SECTION 3 RESULTS AND DISCUSSION

3.1 SUMMARY INFORMATION

The data set assembled included samples representing much of California's geographic scope (Figure 3.1.1). Biases in the spatial coverage are reflected in areas with fewer studies. The scope of the individual studies varied considerably, and a breakdown by study of the contaminants, sample sizes, number of sampling sites, and sampling years is detailed in Appendix 2. We summarized which sport fish, small fish, and bivalve species were most commonly sampled for each contaminant in Table 3.1.1.

3.2 THE NET IMPACT OF POLLUTANTS ON FISHING IN CALIFORNIA

3.2.1. Introduction

Present concentrations of pollutants in many California water bodies are high enough to cause concern for possible impacts on human health and to have a significant impact on the fishing beneficial use. This section evaluates the "net impact" of pollutants on fishing. Fish in California water bodies are exposed to multiple pollutants, and multiple pollutants are passed on to humans with each fish consumed. "Net impact" refers to the comprehensive consideration of all pollutants in a sample. Maps are presented in this section displaying the locations sampled in recent and historic monitoring. For each location, if the median concentration of any pollutant exceeded thresholds delineating the concentration categories used in this report (low, moderate, high, very high – see Methods for full description), this is indicated on the map. The existence of a comprehensive set of thresholds for human health risks (Klasing and Brodberg 2006) and a relatively uniform population (humans) makes this type of assessment possible. There are a very limited number of cases for which thresholds for certain wildlife species and contaminants can reasonably be estimated. The lack of established thresholds and the taxonomic diversity of wildlife populations make it impossible to perform this type of statewide assessment for impacts on the aquatic life beneficial use.

This chapter focuses exclusively on contamination issues relating to the fishing beneficial use (i.e., sport fish and human health concerns). Sufficient small fish data and assessment thresholds were not available to support a parallel assessment of impacts on aquatic life. Maps geared toward impacts on wildlife would have different species represented (i.e., small fish, such as Mississippi silversides) and would apply different thresholds.

It should also 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.

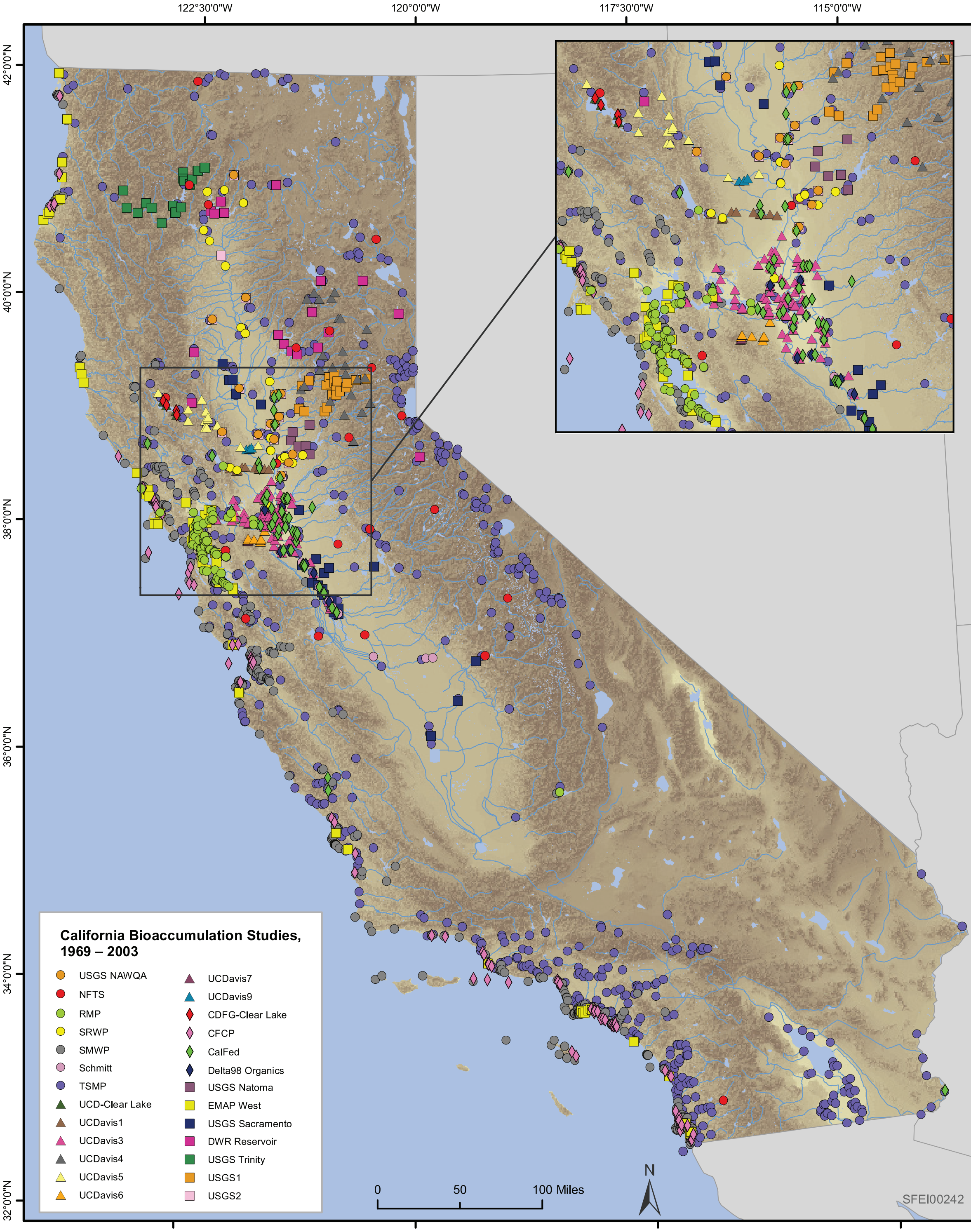


Figure 3.1.1. California Bioaccumulation Studies, 1969 – 2003. Sampling locations for bioaccumulation studies included in the database compiled for this review. Studies conducted from 1969 to 2003. Full titles for each study and additional information are provided in Table 2.1.

**Table 3.1.1.
Most widely sampled species in the review data set.**

POLLUTANT	BIOTA TYPE	NUMBER OF SAMPLES	SPECIES COMMON NAME	POLLUTANT	BIOTA TYPE	NUMBER OF SAMPLES	SPECIES COMMON NAME
Chlordanes	Sport	136	Channel Catfish	Dieldrin	Small	22	Sculpin
Chlordanes	Sport	182	Common Carp	Mercury	Small	45	Bigscale Logperch
Chlordanes	Sport	274	Largemouth Bass	Mercury	Small	39	Sculpin
DDTs	Sport	143	Channel Catfish	Mercury	Small	39	Goldfish
DDTs	Sport	209	Common Carp	Mercury	Small	49	Pacific Staghorn Sculpin
DDTs	Sport	283	Largemouth Bass	PCBs	Small	45	Pacific Staghorn Sculpin
Dieldrin	Sport	143	Channel Catfish	PCBs	Small	22	Sculpin
Dieldrin	Sport	205	Common Carp	PCBs	Small	57	Goldfish
Dieldrin	Sport	277	Largemouth Bass	Chlordanes	Bivalve	1029	California Mussel
Mercury	Sport	1482	Largemouth Bass	Chlordanes	Bivalve	205	Freshwater Clam
Mercury	Sport	656	Rainbow Trout	Chlordanes	Bivalve	96	Pacific Oyster
Mercury	Sport	361	Bluegill	DDTs	Bivalve	1172	California Mussel
PCBs	Sport	146	Channel Catfish	DDTs	Bivalve	205	Freshwater Clam
PCBs	Sport	212	Common Carp	DDTs	Bivalve	96	Pacific Oyster
PCBs	Sport	296	Largemouth Bass	Dieldrin	Bivalve	1005	California Mussel
Chlordanes	Small	54	Goldfish	Dieldrin	Bivalve	205	Freshwater Clam
Chlordanes	Small	45	Pacific Staghorn Sculpin	Dieldrin	Bivalve	96	Pacific Oyster
Chlordanes	Small	22	Sculpin	Mercury	Bivalve	377	Asiatic Clam
DDTs	Small	52	Goldfish	Mercury	Bivalve	1795	California Mussel
DDTs	Small	45	Pacific Staghorn Sculpin	Mercury	Bivalve	196	Freshwater Clam
DDTs	Small	22	Sculpin	PCBs	Bivalve	99	Bay Mussel
Dieldrin	Small	49	Goldfish	PCBs	Bivalve	1416	California Mussel
Dieldrin	Small	45	Pacific Staghorn Sculpin	PCBs	Bivalve	196	Freshwater Clam

3.2.2. Impact of Pollutants on the Fishing Beneficial Use

a. Current Status of Net Impact of Pollutants on Fishing in California

Consumption Advisories

The existence of consumption advisories issued by OEHHA is one important indicator of the impact of pollutants on the fishing beneficial use in California. As of April 2007, consumption advisories were in place for the Trinity River watershed, several lakes and reservoirs in the northern California Coast Range, a region in the northern Sierra Nevada foothills, Lake Natoma and the lower American River, Tomales Bay, San Francisco Bay, the Sacramento-San Joaquin Delta, the Grassland Area, Lake Nacimiento, coastal areas around Santa Monica Bay, Harbor Park Lake, Newport Pier, and the Salton Sea (Figure 3.2.1, Table 3.2.1). In northern California, most of the advisories were triggered by mercury. PCBs also contributed to the need for advisories for San Francisco Bay and Bay Area reservoirs. In contrast, advisories in the Los Angeles area were prompted by organic chemicals (PCBs and legacy pesticides). Advisories due to selenium have been issued for the Grassland Area and the Salton Sea.

The status of consumption advisories is an inaccurate indicator of the status of impact of pollutants on the fishing beneficial use in California because advisories presently exist for only a fraction of the water bodies that are likely to need them. Resource limitations are the primary reason for the lack of more extensive advice. OEHHA has a small staff assigned to advisory development. OEHHA has accelerated the pace of advisory development in recent years. With a larger staff, OEHHA could develop and update advice for the areas in need in a much more timely manner. Limited resources have also constrained the amount of monitoring that has been conducted. Monitoring of many water bodies has been incomplete or nonexistent, making it impossible to issue consumption advice. A lack of comprehensive data for more species (for both metals and organics) has also had a significant role in limiting development of advisories. Also contributing to the lack of more extensive consumption advice is the past inconsistency of monitoring methods. The TSMP database, for example, contains many inconsistencies in the species sampled at each location and the number and size of fish in composites. Recent studies, with guidance from OEHHA, have employed consistent methods that are better suited to development of advisories. Advisories that will cover a large portion of the state (specifically, much of the Central Valley) are currently being developed as part of the CALFED-funded Fish Mercury Project.

303(d) Listings

Inclusion of water bodies on the 303(d) Lists compiled by the SWRCB and the Regional Boards is another important indicator of the impact of pollutants on beneficial uses, including fishing (SWRCB 2003). The 2002 303(d) List included many water bodies that were listed for the pollutants included in this report, including 72 water bodies for mercury, 69 for DDT, 68 for PCBs, 21 for dieldrin, and 27 for chlordanes (Appendix 3). (It should be noted, however, that most, but not all, of these listings are for impacts on fishing.)

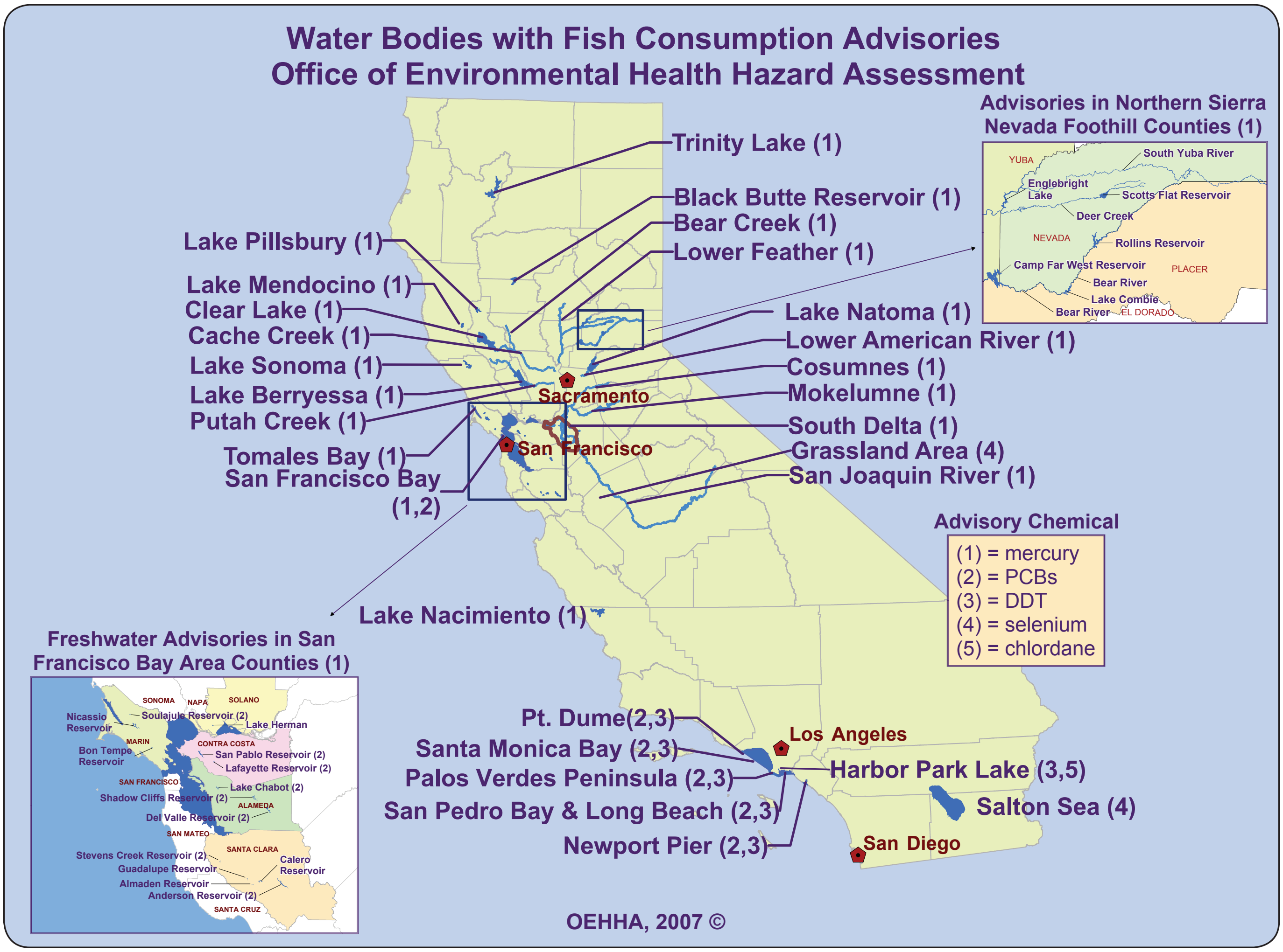


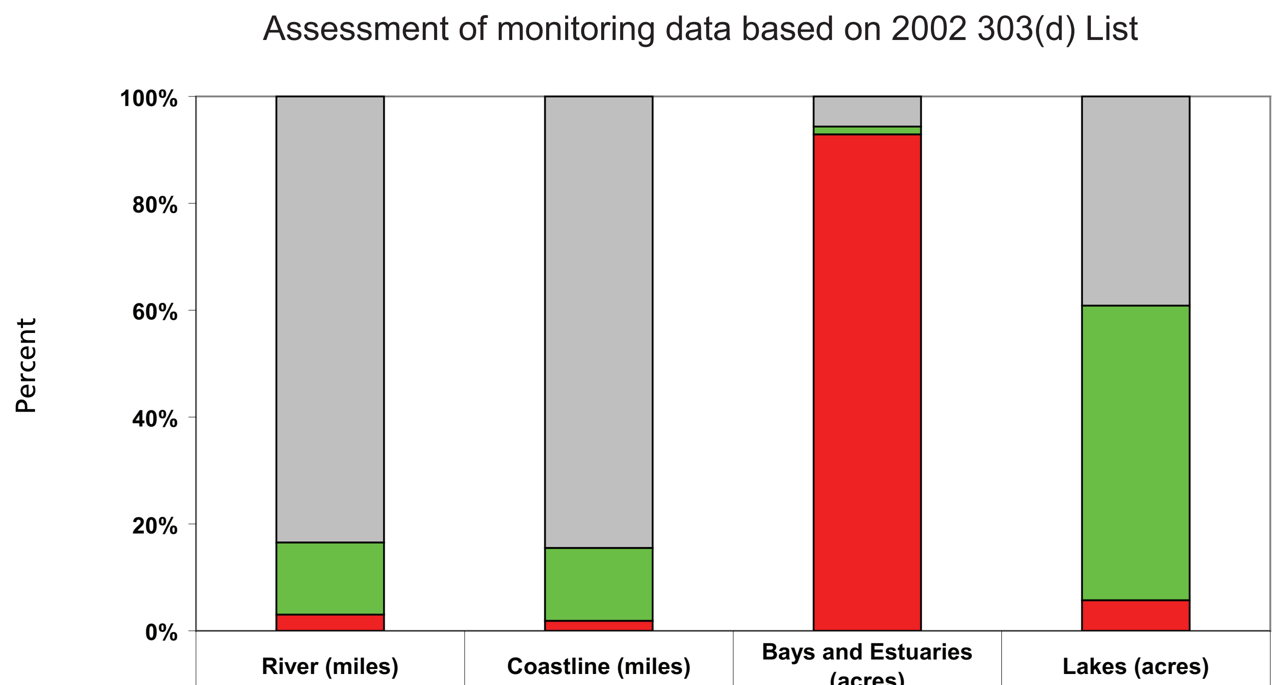
Figure 3.2.1. Consumption advisories in California, 2007. From OEHHA (http://www.oehha.ca.gov/fish/pdf/fishmap2007.pdf).

Table 3.2.1.
Consumption advisories in California in place as of April 2007.

LOCATION	POLLUTANT	YEAR ISSUED
Trinity River Watershed (Trinity County)	Mercury	2005
Black Butte Reservoir (Glenn and Tehama Counties)	Mercury	2003
Lower Feather River (Butte, Yuba And Sutter Counties)*	Mercury	2006 draft
Lake Pillsbury (Lake County)	Mercury	2000
Clear Lake, Cache Creek, and Bear Creek (Lake, Yolo, and Colusa Counties)	Mercury	2005
Putah Creek (Yolo and Solano Counties)	Mercury	2006
Lake Sonoma (Sonoma County) and Lake Mendocino (Mendocino County)*	Mercury	2006 draft
Lake Berryessa (Napa County)	Mercury	2006
Lake Herman (Solano County)	Mercury	1987
San Francisco Bay and Delta Region**	Mercury, PCBs, DDT, dieldrin, chlordane and dioxins	1995
Northern Sierra Nevada Foothills (Nevada, Placer, and Yuba Counties)	Mercury	2003
Lake Natoma and the Lower American River (Sacramento Counties)	Mercury	2004
Lower Cosumnes and Lower Mokelumne Rivers (Sacramento and San Joaquin Counties)*	Mercury	2006 draft
San Joaquin River and South Delta (Contra Costa, San Joaquin, Stanislaus, Merced, Madera, and Fresno Counties)*	Mercury	2007 draft
Tomales Bay (Marin County)	Mercury	2004
Guadalupe Reservoir, Calero Reservoir, Almaden Reservoir, Guadalupe River, Guadalupe Creek, Alamitos Creek, and the associated percolation ponds along the river and creeks (Santa Clara County)	Mercury	Not available
10 Bay Area Reservoirs (Alameda, Contra Costa, Marin, and Santa Clara Counties)**	PCBs and Mercury	2004
Grassland Area (Merced County)	Selenium	Not available
Lake Nacimiento (San Luis Obispo County)	Mercury	2004
Harbor Park Lake (Los Angeles County)	Chlordane and DDT	Not available
Point Dume/ Malibu off shore	PCB and DDT	1991
Malibu Pier	PCB and DDT	1991
Short Bank	PCB and DDT	1991
Redondo Pier	PCB and DDT	1991
Point Vicente Palos Verdes-Northwest	PCB and DDT	1991
Whites Point	PCB and DDT	1991
Los Angeles/Long Beach Harbors (especially Cabrillo Pier)	PCB and DDT	1991

Los Angeles/Long Beach Breakwater (ocean side)	PCB and DDT	1991
Belmont Pier (Pier J)	PCB and DDT	1991
Horseshoe Kelp	PCB and DDT	1991
Newport Pier	PCB and DDT	1991
Salton Sea (Imperial and Riverside Counties)	Selenium	2004

* draft advisory ** interim advisory



	River (miles)	Coastline (miles)	Bays and Estuaries (acres)	Lakes (acres)
Unassessed	176,569	2,895	33,873	654,424
Unimpaired	28,494	467	8,832	922,668
Impaired	6,450	65	560,000	95,592

Figure 3.2.2. Assessment of monitoring data based on the 2002 303(d) List. From USEPA (unpublished).

Based on the final 2002 303(d) List, USEPA (Terry Fleming, USEPA, personal communication) prepared an overall tally of the extents of assessment and impairment relative to the fishing beneficial use for several classes of California water bodies: rivers, coastline, bays and estuaries, and lakes (Figure 3.2.2). "Bays and estuaries" is the category that has been assessed most completely, with 94% of the total area in California assessed. Bays and estuaries are relatively highly impacted by pollutants – of the assessed portion of "bays and estuaries", almost all (99%) were classified as impaired. The listing of San Francisco Bay due to concentrations of multiple pollutants in fish tissue accounts for a large percentage of the impaired area. "Lakes" was the next most completely assessed category, with 61% of total lake area assessed, but only a relatively small percentage (6%) of the lake area was impaired. Large percentages of the total miles of river and coastline in the State were not assessed (83% and 84%, respectively), and 18% and 12% of the assessed miles were impaired.

For lakes, these figures based on the proportion of total area assessed are misleading, however, because they are skewed by the small number of very large lakes that has been sampled. There are 9379 lakes in California. Of these, 5297 are very small (less than 4 ha) – too small to be of much value for fishing. A small proportion of the remaining 4082 lakes larger than 4 hectares have actually been sampled in recent years. Based on numbers of lakes sampled, lakes have not been thoroughly assessed. Based on the data compiled for this study, approximately 127 lakes were sampled in the period 1998 – 2003, or only 3% of the lakes in California larger than 4 hectares. Furthermore, most of the lakes that were sampled were not thoroughly assessed. Many of the lakes that are near population centers and are popular for fishing (Stienstra 2004) have not been sampled in recent years. These lakes that have been studied were not sampled in a representative manner that might allow inference about the large number of unsampled lakes. Overall, therefore, the status of California lakes with respect to impacts on the fishing beneficial use is a major information gap.

Past 303(d) listings are also an inappropriate indicator of the status of the fishing beneficial use. The primary shortcoming is the incomplete coverage of the waters of the state, particularly for rivers and coastline. Another problem with 303(d) listings as an indicator is that they are based on sampling that was biased toward characterization of high-risk areas. A third problem is that 303(d) listings are done by the nine Regional Boards in a manner that is not entirely consistent from region to region.

Recent Monitoring Data

A third index of the status of the fishing beneficial use can be obtained by comparing the most recent monitoring data for the state to current thresholds for human health concern. The principal advantages of this approach are that it provides a consistent statewide assessment based on recently established risk thresholds ("guidance tissue levels", or GTLs) developed by OEHHA (Table 3.2.2) (Klasing and Brodberg 2006), and provides a clear representation of the data that are available. The GTLs are thresholds that will be directly linked to the development of consumption advice and are therefore a useful tool for communicating to the public.

Figure 3.2.3 provides a summary of the impact of pollutants on fishing in California based on the most recent (1998 – 2003) monitoring data available. Locations where at least one of the pollutants included in the analysis (mercury, PCBs, DDT, dieldrin, and chlordane) were monitored in at least one sample are shown on the map. Pollutant concentrations were evaluated using a four-color graduated scheme (green, yellow, orange, and red), representing low, moderate, high, and very high concentrations (Table 3.2.2 – see Methods

Table 3.2.2.
Pollutant concentration categories used in this report. See Methods for description of categories.

Pollutant	Low	Moderate	High	Very High
Chlordane (ppb)	< 300	300 – 1400	> 1400 – 2400	> 2400
DDT (ppb)	< 800	800 – 3500	> 3500 – 7000	> 7000
Dieldrin (ppb)	< 25	25 – 100	> 100 – 200	> 200
PCBs (ppb)	< 30	30 – 140	> 140 – 270	> 270
Mercury (ppm)	< 0.1	0.1 – 0.5	> 0.5 – 0.9	> 0.9

for a more complete description). The color assigned to each location in Figure 3.2.3 represents the highest concentration category for any pollutant based on median concentrations for all of the species sampled. For example, if the highest median concentration for mercury at a location fell into the very high (red) category (> 0.9 ppm) and other pollutants were each in the ranges corresponding to the low (green) category, the location was given a red dot. The Figure is intended to provide an initial overview of the extent of impact of pollutants on fishing by depicting an exposure scenario for each location based on the species with the highest concentrations. It is important to note that at many of these locations there are other species present with much lower concentrations of pollutants (data not shown).

For the studies included in this analysis, a total of 390 locations in California was sampled from 1998 – 2003 (Table 3.2.3). Using the most polluted species at each location, 32% of the locations sampled fell into the low category, 42% in the moderate category, 18% in the high category, and 8% in the very high category.

Most (23) of the 33 locations with at least one species in the very high category were placed there because of high mercury concentrations. Another 10 locations were a result of PCB contamination. None of the very high designations were caused by legacy pesticides. The high mercury sites were primarily located in San Francisco Bay, the Delta, historic mercury mining areas in the northern California Coast Range, and historic gold mining areas in the northern Sierra Nevada. Sites classified as very high due to PCBs were primarily in San Francisco Bay, but also in one Bay Area reservoir (Lake Chabot), and two southern California lakes (Big Bear Lake and Harbor Lake).

A majority (60%) of the locations sampled from 1998 – 2003 had species in the moderate and high categories. Mercury and PCBs were again the primary causes for concern at these locations. Intensive

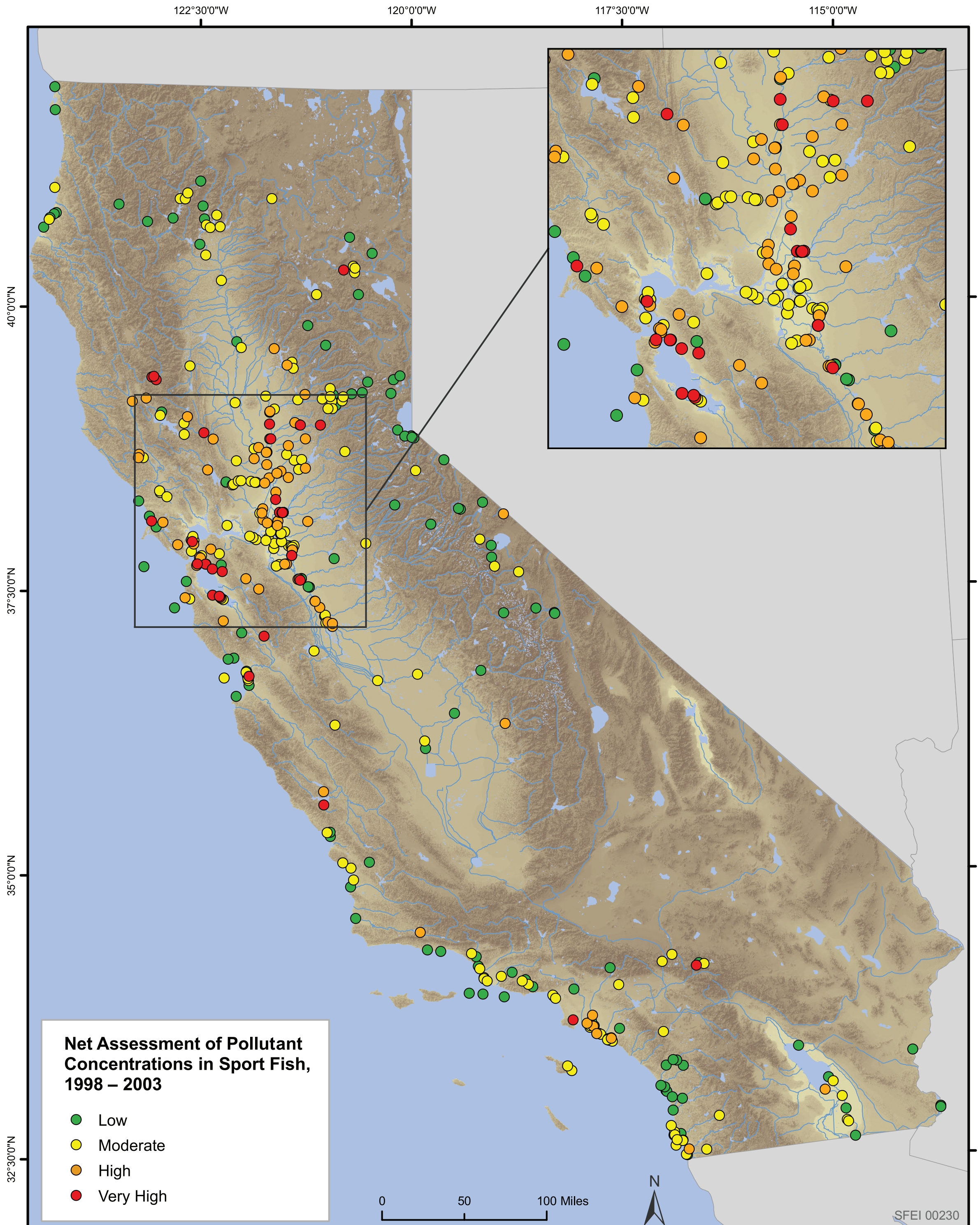


Figure 3.2.3. Net assessment of pollutant concentrations in California sport fish, 1998 – 2003. Based on measurements of several chemicals (mercury, PCBs, DDTs, dieldrin, and chlordanes) in muscle tissue from a variety of fish species. Size limits were applied for evaluation of mercury data (Appendix 1). Dots represent sampling locations. Dot colors correspond to degrees of contamination (low, moderate, high, very high) defined for each pollutant and represent the species with the highest degree of contamination at each location.

sampling focused on mercury was conducted during this period in the Delta region (Davis et al. 2000, 2003), resulting in identification of a dense cluster of moderate and high locations in this area.

Thirty-two percent of the locations sampled fell into the low category. These locations were scattered throughout the state. Areas with a particular prevalence of low concentration locations were the higher elevation water bodies in the Sierra Nevada and a cluster of water bodies in the area north of San Diego. Low concentration locations were relatively scarce in the Delta region.

Figure 3.2.3 also illustrates that some areas of the state were not sampled thoroughly in recent years. Only 33 locations north of Chico were sampled, and many of these were clustered in Humboldt Bay, Trinity Lake, Shasta Lake, and the Susan River. Many areas of the northern part of the state were not sampled at all. Sampling in the portion of California between Chico and Monterey was relatively intense, with especially thorough coverage of the Delta and its nearby tributaries, San Francisco Bay and nearby reservoirs, and Monterey Bay. Most of this sampling, however, has included only mercury analysis, leaving significant information gaps concerning other pollutants. One part of this portion of the state that has received little attention is the central Sierra Nevada and its foothills which encompass many reservoirs and streams. Sampling of reservoirs in general has been insufficient – reservoirs are often large and heterogeneous ecosystems with considerable variation from one arm to the next, and require multiple samples for an adequate representation of condition. Very few samples were collected in the region between Monterey and Santa Barbara, with some concentrated sampling near Morro Bay and San Luis Obispo, and only nine other locations sampled. Sampling in the portion of the state from Santa Barbara south was relatively thorough, especially along the coast near population centers, but many inland reservoirs and streams were not sampled. Overall, the distribution of sampling effort across the state was uneven and non-systematic, often focusing on problem areas. This has resulted in a dataset that provides a skewed assessment at the statewide scale of the impact of pollutants on fishing.

In addition to areas that were not sampled at all, it should be noted that many of the dots shown in Figure 3.2.3 represent very small sample sizes. Of the 390 locations sampled from 1998 – 2003, 139 (36%) were represented by only one sample of one species.

It should also be noted that the analysis presented in Figure 3.2.3 did not include a few other pollutants of concern. Selenium and dioxin were not included and could have had a minor influence on the display. Inclusion of selenium could have resulted in a few more moderate or more contaminated locations in the Salton Sea and San Joaquin Valley. Very few dioxin data exist for 1998 – 2003. Dioxin concentrations in San Francisco Bay have been measured and were above thresholds for concern (Greenfield et al. 2003), but a GTL does not exist for dioxin, and inclusion of dioxins in the San Francisco Bay data would have had a minor influence on the net degree of impairment in that region, since PCBs already place the Bay into the “very high” contamination category. Polybrominated diphenyl ethers (PBDEs) are another class of pollutants of increasing concern, but few data exist for the time period of interest and thresholds for human health concern have not yet been developed.

b. Long-term Trends in Impact of Pollutants on Fishing in California

Trends in the overall impact of pollutants on fishing in California can be evaluated by comparing historic data to the same concentration thresholds applied to the recent monitoring data in the previous section (Table 3.2.3, Figures 3.2.4 and 3.2.5). Sampling intensity was highest in the most recent interval (390 locations sampled) in spite of this interval being shorter than the others. This was principally due to significant studies by USGS and CALFED in northern California during this period. A total of 223 locations were sampled in the 1978 – 1987 interval, and 304 in the 1988 – 1997 interval.

Table 3.2.3. Total number of locations sampled for all pollutants and percentage in each concentration category for three different time intervals from 1978 to 2003.

Time Interval	Total Number of Locations Sampled	Low	Moderate	High	Very High
Recent (1998 – 2003)	390	32%	42%	18%	8%
1988 – 1997	304	57%	28%	9%	6%
1978 – 1987	223	39%	38%	9%	14%

The percentages of locations falling into each concentration category varied across the three time intervals. The primary causes of these changes were probably decreases in concentrations of organic pollutants and biases caused by shifts in the geographic emphasis of sampling. The percentage of locations in the low category was highest (57%) in the 1988 – 1997 interval. This was at least partially due to geographic shifts in sampling. As mentioned previously, sampling in the most recent interval was particularly concentrated in the Delta region, which had a high prevalence of locations in the moderate and high categories. In the 1988 – 1997 period, a relatively large proportion of relatively clean locations were sampled near the Oregon border, in the upper Sacramento River watershed, in the Sierra Nevada, and southern San Diego County.

Concentrations of organics have generally declined across the state, and this probably contributed to the lower numbers of locations in the very high category in the 1988 – 1997 and 1998 – 2003 intervals relative to the 1978 – 1987 interval. In 1978 – 1987, 23 locations fell into the very high category based on PCB concentrations. This number fell to 14 in 1988-1997 and to 10 in 1998 – 2003, in spite of an increased emphasis on San Francisco Bay (with its persistent PCB problem). In the most recent sampling, seven of the red dots attributable to PCBs in the recent period were in San Francisco Bay. The earlier time intervals also included a few locations that could be classified as very high due to concentrations of DDT and dieldrin, while none were observed in the recent interval. Trends in the impact of specific pollutants (mercury, PCBs, and legacy pesticides) on fishing in California are evaluated in more detail, including analysis of time series at selected locations, in later sections of this report.

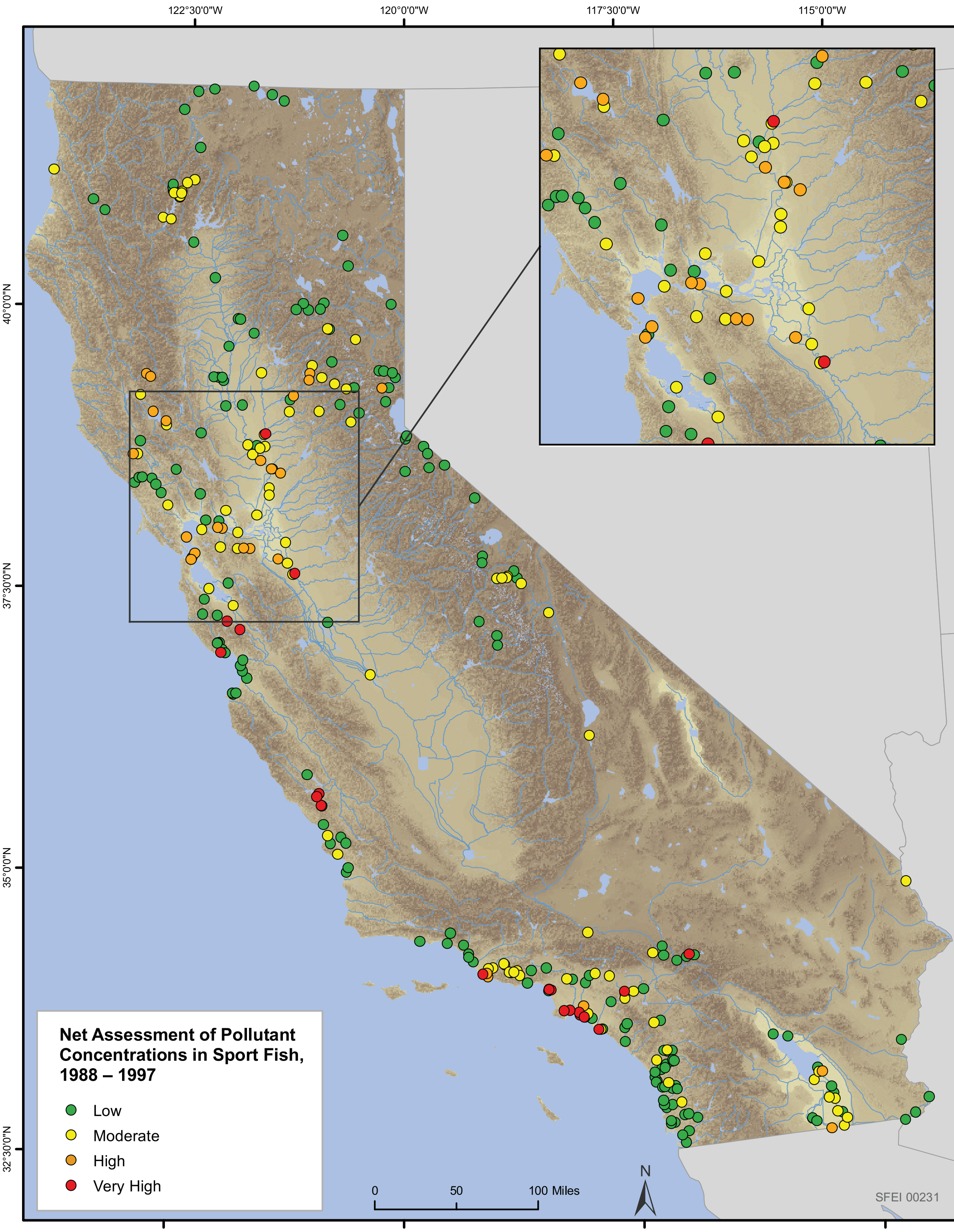


Figure 3.2.4. Net assessment of pollutant concentrations in California sport fish, 1988 – 1997. Based on measurements of several chemicals (mercury, PCBs, DDTs, dieldrin, and chlordanes) in muscle tissue from a variety of fish species. Size limits were applied for evaluation of mercury data (Appendix 1). Dots represent sampling locations. Dot colors correspond to degrees of contamination (low, moderate, high, very high) defined for each pollutant and represent the species with the highest degree of contamination at each location.

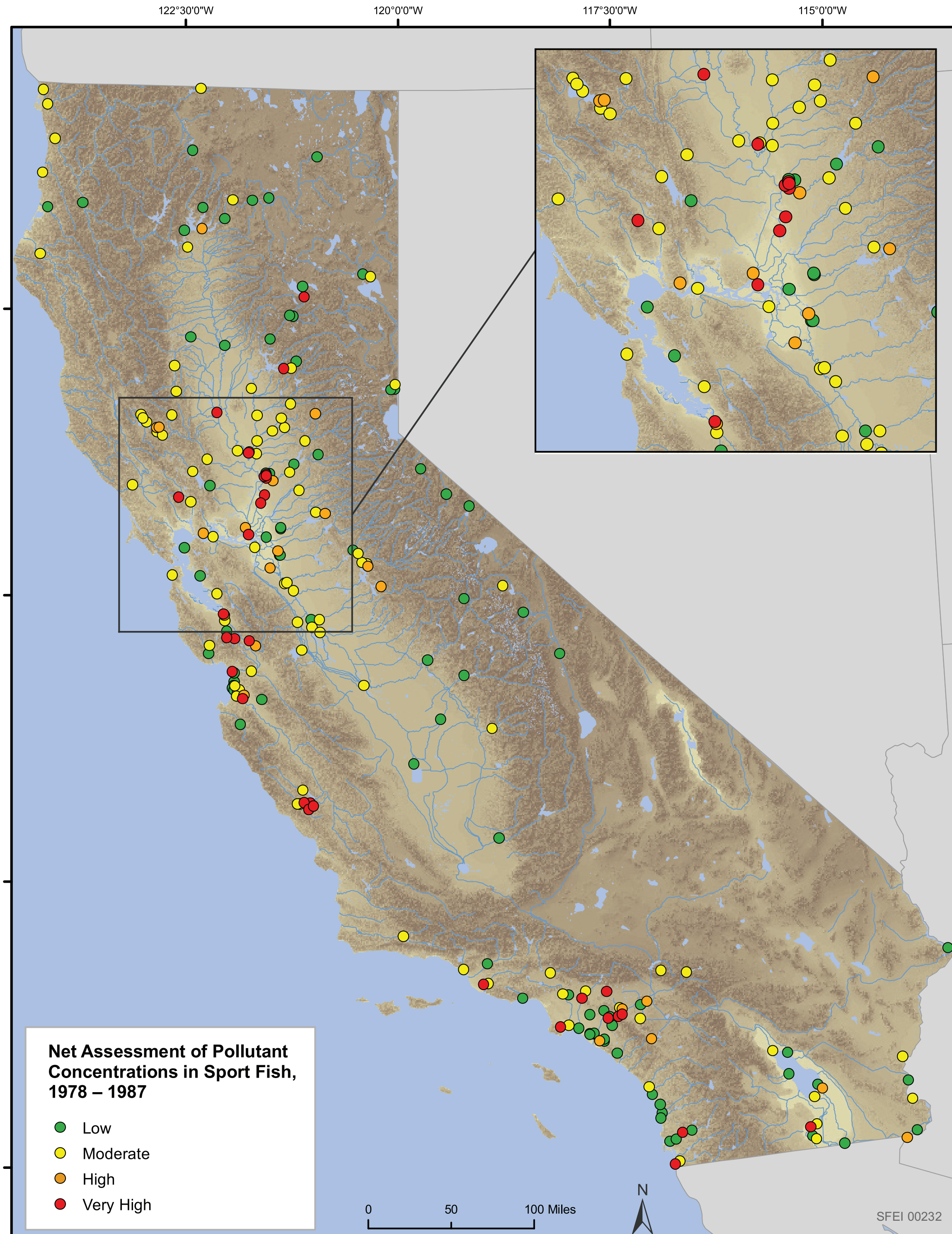


Figure 3.2.5. Net assessment of pollutant concentrations in California sport fish, 1978 – 1987. Based on measurements of several chemicals (mercury, PCBs, DDTs, dieldrin, and chlordanes) in muscle tissue from a variety of fish species. Size limits were applied for evaluation of mercury data (Appendix 1). Dots represent sampling locations. Dot colors correspond to degrees of contamination (low, moderate, high, very high) defined for each pollutant and represent the species with the highest degree of contamination at each location.

In summary, the available data provide a weak basis for evaluation of long-term trends in the impact of pollutants on the fishing beneficial use in California. The geographic focus of sampling has shifted significantly over time, causing apparent but spurious shifts in the impact of pollutants on fishing.

3.2.3. Summary and Recommendations

Pollutants are having a significant impact on fishing in California water bodies. Consumption advisories, 303(d) listings, and the bioaccumulation database as a whole provide three indices of the status of impact. Consumption advisories exist for an increasing number of water bodies, but only a fraction of the areas likely to need them. Lack of suitable data is a major impediment to developing advice for additional water bodies. The 2002 303(d) List indicates that large portions of the state have not been assessed, especially for rivers and coastline. On an area basis, most of the lake area in the state has been assessed, and a relatively small percentage of the total area (6%) is classified as impaired. However, based on numbers of lakes sampled, only 3% of the lakes in California larger than 4 hectares have been sampled in recent years, and these lakes were not sampled in a representative manner that might allow inference about the large number of unsampled lakes. Overall, therefore, the status of California lakes with respect to impacts on fishing is a major information gap. Bays and estuaries have been thoroughly assessed (98% of the area) and are highly impacted (93% of the total area). Evaluation of the most recent monitoring data indicates that, for the locations sampled, 32% have low concentrations of pollutants, 42% have moderate concentrations, 18% have high concentrations, and 8% have very high concentrations. Mercury is the pollutant responsible for the majority of locations assigned to the very high category, with PCBs having a secondary role.

The dataset available for these evaluations, however, has several limitations:

- many areas have not been sampled adequately;
- the distribution of sampling locations has varied over time;
- much of the sampling has not been tailored to the development of consumption advice; and
- much of the sampling has been biased toward characterization of polluted areas.

The evaluation of recent data in this section makes it evident that a sampling design with spatial randomization would be better suited to answering the SWAMP assessment questions related to statewide condition. Such a design would allow for an unbiased statewide assessment of the condition of California water bodies. Indices of net impact during different time intervals would be directly comparable since all areas would be sampled in a representative manner. A randomized design could be developed that samples different locations in proportion to the amount of fishing activity, an important feature with regard to development of consumption advice. A randomized design could also be complemented by other approaches, such as targeted sampling for long-term trends in particular locations or focused efforts to sample lakes of particularly high interest. A combination of randomized and targeted sampling would be an optimal approach for providing the information that water quality managers need from a bioaccumulation monitoring program in California.

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