SECTION 2 METHODS

2.1 CREATING THE DATABASE

To assess statewide impairment from mercury and organic contaminants, a bioaccumulation database was assembled. The 'Bioaccumulation Database' (BD) was created using tissue-contaminant data summarized from numerous studies and sources (Table 2.1). We consulted with colleagues in agencies and universities to obtain data from bioaccumulation studies of regional or statewide importance that were in their final version, having gone through all internal and external QA and review processes required by the data authors. We included all such data sets that we were able to obtain and that passed our internal SFEI review as described below. Those data sets that either were unavailable or did not pass our internal review are listed in Table 2.2.

Data were received in varying formats and designs, and imported into individual Microsoft Access tables for review. Data sets were assessed by internal data QA and metadata review (see description below), with acceptable data sets subsequently arranged into a consistent format. The initial BD format was based on the San Francisco Estuary Institute's Regional Monitoring Program for Water Quality in the San Francisco Estuary (RMP) Fish Bioaccumulation Database. Fields used to store data reflected sample attributes (i.e., collection date, site name, species, contaminant name, fish length, etc.). Fields were populated with a code indicating that data were unavailable ('-77') if information needed for format consistency was not provided (e.g., method detection limits). Once a consistent format was attained for each dataset, fields were standardized between studies (e.g., scientific and common names, length units in mm, latitude/longitude in decimal degrees).

Data uncertainties were addressed with a consistent approach across data sets. Data that were reported as below detection (i.e., non-detect) were treated as zero. This approach was necessary, because many data sets did not contain MDLs, which are necessary for more sophisticated interpolation of values below detection limit. The geographic locations of records with inaccurate or missing coordinates were estimated using Terraserver (http://terraserver.microsoft.com). Identical site names with differing coordinates were evaluated on a case-by-case basis. Where the difference in distance was less than 1 km, the first set of coordinates was used. Where the difference was greater than 1 km, the site names were differentiated (e.g., Belmont Pier 1 and Belmont Pier 2). Where site names differed and coordinates were identical, a single site name was chosen. The final unique combinations of site name and coordinates were compiled in a lookup list.

Table 2.1.
Studies included in the review data set.

Short Name	Agency	Contact	Recent Report
CalFed	CalFed	Jay Davis	Davis, J.A., B.K. Greenfield, G. Ichikawa, and M. Stephenson. 2004. Mercury in Sport Fish from the Delta Region (Task 2A). Final Report submitted to the CALFED Bay-Delta Program for the Project: An Assessment of the Ecological and Human Health Impacts of Mercury in the Bay-Delta Watershed. 63 pp.
CDFG-Clear Lake	OEHHA & CDFG	Margy Gassel (report), David Crane (data)	Gassel, M., S. Klasing, R.K. Brodberg, and S. Roberts. 2005. Health Advisory: Fish Consumption Guidelines for Clear Lake, Cache Creek, and Bear Creek (Lake, Yolo, and Colusa Counties). Office of Environmental Health Hazard Assessment, Sacramento, CA.
CFCP	OEHHA & SWRCB	Margy Gassel (report), Emilie Reyes (data)	Gassel, M., R.K. Brodberg, and S. Roberts. 2002. The Coastal Fish Contamination Program: Monitoring of Coastal Water Quality and Chemical Contamination in Fish and Shellfish in California in California and the World Ocean '02: Revisiting and Revising California's Ocean Agenda.
Delta98 Organics	SFEI	Jay Davis	Davis, J.A., M.D. May, G. Ichikawa, and D. Crane. 2000. Contaminant Concentrations in Fish from the Sacramento-San Joaquin Delta and Lower San Joaquin River, 1998. San Francisco Estuary Institute, Richmond, CA.
DWR Reservoir	DWR	Glen Pearson	Boles, J. 2004. Mercury Contamination in Fish from Northern California Lakes and Reservoirs. Department of Water Resources.
EMAP West	EPA	Dan Guzman	report not available
NFTS	EPA	Michael Walsh (data), Leanne Stahl (report)	CSC Environmental. 2005. Quality Assurance Report for the National Study of Chemical Residues in Lake Fish Tissue: Analytical Data for Years 1 through 4. US EPA. 57 pp.
RMP	SFEI	Jay Davis	Greenfield, B.K., J.A. Davis, R. Fairey, C. Roberts, D. Crane, and G. Ichikawa. 2005. Seasonal, inter-annual, and long-term variation in sport fish contamination, San Francisco Bay. Science of the Total Environment 336:25-43.
Schmitt	CDFG	Christopher Schmitt	Saiki, M. K. and C.J. Schmitt. 1986. Organochlorine chemical residues in bluegills and common carp from the irrigated San Joaquin Valley floor, California. Arch. Environ. Con. Tox. 15: 357-366.
SMWP	SWRCB	Emilie Reyes	Rasmussen, D. 2000. State Mussel Watch Program 1995-1997 Data Report. State Water Resources Control Board, California Environmental Protection Agency.
SRWP	SRWP	Claus Suverkropp	LWA, 2004. Sacramento River Watershed Program. Annual Monitoring Report 2002-2003.
TSMP	SWRCB	Emilie Reyes	Crane, D.B, K. Regaldo, G. Munoz, L. Smith, D. Gilman, M. Hicks, G. Ichikawa, J. Goetzl, A. Bonnema, and W. Heim. 2004. Environmental Chemistry Quality Assurance and Data Report for the Toxic Substances Monitoring Program 2001–2002.
UCDavis1	UC Davis	Darell Slotton	Slotton, D.G., S.M. Ayers, J.E. Reuter, and C.R. Goldman. 1999. Lower Putah Creek 1997-1998 Mercury Biological Distribution Study. Dept. of Environmental Science and Policy, University of California, Davis.

UCDavis2	UC Davis	Darell Slotton	Slotton, D.G., S.M. Ayers, J.E. Reuter, and C.R. Goldman. 1997. Cache Creek Watershed Preliminary Mercury Assessment, Using Benthic Macro-Invertebrates. Division of Environmental Studies, University of California, Davis. Final Report.
UCDavis3	UC Davis	Darell Slotton	Slotton, D.G., S.M. Ayers, T.H. Suchanek, R.D. Weyand, A.M. Liston, C. MacDonald, D.C. Nelson, and B. Johnson. 2002. The Effects of Wetland Restoration on the Production and Bioaccumulation of Methylmercury in the Sacramento-San Joaquin Delta, California. CALFED Mercury Program Draft Final Project Report.
UCDavis4	UC Davis	Darell Slotton	Slotton, D.G., S.M. Ayers, J.E. Reuter, and C.R. Goldman. 1997. Gold mining impacts on food chain mercury in northwestern Sierra Nevada streams (1997 revision), Appendix B in Larry Walker Associates, 1997, Sacramento River watershed mercury control planning project—report for the Sacramento Regional County Sanitation District. 74 pp.
UCDavis5	UC Davis	Darell Slotton	Slotton, D.G., S.M. Ayers, T.H. Suchanek, R.D. Weyand, and A.M. Liston. 2002. Mercury Bioaccumulation and Trophic Transfer in the Cache Creek Watershed, California, in Relation to Diverse Aqueous Mercury Exposure Conditions. CALFED Mercury Program Draft Final Project Report.
UCDavis6	UC Davis	Darell Slotton	Slotton, D.G., S.M. Ayers, and J.E. Reuter. 1996. Marsh Creek Watershed 1995 Mercury Assessment Project, Final Report. Conducted for Contra Costa County, California. 66 pp.
UCDavis7	UC Davis	Darell Slotton	Slotton, D.G., S.M. Ayers, and J.E. Reuter. 1998. Marsh Creek Watershed Mercury Assessment Project: Third Year (1997) Baseline Data Report with 3-yr Review of Selected Data. Report for Contra Costa County, June 1998. 62 pp.
UCDavis9	UC Davis	Darell Slotton	Slotton, D.G., and Ayers, S.M. 2001. Cache Creek Nature Preserve Mercury Monitoring Program, Yolo County, California. Second Semi-Annual Data Report (Spring - Summer 2001). Study and report prepared for Yolo County, California.
UCD Clear Lake	UC Davis	Darell Slotton	not available
USGS Natoma	USGS	Michael Saiki	Saiki, M.K., D.G. Slotton, T.W. May, S.M. Ayers, and C.N. Alpers. 2004. Summary of Total Mercury Concentrations in Fillets of Selected Sport Fishes Collected during 2000-2003 from Lake Natoma, Sacramento County, California: USGS Data Series 103. 21 pp.
USGS NAWQA	USGS	Dorene E. MacCoy	MacCoy, D. E. and J.L. Domagalski. 1999. Trace elements and organic compounds in streambed sediment and aquatic biota from the Sacramento River Basin, California, October and November 1995. USGS, Sacramento, CA. 37 pp.
USGS Sacramento	USGS	Larry R. Brown	Brown, L. R., 1998. Concentrations of chlorinated organic compounds in biota and sediments in streams of the lower San Joaquin River drainage, California. USGS, Sacramento, CA. 23 pp.
USGS Trinity	USGS	Jason May	May, J.T., R.L Hothem, and C.N. Alpers. 2005. Mercury concentrations in fishes from select water bodies in Trinity County, California, 2000-2002. USGS Open-File Report 2005-1321.
USGS1	USGS	Jason May	May, J.T., R.L. Hothem, C.N. Alpers, and M.A. Law.. 2000. Mercury Bioaccumulation in Fish in a Region Affected by Historical Gold Mining: The South Yuba River, Deer Creek, and Bear River Watersheds, California, 1999: USGS Open-File Report 00-367. 30 pp.
USGS2	USGS	Joseph L. Domagal-ski	Domagalski, J.L., P.D. Dileanis, D.L. Knifong, C.M. Munday, J.T. May, B.J. Dawson, J.L. Shelton, and C.N. Alpers. 2000. Water-Quality Assessment of the Sacramento River Basin, California: Water-Quality, Sediment and Tissue Chemistry, and Biological Data, 1995-1998. USGS Open-File Report 2000-391.

Table 2.2. Studies excluded from the review data set, and the reasons for their exclusion.

Study	Full Study Name	Year	Agency	Contact	Reason for Exclusion
CDFG - Berryessa	Regional Mercury Assessment of Putah Creek and Lake Berryessa	1982 – 1984	California Dept. of Fish & Game	Jerry Bruns (RWQCB)	No length or compositing methods given
DWR1	DWR Special Tributary Project - 1998 Fish Sampling	1998	California Dept. of Water Resources	Larry Walker Associates	No length or compositing methods given
DWR1	DWR Special Tributary Project - 1999 Fish Sampling	1999	California Dept. of Water Resources	Larry Walker Associates	No length or compositing methods given
NOAA S/T Benthic Survey	NOAA Status and Trends	1984 – 1992	NOAA	Ed Johnson	No length or compositing methods given
NOAA S/T Mussel Watch	NOAA Status and Trends	1986 – 2003	NOAA	Ed Johnson	No length or compositing methods given
CCAMP	Central Coast Ambient Monitoring Program	1977 – 2001	CCRWQCB	Karen Worcester	Incomplete dataset provided
Delta98	Delta Fish 1998	1998	SFEI	Jay Davis	Mismatched site and length data for mercury only
Guadalupe Fish	Guadalupe River Watershed Mercury TMDL Project	2003	Tetra Tech	Dave Drury	Data not released to SFEI
Oroville Reservoir	Contaminant Accumulation in Fish, Sediments, and the Aquatic Food Chanin, Study Plan W2	2003	California Dept. of Water Resources	Scott McReynolds	Data not released to SFEI
SCCWRP	1994 Pilot Project & Bight 1998 Survey	1994, 1998	Southern California Coastal Water Research Project	Ken Schiff	Data errors not fixed by source
SWAMP Fish	Surface Water Ambient Monitoring Program: Chemical Concentrations in Fish Tissues from Selected Reservoirs and Coastal Areas in the San Francisco Bay Region	2000 – 2002	State Water Resources Control Board	Karen Taberski	Data duplicated in TSMP and CFCP datasets

Internal data quality QA consisted of checking for inconsistencies in reporting and communicating our concerns to original sources for clarification. A review of metadata for each study was also conducted to assess quality. This consisted of an evaluation of data collection methodology (e.g., compositing and clean techniques), lab methods (e.g., duplicates, spikes, and blanks), and data quality (QA/QC). Data were approved for analysis based on the documentation of QA procedures by the study authors, compositing methods (e.g., smallest fish length must be greater than 75% of the largest fish length, as recommended by the EPA), and the collection of sufficient samples for inclusion (i.e., consistent field and lab methods for multiple species, samples, and sites).

2.2 DATA ANALYSIS

DDT, chlordane, and PCB records reflect the summation of individual compound values for each sample. Total mercury and dieldrin records reflect single compounds, not sums. Nearly all (> 90%) of the mercury present in edible fish tissue is methylmercury. Total mercury therefore represents a valid, cost effective estimate of methylmercury concentration in fish tissue. Summation procedures were based on methods from the RMP. Total DDTs were calculated by summing the concentrations of p,p'-DDT, o,p'-DDT, p,p'-DDE, o,p'-DDE, p,p'-DDD, and o,p'-DDD. Total chlordanes were calculated by summing the concentrations of cis-chlordane, trans-chlordane, heptachlor, heptachlor epoxide, cis-nonachlor, trans-nonachlor, and oxychlordane. Total PCBs were calculated by summing Aroclor concentrations (if available) of 1248, 1254, and 1260. If Aroclor data were unavailable, the forty PCB congeners measured by RMP were summed (for example, see Gunther et al. 1999). Data points were excluded if they did not include the individual parameters that RMP designates as being significant portions of a sum (e.g., sum of DDTs must include p,p'-DDE and p,p'-DDD).

Sport fish analyses were conducted on individual and composite muscle tissue samples. For the mercury impairment analyses, size limits for each species were applied to limit the variation in mercury concentration due to fish length (Appendix 1). Average total length size limits were applied to samples analyzed as composites; otherwise individual total length data were used. The size limits were chosen to include a large proportion of the available data and ensure that the smallest fish were at least 75% the length of largest fish within a species. Fork and total length measurements were included in the same analyses, because excluding either one would have drastically reduced the sample size for analysis.

In the three time intervals examined (1998 – 2003, 1988 – 1997, and 1978 – 1987), the median wet weight concentration for each species at a given location was calculated. Medians were chosen, rather than means, because they reduced the influence of the many non-detects in the database. The maximum median concentration among species at a given location was then used for comparison to OEHHA Guidance Tissue Levels (GTLs) to assess impairment. Any species with at least one sample at a given site was included in the analysis. OEHHA's thresholds were used because they trigger consumption advice and are applied consistently across the state. The GTLs are draft values from Klasing and Brodberg (2006).

Long-term time trends were analyzed in sport fish and bivalves using lipid-normalized concentrations of the organic contaminants. Previous studies have documented a significant relationship between tissue lipid content and organochlorine concentrations (Larsson et al. 1993). Statistical evaluations of long-term trends were performed by computing the Spearman rank correlation coefficient (rs) of year versus the lipid-normalized average concentration (Greenfield et al. 2005). Fish length/age is another important factor for accumulation of DDTs and PCBs, and to a lesser extent dieldrin and chlordane (R. Norstrom, personal communication), but the analyses of trends in organics in this report did not attempt to adjust for this factor.

For the long-term time trend analysis of mercury in sport fish, the effect of fish length on mercury concentration was addressed in the following manner. Mercury concentration was regressed on fish length, and the residuals were analyzed as a time series of length-adjusted mercury data. For the one site with sufficient years in the time series, the residual mercury concentrations were regressed on year.

2.3 GIS MAPPING

The map figures were designed using ESRI ArcInfo 9.1 software. All maps are in a California Teale Albers NAD 83 projection. A connection to the GIS from a Microsoft Access 2003 database was established in order to display the results of queries that calculated median concentrations.

After median concentrations were calculated in Access, the highest median concentration among species for each sampling location was used in generating the map figures. Sampling locations were displayed on the maps using latitude and longitude coordinates from the Access database.

We displayed the concentration values in two different ways – categorized by concentration categories and simply as median concentrations. For maps depicting categories, pollutant concentrations are presented in a four-color graduated scheme (green, yellow, orange, and red), representing low, moderate, high, and very high concentrations (Table 3.2.2). The lowest concentrations (low category) are in a range where consumption is strongly encouraged by OEHHA (Klasing and Brodberg 2006). OEHHA is the agency responsible for managing health risks due to contaminated sport fish in California. Locations with concentrations in this category are colored green. The highest concentrations (very high category) are in a range where OEHHA discourages consumption for women of childbearing age and children 17 and younger (Klasing and Brodberg 2006). Locations with concentrations in this category are colored red. Locations with concentrations between these endpoints are colored either yellow (moderate category) or orange (high category). For maps representing the median concentrations directly, we used a single-color bar chart to represent the values.

We created these concentration category and median concentration maps for each contaminant across three different time periods to represent trends over time. To represent the net impact of all pollutants together, we compared the concentration categories for each pollutant at a given site. The worst impairment level from among the pollutants was chosen to represent the site on the net impact map figure. For example, if dieldrin, DDT and chlordanes fell into the low category, while mercury fell in the moderate category and PCBs fell into the very high category at a particular site, then very high was chosen as the concentration category for that site in the net impact analysis.

It should be noted that this analysis of net impact did not attempt to evaluate the potential synergistic or antagonistic interactions of the pollutants under consideration. These potential interactions are a concern, but have not been studied adequately to support such an assessment.

Long-term time trends were mapped separately by site to depict any spatial differences that may have existed in these data.

Literature Cited

Greenfield, B. K., J. A. Davis, R. Fairey, C. Roberts, D. Crane, and G. Ichikawa. 2005. Seasonal, interannual, and long-term variation in sport fish contamination, San Francisco Bay. Sci. Tot. Environ. 336:25-43.

Gunther, A. J., J. A. Davis, D. Hardin, J. Gold, D. Bell, J. Crick, G. Scelfo, J. Sericano, and M. Stephenson. 1999. Long term bioaccumulation monitoring with transplanted bivalves in San Francisco Estuary. Mar. Pollut. Bull. 38:170-181.

Klasing, S., and R. Brodberg. 2006. DRAFT Report: Development of guidance tissue levels and screening values for common contaminants in California sport fish: chlordane, DDTs, dieldrin, methylmercury, PCBs, selenium, and toxaphene. California Office of Environmental Health Hazard Assessment, Sacramento, CA.

Larsson, P., L. Okla, and L. Collvin. 1993. Reproductive status and lipid content as factors in PCB, DDT, and HCH contamination of a population of pike (Esox lucius L.). Environ. Toxicol. Chem. 12:855-861.