*San Francisco Estuary Regional Monitoring Program for Trace Substances*

# Monitoring Trace Organic Contamination in Central Valley Fish: Current Data and Future Steps

## A Report Prepared For the Central Valley Regional Water Quality Control Board


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SFEI Contribution # 99
October 2004

San Francisco Estuary Institute

This report should be cited as:

Greenfield, Ben K., E. Wittner, N. David, S. Shonkoff, and J.A. Davis. 2004. Monitoring Trace Organic Contamination in Delta Fish: Current Data and Future Steps. A report to the Central Valley Regional Water Quality Control Board. SFEI Contribution 99. San Francisco Estuary Institute, Oakland CA.

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## Executive Summary

Contaminant concentrations in Central Valley fish are currently high enough to warrant concern for human health. Although a strategy has been laid out for monitoring mercury contamination in the region, no such plan exists for legacy organochlorine contaminants. Monitoring is needed in fish tissue to support the development of fish advisories, document the spatial extent of the contamination problem, and determine whether concentrations have declined in historically contaminated locations. Agriculturally used pesticides (e.g., DDTs, chlordanes, and dieldrin), PCBs, and the currently banned insecticide toxaphene, are of particular concern.

For this report, historic and recent data were used to map spatial and temporal patterns in contaminant concentrations in Central Valley sport fish. In both historic and recent data, pesticide concentrations were generally higher in the lower San Joaquin River and associated tributaries, intermediate in the Delta and lower Sacramento River, and lower in the Sacramento River watershed above Sacramento. PCBs exhibited the highest concentrations in urban locations including the Sacramento and Stockton areas. Long-term trends predominantly indicated an initial rapid decline in trace organic concentrations, followed by a more gradual decline. Statistical comparisons identified several water bodies where concentrations were significantly lower than human health screening values.

Based on current data and availability of archived fish tissue samples, the following four recommendations are made for future sample collection and analysis:

1. Analyze 23 archived composite fish samples to evaluate 17 locations lacking data on pesticides and PCB contamination. The samples are listed in Table 8.
2. Analyze 22 additional samples from five locations to better characterize human health risks associated with potential contamination in fish tissue. These locations include the Stockton area, the Sacramento area, the Lower San Joaquin River, the Feather River, and the West Delta near Antioch. The samples are listed in Table 10.

3. Analyze 14 archived samples and collect and analyze new samples at 9 historically monitored stations to determine whether concentrations exhibit declining trends. The samples are listed in Table 11.
4. Analyze 6 samples archived from 2002 and 2003 to evaluate new contaminants that have been recently introduced to the watershed and may be bioaccumulating in fish. The samples and compounds are listed in Tables 11 and 13.

## Introduction

Present concentrations of mercury and other contaminants in aquatic food webs in the Bay-Delta watershed are high enough to warrant concern for the health of humans and wildlife. Recent sampling has found that several sport fish species (including largemouth bass, striped bass, channel catfish, and white catfish) have mercury concentrations of high human health concern, exceeding the threshold for concern (0.3 ppm) in a majority of samples and frequently exceeding 1 ppm (Davis et al., 2003). Data for other contaminants are relatively scarce, but sampling in the Sacramento River watershed (Larry Walker Associates, 2001; Larry Walker Associates, 2002) and the Delta region (Davis et al., 2000) have found concentrations of PCBs, DDT, and other chemicals that exceed thresholds for human health concern in some locations (Davis, 2000). Fish consumption advisories have been issued by the California Office of Environmental Health Hazard Assessment for several lakes and reservoirs in the Coast Range (mercury), the Bay-Delta (mercury, PCBs, and other organic contaminants), the northern Sierra Nevada foothills (mercury), and the Grassland Area (selenium).

Other areas in the watershed, especially along tributaries of the Sacramento and San Joaquin Rivers are listed as having water quality impairments due to elevated concentrations of PCBs, DDTs, and Group A pesticides (Group A pesticides include aldrin, dieldrin, chlordanes, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane, endosulfan, and toxaphene). As a result of excess PCB or legacy pesticide contamination, the state of California has placed 11 Central Valley water bodies on the Clean Water Act "303(d) list", a list of waters impaired due to one or more of these contaminants (Central Valley Regional Water Quality Control Board, 2003).

These concentrations pose a serious problem because fishing for food and recreation remains a popular activity throughout the watershed. Nearly 10% of the California population engages in fishing activities (U. S. Department of the Interior et al., 2001). Creel surveys by the California Department of Fish and Game (CDFG) have shown that anglers spend over 2 million hours per year fishing on the Sacramento River alone (California Department of Fish and Game, 2001). The Delta region is also a popular fishing location with hundreds of miles of waterways, abundant boat launches, and two major urban areas within its boundaries. A seafood consumption study in San Francisco Bay indicated that about two-thirds of people fishing have no awareness or limited understanding of the existing San Francisco Bay fish advisory. The study also found that African-Americans and Asians catch, prepare, and eat San Francisco Bay fish in ways that are likely to increase their exposure to chemical contaminants (SFEI, 2000). A recent needs assessment in five counties in the watershed (Lake, Sacramento, San Joaquin, Placer, and Yolo) by the Environmental Health Investigations Branch (EHIB) of the California Department of Health Services found that members of Southeast Asian, Latino, African-American, and Russian communities regularly eat fish, especially striped bass and catfish, from local waters, and have generally low awareness of fish consumption advisories and the health risks of exposure to contaminants in fish.

In spite of the importance of the Delta as a fishing location, documented human health concerns from fish contamination in the region, the existence of a consumption advisory for the Bay, and recent concern over fish tissue contamination in the Sacramento River watershed, little systematic sampling has been conducted in the Delta to evaluate human health risks associated with chemical contamination of fish tissue. Monitoring of chemical contamination of sport fish is a critical need for two primary reasons. First, monitoring is needed to support the development of fish consumption advisories for the region. Issuing consumption advice is the most immediate means of reducing human health risks. Contaminant concentrations in many locations in the Central Valley are high enough to warrant consideration of advisories, but the spatial and temporal coverage of sampling to date has not provided a sufficient basis for advisory development. Second, monitoring is crucial for tracking the impact of actions that will affect water quality, including regulatory actions aiming to reduce water quality impairments for 303(d) listed water bodies. Regular, periodic monitoring of fish contamination will be a critical ingredient to improving water quality and reducing human health risks in this important ecosystem. The California Bay-Delta Authority has developed a Mercury Strategy for the Bay-Delta Ecosystem (Wiener et al., 2003) that lays out a plan for mercury monitoring in the Delta region. In contrast, there currently are no plans for long-term monitoring of trace organic contaminants in the Delta.

The California Department of Fish and Game (CDFG) has an archive of over 500 frozen stored fish samples that were collected from the Central Valley of California as part of contamination monitoring programs between 1998 and 2002. Many of these samples have only been analyzed for mercury, but there is also a widely recognized need to assess PCBs and organochlorine pesticide contamination in fish (Davis et al., 2000; Lee, 2003). The trace organic contaminants that have recently been detected in Central Valley fish at concentrations of concern for human health include PCBs and legacy pesticides. The legacy pesticides of particular concern are total DDTs, chlordanes, dieldrin, and toxaphene (Lee and Jones-Lee, 2002). Water bodies in the Central Valley are listed as impaired for trace organic contamination, and there is recreational and subsistence fishing activity throughout the Central Valley, but the current extent of the fish contamination problem is not well known. High concentrations of a class of emerging organic contaminants, the polybrominated diphenyl ethers (PBDEs), have also recently been detected in the region. PBDE concentrations have been rising rapidly in San Francisco Bay and other parts of the U.S., suggesting that there may also be a growing PBDE problem in the Delta region.

In this report, we briefly summarize current data on trace organic contamination in the Central Valley of California. We use a database of fish contamination analyses, originally compiled by Lee and Jones-Lee (2002), to characterize broad spatial patterns of PCBs and legacy pesticides throughout the region, and statistically compare concentrations at 303(d) listed water bodies to human health screening values. We evaluate these data to make specific recommendations for sampling and analysis of trace organic contaminants in fish of the Central Valley. This includes recommendations of available archived samples that are high priorities for laboratory analysis, as well as recommendations for future sampling locations and methods. The recommended future sampling includes a pilot study to evaluate whether previously unmonitored contaminants, such as PBDEs, are accumulating in Central Valley fishes. We also evaluate what is known about trends in PCB and legacy pesticide contamination, using data from individual sampling locations, region-wide data, and a brief literature evaluation.

There are several programs underway to implement coordinated environmental management and monitoring in California waters. In the Central Valley, these include the Surface Water Ambient Monitoring Program (SWAMP), the Toxic Substances Monitoring Program (TSMP), the Sacramento River Watershed Program, and the California Bay-Delta Authority. As funding becomes available, we hope that the recommendations in this report will be useful for making specific decisions about future sampling and analysis of fish contamination in California waters.

## Monitoring Objectives

There are several objectives that should guide monitoring for contamination in Central Valley fish. These objectives were outlined in discussions with representatives from the environmental management community. Participants in the discussions included the California agency that provides fish consumption recommendations (Bob Brodberg, Office of Environmental Health Hazard Assessment), the agency that implements regulatory processes for 303(d) listed waters (Chris Foe, Central Valley Regional Water Quality Control Board), and a non-profit environmental group concerned with contamination in the region (Bill Jennings, DeltaKeeper). These objectives are applicable in the present study and should also guide future fish contamination monitoring studies.

One important objective is **to provide the data needed to support fish consumption advice where it is warranted.** Often, the initial screening assessment monitoring identifies regions or sites where more detailed site-specific assessment is warranted. Thus, the next phase of monitoring should include replicate sample collection and analysis from higher priority areas to provide a sound quantitative basis for consumption advice. At such locations, multiple samples would be collected to better characterize fish contaminant concentrations, and this information could be used to evaluate risk for humans and wildlife. OEHHA considers 9 samples of individual fish a minimum for issuing advice for a specific location. Few sites have been sampled to this extent.

The second objective is to **characterize the spatial extent of fish contamination throughout the Central Valley**. In particular, fish could be analyzed from water bodies that have not been recently sampled in order to determine whether these water bodies pose a potential threat for human health consumption or for wildlife. Lee and Jones-Lee (2002) list a large number of water bodies that fit this criterion, and also point out that some sampling has not used sufficiently accurate detection limits to compare to human health screening values. Later in this report, we identify archived samples that may be used to screen a number of sites not having recent contamination data.

A final objective of continued monitoring is **to evaluate long-term trends in fish contamination**. For water bodies having historical data, continued monitoring could be used to evaluate whether concentrations in that water body appear to be declining. If sufficient data are available, it may also be possible to determine rates of contaminant decline.

## Spatial Patterns in Central Valley Fish Contamination

Data from a large number of programs and locations has been collected on fish contamination in California waters. We have developed maps of these data to rapidly identify relatively contaminated regions, as well as relatively uncontaminated locations. Identification of high and low contamination areas can help prioritize future data collection efforts.

*Methods*

We used a spatial database of contaminant concentrations in fish to generate contamination maps. This database relies heavily on the work of Lee and Jones-Lee (2002), who published a synthesis of data on fish contamination in the Tulare, San Joaquin, and Sacramento River basins, and provided us with a copy of the database they prepared. This database includes concentrations of measured trace organic contaminants, and sample attribute data. Sample attribute data includes fish species, length, mass, and sample type (i.e., whole body versus filet). We used the database to generate spatial maps of contaminant concentrations in commonly monitored fish species. Additionally, we used the database to display historic or recent sampling locations, alongside locations where archived samples are currently available.

We added several historic and more recent data sources to the database of Lee and Jones-Lee (2002). We also added fish capture location, including latitude and longitude, for every site, in order to generate the maps. Data sources provided by Lee and Jones-Lee included Toxic Substances Monitoring Program data (Rasmussen and Blethrow, 1991; Rasmussen, 1993; Rasmussen, 1995), and the data from Dileanis et al. (1992), Watkins et al. (1985), Brown (1998), CDFG (1984), and MacCoy and Domagalski (1999). Spot-checking of the database with original source data indicated that they were reliable. Additional data sets incorporated were recent Sacramento River Watershed Program data (Larry Walker Associates, 2002), data from the Delta Fish Study funded by the Central Valley Water Board and implemented by SFEI (Davis et al., 2000), historic data collected by the U.S. Fish and Wildlife Service as part of the National Pesticide Monitoring Program (Schmitt et al., 1981; Schmitt et al., 1983; Saiki and Schmitt, 1986), and unpublished data collected since 2000 as part of the Toxic Substances Monitoring Program (Chris Foe, California Regional Water Quality Control Board, *personal communication*) and the U.S. EPA National Fish Tissue Study (Leanne Stahl, U.S. EPA, *personal communication*). At the time of preparation of this report, no data were available from samples collected after 2001. Finally, we used a separate database of archived fish samples (Autumn Bonnema, CDFG, *personal communication*) to develop a listing of sites where archived samples are available.

To graphically depict spatial patterns in contamination, we generated the mean contaminant concentration of samples for each fish species at each sampling location. Sums were obtained for DDTs and chlordanes using the suites of compounds recommended by the Office of Environmental Health Hazard Assessment (OEHHA), as summarized elsewhere (Brodberg and Pollack 1999; Lee and Jones-Lee 2002; Greenfield et al. 2003). Averages were then generated for PCBs, sum of DDTs, sum of chlordanes and dieldrin. Average concentrations were generated separately for samples collected between 1997 and 2001 (i.e., recent samples) and samples collected prior to 1997 (i.e., historic samples). Many of the samples were below detection limits for one or more contaminants. These values were converted to zero, and were averaged with other samples of the same species-site combination, when available. PCB screening value assessments are typically conducted using Aroclor values, but in some cases only total congener data were available above reporting limits. To increase the total spatial coverage of the maps, we chose to include total congener data for individual samples, when Aroclor data were unavailable or below reporting limits. Given the frequent values below detection, and the use of congener data in some instances, these maps do not provide an exact picture of each individual site. Nevertheless, our methodology is appropriate for obtaining a broad assessment of the spatial patterns in contamination on a region-wide basis.

The locations of individual fish sampling points were generated using two methods. Most locations were compiled based on monitoring program data available from the Web or data provided by the authors of the original data sources. Where coordinate information was not available, we used our best professional judgment to create points as close as possible to the text description of the sample location. We obtained these spatial location estimates using the USGS Web-based Geographic Names Information System (GNIS) (http://geonames.usgs.gov/) and TerraServer mapping system (http://terraserver.microsoft.com/default.aspx). A GIS layer was then created using the latitude and longitude decimal degree coordinates of each location. Station location information may be found in Appendix A. The fish sampling history and contaminant information was appended to the GIS data layer. ESRI's ArcGIS 8.3 was used to create two map series. The first map series detailed the type of point, and the status of the data it represents. The second map series showed historic (before 1997) and modern (between 1997 and 2001) contaminant concentrations in four fish species (largemouth bass, white catfish, Sacramento sucker, rainbow trout), for four contaminants (DDTs, PCBs, chlordanes, and dieldrin). These species were selected based on having relatively abundant recent and historical data (Table 1), and broad spatial coverage. All data and maps were developed using ESRI's ArcGIS 8.3, and stored in ESRI's shapefile format, in the Universal Transverse Mercator projection, Zone 10N, datum Nad83, in meters.

Human health screening values were taken from recommendations by OEHHA based on human consumption of sport fish (Brodberg and Pollack, 1999) (Table 2). For further details, refer to Lee and Jones-Lee (2002) and Greenfield et al. (2003).

*Results and Discussion*

Figure 1 indicates the location of archived samples, and points of historic (before 1997) and recent (after 1997) data collection. This figure displays appropriate locations for archived sample analysis based on the presence or absence of recently available data.

Figures 2 through 9 graphically summarize available contamination data for four species frequently caught in the Central Valley. These figures enable visual assessment of the spatial extent of the Central Valley contamination problem. For DDTs, since 1997, concentrations were elevated and frequently above screening values in the lower San Joaquin River, particularly near the city of Stockton. Elevated concentrations were also observed in some samples along the Sacramento River below Sacramento. Concentrations appeared to be moderately elevated in the Delta and relatively low in the Sacramento River above Colusa (Figure 2). Patterns were generally similar for the historic DDT mapping, although there were more incidences of very high concentrations (> 300 ng/g), reflecting the overall decline in DDT contamination since use was restricted in 1972 (Figure 3). The elevated DDT contamination along the San Joaquin River likely resulted from intense agricultural activity in the surrounding watershed (Brown 1998).

Spatial distribution patterns for chlordanes, PCBs, and dieldrin were fairly similar to DDTs, with elevated concentrations in the lower San Joaquin River and in the vicinity of the city of Sacramento (Figures 4 through 9). Since 1997, PCB concentrations were generally above screening values along the lower San Joaquin and Sacramento Rivers and below screening values in the central Delta and in Sacramento River sites upstream of the city of Sacramento, through and above Keswick Reservoir (Figure 4). Three individual stations exhibited particularly high PCB concentrations: Smith Canal at Yosemite Park, Sacramento River at Hood, and American River at Discovery Park (Figure 1; Figure 4), supporting the hypothesis that PCB contamination may be more patchy in distribution than DDTs (Davis et al. 2000). When averaged by site and species, mean chlordane concentrations since 1997 were below screening values at all measured locations (Figure 6), although individual samples did occasionally exhibit screening value exceedances for largemouth bass and white catfish (Table 3c). Dieldrin exceeded screening values at four San Joaquin River watershed locations above the Merced River (Merced River upstream of Hatfield State Park, Mud Slough, San Joaquin River at Lander's Avenue, and the San Luis Reservoir), indicating legacy contamination for dieldrin in this region (Figure 8).

The data prior to 1997 indicated a greater incidence of elevated concentrations than the recent data for all four contaminants. This pattern was particularly striking for DDTs, with many sites exhibiting concentrations greater than 300 ng/g prior to 1997 (Figure 3). For PCBs, a number of sites sampled in the Sacramento vicinity prior to 1997 exhibited concentrations above 200 ng/g, again suggesting localized hot spots (Figure 5). Although more locations were sampled historically, the vast majority of the stations were below detection limits for PCBs, dieldrin, and chlordanes (Figure 5; Figure 7; Figure 9). The high frequency of values below detection limits is indicative of higher detection limits in sampling from the 1970s and 1980s. The stations above screening values in historical sampling are important for follow-up monitoring and are listed in Table 6.

In general, spatial patterns in fish contaminant concentration followed the land use and geomorphology of the region. For example, higher concentrations of agricultural use pesticides (DDTs, chlordanes, and dieldrin) in downstream samples of the Sacramento River, when compared to upstream areas, is consistent with the general increase in agricultural land use activity in the lower portions of the watershed (MacCoy and Domagalski, 1999). Additionally, the maps of historic DDTs and dieldrin indicated higher concentrations in the mainstem San Joaquin River than tributaries along the eastern side of the watershed (Figure 3; Figure 9). Brown (1998) indicated that porous soils and high river discharge on the east side of the basin results in high percolation and dilution of irrigation water, and consequently lower contaminant concentrations. It is interesting to note an apparent decrease in fish contaminant concentrations in the central Delta, as compared to the lower Sacramento and San Joaquin Rivers. This pattern is surprising given the high historic agricultural activity in the area. The same pattern was observed in sport fish mercury concentrations (Davis et al., 2003), and may reflect dilution due to tidal mixing or a variety of other potential mechanisms (Gill et al., 2002).

## Temporal Trends in Central Valley Fish Contamination

Long-term trend evaluation can be useful for setting priorities in management and regulatory listing of water bodies. There are currently a number of water bodies that have sufficient PCB or legacy pesticide contamination to be listed on the 303(d) list of impaired waters in the Central Valley region (Region 5) of California (Table 6) (Central Valley Regional Water Quality Control Board, 2003). Comparison of contamination trends among these water bodies may help in prioritizing limited resources in application of regulatory activities. In theory, it may also be possible to apply statistical models using trend data to evaluate the current and anticipated future rate of decline. However, high interannual variability and limited sample size make it difficult to anticipate future trends based on present data.

*Methods*

Data from two regional studies were used to evaluate trends in organic contaminants in Central Valley fish tissue. The Toxic Substances Monitoring Program (TSMP) and the Sacramento River Watershed Program (SRWP) provided data from 1978 to 2002 for several fish species, mostly using homogenized whole fish for the analysis of PCBs, DDTs, chlordanes, and dieldrin. Both wet weight data and lipid corrected data, were evaluated. Lipid correction was achieved by taking the residuals of a linear regression between contaminant concentration and lipid concentration. Results were similar for wet vs. lipid weight, and we report wet weight results in this report. The reader is referred to Davis et al. (2000) for lipid weight findings.

Historically, the toxicity of PCBs has been expressed by evaluating Aroclor concentrations. In more recent years, selected PCB congeners were measured because the toxic potency of PCBs is congener specific and highly variable. PCB congeners are also easier to detect than the Aroclor equivalents, and data interference due to coeluting chemicals can easily be identified (Davis et al., 1997). When comparing PCB congener concentrations to the sum of Aroclors, the congeners will express slightly lower concentrations (Davis et al., 2000). Due to high incidences of values below reporting limits, trends plots were not generated for chlordanes or dieldrin.

To evaluate any general region-wide trends, all data for white catfish taken from all locations in the database were plotted together. To evaluate trends in individual stations, site-specific plots were also generated. Site and species selection for the trend plots were based on overall data abundance and availability of recent data from the SRWP for the previous five years. In some cases, sites that were very close to each other were combined for trend plotting. Combined sites are indicated on Table 11 and include the Lower American River, the Sacramento River at River Mile 44/Hood, and the Sacramento River at Keswick Reservoir.

*Results and Discussion*

In general, DDT concentrations in white catfish at all sampled sites grouped together suggested an overall decrease in maximum measured values from the 1970s through 2002 (Figure 10d). The incidence of very high concentrations was low after 1990 relative to previous measurements. The grouped sample sites for PCB (Figure 10b), chlordane (Figure 10a), and dieldrin concentrations (Figure 10c) in white catfish also exhibited a region-wide decline in maximum observed values.

When individual sites were evaluated, concentrations generally but not always declined over the sampling period. PCB concentrations in white catfish from the Sacramento River at River Mile 44 exhibited a considerable decline over the years (Figure 11b). In Sacramento sucker from the Lower American River, PCB concentrations generally declined, with the exception of a recent composite sample (Figure 11a). DDT concentrations in Sacramento sucker in the Lower American River declined (Figure 12c), while the concentrations in largemouth bass at the same location remained fairly steady (Figure 12d). For white catfish in Sacramento River at Hood/River Mile 44, DDT concentrations indicated a dramatic decline after 1990 (Figure 12a). However, concentrations in rainbow trout in the Sacramento River at Keswick displayed high variability and did not show apparent declines (Figure 12b). Lipid corrected data generally showed similar patterns to wet weight data (data not shown).

In the Central Valley, PCB and DDT concentrations appeared to be declining at some sites but did not show apparent trends in others sites. This finding may indicate spatial differences in long-term trends for trace organic contaminants. For example, DDT concentrations appeared to decline at Sacramento River Mile 44/Hood, but did not show clear evidence of decline in the Keswick Reservoir sites (Figure 12). This was similar to findings of highly variable decline rates in mollusk trace organic contaminants among different sampling stations of the U.S. and State Mussel Watch Programs (Stephenson et al., 1995; Lauenstein and Daskalakis, 1998). It should be pointed out that the two instances of relatively stable concentrations in Central Valley fish (largemouth bass at

American River and rainbow trout at Keswick) both had consistently lower DDT concentrations than the sites where trends occurred. This may indicate more difficulty detecting trend in less contaminated species such as largemouth bass and rainbow trout.

This dataset provided a limited indication of trends over the past three decades. The older TSMP data incorporated rather sporadic sampling events of trace organics in the Central Valley and made it more difficult to detect long-term trends in contaminant concentrations. The available data cannot be used to predict future rates of decline since the temporal and spatial variation observed in this study is relatively high, and the number of individual sampling years (and sample size within years) is relatively low. For a point of comparison, monitoring of PCB concentrations in Lake Michigan fishes incorporated greater than 250 samples collected over 17 continuous years, in order to determine whether concentrations were predicted to decline towards zero or continue at above-zero concentrations indefinitely (Stow et al., 1999).

Although long-term sediment core studies or continuous fish monitoring programs are not available for the Central Valley, some general findings may be extrapolated from the peer-reviewed literature on other regions. A general observation is that trace organic contaminants decline significantly from their peak values but detectable residues remain present in ecosystems decades after use curtailment. Typically, a rapid decline is observed in the years immediately following use curtailment, followed by a leveling off at a zero or non-zero asymptote (Risebrough, 1995). This leveling off pattern was observed in sediment core evaluations of San Francisco Bay (Venkatesan et al., 1999), Lake Superior (Jeremiason et al., 1994), and White Rock Lake (a reservoir in Dallas, Texas; Van Metre and Callender, 1997). Concentration declines were also observed to flatten over time in mollusks monitored in California and other U.S. Coastal Waters (Stephenson et al., 1995; Lauenstein and Daskalakis, 1998). Finally, biota PCB concentrations in the Great Lakes may have stabilized at a non-zero asymptote, indicating that there may not be significant continued reductions in the future (Stow et al., 1999). For example, statistical modeling indicates that PCB concentrations in Lake Michigan lake trout are only expected to decline 5 to 10% between 2000 and 2007 (Stow et al., 2004). If these results can be extrapolated among regions, they suggest that trace organic contaminant concentrations in Central Valley fish may remain relatively stable for the foreseeable future.

In summary, data from the Central Valley and other regions clearly indicated that overall, trace organic contaminants have declined since production and use were restricted. Nevertheless, actual rates of decline were highly variable among locations, and data are limited from individual sites, making it difficult to predict future rates. Interannual variability is high, rates of decline are low, and annual monitoring may be required for decades, before a specific rate of contaminant decline can be established. Additionally, given the inherent spatial variability in the Central Valley, contaminant trends in one location may not reflect another location. Finally, studies of sediments and biota from other regions suggest that rates of concentration declines are likely to decrease over time, again making rate characterization difficult. These factors should be considered in the development of long-term monitoring strategies for Central Valley fish.

## Statistical Comparisons of 303(d) Listed Waters to Screening Values

As a result of elevated contaminant concentrations in sport fish tissue, many California waters have been placed on the Clean Water Act 303(d) list of impaired water bodies (SFBRWQCB, 2001; Central Valley Regional Water Quality Control Board, 2003; Johnson and Looker, 2003). The State Water Board periodically evaluates the relative management priority of the water bodies that are 303(d) listed for PCBs, Group A pesticides, or DDTs. To assist in this evaluation for the Central Valley region, we statistically compared sport fish concentrations of PCBs, chlordanes, and DDTs to human health screening values developed by OEHHA (Brodberg and Pollock, 1999). This analysis focused on water bodies currently 303(d) listed for PCBs or legacy pesticides (Table 6). If there are instances where contaminant concentrations in fish samples are significantly below screening values, this may warrant lower priority for management actions. If there are cases where concentrations appear to be lower than screening values, but the differences are not statistically significant, it may be possible to demonstrate significant difference by evaluating a limited number of additional tissue samples. Power analysis can be used to estimate the number of additional samples that would need to be collected.

*Methods*

We compared sport fish concentrations in 303(d) listed water bodies (Table 6) to human health screening values recommended by the Office of Environmental Health Hazard Assessment (Table 2) (Brodberg and Pollock, 1999). These comparisons were conducted for PCBs, DDTs, chlordanes, and dieldrin when adequate data were available. Data since 1997 were used and analysis focused on water bodies 303(d) listed for PCBs and legacy pesticides. In some cases, results from multiple stations for a given TMDL-listed water body were combined. Most station locations are presented on Figure 1, and all station coordinates are listed in Appendix A.

For screening value comparisons, we were interested in "worst case scenario" evaluation. Therefore, the following high-lipid species were considered for inclusion on a site-specific basis: white catfish, Sacramento sucker, Sacramento pike minnow, and common carp. Although largemouth bass were frequently sampled, their tissue concentrations were often well below these other species and well below screening values (Table 3). Therefore, largemouth bass were only used when other species data were not available at a given site.

Comparisons were conducted by calculating the t-test statistic, following the equation:

$$T = (\bar{A} - \mu) / (S / \sqrt{n})$$

where $\bar{A}$ = the average concentration for that water body, $\mu$ = the screening value to be compared to, S = the sample standard deviation (STDEV() function in Excel), and $\sqrt{n}$ is the square root of the sample size at that water body (Sokal and Rohlf, 1995). This T statistic was compared to the $T_{df}$ distribution, where df = degrees of freedom = n-1.

In cases where the comparison is not significant at $p < 0.05$, it may be possible to achieve significant differences from screening values by conducting a modest amount of additional sampling. To evaluate this possibility, a power analysis was conducted to determine the sample size required to achieve a significant difference at $p < 0.05$, 90% of the time:

$$N = \sigma^2 \text{ x } (Z_{\alpha/2} + Z_\beta)^2 / (\bar{A} - \mu)^2$$

where N = minimum sample size, $\sigma^2$ = the sample variance (i.e., sample standard deviation squared), $Z_{\alpha/2}$ = the Z-statistic for a two-tailed test, with a 0.05 given probability of type I error ($\alpha = 0.05$; $Z_{\alpha/2} = 1.96$), $Z_\beta$ = the Z-statistic for a test with a given probability of type II error ($\beta = 0.10$; $Z_\beta = 1.28$), $\bar{A}$ = the average concentration for that water body, and $\mu$ = the screening value to be compared to (Sokal and Rohlf, 1995). Like all models, power analysis results are only as reliable as the input data. Because small sample sizes (N = 2-7 samples per station) were available, it should be noted that all estimates of required sample size are only approximate, and may be revised as more data become available.

These significance tests require that the data be normally distributed. Evaluation of normal scores plots, histogram plots, and significance tests were conducted in SAS to determine normality of data distributions. Significance tests evaluated were the Shapiro-Wilk, Kolmogorov-Smirnov, Cramer-von Mises, and Anderson-Darling tests for normality. Data distribution was evaluated for separate fish species using all data and data since 1997. These tests indicated that log-transformation resulted in approximately normal distribution. Therefore, all data were log-transformed prior to conducting T-tests or power analyses.

In addition to the T-test, concentrations were compared to screening values and it was noted when the average log (concentration) was > 10% above or below the log (screening value).

Frequently, for chlordanes and dieldrin in particular, contaminant concentrations were below detection limits for a majority of samples. In these cases, it was not possible to run parametric power analyses. Nevertheless, high incidences of concentrations below detection limits, especially when detection limits were below screening values, was interpreted as evidence of concentrations that don't pose a contamination threat, and likely cause for lower management prioritization.

*Results and Discussion*

<u>General Results</u>

The results of the screening value comparison and power analysis are summarized in Table 12. There were a number of instances where the compared fish samples were significantly lower or higher than screening values. In particular, the west Delta, lower San Joaquin River, lower Feather River, and Kings River may currently have concentrations below screening values for one or more 303(d) listed contaminants. However, for the 9 listed water bodies having adequate data to run screening value comparisons, only one (Kings River) exhibited significantly lower concentrations than screening values for all contaminants evaluated (Table 12). Therefore, most of the water bodies that are 303(d) listed do have the possibility of human health threshold exceedances for at least one class of legacy organochlorine. In many instances, concentrations appeared to be below screening values for dieldrin and chlordane in water bodies on the 303(d) list for these Group A pesticides. Insufficient data were available to run statistical comparison to screening values for Orestimba Creek and Mud Slough.

<u>Individual Water Body Results</u>

For the lower San Joaquin River (SJR) upstream of the Delta, contaminant data on white catfish since 1997 are available at SJR at Landers Ave./Rte. 165 (station # 29), SJR at Vernalis (# 37), SJR around Bowman Road (# 31), and SJR north of Hwy. 4 (# 36). Many largemouth bass samples were also analyzed. For white catfish, samples were significantly below screening values for chlordanes, and were generally below detection limits for dieldrin. However, concentrations were not significantly different from screening values for PCBs, and additional sampling is not likely to resolve a difference (an estimated 239 samples required to demonstrate a difference) for PCBs (Table 12). Therefore, the lower San Joaquin River may warrant consideration for PCB 303(d) listing. Concentrations were > 10% above screening values for DDTs, but the difference was not statistically significant, requiring approximately 14 samples to confirm (Table 12). Given the high expected fishing activity in the lower San Joaquin River, the limited availability of fish data, and the apparent discrepancies between 303(d) listing status and screening value exceedances (Table 12), the lower San Joaquin River should be a high priority for future sampling and analysis. If the site continues to demonstrate concentrations below screening values, the lower SJR may possibly be appropriate for delisting DDTs and Group A pesticides.

West Delta waterways that have been sampled since 1997 include Suisun Bay, San Joaquin River at Antioch, Prospect Slough, and Cache Slough. However, the only waterway that has been sampled for a fish species high in lipids is Cache Slough (Station # 7), for which separate composite white catfish samples were collected in 1999 and 2000. Based on these two samples, DDTs and chlordanes were significantly below screening values, and PCBs were lower than screening values but the result was not significant (Table 12). Dieldrin was below detection in both samples. Power analysis suggested that analysis of one more sample would be sufficient to demonstrate PCBs to be significantly lower than screening values (Table 12). Given the high expected fishing activity in the Delta, the low availability of fish data, and the apparent concentrations below screening values, the West Delta should be a high priority for future sampling and analysis. If regions in the West Delta other than Cache Slough were also below screening values, this would be inconsistent with the 303(d) listing for Group A pesticides.

East Delta stations currently having fish contamination data for largemouth bass and white catfish are Old River Near Paradise Cut (station number 21), Paradise Cut (#22), San Joaquin River around Turner Cut (#32), San Joaquin River Near Potato Slough (#35), Sycamore Slough Near Mokelumne River (#41), and White Slough

Downstream of Disappointment Slough (#44) (c.f. Figure 1). From among these stations, 12 composite samples have been analyzed for largemouth bass, and all of these samples were below the screening value for DDT, dieldrin, chlordanes, and PCBs, suggesting that the largemouth bass fishery is not likely to be at high risk for human health considerations in this region. For 4 composite white catfish samples, DDT and PCB concentrations varied widely, with samples not significantly different from screening values. Power analysis suggested that an inordinately large number of samples would be required to resolve a significant difference between DDT concentrations and screening values for DDTs and PCBs. For chlordanes, concentrations were significantly below screening values, and most samples were below detection for dieldrin (Table 12).

Since 1997, three lower Feather River stations have been sampled (Stations 10, 77, and 78 on Figure 1). Sampling included 5 composite samples of white catfish, Sacramento sucker or Sacramento pike minnow. All 5 of these samples were below screening values, and 4 of 5 samples were below detection limits for chlordanes and dieldrin, suggesting that these Group A pesticides do not currently pose a consumption hazard in the lower Feather River. DDTs were significantly below screening values, but PCBs (Aroclor basis) were not significantly greater or lower than screening values. The power analysis indicated that high sample sizes (estimated at 38 samples) would be required to significantly differentiate PCB concentrations from screening values (Table 12).

For the Colusa Basin Drain, 3 common carp samples were determined to be significantly below the screening value for chlordanes and PCBs. For DDTs and Dieldrin, all 3 samples were above the screening value, but the difference was not significant (Table 12). Given the screening value exceedances for dieldrin, Colusa Basin Drain appears to be appropriately listed for Group A legacy pesticides. Elevated concentrations of DDTs may warrant listing for DDTs as well, although additional sampling would better establish this.

The Kings River is 303(d) listed for toxaphene. Between 2000 and 2001, separate composite samples were evaluated in this water body for three fish species: Sacramento sucker, rainbow trout, bluegill sunfish, smallmouth bass, and channel catfish. These five Kings River fish samples were all below screening values for PCBs, DDTs, and chlordanes (Table 12). All five samples were below detection limits for toxaphene, with a detection limit (20 ppb) below the screening value (30 ppb). If a few more Sacramento sucker samples (or other fatty fish species) are evaluated in this water body, and determined to be below the screening value, this would confirm relatively low human health hazard due to toxaphene in the Kings River. The low concentration of PCBs, DDTs, and Class A pesticides supports the absence of 303(d) listing for these compounds in the Kings River.

Since 1997, 3 largemouth bass and two channel catfish composite samples have been collected at the lower Merced River in proximity to the Hatfield State Recreation Area (station 84 on Figure 1). Comparing the channel catfish samples to the screening values indicated that concentrations were significantly above screening values for PCB total Aroclors and DDTs, above screening values for dieldrin ($p < 0.10$) and not significantly different for chlordane screening values (Table 12).

Mud Slough is currently 303(d) listed for pesticides. It has been sampled only once since 1997. The white catfish composite sample collected in 1998 was well above screening values for total Aroclors, DDTs and dieldrin.

Natomas East Main Drain is currently 303(d) listed for total Aroclors. For Natomas East Main Drain, data were available for 3 largemouth samples. All three of these samples were above screening values for PCBs, but the difference from screening values was not statistically significant. Values were below screening values for DDTs, chlordanes, and dieldrin, consistent with the unlisted status for DDTs and Group A pesticides (Table 12).

Orestimba Creek is 303(d) listed for DDE, as a result of elevated concentrations in tissue samples collected in the early 1990s. Although fish and bivalve samples collected in 1990 and 1992 exceeded screening values for DDTs and dieldrin, recent sport fish sampling has not been conducted. Additional sampling in this location may reveal concentrations that have dropped below screening values.

## General Recommendations For Future Monitoring and Analyses

The remainder of this report recommends the next steps for trace organic contaminant monitoring in Central Valley fish. It begins with general recommendations on the appropriate species, analytes, and sampling period for an optimal trace organics monitoring program. This is followed by detailed and specific recommendations on sampling and analyses to achieve three objectives: screening assessment of potentially contaminated sites, detailed characterization of high priority sites, and trend monitoring. Finally, a special study is recommended to evaluate for the presence of the future "legacy contaminants" in fish tissues.

*Analytical Recommendations*

All archived sample analyses and future monitoring efforts should continue to include PCBs, DDTs, chlordanes, dieldrin, and toxaphene, as these contaminants continue to exhibit screening value exceedances in inland California waters (Table 2, Table 3). Additionally, a screening study should be conducted to evaluate bioaccumulation of dioxins and synthetic organic compounds previously unstudied in Delta fish samples. This proposed screening study will be discussed at the end of this report.

Other pesticides that are commonly reported by analytical labs and for which the U.S. EPA and the California regional regulatory agency (OEHHA) recommend monitoring include: chlorpyrifos, diazinon, endosulfan, endrin, ethion, heptachor epoxide, and hexachlorobenzene. In California waters, these compounds are not typically detected at concentrations near or above human health screening values (Brodberg and

Pollock, 1999; Davis et al., 2000; Greenfield et al., 2003). For example, less than 2% of endrin, endosulfan, and heptachlor epoxide samples were above human health screening values (Table 2). Furthermore, greater than 90% of Toxic Substance Monitoring Program samples collected since 1997 were below reporting limits for aldrin, endrin, endosulfan, heptachlor, and heptachlor epoxide (Table 2). These high incidences of samples below detection and below screening values suggest that compared to DDTs, chlordanes, dieldrin, and toxaphene, these other legacy pesticides are not posing a significant human-health threat.

For monitoring data to have value in regulatory listing decisions and water body prioritization, analyses of target compounds should be sufficiently sensitive to resolve concentrations below the screening values promulgated by OEHHA. Lee and Jones-Lee (2002) point out that for several contaminants, some of the current monitoring data from the Central Valley do not have sufficient analytical sensitivity to compare sample concentrations to screening values (Brodberg and Pollock, 1999). For example, for toxaphene, dieldrin, and heptachlor epoxide, about 15% of samples collected by the Toxic Substances Monitoring Program between 1997 and 2001 were below detection, with detection limits above screening values (Table 2). We concur with the recommendation of Lee and Jones-Lee (2002) that all future sample analyses be sufficiently sensitive to detect concentrations at or below screening values. Specifically, laboratory reporting limits for dieldrin, toxaphene, and heptachlor epoxide should be reduced below the screening values. Personal communication with the principal scientist at the current laboratory used for much of the state fish assessments (Dave Crane, CDFG Water Pollution Control Laboratory, Rancho Cordova, CA, *pers. comm.*) indicated that the current reporting limits are below screening values for toxaphene (RL = 20; SV = 30) and dieldrin (RL = 0.5; SV = 2).

*Target Species*

Target fish species selection is important to establish for any contaminant monitoring program. A complete listing of previously monitored species provides some indication of the relative ease of capture, and available historical data (Table 1). The seven most commonly captured fish species were largemouth bass, white catfish, common carp, channel catfish, Sacramento sucker, rainbow trout, and Sacramento pikeminnow. Species selection criteria could include popularity of the fish for human capture and consumption, widespread distribution and abundance (facilitating capture and comparison among locations), extensive past contaminant monitoring (enabling comparison to historic data), and tendency to accumulate the contaminant to elevated concentrations (Table 3). Species with high lipid content (e.g., catfish species, Sacramento sucker, and carp) readily accumulate trace organic contaminants (Table 3), and are therefore relatively sensitive indicators of potential exposure. For example, channel catfish, white catfish, and common carp had the highest PCB and DDT concentrations of fish sampled in recent years (Table 3). Species that more readily bioaccumulate contaminants are valuable for identification of contaminated sites and worst-case scenario evaluation of potential wildlife and human consumption exposure.

In the Central Valley region and its tributaries, several popular sport fish species (e.g., largemouth bass and striped bass) do not accumulate trace organic contaminants to the same extent as fatty species (Table 3; Table 4) (Greenfield et al., 2003), and are therefore not as sensitive as contamination indicators. For example, since 1997, largemouth bass had lower average PCB, chlordane, and dieldrin concentrations than Sacramento sucker, white catfish, and channel catfish (Table 3). Striped bass and salmon are popular sport fish, but they migrate (Calhoun, 1952), and thus are not appropriate for indicating site-specific conditions (Greenfield et al., 2003).

We recommend that Central Valley monitoring programs focus on white catfish, which is a reasonably widespread fatty fish species having relatively substantial historical and recent data (Table 1; Table 3) (Davis et al., 2000). White catfish is also relatively popular for sport and subsistence fishing. In some locations, it may be difficult to capture white catfish. To improve the probability of characterizing a wide range of locations, we recommend that collection include non-migratory species that readily contaminate trace organic contaminants. We recommend keeping common carp, Sacramento sucker, and channel catfish as secondary target species. These secondary target species should be kept as bycatch, and analyzed if sufficient sample sizes and funds are available. The U.S. EPA (2000) recommends that all contaminant monitoring programs include a pelagic predator and a benthivore, thereby best characterizing contamination throughout the water body. To complement the use of white catfish (a benthivore), future monitoring studies may also wish to target largemouth bass, which is a wide spread pelagic predator. However, a drawback of using largemouth bass is that they accumulate relatively low concentrations of persistent organics due to the relatively low lipid content of their muscle tissue. In upper reaches of the Sacramento and tributaries, rainbow trout are more common and popular as sport fish, are high in lipid, and may be an appropriate target species.

To achieve consistency among separate composite samples, we recommend following a sampling protocol developed by the USEPA (2000), which employs a composite sampling size of five fish. The smallest individual in a composite sample should not be smaller than 75% of the length of the largest fish. All individuals of a composite sample should be caught no more than one week apart, to minimize changes in contaminant concentrations due to changes in lipid content and the reproduction cycle. Recommended size classes for target species can be found in Table 4. In general, each composite sample should provide at least a 200 g composite homogenate of edible tissue for laboratory analysis.

*Recommended Sampling Period*

In the Central Valley, it is difficult to identify an optimal sampling date for contaminant concentrations in fish. Rigorous evaluations of peak fishing activity are not available for most fish species, making it difficult to select dates based on this criterion. In the Delta, fishing occurs year round, both for sport fishing and subsistence fishing (Kyle Murphy, Kathy Hieb, and Gary Ichikawa, CDFG, *personal communication*). Furthermore, anecdotal information suggests that peak sport fishing activity often coincides with spawning activity. During spawning periods, contaminant concentrations are likely to be more variable and difficult to characterize, because lipids are developed and released with eggs (U. S. EPA, 2000). Most of the target Central Valley species' spawning peaks take place in the late spring and early summer (Table 5) (Moyle, 2002), and peak fishing season is April through June because that is when the fish are "spawning and aggressive" (Kyle Murphy, CDFG, *personal communication*).

The U.S. EPA (2000) generally recommends freshwater fish sampling for contaminants occur between August and October because enough time has passed since spawning for lipid content to increase and stabilize. In addition, this is when water levels are typically lower, thus simplifying collection procedures (U. S. EPA, 2000). Recent contaminant sampling in the SRWP, the TSMP, the Delta Fish Study and U.S. EPA's National Fish Tissue Study did occur most often in the late summer and early fall. To maintain consistency with previous data and avoid the variability introduced due to spawning, we recommend that future sampling continue to target the months of August and September. However, if sufficient funds were available, it would also be appropriate to conduct additional sampling during the spawning window in late spring and early summer, when fishing activity may be higher.

*Evaluation of Impacts to Fish and Piscivorous Wildlife*

Most of the monitoring activity and impact assessment in the Central Valley to date has focused on evaluating potential for human health impacts. Another important endpoint is the potential for adverse impacts to fish and to piscivorous wildlife. To our knowledge, regulatory screening values for organic contaminants have not been developed for wildlife targets in California waters. However, there is a substantial literature on toxicity thresholds for wildlife (Beyer et al., 1996) and Environment Canada has developed tissue residue guidelines for DDTs and PCBs. Environment Canada recommend a guideline of 0.79 ng Toxic Equivalents/kg for PCBs (Environment Canada, 1998) and a tissue residue guideline of 14 ng/g for DDTs (Environment Canada, 1997). In the case of DDTs, the majority of Central Valley samples exceed this guideline (Table

3); however, most sampling to date has been of large sport fish, and if impacts to piscivorous wildlife are to be assessed, smaller forage fish should be sampled.

## Specific Recommendations For Three Monitoring Objectives

Previously, we discussed three potentially important monitoring objectives for the Central Valley fish monitoring program:

1. monitoring new locations to characterize the spatial extent of the contamination problem (screening assessment monitoring);
2. collecting sufficient numbers of samples at contaminated or high use areas to conduct site-specific exposure assessments to provide the data needed to support fish consumption advice where it is warranted; and
3. long-term trend evaluation at historically contaminated sites or index sites.

Based on recent and historic contaminant data, and a database of available archived samples, we can make sampling and analysis recommendations for each of these objectives.

*Screening Assessment Monitoring*

There are many locations throughout the Central Valley where fish may be contaminated but for which recent data (e.g., since 1997) are not available. All of these locations are candidates for what we refer to as "screening assessment monitoring". In screening assessment monitoring, a single composite sample would be collected and analyzed from one or two target fish species to evaluate whether the station is a candidate for more site-specific monitoring. As indicated above, the primary target species would be white catfish, with another fatty fish species used when white catfish are unavailable. Screening assessment sites should have a sufficiently large number of fish per composite to be a representative sample of the site. Consistent with targets for the SRWP and the Delta Fish Study, we recommend a target number of 5 fish per composite.

Several tributaries of the San Joaquin River are high priority locations for screening assessment monitoring because they are on the 303(d) list of impaired waters but have almost no recent data on trace organic contamination in fish. These high priority water bodies include the Lower Merced River, the Lower Stanislaus River, and the Lower Tuolumne River. Graphical analyses of current and historic data indicate that the main stem San Joaquin River exhibits generally higher contaminant concentrations than many other regions in the Central Valley. Considering the relatively high degree of contamination on the mainstem San Joaquin River, the San Joaquin River tributaries are appropriate for screening assessment monitoring at new sample sites. It is expected that these sites will have lower concentrations than the San Joaquin River, as they do not have as significant contaminant loads and were not as contaminated as the San Joaquin River in the past (Brown, 1998).

Figure 1 displays all locations at which fish monitoring has been conducted in the Central Valley and associated tributaries. All light grey circles in Figure 1 are locations where contaminant data were collected prior to 1997 but not more recently. As indicated in the spatial maps of historic contamination (Figures 3, 5, 7, and 9), many of these historic sampling locations were below detection for PCBs and legacy pesticides. Locations historically above screening values, but lacking current contamination data are high priorities for screening assessment monitoring. These are indicated on the maps and listed as the boldfaced stations in the second column of Table 6.

The 17 red circles in Figure 1 indicate locations for which CDFG currently has stored archived samples, and for which there are no previous monitoring data of trace organic contaminants (Table 7). Most of these sites are located within the Delta region, which has high fishing activity and would benefit from more extensive contamination characterization. So that sample analysis may proceed as soon as funds are available, we have identified 23 archived samples from these locations for screening assessment monitoring (Table 8).

The sites we have chosen for archived sample analysis fit several criteria. As indicated, they are all in locations that have not been recently analyzed for trace organic contamination. Additionally, archived samples are available at the sites for the target species listed above: white catfish, largemouth bass, channel catfish, common carp, or Sacramento sucker. Finally, where possible, samples collected more recently were chosen over older samples to reduce the possibility of sample quality change over time. For the White Slough at Lodi, Sand Mound Slough, and the Yuba River sites, samples were only available from Year 1 of the CALFED Mercury Study. These samples suffered several thawing events, and for these samples, results should be viewed as estimates (Autumn Bonnema, *Personal Communication*).

Additional locations that are high priorities for screening assessment monitoring are listed in Table 7. These locations lack recent contamination data and were chosen based on two additional criteria. Some of them are 303(d) listed water bodies. Others were identified in our spatial maps as having historic exceedances of screening values but lacking monitoring data since 1997 (Table 7). Also, some of the sites listed in the temporal trends monitoring recommendations section below (i.e., stations for trend analysis having no archived samples) would be appropriate for screening assessment monitoring. Finally, if sufficient funds are available, Lee and Jones-Lee (2002) provide a thorough listing of all water bodies that may benefit from screening assessment monitoring.

*Site-specific Assessment*

Several Central Valley locations have been determined by previous monitoring to have contaminant concentrations in fish or other matrices that exceed human health screening values. These locations are candidates for site-specific assessment, in which fish contaminant concentrations are more rigorously characterized. The goal of site-specific assessment should be to obtain sufficient data for the development of consumption advice specific to that location or region. High fishing activity by anglers who consume what they catch is another appropriate criterion for selection of assessment locations.

Figure 1 identifies five areas that we consider to be high priorities for site-specific assessment: the Stockton area, the Sacramento area, the Lower San Joaquin River, the Feather River, and the West Delta near Antioch. All of these areas have been identified by local experts and managers as having a high degree of human fishing activity (Gary Ichikawa, CDFG; Bob Brodberg, OEHHA; Bill Jennings, DeltaKeeper*, personal communication*) (Shilling, 2003). All of them contain portions listed on the 303(d) list of water bodies impaired by excessive organic contamination. Finally, as discussed previously and elsewhere, these locations tend to have relatively high contaminant concentrations (Davis, 2000; Davis et al., 2000; Lee and Jones-Lee, 2002).

The Office of Environmental Health Hazard Assessment has indicated that a minimum of three composites, each containing three individual fish would be required to initiate site-specific human health assessment, but that greater sample sizes would improve their assessments (Bob Brodberg, OEHHA, *personal communication*). Table 9 lists 13 monitoring stations from the five locations recommended for site-specific assessment. Each of these stations has archived samples available. However, many of the archived samples have been previously analyzed for trace organic contaminants. Six stations in Table 9 (i.e., those not italicized or boldfaced) already have three or more recent analyses conducted for at least one species. The seven boldfaced and italicized stations in Table 9 have had fewer than 3 composite samples recently analyzed for a given species (see last column). We recommend that, where possible, archived samples be analyzed to bring the number of composites to 3 for a species at each site. This would provide at least 3 composites for multiple stations from each location, and should improve ability to make human health assessments.

As a starting point for discussion on appropriate samples for site-specific assessment, we propose 22 analyses in Table 10. In particular, each row of Table 10 lists an archived sample to be recovered and analyzed. We selected and organized these samples based on the following criteria:

1. none of them appear to have been analyzed previously for trace organics;
2. where possible, samples are chosen to obtain a total of three samples for at least one species at a site;
3. the preferred species are white catfish, Sacramento sucker, channel catfish, and carp (species high in lipid content) in order to evaluate worst-case scenario data for a site;
4. at least three individuals should be available per sample; and
5. sampling dates are not mixed among composites.

If these criteria are not deemed appropriate for the objectives of site-specific assessment, these criteria may be modified and new sample recommendations made accordingly.

Certain caveats apply to these sample recommendations. First of all, for many of the stations, samples were only available from Year 1 of the CALFED mercury program. These samples suffered several thawing events (Autumn Bonnema, CDFG, *personal communication*), and sample integrity should be evaluated before embarking on analysis. Secondly, many of the recommended samples are largemouth bass, because there are a greater number of archived samples for this species. Finally, the exact samples for analyses should be very carefully selected to avoid reanalysis of samples already tested for trace organic contaminants. We have attempted to avoid reanalyzed samples in our recommendations, but this should be double-checked.

*Continued Trend Evaluation*

Collection of time-series data has been inconsistent in the Central Valley and no locations have been continuously evaluated for fish contamination. The database contains about a dozen locations that have had contamination data collected and analyzed for a particular fish species on at least four separate years since 1969 (Table 11). If these locations were to be reevaluated for the same fish species (as listed in Table 11), it would be possible to more confidently characterize contaminant trends on a region-wide basis.

For several of these locations, archived fish samples of the appropriate species are available for updating the trend evaluation, resulting in a total of 14 archived composite samples available for trend evaluation (Table 11). The remaining locations would require field collection of the appropriate species. It should be noted that many of the locations that could be usable for trend updates were also historically very contaminated (Table 6; Table 11), so reassessment of these locations would also benefit the screening assessment monitoring.

The locations having the most frequent data collection are the Sacramento River at Hood/River Mi. 44 (14 sampling years), San Joaquin River at Vernalis (eight years), American River at Discovery Park (eight years), and the Sacramento River at Keswick Reservoir (eight years; Table 11). Two of these locations have been selected by the ongoing monitoring programs (e.g., SRWP and TSMP) as top priority future trend monitoring stations.

As we indicated previously, trend evaluation in the Central Valley is confounded by limited data availability and a high degree of spatial variability among regions. Without a program in place for sampling composite fish samples on an annual or semi-annual basis at specific trend locations, it will continue to be difficult to forecast future expected contamination from past trends. To obtain sufficient data for generating predictive statistical models, a significant investment would be required for continuous collection and analysis of multiple samples on a long-term basis (Stow et al., 1999).

## Special Study to Monitor New Contaminants

In the Central Valley, most monitoring for organic contaminants in fish to date has focused on PCBs and legacy pesticides. In the recent past, many new synthetic compounds have been developed for agriculture and other purposes and some of these compounds may potentially bioaccumulate and cause toxicity in fish, wildlife, or humans. It is important to evaluate environmental concentrations of these lesser-known contaminants in order to anticipate potential environmental and human health risks. The majority of new contaminants have not undergone thorough toxicological evaluation and thus they do not have water quality objectives. If action is not taken in the present to monitor new contaminant concentrations in the environment, evaluate their risk, and if necessary, restrict their use, then these chemicals could potentially become the legacy environmental pollutants of the future (Oros and David, 2002). To address this concern, we recommend that a special study be undertaken to evaluate whether such contaminants can bioaccumulate to significant concentrations that pose a threat to Central Valley fishes and their consumers.

Many new contaminants were recently detected in the Bay-Delta aquatic ecosystem (Oros and David, 2002), and could be considered as possible candidates for monitoring in fish (Table 13). Pyrethroid insecticides are prevalent in the environment due to widespread application in agricultural areas. Dioxin (2,3,7,8-tetrachlorodibenzo-*p*-dioxin) and dioxin-like chemicals are highly toxic and have been observed at concentrations above OEHHA screening values in fish in San Francisco Bay (Greenfield et al., 2003). Polybrominated diphenyl ethers (PBDEs), commonly used as flame retardants, have been shown to bioaccumulate in the tissue of common carp (*Cyprinus carpio*), and San Francisco Bay fish and bivalves (Greenfield et al., 2003; Stapeleton et al., 2004a; Stapeleton et al., 2004b) (RMP unpublished data). In addition, very high PBDE concentrations have been observed in Central Valley fish (Dave Crane, CDFG, *unpublished data*). Alkyphenol, p-nonylphenol, and alkylphenol ethoxylates, all nonionic surfactants used in industrial, agricultural, and household applications, accumulate in common carp (Rice et al., 2003) and in fathead minnows (*Pimephales promelas*) (Snyder et al., 2001). Polycyclic musk compounds (e.g., Galaxolde and Tonalide), used as fragrances in perfumes, soaps, laundry detergents, and household cleaning products, are ubiquitous in aquatic environments (Schreurs et al., 2004). These compounds have been observed to bioaccumulate in winter flounder, American eel, lake trout, bivalves in the San Francisco Estuary, and other aquatic biota (Oros and David, 2002; Schreurs et al., 2004) (RMP unpublished data). The aquatic herbicide, copper sulfate, has been added to surface waters for decades and been observed to bioaccumulate and the livers of common carp and largemouth bass (Anderson et al., 2001).

We recommend an initial screening study, in which recently archived samples are analyzed from 4 locations for a subset of the new contaminants listed in Table 13. In Table 11, we have marked 6 samples with asterisks (*) to indicate that they should be analyzed for the new contaminants. Most of the compounds exhibit hydrophobic properties, so target fish species are high in lipid content, including Sacramento sucker, Sacramento pikeminnow, and common carp. Three of the sampling locations are areas already known to have high human impact, including urban sites in the cities of Stockton and Sacramento (American River at Discovery Park and Sacramento River at River Mile 44), and the Colusa Basin Drain, which has exhibited high agricultural pesticide concentrations in the past. The fourth sampling location, Feather River near Nicolaus, generally exhibits lower pesticide concentrations. All six samples should be analyzed for any compounds listed in Table 13 that the analytical lab is able to analyze. Assuming that the CDFG-WPCL laboratory is used, this would include the following compounds: pyrethroid insecticides, PBDEs, p-nonylphenol, alkylphenol polyethoxylates, nitro and polycyclic musks, and phthalates, in addition to analysis for PCBs and organochlorine pesticides. In the future, sites along the lower San Joaquin River that receive agricultural inputs and wastewater tainted effluents should also be analyzed.

## Acknowledgements

This report was developed with the guidance of Bill Jennings (DeltaKeeper), Bob Brodberg (Cal-EPA, OEHHA), Chris Foe (CVRWQCB), Gary Ichikawa (CDFG), and Autumn Bonnema (CDFG). The following people graciously provided us with published and unpublished data: G. Fred Lee (G. Fred Lee and Associates), Gary Ichikawa (CDFG), Autumn Bonnema (CDFG), Claus Suverkropp (Larry Walker Associates), Joe Domagalski (USGS), Larry Brown (USGS), Del Rasmussen (CDWR), Chris Foe (CVRWQCB), Leanne Stahl (U.S. EPA), and Peter Husby (U.S. EPA). G. Fred Lee and Associates are particularly acknowledged for focusing attention on the need for monitoring of sport fish contamination, and for developing and maintaining a thorough database on sport fish contamination in the region. Thanks are also due to Jennifer Hunt and Cristina Grosso for help with database management. Kathy Hieb, Ed Kolodziej, Kyle Murphy, Daniel Oros, and Mike Connor are acknowledged for helpful personal communications. This project was funded by the State Water Resources Control Board as part of a grant to the San Jose State University Foundation. This is SFEI report # 99.

## Tables

Table 1. List of species monitored in the Central Valley of California, with the number of composite samples collected and analyzed since 1969.

| Common Name | Number Samples |
|---|---|
| Largemouth Bass | 141 |
| White Catfish | 94 |
| Common Carp | 88 |
| Channel Catfish | 67 |
| Sacramento Sucker | 54 |
| Asiatic Clam | 37 |
| Rainbow Trout | 29 |
| Sacramento Pike Minnow | 29 |
| Smallmouth Bass | 20 |
| Bluegill | 15 |
| Riffle Sculpin | 11 |
| Brown Trout | 10 |
| Crayfish | 10 |
| Green Sunfish | 9 |
| Asian clam | 8 |
| Black Crappie | 8 |
| Black Bullhead | 7 |
| Brown Bullhead | 6 |
| Goldfish | 6 |
| Red Swamp Crayfish | 6 |
| Striped Bass | 6 |
| Spotted Bass | 4 |
| Golden Shiner | 3 |
| Sacramento blackfish | 3 |
| Bullhead | 2 |
| Corbicula | 2 |
| Hardhead | 2 |
| Mosquitofish | 2 |
| Redear Sunfish | 2 |
| Sculpin | 2 |
| Yellowfin Goby | 2 |
| Caddis Fly Larvae | 1 |
| Crappie | 1 |
| Kokanee | 1 |
| Warmouth | 1 |
| White Bass | 1 |
| White Crayfish | 1 |

Table 2. Comparison of Toxic Substances Monitoring Program (TSMP) fish samples and reporting limits to human health screening values. All TSMP samples in California collected between 1997 and early 2001 were included in the analysis (N=285). Screening values (SV) for fish tissue were calculated according to USEPA guidance. The last column (RL Above SV) indicates that the samples were below reporting limits but the reporting limits were above screening values.

| **Chemical** | **Screening Value (ppb)[e]** | **Typical Reporting Limit [c]** | **Above SV** | **Below SV** | **Below Reporting Limit** | **RL Above SV** |
|---|---|---|---|---|---|---|
| Total DDTs | 100 | 2-5 [b] | 28% | 72% | 15% | 0% |
| Total PCB Aroclors [a] | 20 | 10-25 [b] | 40% | 60% | 51% | 0% |
| Total Chlordanes | 30 | 1-2 [b] | 12% | 88% | 40% | 0% |
| Dieldrin | 2 | 2 [f] | 36% | 51% | 64% | 13% |
| Toxaphene | 30 | 20 | 25% | 61% | 57% | 14% |
| Aldrin | NA | 1 | | | 98% | |
| Endrin | 1000 | 2 | 0% | 100% | 95% | 0% |
| Total endosulfan | 20,000 | 2-5 [d] | 0% | 100% | 95% | 0% |
| Heptachlor | NA | 2 | | | 100% | |
| Heptachlor epoxide | 4 | 2-5 | 1% | 82% | 93% | 17% |

a. Sum of Aroclors 1248, 1254, and 1260
b. Varies among individual compounds
c. Toxic Substances Monitoring Program reporting limits for most samples between 1998 and 2001. Current reporting limits may be lower.
d. Reporting limit for endosulfan I.
e. SV for carcinogens were calculated for a 70 kg adult using a cancer risk of $1 \times 10^{-5}$. A fish consumption value of 21 g/day was used (Brodberg and Pollock, 1999)
f. The current dieldrin reporting limit for the CDFG Water Pollution Control Laboratory is 0.5 ppb.

Table 3. Summary statistics for species commonly monitored in recent years. All data are Region 5 (Central Valley) samples collected between 1997 and 2001. Means and medians are in ng/g wet weight. N = sample size. SV = Screening Value (Brodberg and Pollock, 1999). a) DDTs. b) PCB. Total Aroclors. c) Chlordanes. d) Dieldrin.

a**. DDTS**

| Species | N | Mean | Median | # Above SV | # Below Detection Limit |
|---|---|---|---|---|---|
| Largemouth Bass | 84 | 51 | 21 | 7 | 1 |
| White Catfish | 37 | 111 | 57 | 12 | 0 |
| Sacramento Sucker | 21 | 39 | 29 | 1 | 1 |
| Rainbow Trout | 17 | 5 | 3 | 0 | 4 |
| Sacramento Pike Minnow | 13 | 24 | 19 | 0 | 0 |
| Riffle Sculpin | 8 | 0 | 0 | 0 | 7 |
| Common Carp | 5 | 242 | 149 | 3 | 0 |
| Channel Catfish | 3 | 370 | 498 | 2 | 0 |

**b. PCB AROCLORS**

| Species | N | Mean | Median | # Above SV | # Below Detection Limit |
|---|---|---|---|---|---|
| Largemouth Bass | 72 | 13 | 5 | 17 | 24 |
| White Catfish | 34 | 44 | 23 | 19 | 4 |
| Sacramento Sucker | 20 | 58 | 17 | 9 | 5 |
| Rainbow Trout | 15 | 3 | 0 | 1 | 11 |
| Sacramento Pike Minnow | 11 | 15 | 14 | 3 | 2 |
| Sculpin | 8 | 0 | 0 | 0 | 8 |
| Common Carp | 3 | 79 | 0 | 1 | 2 |
| Channel Catfish | 3 | 72 | 86 | 3 | 0 |

**c. CHLORDANES**

| Species | N | Mean | Median | # Above SV | # Below Detection Limit |
|---|---|---|---|---|---|
| Largemouth Bass | 82 | 2.1 | 1.0 | 1 | 38 |
| White Catfish | 37 | 6.3 | 3.0 | 1 | 2 |
| Sacramento Sucker | 21 | 5.6 | 1.7 | 0 | 9 |
| Rainbow Trout | 15 | 0.4 | 0.0 | 0 | 12 |
| Sacramento Pike Minnow | 15 | 2.9 | 1.1 | 0 | 7 |
| Sculpin | 8 | 0.0 | 0.0 | 0 | 8 |
| Common Carp | 5 | 1.3 | 1.1 | 0 | 2 |
| Channel Catfish | 3 | 22.3 | 22.8 | 0 | 0 |

**d. DIELDRIN**

| Species | N | Mean | Median | # Above SV | # Below Detection Limit |
|---|---|---|---|---|---|
| Largemouth Bass | 79 | 0.5 | 0.0 | 9 | 70 |
| White Catfish | 36 | 0.9 | 0.0 | 7 | 25 |
| Sacramento Sucker | 21 | 0.6 | 0.0 | 2 | 17 |
| Rainbow Trout | 15 | 0.0 | 0.0 | 0 | 14 |
| Sacramento Pike Minnow | 15 | 0.2 | 0.0 | 1 | 14 |
| Sculpin | 8 | 0.0 | 0.0 | 0 | 8 |
| Common Carp | 4 | 6.5 | 3.0 | 3 | 1 |
| Channel Catfish | 2 | 4.5 | 4.5 | 2 | 0 |

Table 4. General traits of candidate species for trace organic contaminant monitoring in the Central Valley.

| Species | Past Sampling Frequency (N)[a] | Popular Sport Fish? | High Organochlorine Exposure? [b] | Life History [c] | Target Size Range [d] | Notes |
|---|---|---|---|---|---|---|
| White Catfish | 94 | Yes | Yes | Benthivore | 229 -330 | |
| Largemouth Bass | 141 | Yes | No | Pelagic Predator | 305 - 438 | |
| Channel Catfish | 67 | No | Yes | Benthivore | 300 - 500 | |
| Common Carp | 88 | No | Yes | Benthivore | 400 - 600 | |
| Sacramento Sucker | 54 | No | Yes | Benthivore | | |
| Rainbow Trout | 29 | Yes | No | Pelagic Predator | 250 - 400 | Abundant in upper reaches |
| Striped Bass | 6 | Yes | No | Pelagic Predator | > 457 (legal limit) | Migratory |
| Salmon spp. | 1 | Yes | No | Pelagic Predator | NA | Migratory |

a. I.e., number of separate samples reported in the database

b. From Table 3 of this report, Davis et al. (2000), Greenfield et al. (2003), and U.S. EPA (2000).

c. U.S. EPA (2000).

d. These are the size ranges commonly included in recent monitoring studies, including Davis et al. (2000; 2003) and Larry Walker Associates (2001; 2002).

Table 5. Peak spawning season of selected fish species from California inland waters.

| **Species** | **Jan** | **Feb** | **Mar** | **Apr** | **May** | **Jun** | **Jul** | **Aug** | **Sep** | **Oct** | **Nov** | **Dec** |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| White Catfish | | | | | | X | X | | | | | |
| Common Carp | | | | X | X | X | | | | | | |
| Sacramento Sucker | | X | X | X | X | X | | | | | | |
| Large Mouth Bass | | | X | X | X | X | | | | | | |
| Bluegill Sunfish | | | X | X | X | X | X | X | X | | | |
| Redear Sunfish | | | | | X | X | X | X | | | | |
| Sacramento Pikeminnow | | | | X | X | | | | | | | |
| Channel Catfish | | | | X | X | X | X | X | | | | |
| White Crappie | | | | X | X | | | | | | | |

All Information cited from Moyle, P.B. 2002

Table 6. Water bodies currently on the 303(d) list and water bodies with historic exceedances of human health screening values for PCBs and legacy organochlorine pesticides. The 303(d) list is a state-developed list of waters that are impaired due to specific contaminants (Central Valley Regional Water Quality Control Board, 2003). Historic exceedance indicates average tissue concentrations exceeded human health screening values for that contaminant prior to 1997. Station IDs refer to individual sampling locations in Figure 1. Boldface Station IDs are high priority locations for additional sampling, because they have not been recently sampled and do not have archived samples available. For these stations, composite samples of five fish of a species high in lipids (e.g., white catfish) should be collected.

| **Name** | **303(d) Listing *** | **Historic Exceedance** | **Station IDs** |
|---|---|---|---|
| Colusa Basin Drain | Group A Pesticides | | 75 |
| Delta Waterways (eastern and western portion) | DDTs, Group A Pesticides | | See Figure 1 |
| Sacramento River (at Sacramento) | None | DDTs | **315** |
| Lower Feather River (Lake Oroville Dam to confluence with Sacramento River) | Group A Pesticides | PCBs | **213** |
| Feather River (above Lake Oroville Dam) | None | PCBs | **215, 295** |
| Lower Merced River | Group A Pesticides | DDTs | **155** |
| Natomas East Main Drainage | PCBs | | 87 |
| Kings River | Toxaphene | | **142** |
| Orestimba Creek | DDEs | | **163** |
| San Luis Reservoir/O'Neill Forebay | None | DDTs, PCBs, Dieldrin | **161, 303** |
| Lower San Joaquin River | DDTs, Group A Pesticides | DDTs, Dieldrin, PCBs, Chlordanes | **314** |
| Salt Slough | None | DDTs, Dieldrin | **110** |
| Mendota Pool | None | DDTs | **145** |
| Willow Creek | None | DDTs | **223** |
| Lower Stanislaus River | Group A Pesticides | | **NA** |
| Stockton Deep Water Channel (Port of Stockton Turning Basin) | PCBs | | 23 |
| Lower Tuolumne River | Group A Pesticides | DDTs | **176** |

* Group A pesticides include aldrin, dieldrin, chlordanes, endrin, heptachlor, heptachlor epoxide, hexachlorocyclohexane, endosulfan, and toxaphene

Table 7. Stations for screening assessment monitoring with archived samples available. For these stations, composite samples should be analyzed for PCBs and legacy pesticides. Specific archived samples are recommended in Table 8.

| Station Name | Station ID |
|---|---|
| American River at Folsom | 2 |
| Big Break | 5 |
| Cosumnes River | 9 |
| Frank's Tract | 11 |
| Little Holland Tract | 15 |
| Mildred Island | 17 |
| Mokelumne River downstream of Cosumnes River | 19 |
| Sand Mound Slough | 30 |
| White Slough at Lodi | 43 |
| Yuba River above confluence with the Feather | 45 |
| Georgiana Slough | 79 |
| Green's Lake | 80 |
| Middle River @ Woodward | 85 |
| Potato Slough | 88 |
| Sacramento River near Isleton | 94 |
| San Joaquin River @ Naval Station | 95 |
| Victoria canal | 100 |

Table 8. Recommended archived samples for trace organic contaminant analysis to fulfill screening assessment monitoring objectives.

| Station Name | ID | Lab Sample Ids | Species [d] | Collection Date | Available [a] | Comments |
|---|---|---|---|---|---|---|
| American River at Folsom | 2 | 2001-2820 | LMB | 11/14/01 | 5 ind | c |
| Big Break | 5 | 2000-1592, 2000-1596, 2000-1598, 2000-1599 | LMB | 10/17/00 | 10 ind | b |
| Cosumnes River | 9 | 2000-1473, 2000-1479 | WCF | 10/2/00 | 2 ind | c |
| Cosumnes River | 9 | 2001-2681 | LMB | 10/1/01 | 5 ind | c |
| Frank's Tract | 11 | 2000-1491, 2000-1492, 2000-1493, 2000-1494 | LMB | 10/5/00 | 10 ind | b |
| Little Holland Tract | 15 | 2000-1568 | WCF | 10/17/00 | 5 ind | c |
| Mildred Island | 17 | 2000-1496, 2000-1497, 2000-1498 | LMB | 10/5/00 | 10 ind | b |
| Mokelumne River downstream of Cosumnes River | 19 | 2000-1481, 2000-1482, 2000-1483 | LMB | 10/3/00 | 10 ind | b |
| Mokelumne River downstream of Cosumnes River | 19 | 2000-1499, 2000-1500 | SSK | 10/3/00 | 10 ind | |
| Sand Mound Slough | 30 | 1999-1415, 1999-1414 | LMB | 10/19/99 | 7 ind | b, e |
| White Slough at Lodi | 43 | 1999-1274, 1999-1273 | LMB | 10/12/99 | 6 ind | b, e |
| White Slough at Lodi | 43 | 1999-1276, 1999-1277 | WCF | 10/12/99 | 5 ind | c, e |
| Yuba River above confluence with the Feather | 45 | 1999-1231 | SSK | 10/5/99 | 5 ind | e |
| Georgiana Slough | 79 | 2001-2319, 2001-2320 | LMB | 10/16/01 | 5 ind | c |
| Green's Lake | 80 | 2000-1636 | LMB | 10/24/00 | 1 ind | |
| Green's Lake | 80 | 2000-1719, 2000-1720 | Carp | 11/2/00 | 10 ind | |
| Middle River @ Woodward | 85 | 2001-2189 | LMB | 9/26/01 | 5 ind | c |
| Potato Slough | 88 | 2000-1585 | LMB | 10/18/00 | 6 ind | b |
| Sacramento River near Isleton | 94 | 2000-1487, 2000-1488, 2000-1489 | LMB | 10/4/00 | 10 ind | b |
| Sacramento River near Isleton | 94 | 2000-1490 | WCF | 10/4/00 | 1 ind | |
| San Joaquin River @ Naval Station | 95 | 2000-1584, 2000-1577, 2000-1556 | LMB | 10/18/00 | 12 ind | b |
| San Joaquin River @ Naval Station | 95 | 2000-1851 | WCF | 11/14/00 | 6 ind | b |
| Victoria canal | 100 | 2001-2187 | LMB | 9/26/01 | 5 ind | c |

a. Combined sample size of all samples in row; ind = individuals
b. Assemble 5 individual fish and run as 1 composite
c. Assemble all individuals (up to 5) and run as 1 composite
d. LMB = largemouth bass; WCF = white catfish; SSK = Sacramento sucker; Carp = common carp
e. Sample suffered multiple freeze-thaw cycles - integrity may be compromised (year 1 CalFed Sample)
f. Sample size unknown

Table 9. Potential stations for site-specific assessment of PCBs and legacy pesticides.

| Station Name [a] | Station ID | Region | # Composites Analyzed Since 1997 [b] |
|---|---|---|---|
| Feather River near Nicolaus | 10 | Feather River | LMB = 3; SSK = 1; WCF = 1; SPM = 2 |
| ***Feather River above Yuba*** | ***77*** | ***Feather River*** | ***LMB = 1*** |
| ***Feather River between Yuba and Bear*** | ***78*** | ***Feather River*** | ***SSK = 1*** |
| American River at Discovery Park | 1 | Sacramento Area | LMB = 2; WCF = 2; SPM = 2; SSK = 5 |
| Sacramento River at RM44 | 27 | Sacramento Area | LMB = 5; WCF = 8; SSK = 2; SPM = 2; SMB = 1 |
| Port of Stockton turning basin | 23 | Stockton Area | LMB = 7; WCF = 1 |
| ***San Joaquin River around Bowman Road*** | ***31*** | ***Stockton Area*** | ***LMB = 1; WCF = 1*** |
| ***San Joaquin River north of Highway 4*** | ***36*** | ***Stockton Area*** | ***LMB = 1; WCF = 1*** |
| ***Smith Canal by Yosemite Park*** | ***38*** | ***Stockton Area*** | ***LMB = 1; WCF = 1*** |
| San Joaquin River at Crow's Landing | 34 | Lower San Joaquin River | LMB = 3 |
| San Joaquin River Vernalis | 37 | Lower San Joaquin River | LMB = 8; WCF = 2 |
| ***Stanislaus River by Caswell State Park*** | ***97*** | ***Lower San Joaquin River*** | ***LMB = 2*** |
| ***San Joaquin River at Antioch*** | ***33*** | ***Antioch/West Delta*** | ***LMB = 1*** |

a. Boldface and italics indicate higher priority due to low number of previous analyses (see text)

b. LMB = largemouth bass; WCF = white catfish; SSK = Sacramento sucker; SPM = Sacramento pike minnow; SMB = smallmouth bass

Table 10. Preliminary listing of recommended archived samples for contaminant analysis to fulfill site-specific assessment objectives
Note: all samples must be carefully checked to insure that they have not already been analyzed.

| Station Name | ID | Region | Previous Analyses | Lab Sample IDs | Recommended for Additional Analyses | | | |
|---|---|---|---|---|---|---|---|---|
| | | | | | Species [a] | Collection Date | Available [b] | # Analyses [c] |
| Feather River above Yuba | 77 | Feather River | LMB = 1 | 2000-1727, 2000-1728, 2000-1729 | LMB | 11/7/00 | 10 ind | 2 [e] |
| | | | | 2000-1745 | SSK | 11/6/00 | 5 ind | 1 |
| Feather River between Yuba and Bear | 78 | Feather River | SSK = 1 | 2000-1736 | SSK | 11/6/00 | 5 ind | 1 |
| | | | | 2000-1733 | Carp | 11/6/00 | 5 ind | 1 |
| | | | | 2000-1730 | CCF | 11/6/00 | 4 ind | 1 |
| San Joaquin River around Bowman Road | 31 | Stockton Area | WCF = 1 | 1999-1173 | WCF | 9/22/99 | 5 ind [d] | 1 |
| | | | | 1999-1832 | WCF | 11/1/99 | 3 ind [d] | 1 |
| | | | LMB = 1 | 1999-1831 | LMB | 11/1/99 | 4 ind [d] | 1 |
| | | | | 1999-1171 | LMB | 9/22/99 | 5 ind [d] | 1 |
| San Joaquin River North of Highway 4 | 36 | Stockton Area | LMB = 1 | 1999-1148, 1999-1828 | LMB | 9/23/99 | 7 ind [d] | 2 [e] |
| | | | WCF = 1 | 1999-1152 | WCF | 9/23/99 | 3 ind [d] | 1 |
| | | | | 1999-1829 | WCF | 11/2/99 | 1 ind [d] | 1 |
| Smith Canal by Yosemite Park | 38 | Stockton Area | LMB = 1 | 1999-1164 | LMB | 9/22/99 | 5 ind [d] | 1 |
| | | | | 1999-1822 | LMB | 11/1/99 | 2 ind [d] | 1 |
| | | | WCF = 1 | 1999-1165 | WCF | 9/22/99 | 5 ind [d] | 1 |
| Stanislaus River by Caswell State Park | 97 | Lower San Joaquin River | LMB = 2 | 2001-2628 | LMB | 10/25/01 | 5 ind | 1 |
| | | | | 2000-1575, 2000-1576 | CCF | 10/25/01 | 5 ind | 1 |
| San Joaquin River at Antioch | 33 | Antioch/West Delta | LMB = 1 | 1999-1236 | LMB | 10/5/99 | 5 ind [d] | 1 |
| | | | | 2001-2676 | LMB | 10/30/01 | 5 ind | 1 |
| | | | | 1999-1237 | SSK | 10/5/99 | 4 ind [d] | 1 |

a. LMB = largemouth bass; WCF = white catfish; SSK = Sacramento sucker; SPM = Sacramento pike minnow; SMB = smallmouth bass; Carp = common carp; CCF = channel catfish.
b. Combined sample size of all samples in row; ind = individuals
c. Samples should be analyzed as composites
d. Sample suffered multiple freeze-thaw cycles - integrity may be compromised (year 1 CalFed Sample)
e. Two analyses should be run only if it is possible to generate or use composites composed of separate fish. If only one composite is available, only one analysis should be run (i.e., do not run lab duplicates)

Table 11. Potential stations for trend analysis (continued on following page).

| Station Name | ID | Species | Available Data | Above SV $_{g}$ | Archive Years | Sample For Analysis | Sample Date | Sample Size | # Analyses |
|---|---|---|---|---|---|---|---|---|---|
| American River at Discovery Park/Watt Avenue Bridge | 1, 3 | LMB$_{i}$ | 78$_{a}$, 80$_{a}$, 81$_{a}$, 82$_{a}$, 83$_{a}$, 90$_{a}$, 99$_{b}$, 00$_{b}$ | PCB | 2002 | 2002-2053, 2002-2054 | 10/1/02 | 1 comp. | 1 |
| | | | | | 2003 | 2003-3787 comp 1 | 9/23&10/13/03 | 5 ind. | 1 |
| | | | | | | 2003-3788 comp 1 | 9/23&10/13/03 | 5 ind. | 1 |
| American River at Discovery Park/Watt Avenue Bridge | 1, 3 | SSK | 78, 81-84, 88, 99-02 | PCB | 2003 | 2003-3792 comp 1 | 9/23/03 | 5 ind. | 1* |
| | | | | | | 2003-3792 comp 2 | 9/23/03 | 5 ind. | 1* |
| Colusa Basin Drain | 75 | Carp | 81, 84, 95, 98, 00 | DDT, Dieldrin | 2002 | 2002-2537 | 12/5/02 | 1 comp. | 1* |
| Sacramento River at River Mile 44/Hood | 27, 201 | WCF | 79-86$_{c}$, 92$_{c}$, 93$_{c}$, 97$_{d}$, 98$_{cd}$, 99$_{d}$, 00$_{d}$ | PCB | | None Available | | | |
| Sacramento River at River Mile 44/Hood | 27, 201 | LMB | 87$_{c}$, 88 $_{c}$, 98 $_{cd}$, 99$_{d}$, 00$_{d}$, 01$_{c}$ | No | 2002 | 2002-2055, 2002-2056 | 10/1/02 | 1 comp. | 1 |
| | | | | | 2003 | 2003-3781 comp 1 | 9/23/03 | 5 ind. | 1 |
| | | | | | | 2003-3781 comp 2 | 9/23/03 | 5 ind. | 1 |
| Sacramento River at River Mile 44/Hood | 27, 201 | SSK | 00$_{d}$, 02$_{d}$ | PCB, DDT | 2003 | 2003-2785 comp 1 | 9/23&10/13/03 | 5 ind. | 1* |
| | | | | | | 2003-2785 comp 2 | 9/23&10/13/03 | 5 ind. | 1* |
| Feather River near Nicolaus | 10 | SPM | 99, 00 | No | 2003 | 2003-4230 comp 2 | 10/14/03 | 5 ind. | 1* |
| San Joaquin River at Vernalis | 37 | WCF | 78, 80, 83, 84, 85, 86, 87, 98 | DDT, PCB | 1999 | 1999-1428 $_{h}$ | 10/20/99 | 1 ind. | 1 |
| | | | | | | 1999-1842 $_{h}$ | 11/1/99 | 1 ind. | 1 |

* Run these samples for PCBs, pesticides, pyrethroid insecticides, PBDEs, p-nonylphenol, alkylphenol polyethoxylates, nitro and polycyclic musks, phthalates, and other unknown contaminants listed in Table 13.

a. American River at Discovery Park
b. American River d/s Watt Avenue Bridge
c. Sacramento River/Hood
d. Sacramento River at RM44
e. Sac. River at Keswick Reservoir
f. Sacramento River below Keswick Reservoir
g. Screening values based on Brodberg and Pollack (1999)
h. Sample suffered multiple freeze-thaw cycles - (year 1 CalFed Sample)
i. LMB = largemouth bass; WCF = white catfish; SSK = Sacramento sucker; CCF = channel catfish; RT = rainbow trout; Carp = common carp; SPM= Sacramento pikeminnow

Table 11. Potential stations for trend analysis (continued from previous page).

| Station Name | ID | Species | Available Data | Above SV $_g$ | Archive Years | Sample For Analysis | Sample Date | Sample Size | # Analyses |
|---|---|---|---|---|---|---|---|---|---|
| Sacramento River at Keswick Reservoir | 81, 91 | RT | $80_e$, $81_e$, $84_e$, $87_e$, $97_f$, $98_f$, $00_f$, $01_f$ | No | | None Available | | | |
| Stanislaus River At Caswell State Park | 97 | CCF | 79, 81, 82, 83, 84, 90 | DDT, PCB, Dieldrin | | None Available | | | |
| Salt Slough | 110 | Carp | 69, 70, 73, 81, 87 | DDT, PCB, Dieldrin, Chlordane | | None Available | | | |
| Kings River | 142 | LMB | 78, 79, 80, 84 | No | | None Available | | | |
| Merced River at Hageman County Park | 155 | CCF | 78, 79, 80, 81, 83 | DDT | | None Available | | | |
| Tuolomne River d/s Shilo Road Bridge | 176 | CCF | 78, 79, 80, 81, 82, 83, 84 | DDT, PCB, Dieldrin, Chlordane | | None Available | | | |
| Feather River/d/s Highway 99 Bridge | 193 | CCF | 78, 80, 82, 90 | DDT, PCB, Dieldrin, Chlordane | | None Available | | | |
| San Joaquin River at Los Banos | 314 | Carp | 70, 71, 73, 79 | DDT, Dieldrin | | None Available | | | |

a. American River at Discovery Park
b. American River d/s Watt Avenue Bridge
c. Sacramento River/Hood
d. Sacramento River at RM44
e. Sac. River at Keswick Reservoir
f. Sacramento River below Keswick Reservoir
g. Screening values based on Brodberg and Pollack (1999)
h. Sample suffered multiple freeze-thaw cycles - (year 1 CalFed Sample)
i. LMB = largemouth bass; WCF = white catfish; SSK = Sacramento sucker; CCF = channel catfish; RT = rainbow trout; Carp = common carp; SPM= Sacramento pikeminnow

Table 12. Comparison of concentrations at 303(d) listed stations to human health Screening Values (SV). Screening Value comparison is based on two-tailed t-test of log-transformed data vs. Office of Environmental Health Hazard Assessment SVs (Brodberg and Pollock, 1999). Power analysis determines total number of samples required to establish significant difference assuming sample mean (log concentrations), $p < 0.05$, and a greater than 90% probability of detecting significant difference. Contaminants indicated in grey cells are 303(d) listed for that water body.

| | Station | | Sample | Screening Value Comparison [a] | | | | Power Analysis Sample Size Required [b] | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Water Body | ID | Species [e] | Size | DDT | PCBs | Chlordanes | Dieldrin | DDT | PCBs | Chlordanes | Dieldrin |
| Colusa Basin Drain | 75 | Carp | 3 | >, ns | < *[c] | < * | >, ns | 5 | Done | Done | 15 |
| East Delta | 21, 22, 32, 35 | WCF | 4 | No Diff. | No Diff. | < * | ND | >1000 | >1000 | Done | ND |
| West Delta | 7 | WCF | 2 | < * | <, ns | < * | ND | Done | 3 | Done | ND |
| Lower San Joaquin River | 29, 31, 36, 37 | WCF | 5 | >, ns | <, ns | < * | ND | 14 | 239 | Done | ND |
| Lower Feather River | 10, 77, 78 | SSK, SPM, WCF | 5 | < ** | No Diff. | ND | ND | Done | 38 | ND | ND |
| Lower Merced River | 84 | CCF | 2 | > * | > ** | <, ns | >, ns | Done | Done | 2 | 1 |
| Stanislaus River | 97 | LMB | 2 | <, ns | <, ns | <, ns | ND | 28 | 24 | 2 | ND |
| Port of Stockton Turning Basin [d] | 23 | LMB | 7 | < ** | > * | < ** | ND | Done | Done | Done | ND |
| Natomas East Main Drain | 87 | LMB | 3 | < * | >, ns | < ** | ND | Done | 5 | Done | ND |
| Kings River [f] | 143, 324 | BG, RT, SSK, SMB, CCF[g] | 5 | <, * | ND | <, ** | ND | Done | ND | Done | ND |
| Lower Tuolumne River | 99, 176 | LMB | 3 | <, ns | <, ns | <, ns | ND | 74 | 111 | 14 | ND |

a. > = average log concentrations at least 10% greater than Screening Value; < = at least 10% less than SV. No Diff.= average log concentrations not more than 10% greater or less than SV. ND = distributional assumptions for power analysis not met because of large number of samples below detection. High incidence of non-detects indicates generally low contamination. ns = $p > 0.05$ * = $p < 0.05$ ** = $p < 0.01$ (two tailed test)

b. Minimum sample size required to achieve 90% chance of significant results. $p < 0.05$ (2 tailed test). Done = significance already achieved given current sample size.

c. PCB total congener data used to achieve distributional requirements.

d. 303(d) listed as Stockton Deep Water Ship Channel

e. LMB = largemouth bass; WCF = white catfish; SSK = Sacramento sucker; CCF = channel catfish; RT = rainbow trout; Carp = common carp; BG = bluegill sunfish; SMB = smallmouth bass

f. 303(d) listed for toxaphene

g. Includes TSMP samples collected in 2001

Table 13. Priority contaminants recommended for special study monitoring in Central Valley fishes.

| Compound class |
| --- |
| Pyrethroid insecticides |
| Dioxins |
| Polybrominated diphenyl ethers |
| p-nonylphenol |
| Alkylphenol polyethoxylates |
| Nitro and Polycyclic musks |
| Ethinyl estradiol |
| Phthalates |
| Estrogens |
| Androgens |

## Figure Captions

**Figure 1.** Previously monitored stations and archived sample locations. Red dots indicate locations were archived samples are available and for which trace organic contaminants have not been previously monitored. Green dots are locations having archived samples that have been previously monitored for trace organics. White dots are stations with no archived samples that were only monitored prior to 1997. Dark gray dots are stations with no archived samples that were monitored after 1997. Pink shaded areas are recommended monitoring locations for additional site-specific monitoring.

**Figure 2.** Measured total DDT concentrations in four fish species sampled recently in the Central Valley of California. Each point represents the mean concentration of all samples analyzed since 1997. At grey points, all samples were below detection limits. See figure legend for further details.

**Figure 3.** Measured total DDT concentrations in four fish species sampled between 1969 and 1996 in the Central Valley of California. Each point represents the mean concentration of all samples analyzed prior to 1997. At grey points, all samples were below detection limits. See figure legend for further details.

**Figure 4.** Measured PCB concentrations in four fish species sampled recently in the Central Valley of California. Each point represents the mean concentration of all samples analyzed since 1997. At grey points, all samples were below detection limits. See figure legend for further details.

**Figure 5.** Measured PCB concentrations in four fish species sampled between 1969 and 1996 in the Central Valley of California. Each point represents the mean concentration of all samples analyzed prior to 1997. At grey points, all samples were below detection limits. See figure legend for further details.

**Figure 6.** Measured chlordane concentrations in four fish species sampled recently in the Central Valley of California. Each point represents the mean concentration of all samples analyzed since 1997. At grey points, all samples were below detection limits. See figure legend for further details.

**Figure 7.** Measured total chlordane concentrations in four fish species sampled between 1969 and 1996 in the Central Valley of California. Each point represents the mean concentration of all samples analyzed prior to 1997. At grey points, all samples were below detection limits. See figure legend for further details.

**Figure 8.** Measured dieldrin concentrations in four fish species sampled recently in the Central Valley of California. Each point represents the mean concentration of all samples analyzed since 1997. At grey points, all samples were below detection limits. See figure legend for further details.

**Figure 9.** Measured dieldrin concentrations in four fish species sampled between 1969 and 1996 in the Central Valley of California. Each point represents the mean concentration of all samples analyzed prior to 1997. At grey points, all samples were below detection limits. See figure legend for further details.

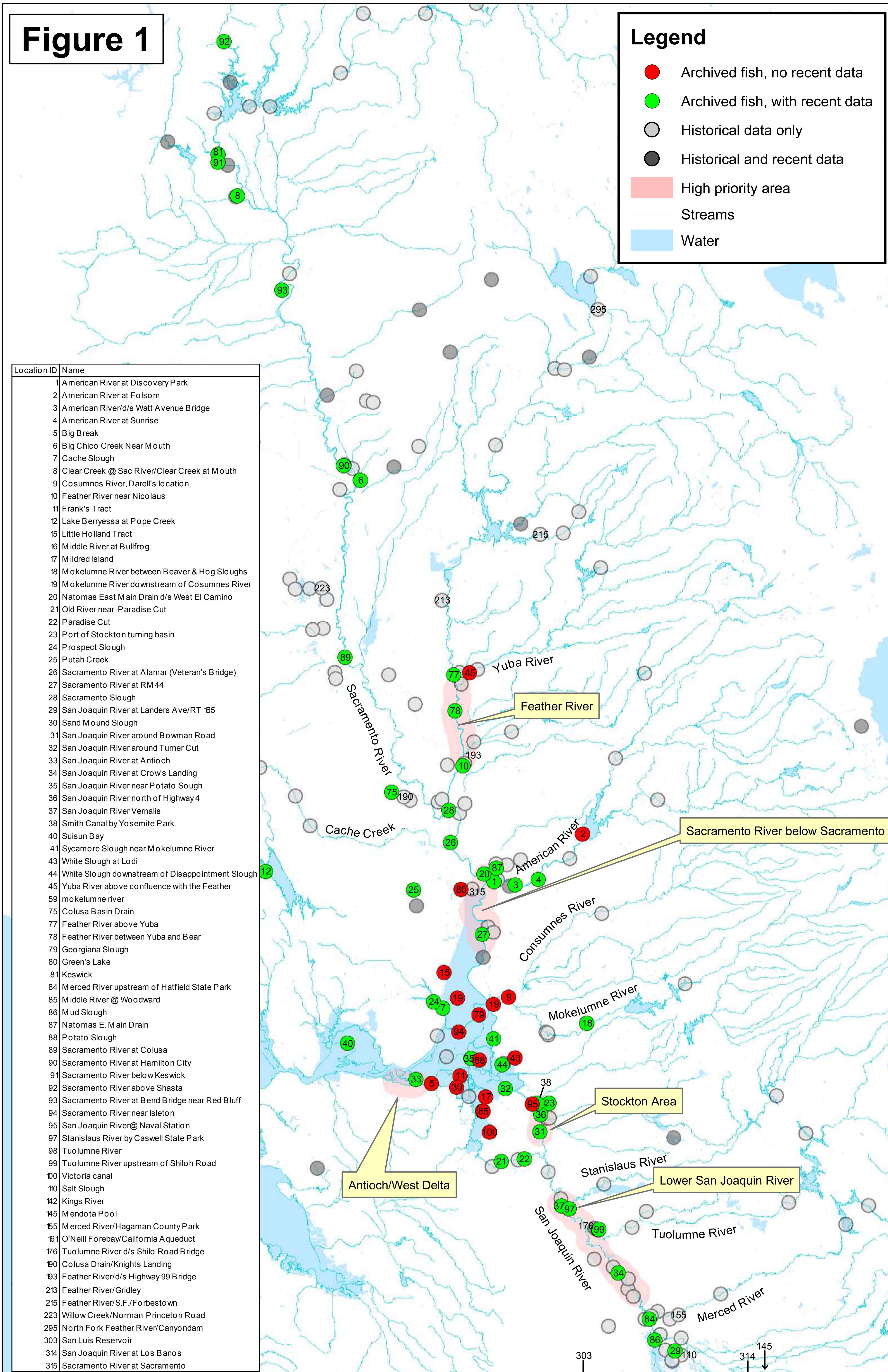
**Figure 10.** Changes over time in contaminant concentrations in white catfish in the Central Valley of California. Each data point represents 1 composite sample collected from one of several different monitoring programs. a. Total chlordanes. b. PCBs. c. Dieldrin. d. Total DDTs.

**Figure 11.** Changes in PCB concentrations (total Aroclors) in fish at selected monitoring stations from 1978 through 2002. Data were collected by the Toxic Substance Monitoring Program (TSMP; black dots) and the Sacramento River Watershed Program (SRWP; white dots). a. Sacramento sucker in the Lower American River. b. White catfish at Sacramento River Mile 44.

**Figure 12.** Changes in DDT concentrations in various species at two Sacramento River sites and at the Lower American River. Data were collected by the Toxic Substance Monitoring Program (TSMP; black dots) and the Sacramento River Watershed Program (SRWP; white dots).

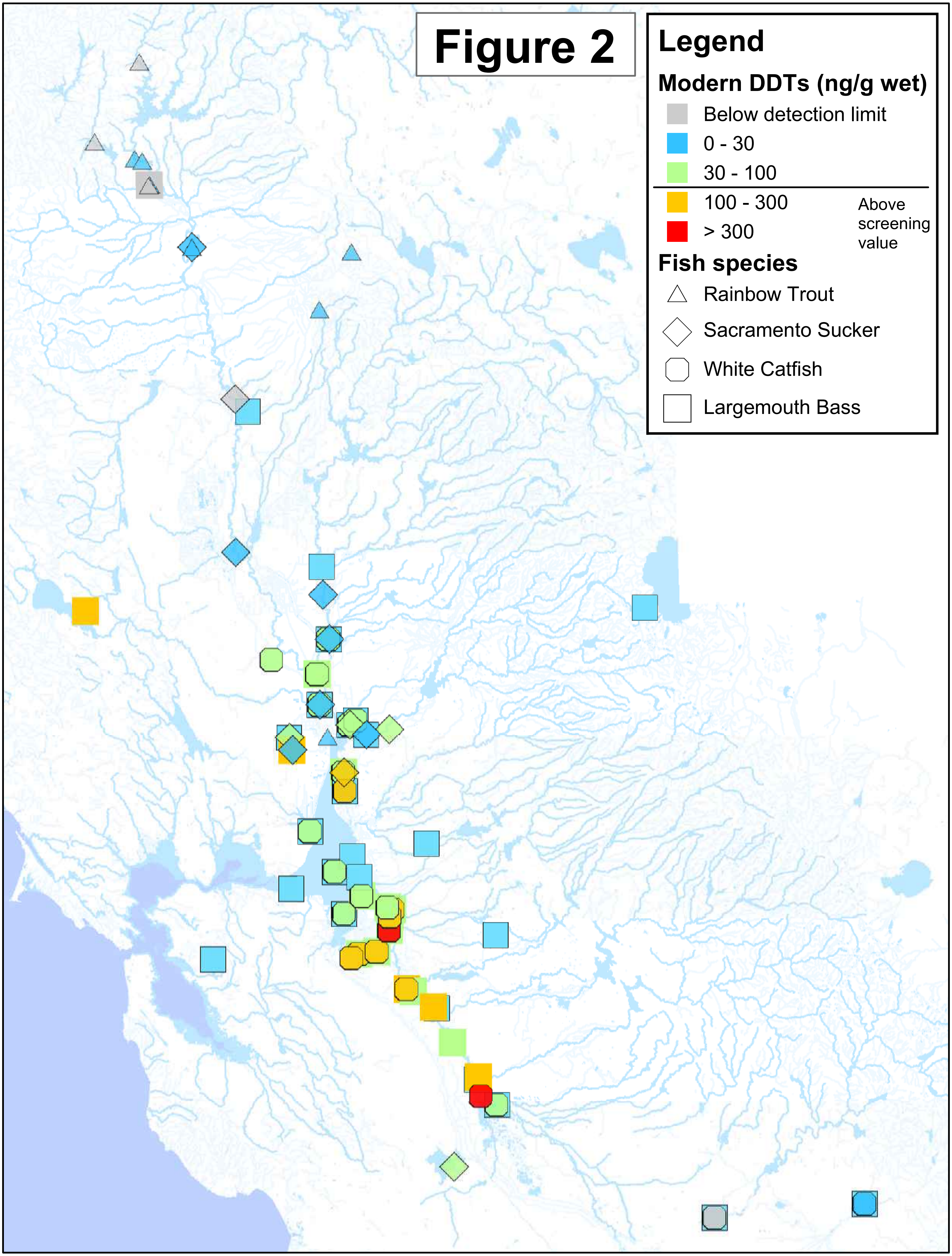
## Figures

# Figure 1




| Location ID | Name |
|---|---|
| 1 | American River at Discovery Park |
| 2 | American River at Folsom |
| 3 | American River/d/s Watt Avenue Bridge |
| 4 | American River at Sunrise |
| 5 | Big Break |
| 6 | Big Chico Creek Near Mouth |
| 7 | Cache Slough |
| 8 | Clear Creek @ Sac River/Clear Creek at Mouth |
| 9 | Cosumnes River, Darell's location |
| 10 | Feather River near Nicolaus |
| 11 | Frank's Tract |
| 12 | Lake Berryessa at Pope Creek |
| 15 | Little Holland Tract |
| 16 | Middle River at Bullfrog |
| 17 | Mildred Island |
| 18 | Mokelumne River between Beaver & Hog Sloughs |
| 19 | Mokelumne River downstream of Cosumnes River |
| 20 | Natomas East Main Drain d/s West El Camino |
| 21 | Old River near Paradise Cut |
| 22 | Paradise Cut |
| 23 | Port of Stockton turning basin |
| 24 | Prospect Slough |
| 25 | Putah Creek |
| 26 | Sacramento River at Alamar (Veteran's Bridge) |
| 27 | Sacramento River at RM 44 |
| 28 | Sacramento Slough |
| 29 | San Joaquin River at Landers Ave/RT 165 |
| 30 | Sand Mound Slough |
| 31 | San Joaquin River around Bowman Road |
| 32 | San Joaquin River around Turner Cut |
| 33 | San Joaquin River at Antioch |
| 34 | San Joaquin River at Crow's Landing |
| 35 | San Joaquin River near Potato Sough |
| 36 | San Joaquin River north of Highway 4 |
| 37 | San Joaquin River Vernalis |
| 38 | Smith Canal by Yosemite Park |
| 40 | Suisun Bay |
| 41 | Sycamore Slough near Mokelumne River |
| 43 | White Slough at Lodi |
| 44 | White Slough downstream of Disappointment Slough |
| 45 | Yuba River above confluence with the Feather |
| 59 | mokelumne river |
| 75 | Colusa Basin Drain |
| 77 | Feather River above Yuba |
| 78 | Feather River between Yuba and Bear |
| 79 | Georgiana Slough |
| 80 | Green's Lake |
| 81 | Keswick |
| 84 | Merced River upstream of Hatfield State Park |
| 85 | Middle River @ Woodward |
| 86 | Mud Slough |
| 87 | Natomas E. Main Drain |
| 88 | Potato Slough |
| 89 | Sacramento River at Colusa |
| 90 | Sacramento River at Hamilton City |
| 91 | Sacramento River below Keswick |
| 92 | Sacramento River above Shasta |
| 93 | Sacramento River at Bend Bridge near Red Bluff |
| 94 | Sacramento River near Isleton |
| 95 | San Joaquin River@ Naval Station |
| 97 | Stanislaus River by Caswell State Park |
| 98 | Tuolumne River |
| 99 | Tuolumne River upstream of Shiloh Road |
| 100 | Victoria canal |
| 110 | Salt Slough |
| 142 | Kings River |
| 145 | Mendota Pool |
| 155 | Merced River/Hagaman County Park |
| 161 | O'Neill Forebay/California Aqueduct |
| 176 | Tuolumne River d/s Shilo Road Bridge |
| 190 | Colusa Drain/Knights Landing |
| 193 | Feather River/d/s Highway 99 Bridge |
| 213 | Feather River/Gridley |
| 215 | Feather River/S.F./Forbestown |
| 223 | Willow Creek/Norman-Princeton Road |
| 295 | North Fork Feather River/Canyondam |
| 303 | San Luis Reservoir |
| 314 | San Joaquin River at Los Banos |
| 315 | Sacramento River at Sacramento |

# Figure 2


Legend
Modern DDTs (ng/g wet)
Below detection limit
0 - 30
30 - 100
100 - 300
> 300
Above screening value
Fish species
Rainbow Trout
Sacramento Sucker
White Catfish
Largemouth Bass

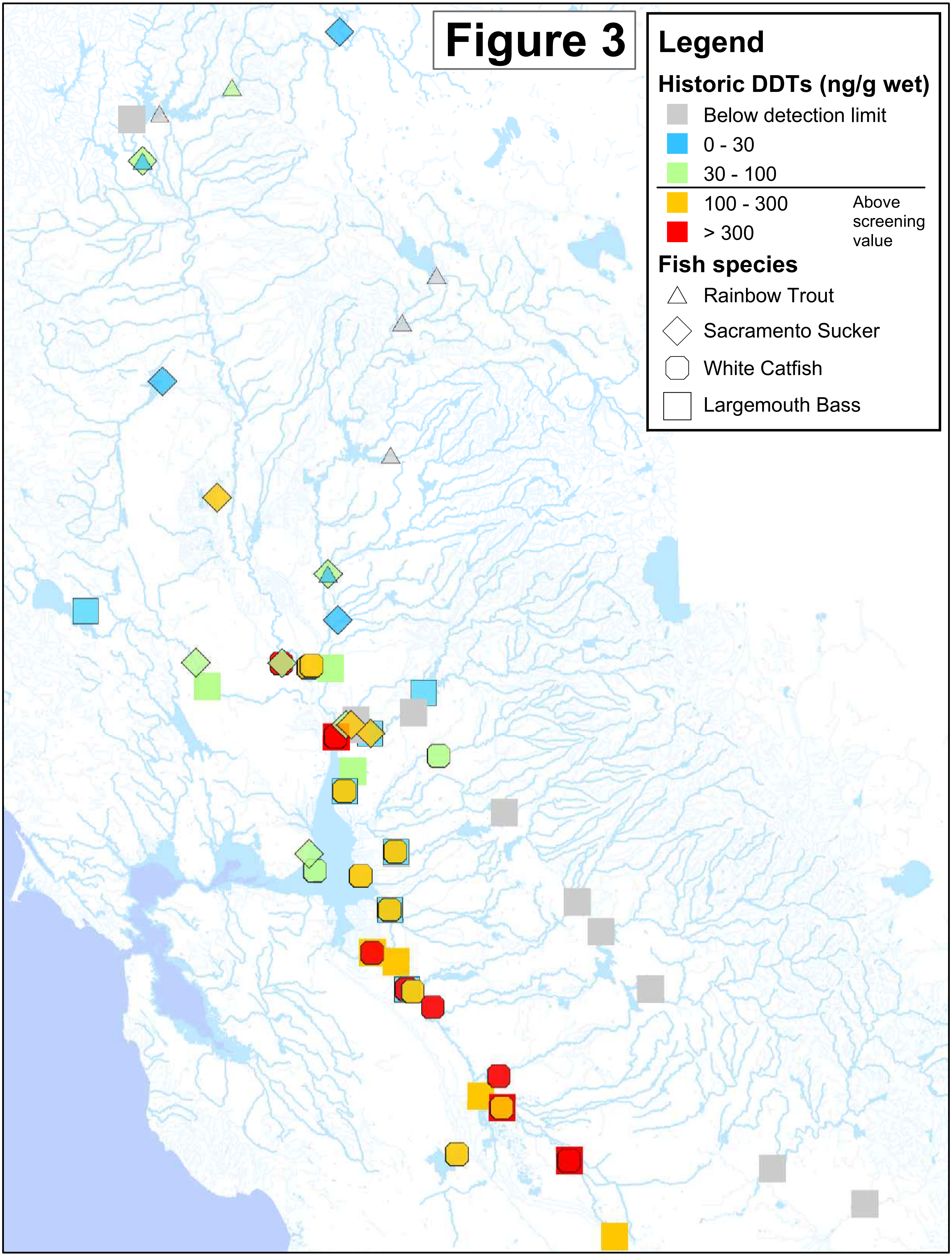


Figure 3
Legend
Historic DDTs (ng/g wet)
Below detection limit
0 - 30
30 - 100
100 - 300
> 300
Above screening value
Fish species
Rainbow Trout
Sacramento Sucker
White Catfish
Largemouth Bass

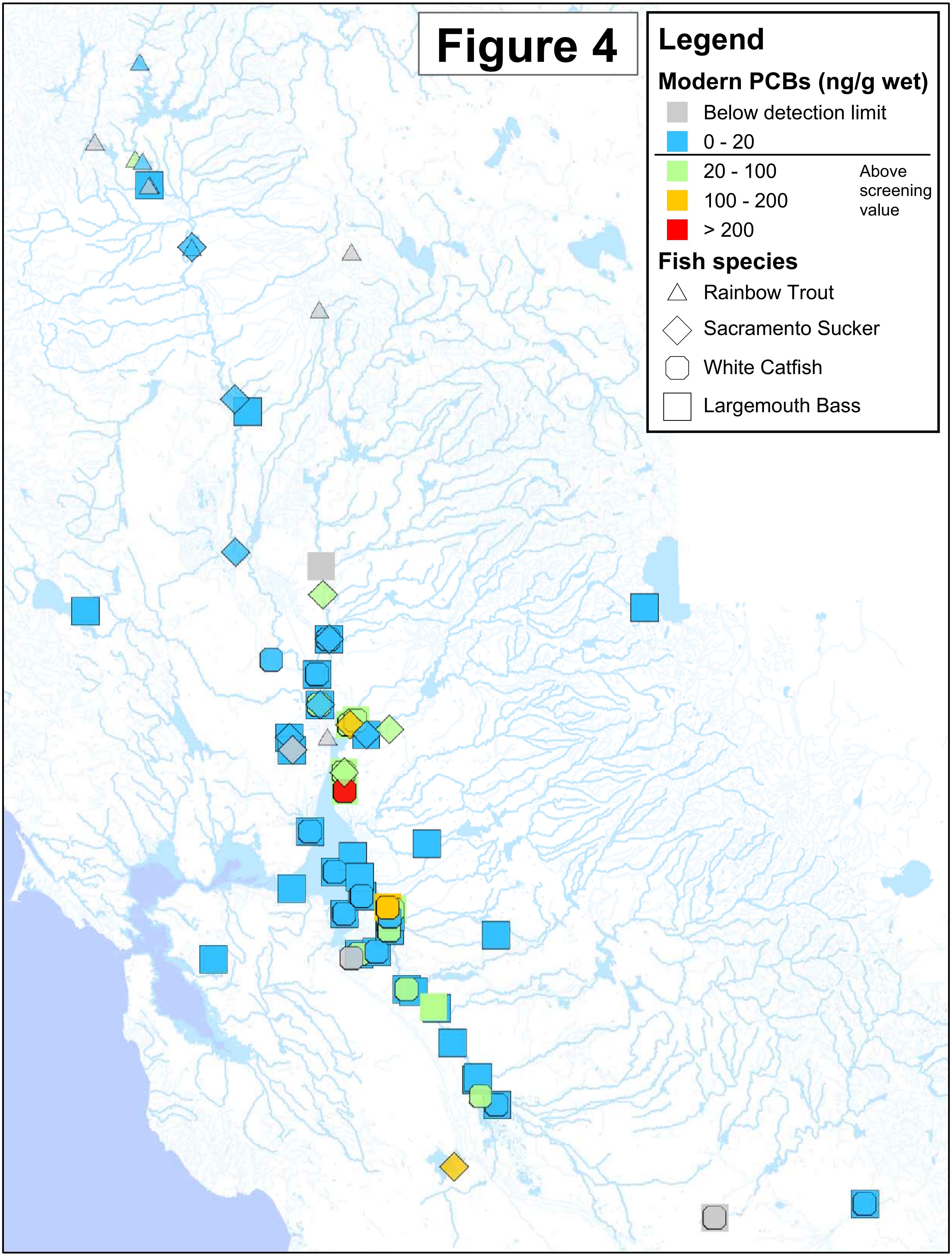


Figure 4
Legend
Modern PCBs (ng/g wet)
Below detection limit
0 - 20
20 - 100
100 - 200
> 200
Above screening value
Fish species
Rainbow Trout
Sacramento Sucker
White Catfish
Largemouth Bass

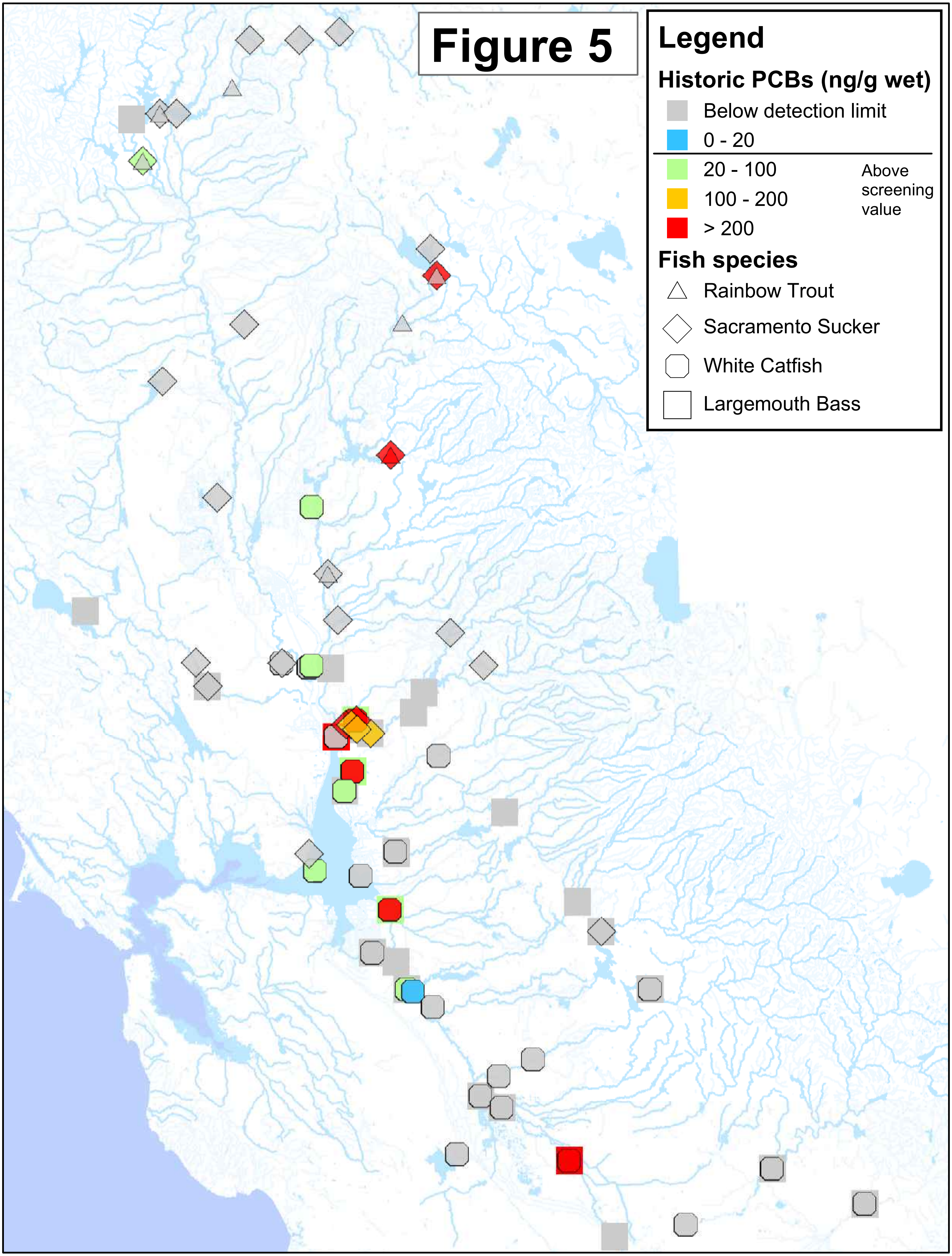


Figure 5
Legend
Historic PCBs (ng/g wet)
Below detection limit
0 - 20
20 - 100
100 - 200
> 200
Above screening value
Fish species
Rainbow Trout
Sacramento Sucker
White Catfish
Largemouth Bass

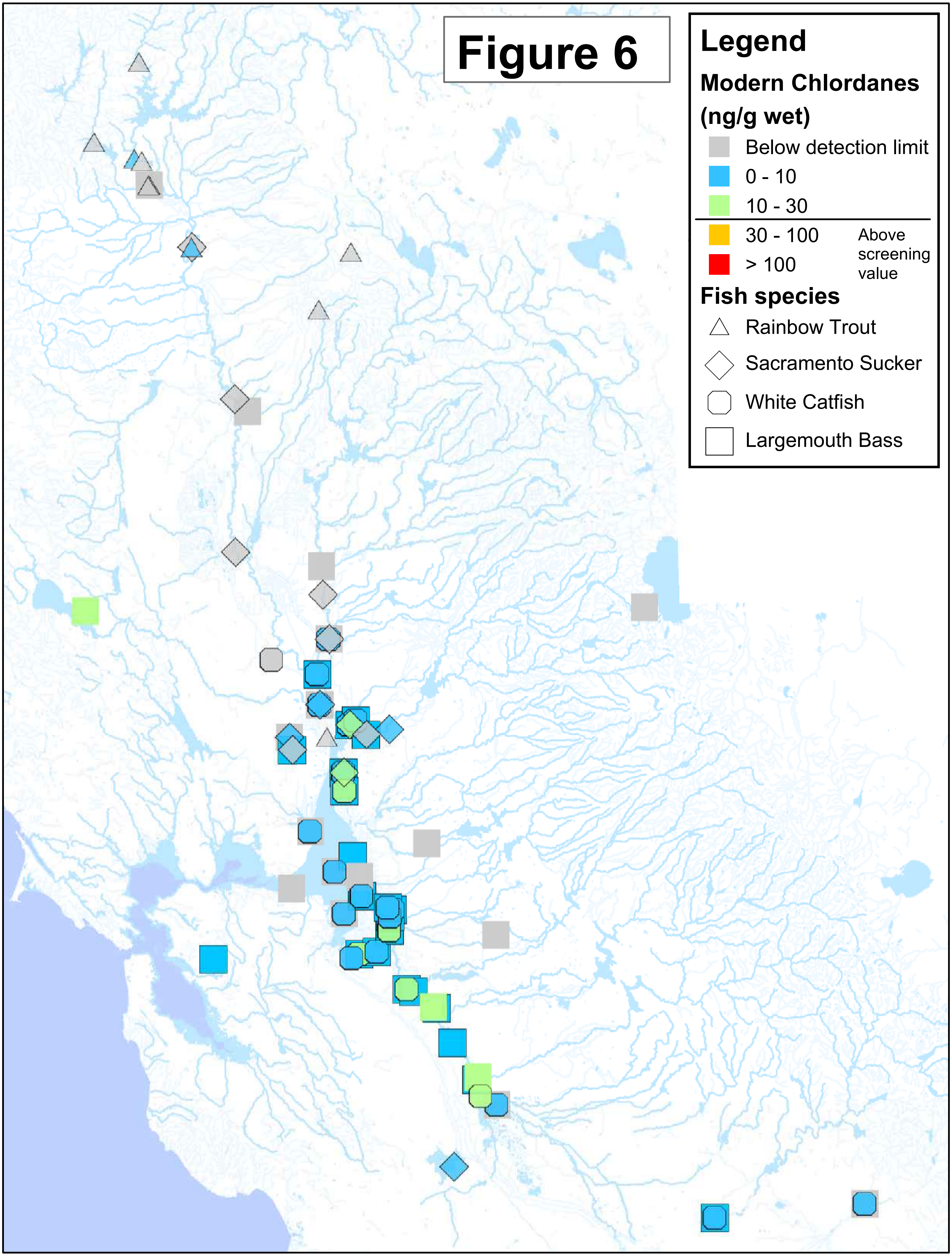


Figure 6
Legend
Modern Chlordanes
(ng/g wet)
Below detection limit
0 - 10
10 - 30
30 - 100
> 100
Above screening value
Fish species
Rainbow Trout
Sacramento Sucker
White Catfish
Largemouth Bass

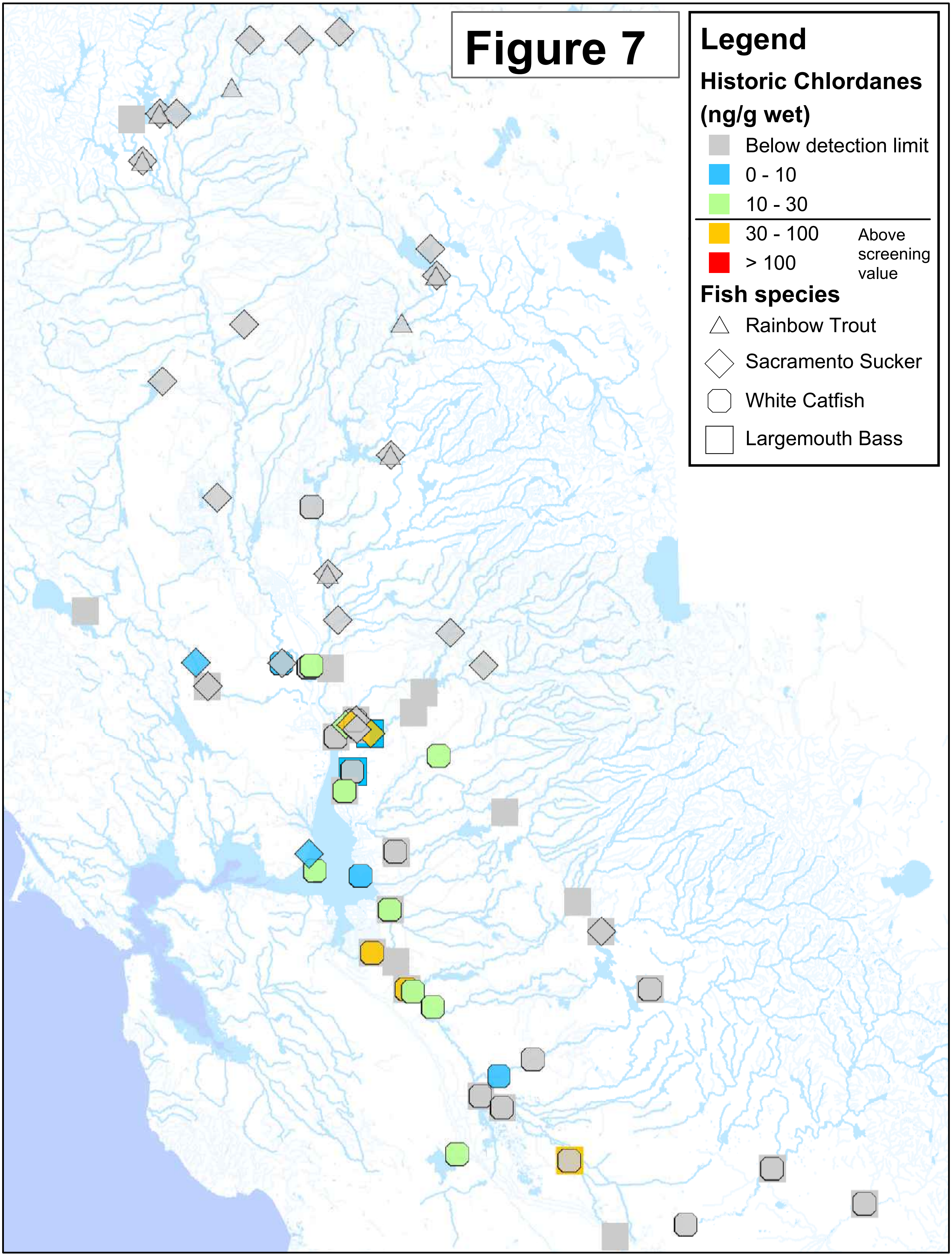


Figure 7
Legend
Historic Chlordanes
(ng/g wet)
Below detection limit
0 - 10
10 - 30
30 - 100
> 100
Above screening value
Fish species
Rainbow Trout
Sacramento Sucker
White Catfish
Largemouth Bass

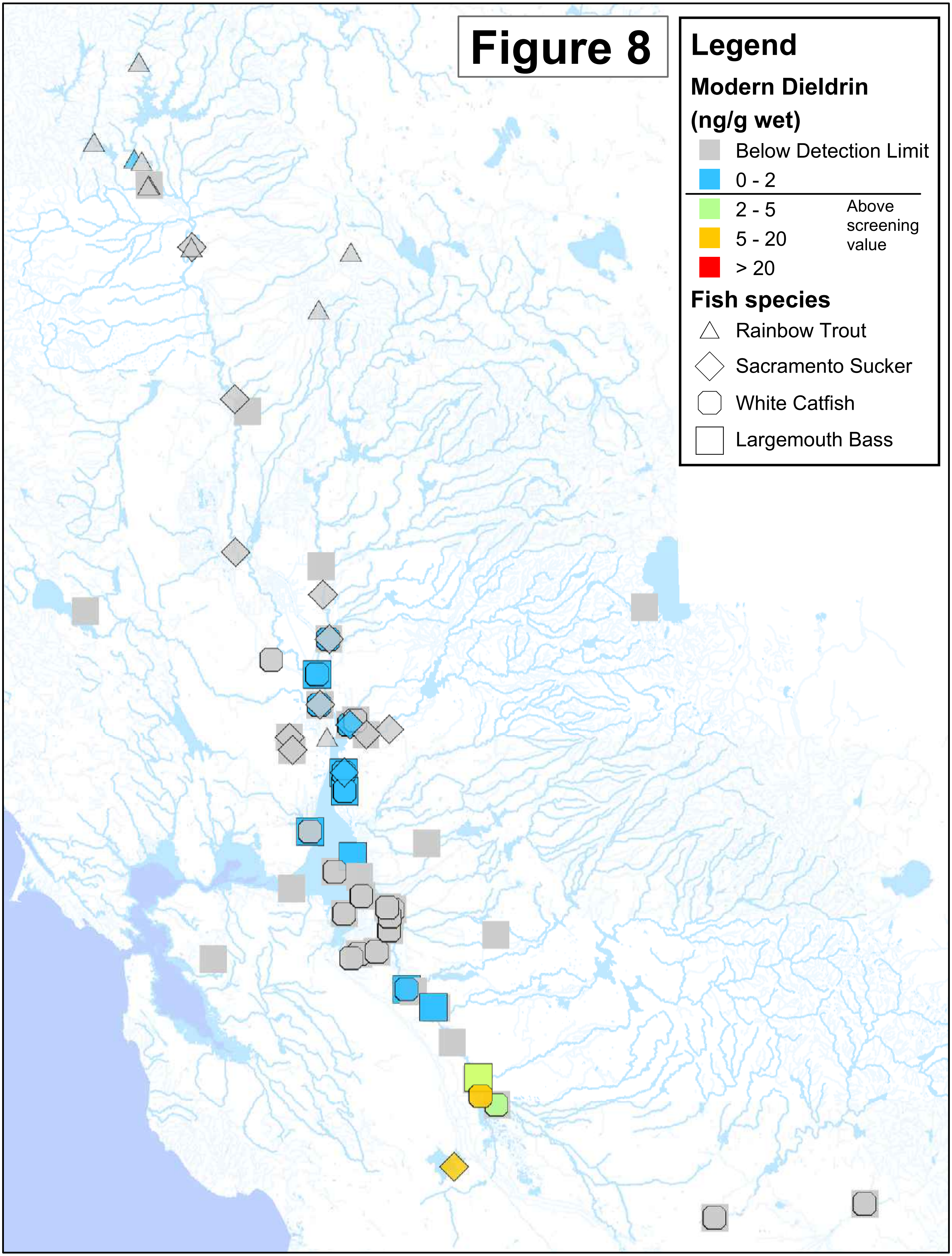


Figure 8
Legend
Modern Dieldrin
(ng/g wet)
Below Detection Limit
0 - 2
2 - 5
5 - 20
> 20
Above screening value
Fish species
Rainbow Trout
Sacramento Sucker
White Catfish
Largemouth Bass

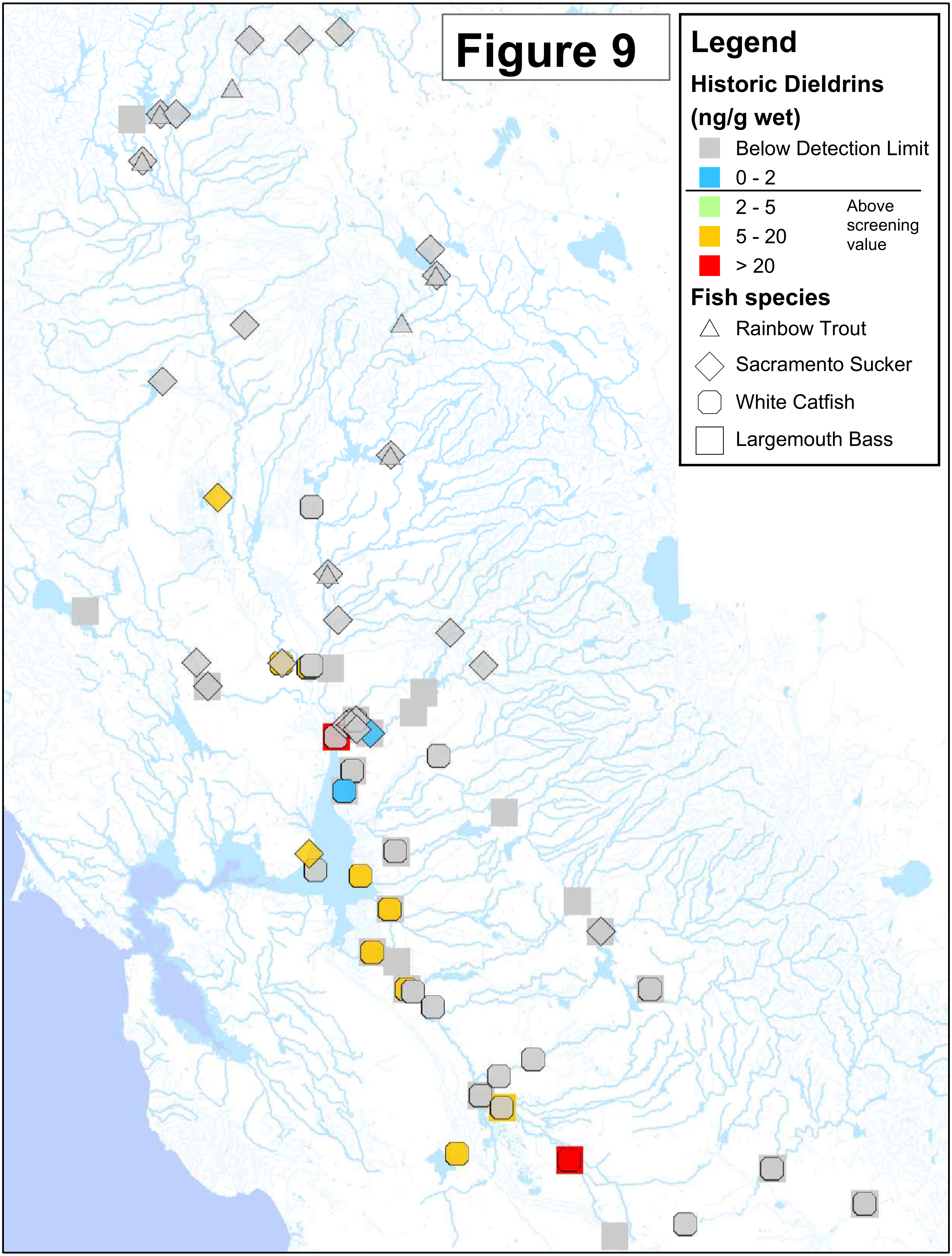


Figure 9
Legend
Historic Dieldrins
(ng/g wet)
Below Detection Limit
0 - 2
2 - 5
5 - 20
> 20
Above screening value
Fish species
Rainbow Trout
Sacramento Sucker
White Catfish
Largemouth Bass

**Figure 10:**

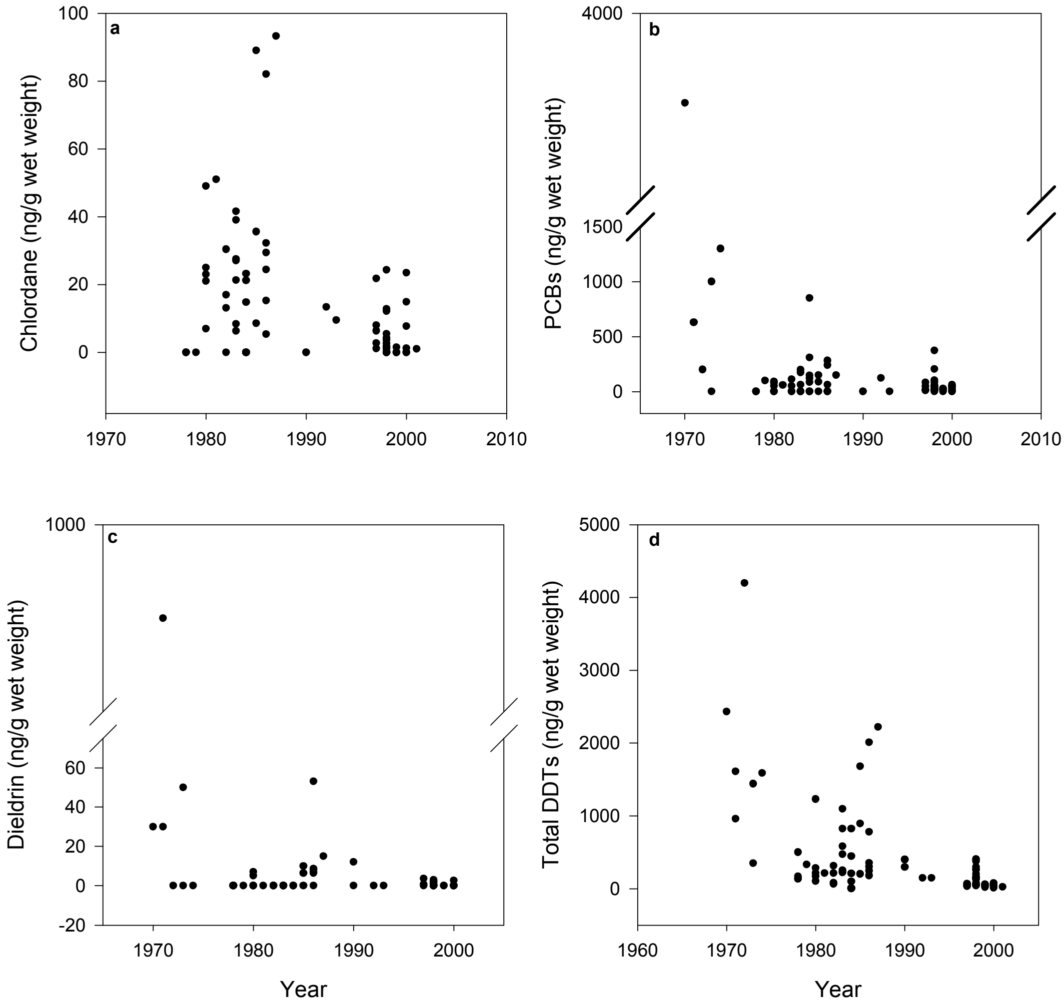
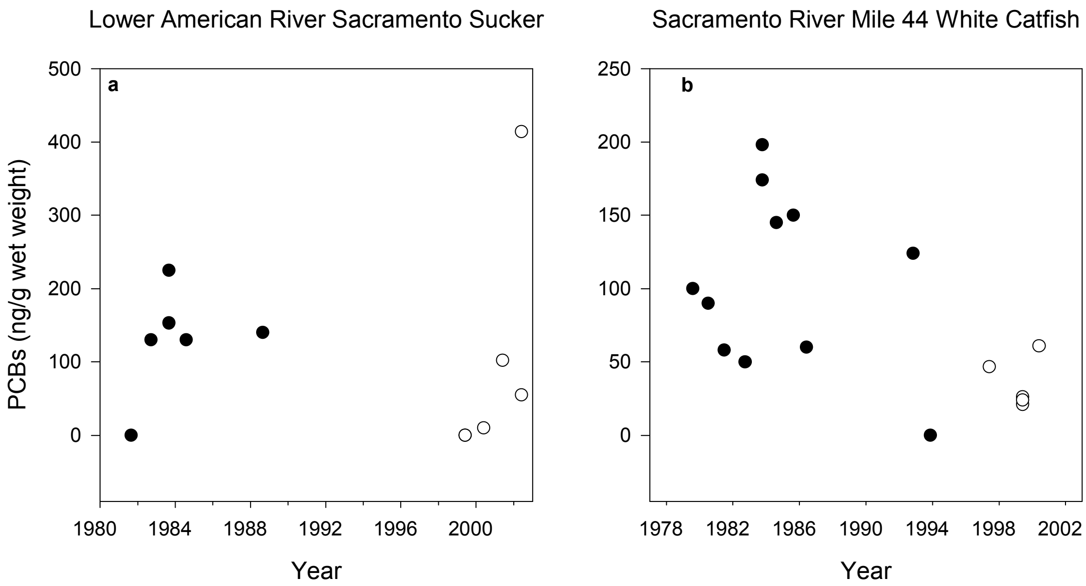
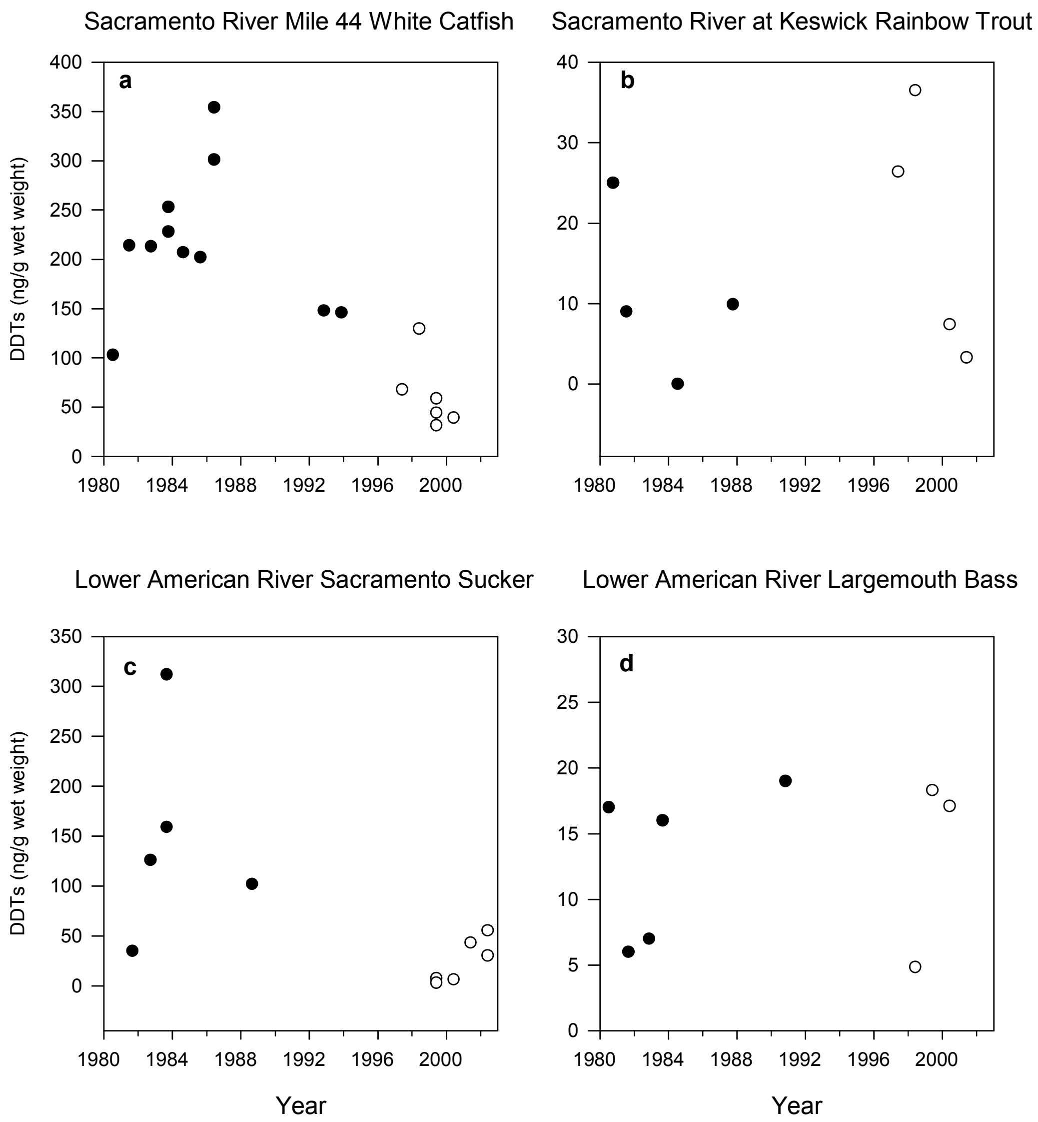

a
Chlordane (ng/g wet weight)
100
80
60
40
20
0
1970
1980
1990
2000
2010
b
PCBs (ng/g wet weight)
4000
1500
1000
500
0
1970
1980
1990
2000
2010
c
Dieldrin (ng/g wet weight)
1000
60
40
20
0
-20
1970
1980
1990
2000
Year
d
Total DDTs (ng/g wet weight)
5000
4000
3000
2000
1000
0
1960
1970
1980
1990
2000
Year

**Figure 11:**



Lower American River Sacramento Sucker
a
PCBs (ng/g wet weight)
500
400
300
200
100
0
1980
1984
1988
1992
1996
2000
Year
Sacramento River Mile 44 White Catfish
b
250
200
150
100
50
0
1978
1982
1986
1990
1994
1998
2002
Year

**Figure 12:**



Sacramento River Mile 44 White Catfish
Sacramento River at Keswick Rainbow Trout
a
b
DDTs (ng/g wet weight)
400
350
300
250
200
150
100
50
0
40
30
20
10
0
1980
1984
1988
1992
1996
2000
Lower American River Sacramento Sucker
Lower American River Largemouth Bass
c
d
DDTs (ng/g wet weight)
350
300
250
200
150
100
50
0
30
25
20
15
10
5
0
Year
Year

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# Appendix A - Complete listing of stations having archived samples or contamination data available.

Location ID = Station ID referred to in text and Figure 1. LATDD = Latitude coordinates in degrees and decimal degrees. LONGDD = Longitude coordinates in degrees and decimal degrees. Archived samples = archived samples available at station (0 = No; 1 = Yes). Recent OC analysis = analyses of PCBs or legacy pesticides since 1997. Contamination data = recent or historic PCB or legacy pesticide data available.

| Location ID | Station Name | LATDD | LONGDD | Archived samples | Recent OC Analysis | Contamination Data |
|---|---|---|---|---|---|---|
| 1 | American River at Discovery Park | 38.603 | -121.495 | 1 | 1 | 1 |
| 2 | American River at Folsom | 38.710 | -121.160 | 1 | 0 | 0 |
| 3 | American River/d/s Watt Avenue Bridge | 38.571 | -121.403 | 1 | 1 | 1 |
| 4 | American River at Sunrise | 38.585 | -121.319 | 1 | 1 | 1 |
| 5 | Big Break | 38.020 | -121.710 | 1 | 0 | 0 |
| 6 | Big Chico Creek Near Mouth | 39.709 | -121.936 | 1 | 1 | 1 |
| 7 | Cache Slough | 38.232 | -121.677 | 1 | 1 | 1 |
| 8 | Clear Creek @ Sac River/Clear Creek at Mouth | 40.507 | -122.374 | 1 | 1 | 1 |
| 9 | Cosumnes River, Darell's location | 38.257 | -121.433 | 1 | 0 | 0 |
| 10 | Feather River near Nicolaus | 38.906 | -121.582 | 1 | 1 | 1 |
| 11 | Frank's Tract | 38.040 | -121.610 | 1 | 0 | 0 |
| 12 | Lake Berryessa at Pope Creek | 38.618 | -122.291 | 1 | 1 | 1 |
| 13 | Lake Nacimiento at Las Tablas Ck | 35.689 | -120.947 | 1 | 0 | 0 |
| 14 | Lake San Antonio at Harris Ck | 35.806 | -120.951 | 1 | 0 | 0 |
| 15 | Little Holland Tract | 38.330 | -121.660 | 1 | 0 | 0 |
| 16 | Middle River at Bullfrog | 37.940 | -121.533 | 1 | 1 | 1 |
| 17 | Mildred Island | 37.980 | -121.520 | 1 | 0 | 0 |
| 18 | Mokelumne River between Beaver & Hog Sloughs | 38.181 | -121.158 | 1 | 1 | 1 |
| 19 | Mokelumne River downstream of Cosumnes River | 38.238 | -121.487 | 1 | 0 | 0 |
| 20 | Natomas East Main Drain d/s West El Camino | 38.603 | -121.514 | 1 | 1 | 1 |
| 21 | Old River near Paradise Cut | 37.799 | -121.469 | 1 | 1 | 1 |
| 22 | Paradise Cut | 37.805 | -121.388 | 1 | 1 | 1 |
| 23 | Port of Stockton turning basin | 37.953 | -121.315 | 1 | 1 | 1 |
| 24 | Prospect Slough | 38.239 | -121.683 | 1 | 1 | 1 |
| 25 | Putah Creek | 38.562 | -121.766 | 1 | 1 | 1 |
| 26 | Sacramento River at Alamar (Veteran's Bridge) | 38.693 | -121.632 | 1 | 1 | 1 |
| 27 | Sacramento River at RM44 | 38.435 | -121.523 | 1 | 1 | 1 |
| 28 | Sacramento Slough | 38.783 | -121.636 | 1 | 1 | 1 |
| 29 | San Joaquin River at Landers Ave/RT 165 | 37.260 | -120.872 | 1 | 1 | 1 |
| 30 | Sand Mound Slough | 38.008 | -121.623 | 1 | 0 | 0 |
| 31 | San Joaquin River around Bowman Road | 37.880 | -121.332 | 1 | 1 | 1 |
| 32 | San Joaquin River around Turner Cut | 38.002 | -121.451 | 1 | 1 | 1 |
| 33 | San Joaquin River at Antioch | 38.032 | -121.766 | 1 | 1 | 1 |
| 34 | San Joaquin River at Crow's Landing | 37.480 | -121.065 | 1 | 1 | 1 |
| 35 | San Joaquin River near Potato Sough | 38.088 | -121.570 | 1 | 1 | 1 |
| 36 | San Joaquin River north of Highway 4 | 37.928 | -121.328 | 1 | 1 | 1 |
| 37 | San Joaquin River Vernalis | 37.671 | -121.259 | 1 | 1 | 1 |
| 38 | Smith Canal by Yosemite Park | 37.960 | -121.339 | 1 | 1 | 1 |
| 39 | Sonoma Lake | 38.700 | -123.048 | 1 | 0 | 0 |
| 40 | Suisun Bay | 38.134 | -122.006 | 1 | 1 | 1 |
| 41 | Sycamore Slough near Mokelumne River | 38.142 | -121.489 | 1 | 1 | 1 |
| 42 | Wiest Lake | 33.042 | -115.492 | 1 | 0 | 0 |
| 43 | White Slough at Lodi | 38.087 | -121.414 | 1 | 0 | 0 |
| 44 | White Slough downstream of Disappointment Slough | 38.069 | -121.460 | 1 | 1 | 1 |
| 45 | Yuba River above confluence with the Feather | 39.166 | -121.553 | 1 | 0 | 0 |
| 52 | Colorado River/u/s Imperial Dam | 32.911 | -114.464 | 0 | 0 | 1 |
| 59 | mokelumne river | 38.238 | -121.487 | 1 | 0 | 0 |
| 69 | Sherman Lake | 38.044 | -121.797 | 0 | 0 | 0 |
| 75 | Colusa Basin Drain | 38.836 | -121.839 | 1 | 1 | 1 |
| 77 | Feather River above Yuba | 39.162 | -121.611 | 1 | 1 | 1 |
| 78 | Feather River between Yuba and Bear | 39.061 | -121.608 | 1 | 1 | 1 |
| 79 | Georgiana Slough | 38.210 | -121.540 | 1 | 0 | 0 |
| 80 | Green's Lake | 38.561 | -121.596 | 1 | 0 | 0 |
| 81 | Keswick | 40.610 | -122.440 | 1 | 1 | 1 |
| 84 | Merced River upstream of Hatfield State Park | 37.350 | -120.960 | 1 | 1 | 1 |
| 85 | Middle River @ Woodward | 37.940 | -121.530 | 1 | 0 | 0 |
| 86 | Mud Slough | 37.292 | -120.943 | 1 | 1 | 1 |
| 87 | Natomas E. Main Drain | 38.620 | -121.468 | 1 | 1 | 1 |
| 88 | Potato Slough | 38.083 | -121.540 | 1 | 0 | 0 |
| 89 | Sacramento River at Colusa | 39.214 | -121.999 | 1 | 1 | 1 |
| 90 | Sacramento River at Hamilton City | 39.751 | -121.996 | 1 | 1 | 1 |
| 91 | Sacramento River below Keswick | 40.601 | -122.443 | 1 | 1 | 1 |
| 92 | Sacramento River above Shasta | 40.939 | -122.419 | 1 | 1 | 1 |
| 93 | Sacramento River at Bend Bridge near Red Bluff | 40.289 | -122.186 | 1 | 1 | 1 |

# Appendix A (continued)

Complete listing of stations having archived samples or contamination data available. Location ID = Station ID referred to in text and Figure 1. LATDD = Latitude coordinates in degrees and decimal degrees. LONGDD = Longitude coordinates in degrees and decimal degrees. Archived samples = archived samples available at station (0 = No; 1 = Yes). Recent OC analysis = analyses of PCBs or legacy pesticides since 1997. Contamination data = recent or historic PCB or legacy pesticide data available.

| Location ID | Station Name | LATDD | LONGDD | Archived samples | Recent OC Analysis | Contamination Data |
|---|---|---|---|---|---|---|
| 99 | Tuolumne River upstream of Shiloh Road | 37.604 | -121.131 | 1 | 1 | 1 |
| 100 | Victoria canal | 37.881 | -121.509 | 1 | 0 | 0 |
| 101 | Del Puerto Creek at Vineyard Road | 37.521 | -121.149 | 0 | 0 | 1 |
| 102 | Dry Creek in Modesto | 37.652 | -120.961 | 0 | 0 | 1 |
| 103 | Kings River at Empire Weir no. 2 | 36.175 | -119.830 | 0 | 0 | 1 |
| 104 | Kings River at People's Weir | 36.485 | -119.539 | 0 | 0 | 1 |
| 105 | Kings River below Pine Flat Reservoir | 36.831 | -119.335 | 0 | 0 | 1 |
| 106 | Merced River near Stevinson | 37.371 | -120.929 | 0 | 0 | 1 |
| 107 | Mokelumne River near Woodbridge | 38.159 | -121.303 | 0 | 0 | 1 |
| 108 | Mud Slough near Gustine | 37.263 | -120.906 | 0 | 0 | 1 |
| 110 | Salt Slough | 37.248 | -120.851 | 0 | 0 | 1 |
| 111 | San Joaquin River near Patterson | 37.498 | -121.082 | 0 | 0 | 1 |
| 112 | San Joaquin River near Stevinson | 37.295 | -120.850 | 0 | 0 | 1 |
| 114 | Spanish Grant Drain | 37.436 | -121.033 | 0 | 0 | 1 |
| 115 | Stanislaus River near Ripon | 37.730 | -121.109 | 0 | 0 | 1 |
| 116 | Tuolumne River at Modesto | 37.607 | -121.014 | 0 | 0 | 1 |
| 117 | Tuolumne River at Old La Grange Bridge | 37.666 | -120.461 | 0 | 0 | 1 |
| 118 | Turlock Irrigation District Lateral no. 5 | 37.464 | -121.031 | 0 | 0 | 1 |
| 119 | American River at Sacramento, CA (J Street) | 38.568 | -121.423 | 0 | 1 | 1 |
| 120 | Arcade Creek near Del Paso Heights, CA | 38.642 | -121.382 | 0 | 0 | 1 |
| 121 | Bear River at Highway 70 near Rio Oso, CA | 38.973 | -121.542 | 0 | 0 | 1 |
| 122 | Cache Creek at Guinda, CA | 38.828 | -122.182 | 0 | 0 | 1 |
| 123 | Colusa Basin Drain at Road 99E near Knights Landing, CA | 38.813 | -121.773 | 0 | 0 | 1 |
| 124 | East Canal at Kirkville Road near Nicolaus, CA | 38.909 | -121.638 | 0 | 0 | 1 |
| 126 | Sacramento River at Freeport, CA | 38.456 | -121.502 | 0 | 0 | 1 |
| 127 | Sacramento River at Verona, CA | 38.774 | -121.597 | 0 | 0 | 1 |
| 128 | Colusa National Wildlife Refuge - Powell Slough near Tract 9 | 39.173 | -122.037 | 0 | 0 | 1 |
| 129 | Colusa National Wildlife Refuge - Small canal near Tract 16 | 39.173 | -122.037 | 0 | 0 | 1 |
| 130 | Delevan National Wildlife Refuge - Canal east of Tract 19 | 39.296 | -122.077 | 0 | 0 | 1 |
| 131 | Delevan National Wildlife Refuge - Stone Corral Creek at southeast corner of Tract 36 | 39.293 | -122.114 | 0 | 0 | 1 |
| 132 | Jack Slough at Highway 70 near Marysville, CA | 39.168 | -121.589 | 0 | 0 | 1 |
| 133 | Sacramento National Wildlife Refuge - North Fork Logan Creek at Norman Road crossing | 39.435 | -122.194 | 0 | 0 | 1 |
| 135 | Stony Creek below Black Butte Dam near Orland, CA | 39.819 | -122.324 | 0 | 0 | 1 |
| 136 | Sutter National Wildlife Refuge - Canal east of Tract 17 | 39.081 | -121.750 | 0 | 0 | 1 |
| 137 | Yuba River near Marysville, CA | 39.176 | -121.524 | 0 | 0 | 1 |
| 138 | Cottonwood Creek near Cottonwood, CA | 40.014 | -121.947 | 0 | 0 | 1 |
| 139 | Deer Creek near Vina, CA | 40.014 | -121.947 | 0 | 0 | 1 |
| 140 | McCloud River below Ladybug Creek near McCloud, CA | 41.094 | -122.116 | 0 | 0 | 1 |
| 141 | Kern River/Bakersfield | 35.450 | -118.914 | 0 | 0 | 1 |
| 142 | Kings River | 36.491 | -119.533 | 0 | 0 | 1 |
| 143 | Kings River/Hwy 99 | 36.498 | -119.529 | 0 | 1 | 1 |
| 144 | Kings River/S.F./Tulare Lake Basin | 36.100 | -119.824 | 0 | 0 | 1 |
| 145 | Mendota Pool | 36.786 | -120.371 | 0 | 0 | 1 |
| 146 | San Joaquin River/Hwy 99 | 36.843 | -119.931 | 0 | 0 | 1 |
| 147 | San Joaquin River/Skaggs Bridge | 36.822 | -120.058 | 0 | 0 | 1 |
| 148 | Courtright Reservoir/Dusy Creek | 37.128 | -118.967 | 0 | 0 | 1 |
| 150 | Huntington Lake/Rancherio Creek | 37.254 | -119.160 | 0 | 0 | 1 |
| 151 | Kesterson N.W.R./Pond 2 | 37.231 | -120.883 | 0 | 0 | 1 |
| 152 | Kesterson N.W.R./Pond 5 | 37.233 | -120.883 | 0 | 0 | 1 |
| 153 | Lake McClure/Main Body | 37.601 | -120.264 | 0 | 0 | 1 |
| 154 | Merced River/East Side Drain | 37.349 | -120.888 | 0 | 0 | 1 |
| 155 | Merced River/Hagaman County Park | 37.360 | -120.859 | 0 | 0 | 1 |
| 156 | Merced River/Hatfield St Recreation Area | 37.358 | -120.953 | 0 | 1 | 1 |
| 157 | Merced River/McConnell State Park | 37.415 | -120.708 | 0 | 0 | 1 |
| 159 | Old River near mouth of Rock Slough | 37.982 | -121.580 | 0 | 0 | 1 |
| 160 | Old River/CV Pumps | 37.785 | -121.502 | 0 | 0 | 1 |
| 161 | O'Neill Forebay/California Aqueduct | 37.089 | -121.051 | 0 | 0 | 1 |
| 162 | Orestimba Cr/Bell Road | 37.333 | -121.102 | 0 | 0 | 1 |
| 163 | Orestimba Creek at River Road | 37.414 | -121.014 | 0 | 0 | 1 |
| 164 | Paradise Cut/Tracy | 37.802 | -121.410 | 0 | 0 | 1 |
| 167 | San Joaquin River/Fremont Ford | 37.306 | -120.923 | 0 | 0 | 1 |
| 168 | San Joaquin River/French Camp Slough | 37.917 | -121.306 | 0 | 0 | 1 |
| 169 | San Joaquin River/Highway 152 Bridge | 37.057 | -120.549 | 0 | 0 | 1 |
| 171 | San Joaquin River/Mossdale | 37.768 | -121.305 | 0 | 0 | 1 |

# Appendix A (continued)

Complete listing of stations having archived samples or contamination data available. Location ID = Station ID referred to in text and Figure 1. LATDD = Latitude coordinates in degrees and decimal degrees. LONGDD = Longitude coordinates in degrees and decimal degrees. Archived samples = archived samples available at station (0 = No; 1 = Yes). Recent OC analysis = analyses of PCBs or legacy pesticides since 1997. Contamination data = recent or historic PCB or legacy pesticide data available.

| Location ID | Station Name | LATDD | LONGDD | Archived samples | Recent OC Analysis | Contamination Data |
|---|---|---|---|---|---|---|
| 296 | Pine Flat Reservoir | 36.872 | -119.273 | 0 | 1 | 1 |
| 297 | Pit River/Lake Britton | 41.012 | -121.676 | 0 | 0 | 1 |
| 298 | Pit River/Lake Shasta | 40.757 | -122.251 | 0 | 0 | 1 |
| 299 | Pit River/Tunnel Reservoir | 41.014 | -121.905 | 0 | 0 | 1 |
| 300 | San Leandro Reservoir | 37.786 | -122.116 | 0 | 1 | 1 |
| 301 | El Capitan Reservoir | 32.912 | -116.781 | 0 | 1 | 1 |
| 302 | Shasta Lake | 40.825 | -122.398 | 0 | 1 | 1 |
| 303 | San Luis Reservoir | 37.044 | -121.071 | 0 | 1 | 1 |
| 304 | Woodward Reservoir | 37.856 | -120.860 | 0 | 1 | 1 |
| 305 | Crag Lake | 38.991 | -120.155 | 0 | 1 | 1 |
| 306 | Petes Valley Reservoir | 40.544 | -120.452 | 0 | 0 | 0 |
| 307 | New Melones Reservoir | 37.992 | -120.507 | 0 | 0 | 0 |
| 308 | Little Grass Valley Reservoir | 39.733 | -120.977 | 0 | 0 | 0 |
| 309 | Guadalupe Reservoir | 37.193 | -121.873 | 0 | 0 | 0 |
| 310 | Lake Thomas Edison | 37.380 | -118.978 | 0 | 0 | 0 |
| 311 | Meadow Lake | 39.412 | -120.496 | 0 | 0 | 0 |
| 312 | Claire Engle Lake | 40.998 | -122.627 | 0 | 0 | 0 |
| 313 | Finnon Reservoir | 38.799 | -120.749 | 0 | 0 | 0 |
| 314 | San Joaquin River at Los Banos | 37.058 | -120.561 | 0 | 0 | 1 |
| 315 | Sacramento River at Sacramento | 38.561 | -121.556 | 0 | 0 | 1 |
| 316 | Lake Oroville | 39.580 | -121.360 | 0 | 1 | 1 |
| 317 | Jewelry Lake | 38.163 | -119.781 | 0 | 1 | 1 |
| 318 | Merced River at George J. Hatfield State Recreational Area | 37.358 | -120.953 | 0 | 0 | 1 |
| 319 | Merced River below California Highway 59 | 36.856 | -119.885 | 0 | 0 | 1 |
| 320 | San Joaquin River at Firebaugh | 36.869 | -120.459 | 0 | 0 | 1 |
| 321 | San Joaquin River at Fremont Ford State Recreational Area | 37.306 | -120.923 | 0 | 0 | 1 |
| 322 | San Joaquin River at South County Park | 37.692 | -121.262 | 0 | 0 | 1 |
| 323 | San Joaquin River near Fort Washington | 36.861 | -119.810 | 0 | 0 | 1 |
| 324 | Kings River at Jackson Avenue | 36.491 | -119.533 | 0 | 1 | 1 |