Technical Report of the Chlorinated Hydrocarbon Workgroup

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Introduction

The mission of the Chlorinated Hydrocarbon Workgroup (CHCWG) was to develop recommendations for a Regional Monitoring Program (RMP) sampling design that optimally meets the objectives of the Program with regard to chlorinated hydrocarbons (CHCs) and to provide a formal justification for the recommended design. Following the guidance of the Five Year Review panel (Bernstein and O'Connor, 1997), these recommendations were based on:

1. RMP data and data from other continuing and historical studies.
2. mass balance models developed to guide redesign.
3. a clear linkage of the design with RMP objectives and management questions.

Based on priorities defined by the Technical Review Committee, the primary focus of the CHCWG was on PCBs.

This report summarizes the recommendations of the CHCWG and provides a summary of the formal justification for the recommendations. The justification is presented in the form of Findings of the Workgroup and explanatory text accompanying the specific recommendations.

The CHCWG was comprised of experts on CHCs in San Francisco Bay and two prominent scientists from outside the region (Eisenreich and Gobas) who have extensive experience in CHC fate and transport in the Great Lakes (Table 1). Significant technical contributions were also made by Andy Gunther of Applied Marine Sciences and Dave Schoellhamer and Sam Luoma of the U.S. Geological Survey. Many others also attended and participated in discussions at the two workgroup meetings.

At the first CHCWG meeting in July 1998, local data on CHCs from the RMP and other programs were summarized. The CHCWG agreed with the Review Panel's recommendation on the importance of developing a mass budget model for PCBs in order to evaluate the likelihood of continuing inputs of PCBs to the Bay and to understand response times in the Bay. The CHCWG provided guidance on the type of model to use to SFEI staff, who then developed the model. Results of the modeling were presented and discussed at the second meeting in December 1998, and provided a foundation for the recommendations developed at that meeting. A summary of the modeling effort is provided below. A more detailed report on the modeling exercise will be prepared this summer.

A Mass Budget Model for PCBs in San Francisco Bay

The objectives of the mass budget modeling effort were to estimate inputs of PCBs to the Bay and the response time (rate of change in concentrations under different management scenarios) of the Bay for PCBs. The CHCWG recommended development of a one-box model for the whole Bay as a first step in understanding the PCB mass budget. The use of a modeling framework developed by Mackay *et al.* (1994) and further refined by Gobas *et al.* (1995, 1998) was recommended by the Workgroup. Figure 1 illustrates the processes included in the model.

Although the principal concern over CHCs in the Bay is due to their accumulation in fish, piscivorous wildlife, and humans, the model does not include a food web component, primarily because of the limited information available on the diets of the fish species used in monitoring and on the diets of their prey. The model predicts concentrations of PCBs in sediment and water over time. Until a food web component can be added to the model, it can be assumed that PCB trends in the food web would be similar to those predicted for sediment and water.

Extensive data on PCB concentrations in the Bay generated by the RMP, the Bay Protection Program (Hunt *et al.,* 1998), and other programs were used as input for the model. The best data on trends in PCB concentrations indicate that no significant decrease occurred from 1982 to 1996, suggesting that the Bay has been at a steady state with loads balancing losses. Reliable data on PCB loads to the Bay are very sparse, but losses from the Bay could be estimated using the RMP database on sediment and water concentrations. If the Bay has been at a steady state, then loads must have been of a similar magnitude as the losses. PCB loads to the Bay were therefore estimated by quantifying PCB losses from the Bay.

Important pathways for PCB loss from the Bay include outflow through the Golden Gate, burial in deep sediment, and volatilization (Figure 1). Approximately 20 kg/yr are estimated to leave the Bay via each of these pathways. Degradation probably has an insignificant effect on the budget. Losses from the Bay are therefore estimated to total approximately 60 kg/yr, and this is considered to also be a reasonable estimate of inputs to the Bay.

Response times of the Bay were estimated using solutions to the mass balance equations. The sensitivity of the model to each input parameter was assessed by running the model with ranges of values of the input parameters. Using the best available estimates of each input parameter, if loads to the Bay were eliminated the total mass of bioavailable PCBs in the active sediment layer (which accounts for 98% of the total) would be predicted to decrease from approximately 450 kg to approximately 150 kg over a 10 year period (Figure 2). The model indicates that loads of 25 - 50 kg/yr could significantly delay reductions in the mass of bioavailable PCBs in the Bay (Figure 3).

It should be acknowledged that the estimates produced by the model are crude approximations. The model is based on estimated values of Baywide annual averages of many input parameters that are often uncertain and highly simplified characterizations of complex features and processes in the Bay. A more detailed treatment of the uncertainty of the model will be provided in the detailed report.

In spite of these weaknesses, the mass budget model does provide several benefits. The model provides a framework for organizing our knowledge of PCBs in the Bay. Although the model estimates are uncertain, this uncertainty can be reduced as better information becomes available. The modeling exercise has helped identify parameters that have the strongest influence on the PCB budget and response times and parameters for which improved estimates would yield the greatest improvement in understanding of PCB fate in the Bay.

As an example, the depth of the active layer of sediment is a critical input parameter, not only for PCBs but for other contaminants that are predominantly particle-bound in the Bay. The depth of this layer has a strong effect on the mass of contaminant available to the food web and the rate of decline in PCB concentrations (Figure 4). Rates of decline in PCB mass in sediment over a 10 year period in the absence of loads to the Bay are predicted to be 44% for an active layer of 15 cm, 67% for an active layer of 7 cm, and 90% for an active layer of 3 cm (Figure 4). The "best" estimate of 7 cm is based on data gathered by USGS for one sampling area in Richardson Bay (Fuller *et al.,* 1999). A Baywide average active sediment depth is difficult to estimate because of the spatial and temporal heterogeneity of Bay sediment, the very limited data available, and the abstract nature of the concept. Clearly, more information on this parameter is needed.

Findings

Finding 1: Chemical measurements demonstrate that CHCs are adversely impacting beneficial uses in the Estuary.

RMP water sampling has frequently found concentrations of PCBs, DDTs, chlordanes, and dieldrin that exceed various water quality objectives. For trace organics, the water quality objectives are based on human exposure through consumption of contaminated fish. PCB concentrations have exceeded the water quality objective in almost every sample analyzed. For example, 43 of 53 samples in 1997 exceeded the 170 pg/L objective (SFEI, 1999). Other trace organics exceeded objectives less frequently in 1997: DDTs in 11 of 53 samples, chlordanes in 6 of 54 samples, and dieldrin in 23 of 52 samples.

Chemical monitoring of fish tissue in the RMP confirms the concern raised by the water data for human exposure through consumption of contaminated fish. RMP fish sampling began in 1997, following a pilot study conducted in 1994 (Fairey *et al.,* 1997) and the issuance of a health advisory for consumption of fish from San Francisco Bay (OEHHA, 1994). The advice was issued due to concern over human exposure to residues of methylmercury, PCBs, dioxins, and organochlorine pesticides in Bay-caught fish. This interim advisory remains in place after completion of the second round of sampling in 1997 (SFEI, 1999). PCBs exceeded the screening value in 51 of 72 Bay samples (Figure 5). Dieldrin, DDT, and chlordane had lower numbers of Bay samples above screening values: 27 of 72 for dieldrin, 16 of 72 for DDTs, and 11 of 72 for chlordanes.

Studies of piscivorous wildlife in the Bay have also found concentrations of CHCs indicative of possible adverse impacts. Concentrations of PCBs in double-crested cormorants (Davis *et al*., 1997; Davis, 1997) and harbor seals (Young *et al*., 1998) appear to be high enough to impair the health of these species. The cormorants and seals rely almost exclusively on Bay fish for their diet and are therefore much more highly exposed to food web contaminants than humans.

Finding 2: Annual changes in concentrations of CHCs in the Bay are likely to be small.

Long-term trend data available for CHCs in the Bay indicate that PCB concentrations have been decreasing very slowly. The most complete long-term time series exists for trace organics in transplanted mussels, which have been deployed in the Bay since 1980 under the California State Mussel Watch (SMW) Program for 1980-1993 and the RMP for 1994-present (Gunther *et al.,* 1999). PCB concentrations showed no perceptible change from 1982 to 1996 (Figure 6). The most recent data (for 1997) were lower; continued sampling will be required to determine whether the 1997 results are indicative of a long-term decline.

Sampling of other matrices also suggests that PCB concentrations are declining very slowly in the Bay, and are not even one order of magnitude lower than peak concentrations in the late 1960s. A few data are available on water column concentrations of PCBs from the 1970s (Risebrough, 1997) and early 1980s (Jarman and Davis, 1997). Both Risebrough (1997) and Jarman and Davis (1997) conclude that PCB concentrations measured by the RMP in recent years are roughly equivalent to the older data.

Risebrough (1997) also presented data on CHCs in shiner surfperch collected from the Bay in 1965, and these can be compared to shiner surfperch data collected in 1994 (Fairey *et al.,* 1997) and 1997 (SFEI, 1999; Table 2). The recently measured PCB concentrations are approximately 20% of those measured over 30 years ago. The decline for DDTs has been greater, with recent concentrations only 3-5% of 1965 values.

Venkatesan *et al.* (1999) measured CHC concentrations in dated sediment cores from two locations in the Bay that provide chronologies spanning several decades and also indicate very gradual long term-declines. In the San Pablo Bay core, which was less affected by mixing than the Richardson Bay core, maximum PCB concentrations were found in sediments deposited around 1970 and were about 2.5 times higher than concentrations in surficial sediments deposited around 1990 (Figure 7). While these data indicate a clear decrease, the magnitude of the decrease is lower than might be expected given the longstanding restrictions on PCB use. In contrast, DDT concentrations in this core declined from a maximum of 57 ng/g dry in sediment deposited around 1965 to 6 ng/g dry in surface sediments deposited around 1990. It is also noteworthy that most of the drop in CHC concentrations in these cores occurred in a short span after the peak concentrations, with a more gradual decline thereafter.

In addition to the empirical evidence of slow rates of decline, available data on sediment mixing suggest that sediment CHC concentrations would be slow to respond to changing inputs. Fuller *et al.* (1999) analyzed radioisotopes in the Richardson Bay and San Pablo Bay sediment cores to examine chronologies of deposition and mixing. They estimated for the Richardson Bay core that 82% of a 1-year pulse input of contaminated sediment would remain in the mixed zone 20 years after deposition.

Finding 3: There are probably continuing inputs of PCBs and other CHCs to the Bay from local tributaries, major rivers, atmospheric deposition, and point sources.

The PCB mass budget modeling described previously led to the conclusion that inputs must have existed in order to explain the lack of decrease observed in bivalves from 1982-1996. If the Bay was indeed at a steady state for this period, then inputs of approximately 60 kg would have been required to balance the estimated losses from the Bay.

The changing PCB fingerprints (congener ratios) observed in RMP water sampling (Jarman *et al.,* 1997) provide additional evidence of “fresh” inputs to the Bay. For example, Central Bay samples in July 1996 had a distinct fingerprint of Aroclor 1248, especially at Red Rock (BC60) and the Golden Gate (BC20). The lower chlorinated congeners found in Aroclor 1248 would not be expected to persist in the Bay over the long term, nor would the fingerprint of a specific Aroclor be expected to be distinctly apparent after years of mixing in the Bay.

The persistence of PCBs combined with their widespread use in the watershed further suggest the likelihood that PCBs are continuing to enter the Bay. Due to their resistance to electrical, thermal, and chemical processes, PCBs were used in a wide variety of applications (e.g., in electrical transformers and capacitors, vacuum pumps, hydraulic fluids, lubricants, inks, and as a plasticizer) from the time of their initial commercial production in 1929 (Brinkmann and de Kok, 1980). In 1979, a final PCB ban was implemented by the U.S. Environmental Protection Agency (U.S. EPA), prohibiting the manufacture, processing, commercial distribution, and use of PCBs except in totally enclosed applications (Rice and O’Keefe, 1995). A significant amount of the world inventory of PCBs may still be in place in industrial equipment (Rice and O’Keefe, 1995). Local U.S. EPA staff estimate that of the 1.5 billion pounds of PCBs that were produced, about 5%, or 8 million pounds, are still in use, mostly in electrical transformers (Brandon Carter, U.S. EPA, personal communication). Pacific Gas and Electric (PG&E), one of the primary historic users of PCBs in the Bay Area, has essentially eliminated use of PCB capacitors and transformers, but does still have a large amount of equipment containing PCB residues as a contaminant (parts per million concentrations) from the production process (Victor Furtado, PG&E, personal communication). Many other industries also used PCBs in many other products. Leakage from or improper handling of such equipment has led to widespread PCB contamination of industrial areas. A significant portion of the Bay shoreline and watershed is industrialized, and PCB contamination has been identified at many sites in the watershed.

Mass budget studies in other aquatic ecosystems have identified tributary inputs, atmospheric deposition, and point sources as primary pathways of PCB loading (Marti and Armstrong, 1990; Mackay *et al.,* 1994; Pearson *et al.,* 1996; Nelson *et al.,* 1998). These same categories are the primary potential pathways to the Bay. The CHCWG divided tributary inputs into inputs from the major rivers (the Sacramento and San Joaquin rivers) and local tributaries (including storm drains) that flow directly into the Bay.

Knowledge of PCB uses and monitoring data suggest that local tributaries could represent a significant pathway for continuing PCB input to the Bay. Drainage from industrial areas with high PCB contamination potential would primarily enter the Bay via local tributaries. Sediment sampling under the Bay Protection Program (Hunt *et al.,* 1998) and the RMP has frequently found high PCB concentrations at the points where local tributaries enter the Bay (Figure 7).

Atmospheric deposition could be a significant source to the Bay. The urban plume (Holsen *et al.*, 1991; Simcik *et al.,* 1997; Zhang *et al.,* submitted) of the San Francisco peninsula would often sit right on the Bay, and local climatic conditions (fog, a turbulent air/water interface) could enhance air/water exchange of contaminants. Also suggestive of the importance of local atmospheric deposition are PCB concentrations in fish from San Pablo Reservoir that are comparable to those in Bay fish (Myrto Petreas, Cal/EPA, personal communication) in spite of no known sources in the local watershed.

The Sacramento and San Joaquin rivers appear to transport moderate masses of PCBs to the Bay and probably relatively large masses of DDT and other organochlorine pesticides. RMP sampling has found typical concentrations of approximately 250 pg/L total (dissolved + particulate) PCBs at the Rivers stations (BG20 and BG30). Combining this concentration with annual average Delta outflow yields an average annual mass load of 7 kg/yr.

This value probably is an underestimate of loads from the rivers, since particle-associated contaminants such as PCBs are transported principally during runoff events early in the wet season and these short duration events are generally not captured by RMP sampling. One possible exception was in January 1997, when RMP water sampling coincided with a record runoff event. Using PCB concentrations and Delta outflow measured at this time an instantaneous mass load of 19 kg/yr is obtained.

In contrast to many other contaminants, total (dissolved + particulate) PCB concentrations at the rivers and Northern Estuary stations were not elevated during the Big Storm. This suggests that the sediment particles washing into the Estuary from the Central Valley were relatively uncontaminated with respect to PCBs. This observation is consistent with previous observations of relatively low TSS-normalized concentrations of PCBs at the Northern Estuary and Rivers stations (Jarman and Davis, 1997). Nevertheless, in spite of these low concentrations and an apparently diluted signal of PCB contamination, events with high flows and sediment transport can still lead to significant mass loading from the Rivers. Given the large amounts of flow and sediment transport involved, mass loading from the Rivers could potentially be a significant component of the PCB mass budget and should be carefully estimated. Potential sources of PCBs in the Central Valley include both areas with industrial development and hydroelectric power generation facilities (CVRWQCB, 1987).

Total (dissolved + particulate) chlordanes and DDTs were among the contaminants that were elevated in the northern reach in the January 1997 sampling. Total DDT concentrations at the rivers were the highest yet observed for these stations in the RMP. Total DDT concentrations were also elevated in January at the Northern Estuary stations. Total concentrations of dieldrin and chlordanes at the Northern Estuary stations were the highest yet observed for these stations in the RMP. The high dissolved + particulate concentrations of DDTs, chlordanes, and dieldrin in the Northern Estuary suggest significant transport of contaminated sediment particles from the Central Valley during the high flows in January. Research by USGS (Kratzer 1998) has documented transport of substantial quantities of particle-associated organochlorine pesticides from tributaries to the San Joaquin River. Other studies have found widespread organochlorine contamination throughout the Central Valley.

PCB loadings from point sources are probably a minor component of the overall budget. Very few reliable data are available on trace organics concentrations in point sources. A few effluent samples were recently analyzed by the City of Palo Alto (Torke 1998) and concentrations ranging from 200 to 3,000 pg/L were detected. If these concentrations are assumed to be typical of Bay Area publicly owned treatment work (POTW) effluents in general, then these effluents are accounting for 0.1 to 2.0 kg/yr of PCB input to the Bay.

Overall, although more information is needed on all of the pathways for PCB input to the Bay, the largest data gaps exist for loads from local tributaries and atmospheric deposition.

Finding 4: Transplanted bivalves and the eggs of piscivorous birds are powerful tools for monitoring long-term trends in CHCs. CHC concentrations in fish tissue can be more variable and therefore less valuable for detection of long- term trends.

Due to the strong tendency of CHCs to accumulate in biota, especially at the top of the food web, biomonitoring is a very effective tool for these contaminants. The use of bivalves for monitoring long-term trends in CHCs was strongly endorsed by the CHCWG. Bivalves are valuable for the strong signal they provide of CHC contamination in the Bay (Gunther *et al.,* 1999), their temporal integrating capacity, the existence of a long term database (Gunther *et al.,* 1999), and their dynamic equilibration with environmental contamination (Russell and Gobas, 1989). Lipid normalization is an effective way to remove the influence of varying lipid content in bivalves. Bivalves are also useful for spatial comparisons, though this advantage has been limited in the RMP because of the limited salinity tolerances of the species used.

Analysis of organochlorines in piscivorous bird eggs has produced the most reliable and powerful data set for long-term trend monitoring in the Great Lakes (Stow, 1995, Hebert *et al.,* 1997, Haffner *et al.,* 1997; Hughes *et al.,* 1998; Hebert, 1998; Pekarik and Weseloh, 1998). Piscivorous birds are high trophic level integrators of food web contamination, their eggs are easy to collect (minimal sampling costs), and the colonies and eggs are reliably present (in contrast to fish).

Given the regulatory importance of concentrations of CHCs in fish, trends in fish tissue need to be monitored. Fish are not as good as bivalves or avian eggs, however, at indicating long term trends. In the Great Lakes, trends in fish have been more variable and harder to interpret than trends in other components of the ecosystem (Madenjian *et al.,* 1994; Stow, 1995b; Stow *et al.,* 1995, 1997). As an example, Stow *et al.* (1995b) estimated that sample sizes in the range of 1000-2000 fish would be required to detect future reductions in PCB concentrations in Lake Michigan because of the high variability in PCB concentrations among individuals. CHC concentrations in fish can fluctuate with changes in food web structure (Kidd *et al.,* 1995, 1998) and with seasonal variation in lipid content. Lipid normalization does not completely remove the influence of variable lipid content, because concentrations in fish lipid are slow to equilibrate with environmental concentrations (Frank Gobas, Simon Fraser University, personal communication).

Finding 5: The RMP is underestimating contamination in the Bay by focusing on chemicals that are no longer in use.

Uses of most CHCs measured in the RMP were subject to heavy restrictions or bans since 1972 for DDT, 1979 for PCBs, 1987 for dieldrin, and 1988 for chlordane. Continued monitoring of the CHCs is clearly needed. However, the CHCs have been replaced by other pesticides, insulators, and flame retardants that are required to be highly toxic and/or persistent in order to serve their purpose. Few of the chemicals that are currently in heavy use and are of potential concern in the Bay are currently monitored by the RMP.

Recommendations

The Findings presented above provided the basis for recommendations by the CHCWG on how to design the RMP to satisfy the objectives and management questions established for the Program. CHCWG recommendations were explicitly tied to RMP objectives and management questions. The CHCWG assumed that the budget available for the RMP would remain approximately equal to its present level, so recommended additions to the Program were accompanied by recommendations of elements that could be reduced.

These recommendations have already been distributed and reviewed, so they are presented below in a condensed form, but in the same format that was used previously.

Sources, Pathways, and Loadings

The group agreed that there are probably continuing inputs of PCBs and other CHCs to the Bay from local tributaries, the major rivers, atmospheric deposition, and point sources. The greatest emphasis in evaluating loadings should be placed on the largest potential sources. Where possible, existing data should be compiled to help identify the largest potential sources and pathways. For example, existing data on possible loads from the Sacramento River should be evaluated (including transport of contaminated sediments during large sediment transport events). Other types of information that could help identify sources and pathways should also be considered, such as PCB fingerprints, PCB/DDT ratios, and fugacity comparisons.

The group recommended a phased approach to begin to evaluate loadings of contaminants to the Bay from local tributaries (including storm drains).

1. Review existing information to identify drainages with the greatest potential for continuing CHC inputs.
   The size and contamination potential of the drainage area should be considered. Existing data on sediment contamination at the mouths of storm drains and tributaries (i.e., Bay Protection Program data) should be reviewed. Other sources of information on CHC contamination in the drainages (e.g., locations with documented PCB contamination) should be also be reviewed.
2. Survey local watersheds to determine potential continuing sources.
   The RMP should sample sediment and bivalves at the outlets of local tributaries and storm drains where existing data are not sufficient to indicate whether the tributary carries contaminated sediment. Drainage areas that are continuing sources would have higher concentrations of CHCs in sediment and bivalves at these outlets. Sampling should be performed at the upper end of the tidal prism (where applicable) at the end of the rainy season. Compositing would allow wide spatial coverage at the outlets.
3. Sample sediments upstream in the tributaries.
   Sediments in the upstream portions of the creeks or storm drains should be sampled to confirm the presence of contamination and to possibly locate the sources of contamination more precisely. The group recognizes that this may be beyond the realm of the RMP, but recommends that this step be taken by whoever is the appropriate entity.
4. Measure loads from largest potential sources.
   Good flow data are essential to estimating loadings, so load estimates should be made on tributaries where these data are available. Load measurements should be made in collaboration with USGS, using USGS methodologies. Hydrologic events should be sampled as appropriate to capture the large fluxes of suspended matter that can occur during storms.

Data from sediments at the outlets of some local tributaries are already available, and some indicate possible upstream sources of contamination. At these locations steps 2 and 3 could be initiated on a pilot study basis. Steps 2 and 3 do not need to be sequential. For example, the RMP could begin a pilot study measuring loads (as described in #3 above) from Coyote Creek, where sampling in the upper reaches of the tidal prism (Estuary Interface Pilot Study) and at the San Jose station (C-3-0) has detected high PCB concentrations.

Water

- Replication is crucial in evaluation of spatial or temporal trends. Some degree of replication should be incorporated as a routine part of the Base Program. At a minimum, duplicate samples should be collected at one station in every sampling cruise. Ideally, side-by-side sampling should be performed to allow estimation of the variance of collection. If this is not possible, other alternatives should be considered, such as collecting a second sample right after a first sample.

- Field recovery, measured by using two samplers in series, should be evaluated on a routine basis for dissolved organics.
- Implicit in the preceding two recommendations is the recommendation that the RMP obtain or gain access to another water sampler.
- Sampling frequency: Available information indicates that annual changes in concentrations of CHCs in the water column are likely to be small. Three cruises per year are therefore not necessary for long-term trend monitoring. Since documenting seasonal variation is not stated as a priority in the *RMP Objectives, Focusing Questions, and Management Questions*, three cruises are not necessary for that purpose either. Annual sampling of the water column is recommended.
- Spatial array: The focusing and management questions both express interest in comparison of embayments. Based on this, the group agreed that the target data for the Base Program was a representative annual average contaminant concentration for each embayment. A rigorous statistical approach should be followed to determine the minimum number of sampling sites and optimal arrangement within each embayment that would yield a good estimate of the annual average concentration for each embayment. Jassby *et al.* (1997) provide an example of this type of analysis. The array should include new stations in the “shallow margins” to address the focusing and management questions about comparing the spine and shallows.
- One of the management questions calls for linking trends in inputs with trends in the Bay. For water, the group thought that measuring trends in inputs is more important than trying to detect trends in the Bay, where the signal is blurred by mixing with past deposits. Measurements along the “spine” are an excellent way of tracking Bay-wide trends.
- An eventual goal should be to develop a mass budget model for each embayment that could be used as a management tool to predict the likely responses to regulatory actions within each embayment.

Bivalves

- The use of bivalves for monitoring long-term trends in CHCs was strongly endorsed by the group and should be continued.
- The possible value of replication in the bivalve sampling should be evaluated.
- Due to the broad scope of the CHCWG meeting, it was not possible to have a detailed discussion on the bivalve sampling. Further aspects of the design of the bivalve component (transplants versus residents, alternate species, etc.) were left to another group.

Fish

- Trends in fish tissue should continue to be monitored. The existing plan calling for sampling of fish every three years is reasonable, given the recommended emphasis on other matrices for long-term trend monitoring.
- Information on the diet composition and trophic position of the monitored fish species are needed to evaluate long-term trends and understand interspecies differences in contaminant accumulation. Measurement of nitrogen isotopes would be a relatively inexpensive way of evaluating trophic position of the fish species, and might provide a way of detecting shifts in food web structure over time. The simultaneous declines observed from 1994-1997 in several

Bay species might be due to a change in food web structure. Characterization of the portions of the Bay food web that include the monitored species is needed.

Eggs of Piscivorous Birds

- Annual monitoring of concentrations of organochlorines and other persistent bioaccumulative contaminants in double-crested cormorant eggs from colonies on the Bay should be added to the RMP. Cormorants are recommended for several reasons: they are resident; they eat Bay fish almost exclusively; and they have been the subject of organochlorine studies in the Bay and elsewhere.

Sediment

- As with water sampling, replication is important and should be incorporated as a routine part of the Base Program. Collecting and analyzing replicate grabs would be best. Replicate sampling performed for the Pilot RMP and in 1994 should be reviewed prior to deciding how much replication is needed.
- As with water, sediment sampling should be reduced to once each year. The resources saved by reducing the frequency of sampling should be re-allocated to more extensive spatial sampling. The more extensive spatial sampling would be done to address the focusing and management questions about comparing the spine and shallows and to provide information on possible loads of CHCs from local tributaries (i.e., step 1 of the "local watershed survey" described under *Water*).
- Detection limits for sediment CHC analyses should be low enough to obtain quantitative data from all samples, or we will compromise our ability to detect temporal or spatial trends. To generate results that can be considered quantitative, the MDLs of the methods employed should be about one-third of the concentrations in field samples with low concentrations. Our current sediment MDLs are not low enough.

Air

- The group did not discuss the Atmospheric Deposition Pilot Study specifically, but the potential significance of atmospheric deposition of PCBs was acknowledged, indicating the value of the Pilot Study. Steve Eisenreich of the CHC workgroup provided detailed comments on the Pilot Study workplan to Pam Tsai.

Selection of Analytes

- The CHCWG agreed that it would be valuable for the RMP to gather information on the many chemicals that are in current use, in contrast to the CHCs which have all been banned for one, two, or three decades. On behalf of the CHCWG, Bob Risebrough has prepared written suggestions for approaching this problem. The writeup is attached (titled: *Observations of Similarities Between Bird-Watching in Amazonian Peru with a California Check-List and the Reporting of Organic Contaminants in the RMP: Suggestions for a Long-Term Approach*). In short, Dr. Risebrough and the CHCWG are proposing a special study that would employ a post-doc to analyze existing chromatography data (generated by the RMP but not analyzed) to identify some of the many large unknown peaks. This special study would address the management question asking which contaminants should be monitored.

Table 1. Members of the CHC Workgroup.

Steve Eisenreich	Rutgers University
Frank Gobas	Simon Fraser University
Wally Jarman	University of Utah
Bob Risebrough	Bodega Bay Institute
Rainer Hoenicke	SFEI
Jay Davis	SFEI

Table 2. Concentrations of PCBs and DDTs in shiner surfperch from the Bay, 1965 (Risebrough, 1997), 1994 (Fairey *et al.,* 1997), and 1997 (SFEI, 1999).

	1965	1994	1997
PCBs	832 (3)	155 (14)	168 (14)
DDTs	1150 (3)	31 (14)	57 (14)

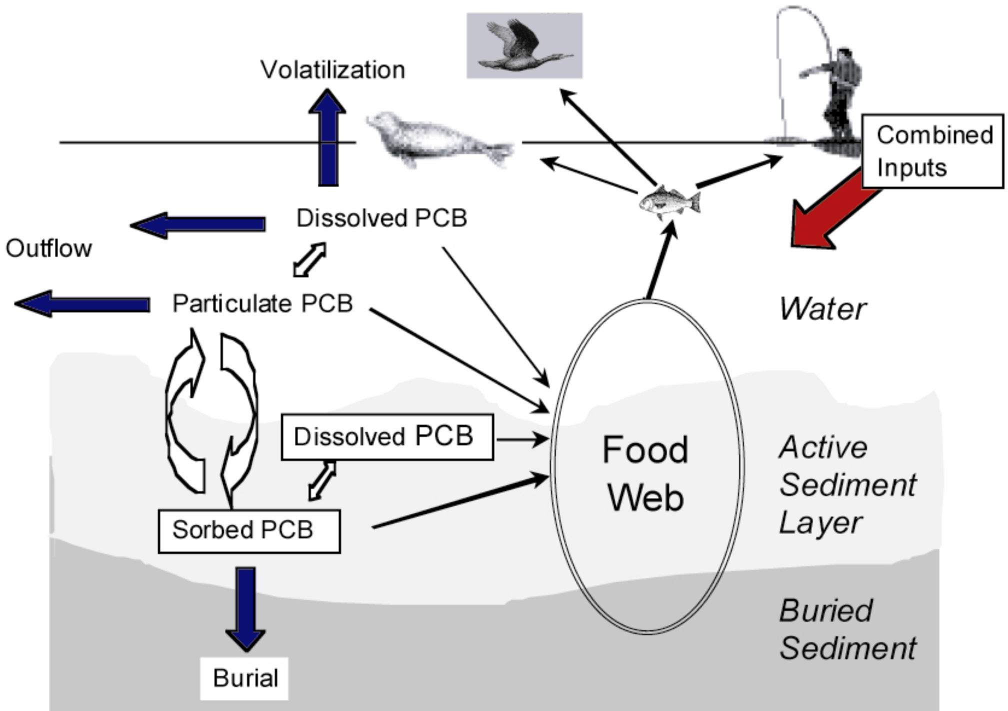

Figure 1. PCB pathways in San Francisco Bay.

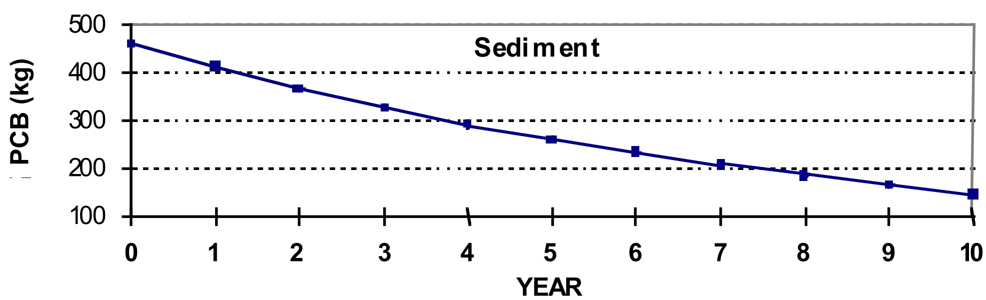

Figure 2. Predicted change in average PCB concentration in Bay sediment assuming no loading of PCBs and using best estimates of all input parameters.

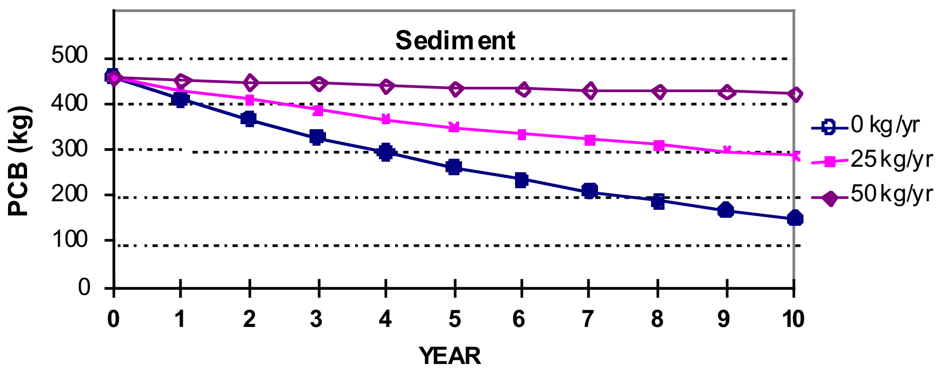

Figure 3. Predicted change in average PCB concentration in Bay sediment assuming different levels of loading of PCBs and using best estimates for all other input parameters.

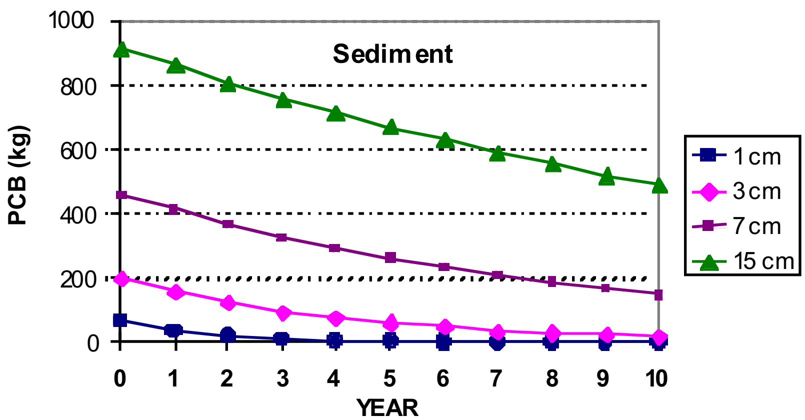

Figure 4. Predicted change in average PCB concentration in Bay sediment assuming different values for depth of the active sediment layer and using best estimates for all other input parameters.

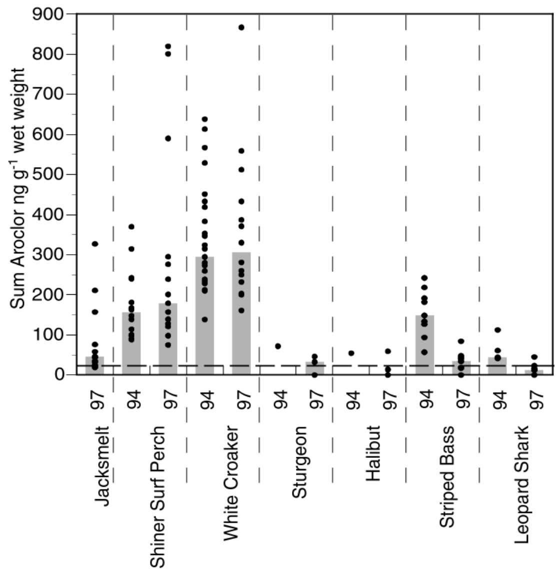

Figure 5. PCB concentrations in Bay fish, expressed as sum of Aroclors (ng/g wet), 1994 and 1997. Points are concentrations in each composite sample analyzed. Bars indicate median concentrations. Line indicates screening value (23 ng/g wet).

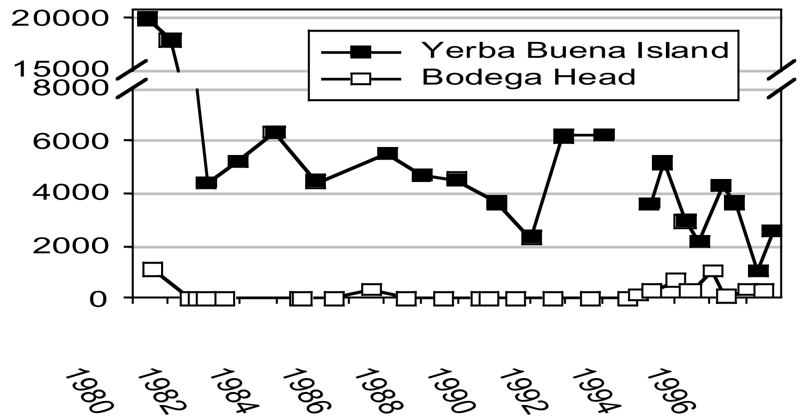

Figure 6. PCB concentrations in transplanted mussels at Yerba Buena Island. Data from Bodega Head controls are also shown. Data from the State Mussel Watch (SMW) Program for 1980-1993 and the RMP for 1994-present.

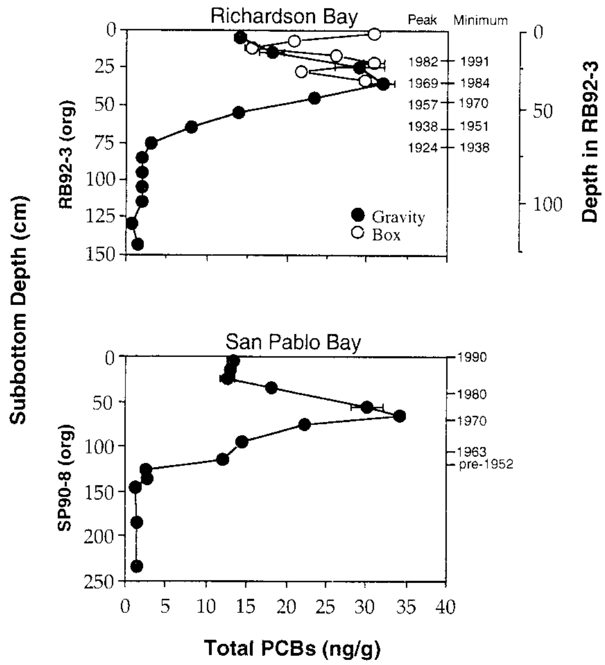

Figure 7. Total PCBs in sediment cores from Richardson and San Pablo Bays. Horizontal bars represent standard deviation of replicate analyses. From Venkatesan *et al.* (1999).

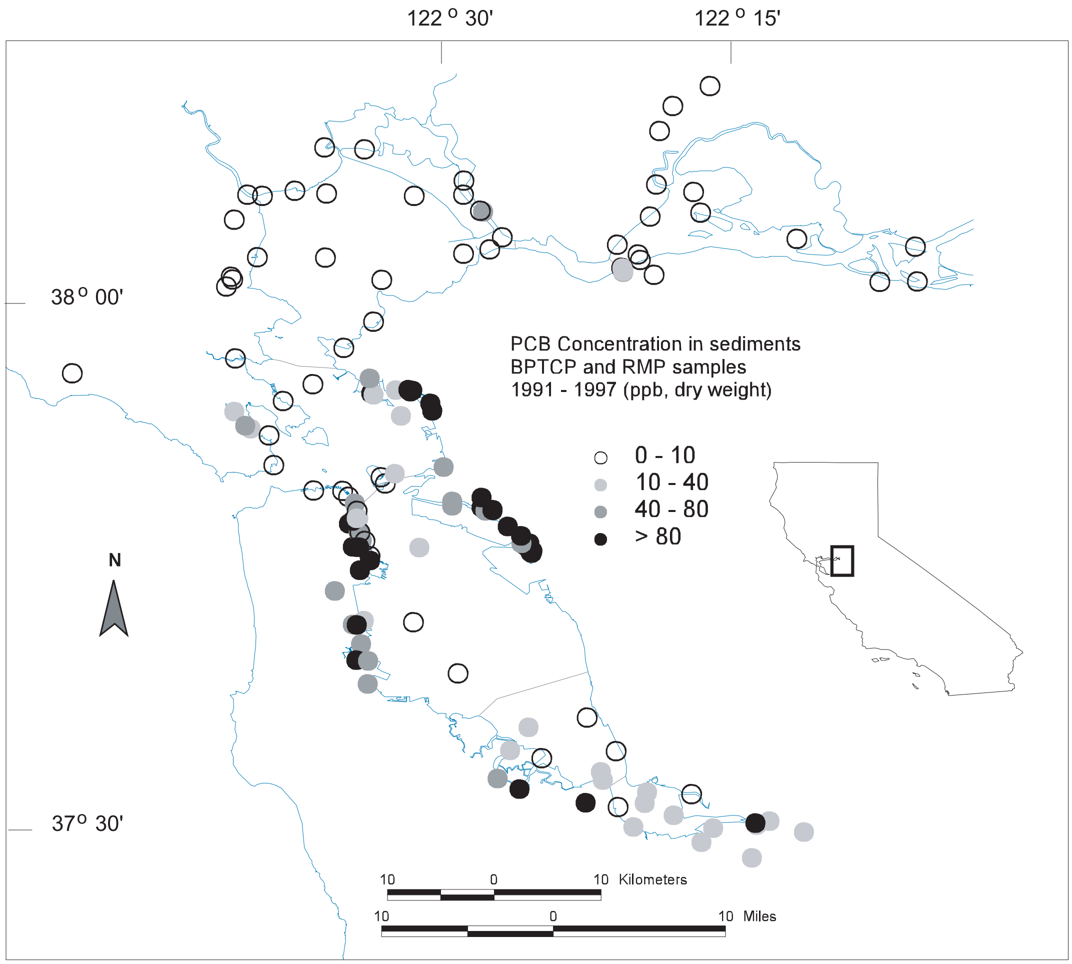

Figure 8. PCB concentrations in Bay sediments measured in the BPTCP and RMP.

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