area are incredibly uncommon (most are based on studies on laboratory organisms). Also necessary for development of effective wildlife standards are biomagnification factors in ecosystems of interest. Such factors can be several orders of magnitude from fish to top predator birds and mammals. The complexity and costs of developing such ecosystem-specific wildlife protection criteria undoubtedly accounts for the sacristy. The crux of the matter is that comparing fillet PCB and OC pesticide concentrations in fish collected in Central Valley water bodies and Delta to wildlife protection criteria that have been developed in other aquatic ecosystems is spurious. Nonetheless, as an exercise, I made some such comparisons below. Readers should be aware that I place very little stock in such comparisons.

Predicting potential adverse wildlife effects from the data gathered in this study is confounded by the nature of samples analyzed. That is, fillets rather than whole fish were analyzed. While we understand that contaminant concentrations in whole fish are usually higher than in fillets, 'correction' factors vary with species, season, year, and spatially. Sacramento suckers channel catfish, and carp constituted the majority of composites analyzed in this study. Adults of these species are not likely to be consumed by birds or other wildlife. Larvae and juvenile of these species may be prey of wildlife, but will be much less OC/PCB contaminated than large adults.

US EPA developed a PCB wildlife protection criterion for the Great Lakes. This criterion is for the ∑PCBs in lake water, so it cannot be compared to PCB concentrations in fish fillet composites in the 2005 dataset. Canada published fish tissue guidelines for PCBs for the protection of wildlife consumers (Canadian Council of Ministers of the Environment, 2001). The guidelines are expressed as toxic equivalency units (TEQs) and apply to whole fish analyses. TEQ refers to total dioxin toxic equivalents. The guidelines are expressed as TEQs because the toxicities of individual congeners vary by a factor of 10,000. To derive TEQs the concentrations of all PCB congeners in the sample must be known. Toxic equivalency factors (TEFs) were developed to compare toxicities of environmental samples with different congener composition. Each congener is assigned a TEF based on its ability to induce a response in the cytochrome enzyme system relative to the most potent inducer, the dioxin 2,3,7,8-TCDD. Within a sample, individual congener concentration is multiplied by its respective TEF and then summed to total TEQs. While this conversion is rather cumbersome, I assert that is the most accurate and robust approach for expressing PCB guidelines. Despite the limitations, the use of TEQs enhances correlations between PCB contamination and observed adverse effects. The Canadian Council of Ministers of the Environment (CCME, 2001) PCB guidelines for mammals and birds are 0.79 and 2.4 ng TEQ/kg (wet weight), respectively.

New York State offered a fish-consuming wildlife protection PCB criterion of 110 ng/g (Newell et al., 1987). The International Joint Commission (IJC) also developed a PCB guideline for protection of fish-consuming birds and other wildlife to be applied to fish in the Great Lakes. That guideline is 100 ng/g (wet weight) expressed as the ∑PCB congeners and applies to whole fish analysis. In the 2005 data set from Central Valley water bodies and the Delta the ∑PCBs in only one composite (channel catfish from the Sacramento River @ Colusa=102 ng/g) of 138 was higher than this guideline. While PCB fish contamination is not extensive or severe in Valley water bodies and the Delta more samples in the 2005 dataset would likely exceed this guideline if whole fish would have been analyzed.

Meador et al. (2002) developed a tissue threshold concentration of PCBs for protection of juvenile salmonids. The threshold that they offer (2400 ng PCBs/g lipid) is lipid-normalized because of the large effect lipid can have on PCB effects and the substantial variability of lipid content in salmonids. None of the lipid-normalized concentrations in composites of fish collected during 2005 from Central Valley water bodies or the Delta exceeded this value. However, lipid-normalization of PCB concentrations in the 2005 data is based on PCBs and lipid content in fillets rather than whole fish.

US EPA developed a DDT wildlife protection criterion for the Great Lakes. This criterion is for the ∑DDTs in lake water, so it cannot be compared to DDT concentrations in fish fillet composites in the 2005 dataset. Canada published a DDT tissue guideline for protection of wildlife consumers of fish (CCME, 1999). The guideline, 14 ng/g (wet weight) is expressed as ∑DDTs and applies to the analysis of whole fish. Birds appear to be more sensitive to DDTs than mammals so the guideline is based primarily on the most sensitive avian species and, therefore, should be protective of mammalian wildlife. The US EPA DDT criterion, 150 ng/g (wet weight-based on whole fish analysis), for wildlife protection is less conservative than the CCME guideline. New York State offered a fish-consuming wildlife protection DDT criterion of 200 ng/g (Newell et al., 1987). Blus (1996) contends that for a majority of avian species the DDT adverse effect concentrations are in the 1000 to 3000 ng/g range and recommends that 1000 ng/g be the wildlife guideline. Beckvar et al. (2005) recommended DDT guidelines for protection of fish. The guidelines for juvenile and adult and for early-life stage fish are 600 and 700 ng/g (wet weight), respectively, based on whole fish analyses.

In the 2005 data DDT concentration in five and one composites of Sacramento sucker and carp, respectively, collected in the San Joaquin River watershed and Delta were above the US EPA criterion. No composite of fish taken during 2005 in the Sacramento River watershed exceeded the US EPA criterion. The number of composites of fish collected in the San Joaquin River watershed and Delta exceeding the more conservative CCME criterion was:

White catfish—13
Sacramento sucker—9
Channel catfish—8
Carp—7
Striped bass—1
Large mouth bass—1
Sacramento pike minnow—1
Sacramento perch—1
Bluegill—1
Red-ear sunfish—1

The number of composites of fish caught in the Sacramento River watershed exceeding the CCME criterion was:

Channel catfish—5
Sacramento sucker—4
Carp—3
White catfish—2
Coho salmon—1
Sacramento pike—1

If whole fish composites would have been analyzed there would have been more exceedances of both criteria. On the other hand, fish analyzed, with the possible exception of bluegill and red-ear sunfish, in these composites are too large for most birds to consume. Smaller fish almost certainly would be less DDT-contaminated.

The New York State dieldrin and chlordane fish tissue guidelines for protection of fish-consuming wildlife are 120 and 500 ng/g, respectively (Newell et al., 1987). Eisler

(1990) proposed a chlordane fish tissue guideline for protection of fish-consuming wildlife as 300 ng/g (wet weight) assessed on whole fish analyses. It is difficult to predict whether dieldrin or chlordane concentrations in whole fish composites of the species collected in the water bodies of the Central Valley and Delta would have exceeded these criteria. I would predict, however, that the smaller fish most birds could consume would not manifest dieldrin or chlordane concentrations above these criteria.

## Recommendations

- Guidelines for fish OC pesticide and PCB, as well as for other persistent organic pollutants (POP) contamination that potentially affect human health are needed so that decisions on CWA 303(d) listing and delisting of water bodies can be rendered. Thus, the CVRWQCB should endorse, adopt, or reject the guidance tissue levels (GTLs) and screening values for fish contaminants proposed by OEHHA in 2006 or adopt alternatives.
- Davis (2008) summarized the importance of monitoring fish for chemicals that bioaccumulate and offered recommendations, including three options, for a bioaccumulation monitoring and human health risk reduction program for California. The SWRCB should consider and respond publically to these recommendations.
- Beyond the Davis (2008) recommendations, I advocate the following: The SWRCB should establish an ongoing and long-term POP monitoring and assessment program that is effectively and consistently funded. While OC pesticide and PCB fish contamination in most Central Valley water bodies has declined such that they pose little or no threat to human health, other POPs (e.g., polybrominated diphenyl ethers, dioxins, polycyclic musk compounds, alkylphenols) that have come into use more recently may be bioaccumulating to levels of concern. Thus, the POP monitoring and assessment program should be inclusive of the 'newer' chemicals rather than focus solely on the 'legacy' contaminants.
- The POP monitoring and assessment program should select the desired statistical methods prior to data collection so that study design will provide appropriate information (see Stow et al., 1998). Studies should be designed such that they allow for causality assignment and establish mechanisms for patterns observed in the data collected.
- Cogent analysis of fish contamination data cannot occur without characterization of variation at individual sites, among sites, and through time (temporal). Moreover, valid comparison of fish contamination among seasons, among sites, or through time requires knowledge of intraspecific variation at individual sites. Thus, a POP program must include a design that addresses the data variation issue. A large majority of data collected to date in California are not amenable to a meaningful characterization of variability. To address the variability issue a significant portion of the POP program must be independent of probabilistic sampling. For valid temporal trend analysis fixed sites must be sampled annually or every other year with multiple samples per site. Davis (2008) summarized the importance of targeted rather than probabilistic sampling, indicating that such sampling is crucial for meeting SWAMP objectives of assessing trends in the

fishing and aquatic life beneficial uses throughout the State, evaluating sources and pathways of factors impacting the fish and aquatic life beneficial uses throughout the State, and evaluating the effectiveness of management actions in improving the fishing and aquatic beneficial uses throughout the State. Definitive comprehension of temporal trends is also essential for precise forecasting of POP contamination declines to levels that do not pose threats to human or wildlife well-being.

- As indicated above, accurate interpretation of fish POP contamination requires knowledge of data variability at individual sites. Characterization of intraspecific variation at individual sites demands multiple samples (individual fish or composites) per site. Without this information comparisons among sites and through time are invalid.
- As documented in this report, as well as in many publications in the literature, there is interspecific variation in level of POP fish contamination at individual sites. Thus, one intraspecific composite per site does not permit prediction of contamination in other fish species. Throughout this report I advocate for analysis of multiple intraspecific samples and multiple species per site.
- Many publications document marked and statistically significant season variation in POP fish contamination. Thus, the POP program should incorporate a characterization of seasonal variation in and causes of fish contamination being cognizant of reproductive cycles and other influences. Failure to do so confounds analysis of spatial and temporal (year-to-year) variation/trends. Such knowledge is needed prior to designation of the POP program sampling period. Peak fishing periods also should be considered in designating a program sampling period. It is not uncommon for lipid content and POP contamination to be higher in fall and early winter, yet optimal sampling period will almost certainly vary from species to species. Ideally, once established, the sampling period for individual species should be no longer than two months.
- Fish species and size to be sampled, human health considerations: For the most part, species that are popular for fishing and human consumption should be selected for sampling and analysis. As indicated above, no one species can provide complete characterization of fish POP contamination, so I endorse sampling multiple species at most sites. Large/older, fatty fish (e.g., channel catfish and carp) usually provide ‘worst-case’ contamination. Data in this report clearly document that white catfish are seldom ‘worst-case’ indicators of POP contamination.
- Species and size to be sampled, wildlife protection considerations: In California freshwater ecosystems large/old, fatty fish are not food items for piscivorus birds (with the possible exception of pelicans and bald eagles) and other wildlife. Therefore, for assessing potential impacts on POP contamination on wildlife, smaller fish species known to be food items should be sampled and analyzed.
- Type of sample to be analyzed: While muscle fillets POP analyses are appropriate for human health considerations, whole fish analyses are optimal for wildlife protection assessments. While cost-effective for low budget monitoring programs composite (fillet or whole fish) samples conceal variation in the level of fish POP contamination. Because characterization of data variability is essential

to accurate interpretation of fish contamination data consideration should be given to analysis of individual fish (fillets or whole fish) rather than composites. Should there be monitoring budget constraints such that a limited number of composites can be analyzed, I advise composite analysis of the largest fish collected applying EPA's (2000) guidance that the smallest individual be no less than 75% of the length of the largest fish in the composite (to achieve intraspecific consistency of separate composite samples). This commendation is rendered with the recognition that smaller fish of a species are often less contaminated.

- As documented in this report, exposure level (POP concentration in food items) is not the only determinant of fish contamination at a site. Lipid content, trophic position, age, growth rate, and other factors are also determinants of level of POP contamination. Thus, the POP monitoring and assessment program should include analysis of contaminant bioaccumulation and biomagnification determinants. The relative importance of determinant factors varies from site to site, seasonally, and from year to year confounding temporal and spatial trend analyses as well as POP decline predictions.
- I recommend a literature review, with probably empirical follow-up, that investigates temporal stability of POPs in frozen (archived) fish samples as well as the optimal methods for packaging and storing such samples.
- Regional Board water quality control plans do not include POP fish contamination objectives or guidelines for protection of fish-eating birds and other wildlife. I endorse the development of such guidelines. While there is a perceived higher priority for assessing the fishing beneficial use of California water bodies, support of the aquatic life beneficial use must be considered. 'Borrowing' wildlife protection guidelines from other aquatic ecosystems is not an option because food webs as well as determinants of bioaccumulation and biomagnification differ markedly among aquatic ecosystems. For example, Environment Canada has a fish DDT contamination wildlife protection guideline of 14 ng/g. This guideline is almost certainly not applicable to California freshwater aquatic ecosystems because food chains are shorter, waters are warmer, and many other physical and ecological parameters differ from Canadian water bodies.
- There are no water bodies in the San Joaquin River watershed CWA 303(d) listed for PCB fish contamination. Neither the east nor west portions of the Delta are listed for PCB fish contamination. While PCB concentration in a composite of Sacramento sucker collected from the San Joaquin River @ Vernalis slightly exceeded (27 ng/g) the OEHHA screening value, PCBs in 22 composites of fish collected from the lower San Joaquin River were below the screening value. Therefore, the 2005 data do not support listing of the lower San Joaquin River. In contrast to PCB concentration in a composite of Sacramento sucker caught from the Tuolumne in 2005, levels in channel catfish and carp from that site were below reporting level. Because there were two Sacramento sucker composites with PCB concentrations slightly exceeding the OEHHA screening level there are sufficient data for 303(d) listing of this river according to SWRCB policy (SWRCB, 2004). I would recommend more data be collected before such an action is considered since old, fatty Sacramento sucker (that do not reflect current

PCB exposure levels) was the only species to manifest PCB levels in excess of the screening level. I recommend multiple composites from five to seven species other than Sacramento sucker from the Tuolumne River be analyzed for PCBs. While one composite of Sacramento sucker collected from the Mokelumne River slightly exceeded (23 ng/g) the OEHHA 1999 screening value, a second composite (13 ng/g) did not. Thus, data are insufficient for 303(d) listing of this water body. My best professional judgment (BPJ) is that the current exposure level (PCB concentration in fish food items) in the Mokelumne River is low (relative to human health concerns).

- The north Delta waterways are 303(d) listed for PCB fish contamination. In this study one composite of Sacramento sucker collected from Prospect Slough contained 20 ng/g PCBs (equal to the OEHHA screening value). PCB concentrations were below reporting level in nine composites of eight other species collected from Prospect Slough. Nine composites from eight species were available from Prospect Slough; five composites from five species were available from oter sites in the northern Delta. The upper 95% confidence limit of the mean and geometric mean PCB concentration in composites from Prospect Slough and in all (14) composites from the nortern Delta do not over lap the OEHHA screening value. On a weight-of-evidence basis these 2005 data do not support 303(d) listing and are insufficient, according to the SWRCB policy document, for listing. I recommend 303(d) delisting the north Delta and tender that monitoring budget could be allocated to higher priority issues than follow-up on the results from the single Sacramento sucker composite.
- The only water body in the Sacramento River watershed 303(d) listed for PCB fish contamination is Natomas East Main Drain (Steelhead Creek). For the current study no fish were available from this water body. I recommend that this site be targeted in the next round of PCB and OC pesticide fish sampling. I further advise that at least two composites from a minimum of five species (e.g., channel catfish, carp, Sacramento sucker, largemouth bass, and white catfish) be analyzed.
- PCB concentration in one composite of Sacramento sucker collected from Potato Slough (east Delta) and from Big Break (west Delta) exceeded the OEHHA 1999 screening value. In four other composites of fish collected from west Delta sites PCBs were below reporting level. PCB concentration in five composites of fish collected from east Delta sites were below the OEHHA screening value; in three of the five composites PCBs were below reporting level. Thus, according to SWRCB policy there are insufficient data for 303(d) listing of the east and west portions of the Delta. My BPJ is that monitoring east and west Delta fish for PCB contamination should not be a high priority. Moreover, the 2005 data from the San Joaquin River watershed and Delta reveal that it is only the older, fatty Sacramento sucker (that do not reflect current PCB exposure levels) that exceed the OEHHA screening value.
- PCB levels in a composite of Sacramento sucker from Clear Creek and a composite of channel catfish from Sacramento Slough slightly exceeded (27 and 21 ng/g, respectively) the OEHHA screening value. However, PCB concentrations in a composite of rainbow trout from Clear Creek and a second

composite of channel catfish from Sacramento Slough were below the reporting level and 13 ng/g, respectively. Because there was only one composite that exceeded the screening value from these two sites, data are insufficient (SWRCB, 2004) for 303(d) listings. My BPJ is that monitoring Clear Creek and Sacramento Slough fish for PCB contamination should not be a high priority. PCB concentrations in a composite of Sacramento sucker from the American River @ Discovery Park and a composite of channel catfish from the Sacramento River @ Colusa exceeded the OEHHA screening value. However, PCB concentrations in a composite of white catfish and three composites of largemouth bass from the American River @ Discovery Park were all below reporting level. PCB concentration in a composite of Sacramento sucker from the Colusa site was below the reporting level. The single composite exceedance of the screening level at these two sites is insufficient for 303(d) listing. Additional data could clarify PCB fish contamination at the Discovery Park and Colusa sites; analysis of multiple composites (at least two per species) from four or five species is recommended.

- PCB concentration in composites of channel catfish (53 ng/g) and carp (26 ng.g) collected at the Veteran's Bridge site exceeded the OEHHA screening level, while a composite of Sacramento sucker (6 ng/g) from the site did not. PCB concentrations in these three composites exactly paralleled lipid content. The two exceedances of the screening level are adequate (SWRCB policy) to 303(d) list this portion of the Sacramento River. However, I recommend that consideration be given (perhaps revising the SWRCB listing and delisting policy?) to the role of fish age and lipid in assessing PCB and OC pesticide contamination. Further, I recommend that consideration also be yielded to the fact that PCB levels in composites of fish from neither the nearest upstream (Grimes) nor downstream (RM 44) sites exceeded the screening level. Additional data also could clarify PCB contamination at the Veteran's Bridge site; analysis of multiple composites from five to six species is recommended.
- The lower San Joaquin River is 303(d) listed for DDT fish contamination. DDT concentration in five composites (three species) of fish collected from the lower San Joaquin River (sites: Crow's Landing, Laird Park, and Vernalis) exceeded the 1999 OEHHA screening level. According to SWRCB policy these data preclude 303(d) delisting of the lower San Joaquin River. Consideration should be given to the fact that DDT levels in 18 composites from fish caught in the lower San Joaquin River (including an additional three composites from Crow's Landing, one from Laird Park, and three from Veranlis) during 2005 were below the 1999 screening level. DDT concentrations in all 23 composites of fish collected from the lower San Joaquin River during 2005 were considerably lower than the 2006 OEHHA-proposed screening level. If the lower screening level is maintained additional data from the Crow's Landing, Laird Park, and Vernalis sites are recommended to clarify DDT fish contamination; I advocate at least two composites from a minimum of four species (e.g., channel catfish, carp, Sacramento sucker, and largemouth bass) be analyzed. I also recommend that fish from smaller tributaries (e.g., Orestimba Creek, Del Puerto Creek, West Stanislaus Main Canal) be analyzed for DDT contamination. If the higher

screening value (20006) is adopted, there are adequate data in this report to support delisting of the lower San Joaquin River.

- The eastern and western portions of the Delta are 303(d) listed for DDT fish contamination. In the 2005 data DDT concentration in one composite of Sacramento sucker from Potato Slough (east Delta) and one composite of Sacramento sucker from Prospect Slough (north Delta) exceeded the 1999 OEHHA screening value. DDT concentration in seven composites of fish collected during 2005 at three other eastern Delta sites was less than 20 ng/g (considerably below the 1999 OEHHA screening value). With the exception of the one Potato Slough Sacramento sucker composite (old, fatty fish that do not reflect current exposure levels), DDT contamination of fish from the east Delta appears to be below the 1999 OEHHA 100 ng/g screening value. However, according to SWRCB policy (SWRCB, 2004) there are insufficient samples below the 1999 OEHHA screening level to delist the eastern Delta. Mean and geometric mean DDT concentrations in nine composites of fish collected in the eastern Delta are below 50 ng/g and the upper 95% confidence limit does not overlap the OEHHA 1999 screening value. In the event that this screening value is maintained I recommend delisting the eastern portion of the Delta (Table 47). DDT levels in all composites of fish collected at eastern Delta sites were considerably lower than the 2006 OEHHA-proposed screening level. If the OEHHA 2006 recommendations are adopted there should ensue a rapid revision of the SWRCB (2004) policy document (especially regarding the number of samples required for delisting) as related to OC pesticides and other bioaccumlative POPs. DDT levels in eight composites of fish collected from western Delta sites were below the OEHHA 1999 screening value; DDT concentration in seven of the composites was 10 ng/g or less. Mean and geometric mean DDT concentrations in eight composites of fish collected in the western Delta are below 12 ng/g and the upper 95% confidence limits do not overlap the OEHHA 1999 screening value. While the 2005 data clearly show that DDT contamination of fish in the west Delta is low, according to SWRCB policy (2004) there are insufficient samples below the screening level (minimum of 26 needed) to 303(d) delist these water bodies. I cannot concur with the SWRCB policy in this case and recommend delisting (Table 47); I contend that monitoring funds could be utilized more prudently on more pressing issues.
- The northern and southern Delta also are listed for DDT fish contamination. DDT levels in a composite of Sacramento sucker collected from Prospect Slough and a composite of carp from Rio Vista were above the 1999 OEHHA screening level. These two composites provide adequate (SWRCB, 2004) data for 303(d) listing of the north Delta if the 1999 OEHHA screening level remains viable, but not if the 2006-recommended screening level is adopted. DDT concentrations in nine composites from eight species collected from Prospect Slough were less than 40 ng/g. Overall, there were 14 composites of fish collected from the north Delta with DDT concentrations below the 1999 OEHHA screening value (11 with DDTs < 40 ng/g). Mean and geometric mean DDT concentratins in 14 composites of fish collected in the northern Delta are below 50 ng/g and the upper 95% confidence limits do not overlap the OEHHA screening value. While some

large/old, fatty fish in areas of the north Delta are DDT-contaminated to an extent potentially harmful to humans, this contamination does not extend to all species and does not translate into present-time high DDT exposure levels. Although inconsistent with current SWRCB policy, I recommend delisting of the northern Delta for DDT fish contamination (Table 47). DDT concentrations in nine composites of fish collected at sites in the southern Delta were below the OEHHA 1999 screening value; in eight of the composites DDT levels were 30 ng/g or less. Mean and geometric mean DDT concentration in 13 composites of fish collected in the southern Delta are below 20 ng/g and the upper 95% confidence limits do not overlap the OEHHA 1999 screening value. The 2005 data indicate low levels of fish DDT contamination (not of concern for human health); thus, I recommend delisting southern Delta waterways (Table 47).

- The lower Tuolumne River is not currently CWA 303(d) listed for DDT fish contamination. The ∑DDTs in two composites of Sacramento sucker caught in the Tuolumne River during 2005 exceeded the OEHHA 1999 screening value. DDTs in composites of carp and channel catfish collected from the Tuolumne in 2005 were 13 and 21 ng/g, respectively, a considerable divergence compared to the Sacramento sucker. These two composites are adequate (SWRCB, 2004) for 303(d) listing of the Tuolumne if the OEHHA screening level remains at 100 ng/g, but not if the 2006 OEHHA-proposed screening value (560 ng/g) is adopted by the CVRWQCB. Lipid content in the Sacramento sucker composites was 7 to 9X higher than in the composites from the other two species; the large difference in lipid content is almost certainly a determining factor in level of DDT contamination. Therefore, I recommend that additional data from multiple species with ‘duplicate’ composites per species be gathered prior to any listing actions. As stated above, I further recommend that consideration be accorded to revising the SWRCB listing and delisting policy to include the role of fish age and lipid in assessing PCB and OC pesticide (as well as other POPs) contamination.
- The lower San Joaquin River is 303(d) listed for Group A pesticide fish contamination. Chlordane concentration in 23 composites of fish collected at sites in the lower San Joaquin River during 2005 was below the OEHHA 1999 screening value; in 17 of those composites chlordane was below the reporting level. Dieldrin concentrations were less than the OEHHA 1999 screening value in 20 composites of fish collected in the lower San Joaquin River, but slightly above the screening value in three composites (range 2.3 to 3.4 ng/g). The upper 95% confidence limits of the mean and geometric mean dieldrin concentration in the 22 composites from fish collected in the lower San Joaquin River do not overlap the OEHHA 1999 screening value. Because there are not 34 composites below the screening value these data are insufficient (SWRCB policy) for delisting the lower San Joaquin River. Clearly, however, Group A pesticide contamination of fish in the lower San Joaquin is neither widespread nor intense. Further, dieldrin concentrations in the in the three composites are considerably below the OEHHA 2006 screening value of 16 ng/g. Thus, I question the value of utilizing monitoring funds for the analysis of another 14 composites and recommend delisting of the lower San Joaquin River based on the weight of evidence (Table 47).

- The lower Merced, lower Tuolumne, and lower Stanislaus Rivers are 303(d) listed for Group A pesticide contamination of fish. Chlordane concentration in four composites of fish collected from the Tuolumne River during 2005 was below reporting level. While dieldrin concentration in a composite of Sacramento sucker caught from the Tuolumne River was 2.5 ng/g, levels in a second Sacramento sucker composite, a carp composite, and a channel catfish composite from fish collected at this site were below reporting level. Although it is apparent that it is only older, very fatty Sacramento sucker from the Tuolumne River that manifest dieldrin levels above the 1999 OEHHA screening value, the 2005 data are not adequate for delisting (SWRCB, 2004) this river (another 24 composites or individual fish samples below the screening level would be needed). Chlordane concentration in three composites of fish collected from the Stanislaus River was below reporting level. Dieldrin levels in three (two Sacramento sucker and one channel catfish) composites from fish collected in the Stanislaus River were non-detect and below reporting level (no composite had a concentration above the OEHHA 1999 screening value). Dieldrin concentrations in two composites of Sacramento sucker, one composite of channel catfish, and one composite of carp collected from the Merced River were all less than reporting level (no composite had a concentration above the 0EHHA 1999 screening value). While it is very clear that dieldrin contamination is not currently a problem in the Merced and Stanislaus Rivers, the 2005 data are insufficient (SWRCB, 2004) to 303(d) delist these water bodies. According to the SWRCB policy a total of 64 additional composites from the Merced, Stanislaus, and Tuolumne Rivers would need to be analyzed (with concentrations below the OEHHA screening value). I do not concur with the need for additional samples and recommend, on a weight-of-evidence basis, delisting of these three water bodies (Table 47). Monitoring funds almost certainly could be spent more productively on more pressing water quality issues. If the 2006 OEHHA recommended screening level of 16 ng/g is adopted by the CVRWQCB, delisting of these water bodies should occur.
- The eastern and western portions of the Delta are 303(d) listed for Group A pesticide fish contamination. Chlordane concentration in eight composites of fish collected from sites in the eastern Delta were below the OEHHA 1999 screening value; in seven of those composites concentration was below reporting level. Dieldrin level was above the OEHHA screening value in only one composite of fish collected from eastern Delta sites; this was in a fat-laden composite of Sacramento sucker from Potato Slough. In eight other composites of fish collected from the eastern Delta dieldrin levels were below the OEHHA screening value. Chlordane concentration in eight composites of fish collected from sites in the western Delta were below the OEHHA 1999 screening value; in seven of those composites concentration was below reporting level. Dieldrin level was above the OEHHA screening value in only one composite of fish collected from western Delta sites; this was in a composite of Sacramento sucker from Big Break (contamination was not intense, being 2.5 ng/g). The upper 95% confidence limits for the mean and geometric dieldrin concentrations in nin and eight composites of fish collected in the eastern and western Delta, respectively, do not overlap the 1999 OEHHA screening value. Dieldrin concentration in no

composite from the eastern or western Delta was above the 2006 OEHHA-proposed screening value. Pursuant to SWRCB policy the 2005 data are inadequate to delist the eastern and western Delta. While the 2005 data illustrate that Group A pesticide contamination of fish from these two areas of the Delta is neither widespread nor intense, twenty and 23 composites or individual fish samples from the east and west Delta, respectively, with dieldrin concentrations below the screening value will be needed for delisting. I am not convinced that the expense of collecting and analyzing this number of samples is warranted and, based on weight of evidence recommend delisting these two areas of the Delta Table 47). Should the 2006 OEHHA-recommended screening level of 16 ng/g be approved by the CVRWQCB, delisting of these water bodies is in order.

- Colusa Basin Drain (CBD) and the lower Feather River are on the CWA 303(d) list for Group A pesticide contamination. Chlordane was not detected in composites of carp and white catfish caught during 2005 at CBD. The concentration of dieldrin in the composite from carp taken at CBD was below the OEHHA 1999 screening value and was not detected in a composite of white catfish from this location. Chlordane was below reporting level in composites of carp, large-mouth bass, and Sacramento sucker (three composites) captured in the lower Feather River. Dieldrin was not detected and below reporting level (two composites) in 'triplicate' composites of Sacramento sucker caught in the lower Feather River. Dieldrin was also below reporting level in composites of carp and largemouth bass collected from the lower Feather River. These data clearly document that there is little or no Group A pesticide fish contamination at either of these sites. Nonetheless, SWRCB policy indicates that 28 samples, with no more than one exceedance, are required for 303(d) delisting a water body. I am doubtful that the expense of collecting and analyzing this number (49 additional from the two water bodies) of samples is prudent use of monitoring funds; my BPJ is that these two water bodies should be delisted. Should the 2006 OEHHA-recommended screening level of 16 ng/g be approved by the CVRWQCB, delisting of these water bodies is definitely in order.
- The northern portion of the Delta is not currently 303(d) listed for Group A pesticide fish contamination. Dieldrin concentration in composites of Sacramento sucker (4.0 ng/g) and carp (2.1 ng/g) collected from Prospect Slough during 2005 exceeded the OEHHA 1999 screening value. While these data are sufficient (SWRCB policy document) for listing the north Delta, I cannot support such a listing. That is, dieldrin levels in eight composites of seven other species collected from Prospect Slough were below the screening value. Further, the Sacramento sucker (not popular for human consumption) composite had high lipid content and dieldrin concentration in the carp composite was near the screening value. Clearly the north Delta should not be listed if the 2006 OEHHA-recommended dieldrin screening value (16 ng/g) is approved by the CVRWQCB.
- Salt Slough is not currently 303(d) listed for Group A pesticide fish contamination. Dieldrin concentration in a composite of channel catfish collected from Salt Slough in 2005 slightly exceeded (2.5 ng/g) the OEHHA 1999 screening value. However, dieldrin level in a second channel catfish composite and a composite of carp collected at this site was below the screening level. Thus,

data are insufficient for 303(d) listing. I am doubtful that the expense of collecting and analyzing additional multiple fish samples from this site is prudent use of monitoring funds.

- No segment of the Sacramento River is currently 303(d) listed for Group A pesticide fish contamination. Because the dieldrin in only one composite (per site) of channel catfish collected at the Colusa and Grimes sites on the Sacramento River, data are insufficient for listing if the sites are considered separately. If considered together the segment of the river between Colusa and Grimes could be 303(d) listed. However, dieldrin level in a composite of Sacramento sucker collected at the Colusa site was below reporting level. Moreover, the data collected in the Sacramento River and watershed document that dieldrin fish contamination is neither widespread nor intense. However, only if the 1999 OEHHA screening level is maintained (to clarify whether dieldrin fish contamination is at a level of concern) I recommend that several (at least two) composites of four to seven species from the Grimes and Colusa sites be analyzed for dieldrin. If the 2006 OEHHA-recommended screening level is approved by the CVRWQB, listing of this segment of the river is not an issue.
- Sacramento Slough is not currently 303(d) listed for Group A pesticide fish contamination. Dieldrin concentration in two composites of channel catfish collected from Sacramento Slough during 2005 slightly exceeded the OEHHA 1999 screening value. These data are ample for listing this water body only if the 1999 screening value is maintained. In the Sacramento River watershed only older, fatty channel catfish manifested dieldrin concentrations slightly above the OEHHA 1999 screening value. Should the 1999 screening value be preserved, I recommend several (at least two) composites of four to seven species from Sacramento Slough be analyzed for dieldrin.
- Consideration should be yielded to revision of the SWRCB (2004) CWA 303(d) listing and delisting policy document as related to bioaccumulated and biomagnified chemicals. Applying the same requirements to fish contamination samples as to water samples seems inappropriate. In particular, the number of fish samples required for delisting seems excessive. This is especially the case in view of data documenting that OC pesticide and PCB fish contamination in most water bodies of the Central Valley are less than or approaching reporting levels and below concentrations of concern to human health.

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# References

Amrhein JF, Stow CA, Wible C. Whole-fish versus filet polychlorinated-biphenyl concentrations: an analysis using classification and regression tree models. Environ Toxicol Chem 1999;18:1817-23.

Beckvar N, Dillon TM, Read LB. Approaches for linking whole-body fish tissue residues of mercury or DDT to biological effects thresholds. Environ Toxicol Chem 2005;24:2094-105.

Bentzen E, Lean DRS, Taylor WD, Mackay D. Role of food web structure on lipid and bioaccumulation of organic contaminants by lake trout (Salvelinus namaycush). Can J Fish Aquat Sci 1996;53:2397-407.

Berglund O, Larsson P, Broman D. Organochlorine accumulation and stable isotope ratios in an Atlantic salmon (Salmo salar) population from the Baltic Sea. Sci Total Environ 2001;281:141-51.

Bettinetti R, Croce V, Galassi S, Volta P. pp'DDT and pp'DDE accumulation in a food chain of Lake Maggiore (northern Italy): testing steady-state condition. Environ Sci Pollut Res 2006;13:59-66.

Blus LJ. DDT, DDD, and DDE in birds. In: Beyer WN, Heinz GH, Redmon-Norwood AW, editors. Environmental contaminants in wildlife; interpreting tissue concentrations. Boca Raton, FL: Lewis Publishers; 1996. p. 49-71.

Borga K, Fisk AT, Hoekstra PF, Muir DCG. Biological and chemical factors of importance in the bioaccumulation and trophic transfer of persistent organochlorine contaminants in arctic marine food webs. Environ Toxicol Chem 2004;23:2367-85.

Borgmann U, Whittle DM. Contaminant concentration trends in lake Ontario lake trout (Salvelinus namaycush): 1997 to 1988. Internat Assoc Great Lakes Res 1991;17:368-81.

Borgmann U, Whittle DM. Bioenergetics and PCB, DDE, and mercury dynamics in lake Ontario lake trout (Salvelinus namaycush): a model based on surveillance data. Can J Fish Aquat Sci 1992;49:1086-96.

Brodberg RK, Pollock GA. Prevalence of selected target chemical contaminants in sport fish from two California lakes: Public health designed screening study 1999. Office of Environmental Health Hazard Assessment, California Environmental Protection Agency, Sacramento, CA.

Burreau S, Zebuhr Y, Broman D, Ishaq R. Biomagnification of PBDEs and PCBs in food webs from the Baltic Sea and the northern Atlantic Ocean. Sci Total Environ 2006;366:659-72.

Burreau S, Zebuhr Y, Broman D, Ishaq R. Biomagnification of polychlorinated biphenyls (PCBs) and polybrominated diphenyl ethers (PBDEs)studied in pike (Esox lucius), perch (Perca fluviatilis) and roach (Rutilus rutilus) from the Baltic Sea. Chemosphere 2004;55:1043-52.

Burreau S, Zebuhr Y, Broman D, Ishaq R. Biomagnification of PBDEs and PCBs in food webs from the Baltic Sea and the northern Atlantic Ocean. Sci Total Environ 2006;366:659-672.

Canadian Council of Ministers of the Environment. 1999. Canadian tissue residue guidelines for the protection of wildlife consumers of aquatic biota: DDT (total). In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Canadian Council of Ministers of the Environment. 2001. Canadian tissue residue guidelines for the protection of wildlife consumers of aquatic biota: Polychlorinated biphenyls (PCBs). Updated. In: Canadian environmental quality guidelines, 1999, Canadian Council of Ministers of the Environment, Winnipeg.

Connor MS, Davis JA, Leatherbarrow J, Greenfield BK, Gunther A, Hardin D, Mumley T, Oram J, Werme C. The slow recovery of San Francisco Bay from the legacy of organochlorine pesticides. Environ Res 2007;105:87-100.

Crimmins BS, Brown PD, Kelso DP, Foster GD. Bioaccumulation of PCBs in aquatic biota from a tidal freshwater marsh ecosystem. Arch Environ Contam Toxical 2002;42:396-404.

Davis JA. Recommendations for a bioaccumulation monitoring and human health risk reduction program for California. San Francisco Estuary Institute, Contribution 545. 2008.

Davis JA, Grenier JL, Melwani AR, Bezalel S, Letteney E, Zhang E. The impact of pollutant bioaccumulation on the fishing and aquatic life support beneficial uses of California water bodies: a review of historic and recent data. San Francisco Estuary Institute. Report to the State Water Resource Control Board. 2008.

Davis JA, Hetzel F, Oram JJ, McKee LJ. Polychlorinated biphenyls (PCBs) in San Francisco Bay. Environ Res 2007. doi:10.1016/j.envres.2007.01.013 .

Davis JA, May MD, Greenfield BK, Fairey R, Roberts C, Ichikawa G, Stoelting MS, Becker JS, Tjeerdema RS. Contaminant concentrations in sport fish from San Francisco Bay 1997. Mar Pollut Bull 2002;44:1117-29.

De Vault DS, Hesselberg R, Rodgers PW, Feist TJ. Contaminant trends in lake trout and walleye from the Laurentian Great Lakes. Internat Assoc Great Lakes Res 1996;22:884-

95.

deVlaming V. Fish tissue analyses of organochlorine pesticides and PCBs in central valley surface waters. Quality Assurance Project Plan (QAPP) UC Davis School of Veterinary Medicine:APC 2006. August 2006.

Dodder NG, Strandberg B, Hites RA. Concentrations and spatial variations of polybrominated diphenyl ethers and several organochlorine compounds in fishes from the Northeastern United States. Environ Sci Technol 2002;36:146-51.

Eisler R. Chlordane hazards to fish, wildlife, and invertebrates: a synoptic review. US Fish and Wildlife Service, Washington DC 1990. Biol Rep 85(1.21).

Fisk AT, Hobson KA, Norstrom RJ. Influence of chemical and biological factors of trophic transfer of persistent organic pollutants in the Northwater Polynya Marine food web. Environ Sci Technol 2001;35:732-8.

Fisk AT, Hoekstra PF, Borga K, Muir DCG. Correspondence. Marine Pollution Bulletin 2003;46:522-24.

Fisk AT, Norstrom RJ, Cymbalisty CD, Muir DCG. Dietary accumulation and depuration of hydrophobic organochlorines: bioaccumulation parameters and their relationship with the octanol/water partition coefficient. Environ Toxicol Chem 1998;17:951-61.

French TD, Campbell LM, Jackson DA, Casselman JM, Scheider WA, Hayton A. Long-term changes in legacy trace organic contaminants and mercury in Lake Ontario salmon in relation to source controls, trophodynamics, and climatic variability. Limnol Oceanogr 2006;51:2794-807.

Fu C, Wu S. Seasonal variation of the distribution of PCBs in sediments and biota in a PCB-contaminated estuary. Chemosphere 2006;62:1786-94.

Greenfield BK, Davis JA, Fairey R, Roberts C, Crane D, Ichikawa G. Seasonal, interannual, and long-term variation in sport fish contamination, San Francisco Bay. Sci Total Environ 2005;336:25-43.

Greenfield BK, Whittner E, David N, Shonkoff S, Davis JA. Monitoring trace organic contamination in central valley fish: current data and future steps. San Francisco Estuary Institute Contribution #99 2004. Report to Central Valley Regional Water Quality Control Board.

Hebert CE, Keenleyside KA. To normalize or not to normalize? Fat is the question. Environ Toxicol Chem 1995;14:801-7.

Heidtke T, Hartig JH, Zarull MA, Yu B. PCB levels and trends within the Detroit River-Western Lake Erie Basin: a historical perspective of ecosystem monitoring. Environ

Monit Assess 2006;112:23-33.

Hickey JP, Batterman SA, Chernyak SM. Trends of chlorinated organic contaminants in great lakes trout and walleye from 1970 to 1988. Arch Environ Contam Toxicol 2006;50:97-110.

Hinck JE, Blazer VS, Denslow ND, Echols KR, Gross TS, May TW, Anderson PJ, Coyle JJ, Tillitt DE. Chemical contaminants, health indicators, and reproductive biomarker responses in fish from the Colorado River and its tributaries. Sci Total Environ 2007;378:376-402.

Hinck JE, Schmitt CJ, Blazer VS, Denslow ND, Bartish TM, Anderson PJ, Coyle JJ, Dethloff GM, Tillitt DE. Environmental contaminants and biomarker responses in fish from the Columbia River and its tributaries: Spatial and Temporal trends. Sci Total Environ 2006;366:549-78.

Huestis SY, Servos MR, Whittle DM, Dixon DG. Temporal and age-related trends in levels of polychlorinated biphenyl congeners and organochlorine contaminants in Lake Ontario lake trout (Salvelinus namaycush). Internat Assoc Great Lakes Res 1996;22:310-30.

Isosaari P, Kiviranta H, Lie O, Lundebye AK, Ritchie G, Vartinainen T. Accumulation and distribution of polychlorinated dibenzo-p-dioxin, dibenzofuran, and polychlorinated biphenyl congeners in Atlantic salmon (Salmo Salar). Environ Toxicol Chem 2004;23:1672-9.

Jackson LJ, Carpenter SR, Manchester-Neesvig J, Stow CA. Current concentratins of PCBs in Lake Michigan invertebrates, a prediction test, and corroboration of hindcast concentrations. J Great Lakes Res 1998;24:808-821.

Jackson LJ, Carpenter SR, Manchester-Neesvig J, Stow CA. PCB congeners in Lake Michigan coho (Oncorhynchus kisutch) and chinook (Oncorhynchus tshawytscha) salmon. Environ Sci Technol 2001;35:856-62.

Jackson LJ, Schindler DE. Field estimates of net trophic transfer of PCBs from prey fishes to Lake Michigan Salmonids. Environ Sci Technol 1996;30:1861-5.

Johnston TA, Fisk AT, Whittle DM, Muir DCG. Variation in organochlorine bioaccumulation by a predatory fish; gender, geography, and data analysis methods. Environ Sci Technol 2002;36:4238-44.

Kidd KA, Bootsma HA, Hesslein RH, Muir DCG, Hecky RE. Biomagnification of DDT through the benthic and pelagic food webs of Lake Malawi, East Africa: importance of trophic level and carbon source. Environ Sci Technol 2001;35:14-20.

Kidd KA, Bschindler DW, Hesslein RH, Muir DCG. Correlation between stable nitrogen isotope ratios and concentrations of organochlorines in biota from a freshwater food web. The Sci Total Environ 1995;160/161;381-90.

Kidd KA, Hesslein RH, Ross BJ, Koczanski K, Stephens GR, Muir DCG. Bioaccumulation of organochlorines through a remote freshwater food web in the Canadian arctic. Environ Pollut 1998;102:91-103.

Kidd KA, Schindler DW, Hesslein RH, Muir DCG. Effects of Trophic position and lipid on organochlorine concentrations in fishes from subarctic lakes in Yukon territory. Can J Fish Aquat Sci 1998;55:869-81.

Kucklick JR, Baker JE. Organochlorines in Lake Superior's food web. Environ Sci Technol 1998;32:1992-98.

Lamon III EC, Carpenter SR, Stow CA. Forecasting PCB concentrations in Lake Michigan salmonids: a dynamic linear model approach. Eco Applic 1998;8:659-68.

Lamon III EC, Carpenter SR, Stow CA. Rates of decrease of polychlorinated biphenyl concentrations in five species of Lake Michigan salmonids. Can j Fish Aquat Sci 1999;56:53-9.

Lamoureux B, Glaser D. Lipid Normalization in fish: why it does or doesn't help and what to do about it. Presentation at 2003 North America SETAC meeting in Austin, TX.

Larry Walker Associates. Quality Assurance Project Plan (QAPP), Revision 1.2.0: Sacramento River Watershed Program Monitoring for 2005-2007. Sacramento River Watershed Program 2006.

Larry Walker Associates. Sacramento River Annual Monitoring Report: 2000-2001. Sacramento River Watershed Program 2002. http://www.sacriver.org/subcommittees/monitoring/documents/SRWP_AMR_00-01_FINAL.pdf.

Larry Walker Associates. Sacramento River Annual Monitoring Report: 2002-2003. Sacramento River Watershed Program 2003. http://www.sacriver.org/subcommittees/monitoring/documents/SRWP_AMR_FINAL_070904.pdf.

Larry Walker Associates. Sacramento River Annual Monitoring Report:1999-2000. Sacramento River Watershed Program 2001. http://www.sacriver.org/subcommittees/monitoring/documents/AMR_99_00_FINAL_REPORT.pdf.

Larsson P, Backe C, Bremle G, Eklov A, Okla L. Persistent pollutants in a salmon population (Salmo salar) of the southern Baltic sea. Can J Fish Aquat Sci 1996;53:62-9.

Larsson P, Okla L, Collvin L. Reproductive status and lipid content as factors in PCB, DDT and HCH contamination of a population of pike (Esox lucius l.). Environ Toxicol Chem 1993;12:855-61.

Leblanc GA. Trophic-level differences in the bioconcentration of chemicals: implications in assessing environmental biomagnification. Environ Sci Technol 1995;29:154-60.

Lee GF, Jones-Lee A. Organochlorine pesticide, PCB and dioxine/furan exessive bioaccumulation management guidance. 2002. G. Fred Lee & Associates, California Water Institute Report TP 02-06 to the California Water Resources Control board/Central Valley Regional Water Quality Control Board. http://www.gfredlee.com/unreliability.of.NAS.Critera.pdf.

Mackay, D. Correlation of bioconcentration factors. Environ Sci Technol 1982;16:274-278.

Mackay D, Fraser A. Bioaccumulation of persistent organic chemicals: mechanisms and models. Environ Pollut 2000;110:375-91.

Madenjian CP, Carpenter SR, Eck GW, Miller MA. Accumulation of PCBs by lake trout (Salvelinus namaycush): an individual-based model approach. Can J Fish Aquat Sci 1993; 50:97-109.

Madenjian CP, Carpenter SR, Rand PS. Why are the PCB concentrations of Salnonine individuals from the same lake so highly variable? Can J Fish Aquat Sci 1994; 51:800-807.

Madenjian CP, Elliot RF, DeSorcie TJ, Stedman RM, O'Connor DV, Rottiers DV. Lipid concentrations in Lake Michigan fishes: seasonal, spatial, ontogenetic, and long-term trends. J Great Lakes Res 2000; 26:427-444.

Madenjian CP, Hesselberg RJ, Desorcie TJ, Schmidt LJ, Stedman RM, Quintal RT, Begnoche LJ, Passino-Reader DR. Estimate of net trophic transfer efficiency of PCBs to Lake Michigan lake trout from their prey. Environ Sci Technol 1998;32:886-91.

Manchester-Neesvig JB, Valters K, Sonzogni WC. Comparison of polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) in Lake Michigan salmonids. Environ Sci Technol 2001;35:1072-7.

McIntyre JK, Beauchamp DA. Age and trophic position dominate bioaccumulation of mercury and organochlorines in the food web of Lake Washington. Sci Total Environ 2007;372:571-84.

Meador JP, Collier TK, Stein JE. Use of tissue and sediment-based threshold concentrations of polychlorinated biphenyls (PCBs) to protect juvenile salmonids listed under the US endangered species act. Aquatic Conserv Mar Freshw Ecosyst 2002;12:493-516.

Miller MA, Madenjian CP, Masnado RG. Patterns of organochlorine contamination in lake trout from Wisconsin waters of the Great Lakes. J Great Lakes Res 1992;18:742-54.

Muir DCG, Ford CA, Grift NP, Metner DA, Lockhart WL. Geographical variation of chlorinated hydrocarbons in burbot (Lota lota) fro remote lakes and rivers in Canada. Arch Environ Contam Toxicol 1990; 19:530-542.

Newell AJ, Johnson DW, Allen LK. Niagara River biota contamination project: fish flesh criteria for piscivorous wildlife. New York State Dept of Environmental Conservation 1987 Technical Report 87-3. Division of Fish and Wildlife Bureau of Environmental Protection.

Nfon E, Cousins IT. Interpreting time trends and biomagnification of PCBs in the Baltic region using the equilibrium lipid partitioning approach. Environ Pollut 2006;144:994-1000.

Niimi AJ, Oliver BG. Distribution of polychlorinated biphenyl congeners and other halocarbons in whole fish and muscle among Lake Ontario salmonids. Environ Sci Technol 1989;23:83-8.

Norstrom RJ. Understanding bioaccumulation of POPs in food webs chemical, biological, ecological and environmental considerations. Environ Sci & Pollut Res 2002; 9:300-303.

OEHHA. Development of guidance tissue levels and screening values for common contaminants in california sport fish: chlordane, DDTs, dieldrin, methylmercury, PCBs, selenium, and toxaphene. Office of Environmental Health Hazard Assessment 2006. http://www.oehha.ca.gov.fish/gtlsv/dpf/draftgtlsvchddt.pdf.

OEHHA. General Protocol for Sport Fish Sampling and Analysis. Office of Environmental Health Hazard Assessment 2005. http://www.oehha.ca.gov/fish/pdf/fishsampling041906.pdf.

Oliver BG, Niimi AJ. Trophodynamic analysis of polychlorinated biphenyl congeners and other chlorinated hydrocarbons in Lake Ontario ecosystem. Environ Sci Technol 1988; 22:388-397.

Olsson A, Valters K, Burreau S. Concentrations of organochlorine substances in relation to fish size and trophic position: a study on perch (perca fluviatilis L.). Environ Sci Technol 2000;34:4878-86.

Persson ME, Larsson P, Holmqvist N, Stenroth P. Large variation in lipid content ΣPCB and δ13C within individual Atlantic salmon (Salmo salar). Environ Pollut 2007;145:131-7.

Pikkarainen A, Parmanne R. Polychlorinated biphenyls and organochlorine pesticides in Baltic herring 1985-2002. Baseline/ Marine Pollut Bull 2006;52:1299-309.

Raldua D, Ferrando P, Duran C, Pedrocchi C. The influence of place of capture, sex, and season on the organochlorine pesticide content in barbel (Barbus graellsi) from northeastern Spain. Chemosphere 1997;35:2245-54.

Rasmussen JB, Rowan DJ, Lean DRS, Carey JH. Food chain structure in Ontario Lakes determines PCB levels in lake trout (Salvelinus namaycush) and other pelagic fish. Can J Fish Aquat Sci 1990;47:2030-8.

Ryan MJ, Stern GA, Diamond M, Croft MV, Roach P, Kidd K. Temporal trends of organochlorine contaminants on burbot and lake trout from the three selected Yukon lakes. Sci Total Environ 2005;351-2:501-22.

Sapota G. Decreasing trend of persistent organic pollutants (POPs) in herring from the southern Baltic Sea. Int J Oceanogr Hydrobiol 2006;35:15-21.

Schmitt CJ. Organochlorine residues in fish from the Mississippi River basin, 1995. Arch Environ Contam Toxicol 2002; 43:81-97.

Schmitt CJ, Hinck JE, Blazer VS, Denslow ND, Dethloff GM, Bartish TM, Coyle JJ, Tillitt DE. Environmental contaminants and biomarker responses in fish from the Rio Grande and its U.S. tributaries: spatial and temporal trends. Sci Total Environ 2005;350:161-93.

Stapleton HM, Skubinna J, Baker JE. Seasonal dynamics of PCB and toxaphene bioaccumulation within a Lake Michigan food web. J Great Lakes Res 2002;28:52-64.

State Water Resources Control Board. Qater Quality Control Policy for Developing California's Clean Water Act Section 303(d) list. Sept 2004.

Stow CA, Carpenter SR, Eby LA, Amrhein JF, Hesselberg RJ. Evidence that PCBs are approaching stable concentrations in Lake Michigan fishes. Eco Applic 1995;5:248-60.

Stow CA, Jackson LJ, Amrhein JF. An examination of the PCB:lipid relationship among individual fish. Can J Fish Aquat Sci 1997;54:1031-8.

Stow CA, Jackson LJ, Carpenter SR. A mixed-order model to assess contaminant declines. Environ Monit Assess 1999;55:435-44.

Stow CA, Lamon EC, Qian SS, Schrank CS. Will Lake Michigan lake trout meet the

Great Lakes strategy 2002 PCB reduction goal? Environ Sci Technol 2004;38:359-63.

Stow CA. Factors associated with PCB concentrations in Lake Michigan salmonids. Environ Sci Technol 1995;29:522-7.

Swackhamer D, Hites RA. Occurrence and bioaccumulation of organochlorine compounds in fishes from Siskiwit Lake, Isle Royale, Lake Superior. Environ Sci Technol 1988; 22:543-548.

Thomann RV, Connolly JP. Model of PCB in the Lake Michigan lake trout food chain. Environ Sci Techno. 1984; 18:65-72.

Webster E, Mackay D, Qiang K. Equilibrium lipid partitioning concentrations as a multi-media synoptic indicator of contaminant levels and trends in aquatic ecosystems. J Great Lakes Res 1999;25:318-29.

Weis P, Ashley JTF. Contaminants in fish of the Hackensack Meadowlands, New Jersey: size, sex, and seasonal relationships as related to health risks. Arch Environ Contam Toxicol 2007;52:80-9.

Zanden MJV, Rasmussen JB. A trophic position model of pelagic food webs: impact on contaminant bioaccumulation in lake trout. Ecolog Monogr 1996;66:451-77.

Table 1. Sites sampled in 2005 for fish tissue analysis of PCBs and OCs.

| Sites Selected By | Watershed | Site Name | GPS Latitude | GPS Longitude |
|---|---|---|---|---|
| UCD | Delta | Beaver Slough (off S Fork Mokelumne River) | 38.20393 | -121.4474 |
| UCD/OEHHA | Delta | Calaveras River | 37.96649 | -121.36825 |
| OEHHA | Delta | Camanche Reservoir | 38.2256 | -120.98029 |
| UCD/OEHHA | Delta | Clifton Court Forebay | 37.8311 | -121.59006 |
| UCD | Delta | Cosumnes River @ Hwy 99 | 38.35929 | -121.34253 |
| UCD/OEHHA | Delta | Frank's Tract | 38.04182 | -121.62649 |
| UCD/OEHHA | Delta | Lost Slough (off Cosumnes River) | 38.26714 | -121.43847 |
| UCD | Delta | Middle River @ Bullfrog | 37.93739 | -121.5306 |
| OEHHA | Delta | Middle River @ Hwy 4 | 37.89104 | -121.48879 |
| UCD/OEHHA | Delta | Mokelumne River @ Lodi Lake | 38.21733 | -121.05276 |
| UCD/OEHHA | Delta | Paradise Cut | 37.80021 | -121.37002 |
| UCD | Delta | Prospect Slough (mid-Prospect) | 38.26284 | -121.6715 |
| UCD | Delta | Sand Mound Slough | 38.0083 | -121.6225 |
| UCD/OEHHA | Delta | Whiskey Slough | 37.96417 | -121.46522 |
| UCD | Delta | Big Break | 38.01355 | -121.72631 |
| UCD | Delta | Discovery Bay | 37.91443 | -121.60072 |
| UCD | Delta | Woodward Island | 37.93869 | -121.56067 |
| UCD/OEHHA | Delta | Old River @ Tracy Blvd | 37.80355 | -121.44653 |
| UCD/OEHHA | Delta | Smith Canal | 37.9602 | -121.3385 |
| SRWP | Sac River | American River @ Discovery Park | 38.60094 | -121.5055 |
| SRWP | Sac River | American River @ Nimbus Dam | 38.68273 | -121.17512 |
| SRWP | Sac River | Clear Creek | 40.50563 | -122.36662 |
| SRWP | Sac River | Colusa Basin Drain @ Rd 99E | 38.8119 | -121.7738 |
| UCD/SRWP | Sac River | Feather River @ Gridley | 39.36549 | -121.64545 |
| UCD/SRWP | Sac River | Feather River @ Nicolaus | 38.89746 | -121.5905 |
| SRWP | Sac River | Sacramento River @ Bend Bridge | 40.25545 | -122.22656 |
| SRWP | Sac River | Sacramento River @ Colusa | 39.13471 | -121.93889 |
| SRWP | Sac River | Sacramento River @ Grimes | 39.04619 | -121.83951 |
| SRWP | Sac River | Sacramento River @ Hamilton City | 39.7515 | -121.99749 |
| SRWP | Sac River | Sacramento River @ Ord Bend | 39.62836 | -121.99236 |
| SRWP | Sac River | Sacramento River @ Rio Vista | 38.15427 | -121.68859 |
| SRWP | Sac River | Sacramento River @ RM44 | 38.4348 | -121.5233 |
| SRWP | Sac River | Sacramento River @ Woodson Bridge | 39.91273 | -122.09313 |
| SRWP | Sac River | Sacramento River @ Veterans Bridge | 38.67506 | -121.6286 |
| SRWP | Sac River | Sacramento Slough @ Karnak | 37.88439 | -121.65232 |
| UCD/SRWP | Sac River | Yuba River @ Marysville | 39.16607 | -121.5529 |

(continued)

Table 1. (continued)

| Sites Selected By | Watershed | Site Name | GIS Latitude | GIS Longitude |
|---|---|---|---|---|
| OEHHA | Sac River | Lake Britton | 41.0189 | -121.62321 |
| OEHHA | Sac River | Shasta Lake | 40.89218 | -122.38187 |
| OEHHA | Sac River | Shasta Lake @ Main Stem | 40.71541 | -122.40836 |
| OEHHA | Sac River | Whiskeytown Lake @ Clear Creek | 40.64779 | -122.61594 |
| SRWP | Sac River | Bear River b/w Feather River and HWY 99 (near Rio Oso) | 38.96172 | -121.5475 |
| OEHHA | Sac River | Baum Lake | 40.93512 | -121.54773 |
| OEHHA | Sac River | Bucks Lake | 39.88745 | -121.18687 |
| OEHHA | Sac River | Bullards Bar Reservoir @ East Arm | 39.39477 | -121.14081 |
| OEHHA | Sac River | East Park Reservoir @ SE Side | 39.329167 | -122.496944 |
| OEHHA | Sac River | Indian Valley Reservoir @ North | 39.1513 | -122.55725 |
| OEHHA | Sac River | Stoney Gorge Reservoir @ Dam | 39.58817 | -122.52608 |
| SRWP | Sac River | American River Hatchery | | |
| SRWP | Sac River | Mt Shasta Hatchery | | |
| SRWP | Sac River | Feather River Hatchery | | |
| SRWP | Sac River | Nimbus Hatchery | | |
| OEHHA | SJ River | Mendota Pool/Mendota (Fresno) Slough | 36.78584 | -120.37166 |
| UCD | SJ River | Merced River @ Hatfield State Park | 37.35606 | -120.96031 |
| UCD | SJ River | Salt Slough @ Hwy 165 | 37.19189 | -120.82478 |
| UCD | SJ River | San Joaquin River @ Crows Landing | 37.48125 | -121.0652 |
| UCD | SJ River | San Joaquin River @ Fremont Ford | 37.30971 | -120.93076 |
| OEHHA | SJ River | San Joaquin River @ Hwy 99 | 36.84256 | -119.93306 |
| OEHHA | SJ River | San Joaquin River @ Mossdale | 37.79239 | -121.31161 |
| UCD | SJ River | San Joaquin River @ Patterson | 37.49783 | -121.08249 |
| UCD | SJ River | San Joaquin River @ Potato Slough | 38.08784 | -121.52031 |
| UCD | SJ River | San Joaquin River @ Vernalis | 37.6713 | -121.2592 |
| UCD/OEHHA | SJ River | San Joaquin River at Laird Park (near J16 and Grayson Rd) | 37.56132 | -121.14727 |
| UCD | SJ River | Stanislaus River @ Caswell State Park | 37.6948 | -121.20478 |
| UCD | SJ River | Tuolumne River @ Shiloh Rd. | 37.60315 | -121.13162 |
| OEHHA | SJ River | Lake Almanor @ North | 40.30962 | -121.19527 |
| OEHHA | SJ River | (New) Hogan Reservoir | 38.16201 | -120.7999 |
| OEHHA | SJ River | Jenkinson Lake | 38.71921 | -120.56369 |
| OEHHA | SJ River | Millerton Lake | 37.01828 | -119.6993 |
| OEHHA | SJ River | Pardee Reservoir | 38.25649 | -120.84867 |
| OEHHA | SJ River | San Joaquin River Hatchery | | |
| SRWP | Sac River | Darrah Springs Hatchery | | |
| OEHHA | Sac River | Colman Hatchery | | |
| OEHHA | SJ River | Moccasin Creek Hatchery | | |

Table 2. Waterways sampled in this project that are on the Central Valley Regional Water Quality Control Board's Clean Water Act §303(d) list due to organochlorine pesticides or PCB contamination.

| Waterway | Listed for |
|---|---|
| Colusa Basin Drain | Group A pesticides |
| Lower Feather River | Group A pesticides |
| Natomas East Main Drainage | PCBs |
| Lower San Joaquin River | DDTs, Group A pesticides |
| Lower Merced River | Group A pesticides |
| Lower Tuolumne River | Group A pesticides |
| Lower Stanislaus River | Group A pesticides |
| Delta waterways (eastern portion) | DDTs, Group A pesticides |
| Delta waterways (western portion) | DDTs, Group A pesticides |
| Delta waterways (northern portion) | DDTs, PCBs |
| Delta waterways (southern portion) | DDTs |

Table 3. OEHHA screening values (ng/g wet weight).

| Chemical | OEHHA Value | OEHHA 2006 Proposed Value | US EPA Value |
|---|---|---|---|
| Chlordane | 30 | 200 | 17 |
| Total DDT | 100 | 560 | 17 |
| Dieldrin | 2 | 16 | 0.4 |
| PCBs | 20 | 20 | 3 |

Table 4. OEHHA guidance tissue levels for selected fish contaminants based on cancer and non-cancer risk* (ppb, wet weight).

**Table 1. Guidance Tissue Levels for Selected Fish Contaminants Based on Cancer and Non-Cancer Risk* (ppb, wet weight)**

| | 12 Meals/ Month (90.0 g/day)** | 8 Meals/ Month (60.0 g/day)** | 4 Meals/ Month (30.0 g/day)** | 1 Meal/ Month (7.5 g/day)** | No Consumption |
|---|---|---|---|---|---|
| **Contaminant Cancer Slope Factor (mg/kg/day)$^{-1}$** | | | | | |
| Chlordane (1.3) | **≤200** | **>200-300** | **>300-600** | **>600-2,390** | **>2,390** |
| DDTs (0.34) | ≤760 | >760-1140 | >1140-2,290 | >2,290-9150 | >9150 |
| Dieldrin (16) | **≤16** | **>16-24** | **>24-49** | **>49-194** | **>194** |
| PCBs (2) | ≤130 | >130-190 | >190-390 | >390-1560 | >1560 |
| Toxaphene (1.2) | **≤220** | **>220-320** | **>320-650** | **>650-2,590** | **>2,590** |
| **Contaminant Reference Dose (mg/kg-day)** | | | | | |
| Chlordane ($5x10^{-4}$) | ≤560 | >560-830 | >830-1670 | >1670-6670 | >6670 |
| DDTs ($5x10^{-4}$) | **≤560** | **>560-830** | **>830-1670** | **>1670-6670** | **>6670** |
| Dieldrin ($5x10^{-5}$) | ≤60 | >60-80 | >80-170 | >170-670 | >670 |
| Methylmercury ($1x10^{-4}$)$^{S}$ | **≤ 80** | **>80-120** | **>120-230** | **>230-930** | **>930** |
| Methylmercury ($3x10^{-4}$)$^{G}$ | **≤230** | **>230-350** | **>350-700** | **>700-2,800** | **>2,800** |
| PCBs ($2x10^{-5}$) | **≤20** | **>20-30** | **>30-70** | **>70-270** | **>270** |
| Selenium ($5x10^{-3}$)$^{-S}$ | **≤2,620** | **>2,620-3,930** | **>3,930-7,870** | **>7,870-31,470** | **>31,470** |
| Selenium ($5x10^{-3}$)$^{+S}$ | **≤1,940** | **>1,940-2,920** | **>2,920-5,830** | **>5,830-23,330** | **>23,330** |
| Toxaphene ($3.5x10^{-4}$) | ≤390 | >390-580 | >580-1170 | >1170-4670 | >4670 |

*The most conservative GTL values for each chemical (cancer slope factor versus reference dose-derived) used for development of fish consumption guidelines are bolded. With the exception of dieldrin, values are rounded to the nearest 10's place.

**g/day represents the average amount of fish consumed daily, distributed over a 30-day period.

$^{S}$GTL for sensitive populations (i.e., women of childbearing age and children 17 and under.)

$^{G}$GTL for general populations (i.e., women beyond childbearing age and men.)

$^{-S}$: GTL for consumers who do not take selenium supplements in excess of the RDA;

$^{+S}$: GTL for consumers who take selenium supplements in excess of the RDA

Table 5. Organochlorine pesticides included in analyses.

| Organochlorine Pesticides analyzed |
| --- |
| Aldrin |
| Chlordane, cis- |
| Chlordane, trans- |
| Dacthal |
| DDD(o,p') |
| DDD(p,p') |
| DDE(o,p') |
| DDE(p,p') |
| DDMU(p,p') |
| DDT(o,p') |
| DDT(p,p') |
| Dieldrin |
| Endosulfan I |
| Endosulfan II |
| Endosulfan sulfate |
| Endrin |
| HCH, alpha |
| HCH, beta |
| HCH, gamma |
| HCH, delta |
| Heptachlor |
| Heptachlor epoxide |
| Hexachlorobenzene |
| Methoxychlor |
| Mirex |
| Nonachlor, cis- |
| Nonachlor, trans- |
| Oxadiazon |
| Oxychlordane |
| Tedion |
| Toxaphene |
| **Surrogates** |
| PCB 209 $C^{13}$(Surrogate) |
| Dibromooctafluorobiphenyl(Surrogate) |
| DDD*(p,p')(Surrogate) |
| DBCE(Surrogate) |

Table 6. PCBs included in analyses.

| Polychlorinated Biphenyl (PCB) Congeners and Arochlor Compounds | |
|---|---|
| PCB 008 | PCB 141 |
| PCB 018 | PCB 149 |
| PCB 027 | PCB 151 |
| PCB 028 | PCB 153 |
| PCB 029 | PCB 156 |
| PCB 031 | PCB 157 |
| PCB 033 | PCB 158 |
| PCB 044 | PCB 170 |
| PCB 049 | PCB 174 |
| PCB 052 | PCB 177 |
| PCB 056 | PCB 180 |
| PCB 060 | PCB 183 |
| PCB 066 | PCB 187 |
| PCB 070 | PCB 189 |
| PCB 074 | PCB 194 |
| PCB 087 | PCB 195 |
| PCB 095 | PCB 200 |
| PCB 097 | PCB 201 |
| PCB 099 | PCB 203 |
| PCB 101 | PCB 206 |
| PCB 105 | PCB 209 |
| PCB 110 | **Surrogate (% Recovery)** |
| PCB 114 | PCB 209 $C^{13}$(Surrogate) |
| PCB 118 | **Calculated values from Lab** |
| PCB 128 | PCB AROCLOR 1248 |
| PCB 137 | PCB AROCLOR 1254 |
| PCB 138 | PCB AROCLOR 1260 |

Table 7. Organochlorine target reporting limits (TRL) for tissue samples. EPA 8081AM using GC-ECD.

| Trace organic parameters in tissue - ng/g (DFG WPCL) | |
|---|---|
| **Organochlorine** | **TRL ppb (ng/g)** |
| Aldrin | 1 |
| Chlordane, cis- | 1 |
| Chlordane, trans- | 1 |
| Dacthal | 1 |
| DDD(o,p') | 1 |
| DDD(p,p') | 1 |
| DDE(o,p') | 2 |
| DDE(p,p') | 2 |
| DDMU(p,p') | 3 |
| DDT(o,p') | 3 |
| DDT(p,p') | 5 |
| Dieldrin | 0.5 |
| Endosulfan I | 2 |
| Endosulfan II | 5 |
| Endosulfan sulfate | 5 |
| Endrin | 2 |
| HCH, alpha | 0.5 |
| HCH, beta | 1 |
| HCH, gamma | 0.5 |
| HCH, delta | 2 |
| Heptachlor | 1 |
| Heptachlor epoxide | 1 |
| Hexachlorobenzene | 0.3 |
| Methoxychlor | 3 |
| Mirex | 1.5 |
| Nonachlor, cis- | 1 |
| Nonachlor, trans- | 1 |
| Oxadiazon | 1 |
| Oxychlordane | 1 |
| Tedion | 2 |
| Toxaphene | Scr |
| **Surrogates** | |
| PCB 209 $C^{13}$(Surrogate) | Reported |
| Dibromooctafluorobiphenyl(Surrogate) | Reported |
| DDD*(p,p')(Surrogate) | Reported |
| DBCE(Surrogate) | Reported |
| Scr: screening data only no QC; separate charge if analyte is requested with QC | |

Table 8. PCB target reporting limits (TRL) for tissue samples. EPA Method 8082M.

| Trace organic parameters in tissue - ng/g (DFG WPCL) | | | |
|---|---|---|---|
| **PCB** | **TRL ppb (ng/g)** | **PCB** | **TRL ppb (ng/g)** |
| PCB 008 | 0.2 | PCB 141 | 0.2 |
| PCB 018 | 0.2 | PCB 149 | 0.2 |
| PCB 027 | 0.2 | PCB 151 | 0.2 |
| PCB 028 | 0.2 | PCB 153 | 0.2 |
| PCB 029 | 0.2 | PCB 156 | 0.2 |
| PCB 031 | 0.2 | PCB 157 | 0.2 |
| PCB 033 | 0.2 | PCB 158 | 0.2 |
| PCB 044 | 0.2 | PCB 170 | 0.2 |
| PCB 049 | 0.2 | PCB 174 | 0.2 |
| PCB 052 | 0.2 | PCB 177 | 0.2 |
| PCB 056 | 0.2 | PCB 180 | 0.2 |
| PCB 060 | 0.2 | PCB 183 | 0.2 |
| PCB 066 | 0.2 | PCB 187 | 0.2 |
| PCB 070 | 0.2 | PCB 189 | 0.2 |
| PCB 074 | 0.2 | PCB 194 | 0.2 |
| PCB 087 | 0.2 | PCB 195 | 0.2 |
| PCB 095 | 0.2 | PCB 200 | 0.2 |
| PCB 097 | 0.2 | PCB 201 | 0.2 |
| PCB 099 | 0.2 | PCB 203 | 0.2 |
| PCB 101 | 0.2 | PCB 206 | 0.2 |
| PCB 105 | 0.2 | PCB 209 | 0.2 |
| PCB 110 | 0.2 | **Surrogate (% Recovery)** | |
| PCB 114 | 0.2 | PCB 209 $C^{13}$(Surrogate) | Reported |
| PCB 118 | 0.2 | **Calculated values from Lab** | |
| PCB 128 | 0.2 | PCB AROCLOR 1248 | 25 |
| PCB 137 | 0.2 | PCB AROCLOR 1254 | 10 |
| PCB 138 | 0.2 | PCB AROCLOR 1260 | 10 |

Table 9. San Joaquin River watershed and Delta fish tissue composites with PCB concentrations ranging from 9 to 17 ng/g

| ***Sites*** | ***Species*** | ***PCB Concentration (ng/g)*** |
|---|---|---|
| San Joaquin River @ Crows Landing | Sacramento Sucker | 11 |
| San Joaquin River @ Vernalis | Carp | 14 |
| Middle River | White Catfish | 9 |
| Smith Canal | White Catfish | 16, 17 |
| Prospect Slough | White Catfish<br>Striped Bass | 10, 12<br>11 |
| Mokelumne River @ Lodi Lake | Sacramento Sucker | 13 |

Table 10. San Joaquin River watershed and Delta fish tissue samples with PCB concentrations at or above 20 ng/g (OEHHA screening value).

| ***Sites*** | ***Species*** | ***PCB Concentration (ng/g)*** |
|---|---|---|
| Tuolumne River @ Shiloh | Sacramento Sucker | 38, 32 |
| Mokelumne River @ Lodi Lake | Sacramento Sucker | 23 |
| San Joaquin River @ Vernalis | Sacramento Sucker | 27 |
| Potato Slough | Sacramento Sucker | 46 |
| Prospect Slough | Sacramento Sucker | 20 |
| Big Break | Sacramento Sucker | 33 |

Table 11. PCB concentrations in composites of different fish species from the San Joaquin River watershed and Delta.

| ***Site*** | ***Species*** | ***Composite Mean Length (mm)*** | ***PCB Concentration (ng/g)*** |
|---|---|---|---|
| Tuolumne River @ Shiloh Rd. | Sacramento Sucker | 456, 467 | 38, 22 |
| | Channel Catfish | 418 | <RL* |
| | Carp | 545 | <RL |
| Merced River @ Hatfield St. Park | Sacramento Sucker | 375, 386 | <RL, <RL |
| | Channel Catfish | 381 | <RL |
| | Carp | 508 | <RL |
| San Joaquin River @ Crows Landing | White Catfish | 236 | <RL |
| | Sacramento Sucker | 421 | 11 |
| | Large Mouth Bass | 394 | <RL |
| | Bluegill | 150 | <RL |
| | Red-ear Sunfish | 182 | <RL |
| | Carp | 475 | <RL |
| | Channel Catfish | 376 | <RL |
| San Joaquin River @ Veranalis | White Catfish | 245 | <RL |
| | Sacramento Sucker | 463 | 27 |
| | Large Mouth Bass | 369 | <RL |
| | Bluegill | 148 | <RL |
| | Red-ear Sunfish | 191 | <RL |
| | Carp | 505 | <RL |
| | Channel Catfish | 338 | <RL |
| Prospect Slough | White Catfish | 255, 253 | 10, 12 |
| | Sacramento Sucker | 434 | 20 |
| | Large Mouth Bass | 357 | <RL |
| | Carp | 517 | <RL |
| | Crappie | 271 | <RL |
| | Striped Bass | 300 | <RL |
| | Sacramento Perch | 140 | <RL |
| | Hitch | 283 | <RL |
| | Sacramento Pike Minnow | 271 | <RL |
| Paradise Cut | White Catfish | 275, 278 | <RL, <RL |
| | Bluegill | 165 | <RL |
| | Red-ear Sunfish | 222 | <RL |
| Frank’s Tract | White Catfish | 343, 278 | <RL, <RL |
| | Bluegill | 157 | <RL |
| | Sacramento Perch | 173 | <RL |

*RL—reporting limit

Table 12. Average PCB concentration in white catfish and Sacramento suckers collected in the San Joaquin River and areas of the Delta during 2005.

| ***Location*** | ***PCB Mean actual (geometric)*** | ***95% Confidence Limits Lower*** | ***Upper*** |
|---|---|---|---|
| San Joaquin River (6 sites) | | | |
| White catfish (n=8) | 3 | 2 | 4 |
| | (3) | (2) | (4) |
| Sacramento sucker (n=2) | 19 | NA | NA |
| | (17) | NA | NA |
| South Delta (7 sites) | | | |
| White catfish (n=12) | 4 | 2 | 6 |
| | (2.75) | (1.7) | (4.6) |
| East Delta (4 sites) | | | |
| White catfish (n=4) | 10 | 0 | 22 |
| | (7) | (2) | (12) |
| Sacramento sucker (n=2) | 25 | NA | NA |
| | (14) | NA | NA |
| West Delta (3 sites) | | | |
| White catfish (n=5) | 3 | 2 | 4 |
| | (3) | (2) | (4) |
| Entire Delta* (15 sites) | | | |
| White catfish (n=23) | 5 | 3 | 7 |
| | (4) | (3) | (5) |
| Sacramento sucker (n=4) | 28 | 0 | 56 |
| | (21) | (16) | (26) |

*Includes the Delta sites in this table and Prospect Slough.
San Joaquin River sites: Fremont Ford, Crow's Landing, Patterson, Laird Park, Vernalis & Mossdale.
South Delta sites: Paradise Cut, Old River, Middle River, Whiskey Slough, Clifton Court, Discovery Bay, & Orwood Tract.
East Delta sites: Potato Slough, Beaver Slough, Smith Canal, & Lost Slough.
West Delta sites: Frank's Tract, Big Break, & Sand Mound Slough.

Table 13. Relationship among PCB contamination fish species, length, and composite lipid content.

| ***Species*** | ***#>RL****<br>***Sample number*** | ***Mean length*****<br>***(95% CI)*** | ***Mean percent lipid***<br>***(95% CI)*** |
|---|---|---|---|
| Sacramento sucker | 9<br>16 | 416<br>(396-437) | 3.27<br>(1.86-4.72) |
| White catfish | 5<br>33 | 279<br>(265-293) | 0.64<br>(0.53-0.74) |
| Carp | 1<br>7 | 531<br>(455-607) | 0.82<br>(0.41-1.23) |
| Channel catfish | 0<br>9 | 393<br>(348-438) | 0.74<br>(0.57-0.91) |
| Large mouth bass | 0<br>3 | 374<br>(352-395) | 0.71<br>(0.36-1.06) |
| Red-ear sunfish | 0<br>7 | 194<br>(179-209) | 0.46<br>(0.40-0.52) |
| Bluegill | 0<br>10 | 148<br>(134-162) | 0.60<br>(0.44-0.76) |
| Crappie | 0<br>1 | 271 | 0.35 |
| Sacramento perch | 0<br>2 | 170 | 0.74 |
| Sac pike minnow | 0<br>1 | 271 | 0.57 |
| Striped bass | 1<br>1 | 301 | 0.91 |
| Hitch | 0<br>1 | 283 | 0.285 |

*RL = reporting level
**Value is actually the average of the average length (mm) of fish in composites

Table 14. Results of regression analyses on composites (n=16) of Sacramento sucker collected in the San Joaquin River watershed and Delta—PCB data.

| ***X and Y axes*** | $R^2$ | ***P value*** |
|---|---|---|
| % lipid vs [PCB] | 0.66 | 0.0001 |
| log % lipid vs. log [PCB] | 0.76 | <0.00001 |
| mean length vs. [PCB] | 0.51 | 0.002 |
| log mean length vs. log [PCB] | 0.52 | 0.002 |
| mean length vs. % lipid | 0.29 | 0.03 |
| log mean length vs. log % lipid | 0.42 | 0.007 |
| lipid-normalized [PCB] vs [PCB] | 0.51 | 0.002 |
| log lipid-normalized [PCB] vs log [PCB] | 0.80 | <0.00001 |
| % lipid vs lipid-normalized [PCB] | 0.05 | 0.38 |
| log % lipid vs log lipid-normalized [PCB] | 0.34 | 0.02 |

Table 15. Regression analysis of contaminant covariance in Sacramento Sucker composites from the San Joaquin River watershed and Delta.

| ***X and Y axes*** | $\boldsymbol{R^2}$ | ***P*** |
|---|---|---|
| log [PCB] vs log [dieldrin] | 0.37 | 0.01 |
| log lipid-normalized [PCB] vs lipid-normalized [dieldrin] | 0.01 | 0.75 |
| log [PCB] vs log [DDT] | 0.54 | 0.001 |
| log lipid-normalized [PCB] vs lipid-normalized [DDT] | 0.23 | 0.06 |
| log [dieldrin] vs log [DDT] | 0.74 | <0.0001 |
| log lipid-normalized [dieldrin] vs lipid-normalized [DDT] | 0.02 | 0.57 |

Table 16. Rank correlation analysis of contaminant covariance in Sacramento sucker composites from the San Joaquin River watershed and Delta.

| X and Y axes | Rho | P |
|---|---|---|
| log [PCB] vs log [dieldrin] | 0.45 | 0.004 |
| log lipid-normalized [PCB] vs lipid-normalized [dieldrin] | 0.05 | 0.37 |
| log [PCB] vs log [DDT] | 0.61 | 0.0003 |
| log lipid-normalized [PCB] vs lipid-normalized [DDT] | 0.22 | 0.06 |
| log [dieldrin] vs log [DDT] | 0.89 | <0.0001 |
| log lipid-normalized [dieldrin] vs lipid-normalized [DDT] | 0.14 | 0.15 |

Table 17. Results of regression analyses on composites (n=32) of white catfish collected in the San Joaquin River watershed and Delta—PCB data.

| ***X and Y axes*** | ***$R^2$*** | ***P value*** |
|---|---|---|
| % lipid vs. [PCB] | 0.0003 | 0.92 |
| log % lipid vs. log [PCB] | 0.08 | 0.11 |
| mean length vs. [PCB] | 0.02 | 0.42 |
| log mean length vs. log [PCB] | 0.005 | 0.70 |
| mean length vs. % lipid | 0.22 | 0.006 |
| log mean length vs. log % lipid | 0.10 | 0.07 |

Table 18. San Joaquin River watershed and Delta fish tissue composites with dieldrin concentrations ranging from 1.1 to 1.9 ng/g.

| ***Site*** | ***Species*** | ***Dieldrin Concentration (ng/g)*** |
|---|---|---|
| Salt Slough | Channel Catfish<br>Carp | 1.6<br>1.35 |
| Merced River @ Hatfield Park | Sacramento Sucker | 1.4 |
| Tuolumne River @ Shiloh | Sacramento Sucker | 1.25 |
| San Joaquin River @ Fremont Ford | White Catfish | 1.9 |
| San Joaquin River @ Crows Landing | Large Mouth Bass<br>Bluegill<br>Carp<br>Channel Catfish | 1.2<br>1.7<br>1.5<br>1.4 |
| San Joaquin River @ Laird Park | White Catfish | 1.3 |
| San Joaquin River @ Vernalis | Large Mouth Bass<br>Bluegill<br>Channel Catfish | 1.1<br>1.4<br>1.1 |
| Whiskey Slough | White Catfish | 1.1 |
| Discovery Bay | Channel Catfish | 1.4 |

Table 19. San Joaquin River watershed and Delta fish tissue composites with dieldrin concentrations above 2.0 ng/g (OEHHA screening value).

| ***Site*** | ***Species*** | ***Dieldren Concentration (ng/g)*** |
|---|---|---|
| Salt Slough | Channel Catfish | 2.5 |
| Tuolumne River @ Shiloh | Sacramento Sucker | 2.5 |
| San Joaquin River @ Crows Landing | Sacramento Sucker | 2.3 |
| San Joaquin River @ Vernalis | Sacramento Sucker<br>Carp | 3.4<br>2.5 |
| Potato Slough | Sacramento Sucker | 13.9 |
| Prospect Slough | Sacramento Sucker<br>Carp | 4.0<br>2.1 |
| Big Break | Sacramento Sucker | 2.2 |

Table 20. Dieldrin concentrations in composites of different fish species from the San Joaquin River watershed and Delta.

| ***Site*** | ***Species*** | ***Composite Mean Length (mm)*** | ***Dieldrin Concentration (ng/g)*** |
|---|---|---|---|
| Tuolumne River @ Shiloh Rd. | Sacramento Sucker | 456, 467 | 1.25, 2.5 |
| | Channel Catfish | 418 | 0.8 |
| | Carp | 545 | 0.9 |
| Meced River @ Hatfield State Park | Sacramento Sucker | 375, 386 | 1.4, 0.8 |
| | Channel Catfish | 381 | 0.9 |
| | Carp | 508 | 0.5 |
| San Joaquin River @ Crows Landing | White Catfish | 236 | 0.7 |
| | Sacramento Sucker | 421 | 2.3 |
| | Large Mouth Bass | 394 | 1.2 |
| | Bluegill | 150 | 1.7 |
| | Red-ear Sunfish | 182 | <RL |
| | Carp | 475 | 1.5 |
| | Channel Catfish | 376 | 1.4 |
| San Joaquin River @ Veranalis | White Catfish | 245 | 0.6 |
| | Sacramento Sucker | 463 | 3.4 |
| | Large Mouth Bass | 369 | 1.1 |
| | Bluegill | 148 | 1.4 |
| | Red-ear Sunfish | 191 | 0.5 |
| | Carp | 505 | 2.5 |
| | Channel Catfish | 338 | 1.1 |
| Prospect Slough | White Catfish | 255, 253 | 1.4, 0.8 |
| | Sacramento Sucker | 434 | 4.0 |
| | Large Mouth Bass | 357 | 0.6 |
| | Carp | 517 | 2.1 |
| | Crappie | 271 | 0.5 |
| | Striped Bass | 300 | 0.6 |
| | Sacramento Perch | 140 | 1.4 |
| | Hitch | 283 | 0.6 |
| | Sacramento Pike Minnow | 271 | 0.5 |
| Paradise Cut | White Catfish | 275, 278 | 0.4, 0.6 |
| | Bluegill | 165 | 0.7 |
| | Red-ear sunfish | 222 | 0.6 |
| Frank’s Tract | White catfish | 343, 337 | 0.8, 0.6 |
| | Bluegill | 157 | 0.85 |
| | Sacramento perch | 173 | <RL |

Table 21. Average dieldrin concentration in white catfish and Sacramento suckers collected in the San Joaquin River and areas of the Delta during 2005.

| Location | Dieldrin Mean actual (geometric) | 95% Confidence Limits Lower | Upper |
|---|---|---|---|
| San Joaquin River (6 sites) | | | |
| White catfish (n=8) | 0.9 | 0.5 | 1.3 |
| | (0.9) | (0.7) | (1.1) |
| Sacramento sucker (n=2) | 2.85 | NA | NA |
| | (2.8) | NA | NA |
| South Delta (7 sites) | | | |
| White catfish (n=12) | 0.6 | 0.5 | 0.7 |
| | (0.55) | (0.46) | (0.64) |
| East Delta (4 sites) | | | |
| White catfish (n=4) | 0.4 | 0.2 | 0.5 |
| | (0.4) | (0.035) | (0.073) |
| Sacramento sucker (n=2) | 7.35 | NA | NA |
| | (3.6) | NA | NA |
| West Delta (3 sites) | | | |
| White catfish (n=5) | 0.5 | 0.4 | 0.6 |
| | (0.5) | (0.4) | (0.6) |
| Entire Delta* (15 sites) | | | |
| White catfish (n=23) | 0.6 | 0.5 | 0.7 |
| | (0.5) | (0.45) | (0.55) |
| Sacramento sucker (n=4) | 5.1 | 0 | 14.7 |
| | (3.2) | (0) | (19) |

*Includes the Delta sites in this table and Prospect Slough.
San Joaquin River sites: Fremont Ford, Crow's Landing, Patterson, Laird Park, Vernalis & Mossdale.
South Delta sites: Paradise Cut, Old River, Middle River, Whiskey Slough, Clifton Court, Discovery Bay, & Orwood Tract.
East Delta sites: Potato Slough, Beaver Slough, Smith Canal, & Lost Slough.
West Delta sites: Frank's Tract, Big Break, & Sand Mound Slough.

Table 22. Relationship among dieldrin contamination, fish species, length, and composite lipid content.

| ***Species*** | ***#>RL****<br>***Sample number*** | ***Mean length*****<br>***(95% CI)*** | ***Mean percent lipid***<br>***(95% CI)*** |
|---|---|---|---|
| Sacramento sucker | 14<br>16 | 416<br>(396-437) | 3.27<br>(1.86-4.72) |
| White catfish | 17<br>33 | 279<br>(265-293) | 0.64<br>(0.53-0.74) |
| Carp | 6<br>7 | 531<br>(455-607) | 0.82<br>(0.41-1.23) |
| Channel catfish | 7<br>9 | 393<br>(348-438) | 0.74<br>(0.57-0.92) |
| Large mouth bass | 3<br>3 | 374<br>(352-395) | 0.71<br>(0.36-1.06) |
| Red-ear sunfish | 2<br>7 | 194<br>(179-209) | 0.48<br>(0.45-0.51) |
| Bluegill | 6<br>10 | 148<br>(134-162) | 0.60<br>(0.44-0.76) |
| Crappie | 1<br>1 | 271 | 0.35 |
| Sacramento perch | 1<br>2 | 170 | 0.74 |
| Sac pike minnow | 1<br>1 | 271 | 0.57 |
| Striped bass | 1<br>1 | 301 | 0.91 |
| Hitch | 1<br>1 | 283 | 0.285 |

*RL = reporting level
**Value is actually the average of the average length (mm) of fish in composites

Table. 23. Dieldrin contamination ratios in fish collected from the San Joaquin River watershed and Delta during 2005.

| ***Site*** | | ***Contamination Ratio (species/Sacramento sucker)*** | | | | |
|---|---|---|---|---|---|---|
| | | ***White Catfish*** | ***Carp*** | ***Channel Catfish*** | ***Largemouth Bass*** | ***Bluegill*** |
| San Joaquin @ Crown's Landing | Actual | 0.30 | 0.65 | 0.61 | 0.52 | 0.74 |
| | Size- adjusted | 0.43 | 0.56 | 0.92 | 0.55 | 1.21 |
| San Joaquin @ Vernalis | Actual | 0.18 | 0.73 | 0.32 | 0.32 | 0.41 |
| | Size-adjusted | 0.26 | 0.68 | 0.41 | 0.41 | 0.69 |
| Prospect Slough | Actual | 0.35 | 0.52 | | 0.15 | |
| | Size-adjusted | 0.49 | 0.42 | | 0.18 | |

Table 24. Results of regression analyses on composites (n=16) of Sacramento sucker collected in the San Joaquin River watershed and Delta—dieldrin data.

| X and Y axes | $R^2$ | P value |
|---|---|---|
| % lipid vs. [dieldrin] | 0.93 | <0.00001 |
| log % lipid vs. log [dieldrin] | 0.81 | <0.00001 |
| mean length vs. [dieldrin] | 0.15 | 0.14 |
| log mean length vs. log [dieldrin] | 0.18 | 0.10 |
| mean length vs. % lipid | 0.29 | 0.03 |
| log mean length vs. log % lipid | 0.42 | 0.007 |
| lipid-normalized [dieldrin] vs [dieldrin] | 0.47 | 0.003 |
| log lipid-normalized [dieldrin] vs log [dieldrin] | 0.13 | 0.18 |
| % lipid vs lipid-normalized [dieldrin] | 0.36 | 0.01 |
| log % lipid vs log lipid-normalized [dieldrin] | 0.03 | 0.49 |

Table 25. Results of regression analyses on composites (n=32) of white catfish collected in the San Joaquin River watershed and Delta—dieldrin data.

| X and Y axes | $R^2$ | P value |
|---|---|---|
| % lipid vs. [dieldrin] | 0.06 | 0.16 |
| log % lipid vs. log [dieldrin] | 0.08 | 0.11 |
| mean length vs. [dieldrin] | -0.11 | 0.06 |
| log mean length vs. log [dieldrin] | -0.13 | 0.04 |
| mean length vs. % lipid | 0.22 | 0.006 |
| log mean length vs. log % lipid | 0.10 | 0.07 |

Table 26. San Joaquin River watershed and Delta fish tissue composites with DDT concentrations ranging from 51 to 99 ng/g.

| Site | Species | DDT Concentration (ng/g) |
|---|---|---|
| San Joaquin River @ Crow's Landing | Large mouth bass<br>Carp<br>Channel catfish | 60<br>52<br>81 |
| San Joaquin River @ Vernalis | Large mouth bass<br>Bluegill<br>Channel catfish | 83<br>59<br>78 |
| Big Break | Sacramento sucker | 66 |
| Discovery Bay | Channel catfish | 87 |
| Merced River | Sacramento sucker | 55 |

Table 27. San Joaquin River watershed and Delta fish tissue composites with DDT concentrations above 100 ng/g (OEHHA screening value).

| Site | Species | DDT Concentration (ng/g) |
|---|---|---|
| Tuolumne River @ Shiloh | Sacramento sucker | 339, 269 |
| San Joaquin @ Crow's Landing | Sacramento sucker | 127 |
| San Joaquin @ Laird Park | White catfish | 211, 113 |
| San Joaquin @ Vernalis | Sacramento sucker<br>Carp | 338<br>232 |
| Potato Slough | Sacramento sucker | 346 |
| Prospect Slough | Sacramento sucker | 213 |

Table 28. DDT concentrations in composites of different fish species from the San Joaquin River watershed and Delta.

| Site | Species | Composite Mean Length (mm) | DDT Concentration (ng/g) |
|---|---|---|---|
| Tuolumne River @ Shiloh Rd. | Sacramento Sucker | 456, 467 | 339, 269 |
| | Channel Catfish | 418 | 21 |
| | Carp | 545 | 20 |
| Merced River @ Hatfield St. Park | Sacramento Sucker | 375, 386 | 55, 20 |
| | Channel Catfish | 381 | 11 |
| | Carp | 508 | 6 |
| San Joaquin River @ Crow's Landing | White Catfish | 236 | 33 |
| | Sacramento Sucker | 421 | 127 |
| | Large Mouth Bass | 394 | 59 |
| | Bluegill | 150 | 41 |
| | Red-ear Sunfish | 182 | 15 |
| | Carp | 475 | 52 |
| | Channel Catfish | 376 | 81 |
| San Joaquin River @ Veranalis | White Catfish | 245 | 29 |
| | Sacramento Sucker | 463 | 338 |
| | Large Mouth Bass | 369 | 83 |
| | Bluegill | 148 | 60 |
| | Red-ear Sunfish | 191 | 17 |
| | Carp | 505 | 232 |
| | Channel Catfish | 338 | 78 |
| Prospect Slough | White Catfish | 255, 253 | 30, 36 |
| | Sacramento Sucker | 434 | 213 |
| | Large Mouth Bass | 357 | 6 |
| | Carp | 517 | 30 |
| | Crappie | 271 | 6 |
| | Striped Bass | 300 | 25 |
| | Sacramento Perch | 140 | 28 |
| | Hitch | 283 | 3 |
| | Sacramento Pike Minnow | 271 | 35 |
| Paradise Cut | White Catfish | 275, 278 | 16, 24 |
| | Bluegill | 165 | 12 |
| | Red-ear sunfish | 222 | 9 |
| Frank's Tract | White Catfish | 343, 337 | 8, 5 |
| | Bluegill | 157 | <RL |
| | Sacramento perch | 173 | <RL |

Table 29. Average DDT concentration in white catfish and Sacramento suckers collected in the San Joaquin River and areas of the Delta during 2005.

| Location | DDT Mean actual (geometric) | 95% Confidence Limits Lower | Upper |
|---|---|---|---|
| San Joaquin River (6 sites) | | | |
| White catfish (n=8) | 62 | 6 | 112 |
| | (43) | (21) | (85) |
| Sacramento sucker (n=2) | 232 | NA | NA |
| | (207) | NA | NA |
| South Delta (7 sites) | | | |
| White catfish (n=12) | 15 | 11 | 19 |
| | (14) | (11) | 18 |
| East Delta (4 sites) | | | |
| White catfish (n=4) | 9 | 2 | 16 |
| | (9) | (4) | (1.21) |
| Sacramento sucker (n=2) | 180 | NA | NA |
| | (68) | NA | NA |
| West Delta (3 sites) | | | |
| White catfish (n=5) | 6 | 3 | 9 |
| | (6) | (3) | (9) |
| Entire Delta* (20 sites) | | | |
| White catfish (n=23) | 14 | 10 | 18 |
| | (12) | (9) | (15) |
| Sacramento sucker (n=4) | 159 | 0 | 398 |
| | (89) | (9) | (912) |

*Includes the Delta sites in this table and Prospect Slough.

San Joaquin River sites: Fremont Ford, Crow's Landing, Patterson, Laird Park, Vernalis & Mossdale.

South Delta sites: Paradise Cut, Old River, Middle River, Whiskey Slough, Clifton Court, Discovery Bay, & Orwood Tract.

East Delta sites: Potato Slough, Beaver Slough, Smith Canal, & Lost Slough.

West Delta sites: Frank's Tract, Big Break, & Sand Mound Slough.

Table 30. DDT contamination ratios in fish collected from the San Joaquin River watershed and Delta during 2005.

| ***Site*** | | ***Contamination Ratio (species/Sacramento sucker)*** | | | | |
|---|---|---|---|---|---|---|
| | | ***White Catfish*** | ***Carp*** | ***Channel Catfish*** | ***Largemouth Bass*** | ***Bluegill*** |
| San Joaquin @ Crown's Landing | Actual | 0.25 | 0.15 | 0.64 | 0.46 | 0.32 |
| | Size- adjusted | 0.36 | 0.13 | 0.71 | 0.49 | 0.53 |
| San Joaquin @ Vernalis | Actual | 0.09 | 0.69 | 0.23 | 0.25 | 0.18 |
| | Size-adjusted | 0.13 | 0.76 | 0.29 | 0.30 | 0.30 |
| Prospect Slough | Actual | 0.17 | 0.14 | | 0.03 | |
| | Size-adjusted | 0.24 | 0.11 | | 0.03 | |

Table 31. Results of regression analyses on composites (n=16) of Sacramento sucker collected in the San Joaquin River watershed and Delta—DDT data.

| ***X and Y axes*** | ***$R^2$*** | ***P value*** |
|---|---|---|
| % lipid vs. [DDT] | 0.63 | 0.0002 |
| log % lipid vs. log [DDT] | 0.79 | <0.00001 |
| mean length vs. [DDT] | 0.20 | 0.07 |
| log mean length vs. log [DDT] | 0.31 | 0.02 |
| mean length vs. % lipid | 0.29 | 0.03 |
| log mean length vs. log % lipid | 0.42 | 0.007 |
| lipid-normalized [DDT] vs [DDT] | 0.39 | 0.009 |
| log lipid-normalized [DDT] vs log [DDT] | 0.74 | <0.00001 |
| % lipid vs lipid-normalized [DDT] | 0.17 | 0.11 |
| log % lipid vs log lipid-normalized [DDT] | 0.55 | 0.0009 |

Table 32. Results of regression analyses on composites (n=32) of white catfish collected in the San Joaquin River watershed and Delta—DDT data.

| ***X and Y axes*** | $R^2$ | ***P value*** |
|---|---|---|
| % lipid vs. [DDT] | 0.0001 | 0.95 |
| log % lipid vs. log [DDT] | 0.0008 | 0.88 |
| mean length vs. [DDT] | 0.21* | 0.007 |
| log mean length vs. log [DDT] | 0.32* | 0.0006 |
| mean length vs. % lipid | 0.22 | 0.006 |
| log mean length vs. log % lipid | 0.10 | 0.07 |

*Slope of regression is negative.

Table 33. Sacramento River watershed fish tissue composites with PCB concentrations ranging from 12 to 19 ng/g.

| ***Sites*** | ***Species*** | ***PCB Concentration (ng/g)*** |
|---|---|---|
| Sacramento Slough @ Karnak | Channel catfish | 13 |
| Sacramento River @ RM 44 | Sacramento sucker | 15 |
| Sacramento River @ Rio Vista | Sacramento sucker<br>Carp<br>White catfish | 19<br>13<br>12 |

Table 34. Sacramento River watershed fish tissue composites with PCB concentrations greater than 20 ng/g (OEHHA screening value).

| ***Site*** | ***Species*** | ***PCB Concentration (ng/g)*** |
|---|---|---|
| Clear Creek | Sacramento sucker | 27 |
| Sacramento Slough @ Karnak | Channel catfish | 21 |
| American River @ Discovery Park | Sacramento sucker | 44 |
| Sacramento River @ Colusa | Channel catfish | 102 |
| Sacramento River @ Veteran's Bridge | Channel catfish<br>Carp | 53<br>26 |

Table 35. Composite PCB concentrations in fish collected in the Sacramento watershed.

| Species | SR Watershed | | SR Main stem | |
|---|---|---|---|---|
| | ***Mean*** | ***Median*** | ***Mean*** | ***Median*** |
| Sacramento sucker | 9 (4, 15)* n=17 | 6 | 7 (1, 13) n=8 | 6 |
| SS+CC+C** | 15 (7, 24) n=26 | 7 | 20 (7, 24) n=13 | 9 |

*Lower and upper 95% confidence limits
**SS=Sacramento sucker; CC=channel catfish; C=carp

Table 36. Lipid content and fish length in composites collected in the Sacramento River watershed.

| ***Species*** | ***Composite mean lipid content (%)*** | ***Composite mean fish length (mm)*** |
|---|---|---|
| Sacramento sucker<br>n=17 | 1.66 (1.12, 2.19)* | 424 (394, 453)* |
| Rainbow trout<br>n=5 | 1.22 (0.62, 1.81) | 348 (302, 394) |
| Channel catfish<br>n=5 | 3.38 (0.68, 6.07) | 460 (362, 558) |
| Carp<br>n=4 | 1.13 (0.64, 1.62) | 495 (442, 548) |
| White catfish<br>n=3 | 0.98 (0, 2.20) | 266 (199, 333) |
| Coho salmon<br>n=4 | 2.24 (0.86, 3.62) | 842 (831, 853) |

*Lower and upper 95% confidence limits.

Table 37. Results of regression analyses on composites (n=17) of Sacramento sucker collected in the Sacramento River watershed—PCB data.

| ***X and Y axes*** | ***$R^2$*** | ***P value*** |
|---|---|---|
| % lipid vs. [PCB] | 0.83 | <0.00001 |
| log % lipid vs. log [PCB] | 0.51 | 0.001 |
| mean length vs. [PCB] | 0.11 | 0.19 |
| log mean length vs. log [PCB] | 0.15 | 0.12 |
| mean length vs. % lipid | 0.14 | 0.13 |
| log mean length vs. log % lipid | 0.16 | 0.11 |
| lipid-normalized [PCB] vs [PCB] | 0.55 | 0.0006 |
| log lipid-normalized [PCB] vs log [PCB] | 0.60 | 0.0002 |
| % lipid vs lipid-normalized [PCB] | 0.26 | 0.03 |
| log % lipid vs log lipid-normalized [PCB] | 0.22 | 0.055 |

Table 38. Regression analysis of contaminant covariance in Sacramento sucker composites from the Sacramento River watershed.

| ***X and Y axes*** | $R^2$ | ***P*** |
|---|---|---|
| log [PCB] vs log [dieldrin] | 0.57 | 0.0005 |
| log lipid-normalized [PCB] vs lipid-normalized [dieldrin] | 0.44 | 0.004 |
| log [PCB] vs log [DDT] | 0.66 | 0.0001 |
| log lipid-normalized [PCB] vs lipid-normalized [DDT | 0.39 | 0.007 |
| log [dieldrin] vs log [DDT] | 0.75 | <0.0001 |
| log lipid-normalized [dieldrin] vs lipid-normalized [DDT] | 0.55 | 0.0006 |

Table 39. Rank correlation analysis of contaminant covariance in Sacramento sucker composites from the Sacramento River watershed.

| ***X and Y axes*** | ***Rho*** | ***P*** |
|---|---|---|
| [PCB] vs [dieldrin] | 0.84 | <0.0001 |
| lipid-normalized [PCB] vs lipid-normalized [dieldrin] | 0.30 | 0.02 |
| [PCB] vs [DDT] | 0.68 | <0.0001 |
| lipid-normalized [PCB] vs lipid-normalized [DDT] | 0.39 | 0.007 |
| [dieldrin] vs [DDT] | 0.73 | <0.0001 |
| lipid-normalized [dieldrin] vs lipid-normalized [DDT] | 0.64 | 0.0001 |

Table 40. Sacramento River watershed fish tissue composites with dieldrin concentrations ranging from 1.1 to 1.7 ng/g.

| ***Site*** | ***Species*** | ***Dieldrin Concentration (ng/g)*** |
|---|---|---|
| Colusa Basin Drain | Carp | 1.1 |
| American River @ Discovery Park | Sacramento sucker | 1.6 |
| Sacramento River @ Veteran's Bridge | Channel catfish<br>Carp | 1.5<br>1.0 |
| Sacramento River @ RM 44 | Sacramento sucker | 1.0 |
| Sacramento River @ Rio Vista | Sacramento sucker | 1.7 |

Table 41. Sacramento River watershed fish tissue composites with dieldrin concentrations at or above 2.0 ng/g (OEHHA screening value).

| ***Sites*** | ***Species*** | ***Dieldrin Concentration (ng/g)*** |
|---|---|---|
| Sacramento Slough @ Karnak | Channel catfish | 3.1, 2.4 |
| Sacramento River @ Colusa | Channel catfish | 2.0 |
| Sacramento River @ Grimes | Channel catfish | 3.7 |

Table 42. Average dieldrin concentration in fish collected in the Sacramento River watershed.

| ***Species*** | ***SR watershed Mean [dieldrin]*** | ***SR main stem Mean [dieldrin]*** |
|---|---|---|
| Sacramento sucker | 0.4 (0.1, 0.7)* n=17 | 0.45 (0, 1.0) n=8 |
| SS+CC+C** | 0.9 (0.5, 1.3) n=26 | 1.0 (0.3, 1.6) n=13 |

*Lower and upper 96% confidence limits.
**SS=Sacramento sucker; CC=channel catfish; C=carp

Table 43. Results of regression analyses on composites (n=17) of Sacramento sucker collected in the Sacramento River watershed—dieldrin data.

| ***X and Y axes*** | $R^2$ | ***P value*** |
|---|---|---|
| % lipid vs. [dieldrin] | 0.72 | <0.00001 |
| log % lipid vs. log [dieldrin] | 0.71 | <0.00001 |
| mean length vs. [dieldrin] | 0.16 | 0.12 |
| log mean length vs. log [dieldrin] | 0.19 | 0.08 |
| mean length vs. % lipid | 0.14 | 0.13 |
| log mean length vs. log % lipid | 0.16 | 0.11 |
| lipid-normalized [dieldrin] vs [dieldrin] | 0.71 | <0.00001 |
| log lipid-normalized [dieldrin] vs log [dieldrin] | 0.60 | 0.0003 |
| % lipid vs lipid-normalized [dieldrin] | 0.31 | 0.02 |
| log % lipid vs lipid-normalized log [dieldrin] | 0.32 | 0.02 |

Table 44. Sacramento River watershed fish tissue composites with DDT concentrations ranging from 50 to 92 ng/g.

| ***Site*** | ***Species*** | ***DDT Concentration (ng/g)*** |
|---|---|---|
| Colusa Basin Drain | Carp | 66 |
| Sacramento Slough @ Karnak | Channel catfish | 61 |
| Sacramento River @ Colusa | Channel catfish | 88 |
| Sacramento River @ Veteran's Bridge | Carp | 59 |
| Sacramento River @ RM 44 | Sacramento sucker | 50 |
| Sacramento River @ Rio Vista | Sacramento sucker | 92 |

Table 45. Composite DDT concentrations in fish collected in the Sacramento SR) watershed.

| ***Species*** | ***SR Watershed*** | | ***SR Main stem*** | |
|---|---|---|---|---|
| | ***Mean*** | ***Median*** | ***Mean*** | ***Median*** |
| Sacramento sucker | 15 (3, 27)*<br>n=17 | 7 | 23 (0, 50)<br>n=8 | 7.5 |
| SS+CC+C** | 35 (19, 51)<br>n=26 | 15 | 49 (19, 78)<br>n=13 | 44 |

*Lower and upper 95% confidence limits
**SS=Sacramento sucker; CC=channel catfish; C=carp

Table 46. Results of regression analyses on composites (n=17) of Sacramento sucker collected in the Sacramento River watershed—DDT data.

| ***X and Y axes*** | $R^2$ | ***P value*** |
|---|---|---|
| % lipid vs. [DDT] | 0.32 | 0.02 |
| log % lipid vs. log [DDT] | 0.37 | 0.009 |
| mean length vs. [DDT] | 0.13 | 0.15 |
| log mean length vs. log [DDT] | 0.38 | 0.009 |
| mean length vs. % lipid | 0.14 | 0.13 |
| log mean length vs. log % lipid | 0.16 | 0.11 |
| lipid-normalized [DDT] vs [DDT] | 0.79 | <0.00001 |
| log lipid-normalized [DDT] vs log [DDT] | 0.82 | <0.00001 |
| % lipid vs lipid-normalized [DDT] | 0.07 | 0.30 |
| log % lipid vs log lipid-normalized [DDT] | 0.05 | 0.37 |

Table 47. Recommendations for CWA 303(d) delisting of Central Valley and Delta water bodies (if 1999 OEHHA screening values are maintained).* See Recommendations section for details.

| Listed Water Bodies (listed for) | Recommendation |
|---|---|
| Colusa Basin Drain (Group A pesticides) | Delist |
| Lower Feather River (Group A pestidices) | Delist |
| Natomas East Main Drain (PCBs) | Additional data needed |
| Lower San Joaquin River | |
| (Group A pesticides) | Delist |
| (DDTs) | Additional data needed |
| Lower Merced River (Group A pesticides) | Delist |
| Lower Tuolumne River (Group A pesticides) | Delist |
| Lower Stanislaus River (Group A pesticides) | Delist |
| Delta (eastern portion) | |
| (Group A pesticides) | Delist |
| (DDTs) | Delist |
| Delta (western portion) | |
| (Group A pesticides) | Delist |
| (DDTs) | Delist |
| Delta (northern portion) | |
| (DDTs) | Delist |
| (PCBs) | Delist |
| Delta (southern portion) (DDTs) | Delist |

* All water bodies should be delisted if 2006 OEHHA-recommended screening value is adopted.

Table C1. Tissue PCB residues in fish collected in Central Valley water bodies during 2005. (OEHHA screening value is 20 ng/g wet weight).

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| Sacramento sucker | Big Break | 33 |
| | Cosumnes River | <RL |
| | Cosumnes River | <RL |
| | Lodi Lake | 23 |
| | Lodi Lake | 13 |
| | Lost Slough | <RL |
| | Merced River | <RL |
| | Merced River | <RL |
| | Prospect Slough | 20 |
| | SJR @ Vernalis | 27 |
| | SJR @ Crows Landing | 11 |
| | Potato Slough | 46 |
| | Stanislaus River | <RL |
| | Stanislaus River | <RL |
| | Tuolumne River | 38 |
| | Tuolumne River | 32 |
| | American River @ Discovery Park | 44 |
| | American River @ Nimbus Dam | <RL |
| | Bear River | 11 |
| | Clear Creek | 27 |
| | Feather River @ Nicolaus | <RL |
| | Feather River @ Gridley | <RL |
| | Feather River @ Gridley | ND |
| | Sacramento River @ Bend Bridge | <RL |
| | Sacramento River @ Colusa | <RL |
| | Sacramento River @ Hamilton | ND |
| | Sacramento River @ Ord Bend | <RL |
| | Sacramento River @ Rio Vista | 19 |
| | Sacramento River @ RM 44 | 15 |
| | Sacramento River @ Veterans Bridge | <RL |
| | Sacramento River @ Woodson Bridge | <RL |
| | Lake Almanor | <RL |
| | Yuba River | <RL |
| | Whiskeytown Reservoir | <RL |

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| White catfish | Big Break | <RL |
| | Beaver Slough | <RL |
| | Beaver Slough | <RL |
| | Calaveras River | <RL |
| | Calaveras River | <RL |
| | Clifton Court Forebay | <RL |
| | Discovery Bay | <RL |
| | Frank’s Tract | <RL |
| | Frank’s Tract | <RL |
| | Middle River | <RL |
| | Middle River | 9 |
| | Old River | <RL |
| | Old River | <RL |
| | Sand Mound Slough | <RL |
| | Sand Mound Slough | <RL |
| | Paradise Cut | <RL |
| | Prospect Slough | 10 |
| | Prospect Slough | 12 |
| | Orwood Tract | <RL |
| | Orwood Tract | <RL |
| | SJR @ Vernalis | <RL |
| | SJR @ Crows Landing | <RL |
| | SJR @ Fremont | <RL |
| | SJR @ Fremont | <RL |
| | SJR @ Laird Ave | <RL |
| | SJR @ Laird Ave | <RL |
| | SJR @ Patterson | <RL |
| | Whiskey Slough | <RL |
| | Whiskey Slough | <RL |
| | Smith Canal | 17 |
| | Smith Canal | 16 |
| | SJR @ Mossdale | <RL |
| | American River @ Discovery Park | <RL |
| | Colusa Basin Drain | ND |
| | Sacramento River @ Rio Vista | 12 |

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| Channel catfish | Merced River | <RL |
| | Tuolumne River | <RL |
| | Cosumnes River | <RL |
| | Discovery Bay | <RL |
| | SJR @ Vernalis | <RL |
| | SJR @ Crows Landing | <RL |
| | Stanislaus River | <RL |
| | Salt Slough | <RL |
| | Salt Slough | <RL |
| | Camanche Reservoir | <RL |
| | New Hogan Reservoir | ND |
| | Mendota Pool | <RL |
| | Pardee Reservoir | 18.5 |
| | East Park Reservoir | ND |
| | Indian Valley Reservoir | ND |
| | Sacramento River @ Colusa | 102 |
| | Sacramento River @ Grimes | <RL |
| | Sacramento River @ Veterans Bridge | 53 |
| | Sacramento Slough @ Karnak | 13 |
| | Sacramento Slough @ Karnak | 21 |
| Carp | Prospect Slough | <RL |
| | SJR @ Vernalis | 14 |
| | SJR @ Crows Landing | <RL |
| | SJR @ Hwy 99 | <RL |
| | Merced River | <RL |
| | Tuolumne River | <RL |
| | Salt Slough | <RL |
| | Millerton Lake | ND |
| | Colusa Basin Drain | ND |
| | Feather River @ Nicolaus | <RL |
| | Sacramento River @ Rio Vista | 13 |
| | Sacramento River @ Veterans Bridge | 21 |
| | Bullard Bar Reservoir | <RL |
| | Lake Britton | ND |
| Red-ear sunfish | Calaveras River | <RL |
| | Calaveras River | <RL |
| | SJR @ Vernalis | <RL |
| | SJR @ Crows Landing | <RL |
| | SJR @ Laird Park | <RL |
| | Paradise Cut | <RL |
| | Smith Canal | <RL |
| | Bear River @ Rio Oso | ND |

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| Bluegill | SJR @ Vernalis | <RL |
| | SJR @ Crows Landing | <RL |
| | Calaveras River | <RL |
| | Clifton Court Forebay | <RL |
| | Frank’s Tract | <RL |
| | Lust Slough | <RL |
| | Middle River | <RL |
| | Old River | <RL |
| | Paradise Cut | <RL |
| | Whiskey Slough | <RL |
| Large-mouth bass | SJR @ Vernalis | <RL |
| | SJR @ Crows Landing | <RL |
| | Prospect Slough | <RL |
| | American River @ Paradise Park | <RL |
| | American River @ Paradise Park | <RL |
| | American River @ Paradise Park | <RL |
| | Feather River @ Nicolaus | <RL |
| | Sacramento River @ RM 44 | <RL |
| Rainbow trout | Lodi Lake | <RL |
| | Moccasin Creek Hatchery | <RL |
| | SJR Hatchery | <RL |
| | American River Hatchery | <RL |
| | Clear Creek | <RL |
| | Darrah Springs Hatchery | <RL |
| | Mount Shasta Hatchery | <RL |
| | Sacramento River @ Bend Bridge | <RL |
| | Yuba River @ Marysville | <RL |
| | Baum Lake | <RL |
| | Buck’s Lake | ND |
| | Shasta Lake | <RL |
| Chinook salmon | Mokelumne River Hatchery | 10 |
| | Merced River Hatchery | 9 |
| | Sacramento River @ RM 44 | <RL |
| | Shasta Lake | 10 |
| | Feather River Hatchery | <RL |
| | Nimbus Hatchery | <RL |
| | Coleman Hatchery | 19 |
| Striped bass | Prospect Slough | 11 |
| Sacramento perch | Prospect Slough | <RL |
| | Frank’s Tract | <RL |
| Sacramento pike minnow | Prospect Slough | <RL |
| | Feather River @ Nicolaus | 8 |
| | Whiskeytown Reservoir | 54 |

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| Crappie | Prospect Slough | <RL |
| Hitch | Prospect Slough | <RL |
| Kokanee | Pardee Reservoir | 13 |
| Lake trout | Buck’s Lake | ND |
| Steelhead trout | Lake Alamanor | <RL |
| Pumpkinseed | Shasta @ Main | ND |
| Brook trout | Whiskeytown Reservoir | <RL |

Table C2. Tissue chlordane residues in fish collected in Central Valley water bodies during 2005. (1999 OEHHA screening value is 30 ng/g wet weight; 2006 OEHHA recommended screening value is 200 ng/g)).

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| Sacramento sucker | Big Break | 4 |
| | Cosumnes River | <RL |
| | Cosumnes River | <RL |
| | Lodi Lake | 3 |
| | Lodi Lake | 2 |
| | Lost Slough | <RL |
| | Merced River | 1 |
| | Merced River | <RL |
| | Prospect Slough | 4 |
| | SJR @ Vernalis | 3 |
| | SJR @ Crows Landing | 1 |
| | Potato Slough | 11 |
| | Stanislaus River | <RL |
| | Stanislaus River | <RL |
| | Tuolumne River | 1.2 |
| | Tuolumne River | 2.5 |
| | American River @ Discovery Park | 7 |
| | American River @ Nimbus Dam | <RL |
| | Bear River | <RL |
| | Clear Creek | <RL |
| | Feather River @ Nicolaus | <RL |
| | Feather River @ Gridley | <RL |
| | Feather River @ Gridley | ND |
| | Sacramento River @ Bend Bridge | ND |
| | Sacramento River @ Colusa | <RL |
| | Sacramento River @ Hamilton | ND |
| | Sacramento River @ Ord Bend | ND |
| | Sacramento River @ Rio Vista | 3 |
| | Sacramento River @ RM 44 | <RL |
| | Sacramento River @ Veterans Bridge | <RL |
| | Sacramento River @ Woodson Bridge | <RL |
| | Lake Almanor | <RL |
| | Yuba River | ND |
| | Yuba River | ND |
| | Whiskeytown Reservoir | <RL |

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| White catfish | Big Break | <RL |
| | Beaver Slough | <RL |
| | Beaver Slough | <RL |
| | Calaveras River | <RL |
| | Calaveras River | <RL |
| | Clifton Court Forebay | ND |
| | Discovery Bay | <RL |
| | Frank's Tract | <RL |
| | Frank's Tract | <RL |
| | Middle River | <RL |
| | Middle River | <RL |
| | Old River | <RL |
| | Old River | <RL |
| | Sand Mound Slough | <RL |
| | Sand Mound Slough | <RL |
| | Paradise Cut | <RL |
| | Paradise Cut | <RL |
| | Prospect Slough | <RL |
| | Prospect Slough | <RL |
| | Orwood Tract | <RL |
| | Orwood Tract | <RL |
| | SJR @ Vernalis | <RL |
| | SJR @ Crows Landing | <RL |
| | SJR @ Fremont | <RL |
| | SJR @ Fremont | <RL |
| | SJR @ Laird Ave | 6 |
| | SJR @ Laird Ave | 3 |
| | SJR @ Patterson | <RL |
| | Whiskey Slough | <RL |
| | Whiskey Slough | <RL |
| | Smith Canal | <RL |
| | Smith Canal | <RL |
| | SJR @ Mossdale | <RL |
| | American River @ Discovery Park | <RL |
| | Colusa Basin Drain | ND |
| | Sacramento River @ Rio Vista | <RL |

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| Channel catfish | Merced River | <RL |
| | Tuolumne River | <RL |
| | Cosumnes River | <RL |
| | Discovery Bay | <RL |
| | SJR @ Vernalis | 1 |
| | SJR @ Crows Landing | <RL |
| | Stanislaus River | <RL |
| | Salt Slough | <RL |
| | Salt Slough | <RL |
| | Camanche Reservoir | ND |
| | New Hogan Reservoir | ND |
| | Mendota Pool | <RL |
| | Pardee Reservoir | <RL |
| | East Park Reservoir | ND |
| | Indian Valley Reservoir | ND |
| | Sacramento River @ Colusa | 4 |
| | Sacramento River @ Grimes | <RL |
| | Sacramento River @ Veterans Bridge | 3.5 |
| | Sacramento Slough @ Karnak | <RL |
| | Sacramento Slough @ Karnak | <RL |
| Carp | Prospect Slough | <RL |
| | SJR @ Vernalis | 3 |
| | SJR @ Crows Landing | <RL |
| | SJR @ Hwy 99 | 2 |
| | Merced River | <RL |
| | Tuolomne River | <RL |
| | Salt Slough | <RL |
| | Millerton Lake | <RL |
| | Colusa Basin Drain | ND |
| | Feather River @ Nicolaus | <RL |
| | Sacramento River @ Rio Vista | 3 |
| | Sacramento River @ Veterans Bridge | 3 |
| | Bullard Bar Reservoir | <RL |
| | Lake Britton | <RL |

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| Red-ear sunfish | Calaveras River | <RL |
| | Calaveras River | ND |
| | SJR @ Vernalis | <RL |
| | SJR @ Crows Landing | <RL |
| | SJR @ Laird Park | <RL |
| | Paradise Cut | <RL |
| | Smith Canal | <RL |
| | Bear River @ Rio Oso | ND |
| | Bear River @ Rio Oso | ND |
| Bluegill | SJR @ Vernalis | <RL |
| | SJR @ Crows Landing | <RL |
| | Calaveras River | <RL |
| | Clifton Court Forebay | 2 |
| | Frank's Tract | <RL |
| | Lost Slough | <RL |
| | Middle River | <RL |
| | Old River | <RL |
| | Paradise Cut | <RL |
| | Whiskey Slough | <RL |
| Large-mouth bass | SJR @ Vernalis | <RL |
| | SJR @ Crows Landing | <RL |
| | Prospect Slough | <RL |
| | American River @ Discovery Park | <RL |
| | American River @ Discovery Park | <RL |
| | American River @ Discovery Park | <RL |
| | Feather River @ Nicolaus | <RL |
| | Sacramento River @ RM 44 | 2 |
| Rainbow trout | Lodi Lake | <RL |
| | Moccasin Creek Hatchery | <RL |
| | Jenkinson Lake | ND |
| | SJR Hatchery | <RL |
| | American River Hatchery | ND |
| | Clear Creek | <RL |
| | Darrah Springs Hatchery | ND |
| | Mount Shasta Hatchery | ND |
| | Sacramento River @ Bend Bridge | <RL |
| | Yuba River @ Marysville | ND |
| | Baum Lake | ND |
| | Buck's Lake | ND |
| | Shasta Lake | <RL |

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| Chinook salmon | Mokelumne River Hatchery | <RL |
| | Merced River Hatchery | <RL |
| | Sacramento River @ RM 44 | <RL |
| | Shasta Lake | <RL |
| | Feather River Hatchery | <RL |
| | Nimbus Hatchery | <RL |
| | Coleman Hatchery | 3 |
| Striped bass | Prospect Slough | 11 |
| Sacramento perch | Prospect Slough | <RL |
| | Frank’s Tract | <RL |
| Sacramento pike minnow | Prospect Slough | <RL |
| | Feather River @ Nicolaus | 2 |
| | Whiskeytown Reservoir | 4 |
| Crappie | Prospect Slough | <RL |
| Hitch | Prospect Slough | <RL |
| Kokanee | Pardee Reservoir | <RL |
| Lake trout | Buck’s Lake | ND |
| Steelhead trout | Lake Alamanor | ND |
| Pumpkinseed | Shasta @ Main | ND |
| Brook trout | Whiskeytown Reservoir | <RL |

Table C3. Tissue dieldrin residues in fish collected in Central Valley water bodies during 2005. (1999 OEHHA screening value is 2 ng/g wet weight; 2006 OEHHA recommended screening value is 16 ng/g).

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| Sacramento sucker | Big Break | 2.1 |
| | Cosumnes River | <RL |
| | Cosumnes River | 0.6 |
| | Lodi Lake | 0.6 |
| | Lodi Lake | 0.5 |
| | Lost Slough | <RL |
| | Merced River | 1.4 |
| | Merced River | 0.8 |
| | Prospect Slough | 4.0 |
| | SJR @ Vernalis | 3.4 |
| | SJR @ Crows Landing | 2.3 |
| | Potato Slough | 13.9 |
| | Stanislaus River | 0.5 |
| | Stanislaus River | 0.7 |
| | Tuolumne River | 6 |
| | Tuolumne River | 5 |
| | American River @ Discovery Park | 1.6 |
| | American River @ Nimbus Dam | <RL |
| | Bear River | <RL |
| | Clear Creek | <RL |
| | Feather River @ Nicolaus | <RL |
| | Feather River @ Gridley | <RL |
| | Feather River @ Gridley | ND |
| | Sacramento River @ Bend Bridge | ND |
| | Sacramento River @ Colusa | <RL |
| | Sacramento River @ Hamilton | ND |
| | Sacramento River @ Ord Bend | ND |
| | Sacramento River @ Rio Vista | 1.7 |
| | Sacramento River @ RM 44 | 1.0 |
| | Sacramento River @ Veterans Bridge | <RL |
| | Sacramento River @ Woodson Bridge | <RL |
| | Lake Almanor | ND |
| | Yuba River | ND |
| | Yuba River | ND |
| | Whiskeytown Reservoir | 0.5 |

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| White catfish | Big Break | <RL |
| | Beaver Slough | <RL |
| | Beaver Slough | <RL |
| | Calaveras River | <RL |
| | Calaveras River | <RL |
| | Clifton Court Forebay | <RL |
| | Discovery Bay | <RL |
| | Frank’s Tract | 0.8 |
| | Frank’s Tract | 0.6 |
| | Middle River | 0.6 |
| | Middle River | 0.6 |
| | Old River | <RL |
| | Old River | <RL |
| | Sand Mound Slough | <RL |
| | Sand Mound Slough | <RL |
| | Paradise Cut | <RL |
| | Paradise Cut | 0.6 |
| | Prospect Slough | 1.4 |
| | Prospect Slough | 0.8 |
| | Orwood Tract | 0.5 |
| | Orwood Tract | <RL |
| | SJR @ Vernalis | 0.6 |
| | SJR @ Crows Landing | 0.7 |
| | SJR @ Fremont | 1.0 |
| | SJR @ Fremont | 1.9 |
| | SJR @ Laird Ave | 1.3 |
| | SJR @ Laird Ave | 0.9 |
| | SJR @ Patterson | 0.6 |
| | Whiskey Slough | 0.9 |
| | Whiskey Slough | 1.0 |
| | Smith Canal | <RL |
| | Smith Canal | <RL |
| | SJR @ Mossdale | <RL |
| | American River @ Discovery Park | ND |
| | Colusa Basin Drain | 0.7 |
| | Sacramento River @ Rio Vista | 0.7 |

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| Channel catfish | Merced River | 0.9 |
| | Tuolumne River | 0.8 |
| | Cosumnes River | <RL |
| | Discovery Bay | 1.4 |
| | SJR @ Vernalis | 1.1 |
| | SJR @ Crows Landing | 1.4 |
| | Stanislaus River | ND |
| | Salt Slough | 2.5 |
| | Salt Slough | 1.6 |
| | Camanche Reservoir | ND |
| | New Hogan Reservoir | ND |
| | Mendota Pool | <RL |
| | Pardee Reservoir | <RL |
| | East Park Reservoir | ND |
| | Indian Valley Reservoir | ND |
| | Sacramento River @ Colusa | 2.0 |
| | Sacramento River @ Grimes | 3.7 |
| | Sacramento River @ Veterans Bridge | 1.5 |
| | Sacramento Slough @ Karnak | 3.1 |
| | Sacramento Slough @ Karnak | 2.4 |
| Carp | Prospect Slough | 2.1 |
| | SJR @ Vernalis | 2.5 |
| | SJR @ Crows Landing | 1.5 |
| | SJR @ Hwy 99 | <RL |
| | Merced River | 0.5 |
| | Tuolumne River | 0.9 |
| | Salt Slough | 1.4 |
| | Millerton Lake | ND |
| | Colusa Basin Drain | 1.1 |
| | Feather River @ Nicolaus | <RL |
| | Sacramento River @ Rio Vista | 0.9 |
| | Sacramento River @ Veterans Bridge | 1.0 |
| | Bullard Bar Reservoir | ND |
| | Lake Britton | ND |

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| Red-ear sunfish | Calaveras River | <RL |
| | Calaveras River | ND |
| | SJR @ Vernalis | 0.5 |
| | SJR @ Crows Landing | <RL |
| | SJR @ Laird Park | <RL |
| | Paradise Cut | 0.6 |
| | Smith Canal | <RL |
| | Bear River @ Rio Oso | ND |
| | Bear River @ Rio Oso | <RL |
| Bluegill | SJR @ Vernalis | 1.4 |
| | SJR @ Crows Landing | 1.7 |
| | Calaveras River | 0.5 |
| | Clifton Court Forebay | 0.9 |
| | Frank’s Tract | 0.8 |
| | Lost Slough | <RL |
| | Middle River | <RL |
| | Old River | <RL |
| | Paradise Cut | 0.7 |
| | Whiskey Slough | <RL |
| Large-mouth bass | SJR @ Vernalis | 1.1 |
| | SJR @ Crows Landing | 1.2 |
| | Prospect Slough | 0.6 |
| | American River @ Discovery Park | <RL |
| | American River @ Discovery Park | 0.5 |
| | American River @ Discovery Park | 0.6 |
| | Feather River @ Nicolaus | <RL |
| | Sacramento River @ RM 44 | <RL |
| Rainbow trout | Lodi Lake | <RL |
| | Moccasin Creek Hatchery | ND |
| | Jenkinson Lake | ND |
| | SJR Hatchery | ND |
| | American River Hatchery | ND |
| | Clear Creek | <RL |
| | Darrah Springs Hatchery | <RL |
| | Mount Shasta Hatchery | <RL |
| | Sacramento River @ Bend Bridge | <RL |
| | Yuba River @ Marysville | ND |
| | Baum Lake | ND |
| | Buck’s Lake | ND |
| | Shasta Lake | ND |

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| Chinook salmon | Mokelumne River Hatchery | 0.9 |
| | Merced River Hatchery | 1.3 |
| | Sacramento River @ RM 44 | 0.8 |
| | Shasta Lake | <RL |
| | Feather River Hatchery | <RL |
| | Nimbus Hatchery | 0.5 |
| | Coleman Hatchery | 1.0 |
| Striped bass | Prospect Slough | 0.6 |
| Sacramento perch | Prospect Slough | 1.4 |
| | Frank’s Tract | <RL |
| Sacramento pike minnow | Prospect Slough | 0.5 |
| | Feather River @ Nicolaus | <RL |
| | Whiskeytown Reservoir | 0.6 |
| Crappie | Prospect Slough | 0.5 |
| Hitch | Prospect Slough | 0.6 |
| Kokanee | Pardee Reservoir | <RL |
| Lake trout | Buck’s Lake | ND |
| Steelhead trout | Lake Alamanor | ND |
| Pumpkinseed | Shasta @ Main | <RL |
| Brook trout | Whiskeytown Reservoir | <RL |

Table C4. Tissue DDT residues in fish collected in Central Valley water bodies during 2005. (1999 OEHHA screening value is 100 ng/g wet weight; 2006 OEHHA recommended screening value is 560 ng/g).

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| Sacramento sucker | Big Break | 66 |
| | Cosumnes River | 7 |
| | Cosumnes River | 7 |
| | Lodi Lake | 28 |
| | Lodi Lake | 14 |
| | Lost Slough | 13 |
| | Merced River | 55 |
| | Merced River | 20 |
| | Prospect Slough | 213 |
| | SJR @ Vernalis | 337 |
| | SJR @ Crows Landing | 127 |
| | Potato Slough | 346 |
| | Stanislaus River | 3 |
| | Stanislaus River | 14 |
| | Tuolumne River | 339 |
| | Tuolumne River | 269 |
| | American River @ Discovery Park | 29 |
| | American River @ Nimbus Dam | 8 |
| | Bear River | 8 |
| | Clear Creek | 7 |
| | Feather River @ Nicolaus | 8 |
| | Feather River @ Gridley | 5 |
| | Feather River @ Gridley | <RL |
| | Sacramento River @ Bend Bridge | <RL |
| | Sacramento River @ Colusa | 10 |
| | Sacramento River @ Hamilton | <RL |
| | Sacramento River @ Ord Bend | 4 |
| | Sacramento River @ Rio Vista | 92 |
| | Sacramento River @ RM 44 | 50 |
| | Sacramento River @ Veterans Bridge | 20 |
| | Sacramento River @ Woodson Bridge | 5 |
| | Lake Almanor | 3 |
| | Yuba River | 5 |
| | Yuba River | <RL |
| | Whiskeytown Reservoir | <RL |

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| White catfish | Big Break | 6 |
| | Beaver Slough | 5 |
| | Beaver Slough | 8 |
| | Calaveras River | 11 |
| | Calaveras River | 14 |
| | Clifton Court Forebay | 9 |
| | Discovery Bay | 14 |
| | Frank’s Tract | 9 |
| | Frank’s Tract | 6 |
| | Middle River | 18 |
| | Middle River | 30 |
| | Old River | 11 |
| | Old River | 10 |
| | Sand Mound Slough | 8 |
| | Sand Mound Slough | 3 |
| | Paradise Cut | 17 |
| | Paradise Cut | 24 |
| | Prospect Slough | 30 |
| | Prospect Slough | 36 |
| | Orwood Tract | 9 |
| | Orwood Tract | 10 |
| | SJR @ Vernalis | 29 |
| | SJR @ Crows Landing | 32 |
| | SJR @ Fremont | 23 |
| | SJR @ Fremont | 34 |
| | SJR @ Laird Ave | 211 |
| | SJR @ Laird Ave | 113 |
| | SJR @ Patterson | 36 |
| | Whiskey Slough | 17 |
| | Whiskey Slough | 13 |
| | Smith Canal | 11 |
| | Smith Canal | 15 |
| | SJR @ Mossdale | 18 |
| | American River @ Discovery Park | 9 |
| | Colusa Basin Drain | 44 |
| | Sacramento River @ Rio Vista | 29 |

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| Channel catfish | Merced River | 11 |
| | Tuolumne River | 21 |
| | Cosumnes River | 8 |
| | Discovery Bay | 87 |
| | SJR @ Vernalis | 78 |
| | SJR @ Crows Landing | 81 |
| | Stanislaus River | 24 |
| | Salt Slough | 23 |
| | Salt Slough | 34 |
| | Camanche Reservoir | <RL |
| | New Hogan Reservoir | <RL |
| | Mendota Pool | 6 |
| | Pardee Reservoir | <RL |
| | East Park Reservoir | 3 |
| | Indian Valley Reservoir | <RL |
| | Sacramento River @ Colusa | 88 |
| | Sacramento River @ Grimes | 44 |
| | Sacramento River @ Veterans Bridge | 109 |
| | Sacramento Slough @ Karnak | 61 |
| | Sacramento Slough @ Karnak | 48 |
| Carp | Prospect Slough | 30 |
| | SJR @ Vernalis | 232 |
| | SJR @ Crows Landing | 52 |
| | SJR @ Hwy 99 | 23 |
| | Merced River | 6 |
| | Tuolumne River | 20 |
| | Salt Slough | 13 |
| | Millerton Lake | <RL |
| | Colusa Basin Drain | 66 |
| | Feather River @ Nicolaus | 24 |
| | Sacramento River @ Rio Vista | 149 |
| | Sacramento River @ Veterans Bridge | 59 |
| | Bullard Bar Reservoir | 4 |
| | Lake Britton | <RL |

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| Red-ear sunfish | Calaveras River | 7 |
| | Calaveras River | 5 |
| | SJR @ Vernalis | 16 |
| | SJR @ Crows Landing | 14 |
| | SJR @ Laird Park | 18 |
| | Paradise Cut | 9 |
| | Smith Canal | 6 |
| | Bear River @ Rio Oso | <RL |
| | Bear River @ Rio Oso | 4 |
| Bluegill | SJR @ Vernalis | 58 |
| | SJR @ Crows Landing | 38 |
| | Calaveras River | 5 |
| | Clifton Court Forebay | <RL |
| | Frank’s Tract | <RL |
| | Lost Slough | 4 |
| | Middle River | 8 |
| | Old River | ND |
| | Paradise Cut | 12 |
| | Whiskey Slough | <RL |
| Large-mouth bass | SJR @ Vernalis | 81 |
| | SJR @ Crows Landing | 57 |
| | Prospect Slough | 5 |
| | American River @ Discovery Park | <RL |
| | American River @ Discovery Park | 4 |
| | American River @ Discovery Park | 5 |
| | Feather River @ Nicolaus | 2 |
| | Sacramento River @ RM 44 | 4 |
| Rainbow trout | Lodi Lake | 4 |
| | Moccasin Creek Hatchery | <RL |
| | Jenkinson Lake | <RL |
| | SJR Hatchery | <RL |
| | American River Hatchery | <RL |
| | Clear Creek | 4 |
| | Darrah Springs Hatchery | <RL |
| | Mount Shasta Hatchery | <RL |
| | Sacramento River @ Bend Bridge | <RL |
| | Yuba River @ Marysville | 11 |
| | Baum Lake | <RL |
| | Buck’s Lake | <RL |
| | Shasta Lake | 2 |

| ***Species*** | ***Site*** | ***Concentration (ng/g)*** |
|---|---|---|
| Chinook salmon | Mokelumne River Hatchery | 13 |
| | Merced River Hatchery | 15 |
| | Sacramento River @ RM 44 | 15 |
| | Shasta Lake | 2 |
| | Feather River Hatchery | 8 |
| | Nimbus Hatchery | 12 |
| | Coleman Hatchery | 20 |
| Striped bass | Prospect Slough | 25 |
| Sacramento perch | Prospect Slough | 28 |
| | Frank's Tract | <RL |
| Sacramento pike minnow | Prospect Slough | 34 |
| | Feather River @ Nicolaus | 10 |
| | Whiskeytown Reservoir | 28 |
| Crappie | Prospect Slough | 29 |
| Hitch | Prospect Slough | 3 |
| Kokanee | Pardee Reservoir | <RL |
| Lake trout | Buck's Lake | <RL |
| Steelhead trout | Lake Alamanor | <RL |
| Pumpkinseed | Shasta @ Main | ND |
| Brook trout | Whiskeytown Reservoir | <RL |