Applying Sediment Quality Objective Assessments to San Francisco Bay Samples from 2008-2012

Draft Report

RMP Contribution xxx

June xx, 2013

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Introduction

Sediment quality can influence ecosystem health: benthic communities are directly exposed to chemicals in sediment, and sediment contaminants can be transferred to the water column and up through the food chain, causing significant tissue contamination in higher trophic level species (Barnett et al., 2008; Anderson et al., 2007). Therefore, understanding San Francisco Bay sediment quality is useful in determining if contaminants are adversely impacting aquatic life.

Although both chemistry and toxicity in San Francisco Bay sediments have been analyzed by the Regional Monitoring Program for Water Quality in San Francisco Bay (RMP) since 1993, until recently the Program was missing a benthic community monitoring component. Additionally, the chemistry and toxicity scores were not integrated to evaluate sediment quality. A single indicator cannot reliably evaluate whether contaminants in sediment pose a risk to ecosystem health (Bay and Weisberg 2012). The State Water Resources Control Board (State Water Board) addressed this issue by adopting a set of narrative sediment quality objectives (SQOs) and a standardized assessment framework as part of their 2009 "Water Quality Control Plan for Enclosed Bays and Estuaries" (Beegan and Bay 2012, SWRCB 2009). The SQO framework uses multiple lines of evidence (MLOE), known as the sediment triad approach, to assess sediment quality as measured by chemistry, toxicity, and benthic community condition. Incorporating MLOE increases confidence in accurately predicting sediment quality. The sediment quality triad has been in use since Long and Chapman (1985) first described the MLOE approach. However, a standardized method for assessing sediment quality using MLOE was not established in California until the State Water Board adopted the SQO assessment framework.

In San Francisco Bay SQO assessments have been applied at a limited number of historical sampling stations. Thompson and Lowe (2008) completed SQO assessments on seven historical sites sampled by the RMP along the spine of the Bay from 1994 through 2001. However, spine sampling does not provide a representative assessment of the Bay nor does it characterize sediment quality in areas that are likely to be most contaminated (e.g., the margins of the Bay). SQO assessments were also conducted for 40 samples collected in 2000 for a USEPA Western Environmental Monitoring and Assessment Program (WEMAP) survey that used a randomized sampling design (Barnett et al., 2008). The majority of the stations were listed as Possibly or Likely Impacted when the randomly selected stations were assessed. However, the 2000 survey only included one year of data; the precision and accuracy of the results would be improved by completing SQO assessments for San Francisco Bay sediment over multiple years (Barnett et al., 2008).

The current study completed SQO assessments on RMP Status and Trends stations from 2008 through 2012. The goal of the study was to determine spatial and temporal trends in sediment quality throughout the Bay. Additionally, results from the previous two SQO studies were compared to the 2008-2012 results. SQO assessments were completed for samples from 125 RMP Status and Trends (S&T) sites (25 sites each year). The RMP S&T sites at the Sacramento and San Joaquin Rivers were removed from the analyses because the benthic community indices were not calibrated for the freshwater environment. From 2008 to 2010 the RMP S&T program sampled sediment throughout the Bay annually, alternating between the wet and dry season. SQO assessments were conducted on samples from S&T stations because the program uses a randomized sampling design and because the inclusion of both wet and dry season samples allows an analysis of the effects of seasonality on sediment quality.

This study addresses the following two RMP management questions:

1) Are chemical concentrations in the Estuary at levels of potential concern and are associated impacts likely?

2) Have the concentrations, masses, and associated impacts of contaminants in the Estuary increased or decreased?

Methods:

Field Methods

S&T sampling stations were selected using the RMP's stratified, random sampling design (see 2011 AMR, Introduction). Forty-five in-Bay samples (40 random and five historical) were collected during the dry season in 2008, 2009, and 2011; and 25 in-Bay samples were collected during the wet season in 2010 and 2012. SQO assessments were conducted on all 25 of the wet season samples; SQO assessments were performed on 25 dry season sampling stations that were chosen randomly from each subembayment (all of the stations sampled annually were included).

Samples were collected using a double $0.05 m^2$ surface area Young-modified Van Veen grab. A composite sample was obtained by collecting the top 5 cm of sediment from two or three grab samples taken at each site. Sampling equipment was cleaned with detergent, acid, and methanol, and then rinsed with ultrapure water at each sampling location. Benthic samples from one of the tandem grabs were screened through 0.5- and 1.0-mm nested sieves before being placed into sample jars.

Laboratory Methods

Trace organic analyses were completed by the East Bay Municipal Utility District (EBMUD) laboratory using EPA Method 8270 (PAHs), EPA Method 1668A (PCBs), and a modified version of EPA Method 1668A (pesticides). Mercury analyses were conducted by Brooks Rand Ltd. (BR) using EPA 1631 and a modified version of EPA 6020A. Other trace metal analyses were conducted by the City and County of San Francisco (CCSF) using a modified version EPA digest Method 3050B and a modified EPA analysis Method 6020A.

Toxicity tests were conducted by the UC Davis-Granite Canyon laboratory. Both an acute and a sublethal toxicity test were performed: 1) a 10-day whole-sediment toxicity test using the amphipod *Eohaustorius estuarius* with percent survival as the endpoint and 2) a 48-hour sediment-water interface toxicity (SWI) test using the bivalve *Mytilus galloprovincialis* with the percentage of embryos that developed normally and were alive as the endpoint. Five replicates were prepared for each test and the mean of the replicates' percent survival or development was reported. For the acute amphipod toxicity test, EPA Method 600/R-94-025 was used. For the sublethal bivalve test, EPA Method 600/R-95-136M was used. Benthic community analyses were completed by CCSF-Oceanside Biology Lab and Moss Landing Marine Laboratories-Oakden Lab.

SQO Assessment Methods

Data compilation was performed by SFEI and sent to the Southern California Coastal Water Research Project (SCCWRP) for SQO assessment analyses. Three LOEs were used to assess sediment quality: chemistry, toxicity, and benthic community condition. Four response categories classified the level of chemical exposure, benthic disturbance, or toxicity (Table 1).

Table 1: Categorical scores for the three lines of evidence.

Category Score	Chemistry LOE	Benthic LOE	Toxicity LOE
1	Minimal Exposure	Reference	Nontoxic
2	Low Exposure	Low Disturbance	Low Toxicity
3	Moderate Exposure	Moderate Disturbance	Moderate Toxicity
4	High Exposure	High Disturbance	High Toxicity

The contaminants included in the chemistry LOE calculation are listed in Table 2. The chemistry LOE was calculated by integrating two sediment quality guideline values: 1) the California Logistic Regression Model (CA LRM) and 2) the Chemical Score Index (CSI) (Bay and Weisberg 2012). The CA LRM uses logistic regressions to predict the probability of sediment toxicity based on pollutant concentrations (Bay et al. 2012). The CA LRM score is the highest p value (probability of observing a toxic effect) obtained from the regressions and is used to classify the chemistry exposure level.. The CSI predicts the magnitude of benthic community disturbance based on contaminant concentrations (Ritter et al. 2012). The concentration of each contaminant is compared to threshold values and assigned a benthic disturbance category. The CSI score is the weighted average of each benthic disturbance category multiplied by a weighting factor (based on the strength of the association between the chemical score and the benthic response). The CA LRM and CSI are averaged to obtain a chemistry LOE score; the scores are then assigned to one of four response categories (Table 1).

Table 2: Sediment contaminants evaluated in the SQO assessments.

Cadmium (mg/kg)	LPAH (ug/kg)[b]	DDEs, total (ug/kg)
Copper (mg/kg)	Alpha Chlordane (ug/kg)	DDTs, total (ug/kg)[c]
Lead (mg/kg)	Gamma Chlordane (ug/kg)	4,4'-DDT (ug/kg)
Mercury (mg/kg)	Dieldrin (ug/kg)	PCBs, total (ug/kg)[d]
Zinc (mg/kg)	Trans Nonachlor (ug/kg)	
HPAH (ug/kg)[a]	DDDs, total (ug/kg)	

[a] Total HPAHs are equivalent to the sum of Pyrene, Fluoranthene, Benzo(a)anthracene, Chrysene, Benzo(a)pyrene, Benzo(e)pyrene, and Perylene
[b] Total LPAHs are equivalent to the sum of Naphthalene, 1-methylnaphthalene, 2-methylnapthalene, Acenaphthene, Biphenyl, Fluorene, Phenanthrene, 1-methylphenanthrene, Anthracene
[c] Total DDTs are equivalent to the sum of 2,4’-DDT and 4,4’-DDT
[d] Total PCBs are equivalent to the sum of PCB 8, PCB 18, PCB 28, PCB 44, PCB 52, PCB 66, PCB 101, PCB 105, PCB 110, PCB 118, PCB 128, PCB 138, PCB 153, PCB 180, PCB 187, PCB 195

The toxicity LOE scores were based on the results of both the acute and sublethal toxicity tests (Greenstein and Bay 2012). The scores were based on threshold levels of percent survival or percentage of larvae normal-alive, as well as if the results were statistically different from the controls (Table 3). The average of the two scores became the overall toxicity LOE score (Nontoxic, Low, Moderate, or High toxicity).

Table 3: Category scores (1-4) for the acute and sublethal toxicity tests

Category Score		**1**	**2**	**3**	**4**
	Statistical Significance	**Nontoxic (%)**	**Low Toxicity (% of control)**	**Moderate Toxicity (% of control)**	**High Toxicity (% of control)**
***Eohaustorius* Survival**	Significant	90-100	82-89	59-81	<59
***Mytilus* Normal**	Significant	80-100	77-79	42-76	<42

For polyhaline environments, salinity between 18 and 30 ppt, the benthic LOE score is the median of four benthic index scores: 1) the Index of Biotic Integrity (IBI), 2) the Relative Benthic Index (RBI), 3) the Benthic Response Index (BRI), and 4) the River Invertebrate Prediction and Classification System (RIVPACS) (Ranasinghe et al. 2009). For mesohaline and oligohaline environments, salinities between 5 and 18 ppt and below 5 ppt respectively, the benthic LOE score is the median of three benthic indices: 1) a modified IBI, 2) a modified RBI, and 3) the AZTI Marine Biotic Index (AMBI).

The SQO assessment framework evaluates two questions: 1) is there biological degradation? and 2) is the chemical exposure high enough to generate a biological response? (Bay and Weisberg 2012). To answer whether there is biological degradation, the toxicity and benthic LOE scores are evaluated; the benthic score is given more weight because the benthic community condition is a more direct indicator of sediment quality than toxicity tests. To determine whether there is chemical exposure that will cause a biological response, the toxicity and chemistry LOE scores are considered. The final data integration step combines the severity of the biological effect and the potential for chemically mediated effects to assign the site one of six station assessments:

Table 4: SQO station assessment categories.

Station Assessment	**Description**
Unimpacted	Confident that contamination is not causing significant adverse impacts to benthic macroinvertebrates at the site.
Likely Unimpacted	Contamination is not expected to cause adverse impacts to benthic macroinvertebrates, but some disagreement among LOEs reduces certainty that the site is unimpacted.
Possibly Impacted	Contamination at the site may be causing adverse impacts to benthic macroinvertebrates, but the level of impact is either small or is uncertain because of disagreement among LOEs.
Likely Impacted	Evidence of contaminant-related impacts to benthic macroinvertebrates is persuasive, in spite of some disagreement among LOEs.
Clearly Impacted	Sediment contamination at the site is causing clear and severe adverse impacts to benthic macroinvertebrates
Inconclusive	Disagreement among the LOEs suggests that either data are suspect or additional information is needed for classification.

It is important to note that the Possibly Impacted category has the highest uncertainty compared to the other station assessments. Additionally, both biological effects and chemical effects must be present for a site to be listed as Impacted (Barnett et al. 2008).

Percent Area Calculation

The percent area that represented the various LOE categorizations and station assessments was determined using each subembayment's area weight (area of the sampling frame divided by the number of sites sampled). The affected area was defined as the number of sites within a certain subembayment possessing a particular assessment (e.g. Possibly Impacted, Moderate Toxicity, Low Chemical Exposure, etc.) multiplied by the area weight of the subembayment. The affected area was then divided by the total area of the Bay to determine the percent area affected.

Each year, one or two of the sample stations were repeat stations (i.e. stations that are sampled every year by the RMP). The repeat stations were weighted equally with other sampling stations in the subembayments. Therefore, percent area represented by each station assessment and LOE from 2008 to 2012 may be biased because the repeat stations are overrepresented in the calculation.

The percent area with poor sediment quality is the sum of the percent area represented by the Likely Impacted and Possibly Impacted station assessments. The percent area with good sediment quality is the sum of the percent area represented by the Likely Unimpacted and Unimpacted station assessments

Results

Bay-wide sediment quality

SQO assessments were completed for 2008 through 2012 S&T sediment samples. The SQO station assessments were compared across the Bay to elucidate time series trends in sediment quality. Individual lines of evidence (chemistry, toxicity, and benthos) were also compared temporally and spatially within each subembayment.

None of the randomized sampling stations from 2008 to 2012 were listed as Clearly Impacted (Figure 1). The most common station assessment was Possibly Impacted, with 40% of the Bay

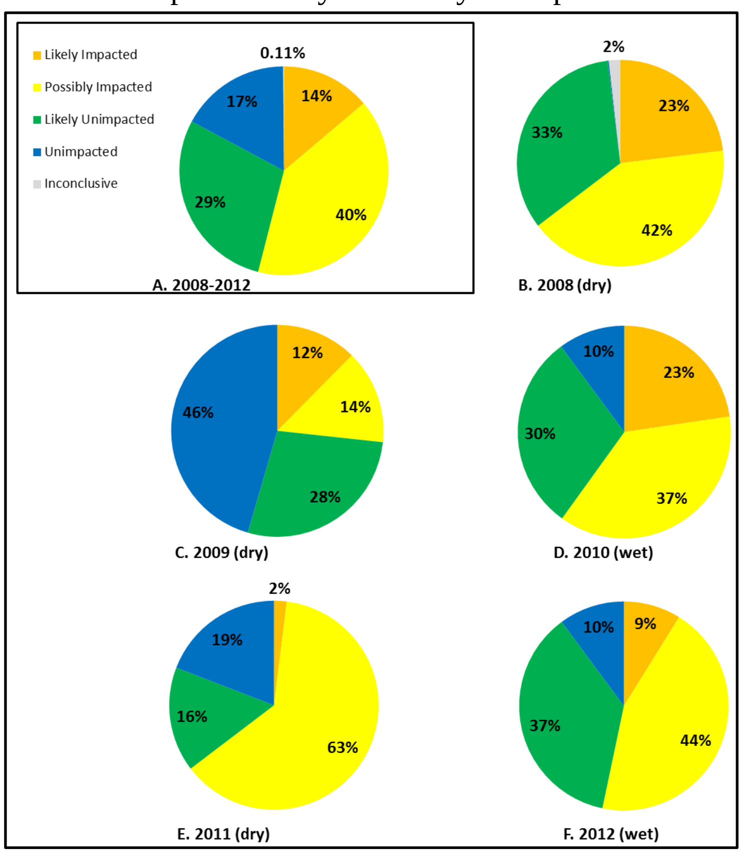

Figure 1: Percent area in the Bay classified as a particular station assessment from 2008 through 2012.

classified as such from 2008 to 2012 (Figure 1A). Over a third of the Bay was categorized as Possibly Impacted every year, except for in 2009. In 2009, 46 percent of the Bay was listed as Unimpacted (Figure 1C).

The prevalence of impacted sites appears to have decreased over time; from 2008 to 2010, 19% of the Bay was classified as Likely Impacted, while 6% of the Bay was listed as Likely Impacted from 2011 to 2012. The decrease in the number of sites classified as Likely Impacted coincides with the increase in the number of sites listed as Possibly Impacted in 2011 and 2012 (over 50% of the sites). Overall, the percent area listed as impacted (Possibly, Likely, or Clearly Impacted) appears to have decreased from the 2000 WEMAP study to the 2012 S&T sampling effort (Figure 2). The year with the lowest prevalence of sediment contamination was in 2009, with only 27 percent of the Bay classified as impacted.

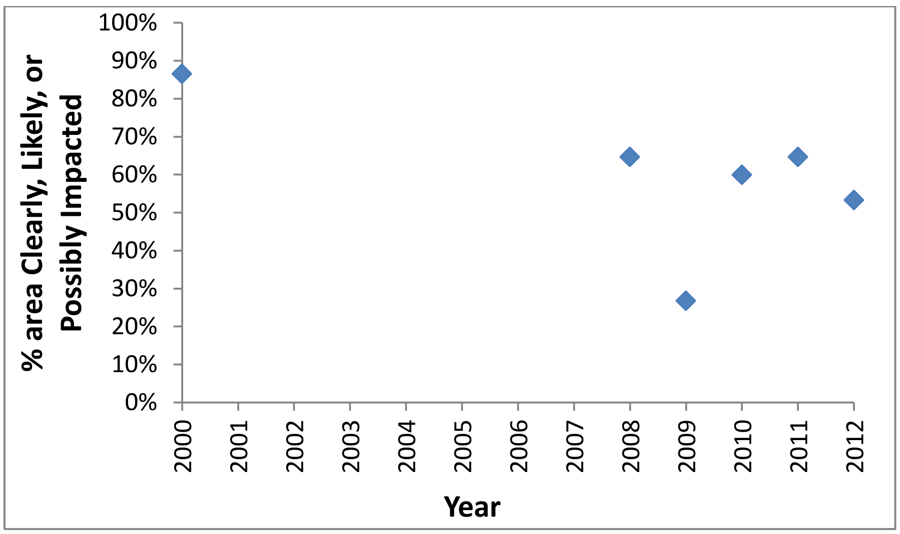

Figure 2: Percent area listed as Clearly, Likely, or Possibly Impacted from the 2000 WEMAP survey and the 2008-2012 S&T sampling.

Sediment Quality in Individual Subembayments

Analogous to the results for the entire Bay, over a third of the area in each subembayment was classified as Possibly Impacted from 2008 through 2012, except for in San Pablo Bay. The majority of the area in San Pablo Bay was categorized as Likely Unimpacted (48%). In fact, San Pablo Bay possessed the best sediment quality in the Bay; 80% of the subembayment was listed as Likely Unimpacted or Unimpacted and none of the sites were listed as Likely Impacted from 2008 through 2012 (Table 5 & Figure 3).

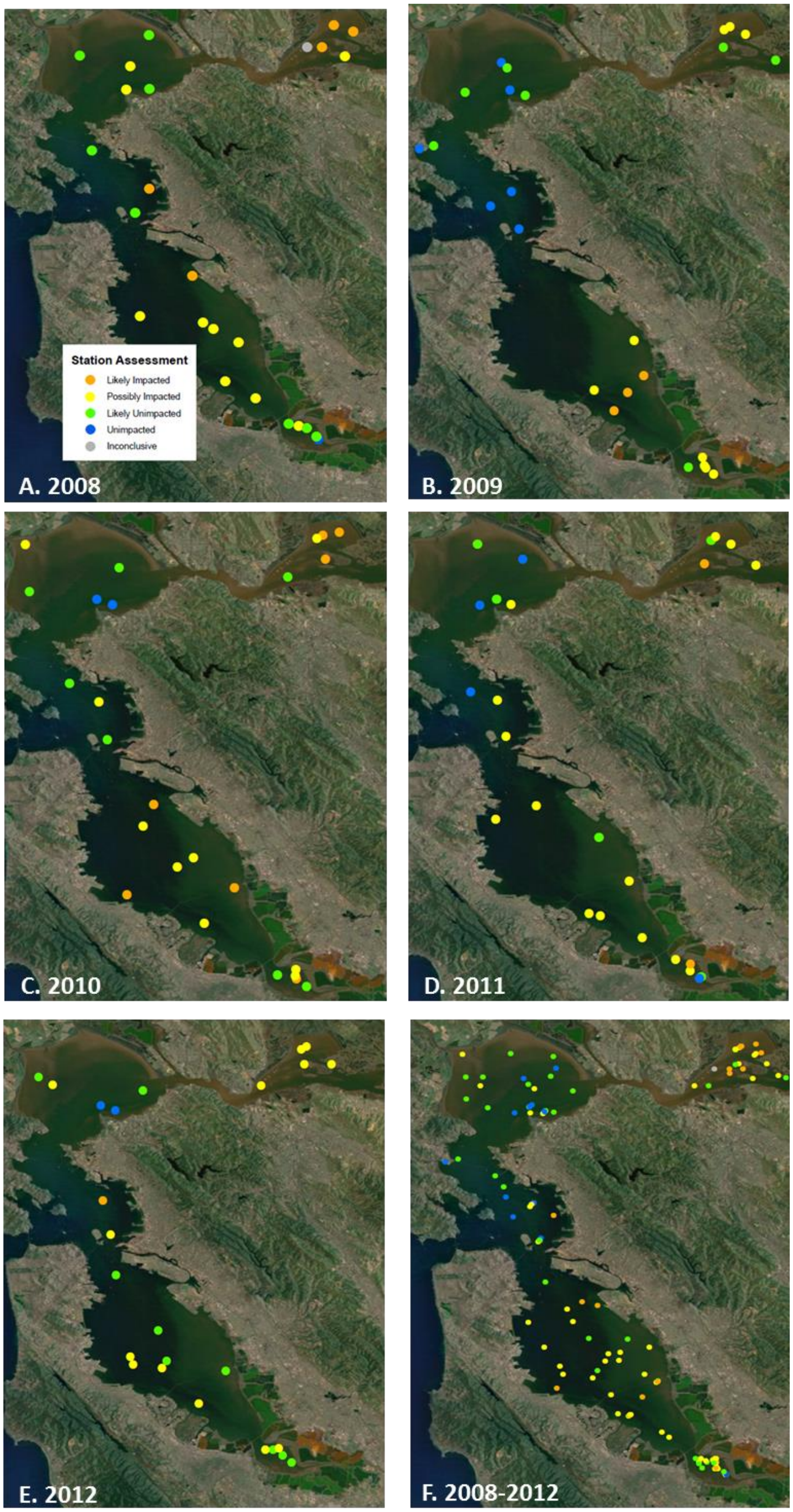

Figure 3: Spatial representation of station assessments for a) 2008 b) 2009 c) 2010 d) 2011 e) 2012 and f) 2008-2012.

The percent area of Lower South Bay with poor sediment quality was the same as in Central Bay, 52% of the area in the two subembayments was listed as either Possibly or Likely Impacted (Table 5). South Bay and Suisun Bay were significantly more impacted, 88% and 80% of the area possessed poor sediment quality respectively.

Table 5: Percent area in each subembayment with poor sediment quality (Possibly and Likely Impacted), good sediment quality (Likely Unimpacted and Unimpacted), and inconclusive sediment quality from 2008 through 2012.

	% Area with Poor Sediment Quality	% Area with Good Sediment Quality	Inconclusive
Lower South Bay	52%	48%	0%
South Bay	88%	12%	0%
Central Bay	52%	48%	0%
San Pablo Bay	20%	80%	0%
Suisun Bay	80%	16%	4%

Individual LOEs

LOE categorizations were examined to determine if a particular LOE influenced the Possibly and Likely station assessments in the Bay. Sediment condition in the Bay was driven by toxicity and benthic community condition, both biological effects (Table 6). Chemical exposure was listed as Minimal or Low every year, except for in 2008 when 20% of Lower South Bay classified as possessing moderate chemical exposure.

A substantial portion of the Bay was characterized by moderate or high toxicity, 60% of Bay sediment was toxic from 2008 through 2012 (Table 7). Every year, except for in 2009, over 50% of the Bay was listed as Moderately or Highly toxic. Similarly, over 50% of the area in each subembayment was classified as toxic from 2008 through 2012, except for San Pablo Bay where only 36% of the area possessed Moderate or High toxicity (Table 6). The prevalence of toxic sediments appears to be lower in the Northern subembayments. In Lower South Bay and South Bay over 70% of the area was listed as toxic, while Suisun Bay 52% of the area was classified as Moderately or Highly toxic (Table 6).

Benthic community condition was spatially and temporally more variable than toxicity. The benthic community was considerably more impacted in South Bay and Suisun Bay than in the other three subembayments, 48% and 72% of the area was Moderately or Highly degraded in the two subembayments respectively (Table 6). Temporally, the two years with the most impacted benthos were in 2008 and 2010, approximately 40% of the Bay was Moderately or Highly disturbed (Table 7). In contrast, the benthic community condition in 2009 and 2011 was only Moderately or Highly disturbed in 24% and 2% of the Bay respectively.

Table 6: Percent area with Moderate or High chemical exposure, toxicity, and benthic disturbance in each subembayment.

	Chemical Exposure	Toxicity	Benthic Disturbance
Lower South Bay	4%	72%	8%
South Bay	0%	76%	48%
Central Bay	0%	68%	24%
San Pablo Bay	0%	36%	4%
Suisun Bay	0%	52%	72%

Table 7: Percent area with Moderate or High chemical exposure, toxicity,and benthic disturbance from 2008-2012.

	Toxicity	Benthic Disturbance
2008	73%	44%
2009	29%	24%
2010	72%	39%
2011	74%	2%
2012	53%	32%
2008-2012	60%	28%

It is important to note that each subembayment was also characterized by considerable temporal variability. In Lower South Bay, for example, 100% of the area was moderately toxic in 2009, 2010, and 2012 (Table 6). But in 2008, 100% of the area possessed Low toxicity. Similarily, 100% of the area in Suisun Bay had a Moderately or Highly disturbed benthos in 2008, 2010, and 2012. In 2009 and 2011, 40% and 20% of the subembayment possessed an impacted benthos respectively.

Discussion

The lack of any Clearly Impacted stations from 2008 to 2012 indicates that, in general, contamination in the open Bay is not high enough to cause severe impacts on the benthic community (Bay et al., 2009). A substantial fraction of San Francisco Bay (40% of the Bay's area) remained Possibly Impacted from 2008 through 2012 and was characterized by Moderate toxicity (60% of Bay sediment). The Possibly Impacted assessment characterized the majority of the impacted sediment because of the presence of sediment toxicity without chemical exposure or a disturbed benthos. This result is consistent with the SQO assessment scores from the 2000 WEMAP survey; 77% of the Bay was classified as Possibly Impacted (Barnett et al., 2008).

Additionally, moderate toxicity is typical of San Francisco Bay, approximately a third of Bay samples from 1991 through 1999 were listed as toxic (Phillips et al., 2008). Similar to the 2000 SQO assessment results, Moderate or High toxicity and benthic community disturbance was observed in regions with Low or Minimal chemical exposure. The Low chemical exposure in the Bay is distinctive; in Southern California, there was a higher percent area with High or Moderate chemical exposure than in the Bay, with lower levels of toxicity and benthic community disturbance (Barnett et al., 2008). Therefore, it is possible that non-contaminant factors or contaminants not included in the SQO assessment analysis are affecting benthic community disturbance or toxicity in the Bay.

Sediment quality may have improved over time in the Bay. The percent area listed as Possibly Impacted station assessment or greater was highest in 2000 (82.5%) and decreased to 53% by 2012. Additionally, the percentage area listed as Likely Impacted was lower in 2011 and 2012 than the three previous years. If the dry and wet seasons are analyzed separately, the sediment quality still appears to have improved over time. The percent area designated as Likely Impacted was greater, and the percent area classified as Unimpacted was lower in the 2000 and 2008 dry season sampling years than in 2009 and 2011. However, when comparing sediment quality from 1994-2001 and 2008-2012 at BC11 and BD 41, two historical stations along the spine of the Bay, there was no apparent trend over time. Comparing sediment quality across the entire Bay provided a clearer picture of time series trends than analyzing sediment quality at individual stations over time.

San Pablo Bay was clearly the least impacted of the five subembayments. Although, toxicity was prevalent in all of the subembayments, including San Pablo Bay, the benthic community was mainly disturbed in South Bay and Suisun Bay. In order for a station to be listed as Likely Impacted, two LOEs must be listed as impacted. Therefore, South Bay and Suisun Bay were most likely the two most impacted subembayments (88% and 80% of the area possessed poor sediment quality respectively) because the regions were characterized by both an impacted benthos and toxic sediments.

In Suisun Bay the benthos was impacted in 2008, 2010, and 2012. Both 2010 and 2012 were wet season sampling years; thus, seasonality may be affecting the benthic community condition in more than toxicity. The SQO guidance document (Bay et al., 2009) suggests choosing to conduct SQO assessments during one season to avoid the effects of seasonality. However, the sediment quality in 2008 was similar to the two wet season years, making the link to seasonality uncertain.

The cause of moderate toxicity in the Bay is also unknown. A Mission Creek toxicity identification evaluation (TIE; Phillips et al. 2008) found that the cause of toxicity was most likely a mix of organic chemicals; however, specific contaminants or other non-contaminant stressors could not be positively identified. Although sediment quality may be improving over time, identifying the cause(s) of baywide moderate toxicity is needed in order to understand why most Bay sediments are Possibly Impacted.

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Appendix

Table A-1: SQO MLOE results and station assessments for Lower South Bay from 2008-2012.

Lower South Bay					
Year	*Station Name*	*Chemical Exposure*	*Toxicity*	*Benthic Disturbance*	*Station Assessment*
	BA10	Low	Low	Reference	Unimpacted
2008	LSB037S	Moderate	Low	Low	Possibly Impacted
	LSB038S	Low	Low	Low	Likely Unimpacted
	LSB039S	Low	Low	Low	Likely Unimpacted
	LSB040S	Low	Low	Low	Likely Unimpacted
2009	BA10	Low	Moderate	Low	Possibly Impacted
	LSB002S	Low	Moderate	Low	Possibly Impacted
	LSB016S	Low	Moderate	Low	Possibly Impacted
	LSB082S	Low	Moderate	Low	Possibly Impacted
	LSB108S	Low	Moderate	Reference	Likely Unimpacted
2010	BA10	Nontoxic	Moderate	Low	Likely Unimpacted
	LSB002S	Low	Moderate	Moderate	Likely Impacted
	LSB072S	Low	Moderate	Low	Possibly Impacted
	LSB109S	Low	Moderate	Reference	Likely Unimpacted
	LSB140S	Low	Moderate	Low	Possibly Impacted
2011	BA10	Low	Low	Reference	Unimpacted
	LSB002S	Low	Moderate	Low	Possibly Impacted
	LSB024S	Low	Moderate	High	Likely Impacted
	LSB070S	Low	Low	Low	Likely Unimpacted
	LSB121S	Low	Moderate	Low	Possibly Impacted
2012	BA10	Minimal	Moderate	Low	Likely Unimpacted
	LSB002S	Low	Moderate	Reference	Likely Unimpacted
	LSB044S	Low	Moderate	Reference	Likely Unimpacted
	LSB045S	Low	Moderate	Low	Possibly Impacted
	LSB112S	Low	Moderate	Low	Possibly Impacted

Table A-2: SQO MLOE results and station assessments for South Bay from 2008-2012.

South Bay					
Year	*Station Name*	*Chemical Exposure*	*Toxicity*	*Benthic Disturbance*	*Station Assessment*
2008	BA41	Low	High	Low	Possibly Impacted
	SB037S	Low	Low	Moderate	Possibly Impacted
	SB038S	Low	Moderate	Low	Possibly Impacted
	SB039S	Low	Low	Moderate	Possibly Impacted
	SB040S	Low	High	Low	Possibly Impacted
2009	BA41	Low	High	Moderate	Likely Impacted
	SB002S	Low	High	Moderate	Likely Impacted
	SB016S	Low	Low	Moderate	Possibly Impacted
	SB060S	Low	Low	Moderate	Possibly Impacted
	SB106S	Low	Moderate	Moderate	Likely Impacted
2010	BA41	Low	Low	High	Possibly Impacted
	SB002S	Low	Moderate	Moderate	Likely Impacted
	SB087S	Minimal	Moderate	Moderate	Possibly Impacted
	SB091S	Low	Moderate	Moderate	Likely Impacted
	SB095S	Minimal	Moderate	Moderate	Possibly Impacted
2011	BA41	Low	Moderate	Low	Possibly Impacted
	SB002S	Low	Moderate	Low	Possibly Impacted
	SB024S	Low	High	Low	Possibly Impacted
	SB041S	Minimal	Moderate	Low	Likely Unimpacted
	SB102S	Low	Moderate	Low	Possibly Impacted
2012	BA41	Low	Moderate	Low	Possibly Impacted
	SB002S	Low	Moderate	Reference	Likely Unimpacted
	SB027S	Low	Moderate	Low	Possibly Impacted
	SB045S	Minimal	Low	Low	Likely Unimpacted
	SB097S	Minimal	High	Low	Possibly Impacted

Table A-3: SQO MLOE results and station assessments for Central Bay from 2008-2012.

Central Bay					
Year	*Station Name*	*Chemical Exposure*	*Toxicity*	*Benthic Disturbance*	*Station Assessment*
2008	BC11	Low	Moderate	Reference	Likely Unimpacted
	CB037S	Low	High	Moderate	Likely Impacted
	CB038S	Low	Moderate	Moderate	Likely Impacted
	CB039S	Low	Moderate	Reference	Likely Unimpacted
	CB040S	Low	Low	Moderate	Possibly Impacted
2009	BC11	Low	Low	Reference	Unimpacted
	CB001S	Low	Nontoxic	Low	Unimpacted
	CB043S	Low	Nontoxic	Low	Unimpacted
	CB075S	Low	Low	Low	Likely Unimpacted
	CB121S	Low	Nontoxic	Reference	Unimpacted
2010	BC11	Low	Moderate	Reference	Likely Unimpacted
	CB001S	Low	Moderate	Low	Possibly Impacted
	CB042S	Low	Moderate	Moderate	Likely Impacted
	CB055S	Low	Moderate	Reference	Likely Unimpacted
	CB122S	Low	Moderate	Low	Possibly Impacted
2011	BC11	Low	Moderate	Low	Possibly Impacted
	CB001S	Low	High	Low	Possibly Impacted
	CB023S	Low	Low	Reference	Unimpacted
	CB088S	Low	Moderate	Low	Possibly Impacted
	CB112S	Low	Moderate	Low	Possibly Impacted
2012	BC11	Low	Moderate	Low	Possibly Impacted
	CB001S	Low	High	Moderate	Likely Impacted
	CB046S	Low	High	Low	Possibly Impacted
	CB110S	Low	Moderate	Reference	Likely Unimpacted
	CB129S	Minimal	Nontoxic	High	Likely Unimpacted

Table A-4: SQO MLOE results and station assessments for San Pablo Bay from 2008-2012.

San Pablo Bay					
Year	*Station Name*	*Chemical Exposure*	*Toxicity*	*Benthic Disturbance*	*Station Assessment*
2008	BD31	Low	High	Low	Possibly Impacted
	SPB037S	Low	Low	Low	Likely Unimpacted
	SPB038S	Low	Moderate	Reference	Likely Unimpacted
	SPB039S	Low	Moderate	Reference	Likely Unimpacted
	SPB040S	Low	High	Reference	Possibly Impacted
2009	BD31	Low	Nontoxic	Low	Unimpacted
	SPB002S	Low	Moderate	Reference	Likely Unimpacted
	SPB016S	Low	Low	Reference	Unimpacted
	SPB080S	Low	Moderate	Reference	Likely Unimpacted
	SPB135S	Low	Low	Low	Likely Unimpacted
2010	BD31	Low	Low	Reference	Unimpacted
	SPB002S	Low	Low	Reference	Unimpacted
	SPB043S	Low	Moderate	Low	Possibly Impacted
	SPB051S	Low	Low	Low	Likely Unimpacted
	SPB120S	Low	Low	Low	Likely Unimpacted
2011	BD31	Low	Low	Low	Likely Unimpacted
	SPB002S	Low	Moderate	Low	Possibly Impacted
	SPB023S	Low	Moderate	Reference	Likely Unimpacted
	SPB088S	Low	Low	Reference	Unimpacted
	SPB132S	Low	Low	Reference	Unimpacted
2012	BD31	Low	Nontoxic	Low	Unimpacted
	SPB002S	Low	Low	Reference	Unimpacted
	SPB027S	Low	Low	Low	Likely Unimpacted
	SPB041S	Low	Low	Moderate	Possibly Impacted
	SPB110S	Low	Low	Low	Likely Unimpacted

Table A-5: SQO MLOE results and station assessments for Suisun Bay from 2008-2012.

Suisun Bay					
Year	*Station Name*	*Chemical Exposure*	*Toxicity*	*Benthic Disturbance*	*Station Assessment*
2008	BF21	Low	High	High	Likely Impacted
	SU037S	Low	Moderate	Moderate	Likely Impacted
	SU039S	Minimal	Low	High	Inconclusive
	SU040S	Low	Low	High	Possibly Impacted
	SU080S	Low	Moderate	Moderate	Likely Impacted
2009	BF21	Low	High	Low	Possibly Impacted
	SU016S	Low	High	Low	Possibly Impacted
	SU073S	Low	Moderate	Low	Possibly Impacted
	SU085S	Low	Reference	High	Likely Unimpacted
	SU090S	Low	Reference	High	Likely Unimpacted
2010	BF21	Low	High	Moderate	Likely Impacted
	SU060S	Low	Moderate	Moderate	Likely Impacted
	SU073S	Low	Low	Moderate	Possibly Impacted
	SU084S	Low	Moderate	Moderate	Likely Impacted
	SU109S	Minimal	Low	Moderate	Likely Unimpacted
2011	BF21	Low	High	Low	Possibly Impacted
	SU024S	Low	Moderate	Low	Possibly Impacted
	SU073S	Low	Low	Low	Likely Unimpacted
	SU044S	Low	Moderate	Moderate	Likely Impacted
	SU048S	Low	High	Reference	Possibly Impacted
	BF21	Low	Low	Moderate	Possibly Impacted
2012	SU027S	Low	Low	Moderate	Possibly Impacted
	SU073S	Low	Low	Moderate	Possibly Impacted
	SU128S	Low	Low	Moderate	Possibly Impacted
	SU131S	Low	Low	Moderate	Possibly Impacted