

# Contaminants of Emerging Concern in San Francisco Bay: A Summary of Occurrence Data and Identification of Data Gaps

## FINAL REPORT

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## Executive Summary

Contaminants of emerging concern (CECs) can be broadly defined as any synthetic or naturally occurring chemical that is not regulated or commonly monitored in the environment but has the potential to enter the environment and cause adverse ecological or human health impacts. The Regional Monitoring Program for Water Quality in the San Francisco Bay (RMP) has been investigating CECs since 2000, and developed a formal workgroup to address the issue in 2006. The RMP Emerging Contaminants Workgroup (ECWG) includes representatives from RMP stakeholder groups and an advisory panel of expert researchers that work together to address the workgroup's guiding management question – Which CECs have the potential to adversely impact beneficial uses in San Francisco Bay? The overarching goal of the ECWG is to develop cost-effective strategies to identify and monitor CECs so that potentially problematic chemicals can be identified as early as possible, thus minimizing impacts to the Estuary.

Considerable guidance regarding CECs in coastal California embayments was provided by the California State Water Resources Control Board's CEC Science Advisory Panel, as outlined in their report, "Monitoring Strategies for Chemicals of Emerging Concern in California's Aquatic Ecosystems." The Panel provided a) a conceptual, risk-based screening framework to assess and identify CECs for monitoring in California receiving waters; b) application of the risk-based screening framework to identify a list of CECs for initial monitoring; c) an adaptive, phased monitoring approach with interpretive guidelines that direct and update management actions commensurate with potential risk; and d) identification of research needs, including development of bioanalytical screening methods, linking molecular responses with higher order effects, and filling key data gaps.

The Panel identified those CECs presenting the greatest risk to ecological receptors or human health by comparing measured or predicted environmental concentrations (MECs or PECs) with monitoring trigger levels (MTLs; derived by dividing toxicity benchmarks such as no or lowest observable effects concentrations (NOECs and LOECs) by appropriate safety factors). CECs with a monitoring trigger quotient ( $MTQ = MEC \text{ [or PEC] / MTL} > 1.0$ ) were identified for monitoring. When the MTQ was  $\leq 1.0$ , the Panel assumed the potential risk associated with the CEC did not currently warrant consideration for monitoring. A total of 82

organic chemicals were selected for initial screening, largely based on availability of occurrence and toxicity data.

For coastal embayments like San Francisco Bay, the Panel recommended monitoring of seven different CECs in Bay receiving waters, including pesticides (bifenthrin, permethrin, chlorpyrifos), chemicals associated with consumer products (bisphenol A, galaxolide), and natural hormones (17-beta estradiol, estrone). For Bay sediments, the screening suggested prioritizing polybrominated diphenyl ether (PBDE) flame retardants (BDE-47, BDE-99) and two pyrethroid pesticides (bifenthrin, permethrin). In biological tissues, the Panel prioritized monitoring of two PBDEs (BDE-47 and BDE-99) and perfluorooctane sulfonate (PFOS).

The adaptive, phased monitoring approach recommended by the Panel begins with the instruction to develop initial CEC list(s) based on the Panel screening framework. Phase 2 involves implementing monitoring of the Phase 1 list of initial CECs. In Phase 3, monitoring and response plans are assessed and updated. Finally, in Phase 4, managers develop action plans to minimize the impacts of CECs.

This report summarizes the information available for CECs in San Francisco Bay as part of Phase 3 assessment of monitoring and response plans with respect to current data. Each CEC or CEC class was described in terms of available occurrence studies for the Bay, comparison to levels in other locations where possible, and comparison to toxicity thresholds where available. Finally, each CEC or CEC class was assigned to a tier in the risk and management action framework based on Bay occurrence data and toxicity information (framework in Table 2; CEC tier assignments in Table 4). The criteria listed below were used for placement in each tier.

**Tier I (Possible Concern)** – Uncertainty in measured or predicted Bay concentrations or in toxicity thresholds suggests uncertainty in the level of effect on Bay wildlife. CECs in Tier I include: Alternative flame retardants (BEH-TEBP, EH-TBB, DBDPE, PBEB, BTBPE, HBB, DP, TDCPP, TCEP, TCPP, TBEP, TPhP, other organophosphates); Bisphenol A; Bis(2-ethylhexyl) phthalate (BEHP or DEHP) and Butylbenzyl phthalate (BBzP); Poly- and perfluorinated alkyl substances (PFASs, also known as PFCs) other than PFOS; Short-chain chlorinated paraffins; Other pesticides; and Single-walled carbon nanotubes.

**Tier II (Low Concern)** – Bay occurrence data or PECs suggest a high probability of no effect on Bay wildlife (i.e., Bay concentrations are well below toxicity thresholds and potential toxicity to wildlife is sufficiently characterized). CECs in Tier II include: Pyrethroids; Pharmaceuticals and personal care products (PPCPs); and Hexabromocyclododecane (HBCD).

**Tier III (Moderate Concern)** – Bay occurrence data suggest a high probability of a low level effect on Bay wildlife (e.g., frequent detection at concentrations greater than the PNEC or NOEC but less than EC<sub>10</sub>, the effect concentration where 10% of the population exhibit a response, or another low level effects threshold). CECs in Tier III include: PFOS; Fipronil; Nonylphenol and nonylphenol ethoxylates; and PBDEs.

**Tier IV (High Concern)** – Bay occurrence data suggest a high probability of a moderate or high level effect on Bay wildlife (e.g., frequent detection at concentrations greater than the EC<sub>10</sub> or another effects threshold). No CECs were assigned to Tier IV for the Bay.

Data gaps were identified by comparing available CEC monitoring data to the Panel recommendations. For example, targeted monitoring of Bay surface waters for bifenthrin, galaxolide (HHCB), and the hormones estrone and 17-beta estradiol has not yet been conducted. In 2010, bisphenol A was analyzed in Bay surface waters and not detected, though detection limits were higher than the monitoring trigger level of 6 ng/L recommended by the Panel. The Panel also recommended the collection of occurrence data on other chemicals that were not initially recommended for monitoring by the Panel at the time due to a lack of occurrence or toxicity data, but that may be relevant due to increasing use, elevated environmental occurrence, or high toxic potency. One such class of CECs, natural or synthetic hormones (progesterone, levonorgestrel, and cis-androstenedione), has not been analyzed in Bay samples. The RMP has acquired some occurrence data for members of another class, current use organophosphate flame retardants. Several members of a third class, current use pesticides, have also been monitored in the Bay, as suggested by the Panel.

The Panel recommended development or refinement of environmental fate models to predict environmental concentrations of CECs based on their production volume, use, and environmental fate as a means of prioritizing chemicals on which to focus method development

and toxicological investigations. Aside from applying the PCB box model to PBDEs, fate models have not been used for predicting CEC concentrations in San Francisco Bay.

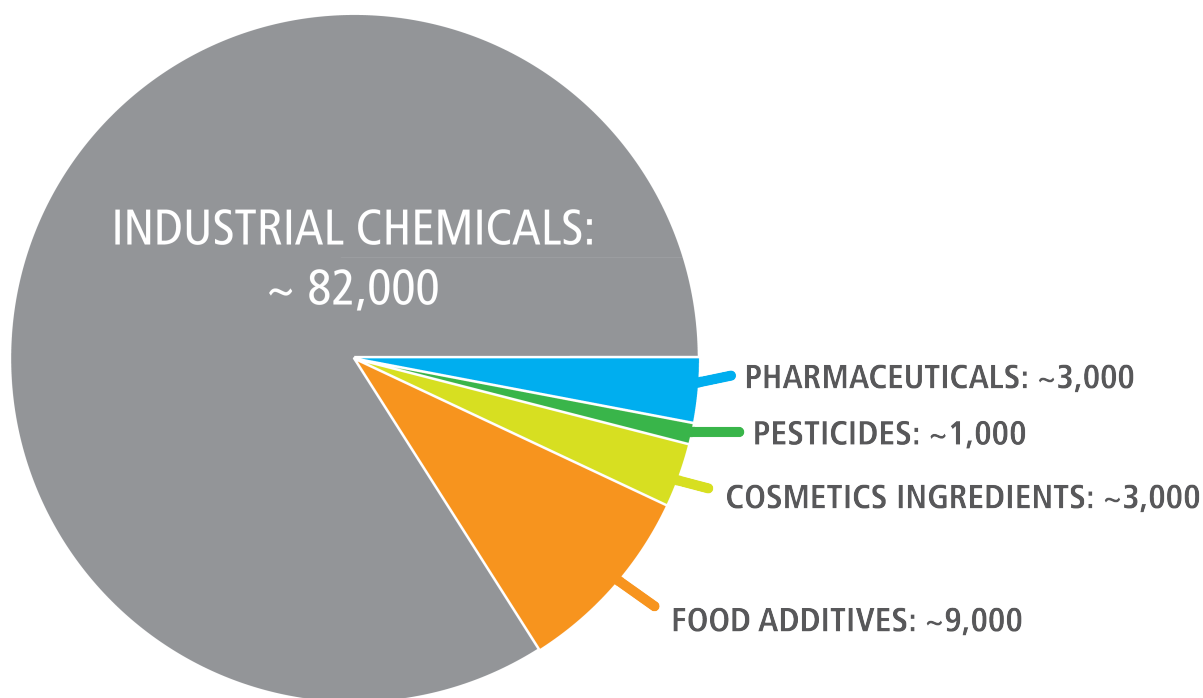
The Panel anticipated and recommended a shift away from a chemical-specific monitoring paradigm to one in which biological responses are targeted to address the thousands of chemicals that are potentially present in receiving waters. The RMP is developing bioanalytical tools that may be used in the future to measure the aggregate estrogenicity of the contaminant mixtures found in Bay samples. The Panel also recommended conducting a pilot investigation using non-targeted analysis to screen for newly discharged CECs. Non-targeted screening analyses of San Francisco Bay mussels and harbor seals were initiated in 2010 in collaboration with the National Institute of Standards and Technology (NIST) and other researchers. The results from this study, including a list of compounds identified in the samples, are expected in 2013.

The information summarized in this report will serve as the basis for development of a long-term strategy for future CEC monitoring in San Francisco Bay. The CEC Strategy will consider new information as it becomes available and take a pro-active approach to identifying ‘new’ CECs for which toxicity information may not yet be available.

## 1.0 Introduction

### 1.1 The CEC Challenge

Over the past 30 years more than 100,000 chemicals have been registered or approved for commercial use in the US. These substances include more than 82,000 industrial chemicals, 9,000 food additives, 3,000 cosmetics ingredients, 1,000 pesticide active ingredients, and 3,000 pharmaceutical drugs (Muir and Howard 2006; Benotti et al. 2009) (Figure 1). For industrial chemicals alone, production and import in the US totaled 27 trillion pounds in 2005, an 80% increase from 2002 (Wilson and Schwarzman 2009). Global chemical production is projected to continue growing by about 3% per year, and double every 24 years. The primary challenge for regulators and scientists is managing this ever-growing amount and variety of chemicals to ensure that they do not adversely impact human and environmental health.



**Figure 1. Estimated number and categories of chemicals in commerce registered for use in the United States over the past 30 years. Adapted from Muir and Howard (2006).**

Only a very small fraction of the large number of chemicals in use is routinely monitored in the environment. These generally include persistent, bioaccumulative, and toxic compounds such as polychlorinated biphenyls (PCBs), chlorinated pesticides, heavy metals such as mercury, and other chemicals on the United States Environmental Protection Agency (USEPA) list of 128 regulated priority pollutants. The risks that these historically prioritized contaminants pose to ecosystem and human health are relatively well established, and compliance monitoring is conducted as part of risk reduction actions. However, for most chemicals currently in use, major information gaps limit the ability of scientists to assess their potential risks, and monitoring of these chemicals does not routinely occur. As a result, many chemicals that have not been adequately tested for their potential impacts to humans and wildlife are continuously released to the environment.

Over the last decade, researchers and government agencies have begun to collect occurrence, fate, and toxicity data on a variety of chemicals that have not yet been regulated for environmental impacts. Analytical methods have progressed to the point that it is possible to measure trace quantities (below parts per trillion) of many contaminants in water, which has led to frequent detection of a variety of previously unmonitored chemicals in the environment. These chemicals have been classified as contaminants of emerging concern (CECs). CECs can be broadly defined as any synthetic or naturally occurring chemical that is not regulated or commonly monitored in the environment but has the potential to enter the environment and cause adverse ecological or human health impacts. Pharmaceuticals and personal care products (PPCPs), current use pesticides, and industrial chemicals such as flame retardants and perfluorinated compounds (PFCs or more recently termed poly- and perfluorinated alkyl substances [PFASs]) constitute the majority of chemicals that are commonly considered CECs due to their high volume use, potential for toxicity in non-target species, and the increasing number of studies that report their occurrence in the environment.

Determining which of the thousands of chemicals in commerce are CECs and whether or not they may be a problem is a formidable challenge. For most chemicals in use, a number of limitations prevent researchers from assessing their potential risks:

- The identities of chemicals used in commercial formulations, their applications, and product-specific uses are characterized as confidential business information or are not readily available for other reasons.
- Methods to reliably measure most chemicals in use do not exist. Development of new analytical methods for chemicals is expensive, so researchers tend to focus their method development efforts on chemicals deemed to be the highest priority risk.
- Little to no information exists on chronic toxicity for realistic exposures, toxicity in non-target species (particularly for pharmaceuticals), or sensitive toxicological endpoints such as endocrine disruption. Knowledge of toxic modes of action for most CECs is minimal, and details of toxicity studies conducted by chemical manufacturers are typically not available for public review.

Such large obstacles make it difficult for researchers and regulators to pre-emptively target CECs for monitoring and control. For the vast majority of chemicals in use today, occurrence, persistence, and toxicity data are still needed to establish exposure and risk thresholds to protect the beneficial uses of aquatic ecosystems.

## **1.2 The RMP Emerging Contaminants Workgroup**

The Regional Monitoring Program for Water Quality in the San Francisco Bay (RMP) has been investigating CECs since 2000 and developed a formal workgroup to address the issue in 2006. The RMP Emerging Contaminants Workgroup (ECWG) includes representatives from RMP stakeholder groups and an advisory panel of expert researchers that work together to address the workgroup's guiding management question – Which CECs have the potential to adversely impact beneficial uses in San Francisco Bay? The overarching goal of the ECWG is to develop cost-effective strategies to identify and monitor CECs so that potentially problematic chemicals can be identified as early as possible, thus minimizing impacts to the Bay. The ECWG works toward this goal by evaluating available information on chemical occurrence, fate, toxicity, volume use, potential sources, and analytical method capability, and then recommends CECs for investigation in special studies. Each year the highest priority studies are conducted, and the results guide whether or not these CECs are added to routine monitoring by the RMP. Using this process, the RMP has generated one of the most comprehensive datasets for CECs in

aquatic ecosystems. CECs investigated to date include PFASs (also known as PFCs), alkylphenols, more than 100 PPCPs, and a variety of flame retardants including polybrominated diphenyl ethers (PBDEs) and their replacements. Among the CECs studied to date by the RMP, PBDEs, PFASs, and pyrethroid pesticides have been added to the routine monitoring program.

### **1.3 Report Objectives**

This report was developed as part of a continuous effort to refine approaches for supporting the management of CECs in San Francisco Bay. The specific objectives of the report were to:

- Summarize recommendations from the California State Water Resources Control Board's CEC Science Advisory Panel in their report on "Monitoring Strategies for Chemicals of Emerging Concern in California's Aquatic Ecosystems" (Section 2),
- Summarize the information available for CECs in San Francisco Bay (Section 3), and
- Identify data gaps by comparing available CEC monitoring data to the Science Advisory Panel recommendations (Section 4).

Information summarized in this report will be used to guide discussion of future CEC studies and serve as the basis for development of a strategy for future monitoring of CECs in San Francisco Bay (forthcoming document).

## **2.0 Recommendations from a Science Advisory Panel for Monitoring CECs in California's Aquatic Ecosystems**

In response to the CEC challenge, the California State Water Resources Control Board tasked a group of leading scientists to address the issues associated with CECs in the State's aquatic systems that receive discharge of treated municipal wastewater effluent and stormwater. The group was charged with identifying potential sources and evaluating the fate and effects of CECs, and ultimately with providing guidance for developing monitoring programs that assess those chemicals with the highest potential to cause effects in the State's receiving waters. The final report, "Monitoring Strategies for CECs in California's Aquatic Ecosystems" was released in 2012, and provides the results from the Panel's deliberations (Anderson et al. 2012).

The Panel provided the following products, which are intended to assist the State in developing a monitoring process for CECs:

- a conceptual, risk-based screening framework to assess and identify CECs for monitoring in California receiving waters;
- application of the risk-based screening framework to identify a list of CECs for initial monitoring;
- an adaptive, phased monitoring approach with interpretive guidelines that direct and update management actions commensurate with potential risk; and
- identification of research needs, including development of bioanalytical screening methods, linking molecular responses with higher order effects, and filling key data gaps.

The sections below briefly summarize these products and focus on aspects of the report that are most relevant to monitoring CECs in San Francisco Bay. The full report is available at <http://www.sccwrp.org/ResearchAreas/Contaminants/ContaminantsOfEmergingConcern/EcosystemsAdvisoryPanel.aspx>.

## **2.1 Risk-based Approach**

The universe of known chemicals considered by the Panel was derived from several databases, reports, and studies. These include the USEPA's Candidate Contaminant List 3, high production volume chemicals, and CECs previously identified in peer-reviewed toxicity and occurrence studies. A total of 82 organic chemicals were selected for initial screening, largely based on availability of occurrence and toxicity data. The following points briefly describe the chemical-by-chemical, risk-based framework developed by the Panel for assessing and identifying CECs for monitoring in California receiving waters.

- *Develop monitoring trigger levels (MTLs) for CECs that pose the greatest potential risk to aquatic systems based on published effects concentrations.* MTLs were derived by dividing toxicity benchmarks by appropriate safety factors. Toxicity benchmarks, including no observable effects concentrations (NOECs), lowest observable effects

concentrations (LOECs), and predicted no effects concentrations (PNECs), were compiled from published studies. The Panel focused on chemicals with NOECs < 0.1 mg/L for aqueous exposure and on the most sensitive receptor of interest.

- *Determine measured or predicted environmental concentrations (MECs or PECs) for which MTLs could be estimated.* Occurrence data for CECs were compiled using a tiered relevance framework with preference given to data generated within California. Data were collected from a number of sources and included data generated by the RMP. The maximum MEC was used as a conservative representation of potential exposure. PECs were calculated using dilution factors for estuary and oceanic sources from wastewater treatment plant (WWTP) effluent and stormwater model parameters. The Panel considered only those CECs for which NOECs < 0.1 mg/L have been reported.
- *Identify those CECs that present the greatest risk to ecological receptors or human health by comparing MECs and PECs to MTLs.* CECs with a monitoring trigger quotient (MTQ = MEC [or PEC]/MTL) > 1.0 were identified for monitoring. When the MTQ was ≤ 1.0, the Panel assumed the potential risk associated with the CEC did not currently warrant consideration for monitoring.
- *Apply this risk-based screening framework to each of three representative scenarios that capture the key types of exposure to CECs in the State's inland, coastal, and marine receiving water systems: effluent-dominated inland waterway, coastal embayment ("Estuary"), and ocean discharge of treated wastewater effluent.* The coastal embayment ("Estuary") scenario, which addresses direct and indirect (i.e., upstream) discharge of WWTP effluent and stormwater runoff, applies to San Francisco Bay. To estimate exposure for the coastal embayment scenario, PECs were derived from MECs obtained in the effluent-dominated inland waterway scenario with a ten-fold dilution to simulate embayment dilution.

The lack of occurrence and toxicity information for many CECs limited the Panel's ability to evaluate the risks of CECs potentially impacting the environment. Given the

uncertainties associated with CECs, the Panel concluded that providing an adaptive framework (i.e., one that can be modified through periodic re-evaluation as additional data or methodologies come forward) was the best approach to develop guidance for assessing the environmental risk of CECs at this time.

## **2.2 CEC Lists for Coastal Embayments (Estuaries)**

Table 1 lists the CECs identified by the Advisory Panel for monitoring in coastal embayments like San Francisco Bay. For aqueous exposure, seven compounds had MTQs > 1.0 and included hormones, personal care products, and current use pesticides. The MTQ for all of these compounds also exceeded 1.0 for the effluent-dominated inland waterway scenario, indicating a high priority for potential monitoring. For sediment exposure, four compounds had MTQs > 1.0. The occurrence of bifenthrin and permethrin in sediments and in aqueous exposures for both the effluent-dominated inland waterway and coastal embayment scenarios supports prioritization for pyrethroid pesticide monitoring. In tissues, the Panel recommended monitoring BDE-47, BDE-99 and PFOS.

The panel emphasized that these CECs represent an initial prioritization list based on available data and a number of assumptions. While their identification at this time represents a conservative screening of “CECs at large,” the information available for performing such screening continues to grow rapidly. The Panel recommended that this list be considered an initial list that will evolve over time, to which more CECs may be added and others removed.

## **2.3 Monitoring Approach and Implementation**

The Panel recommended an adaptive monitoring approach with four sequential phases that balance the potential risks identified for CECs, including uncertainty, against escalating management actions.

**Table 1. CECs identified by the Advisory Panel for monitoring in coastal embayments**

<b>Surface waters</b>	<b>Sediments</b>	<b>Tissue</b>
17-beta estradiol (hormone)	Bifenthrin (pesticide)*	BDE-47, BDE-99 (PBDE flame retardants)*
Estrone (hormone)	Permethrin (pesticide)*	PFOS (PFAS)*
Bisphenol A (PPCP)*	BDE-47, BDE-99 (PBDE flame retardants)*	
HHCB - Galaxolide (PPCP)**	PFOS (PFAS)*	
Bifenthrin (pesticide)**		
Permethrin (pesticide)*		
Chlorpyrifos (pesticide)*		

PPCP = pharmaceutical and personal care product; PFAS = Poly- and perfluorinated alkyl substance; \* Indicates compound has been monitored in the Bay as part of an RMP study;

\*\* Indicates qualitative data from passive samplers are available (see Appendix E).

### **2.3.1 Phase 1 – Develop Initial CEC List(s) Based on Panel Screening Framework**

The Panel identified an initial list of CECs by comparing MECs/PECs to MTLs based on biological effects thresholds and incorporating appropriate safety factors (Section 2.2). If analytical methods are not available, they would need to be developed, or PECs would need to be estimated (e.g., using a conceptual source and fate model), before the CEC could be considered for Phase 2 monitoring.

### **2.3.2 Phase 2 – Implement Monitoring of Phase 1 List of Initial CECs**

Phase 2 involves implementation of monitoring for CECs that have MTQs > 1. The overall objectives of Phase 2 are to:

- 1) verify the occurrence of targeted CECs in aqueous, sediment, and tissue samples;
- 2) initiate compiling a dataset as part of special studies that characterize their occurrence in sources and receiving waters (e.g., WWTP effluents and effluent-dominated receiving waters, stormwater-impacted freshwaters, marine waters, coastal embayment and estuarine waters,

and background receiving water, and in the appropriate environmental matrices [water, sediment, and tissue]);

- 3) begin to evaluate potential improved or supplemental methods and surrogate measures including non-targeted analysis, passive sampling devices, and bioassays for CECs and antibiotic resistance (see Section 2.4.1); and
- 4) initiate development of conceptual models to aid with monitoring data assessments (Phase 3) and policy analysis.

The Panel provided guidance for development of monitoring workplans for various discharge scenarios (see Table 8.2 in Anderson et al. 2012 for details) and recommended that the monitoring efforts be conducted as part of special studies coordinated through ongoing monitoring programs in the region (e.g., RMP).

### **2.3.3 Phase 3 – Assess/Update Monitoring and Response Plans**

Phase 3 involves reassessment of the Phase 2 monitoring efforts. The goal is to update the list of CECs based on results of monitoring using conventional and non-targeted methods, and pilot studies using bioassays (see Section 2.4.1). This will include reviewing newly available toxicity and occurrence data and subsequent updating of MTLs and MECs/PECs for re-calculation of MTQs. In essence, the intent is to evaluate the Phase 2 results within the context of a tiered risk-based monitoring and management action framework. An example of such a framework for San Francisco Bay is presented in Table 2.

### **2.3.4 Phase 4 – Action Plans to Minimize Impacts**

If the assessment and update conducted as part of Phase 3 indicates that certain CECs will persist and continue to present significant risks, then during Phase 4 the current Panel (or equivalent) would provide guidance on the development and assessment of specific action plans for consideration by the State for implementation as part of State policies, permits, and/or statewide guidance.

**Table 2. The conceptual tiered risk and management action framework for San Francisco Bay.** The framework is based on the framework proposed by a statewide work group in 2009 for prioritizing and monitoring CECs (California Ocean Protection Council et al. 2009). \* Subject to State Water Resources Control Board action with public review.

<b>Risk Level Description</b>	<b>Monitoring Strategy</b>	<b>Water Quality Management Actions*</b>
Tier I (Possible Concern) – Potential for concerns or uncertainty in measured or predicted Bay concentrations or toxicity thresholds suggest uncertainty in the level of effect on Bay wildlife.	Screening level monitoring to determine presence in water, sediment, or biota.  Screening level monitoring for presence in wastewater or runoff.	Maintain (ongoing/periodic) effort to identify and prioritize emerging contaminants of potential concern.  Track international and national efforts to identify high priority CECs.  Develop biological screening methods and identify available analytical methods.
Tier II (Low Concern) – Bay occurrence data or predicted environmental concentrations suggest a high probability of no effect on Bay wildlife.	Discontinue or conduct periodic screening level monitoring in water, sediment, or biota.  Periodic screening level monitoring for chemical(s) detected in wastewater or runoff to track trends.	Low-cost source identification and control.  Low-level pollution prevention.  Track product use and market trends.
Tier III (Moderate Concern) – Bay occurrence data suggest a high probability of a low level effect on Bay wildlife.	Consider including in Status and Trends Monitoring.  Special studies of fate, effects, and sources, pathways, and loadings.	Action plan/strategy.  Aggressive pollution prevention.  Low-cost control/treatment actions.
Tier IV (High Concern) – Bay occurrence data suggest a high probability of a moderate or high level effect on Bay wildlife.	Studies to support TMDL or alternative management plan.	303(d) listing.  TMDL or alternative management plan.  Aggressive control/treatment actions for all controllable sources.

## **2.4 Recommended Research Initiatives**

### **2.4.1 Develop Bioanalytical Screening Tools for Efficient, Integrated Monitoring and Assessment**

To complement current chemical-specific analytical methods, researchers are developing bioanalytical techniques that integrate the exposure of CECs acting with a common mode of action and producing a response that can be linked to higher order impacts (e.g., survival, growth, and reproduction). These bioassays can potentially be used to measure synergistic, additive, and antagonistic interactions among compounds that may be present as a mixture, e.g., in highly complex effluents. This is important, as toxicity evaluations based on single chemical analyses will generally miss the potential for these interactions in mixtures, thus providing false indication of potential risk. In their report, the Panel provided a summary of the current state of knowledge regarding the potential application of these tools for monitoring CECs in receiving waters and recommended future avenues for research (Anderson et al. 2012).

For a number of reasons, the Panel recommended a shift away from a chemical specific monitoring paradigm to one in which biological responses are targeted to address the thousands of chemicals that are potentially present in receiving waters. They concluded that bioanalytical tools show promise but have not been adapted and/or validated for environmental (i.e., receiving water) matrices, nor have they been adequately linked to effects at higher levels of biological organization. The Panel highlighted several research needs focused on the continued development of a variety of bioassay types (see Anderson et al. 2012 for details).

### **2.4.2 Fill Data Gaps on CEC Sources, Fate, Occurrence, and Toxicity**

During the transition from chemical-specific to bioanalytical monitoring, the Panel also saw value in filling data gaps on source contributions, occurrence, and toxicity of key CECs, and in developing environmental fate models that can be used to estimate the concentrations of CECs more cost effectively, particularly if analytical methods are not available (see Anderson et al. 2012 for details).

### 2.4.3 Assess the Relative Risk of CECs and Other Monitored Chemicals

The Panel also stressed the need to evaluate the risk posed by CECs relative to other stressors, including priority pollutants and other currently monitored chemicals, to provide decision makers with the information needed to make efficient use of all monitoring resources.

## 3.0 CECs in San Francisco Bay

Sections 3.1-3.7 summarize the information available regarding the occurrence and potential toxicity of CECs in San Francisco Bay. The CEC compound classes for which Bay occurrence data are available are listed in Table 3. For each compound class, the following information is discussed.

**Table 3. CEC compound classes for which Bay occurrence data are available**

<b>Compound Class</b>	<b>Compounds</b>
Pharmaceuticals	~100 active ingredients and their metabolites
Personal care products and related compounds	bisphenol A, triclosan, triclocarban, DEET, phthalates, pigments, dyes, fragrances, plasticizers, and others
Alkylphenols	Nonylphenol, octylphenol, nonylphenol mono- and diethoxylates
Flame retardants	PBDEs, HBCD, DBDPE, PBEB, BTBPE, EH-TBB, BEH-TEBP, HBB, Dechlorane Plus, organophosphates
Perfluorinated chemicals (PFAS)	Carboxylic acids and sulfonates, precursors
Current use pesticides	Includes 60+ compounds
Short chain chlorinated paraffins	C <sub>10</sub> -C <sub>13</sub> compounds
Nanomaterials	Single-walled carbon nanotubes

*Bay Occurrence Studies* – Appendix Tables A1-7 list the availability of CEC data by year and matrix. Appendix Tables B1-B7 list the CEC maximum concentrations detected in each matrix for the data listed in the Appendix A Tables. The majority of these data were generated by the RMP but data from other research groups were included if available. The tables in Appendices

C, D, and E and figures in Appendix F provide the CEC data acquired as part of the NOAA Mussel Watch California CEC Pilot Study. All of these samples were collected in 2010 and include CEC data for resident mussels (four NOAA Mussel Watch sites), deployed mussels (five RMP Status and Trends sites), and passive samplers (deployed at four sites in the Bay and its tributaries). The figures in Appendix F show the site-specific concentrations of selected CECs in mussels collected from Mussel Watch sites throughout the state as part of the pilot study.

*Comparison to Other Locations* – Where possible, the available occurrence data are compared to data available from other locations in California and the United States.

*Comparison to Toxicity Thresholds* – Bay occurrence data were compared to available toxicity benchmarks to provide information on the potential risk of these CECs to Bay wildlife. Toxicity data compiled for the Panel report (Anderson et al. 2012) represent the threshold data available for most of the CECs investigated in the Bay to date and were thus used for comparison in this report. Additional toxicity data were considered where noted.

*Management Action Tier* – Each CEC or CEC class was assigned a tier in the risk and management action framework based on available Bay occurrence data and toxicity information (framework in Table 2; CEC tier assignments in Table 4). The criteria listed below were used for placement in each tier.

**Tier I (Possible Concern)** – Uncertainty in measured or predicted Bay concentrations or toxicity thresholds suggest uncertainty in the level of effect on Bay wildlife.

**Tier II (Low Concern)** – Bay occurrence data or predicted environmental concentrations (PECs) suggest a high probability of no effect on Bay wildlife (i.e., Bay concentrations are well below toxicity thresholds and potential toxicity to wildlife is sufficiently characterized)

**Tier III (Moderate Concern)** – Bay occurrence data suggest a high probability of a low level effect on Bay wildlife (e.g., frequent detection at concentrations greater than the PNEC or NOEC but less than EC<sub>10</sub>, the effect concentration where 10% of the population exhibit a response, or another low level effects threshold).

**Tier IV (High Concern)** – Bay occurrence data suggest a high probability of a moderate or high level effect on Bay wildlife (e.g., frequent detection at concentrations greater than the EC<sub>10</sub> or another effects threshold).

A CEC is only assigned to a tier in the framework if it has been analyzed in Bay samples or a PEC has been estimated. Secondary factors that may impact tier assignments for each CEC include trends in use of the chemical or in Bay concentrations over time. The tier assignments for each CEC in this report were based on available information and will be continually updated as new information on the potential risk of the CEC becomes available. The assignments provide guidance to regulators considering management actions for CECs in the Bay.

### **3.1 Pharmaceuticals, Personal Care Products, and Related Compounds**

#### *Bay Occurrence Studies*

Pharmaceuticals and personal care product (PPCPs) ingredients have been analyzed in Bay surface waters, sediments, and mussel tissue. A small-scale study conducted in 2006 in South Bay surface waters included analysis of 39 PPCPs (Harrold et al. 2009). More than 100 PPCPs were analyzed in Bay samples collected in 2010 as part of two different pilot studies – a small-scale pilot study that analyzed co-located surface waters, sediments, and benthic mussels from five nearshore sites in Central, South, and Lower South Bays (Klosterhaus et al. 2013); and the statewide NOAA Mussel Watch California CEC Pilot Study, which analyzed PPCPs and several other CEC classes in resident mussels along the California coast (manuscripts in preparation). PPCPs and related compounds were also analyzed in polar organic chemical integrative samplers (POCIS) as part of the NOAA Mussel Watch pilot study. POCIS are passive samplers that can be used to obtain an index of surface water concentrations.

Several PPCPs were detected in the Bay samples (Appendix Tables B1, B2). For the pharmaceuticals, maximum concentrations in each matrix were 1,060 ng/L in water (sulfamethoxazole), 678 ng/g dry weight in sediments (ciprofloxacin), and about 90 ng/g dry weight in mussels (lomefloxacin and sulfamethazine). For personal care products and related compounds, maximum concentrations in each matrix were 459 ng/L in water (bis(2-ethylhexyl) phthalate, also known as di(2-ethylhexyl) phthalate or DEHP), 605 ng/g dry weight in sediments

(bis(2-ethylhexyl) phthalate), 2,620 ng/g dry weight in mussels (di-n-butyl phthalate), and 1,880 ng/g wet weight in cormorant eggs (bis(2-ethylhexyl) phthalate). The passive sampler results were not included in these summaries of surface water concentrations; these data are provided in Appendix E.

### *Comparison to Other Locations*

Concentrations of PPCPs in the Bay were typically one or more orders of magnitude lower than those typically reported for sites in freshwater systems, which are often located near wastewater outfalls, and were in closer agreement to concentrations reported for other marine and estuarine environments, where wastewater discharges are also common but dilution occurs to a greater extent (Klosterhaus et al. 2013). Within California, few PPCP occurrence data for coastal systems are available for comparison to Bay data. Where comparisons were possible, concentrations in San Francisco Bay mussels were generally comparable or lower than concentrations in mussels at other coastal sites in California (Appendix F); results were compound dependent and were complicated by a large number of compounds that were not detected or not consistently detected among sites. Also, where comparisons were possible, PPCP concentrations in Bay surface waters were typically at least one order of magnitude lower than concentrations at a Southern California ocean wastewater outfall and more comparable to concentrations in ocean water (Anderson et al. 2012). One exception, sulfamethoxazole, had a maximum level of about half that detected at the Southern California wastewater outfall.

### *Comparison to Toxicity Thresholds*

The concentrations of PPCPs detected in the San Francisco Bay samples were generally an order of magnitude or more below concentrations expected to elicit toxic effects in aquatic organisms. Two exceptions were bis(2-ethylhexyl) phthalate and butylbenzyl phthalate in Bay sediments. For bis(2-ethylhexyl) phthalate, concentrations in the ambient Bay ranged from below detection limits to 605 ng/g dry weight, which are below the low apparent effects threshold (LAET) of 1,300 ng/g and the high apparent effects threshold (HAET) of 3,100 ng/g (PTI Environmental Services 1988; Vidal and Bay 2005). For butylbenzyl phthalate, concentrations in the ambient Bay ranged from 14-323 ng/g dry weight, which exceed the LAET of 63 ng/g dry weight by as much as five times but are below the HAET (900 ng/g). These LAETs and HAETs

were developed using a variety of toxicity tests and benthic community effects and represent the lowest and highest nontoxic concentrations of a chemical, respectively (PTI Environmental Services 1988). However, the LAETs and HAETs were derived using Puget Sound sediment samples containing complex mixtures of contaminants. As a result, they do not indicate a strong causal linkage between a specific chemical and benthic effects, and were intended for use only as regional guidelines. Although analyses of phthalates are often beset by lab-introduced contamination, the reported concentrations for ambient San Francisco Bay sediments were those at least three times higher than batch blank concentrations, and thus are likely not primarily blank contamination signals.

A third exception, the antibiotic sulfamethoxazole, was detected at three southern Bay sites at concentrations similar to or exceeding a PNEC of 118 ng/L based on a chronic algal toxicity study (Grung et al. 2008). Twelve other Bay water samples taken as part of two different studies indicated levels were typically below the PNEC.

In general, the majority of toxicity data currently available for PPCPs are based on acute effects studies, and the potential for sub-lethal effects remains a concern. Pharmaceuticals are inherently biologically active compounds, thus accumulation in mussels may indicate a particular potential for effects, and for some compounds, effects may occur even without accumulation. In general, however, few PPCP toxicity studies have evaluated effects due to long-term exposures to environmentally relevant concentrations, particularly via sediments. Addressing these data gaps, along with developing an improved understanding of the potential for impacts due to exposure to the vast number and types of chemicals typically present in urban aquatic environments (i.e., effects of chemical mixtures) are needed to thoroughly assess the risk of PPCPs and other compounds to Bay wildlife. Surface waters and sediments near wastewater or stormwater outfalls in the Bay may exhibit higher concentrations and an increased likelihood of impacts.

### *Management Action Tier*

The pharmaceuticals and other personal care product ingredients analyzed in the Bay to date (see list in Appendix Tables B1 and B2) are generally classified as Tier II (Low Concern) CECs. Most PPCPs have been detected at concentrations in the Bay well below available toxicity

thresholds and toxicity to aquatic species appears to be sufficiently well characterized. Sulfamethoxazole exceeded a toxicity threshold at just a few sites, and is therefore also considered a Tier II (Low Concern) CEC. Bis(2-ethylhexyl) phthalate and butylbenzyl phthalate were detected at concentrations in the same range as sediment LAET and HAET values (Table 4); however, there is uncertainty regarding the application of these thresholds to Bay sediments because they do not have a strong causal linkage to specific chemicals, and in some cases are not directly linked to effects on macrobenthos. These two phthalates were classified as Tier I (Possible Concern). In addition, bisphenol A was identified by the CEC State Panel as a constituent to monitor; San Francisco Bay studies to date are limited and have had elevated detection limits. As a result bisphenol A is classified as a Tier I (Possible Concern) chemical.

### **3.2 Alkylphenols and Alkylphenol Ethoxylates (APs and APEs)**

#### *Bay Occurrence Studies*

Nonylphenol (NP), octylphenol (OP), and nonylphenol mono- and diethoxylates (NP1EO and NP2EO, respectively) have been analyzed in Bay samples. NP was analyzed in surface waters, sediments, and bivalves (Hoenicke et al. 2007) as part of RMP Status and Trends monitoring from 2002-2004. NP, OP, NP1EO and NP2EO were analyzed in Bay surface waters, sediments, and mussels collected in 2010 as part of a small-scale pilot study which analyzed co-located surface waters, sediments, and benthic mussels from five nearshore sites in Central, South, and Lower South Bays (Klosterhaus et al. 2012a, 2013). NP, OP, NP1EO and NP2EO were analyzed in Bay mussels collected in 2010 as part of the statewide NOAA Mussel Watch California CEC Pilot Study (manuscript in preparation). NP and NP1EO and NP2EO were also analyzed in cormorant eggs in 2002 and 2004 (<http://www.sfei.org/rmp/wqt>). In addition, NP was analyzed in small fish collected in 2006 as part of a California coastal survey (Diehl et al. 2012).

NP, NP1EO, and NP2EO were detected in the Bay samples (Appendix Table B3). OP has not been detected. In surface waters, NP concentrations were less than 100 ng/L, and NP1EO and NP2EO have not been detected. The saltwater chronic criteria for NP is substantially higher than observed concentrations, 1.7 ug/L. In sediments, NP, NP1EO, and NP2EO were all consistently detected at moderately high concentrations, with a median of 35 ppb for NP. In mussel samples

collected by SFEI, detection of these contaminants was sporadic, but the maximum concentrations of NP, NP1EO, and NP2EO of 1,290, 300, and 1,420 ng/g dry weight were very high relative to other contaminants detected in these bivalves. Maximum concentrations of NP, NP1EO, and NP2EO in resident Bay mussel samples collected in 2010 as part of the statewide Mussel Watch study were much lower – 223, 300, and 67 ng/g dry weight, respectively – but still high relative to other contaminants that are found in Bay mussels. In small fish and cormorant eggs, maximum concentrations of NP and NPEs were 420 and 228 ng/g wet weight, respectively, also relatively high compared to other contaminants that accumulate in these species.

#### *Comparison to Other Locations*

NP, NP1EO, and NP2EO concentrations in the Bay were typically at least an order of magnitude lower than those reported for sites in effluent-dominated systems and were in closer agreement to concentrations reported for other marine and estuarine environments (Klosterhaus et al. 2012a). Within California, relatively few occurrence data are available for comparison. In the recent statewide Mussel Watch study, concentrations of NP in San Francisco Bay mussels collected were comparable or lower than concentrations in mussels at other coastal sites in California (Appendix F). However, concentrations of NP1EO and NP2EO in mussels were among the highest in the state, similar to several sites in Southern California (Appendix F). Concentrations of NP in small fish were comparable to those in small fish from other California estuaries (Diehl et al. 2012).

#### *Comparison to Toxicity Thresholds*

Concentrations of APs and APEs detected in the San Francisco Bay samples were generally an order of magnitude or more below concentrations expected to elicit toxic effects in aquatic organisms (Klosterhaus et al. 2012a). An exception is a study suggesting the potential for impacts on barnacle settlement due to exposure to NP concentrations of 60 ng/L in water (Billinghurst et al. 1998). In general, few toxicity studies have evaluated effects due to long-term exposures to environmentally relevant concentrations, particularly via sediments. While available toxicity data suggest a low potential for effects at the nearshore Bay sites investigated, water and sediment near wastewater or stormwater outfalls in the Bay may contain higher concentrations that could increase the likelihood of impacts. Studies suggest that effects from

APEs and their degradation products may be additive; thus organisms living near wastewater discharges may be the most susceptible, particularly since they can be continuously exposed to many estrogenic substances that have been identified in wastewater effluent. Another cause for concern for APs and APEs is the potential for synergistic effects in combination with other pollutants. Schlenk et al. (2012) found that mixtures of pesticides with environmentally relevant concentrations of APs and APEs resulted in significantly greater vitellogenin production in adult male Japanese medaka (*Oryzias latipes*) in *in vivo* exposures, and suggested that this type of combined estrogenic potency may have a role in the decline of key fish populations in the Bay-Delta. The synergistic action of the APs and APEs may be due to enhanced uptake of pesticides or to effects on enzyme induction. The RMP is developing bioanalytical tools that may be used in the future to measure the aggregate estrogenicity of the contaminant mixtures found in Bay samples.

#### *Management Action Tier*

NP, NP1EO, and NP2EO are classified as Tier III (Moderate Concern) CECs in San Francisco Bay (Table 4). Though concentrations in the Bay are well below most toxicity thresholds, they are a cause for concern due to the detection of NP in surface waters at concentrations that impacted barnacle settlement in a laboratory study (Billingham et al. 1998), their continued use in industrial surfactant products, their persistence in sediments, and the potential for synergistic effects in combination with other contaminants such as pesticides. Detection of APs and the potential presence of other estrogenic compounds in the Bay due to wastewater discharges suggests the need for determining estrogenic potency in Bay samples.

### **3.3 Flame Retardants**

#### *Bay Occurrence Studies*

Polybrominated diphenyl ethers (PBDEs) and several other flame retardant chemicals have been analyzed in San Francisco Bay samples. Since 2002, PBDEs in surface waters, sediments, bivalves, sport fish, and cormorant eggs have been routinely analyzed as part of RMP Status and Trends monitoring (<http://www.sfei.org/rmp/wqt>). Other researchers have also analyzed PBDEs in Bay mussels, fish, bird eggs, and harbor seals (references in Appendix Table

A3). Concentrations and mass loadings of PBDEs from Bay tributaries have been estimated as part of RMP monitoring (McKee et al. 2006; David et al. 2012; Gilbreath et al. 2012), and in 2008 a mass budget of PBDEs in the Bay was developed as a first step towards understanding the local sources and transport processes controlling PBDE fate (Oram et al. 2008). In addition to PBDEs, several alternative halogenated flame retardants were monitored in Bay samples collected between 2006-2008 as part of a small screening survey (Klosterhaus et al. 2012b). Organophosphate flame retardants, some of which are PBDE replacements, were also recently analyzed in cormorant eggs collected from the Bay in 2009 (data unpublished). Semiquantitative measurements for three organophosphate flame retardants in sediment samples from 2007 are provided in Appendix Table B4. Site-specific flame retardant concentrations in resident San Francisco Bay mussel samples analyzed as part of the NOAA Mussel Watch California CEC Pilot Study are provided in Appendix Table C3; analytes include PBDEs, other brominated flame retardants, and organophosphates. Finally, qualitative data from passive water samplers deployed as part of this national mussel study indicate detection of several organophosphate flame retardants in Bay waters (Appendix Table E2).

PBDEs have been detected in the majority of the Bay samples analyzed (Appendix Table B4). Concentrations in surface waters have been low ( $\Sigma\text{PBDE} \leq 1 \text{ ng/L}$ ), while concentrations in stormwater runoff have been as high as 425 ng/L. Sediment concentrations in the ambient Bay are typically  $< 10 \text{ ng/g}$  dry weight (maximum 50 ng/g) and are often dominated by BDE-209. In wildlife, concentrations have been highest in aquatic bird eggs (maximum 63,300 ng/g lipid in terns and 24,000 ng/g lipid in cormorants), followed by seal blubber (maximum 11,000 ng/g lipid for adults and 63,000 ng/g lipid for pups; Greig et al. 2011) and sport fish (maximum 4,300 ng/g lipid and 94.8 ng/g wet weight or ppb). Maximum concentrations in bivalves were 229 ng/g dry weight. Congeners present in the PentaBDE mixture are predominant in tissues and with the exception of a small number of bivalve and seal samples, BDE-209 has not been detected in any wildlife samples. PBDE concentrations in Bay water and sediment have remained fairly consistent since the RMP began monitoring in 2002, a year before a partial phase-out the PentaBDE and OctaBDE mixtures began. More recent measurements suggest concentrations of PentaBDE component BDE-47 may be declining in sediment. Wildlife samples show clear declines in PBDE contamination for bivalves, sport fish, and cormorant eggs over the past ten years. Tern egg measurements, obtained in 2009 by the RMP, also suggested declines relative to

the maximum value previously measured by CalEPA scientists (2002 maximum 63,300 ng/g lipid [She et al. 2008]; 2009 maximum 2,400 ng/g lipid). Levels of PBDEs in adult harbor seals may be stabilizing or declining relative to earlier CalEPA measurements (She et al. 2002).

Several other flame retardants have also been detected in Bay samples, but with the exception of some organophosphate compounds in sediments, they have been detected at concentrations at least one order of magnitude lower than PBDEs (Appendix Table B4). Non-PBDE flame retardants detected in Bay wildlife were hexabromocyclododecane (HBCD), Dechlorane Plus (DP), pentabromoethylbenzene (PBEB), bis(2,4,6 tribromophenoxy) ethane (BTBPE), tris(1-chloropropyl)phosphate (TCPP), tris(2-chloroethyl)phosphate (TCEP), tris(2-butoxyethyl)phosphate (TBEP), and triphenylphosphate (TPhP). Brominated flame retardants that were analyzed but not detected in Bay samples were EH-TBB and BEH-TEBP (the brominated components of the PentaBDE replacement commercial mixture, Firemaster 550), decabromodiphenylethane (DBDPE, a Deca-BDE replacement), and hexabromobenzene (HBB). The organophosphates TDCPP, TCPP, and TPhP have been detected in Bay sediments at estimated concentrations that are comparable to the PBDE and PCB concentrations in the same samples. TCPP, TCEP, and TBEP were detected in cormorant eggs, while several other organophosphate flame retardants were analyzed but were not detected (Appendix Table B4). It is hypothesized that some of these may be taken up by aquatic organisms (e.g., TDCPP) but are easily metabolized.

In addition to quantitative measurements, passive water samplers (POCIS) deployed by SFEI as part of the NOAA Mussel Watch Contaminants of Emerging Concern (CECs) Early Warning Network: California Pilot Project indicated the presence of several organophosphate flame retardants in San Francisco Bay waters: TCPP, TDCPP, TCEP, tributyl phosphate (TBP), and TPhP (Appendix Table E2). TBEP and tris(2-ethylhexyl)phosphate (TEHP) were not detected.

### *Comparison to Other Locations*

PBDE concentrations in humans and wildlife in California, and the San Francisco Bay Area in particular, have historically been among the highest reported in the world (Shaw and Kannan 2009). However, RMP data indicate levels are now declining in a number of Bay

wildlife species. Within California, concentrations of PBDEs in San Francisco Bay mussels were among the highest in the state, but were comparable to concentrations in mussels at other coastal sites in southern California (Kimbrough et al. 2009; Appendix F). Levels in Bay fish were comparable to those found in other urban, coastal regions of North America, and were typically higher than those found in fish from less urban regions along the coasts of California and the Pacific Northwest (Brown et al. 2006; Shaw and Kannan 2009; Ikonomou et al. 2011). Levels in cormorants are similar to or greater than those found in other fish-eating bird eggs of North America, though lower than the most extreme value measured in San Francisco Bay tern eggs at around the same time, 63,300 ng/g lipid (She et al. 2008; Henny et al. 2009; Chen and Hale 2010).

Overall San Francisco Bay sediment measurements for BDE-209 (DecaBDE component) and BDE-47 (PentaBDE component) were similar to the area-weighted geometric means of the offshore region of the Southern California Bight, as opposed to the more contaminated coastal embayment regions, especially at or near river mouths (Dodder et al. 2012). San Francisco Bay sediments were considered to be only in the ‘medium’ range of PBDE concentrations among the 122 samples collected at US coastal sites in a recent NOAA Mussel Watch survey (Kimbrough et al. 2009). In particular, sediment concentrations were comparable or lower than those in other urbanized US estuaries such as the Hudson-Raritan Estuary, Galveston Bay, and Narragansett Bay. Notably, these measurements did not include contributions from BDE-209, the dominant form of PBDEs in Bay sediment.

### *Comparison to Toxicity Thresholds*

PBDEs have been associated with a wide variety of reproductive, developmental, and neurobehavioral effects, including those related to disruption of the endocrine system. However, only a relatively small number of studies have investigated PBDE toxicity in wildlife, and many of these have been conducted at concentrations higher than those typically observed in the environment (Shaw and Kannan 2009). In studies with fish, increased susceptibility to pathogenic microorganisms (Arkoosh et al. 2010) has been observed in subyearling Chinook salmon (*Oncorhynchus tshawytscha*) with PBDE concentrations comparable to those found in Bay fish, particularly samples of white sturgeon (*Acipenser transmontanus*) and anchovy

(*Engraulidae*) collected in 2003 and white croaker (*Genyonemus lineatus*; analyzed with skin) collected in 2006. While all fish collected in 2009 had levels of PBDEs less than half the level associated with impaired immune function in this study, no specific toxicity thresholds (e.g., NOAEL or LOAEL) have been identified, so it is unclear whether Bay fish may be susceptible to adverse effects at present. Though effects such as altered locomotion behavior (Chou et al. 2010) and thyroid disruption (Lema et al. 2008) have been observed in other fish species, they have only occurred in fish with PBDE concentrations significantly higher than those found in Bay fish.

A study of polychaete larval settlement and growth found BDE-47 exposure triggered effects in three species at a sediment concentration of 3.0 ng/g dry weight, and no effect at a concentration of 0.5 ng/g (Lam et al. 2010). In Bay sediments, 37% of samples exceeded 0.5 ng/g BDE-47, and just one Bay sample and two Bay margin “hot spot” samples exceeded 3.0 ng/g BDE-47. Lam et al. (2010) did not specifically characterize 0.5 and 3.0 ng/g BDE-47 as a NOEC and LOEC, respectively; however, the high frequency of Bay sediment BDE-47 levels between these values suggests the potential for low level adverse effects to benthic organisms.

In harbor seals, higher PBDE levels in blood samples were associated with higher white blood cell counts, suggesting that high levels of contaminants might be linked to increased rates of infection (Neale et al. 2005). There was an inverse correlation between total PBDEs and red blood cells, though the relationship was not strong enough to support a clear connection to anemia. Although the results of this study did not tie PBDEs directly to disease, the trends suggest contaminant-induced alterations in Bay harbor seals, especially in individuals with relatively high contaminant burdens (Neale et al. 2005). Further study to determine the contribution of PBDE contamination to the morbidity and mortality of the Bay harbor seal population is warranted. In particular, studies on exposure-related effects in young seals that lose weight during the post-weaning fast are needed, as this group contained the highest levels of PBDE contamination observed in blubber (Greig et al. 2011). During the fasting period, contaminants like PBDEs are mobilized from blubber into the blood, where they may cause adverse health effects on various systems just as young seals are learning to forage and experiencing their first parasitic infections.

PBDEs have been associated with various reproductive effects in American kestrels (McKernan et al. 2009) and osprey (Henny et al. 2009) at concentrations within range of those found in San Francisco Bay tern eggs (She et al. 2008), but higher than those observed in cormorant eggs in the Bay. However, in a recent study using common tern eggs from Chesapeake Bay, reproductive and developmental effects were not observed at concentrations approximating PBDE concentrations in Forster's tern eggs from San Francisco Bay (Rattner et al. 2011). In addition, PBDE concentrations in sport fish were well below the lowest California Office of Environmental Health Hazard Assessment threshold for fish consumption, indicating that PBDE concentrations in Bay sport fish are not a concern with regard to human health (Klasing and Brodberg 2011).

Relatively few studies have investigated the potential human health effects of the non-PBDE flame retardants analyzed in Bay samples and toxicity threshold data for wildlife are extremely limited (Shaw et al. 2010). TCEP has been identified by the European Chemicals Agency as a Substance of Very High Concern because of its reproductive toxicity (European Union 2009) and has been associated with carcinogenic effects (World Health Organization 1998). TDDCP has the potential to act as a mutagen, carcinogen, neurotoxin, and endocrine disruptor (Meeker and Stapleton 2010; Shaw et al. 2010; Dishaw et al. 2011). Both TCEP and TDCPP are on the California Proposition 65 list of carcinogens.

#### *Management Action Tier*

PBDEs are classified as Tier III (Moderate Concern) CECs in San Francisco Bay due to lingering concerns about potential toxic effects in harbor seals (Neale et al. 2005), sport fish (Arkoosh et al. 2010), and benthic organisms (Lam et al. 2010). In contrast, the results of a recent toxicity study suggest that PBDE concentrations may not be adversely impacting Bay birds (Rattner et al. 2011), and Bay sport fish have levels of contamination below those considered a concern with respect to human health (Klasing and Brodberg 2011). Concentrations in wildlife appear to be declining due to the prior phase-out of PentaBDE and OctaBDE. Periodic monitoring is warranted to verify continuing declines (Table 4).

The other flame retardants analyzed (TDCPP, TCEP, BEH-TEBP, EH-TBB, TPhP, DBDPE, DP, PBEB, BTBPE, HBB, and the other OPs analyzed thus far in Bay bird eggs

[Appendix Table B4]) are classified as Tier I (Possible Concern) CECs. TDCPP, TCEP, TBEP, TPhP, DP, and BTBPE have been detected in the Bay. TDCPP and TCEP have been associated with toxic impacts in mammalian toxicity models. However, for all of these compounds, limited toxicity data are available for aquatic species. In the case of TPhP, the available information is conflicting with regard to ecosystem risk (see for example van der Veen and de Boer 2012). TDCPP, BEH-TEBP, DBDPE, DP, TPhP and BTBPE are high production volume chemicals (> 1 million pounds produced or imported in the US per year). TDCPP, TCPP, BEH-TEBP, EH-TBB, TPhP, DBDPE, and BTBPE are known PBDE replacements.

HBCD has been detected in the Bay at low concentrations. There are few studies on the ecotoxicology of this compound (Birnbaum and Staskal 2012). The EC<sub>50</sub> for algae varies between 9.3 ug/L and 0.34 mg/L, concentrations that are above the solubility of HBCD (Birnbaum and Staskal 2012). HBCD is a high production volume chemical; however, reductions in use of HBCD may be forthcoming as a result of its addition to the Stockholm Convention list of Persistent Organic Pollutants. Given the likely reduction of HBCD and the low levels detected in Bay biota, HBCD is classified as Tier II (Low Concern).

### **3.4 Perfluorinated Compounds**

#### *Bay Occurrence Studies*

Since 2006, the RMP has conducted studies of perfluorinated compounds (PFCs, or as the research community now refers to them, poly- and perfluorinated alkyl substances [PFASs]) in San Francisco Bay matrices including seals, cormorant eggs, sport fish, small fish, mussels, sediments, tributaries, wastewater effluent and ambient Bay water. In addition, researchers at Stanford and the University of California at Berkeley (unpublished data) have evaluated PFASs in Bay Area sediments, effluent, and tributaries (Appendix Table A4).

PFASs are long-chain carbon molecules (typically 4 to 12 carbons) that contain a variety of moieties at the end of the chain (sulfonates, alcohols, etc.). Because PFASs are both oleophobic and hydrophobic (oil and water repelling), and highly stable, they are widely used in industrial and consumer applications such as fire-fighting foams, stain-resistant coatings, adhesives, electronics, and electroplating. Perfluorooctane sulfonate (PFOS) and

perfluorooctanoate (PFOA) were used extensively until 2002, when elevated concentrations of PFOS were identified in the general US blood supply and PFOS production in the US ceased. Nonetheless, because of their stability and resistance to biological and chemical degradation, PFOS and PFOA are the primary PFASs observed in the environment. In addition, they are the terminal degradation products for longer-chained PFASs that continue to be used and discharged to the environment.

PFOS and PFOA are the primary PFASs detected in the Bay, although other PFASs are observed infrequently at lower concentrations (Appendix Table B5). PFOS is the primary PFAS detected in biological matrices such as seal blood, bird eggs, sport fish and small fish. In contrast, PFOA is the primary PFAS detected in abiotic media such as surface waters and tributaries. Detection of PFOS and PFOA precursor compounds such as N-ethyl perfluorooctanesulfonamide and N-methyl perfluorooctanesulfonamido-ethanol has been sporadic, in part because new analytical methods were being developed during the RMP studies.

Initial RMP studies conducted from 2006-2009 evaluated concentrations of PFASs in apex predators such as seals and cormorants (Sedlak and Greig 2012). The mean concentration of PFOS in seal blood was an order of magnitude higher in the Bay than at the reference site (Tomales Bay). South Bay seals and bird eggs had the highest PFOS concentrations (maximum concentrations of 1,960 ng/mL and 1,760 ng/g ww for seal and bird eggs, respectively), suggesting localized sources in South Bay or reduced dilution. Other PFASs were detected in both matrices at much lower concentrations. Bird eggs analyzed in 2006 and 2009 had similar concentrations, suggesting no temporal trends.

In 2009, small fish from the Bay margins were analyzed for PFASs in an attempt to characterize the uptake of PFASs into the foodweb. PFOS was detected in most small fish sampled at concentrations as high as 80 ng/g ww. No other PFASs were detected in significant concentrations in small fish. Sport fish were also sampled in 2009 from five Bay Area recreational fishing sites. Of the 20 samples analyzed, only four had detectable concentrations of PFOS and exhibited little correlation with trophic level (maximum concentration of 18 ng/g ww). PFASs have been analyzed in mussels at several sites in the Bay and were largely not detected (Appendix Tables C5 and D3).

Further inquiry into the potential sources and pathways of these compounds led to a study of select tributaries, effluent and ambient Bay water and sediment in 2009 and 2010. Concentrations detected in tributaries and effluents were on the same order of magnitude (mean values between 20 to 30 ng/L PFOA and 7 to 24 ng/L PFOS). Mean concentrations observed in Bay waters were approximately half these values (7 ng/L PFOS and 11 ng/L PFOA); although preliminary data to date suggest the influence of localized ambient Bay water hot spots with concentrations as high as 44 and 76 ng/L for PFOS and PFOA respectively.

PFOS was an order of magnitude higher than other PFASs in sediment (3 ng/g dw). Research conducted by scientists at Stanford (Higgins et al. 2005) identified similar concentrations of PFOS in Bay Area sediment (ranging from 0.58 to 3.07 ng/g dw). Higgins et al. (2005) identified significant concentrations of the PFOA and PFOS precursors in Bay sediments (at concentrations similar to PFOA and PFOS), suggesting that these precursors represent a substantial reservoir.

#### *Comparison to Other Locations*

Concentrations of PFOS in Bay Area seal blood and bird eggs are some of the highest reported in the literature, with maximum measurements of 1,960 ng/mL and 1,760 ng/g ww, respectively (Sedlak and Greig 2012; Appendix Table B5). Concentrations of PFOS in seal blood observed elsewhere were as high as 887 ng/g (Ahrens et al. 2009); in dolphin blood, they were as high as 3,073 ng/g (Houde et al. 2005). Some of the highest PFOS concentrations detected worldwide were in Baltic Sea cormorants (706 ng/g, Lofstrand et al. 2008). Interestingly, Bay Area concentrations of PFOS in small fish and sport fish are typical of concentrations observed elsewhere.

Concentrations of PFOS and PFOA in tributaries, effluents, and sediments are site-specific and exhibit considerable variation depending on proximity to local sources and urban areas. In a study of 88 tributary surface waters in the Upper Mississippi Basin (Nakayama et al. 2010), the median concentrations of PFOA and PFOS were 2.07 and 3.01 ng/L, respectively. These concentrations were lower than San Francisco Bay stormwater and surface waters; however, they represent a range of values from a very large (multi-state) watershed. In tributaries receiving direct releases of PFASs, concentrations as high as 11,300 ng/L PFOA in surface

waters have been reported (Moody et al. 2002). Similarly, concentrations reported in effluents vary tremendously depending on the service area. Average effluent concentrations observed in the RMP study are in agreement with a national study of ten wastewater treatment plants in the US (PFOS 23.4 ng/L versus 23.6 in the RMP study and PFOA 30.3 ng/L versus 31.2 ng/L (Schultz et al. 2006). Concentrations as high as 700 ng/L have been reported for PFOS and PFOA in wastewater effluent (Sinclair and Kannan 2006).

#### *Comparison to Toxicity Thresholds*

Very little information is available on the toxicological effects of PFASs to seals; thresholds specific to pinnipeds have not been developed. Suppression of immune systems has been observed for both rats and seals exposed to PFOS. In addition, increased incidences of disease and mortality have been reported in the literature for rats and sea otters as a result of exposure to PFOS. In a study of California sea otters (Kannan et al. 2006), a significant correlation between PFOS concentration in livers and incidence of disease was observed. Concentrations of PFOS in the livers of these sea otters ranged from 1-884 ng/g ww.

Adverse effects associated with avian exposure to PFOS include reduced body weight, increased liver weight, and reduced hatching and pipping success. A PNEC of 1000 ng/mL has been developed for birds based on studies of quail (Houde et al. 2005; Newsted et al. 2005). Some of the egg concentrations observed in the South Bay were higher than this PNEC.

#### *Management Action Tier*

PFOS is classified as a Tier III (Moderate Concern) CEC in San Francisco Bay (Table 4). High concentrations in South Bay seals and bird eggs, bird egg concentrations higher than the PNEC, and no sign of a decreasing trend in these concentrations suggest local, continuous sources.

Other PFASs are classified as Tier I (Possible Concern) CECs because they have either not been detected in the Bay or were detected at very low concentrations and their toxicity is not well characterized for aquatic species.

### 3.5 Pesticides

#### *Bay Occurrence Studies*

A suite of pesticides has been analyzed by the RMP since its inception, with target analytes changing (mostly added) as use patterns and analytical capabilities have evolved. The current-use (i.e., not completely banned) pesticides most frequently detected in San Francisco Bay area surface waters were organophosphates and pyrethroids (Appendix Table B6). Although the organophosphates such as diazinon have been trending downward (e.g., maximum concentration of 22 ng/L for 2000-2004, versus 0.5 ng/L for 2005-2010) due to elimination of their urban uses after 2004 over concerns about their toxicity in urban creeks, they have been supplanted by increasing use of pyrethroids. Pyrethroids such as permethrin were often found at much higher concentrations in stormwater samples (maximum 285 ng/L) compared to the ambient Bay (<0.4 ng/L), in accordance with their expected urban usage. Pyrethroids were also often detected in ambient surface sediments, as they tend to partition to solid organic materials due to their hydrophobicity. Restrictions implemented in 2012 by state pesticide regulators should reduce pyrethroid-caused toxicity in urban runoff. Another commonly used pesticide, fipronil, is only moderately hydrophobic ( $\log K_{oc} \sim 3$ ), but its degradation products fipronil desulfinyl, -sulfide, and -sulfone are more hydrophobic ( $\log K_{oc} \sim 3.5$ ) and were mostly detected in ambient sediments on the single occasion they were included in recent Bay monitoring, with concentrations up to 0.56 ng/g for the sulfone.

The herbicides dacthal and oxadiazon have been routinely monitored by the RMP in Bay surface waters, showing higher concentrations (maximum 0.6 and 12 ng/L respectively), for sites with higher riverine input relative to dilution and flushing by tidal ocean waters such as Suisun and Lower South Bay. Annual monitoring for these herbicides indicates no consistent, long term trends in concentrations detected at fixed Bay stations. Other herbicides such as ametryn, atrazine, diuron, hexazinone, and simazine have also been detected on the one occasion they were analyzed in Bay surface waters.

The algaecide Irgarol, commonly used in marine antifouling coatings, and its major metabolite (GS26575) were also detected in ambient surface waters in selected studies at concentrations up to 712 ng/L (Sapozhnikova et al. 2008; Hall et al. 2009). Although Irgarol has

not been monitored routinely or widely in the Bay, it would be expected that, similar to those studies, high concentrations would be detected only in enclosed marinas with relatively low flushing rates, and relatively low concentrations would be detected in well-flushed open waters nearby.

#### *Comparison to Other Locations*

Concentrations and trends of organophosphate pesticides and other pesticides in San Francisco Bay are comparable with those for other regions of the US. Uses and ambient concentrations of the organophosphate pesticides have declined significantly nationwide, while those of alternatives such as fipronil (Ryberg et al. 2010) and pyrethroids have risen.

Pyrethroids in the Southern California Bight region were concentrated near urban runoff pathways, with ambient concentrations of total pyrethroids around  $5.1 \pm 3.1$  ng/g, and higher concentrations in marinas and estuaries of  $22.1 \pm 26.5$  ng/g. Pyrethroids also commonly showed a gradient of decreasing concentrations with increasing distance from mouths of urban creeks within estuaries (Zamora-Ley et al. 2006; Lao et al. 2011). A survey of creek sediments in seven metropolitan areas spread across the US also showed a similar range of pyrethroid concentrations, typically 5 ng/g or less, with individual samples up to 38 ng/g (Kuivila et al. 2012).

Irgarol and its metabolites have been detected in high concentrations in other areas of the US; for Irgarol, up to 635 ng/L in Key Largo, FL (Zamora-Ley et al. 2006), 304 ng/L in a San Diego, CA marina (Sapozhnikova et al. 2007), and 585 ng/L in an Annapolis, MD marina (Hall et al. 2004).

#### *Comparison to Toxicity Thresholds*

Ambient concentrations of the organophosphate pesticides diazinon and chlorpyrifos are generally well below their effects thresholds for ambient waters. For San Francisco Bay, there is a numeric diazinon target of less than 100 ng/L in urban creeks. Similarly the lowest published NOEC for chlorpyrifos is less than 4.6 ng/L, which reduces mysid shrimp reproduction by 85%. Current ambient concentrations are generally much lower (diazinon < 0.5 ng/L, chlorpyrifos < 1.2 in 2009) and thus represent little risk to resident species in the Bay.

On the other hand, pyrethroid pesticides frequently approach or may be above effects levels, particularly for locations nearer their sources. Ten-day LC<sub>50</sub> concentrations in sediments for individual pyrethroids (estimated for sediments with 1% organic carbon) ranged from 2 to 10 ng/g (Amweg et al. 2005). Although few individual pyrethroid compounds approach that concentration in Bay sediments, many of the highest concentrations approach 1 ng/g. Toxic effects for the pyrethroids are cumulative due to their similarities in structure and mode of action, so although no individual compound may exceed its LC<sub>50</sub>, the combined effects of all the pyrethroid compounds present in a sample may be toxic.

Fipronil and its metabolites are highly toxic, with a freshwater NOEC of 9,800 ng/L for the parent compound (*Daphnia pulex*), and toxicity for metabolites 1.9 to 6.6 times higher (NOEC ~1,500 ng/L). Estuarine and marine organisms are more sensitive, with a mysid shrimp EC<sub>50</sub> of 140 ng/L, and estimated NOEC of < 5 ng/L. If marine organisms are similarly more sensitive to the metabolites, the respective EC<sub>50</sub> and NOEC will be 21 and 0.8 ng/L. With the highest sediment concentration of 0.56 ng/g (for the sulfone), dissolved porewater concentrations (18 ng/L assuming 1% OC in sediment and log K<sub>oc</sub> of ~3.5) may exceed thresholds at the most contaminated locations.

The lowest regulatory toxicity threshold for dacthal is an EC<sub>50</sub> for eastern oyster shell deposition of 620,000 ng/L (<http://www.epa.gov/oppsrrd1/REDs/0270red.pdf>). The maximum concentration found in Bay ambient water was 0.62 ng/L, six orders of magnitude lower, and even the highest stormwater concentration of 30.5 ng/L is still well below. For oxadiazon, the lowest thresholds are a marine diatom EC<sub>50</sub> of 5,200 ng/L and a NOAEC of < 8,000 ng/L for duckweed ([http://www.epa.gov/oppsrrd1/REDs/oxadiazon\\_red.pdf](http://www.epa.gov/oppsrrd1/REDs/oxadiazon_red.pdf)). Again, even maximum stormwater concentrations (398 ng/L) are still lower. Ambient concentrations for other herbicides are similarly well below even sub-lethal effects levels, with most thresholds in the µg/L range (e.g., 0.1 µg/L for atrazine endocrine disruption in frogs), compared to maximum ambient concentrations of < 100 ng/L or lower for most.

The primary toxic effects of concern for Irgarol are their impacts on algal growth, so a 10<sup>th</sup> percentile of observed plant effects of 193 ng/L for Irgarol, and 5,622 ng/L for the GS26575 metabolite were suggested as risk assessment thresholds (Hall et al. 2009), with a microcosm

NOEC of 323 ng/L as another possible metric. A summer event average and sample maximum concentration of Irgarol found in one Bay Area marina (Loch Lomond) exceeded both these targets on one occasion, with another (Berkeley) showing an event average and maximum concentration near these targets. However, the concentrations at these marinas for fall sampling, and at other marinas for all events, were below both these thresholds.

#### *Management Action Tier*

Pyrethroid pesticides are classified as Tier II (Low Concern) CECs in San Francisco Bay (Table 4), in large part due to infrequent and low detection of these compounds in the Bay. Pyrethroids remain a high concern for the surrounding watersheds.

Fipronil, including its metabolites, are classified as Tier III (Moderate Concern) CECs in the Bay. Most of the available toxicity information is on the parent compound, but if the relatively higher toxicity of its metabolites found for freshwater organisms occurs also for estuarine and marine organisms, calculated porewater concentrations could exceed effects thresholds at the highest concentration sites. Estuarine studies with effects thresholds for sediment concentrations, and/or measurements of ambient water concentrations, would be needed to better assess the risk.

With effects levels generally a factor of ten or more higher than ambient concentrations, the other current use pesticides analyzed thus far in San Francisco Bay (Appendix Table B6) are classified as Tier I (Possible Concern) CECs in the Bay. Concentrations in the Bay are generally below toxicity thresholds but some uncertainty in toxicity to aquatic species exists. Those with concentrations nearer or occasionally exceeding (e.g., Irgarol in limited environments and times) their effects thresholds should be periodically reexamined to see if updated toxicity information or trends in use and ambient concentrations warrant increased attention.

### **3.6 Short-chain Chlorinated Paraffins**

#### *Bay Occurrence Studies*

Short-chain chlorinated paraffins (SCCPs) (C<sub>10</sub>-C<sub>13</sub> congeners) were analyzed in a small number of sport fish and bird egg samples collected in 2006 and seal blubber samples collected

in 2007 as part of a pilot study. SCCPs were detected in the most of the samples (Appendix Table B7); however, the data should be considered ‘estimated’ values only due to internal standard recovery issues in the analytical method used. Seal blubber contained the highest  $\Sigma$ SCCP concentrations (25-50 ng/g wet weight), followed by cormorant eggs (4-6 ng/g wet weight), and then sport fish (< 1-1 ng/g wet weight).

#### *Comparison to Other Locations*

To our knowledge, SCCP data from other locations in California or other marine environments in the US are not available for comparison. SCCP concentrations in Bay fish were at least one order of magnitude lower than fish in the Great Lakes (UNEP 2009). SCCP concentrations in Bay seals were at least one order of magnitude lower than marine mammals in the Arctic (UNEP 2009).

#### *Comparison to Toxicity Thresholds*

Though SCCPs have been identified as persistent, bioaccumulative, and toxic substances (USEPA 2009), effects have typically been observed at concentrations that are several orders of magnitude higher than the concentrations detected in Bay wildlife (UNEP 2009). It is important to note, however, that analytical methods challenges have resulted in substantial uncertainties in the development of toxicity and occurrence data for these compounds (Sverko et al. 2012).

#### *Management Action Tier*

SCCPs are classified as Tier I (Possible Concern) CECs in San Francisco Bay (Table 4). Though concentrations in the Bay were low relative to available toxicity thresholds, there is uncertainty in the quality of the existing occurrence and toxicity data (Sverko et al. 2012). SCCPs are current use, high production volume chemicals that have been identified as persistent, bioaccumulative, and toxic substances by the USEPA (USEPA 2009). The USEPA has recently announced an action plan that may lead to bans or restrictions on the manufacture and use of SCCPs (USEPA 2009).

### **3.7 Nanomaterials**

#### *Bay Occurrence Studies*

Bay sediments collected in 2007 as part of RMP Status and Trends monitoring and resident Bay mussels collected in 2010 as part of the NOAA Mussel Watch California CEC Pilot Study have been analyzed for the presence of single-walled carbon nanotubes (SWNT). SWNT were not detected in any samples. No other nanomaterials have been analyzed in Bay samples. Analytical methods for the analysis of other nanomaterials in environmental samples are not currently available.

#### *Comparison to Other Locations*

SWNT were not detected in any mussel samples from California as part of the NOAA Mussel Watch California CEC Pilot Study. To our knowledge, SWNT have not been analyzed in environmental matrices from other locations.

#### *Comparison to Toxicity Thresholds*

Studies have reported minimal effects due to exposure to SWNT in sediments (Petersen et al. 2011). When observed, effects generally occur at concentrations in the mg/g range. Toxic effects due to exposure to SWNT in water have been observed, but often only at concentrations in the mg/L range. Toxic effects from exposure to carbon nanotube are thought to occur primarily as a consequence of interactions with epithelial surfaces since there is an apparent lack of carbon nanotube absorption across epithelial membranes (Petersen et al. 2011).

#### *Management Action Tier*

SWNTs are classified as a Tier I (Possible Concern) CECs in San Francisco Bay. They have not been detected in Bay samples but potential toxicity to aquatic species is unknown.

**Table 4. Current status of CECs in the tiered risk-management action framework for San Francisco Bay** (see Section 2 of this report for framework details).

Management Tier	Compound(s)	Rationale
Tier III: Moderate Concern	PFOS	Bird egg concentrations greater than PNEC, high concentrations in seal blood, high volume use of precursors
	Fipronil	May be above toxicity thresholds at some sites for calculated porewater concentrations, need better ambient data and/or toxicity thresholds for sediment matrices to better assess risk
	Nonylphenol, Nonylphenolethoxylates	Bay concentrations below most toxicity thresholds, possible impacts on larval barnacle settlement, possible synergistic effects with pyrethroids, high volume use, estrogenic activity
	PBDEs	Detected in Bay wildlife, toxicity in mammalian models, bird egg concentrations below toxicity threshold, sport fish concentrations below CA fish contaminant goal, possible immune system impacts on fish, possible blood impacts on seals, use declining
Tier II: Low Concern	Pyrethroids	Detected infrequently and in low concentrations in Bay sediments, of concern in watersheds, tributary sediment concentrations comparable or higher than toxicity thresholds, toxic at low concentrations, high volume use
	Pharmaceuticals, Personal care product ingredients*	Concentrations below toxicity thresholds, toxicity to aquatic species sufficiently characterized
	HBCD	Concentrations are low; likely reduction in use

Tier I: Possible Concern	Alternative Flame Retardants (BEH-TEBP, EH-TBB, DBDPE, PBEB, BTBPE, HBB, DP, TDCPP, TCEP, TCPP, TBEP, TPhP, other organophosphates)	Detection of some in sediments or bird eggs, toxicity for some in mammalian models, limited toxicity data for aquatic species, high volume use or PBDE replacements
	Bisphenol A	Analyzed but not detected in surface waters (< 2500 ng/L) or sediments (< 2600 ng/g), PNEC=60 ng/L
	Bis(2-ethylhexyl) phthalate (BEHP or DEHP)	Sediment concentrations in the same range as low apparent effects threshold (but threshold not directly linked to specific chemicals)
	Butylbenzyl phthalate	Sediment concentrations greater than low apparent effects threshold (but threshold not directly linked to specific chemicals or effects in macrobenthos)
	PFASs other than PFOS	Detection of some compounds, possible impacts to marine mammals from PFOA, toxicity to aquatic species not sufficiently characterized
	Short-chain chlorinated paraffins	Concentrations below toxicity thresholds, uncertainties in toxicity data, high volume use
	Other pesticides**	Concentrations below toxicity thresholds, uncertainty in toxicity to Bay wildlife
	Single-walled carbon nanotubes	Not detected, toxicity information not available, high volume use

\*For full list of PPCPs considered to be in this classification, see Appendix Tables B1 and B2.

\*\*For full list of pesticides considered to be in this classification see Appendix Table B6. RMP will convene a workshop in 2013 to address current use pesticides.

## **4.0 Identification of Data Gaps**

As previously mentioned, substantial gaps in knowledge exist regarding the identification, occurrence, fate, and potential impacts of long-term exposure to CECs in aquatic environments (Section 1). Because it is not possible to evaluate all potential CECs on a chemical-by-chemical basis, a Science Advisory Panel was convened to recommend approaches for CEC monitoring, including an initial list of CECs to target (Section 2). Sections 4.1-4.3 address the recommendations made in the Panel report (Anderson et al. 2012) and identify data gaps by comparing these recommendations to the CEC monitoring efforts conducted thus far in San Francisco Bay (Section 3).

The RMP is essentially in Phase 3 of the monitoring approach recommended by the Panel, which involves reassessment of monitoring efforts and updating the list of target CECs (Anderson et al. 2012). Over the last several years the RMP has identified priority CECs (Phase 1) and then conducted studies to generate data to determine whether further monitoring of these CECs is needed (Phase 2). This CEC synthesis report assists in meeting the objectives of Phase 3 by summarizing the occurrence data available and evaluating these in the context of the tiered risk and management action framework (Tables 2 and 4). This information will support the San Francisco Bay Regional Water Quality Control Board in their consideration of management actions for these CECs in the Bay (Phase 4).

### **4.1 Targeted Chemical Monitoring**

Table 1 lists the CECs identified by the Advisory Panel for monitoring in coastal embayments, the scenario examined by the Panel that applies to San Francisco Bay. The RMP has been acquiring occurrence data for the CECs recommended for monitoring in sediments (BDE-47 and BDE-99, PFOS, bifenthrin and permethrin) and tissues (BDE-47, BDE-99, and PFOS) (see Sections 3.3-3.5). In water, the RMP has only acquired occurrence data for two of the seven CECs recommended for monitoring (chlorpyrifos and permethrin). Bifenthrin, galaxolide (HHCB), and the hormones estrone and 17-beta estradiol have not been analyzed in Bay surface waters. In 2010, bisphenol A was analyzed in Bay surface waters and not detected, though detection limits were quite high (2470 ng/L, over 400 times higher than the monitoring trigger level of 6 ng/L recommended by the Panel).

The Panel also recommended the collection of occurrence data on other chemicals that were not recommended for monitoring by the Panel at that time due to a lack of occurrence or toxicity data, but that may be relevant due to increasing use, elevated environmental occurrence, or high toxic potency. Examples of these types of compounds are:

- Natural and synthetic hormones (progesterone, levonorgestrel, and cis-androstenedione)
- Current use flame retardants (chlorinated organophosphates), and
- Current use pesticides (additional pyrethroids and fipronil and its degradates in sediments; herbicides such as diuron).

Natural or synthetic hormones have not been analyzed in Bay samples. The RMP has acquired some occurrence data for several current use organophosphate flame retardants (Section 3.3). Two of these are the chlorinated alkylphosphate flame retardants (TCPP and TDCPP) used as PentaBDE replacements. Several current use pesticides have also been monitored in the Bay (Section 3.5).

In addition, the Panel recommended development or refinement of environmental fate models to predict environmental concentrations of CECs based on their production volume, use, and environmental fate as a means for prioritizing chemicals on which to focus method development and toxicological investigations. Aside from applying the PCB box model to PBDEs, fate models have not been used for predicting CEC concentrations in San Francisco Bay (Oram et al. 2008).

## **4.2 Non-targeted Approaches to Monitoring**

### **4.2.1 Bioanalytical Screening**

As noted previously, the Panel anticipated and recommended a shift away from a chemical-specific monitoring paradigm to one in which biological responses are targeted to address the thousands of chemicals that are potentially present in receiving waters. They concluded that these bioanalytical tools show promise but have not yet been adapted and/or validated for environmental (i.e., receiving water) matrices, nor have they been adequately linked

to effects at higher levels of biological organization. In their report, the Panel listed several key research needs to advance the development and validation of these tools (Anderson et al. 2012). The RMP has not previously applied these types of tools to monitoring chemical contaminants in San Francisco Bay.

As a result, the RMP is sponsoring the development of a bioanalytical tool for the Bay that will link cellular effects (e.g., changes in hormones that affect genetic signaling and processing) to organism effects (e.g., growth, reproduction, and survival). The study will be conducted by researchers at University of Florida and SCCWRP. The work will use silversides (*Menidia beryllina*), a model estuarine fish, to evaluate the estrogenic effects of four endocrine disrupting compounds recently recommended for monitoring in California's estuaries by the State's Science Advisory Panel for CECs: estrone, bisphenol A, 4-nonylphenol, and galaxolide (HHCB). Assuming responsive bioassays correlated to measured effects in fish are identified, fish will then be exposed to field collected samples from San Francisco wastewater treatment plants and ambient Bay waters as well as select locations in southern California, to assess overall estrogenicity.

A key strength of this type of bioassay is that it can be used to assess the cumulative effects of exposure to multiple CECs with common modes of action. This tool may prove particularly relevant to identifying potential harm caused to organisms living near outfalls and therefore likely to be exposed to a variety of estrogenic chemicals at concentrations relatively higher than found in the greater Bay. Successful application of this bioassay tool may also result in identification of specific estrogenic contaminants that merit chemical-specific monitoring studies.

#### **4.2.2 Non-targeted Screening**

The Panel also recommended conducting a pilot investigation using non-targeted analysis to screen for unidentified or unknown CECs. These methods are useful for creating an inventory of bioaccumulative compounds in tissues or compounds present in abiotic matrices (e.g., sediment, wastewater) and can be used as a screening tool for directing targeted chemical or toxicity identification evaluations. The Panel report explains these techniques in more detail (Anderson et al. 2012).

Non-targeted screening analyses of San Francisco Bay mussels and harbor seals were initiated in 2010 in collaboration with the National Institute of Standards and Technology (NIST) and other researchers. The results from this study, including a list of compounds identified in the samples, are expected in 2013.

## **5.0 Development of a CEC Monitoring Strategy**

The information summarized in this report will serve as the basis for development of a long-term strategy for future CEC monitoring in San Francisco Bay. The RMP CEC Strategy will be completed in 2013 and will outline a general approach and workplan for monitoring studies to be conducted over the next several years. It is anticipated that the CEC Strategy will continue to include targeted monitoring studies, but will also include non-target screening analyses and begin to incorporate the use of bioanalytical tools as they become validated for application to environmental samples. The CEC Strategy will also consider new information as it becomes available and continue to take a pro-active approach to identifying ‘new’ CECs for which toxicity information may not yet be available.

## 6.0 References

- Ahrens, L., U. Siebert and R. Ebinghaus. 2009. Temporal trends of polyfluoroalkyl compounds in harbor seals (*Phoca vitulina*) from the German Bight, 1999-2008. *Chemosphere*, 76, 151-158.
- Amweg, E.L., D.P. Weston and N.M. Ureda. 2005. Use and toxicity of pyrethroid pesticides in the Central Valley, California, USA. *Environmental Toxicology and Chemistry*, 24, 966-972.
- Anderson, P.D., N.D. Denslow, J.E. Drewes, A.W. Olivieri, D. Schlenk, G.I. Scott and S.A. Snyder. 2012. *Monitoring Strategies for Chemicals of Emerging Concern (CECs) in California's Aquatic Ecosystems*. Costa Mesa, CA.
- Arkoosh, M.R., D. Boylen, J. Dietrich, B.F. Anulacion, Ginaylitalo, C.F. Bravo, L.L. Johnson, F.J. Loge and T.K. Collier. 2010. Disease susceptibility of salmon exposed to polybrominated diphenyl ethers (PBDEs). *Aquatic Toxicology*, 98, 51-59.
- Birnbaum, L and D. Staskal. 2004. Brominated flame retardants: Cause for concern? *Environmental Health Perspectives*, 112, 9-17.
- Benotti, M.J., R.A. Trenholm, B.J. Vanderford, J.C. Holady, B.D. Stanford and S.A. Snyder. 2009. Pharmaceuticals and endocrine disrupting compounds in U.S. drinking water. *Environmental Science and Technology*, 43, 597-603.
- Billinghurst, Z., A.S. Clare, T. Fileman, J. McEvoy, J. Readman and M.H. Depledge. 1998. Inhibition of barnacle settlement by the environmental oestrogen 4-nonylphenol and the natural oestrogen 17 beta oestradiol. *Marine Pollution Bulletin*, 36, 833-839.
- Brown, F.R., J. Winkler, P. Visita, J. Dhaliwal and M. Petreas. 2006. Levels of PBDEs, PCDDs, PCDFs, and coplanar PCBs in edible fish from California coastal waters. *Chemosphere*, 64, 276-286.
- California Ocean Protection Council, California Ocean Science Trust, National Water Research Institute, San Francisco Estuary Institute, Southern California Coastal Water Research Project and University of California, Irvine Urban Water Research Center. 2009. *Managing Contaminants of Emerging Concern in California: Developing Processes for Prioritizing, Monitoring, and Determining Thresholds of Concern*. Costa Mesa, CA.

- Chen D. and R.C. Hale. 2010. A global review of polybrominated diphenyl ether flame retardant contamination in birds. *Environment International*, 36, 800-811.
- Chou, C.T., Y.C. Hsiao, F.C. Ko, J.O. Cheng, Y.M. Cheng and T.H. Chen. 2010. Chronic exposure of 2,2',4,4'-tetrabromodiphenyl ether (PBDE-47) alters locomotion behavior in juvenile zebrafish (*Danio rerio*). *Aquatic Toxicology*, 98, 388-395.
- David, N., D.C. Gluchowski, J.E. Leatherbarrow, D. Yee and L.J. McKee. 2012. Estimation of Loads of Mercury, Selenium, PCBs, PAHs, PBDEs, Dioxins, and Organochlorine Pesticides from the Sacramento-San Joaquin River Delta to San Francisco Bay. San Francisco Estuary Institute.
- Diehl, J., S.E. Johnson, K. Xia, A. West and L. Tomanek. 2012. The distribution of 4-nonylphenol in marine organisms of North American Pacific Coast estuaries. *Chemosphere*, 87, 490-497.
- Dishaw, L.V., C.M. Powers, I.T. Ryde, S.C. Roberts, F.J. Seidler, T.A. Slotkin and H.M. Stapleton. 2011. Is the PentaBDE replacement, tris (1,3-dichloro-2-propyl) phosphate (TDCPP), a developmental neurotoxicant? Studies in PC12 cells. *Toxicology and Applied Pharmacology*, 256, 281-289.
- Dodder N.G., K.A. Maruya, G.G. Lauenstein, J. Ramirez, K.J. Ritter and K.C. Schiff. 2012. Distribution and sources of polybrominated diphenyl ethers in the Southern California Bight. *Environmental Toxicology and Chemistry*, 31, 2239-2245.
- European Union. 2009. Risk Assessment report for Tris(2-chloroethyl) phosphate, TCEP CAS-No.: 115-96-8.
- Gilbreath, A., D. Yee and L. McKee. 2012. Concentrations and loads of trace contaminants in a small urban tributary, San Francisco Bay, California. A Technical Report of the Sources Pathways and Loading Work Group of the Regional Monitoring Program for Water Quality: Contribution No. 650. San Francisco Estuary Institute. Richmond, CA.
- Greig, D.J., G.M. Ylitalo, E.A. Wheeler, D. Boyd, F.M. Gulland, G.K. Yanagida, et al. 2011. Geography and stage of development affect persistent organic pollutants in stranded and wild-caught harbor seal pups from central California. *Science of the Total Environment*, 409, 3537-3547.

- Hall, L.W., Jr., W.D. Killen, R.D. Anderson, R. Balcomb and P. Gardinali. 2009. Ecological risk of Irgarol 1051 and its major metabolite in coastal California marinas and reference areas. *Marine Pollution Bulletin*, 58, 702-710.
- Hall, L.W., Jr., W.D. Killen and P.R. Gardinali. 2004. Occurrence of Irgarol 1051 and its major metabolite in Maryland waters of Chesapeake Bay. *Marine Pollution Bulletin*, 48, 554-562.
- Harrold, K.H., D. Yee, M. Sedlak, S.L. Klosterhaus, J.A. Davis, M. Woudneh and P. Riley. 2009. Pharmaceuticals and Personal Care Products in Wastewater Treatment Plant Influent and Effluent and Surface Waters of Lower South San Francisco Bay. San Francisco Estuary Institute. Oakland, CA.
- Henny, C.J., J.L. Kaiser, R.A. Grove, B.L. Johnson and R.J. Letcher. 2009. Polybrominated diphenyl ether flame retardants in eggs may reduce reproductive success of ospreys in Oregon and Washington, USA. *Ecotoxicology*, 18, 802-813.
- Higgins, C.P., J.A. Field, C.S. Criddle and R.G. Luthy. 2005. Quantitative determination of perfluorochemicals in sediments and domestic sludge. *Environmental Science and Technology*, 39, 3946-3956.
- Hoehn, E., M.H. Plumlee and M. Reinhard. 2007. Natural attenuation of downwelling streams for perfluorochemicals and other emerging contaminants. *Water Science and Technology*, 56, 59-64.
- Hoenicke, R., D.R. Oros, J.J. Oram and K.M. Taberski. 2007. Adapting an ambient monitoring program to the challenge of managing emerging pollutants in the San Francisco Estuary. *Environmental Research*, 105, 132-144.
- Houde, M., R.S. Wells, P.A. Fair, G.D. Bossart, A.A. Hohn, T.K. Rowles, J.C. Sweeney, K.R. Solomon and D.C. Muir. 2005. Polyfluoroalkyl compounds in free-ranging bottlenose dolphins (*Tursiops truncatus*) from the Gulf of Mexico and the Atlantic Ocean. *Environmental Science and Technology*, 39, 6591-6598.
- Hwang, H.M., P.G. Green and T.M. Young. 2006. Tidal salt marsh sediment in California, USA. Part 1: occurrence and sources of organic contaminants. *Chemosphere*, 64, 1383-1392.
- Ikonomou M.G., H.J. Teas, R. Gerlach, D. Higgs and R.F. Addison. 2011. Residues of PBDEs in northeastern Pacific marine fish: evidence for spatial and temporal trends. *Environmental Toxicology and Chemistry*, 30, 1261-1271.

- Kannan, K., T. Agusa, E. Perrotta, N.J. Thomas and S. Tanabe. 2006. Comparison of trace element concentrations in livers of diseased, emaciated and non-diseased southern sea otters from the California coast. *Chemosphere*, 65, 2160-2167.
- Kimbrough, K.L., W.E. Johnson, G.G. Lauenstein, J.D. Christensen and D.A. Apeti. 2009. An Assessment of Polybrominated Diphenyl Ethers (PBDEs) in Sediments and Bivalves of the U.S. Coastal Zone. Silver Spring, MD.
- Klasing, S. and R. Brodberg. 2011. Development of Fish Contaminant Goals and Advisory Tissue Levels for Common Contaminants in California Sport Fish: Polybrominated Diphenyl Ethers (PBDEs). Pesticide and Environmental Toxicology Branch Office of Environmental Health Hazard Assessment California Environmental Protection Agency.
- Klosterhaus, S., R.M. Allen and J.A. Davis. 2012a. Contaminants of Emerging Concern in the San Francisco Estuary: Alkylphenol Ethoxylates. RMP Contribution #657. San Francisco Estuary Institute. Richmond, CA.
- Klosterhaus, S.L., H.M. Stapleton, M.J. La Guardia and D.J. Greig. 2012b. Brominated and chlorinated flame retardants in San Francisco Bay sediments and wildlife. *Environment International*, 47, 56-65.
- Klosterhaus, S., Grace, R., Hamilton, C. and D. Yee. 2013. Method validation and reconnaissance of pharmaceuticals, personal care products, and alkylphenols in surface waters, sediments, and mussels in an urban estuary. *Environment International*, 54, 92-99.
- Kuivila, K.M., M.L. Hladik, C.G. Ingersoll, N.E. Kemble, P.W. Moran, D.L. Calhoun, L.H. Nowell and R.J. Gilliom. 2012. Occurrence and potential sources of pyrethroid insecticides in stream sediments from seven U.S. metropolitan areas. *Environmental Science and Technology*, 46, 4297-4303.
- Lam, C., R. Neumann, P.K. Shin, D.W. Au, P.Y. Qian and R.S. Wu. 2010. Polybrominated diphenylethers (PBDEs) alter larval settlement of marine benthic polychaetes. *Environmental Science and Technology*, 44, 7130-7137.
- Lao, W., L. Tiefenthaler, D.J. Greenstein, K.A. Maruya, S.M. Bay, K. Ritter and K. Schiff. 2011. Pyrethroids in southern California coastal sediments. Southern California Coastal Water Research Project.

- Lema, S.C., J.T. Dickey, I.R. Schultz and P. Swanson. 2008. Dietary exposure to 2,2',4,4'-tetrabromodiphenyl ether (PBDE-47) alters thyroid status and thyroid hormone-regulated gene transcription in the pituitary and brain. *Environmental Health Perspectives*, 116, 1694-1699.
- Lofstrand, K., H. Jorundsdottir, G. Tomy, J. Svavarsson, P. Weihe, T. Nygard and K. Bergman. 2008. Spatial trends of polyfluorinated compounds in guillemot (*Uria aalge*) eggs from North-Western Europe. *Chemosphere*, 72, 1475-1480.
- Lowe, S., B. Anderson, and B. Phillips. 2007. Final Project Report: Investigations of Sources and Effects of Pyrethroid Pesticides in Watersheds of the San Francisco Bay Estuary. Proposition 13 PRISM Grant # 041355520. SFEI Contribution #523. San Francisco Estuary Institute, Oakland, CA.
- McKee, L., J. Oram, J. Leatherbarrow, A. Bonnema, W. Heim and M. Stephenson. 2006. Concentrations and loads of mercury in the lower Guadalupe River, San Jose, California: Water Years 2003, 2004, and 2005. A Technical Report of the Regional Watershed Program: SFEI Contribution 424. San Francisco Estuary Institute. Oakland, CA.
- McKernan, M.A., B.A. Rattner, R.C. Hale and M.A. Ottinger. 2009. Toxicity of polybrominated diphenyl ethers (DE-71) in chicken (*Gallus gallus*), mallard (*Anas platyrhynchos*), and American kestrel (*Falco sparverius*) embryos and hatchlings. *Environmental Toxicology and Chemistry* 28, 1007-1017.
- Meeker, J.D. and H.M. Stapleton. 2010. House dust concentrations of organophosphate flame retardants in relation to hormone levels and semen quality parameters. *Environmental Health Perspectives*, 118, 318-323.
- Moody, C.A., J.W. Martin, W.C. Kwan, D.C.G. Muir and S.C. Mabury. 2002. Monitoring perfluorinated surfactants in biota and surface water samples following an accidental release of fire-fighting foam into Etobicoke Creek. *Environmental Science and Technology*, 36, 545-551.
- Muir, D.C. and P.H. Howard. 2006. Are there other persistent organic pollutants? A challenge for environmental chemists. *Environmental Science and Technology*, 40, 7157-7166.
- Nakayama, S.F., M.J. Strynar, J.L. Reiner, A.D. Delinsky and A.B. Lindstrom. 2010. Determination of perfluorinated compounds in the upper Mississippi River Basin. *Environmental Science and Technology*, 44, 4103-4109.

- Neale, J.C., F.M. Gulland, K.R. Schmelzer, J.T. Harvey, E.A. Berg, S.G. Allen, et al. 2005. Contaminant loads and hematological correlates in the harbor seal (*Phoca vitulina*) of San Francisco Bay, California. *Journal of Toxicology and Environmental Health Part A*, 68, 617-633.
- Newsted, J.L., P.D. Jones, K. Coady and J.P. Giesy. 2005. Avian toxicity reference values for perfluorooctane sulfonate. *Environmental Science and Technology*, 39, 9357-9362.
- Oram, J.J., L.J. McKee, C.E. Werme, M.S. Connor, D.R. Oros, R. Grace and F. Rodigari. 2008. A mass budget of polybrominated diphenyl ethers in San Francisco Bay, CA. *Environment International*, 34, 1137-1147.
- Petersen, E.J., L. Zhang, N.T. Mattison, D.M. O'Carroll, A.J. Whelton, N. Uddin, T. Nguyen, Q. Huang, T.B. Henry, R.D. Holbrook and K.L. Chen. 2011. Potential release pathways, environmental fate, and ecological risks of carbon nanotubes. *Environmental Science and Technology*, 45, 9837-9856.
- PTI Environmental Services. 1988. Sediment Quality Values Refinement: Volume 1. Update and Evaluation of Puget Sound AET. Office of Puget Sound, USEPA. Bellevue, WA.
- Rattner, B.A., R.S. Lazarus, G.H. Heinz, N.K. Karouna-Renier and R.C. Hale. 2011. Apparent Tolerance of Common Tern (*Sterna hirundo*) Embryos to a Pentabrominated Diphenyl Ether Mixture (DE-71). Regional Monitoring Program.
- Ryberg, K.R., A.V. Vecchia, J.D. Martin and R.J. Gilliom. 2010. Trends in Pesticide Concentrations in Urban Streams in the United States, 1992–2008. Scientific Investigations Report 2010–5139. US Geological Survey.
- Sapozhnikova, Y., E. Wirth, K. Schiff, J. Brown and M. Fulton. 2007. Antifouling pesticides in the coastal waters of Southern California. *Marine Pollution Bulletin*, 54, 1972-1978.
- Sapozhnikova, Y., E. Wirth, N. Singhasemanon, J. Bacey and M. Fulton. 2008. Distribution of antifouling biocides in California marinas. *Journal of Environmental Monitoring*, 10, 1069-1075.
- Schlenk, D., R. Lavado, J. Loyo-Rosale, J. Wesley, L. Maryoung, N. Riar, I. Werner, and D. Sedlak. 2012. Reconstitution studies of pesticides and surfactants exploring the cause of estrogenic activity observed in surface waters of the San Francisco Bay Delta. *Environmental Science and Technology*, 46, 9106–9111.

- Schultz, M.M., C.P. Higgins, C.A. Huset, R.G. Luthy, D.F. Barofsky and J.A. Field. 2006. Fluorochemical mass flows in a municipal wastewater treatment facility. *Environmental Science and Technology*, 40, 7350-7357.
- Sedlak, M.D. and D.J. Greig. 2012. Perfluoroalkyl compounds (PFCs) in wildlife from an urban estuary. *Journal of Environmental Monitoring*, 14, 146-154.
- Shaw, S.D., A. Blum, R. Weber, K. Kannan, D. Rich, D. Lucas, C.P. Koshland, D. Dobraca, S. Hanson and L.S. Birnbaum. 2010. Halogenated flame retardants: do the fire safety benefits justify the risks? *Reviews on Environmental Health*, 25, 261-305.
- Shaw, S.D. and K. Kannan. 2009. Polybrominated diphenyl ethers in marine ecosystems of the American continents: foresight from current knowledge. *Reviews on Environmental Health*, 24, 157-229.
- She, J., A. Holden, T.L. Adelsbach, M. Tanner, S.E. Schwarzbach, J.L. Yee and K. Hooper. 2008. Concentrations and time trends of polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) in aquatic bird eggs from San Francisco Bay, CA 2000-2003. *Chemosphere*, 73, S201-209.
- She, J., M. Petreas, J. Winkler, P. Visita, M. McKinney and D. Kopec. 2002. PBDEs in the San Francisco Bay Area: measurements in harbor seal blubber and human breast adipose tissue. *Chemosphere*, 46, 697-707.
- Sinclair, E. and K. Kannan. 2006. Mass loading and fate of perfluoroalkyl surfactants in wastewater treatment plants. *Environmental Science and Technology*, 40, 1408-1414.
- Sverko, E., G.T. Tomy, C.H. Marvin and D.C.G. Muir. 2012. Improving the quality of environmental measurements on short chain chlorinated paraffins to support global regulatory efforts. *Environmental Science and Technology*, 46, 4697-4698.
- UNEP. 2009. United Nations Environment Programme. Stockholm Convention on Persistent Organic Pollutants (POPs). Persistent Organic Pollutants Review Committee. Revised Draft Risk Profile: Short-Chained Chlorinated Paraffins. UNEP/POPS/POPRC.5/2.
- USEPA. 2009. Short-Chain Chlorinated Paraffins (SCCPs) and Other Chlorinated Paraffins Action Plan.
- Van der Veen I. and J. de Boer. 2012. Phosphorus flame retardants: Properties, production, environmental occurrence, toxicity and analysis. *Chemosphere*, 88, 1119-1153.

- Vidal, D.E. and S.M. Bay. 2005. Comparative sediment quality guideline performance for predicting sediment toxicity in southern California, USA. *Environmental Toxicology and Chemistry*, 24, 3173-3182.
- Wilson, M.P. and M.R. Schwarzman. 2009. Toward a new U.S. chemicals policy: rebuilding the foundation to advance new science, green chemistry, and environmental health. *Environmental Health Perspectives*, 117, 1202-1209.
- World Health Organization. 1998. Environmental Health Criteria 209, Flame Retardants: Tris(chloropropyl) phosphate and tris(2-chloroethyl) phosphate.
- Zamora-Ley, I.M., P.R. Gardinali and F.J. Jochem. 2006. Assessing the effects of Irgarol 1051 on marine phytoplankton populations in Key Largo Harbor, Florida. *Marine Pollution Bulletin*, 52, 935-941.

## **7.0 Appendices**

Appendix A – CEC occurrence data for San Francisco Bay by year

Appendix B – Maximum concentrations and frequencies of detection of CECs analyzed in San Francisco Bay by compound class and matrix

Appendix C – Site-specific CEC concentrations in resident San Francisco Bay mussel samples analyzed as part of the NOAA Mussel Watch California CEC Pilot Study. These samples were collected in 2010.

Appendix D – Site-specific CEC concentrations in 2010 RMP deployed mussel samples analyzed as part of the NOAA Mussel Watch California CEC Pilot Study

Appendix E – Site-specific CEC concentrations in passive samplers deployed in San Francisco Bay as part of the NOAA Mussel Watch California CEC Pilot Study. These samples were deployed in 2010.

Appendix F – Site-specific concentrations of select CECs in mussels collected from Mussel Watch sites in 2010 as part of the National Mussel Watch California CEC Pilot Study

## **Appendix A – CEC occurrence data for San Francisco Bay by year**

The following tables indicate the availability of CEC occurrence data for each matrix by year of sample collection. All data were collected by the RMP unless otherwise indicated. CEC data collected using passive samplers as part of the NOAA Mussel Watch CEC Pilot Study are not included in these tables and are instead available in Appendix E.

**Table A1. Pharmaceuticals, Personal Care Product Ingredients, and Related Compounds**

<b>Compound Class</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>
<b>Pharmaceuticals</b>											
<i>Surface Waters</i>							X				X
<i>Sediments</i>											X
<i>Bivalves</i>											X <sup>a</sup>
<b>Triclosan, Triclocarban</b>											
<i>Surface Waters</i>											X
<i>Sediments</i>									X <sup>b</sup>		X
<i>Bivalves</i>											X <sup>a</sup>
<b>Musks</b>											
<i>Bivalves</i>			X	X	X						
<i>Aquatic Bird Eggs</i>			X		X						
<b>Bisphenol A</b>											
<i>Surface Waters</i>											X
<i>Sediments</i>											X
<i>Bivalves</i>											X <sup>a</sup>
<b>Phthalates</b>											
<i>Surface Waters</i>			X	X							
<i>Sediments</i>			X	X <sup>c</sup>							
<i>Bivalves</i>				X	X						
<i>Aquatic Bird Eggs</i>			X		X						
<b>DEET</b>											
<i>Surface Waters</i>											X
<i>Sediments</i>											X
<i>Bivalves</i>											X <sup>a</sup>

<sup>a</sup> Includes samples analyzed as part of the NOAA Mussel Watch CA Pilot Study; <sup>b</sup> Triclosan only; <sup>c</sup> Includes (Hwang et al. 2006)

**Table A2. Alkylphenols and Alkylphenol Ethoxylates**

	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
<b>Nonylphenol</b>											
<i>Surface Waters</i>			X	X							X
<i>Sediments</i>			X	X							X
<i>Bivalves</i>			X	X	X						X <sup>a</sup>
<i>Small Fish</i>							X <sup>b</sup>			X <sup>b</sup>	
<i>Aquatic Bird Eggs</i>			X		X						
<b>Nonylphenol-ethoxylates</b>											
<i>Surface Waters</i>											X
<i>Sediments</i>											X
<i>Bivalves</i>				X	X						X <sup>a</sup>
<i>Aquatic Bird Eggs</i>			X		X						
<b>Octylphenol</b>											
<i>Surface Waters</i>											X
<i>Sediments</i>											X
<i>Bivalves</i>											X <sup>a</sup>

<sup>a</sup> Includes samples analyzed as part of the NOAA Mussel Watch CA Pilot Study (mussel tissue or passive samplers); <sup>b</sup> Small fish only (Diehl et al. 2012)

**Table A3. Flame Retardants**

<b>Compound Class</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>
<b>PBDEs</b>											
<i>Surface Waters</i>			X	X	X	X	X	X	X	X	X
<i>Stormwater</i>						X	X	X	X	X	X
<i>Sediments</i>			X	X	X	X	X	X	X	X	X
<i>Bivalves</i>			X	X		X	X		X		X <sup>e</sup>
<i>Fish</i>	X <sup>a</sup>			X			X			X	
<i>Aquatic Bird Eggs</i>	X <sup>b</sup>	X <sup>b</sup>	X <sup>b</sup>	X <sup>b</sup>	X		X		X	X	
<i>Harbor Seals</i> <sup>c</sup>							X <sup>g</sup>	X	X		
<b>Hexabromocyclododecane</b>											
<i>Sediments</i>								X			
<i>Mussels</i>											X <sup>e</sup>
<i>Fish</i>							X				
<i>Aquatic Bird Eggs</i>									X		
<i>Harbor Seals</i>								X	X		
<b>Pentabromoethylbenzene</b>											
<i>Sediments</i>								X			
<i>Mussels</i>									X		
<i>Fish</i>							X				
<i>Aquatic Bird Eggs</i>									X		
<i>Harbor seals</i>								X	X		
<b>Decabromodiphenylethane</b>											
<i>Sediments</i>								X			
<b>Hexabromobenzene</b>											
<i>Sediments</i>								X			
<i>Mussels</i>									X		
<i>Fish</i>							X				
<i>Aquatic Bird Eggs</i>									X		
<i>Harbor Seals</i>								X	X		

<b>Compound Class</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>
<b>Bis(2-ethylhexyl)tetrabromophthalate</b>											
<i>Sediments</i>								X			
<i>Mussels</i>									X		X <sup>e</sup>
<i>Aquatic Bird Eggs</i>									X		
<b>2-ethylhexyl 2,3,4,5-tetrabromobenzoate</b>											
<i>Sediments</i>								X			
<i>Mussels</i>									X		X <sup>e</sup>
<i>Fish</i>							X				
<i>Aquatic Bird Eggs</i>									X		
<i>Harbor Seals</i>								X	X		
<b>1,2-bis(2,4,6 tribromophenoxy)ethane</b>											
<i>Sediments</i>								X			
<i>Mussels</i>									X		X <sup>e</sup>
<i>Fish</i>							X				
<i>Aquatic Bird Eggs</i>									X		
<i>Harbor Seals</i>								X	X		
<b>Dechlorane Plus</b>											
<i>Sediments</i>								X			
<i>Mussels</i>									X		
<i>Fish</i>							X				
<i>Aquatic Bird Eggs</i>									X		
<i>Harbor seals</i>								X	X		
<b>Organophosphates</b>											
<i>Surface Waters</i>											
<i>Sediments</i>								X			
<i>Bivalves</i>			X <sup>d</sup>	X <sup>d</sup>							X <sup>e</sup>
<i>Aquatic Bird Eggs</i>			X <sup>d</sup>		X <sup>d</sup>					X	

<sup>a</sup> Includes analysis by Brown et al. (Brown et al. 2006). <sup>b</sup> Includes analysis by She et al. (2008); <sup>c</sup> Harbor seal blubber samples collected from 1989-1998 analyzed previously (She et al. 2002; She et al. 2008); <sup>d</sup> Triphenyl phosphate only; <sup>e</sup> Includes samples analyzed as part of the NOAA Mussel Watch CA Pilot Study; <sup>g</sup> seal blood only

**Table A4. Perfluorinated Chemicals**

<b>PFASs</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>
<i>Surface Waters</i>										X	X
<i>Stormwater, Tributaries</i>							X <sup>a</sup>			X	
<i>Effluent</i>										X	
<i>Sediments</i>					X <sup>b</sup>					X	
<i>Bivalves</i>											X <sup>c</sup>
<i>Small Fish</i>										X	
<i>Sport Fish</i>										X	
<i>Bird Eggs</i>							X			X	
<i>Harbor Seal Blood</i>					X		X	X	X		

<sup>a</sup> Hoehn et al. 2007, study of South Bay tributaries; <sup>b</sup> Higgins et al. 2005 study of San Francisco Bay sediments; <sup>c</sup> Includes samples analyzed as part of the NOAA Mussel Watch CA Pilot Study

**Table A5. Current Use Pesticides**

<b>Pesticide</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>
<b>Allethrin</b>											
<i>Sediment</i>									X	X	X <sup>a</sup>
<i>Stormwater</i>									X		X <sup>a</sup>
<b>Ametryn</b>											
<i>Surface Water</i>									X		
<b>Atrazine</b>											
<i>Surface Water</i>									X		
<i>Bivalves</i>											X <sup>a</sup>
<b>Azinphos methyl</b>											
<i>Surface Water</i>									X		
<b>Bifenthrin</b>											
<i>Sediment</i>									X	X	X <sup>a</sup>
<i>Stormwater</i>									X		X <sup>a</sup>
<i>Tributary Sediment</i>						X <sup>e</sup>					
<b>Chlorothalonil</b>											
<i>Bivalves</i>											X <sup>a</sup>
<b>Chlorpyrifos</b>											
<i>Surface Water</i> <sup>d</sup>	X	X	X	X		X			X	X	
<i>Bivalves</i>			X	X							X <sup>a</sup>
<b>Chlorpyrifos methyl</b>											
<i>Surface Water</i> <sup>d</sup>									X		
<b>Chlorpyrifos,</b>											
<i>Bivalves</i>											X <sup>a</sup>
<b>Chlorpyrifos, oxon</b>											
<i>Bivalves</i>											X <sup>a</sup>
<b>Chlorpyrifos, oxy</b>											
<i>Bivalves</i>											X <sup>a</sup>
<b>Cinerin-1</b>											
<i>Stormwater</i>									X		
<b>Cinerin-2</b>											
<i>Stormwater</i>									X		

<b>Pesticide</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>
<b>Cyanazine</b>											
<i>Surface Water</i>									X		
<i>Bivalves</i>											X <sup>a</sup>
<b>Cyfluthrin, total</b>											
<i>Sediment</i>									X	X	X
<i>Stormwater</i>									X		X
<i>Tributary Sediment</i>						X <sup>c</sup>					
<b>Cyhalothrin,</b>											
<i>Sediment</i>									X	X	X
<i>Stormwater</i>									X		X
<b>Cypermethrin</b>											
<i>Bivalves</i>											X <sup>a</sup>
<b>Cypermethrin, total</b>											
<i>Surface Water</i>									X		
<i>Sediment</i>									X	X	X
<i>Tributary Sediment</i>						X <sup>c</sup>					
<i>Stormwater</i>									X		X
<b>Dacthal</b>											
<i>Surface Water</i> <sup>d</sup>	X	X	X	X	X	X	X	X	X	X	
<i>Stormwater</i>		X	X				X		X		X
<i>Bivalves</i>			X	X							X <sup>a</sup>
<b>DCBP(p,p')</b>											
<i>Bivalves</i>			X	X							
<b>Deltamethrin</b>											
<i>Sediment</i>									X		
<b>Desethylatrazine</b>											
<i>Bivalves</i>											X <sup>a</sup>
<b>Diazinon</b>											
<i>Surface Water</i> <sup>d</sup>	X	X	X	X		X			X	X	
<i>Bivalves</i>			X	X							X <sup>a</sup>
<b>Diazinon, oxon</b>											
<i>Bivalves</i>											X <sup>a</sup>

<b>Pesticide</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>
<b>Diazoxon</b>											
<i>Surface Water</i>									X		
<b>Dimethoate</b>											
<i>Surface Water</i>									X		
<i>Bivalves</i>											X <sup>a</sup>
<b>Disulfoton</b>											
<i>Surface Water</i>									X		
<b>Disulfoton sulfone</b>											
<i>Surface Water</i>									X		
<b>Diuron</b>											
<i>Surface Water</i>							X <sup>b</sup>				
<b>Esfenvalerate/ Fenvalerate, total</b>											
<i>Sediment</i>									X	X	X
<i>Stormwater</i>											X
<b>Esfenvalerate/ Fenvalerate-1</b>											
<i>Stormwater</i>									X		
<b>Ethion</b>											
<i>Surface Water</i>									X		
<i>Bivalves</i>											X <sup>a</sup>
<b>Fenitrothion</b>											
<i>Surface Water</i>									X		
<i>Bivalves</i>											X <sup>a</sup>
<b>Fenpropathrin</b>											
<i>Sediment</i>									X	X	X
<i>Stormwater</i>									X		X
<b>Fipronil desulfinyl</b>											
<i>Sediment</i>										X	X
<b>Fipronil sulfide</b>											
<i>Sediment</i>										X	X
<b>Fipronil sulfone</b>											

<b>Pesticide</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>
<i>Sediment</i>											X
<b>Flucythrinate</b>											
<i>Stormwater</i>									X		
<b>Fonofos</b>											
<i>Surface Water</i>									X		
<i>Bivalves</i>											X <sup>a</sup>
<b>Hexazinone</b>											
<i>Surface Water</i>									X		
<i>Bivalves</i>											X <sup>a</sup>
<b>Irgarol and metabolite GS26575</b>											
<i>Surface Water</i>							X <sup>b,c</sup>				
<b>Jasmolin-1</b>											
<i>Stormwater</i>									X		
<b>Jasmolin-2</b>											
<i>Stormwater</i>									X		
<b>Malathion</b>											
<i>Surface Water</i>									X		
<i>Bivalves</i>											X <sup>a</sup>
<b>Methamidophos</b>											
<i>Surface Water</i>									X		
<b>Methoxychlor</b>											
<i>Surface Water</i> <sup>d</sup>	X	X							X		
<i>Bivalves</i>			X	X							
<b>Metribuzin</b>											
<i>Surface Water</i>									X		
<i>Bivalves</i>											X <sup>a</sup>
<b>Octachlorostyrene</b>											
<i>Surface Water</i>									X		
<b>Oxadiazon</b>											
<i>Surface Water</i> <sup>d</sup>	X	X	X	X	X	X	X	X			
<i>Stormwater</i>		X	X				X		X		
<i>Bivalves</i>			X	X							

<b>Pesticide</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>
<b>Parathion, Ethyl</b>											
<i>Surface Water</i>									X		
<i>Bivalves</i>			X	X							X <sup>a</sup>
<b>Parathion, Methyl</b>											
<i>Surface Water</i>									X		
<i>Bivalves</i>			X	X							X <sup>a</sup>
<b>Permethrin, total</b>											
<i>Surface Water</i>									X		
<i>Tributary Sediment</i>						X <sup>e</sup>					
<i>Stormwater</i>									X		X
<i>Bivalves</i>											X <sup>a</sup>
<b>Permethrin, cis-</b>											
<i>Sediment</i>									X	X	X
<b>Permethrin, trans-</b>											
<i>Sediment</i>									X	X	X
<b>Perthane</b>											
<i>Surface Water</i>									X		
<b>Phenothrin</b>											
<i>Sediment</i>									X	X	X
<i>Stormwater</i>									X		X
<b>Phorate</b>											
<i>Surface Water</i>									X		
<b>Phosmet</b>											
<i>Surface Water</i>									X		
<i>Bivalves</i>											X <sup>a</sup>
<b>Pirimiphos methyl</b>											
<i>Surface Water</i>									X		
<b>Pirimiphos, methyl</b>											
<i>Bivalves</i>											X <sup>a</sup>
<b>Prallethrin</b>											
<i>Sediment</i>									X	X	X
<i>Stormwater</i>									X		X
<b>Pyrethrin-1</b>											

<b>Pesticide</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>
<i>Stormwater</i>									X		
<b>Pyrethrin-2</b>											
<i>Stormwater</i>									X		
<b>Quintozene</b>											
<i>Bivalves</i>											X <sup>a</sup>
<b>Resmethrin</b>											
<i>Sediment</i>									X	X	X
<i>Stormwater</i>									X		X
<b>Simazine</b>											
<i>Surface Water</i>									X		
<i>Bivalves</i>											X <sup>a</sup>
<b>Tecnazene</b>											
<i>Surface Water</i>									X		
<b>Terbufos</b>											
<i>Surface Water</i>									X		
<i>Bivalves</i>											X <sup>a</sup>
<b>Tetramethrin</b>											
<i>Sediment</i>									X	X	X

<sup>a</sup> Samples analyzed as part of the NOAA Mussel Watch CA Pilot Study; <sup>b</sup> (Sapozhnikova et al. 2008); <sup>c</sup> (Hall et al. 2009); <sup>d</sup> Data available for samples collected prior to 2000; <sup>e</sup> (Lowe et al. 2007)

**Table A6. Short-Chain Chlorinated Paraffins**

<b>SCCPs</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>
<i>Sport Fish</i>							X				
<i>Aquatic Bird Eggs</i>							X				
<i>Harbor Seal Blubber</i>								X			

**Table A7. Nanomaterials**

<b>Single-walled carbon nanotubes</b>	<b>2000</b>	<b>2001</b>	<b>2002</b>	<b>2003</b>	<b>2004</b>	<b>2005</b>	<b>2006</b>	<b>2007</b>	<b>2008</b>	<b>2009</b>	<b>2010</b>
<i>Sediments</i>								X			
<i>Mussels</i>											X <sup>a</sup>

<sup>a</sup> NOAA Mussel Watch CA Pilot Study

## **Appendix B – Maximum concentrations and frequencies of detection of CECs analyzed in San Francisco Bay by compound class and matrix**

The following tables contain the maximum concentrations and frequencies of detection for CECs analyzed in San Francisco Bay samples. The tables include data collected as part of RMP studies, other researchers (where indicated), and mussel samples collected in 2010 and analyzed as part of the National NOAA Mussel Watch California CEC Pilot Study (all studies indicated in Appendix A). CEC data collected using passive samplers as part of the Mussel Watch Pilot Study are not included in these tables and are instead available in Appendix E.

**Table B1. Maximum concentrations and frequencies of detection of pharmaceuticals**

<b>Compound</b>	<b>Surface Waters (ng/L)</b>		<b>Sediments (ng/g dw)</b>		<b>Mussels (ng/g dw)</b>	
Acetaminophen	<270		<61		<99	
<b>Albuterol</b>	<b>1</b>	<b>1/15</b>	<0.3		<4.9	
Alprazolam	<0.3		<0.3		<1.9	
<b>Amitriptyline</b>	<b>0.6</b>	<b>2/5</b>	<1.4		<b>6.2</b>	<b>8/14</b>
<b>10-hydroxy-amitriptyline</b>	<b>0.3</b>	<b>2/5</b>	<0.2		<0.6	
Amlodipine	<1.5		<1.8		<6.6	
<b>Amphetamine</b>	<b>9.7</b>	<b>2/5</b>	<b>3.3</b>	<b>2/5</b>	<b>31</b>	<b>5/14</b>
<b>Atenolol</b>	<b>37</b>	<b>5/5</b>	<0.9		<b>13</b>	<b>3/14</b>
Atorvastatin	<25		<5.1		<13	
Azithromycin	<1.5		NQ		<11	
<b>Benzoylcegonine</b>	<b>7.2</b>	<b>5/5</b>	<0.3		<1.3	
Benztropine	<0.3		<0.3		<1.1	
Betamethasone	<5.0		<4.0		<20	
<b>Caffeine</b>	<b>132</b>	<b>12/15</b>	<b>34</b>	<b>3/5</b>	<59	
Carbadox	<25.1		NQ		<5.9	
<b>Carbamazepine</b>	<b>44</b>	<b>5/5</b>	NQ		<b>35</b>	<b>5/14</b>
Cefotaxime	<21		NQ		<24	
Cimetidine	<3.0		<6.0		<37	
<b>Ciprofloxacin</b>	<6.0-1300 <sup>a</sup>		<b>678</b>	<b>2/2</b>	<24	
<b>Clarithromycin</b>	<b>18</b>	<b>2/5</b>	<1.5		<5.9	
Clinafloxacin	<48		NQ		<56	
Clonidine	<25		<5.1		<13.9	
Cloxacillin	<1.7		NQ		<12	
<b>Cocaine</b>	<b>2.4</b>	<b>4/5</b>	<b>0.2</b>	<b>1/4</b>	<b>1.6</b>	<b>4/14</b>
Codeine	<15-3830 <sup>a</sup>		<3.1		<45	
<b>Cotinine</b>	<b>25</b>	<b>4/15</b>	<1.5		<14	
<b>Dehydronifedipine</b>	<b>1.3</b>	<b>4/5</b>	NQ		<b>4.8</b>	<b>5/14</b>
<b>Desmethyldiltiazem</b>	<b>1.7</b>	<b>2/5</b>	NQ		<1.0	
<b>Diazepam</b>	<b>0.5</b>	<b>1/5</b>	<0.3		<3.0	
<b>Digoxigenin</b>	<568		NQ		<b>73</b>	<b>3/14</b>

Digoxin	<15-5970 <sup>a</sup>		NQ		<24	
<b>Diltiazem</b>	<b>13.7</b>	<b>12/15</b>	NQ		<b>1.5</b>	<b>4/14</b>
1,7-Dimethylxanthine	<150		<151		<235	
<b>Diphenhydramine</b>	<b>1.9</b>	<b>4/5</b>	NQ		<b>42</b>	<b>11/14</b>
<b>Enalapril</b>	<1.5		<0.3		<b>1</b>	<b>2/14</b>
<b>Enrofloxacin</b>	<6.6-1400 <sup>a</sup>		NQ		<b>11</b>	<b>1/9</b>
<b>Erythromycin-H2O</b>	<b>41.6</b>	<b>14/15</b>	<b>3.4</b>	<b>1/5</b>	<b>2.1</b>	<b>5/14</b>
Flumequine	<2.5		NQ		<5.4	
Fluocinonide	<6.0		<6.1		<37	
<b>Fluoxetine</b>	<34.4		<7.1		<b>7.2</b>	<b>4/14</b>
Fluticasone propionate	<2.5		<2.0		<7.9	
Furosemide	<170		<41		<164	
<b>Gemfibrozil</b>	<b>38</b>	<b>15/15</b>	<1.6		<12	
Glipizide	<6.0		<6.2		<23	
Glyburide	<3.0		<3.1		<36	
Hydrochlorothiazide	<20		<21		<82	
<b>Hydrocodone</b>	<b>7.2</b>	<b>1/5</b>	<1.5		<46	
Hydrocortisone	<593		<61		<783	
<b>Ibuprofen</b>	<b>38</b>	<b>1/15</b>	<16		<58	
Ibuprofen, 2-hydroxy-	<79		<83		<308	
Lincomycin	<7.0		NQ		<12	
<b>Lomefloxacin</b>	<3.8		NQ		<b>90</b>	<b>6/9</b>
<b>Meprobamate</b>	<b>36</b>	<b>5/5</b>	<4.0		<16	
Metformin	NQ		<53		<346	
<b>Methylprednisolone</b>	<4.0		<4.0		<b>46</b>	<b>1/14</b>
<b>Metoprolol</b>	<b>26</b>	<b>3/5</b>	<1.5		<7.9	
Miconazole	<1.5		NQ		<5.9	
<b>Naproxen</b>	<b>8.2</b>	<b>1/5</b>	<3.1		<12	
Norfloxacin	<53-2760 <sup>a</sup>		NQ		<103	
Norfluoxetine	<1.5		<4.6		<5.9	
Norgestimate	<34.4		NQ		<7.4	
Norverapamil	<0.2		<0.2		<0.6	

<b>Ofloxacin</b>	<15		NQ		<b>12.6</b>	<b>1/9</b>
Ormetoprim	<0.6		NQ		<2.4	
Oxacillin	<3.0		NQ		<12	
Oxolinic acid	<3.5		NQ		<8.1	
Oxycodone	<3.0		<0.6		<33	
Paroxetine	<4.0		<4.0		<6	
Penicillin G	<4.0		NQ		<12	
Penicillin V	<3.0		NQ		<12	
Prednisolone	<19		<6.1		<57	
Prednisone	<45		<20		<102	
Promethazine	<0.4		<0.4		<5.0	
<b>Propoxyphene</b>	<b>0.7</b>	<b>2/5</b>	<4.5		<3.2	
<b>Propranolol</b>	<2.0		<2.0		<b>8.2</b>	<b>1/14</b>
<b>Ranitidine</b>	<3.0		<0.6		<b>24</b>	<b>6/14</b>
Roxithromycin	<9.9		<0.3		<1.2	
Sarafloxacin	<15		NQ		<59	
<b>Sertraline</b>	<0.4		<0.4		<b>19</b>	<b>10/14</b>
Simvastatin	<20		<18		<78	
Sulfachloropyridazine	<1.5-251 <sup>a</sup>		<1.5		<5.9	
Sulfadiazine	<1.5		<1.5		<5.9	
Sulfadimethoxine	<0.3-223 <sup>a</sup>		<0.6		<2.8	
Sulfamerazine	<1.2-105 <sup>a</sup>		<1.1		<4.2	
<b>Sulfamethazine</b>	<0.6-351 <sup>a</sup>		<1.5		<b>89</b>	<b>1/14</b>
<b>Sulfamethizole</b>	<b>16</b>	<b>1/15</b>	<0.8		<b>1.5</b>	<b>1/14</b>
<b>Sulfamethoxazole</b>	<b>1060</b>	<b>12/15</b>	<b>0.7</b>	<b>1/5</b>	<4.7	
Sulfanilamide	<15		<15		<59	
Sulfathiazole	<100		<1.5		<5.9	
Theophylline	<60		<61		<235	
<b>Thiabendazole</b>	<b>2.5</b>	<b>1/5</b>	<b>9.1</b>	<b>2/5</b>	<5.9	
Trenbolone	<4.0		<4.0		<16	
Trenbolone acetate	<0.7		<0.6		<5.7	
<b>Triamterene</b>	<b>9.6</b>	<b>5/5</b>	<b>11</b>	<b>5/5</b>	<b>9.1</b>	<b>4/14</b>

<b>Trimethoprim</b>	<b>8.54</b>	<b>3/15</b>	<b>18</b>	<b>1/5</b>	<5.9	
Tylosin	<104		<6.1		<24	
<b>Valsartan</b>	<b>92</b>	<b>5/5</b>	NQ		<16	
<b>Verapamil</b>	<0.2		NQ		<b>1</b>	<b>1/14</b>
<b>Virginiamycin</b>	<34.4		NQ		<b>14</b>	<b>2/10</b>
Warfarin	<1.5		<1.6		<5.9	

**Compounds in bold were detected in at least one matrix;** <sup>a</sup> For '<XX', XX=maximum MDL for all samples in most cases; where the maximum MDL from the earlier, Harrold et al. (2009) study is over 50x greater than that of the Klosterhaus et al. (2013) study, both are listed to reflect significant improvements to the analytical method; dw=dry weight; ww=wet weight; NQ=not quantifiable;

**Table B2. Maximum concentrations and frequencies of detection of personal care products and related compounds**

<b>Compound</b>	<b>Surface Waters (ng/L)</b>		<b>Sediments (ng/g dw)</b>		<b>Mussels (ng/g dw)</b>		<b>Cormorant Eggs (ng/g ww)</b>	
Bisphenol A	<2470		<2580		<10,200		NA	
<b>N, N-diethyl-m-toluamide (DEET)</b>	<b>21</b>	<b>5/5</b>	<b>3.4</b>	<b>2/5</b>	<b>92</b>	<b>10/10</b>	NA	
<b>Celestolide</b>	NA		NA		<b>93</b>	<b>5/39</b>	<2	
<b>Galaxolide</b>	NA		NA		<b>855</b>	<b>19/39</b>	<b>1</b>	<b>1/13</b>
<b>Tonalide</b>	NA		NA		<b>516</b>	<b>24/39</b>	<b>1</b>	<b>2/13</b>
<b>Versalide</b>	NA		NA		<b>56</b>	<b>3/39</b>	<2	
Musk ambrette	NA		NA		<20		<5	
Musk ketone	NA		NA		<20		<1	
Musk moskene	NA		NA		<20		<5	
Musk xylene	NA		NA		<20		<1	
<b>Bis(2-ethylhexyl) phthalate</b>	<b>459</b>	<b>5/15</b>	<b>605,</b> (32,000 <sup>a</sup> )	<b>10/10</b>	<b>968</b>	<b>11/22</b>	<b>1880</b>	<b>4/11</b>
<b>Butylbenzyl phthalate</b>	<b>14</b>	<b>7/11</b>	<b>323</b>	<b>22/22</b>	<10		<b>46</b>	<b>1/11</b>
<b>Di-n-butyl phthalate</b>	<b>35</b>	<b>6/13</b>	<b>94</b>	<b>10/11</b>	<b>2620</b>	<b>21/22</b>	<b>512</b>	<b>2/11</b>
<b>Triclocarban</b>	<3.0		<b>33</b>	<b>3/5</b>	<b>11</b>	<b>2/10</b>	NA	
<b>Triclosan</b>	<60		<b>41</b>	<b>9/17</b>	<238		NA	

**Compounds in bold were detected in at least one matrix;** <sup>a</sup> Stege Marsh only, all but highest concentration (32,000 ng/g) below 3000 ng/g; dw=dry weight; ww=wet weight; NA=not analyzed

**Table B3. Maximum concentrations and frequencies of detection of alkylphenols and alkylphenol ethoxylates**

<u>Compound</u>	<u>Surface Waters (ng/L)</u>		<u>Sediments (ng/g dw)</u>		<u>Mussels (ng/g dw)</u>		<u>Small Fish (ng/g ww)</u>		<u>Cormorant Eggs (ng/g ww)</u>	
4-Nonylphenol	73	60/99	86	7/70	1290	12/45	420	6/6	123	2/10
Octylphenol	<3.0		<0.3		<7		NA		NA	
Nonylphenol-ethoxylates <sup>a</sup>					3550	11/22			228	2/10
4-Nonylphenol monoethoxylates	<16		40	5/70	300	9/10	NA		NA	
4-Nonylphenol diethoxylates	<23		19	4/70	1420	9/10	NA		NA	

Compounds in bold were detected in at least one matrix; dw=dry weight; ww=wet weight; <sup>a</sup> RMP analysis from 2002-2004 did not distinguish between mono- or diethoxylates

**Table B4. Maximum concentrations and frequencies of detection of flame retardants<sup>a</sup>**

<b><u>Compound</u></b>	<b><u>Surface Waters</u> <u>(ng/L)</u></b>		<b><u>Stormwater (ng/L)</u></b>		<b><u>Sediments</u> <u>(ng/g dw)</u></b>		<b><u>Bivalves</u> <u>(ng/g)</u></b>	
<b>ΣPBDEs</b>	<b>1.4</b>		<b>425</b>		<b>54</b>		<b>229 (dw)</b>	
<b>BDE-47 + BDE-99</b>	<b>0.5</b>	<b>275/275</b>	<b>37</b>	<b>60/60</b>	<b>8</b>	<b>403/403</b>	<b>76.7 (dw)</b>	<b>64/67</b>
<b>BDE-209</b>	<b>2.7</b>	<b>75/99</b>	<b>160</b>	<b>40/40</b>	<b>52</b>	<b>341/345</b>	<b>34 (dw)</b>	<b>16/20</b>
<b>S Hexabromocyclododecane</b>	NA		NA		<b>1.7</b>	<b>10/10</b>	<b>1.3 (dw)</b>	<b>1/3</b>
<b>Pentabromoethylbenzene</b>	NA		NA		<b>0.1</b>	<b>6/10</b>	<b>0.02 (ww)</b>	<b>2/10</b>
Decabromodiphenyl ethane	NA		NA		<24		NA	
<b>1,2-bis(2,4,6 tribromophenoxy)ethane</b>	NA		NA		<b>0.06</b>	<b>5/10</b>	<1 (dw)	
Hexabromobenzene	NA		NA		<0.02		<0.04 (ww)	
2-ethylhexyl 2,3,4,5-tetrabromobenzoate	NA		NA		<0.01		<1 (dw)	
Bis(2-ethylhexyl)-tetrabromophthalate	NA		NA		<0.20		<1 (dw)	
<b>Dechlorane Plus</b>	NA		NA		<b>0.9</b>	<b>10/10</b>	<b>0.05 (ww)</b>	<b>5/10</b>
<b>Tris(1,3-dichloro-2-propyl) phosphate</b>	NA		NA		<b>19<sup>b</sup></b>	<b>10/10</b>	<1 (dw)	
<b>Tris(2-chloroisopropyl) phosphate</b>	NA		NA		<b>16<sup>b</sup></b>	<b>8/10</b>	<1 (dw)	
Tris(2-chloroethyl) phosphate	NA		NA		NA		<1 (dw)	
<b>Triphenyl phosphate</b>	NA		NA		<b>20<sup>b</sup></b>	<b>8/10</b>	<b>378 (dw)</b>	<b>12/24</b>
Tris(2-butoxyethyl) phosphate	NA		NA		NA		NA	
Tripropylphosphate	NA		NA		NA		NA	
Tris(2,3-dibromopropyl) phosphate	NA		NA		NA		NA	
Tributyl phosphate	NA		NA		NA		NA	
Tricresyl phosphate	NA		NA		NA		NA	
2-Ethylhexyl-diphenyl phosphate	NA		NA		NA		NA	
Tris(2-bromo-4-methylphenyl) phosphate	NA		NA		NA		NA	
Tris(2-ethylhexyl) phosphate	NA		NA		NA		NA	

<u>Compound</u>	<u>Sport fish (ng/g ww)</u>		<u>Aquatic Bird Eggs (ng/g ww)</u>		<u>Harbor Seal Blubber (ng/g lipid)</u>	
<b>ΣPBDEs</b>	<b>91</b>		<b>961 (63,300 lw)<sup>c</sup></b>		<b>8,325</b>	
<b>BDE-47 + BDE-99</b>	<b>73</b>	<b>193/289</b>	<b>684</b>	<b>46/46</b>	<b>2,425</b>	<b>8/8</b>
<b>BDE-209</b>	<3		<53		<b>672</b>	<b>1/4</b>
<b>S Hexabromocyclododecane</b>	<b>0.4</b>	<b>10/14</b>	<b>1.8</b>	<b>3/3</b>	<b>19</b>	<b>17/17</b>
<b>Pentabromoethylbenzene</b>	<0.08		<0.03		<b>0.5</b>	<b>16/18</b>
Decabromodiphenyl ethane	NR		NR		NR	
1,2-bis(2,4,6 tribromophenoxy)ethane	<0.14		<0.06		<0.1	
<b>Hexabromobenzene</b>	<b>14.2 (lw)<sup>d</sup></b>	<b>2/14<sup>d</sup></b>	<0.3		<1	
2-ethylhexyl 2,3,4,5-tetrabromobenzoate	<1.4		<0.3		<1	
Bis(2-ethylhexyl)-tetrabromophthalate	NA		<0.6		NR	
<b>Dechlorane Plus</b>	<b>0.06</b>	<b>11/14</b>	<b>0.09</b>	<b>3/3</b>	<b>7</b>	<b>10/17</b>
Tris(1,3-dichloro-2-propyl) phosphate	NA		<0.01		NA	
<b>Tris(2-chloroisopropyl) phosphate</b>	NA		<b>1</b>	<b>9/9</b>	NA	
<b>Tris(2-chloroethyl) phosphate</b>	NA		<b>3.3</b>	<b>9/9</b>	NA	
Triphenyl phosphate	NA		<0.06		NA	
<b>Tris(2-butoxyethyl) phosphate</b>	NA		<b>1.2</b>	<b>9/9</b>	NA	
Tripropylphosphate	NA		<0.06		NA	
Tris(2,3-dibromopropyl) phosphate	NA		<0.12		NA	
Tributyl phosphate	NA		<0.01		NA	
Tricresyl phosphate	NA		<0.1		NA	
2-Ethylhexyl-diphenyl phosphate	NA		<0.05		NA	
Tris(2-bromo-4-methylphenyl) phosphate	NA		<0.1		NA	
Tris(2-ethylhexyl) phosphate	NA		<0.05		NA	

**Compounds in bold were detected in at least one matrix;** <sup>a</sup> Many of the organophosphate compounds are also used as plasticizers; <sup>b</sup> estimated values only because labeled internal standards not available at time of analysis; <sup>c</sup> Maximum concentration in lipid weight (wet weight not provided) for Forster's terns in She et al. (2008); <sup>d</sup> These detections did not pass the analytical laboratory's quality assurance criteria; NA=not analyzed; NR=not reportable

**Table B5. Maximum concentrations and frequencies of detection of perfluorinated chemicals in San Francisco Bay**

<b><u>Compound</u></b>	<b><u>Surface water (ng/L)</u></b>		<b><u>Storm-water (ng/L)</u></b>		<b><u>Effluent (ng/L)<sup>a</sup></u></b>
<b>N-Ethyl-perfluorooctane-sulfonamide</b>	<b>5.36</b>	<b>1/10</b>	<b>&lt;9.2</b>		<b>&lt;4.8</b>
N-Ethyl-perfluorooctane-sulfonamido-ethanol	<0.6		<1.0		<0.5
N-Methyl-perfluorooctane-sulfonamide	<5.4		<18		<9.2
N-Methyl-perfluorooctane-sulfonamido-ethanol	<2.0		<2.1		<1.2
<b>Perfluorobutanesulfonate</b>	<b>7.89</b>	<b>1/11</b>	<b>6.5</b>	<b>2/7</b>	<b>6</b>
<b>Perfluorobutanoate</b>	<b>62.2</b>	<b>3/11</b>	<b>18</b>	<b>6/7</b>	<b>7.4</b>
<b>Perfluorodecanoate</b>	<b>12</b>	<b>1/11</b>	<b>29</b>	<b>4/7</b>	<b>3.8</b>
<b>Perfluorododecanoate</b>	<b>&lt;1.0</b>		<b>1.7</b>	<b>3/8</b>	<b>&lt;1.0</b>
<b>Perfluoroheptanoate</b>	<b>67</b>	<b>5/11</b>	<b>26</b>	<b>5/7</b>	<b>5.3</b>
<b>Perfluorohexanesulfonate</b>	<b>13</b>	<b>4/11</b>	<b>10</b>	<b>4/7</b>	<b>5.5</b>
<b>Perfluorohexanoate</b>	<b>221</b>	<b>7/11</b>	<b>32</b>	<b>7/7</b>	<b>17</b>
<b>Perfluorononanoate</b>	<b>15</b>	<b>5/12</b>	<b>24</b>	<b>6/7</b>	<b>12</b>
<b>Perfluorooctane-sulfonamide</b>	<b>&lt;1.0</b>		<b>1.1</b>	<b>1/7</b>	<b>&lt;1.0</b>
<b>Perfluorooctanesulfonate</b>	<b>44</b>	<b>6/11</b>	<b>14</b>	<b>6/7</b>	<b>24</b>
<b>Perfluorooctanoate</b>	<b>76</b>	<b>9/11</b>	<b>69</b>	<b>7/7</b>	<b>32</b>
<b>Perfluoropentanoate</b>	<b>151</b>	<b>7/12</b>	<b>6.5</b>	<b>4/8</b>	<b>6.7</b>
<b>Perfluoroundecanoate</b>	<b>&lt;1.0</b>		<b>4.7</b>	<b>3/7</b>	<b>&lt;1.0</b>
Perfluorodecane sulfonate	NA		NA		NA

<b><u>Compound</u></b>	<b><u>Sediments (ng/g dw)</u></b>		<b><u>Bivalves (ng/g dw)</u></b>		<b><u>Small Fish (ng/g ww)</u></b>	
<b>N-Ethyl-perfluorooctane-sulfonamide</b>	<3.0		NA		<5.0	
N-Ethyl-perfluorooctane-sulfonamido-ethanol	<3.0		NA		<5.0	
N-Methyl-perfluorooctane-sulfonamide	<3.0		NA		<5.0	
N-Methyl-perfluorooctane-sulfonamido-ethanol	<3.0		NA		<5.0	
Perfluorobutanesulfonate	<3.0		<39		<5.0	
<b>Perfluorobutanoate</b>	<3.0		<20		<5.0	
<b>Perfluorodecanoate</b>	<b>0.5</b>	<b>5/11</b>	<20		<b>3.4</b>	<b>1/14</b>
<b>Perfluorododecanoate</b>	<b>0.473</b>	<b>6/11</b>	<b>2.2</b>	<b>1/14</b>	<5.0	
<b>Perfluoroheptanoate</b>	<b>0.2</b>	<b>1/11</b>	<20		<5.0	
<b>Perfluorohexanesulfonate</b>	<3.0		<b>30</b>	<b>2/14</b>	<b>7.5</b>	<b>1/14</b>
<b>Perfluorohexanoate</b>	<b>0.148</b>	<b>1/11</b>	<20		<5.0	
<b>Perfluorononanoate</b>	<b>0.6</b>	<b>6/11</b>	<20		<5.0	
<b>Perfluorooctane-sulfonamide</b>	<b>0.3</b>	<b>4/11</b>	<b>6.6</b>	<b>1/14</b>	<b>9.6</b>	<b>2/14</b>
<b>Perfluorooctanesulfonate</b>	<b>3.2</b>	<b>10/11</b>	<b>417</b>	<b>1/14</b>	<b>80</b>	<b>9/14</b>
<b>Perfluorooctanoate</b>	<b>1.1</b>	<b>6/11</b>	<20		<5.0	
<b>Perfluoropentanoate</b>	<3.0		<20		<5.0	
<b>Perfluoroundecanoate</b>	<b>0.2</b>	<b>4/11</b>	<20		<5.0	
Perfluorodecane sulfonate	NA		<1.0		NA	

<u>Compound</u>	<u>Sport Fish (ng/g ww)</u>		<u>Cormorant Eggs (ng/g ww)</u>		<u>Harbor Seal Blood (ng/mL)</u>	
N-Ethyl-perfluorooctane-sulfonamide	NA		NA		NA	
N-Ethyl-perfluorooctane-sulfonamido-ethanol	NA		NA		NA	
N-Methyl-perfluorooctane-sulfonamide	NA		NA		NA	
N-Methyl-perfluorooctane-sulfonamido-ethanol	NA		NA		NA	
Perfluorobutanesulfonate	<5.0		<9.3		<5	
<b>Perfluorobutanoate</b>	<2.5		<b>3.2</b>	<b>1/28</b>	<b>0.6</b>	<b>1/37</b>
<b>Perfluorodecanoate</b>	<2.5		<b>28</b>	<b>26/28</b>	<b>32.7</b>	<b>36/37</b>
<b>Perfluorododecanoate</b>	<2.5		<b>20</b>	<b>27/28</b>	<b>15</b>	<b>27/37</b>
<b>Perfluoroheptanoate</b>	<2.5		<4.6		<b>3.4</b>	<b>7/37</b>
<b>Perfluorohexanesulfonate</b>	<5.0		<b>40</b>	<b>14/28</b>	<b>154</b>	<b>34/37</b>
<b>Perfluorohexanoate</b>	<2.5		<4.6		<1.1	
<b>Perfluorononanoate</b>	<2.5		<b>39.5</b>	<b>26/28</b>	<b>43</b>	<b>37/37</b>
<b>Perfluorooctane-sulfonamide</b>	<b>4.2</b>	<b>8/251</b>	<b>3.1</b>	<b>2/28</b>	<2.5	
<b>Perfluorooctanesulfonate</b>	<b>18</b>	<b>84/251</b>	<b>1760</b>	<b>28/28</b>	<b>1960</b>	<b>37/37</b>
<b>Perfluorooctanoate</b>	<2.5		<b>29</b>	<b>13/28</b>	<b>11</b>	<b>22/37</b>
<b>Perfluoropentanoate</b>	<2.5		<4.6		<0.5	
<b>Perfluoroundecanoate</b>	<2.5		<b>11</b>	<b>28/28</b>	<b>22</b>	<b>37/37</b>
Perfluorodecane sulfonate	NA		NA		NA	

**Compounds in bold were detected in at least one matrix;** NA=not analyzed; <sup>a</sup> These values represent an average of six sites; At the request of the dischargers, the sites are anonymous.

**Table B6. Maximum concentrations and frequencies of detection of current use pesticides**

<u>Analyte Name</u>	<u>Surface waters (ng/L)</u>		<u>Stormwater (ng/L)</u>		<u>Sediment (ng/g dw)</u>		<u>Tributary Sediment (ng/g dw)</u>	<u>Bivalves (ng/g dw)</u>	
<b>Allethrin</b>	NA		<76		<b>14</b>	<b>11/81</b>	NA	NA	
<b>Ametryn</b>	<b>0.15</b>	<b>2/7</b>	NA		NA		NA	NA	
<b>Atrazine</b>	<b>0.57</b>	<b>7/7</b>	NA		NA		NA	<100	
Azinphos methyl	<0.81		NA		NA		NA	NA	
<b>Bifenthrin</b>	NA		<b>46</b>	<b>10/15</b>	<b>1</b>	<b>23/77</b>	10.3	NA	
Chlorothalonil	NA		NA		NA		NA	<1.0	
<b>Chlorpyrifos</b>	<b>1.2</b>	<b>152/474</b>	NA		NA		NA	<b>1.66</b>	<b>1/3</b>
<b>Chlorpyrifos methyl</b>	<0.01		NA		NA		NA	<b>0.76</b>	<b>1/3</b>
Chlorpyrifos, oxon	NA		NA		NA		NA	<7.3	
<b>Chlorpyrifos, oxy</b>	NA		NA		NA		NA	<b>0.14</b>	<b>1/3</b>
Cinerin-1	NA		<80		NA		NA	NA	
Cyanazine	<0.16		NA		NA		NA	<144	
<b>Cyfluthrin, total</b>	NA		<22		<b>1.1</b>	<b>1/81</b>	<b>8.6</b>	NA	
<b>Cyhalothrin, lambda, total</b>	NA		<b>6.1</b>	<b>2/15</b>	<b>0.35</b>	<b>2/73</b>	NA	NA	
<b>Cypermethrin, total</b>	<b>32</b>	<b>1/7</b>	<5.6		<b>0.78</b>	<b>2/81</b>	<b>4.2</b>	<14	
<b>Dacthal</b>	<b>0.62</b>	<b>579/627</b>	<b>31</b>	<b>45/48</b>	NA		NA	<b>0.64</b>	<b>3/32</b>
DCBP(p,p')	NA		NA		NA		NA	<14	
Deltamethrin	NA		NA		<0.50		NA	NA	
Desethylatrazine	NA		NA		NA		NA	<2.8	
<b>Diazinon</b>	<b>22</b>	<b>275/477</b>	NA		NA		NA	<119	
Diazoxon	<0.06		NA		NA		NA	<16	
Dimethoate	<0.27		NA		NA		NA	<118	
Diuron	NA		NA		NA		NA	NA	
<b>Esfenvalerate/Fenvalerate, total</b>	NA		<4.2		<b>0.58</b>	<b>2/81</b>	NA	NA	
Esfenvalerate/Fenvalerate-1	NA		<0.70		NA		NA	NA	
Ethion	<0.03		NA		NA		NA	<4.0	
Fenitrothion	<0.04		NA		NA		NA	<12	
Fenpropathrin	NA		<6.4		<2.2		NA	NA	
<b>Fipronil desulfinyl</b>	NA		NA		<b>0.16</b>	<b>77/109</b>	NA	NA	
<b>Fipronil sulfide</b>	NA		NA		<b>0.05</b>	<b>98/98</b>	NA	NA	

<b>Fipronil sulfone</b>	NA		NA		<b>0.56</b>	<b>61/65</b>	NA		NA	
Flucythrinate	NA		<0.5		NA		NA		NA	
Fonofos	<0.02		NA		NA		NA		<1.8	
<b>Hexazinone</b>	<b>23</b>	<b>7/7</b>	NA		NA		NA		<49	
<b>Irgarol 1051</b>	<b>712</b>		NA		NA		NA		NA	
Jasmolin-1	NA		<280		NA		NA		NA	
M1 (Irgarol 1051 metabolite)	217		NA		NA		NA		NA	
Malathion	<0.48		NA		NA		NA		<35	
<b>Methoxychlor</b>	<b>0.09</b>	<b>8/77</b>	NA		NA		NA		<26	
<b>Metribuzin</b>	<b>0.2</b>	<b>1/7</b>	NA		NA		NA		<22	
Octachlorostyrene	<0.01		NA		NA		NA		NA	
<b>Oxadiazon</b>	<b>12</b>	<b>560/635</b>	<b>398</b>	<b>40/41</b>	NA		NA		<16	
Parathion, Ethyl	<0.08		NA		NA		NA		<20	
Parathion, Methyl	<0.18		NA		NA		NA		<88	
<b>Permethrin, cis-</b>	NA		NA		<b>1.3</b>	<b>23/59</b>	NA		NA	
<b>Permethrin, total</b>	<0.40		<b>285</b>	<b>15/15</b>	NA		<b>20.5</b>		<26	
<b>Permethrin, trans-</b>	NA		NA		<b>1.6</b>	<b>33/73</b>	NA		NA	
Perthane	<0.36		NA		NA		NA		NA	
<b>Phenothrin</b>	NA		<6.7		<b>4.8</b>	<b>2/81</b>	NA		NA	
Phosmet	<0.10		NA		NA		NA		<16	
Pirimiphos methyl	<0.01		NA		NA		NA		NA	
Prallethrin	NA		<142		<1.1		NA		NA	
Pyrethrin-1	NA		<312		NA		NA		NA	
<b>Quintozene</b>	NA		NA		NA		NA		<b>1.1</b>	<b>1/3</b>
Resmethrin	NA		<24		<1.1		NA		NA	
<b>Simazine</b>	<b>4.2</b>	<b>7/7</b>	NA		NA		NA		<57	
<b>Tecnazene</b>	<b>0.01</b>	<b>3/7</b>	NA		NA		NA		<b>0.5</b>	<b>1/3</b>
Terbufos	NA		NA		NA		NA		<3.6	
Tetramethrin	NA		NA		<0.7		NA		NA	

NA=not analyzed

**Table B7. Maximum concentrations of short-chain chlorinated paraffins (SCCPs) <sup>a</sup>**

<b>Compound</b>	<b>Sport Fish (ng/g ww)</b>	<b>Cormorant Eggs (ng/g ww)</b>	<b>Harbor Seal Blubber (ng/g ww)</b>
ΣSCCPs	1.0	6	50

<sup>a</sup> Estimated values only due to internal standard recovery issues

**Table B8. Maximum concentrations of single-walled carbon nanotubes**

<b>Compound</b>	<b>Sediments (ng/g dw)</b>	<b>Mussels (ng/g)</b>
Single-walled carbon nanotubes	<MDL	<MDL

**Appendix C – Site-specific CEC concentrations in resident San Francisco Bay mussel samples analyzed as part of the NOAA Mussel Watch California CEC Pilot Study. These samples were collected in 2010.**

**Table C1. Pharmaceutical and personal care product concentrations in resident mussels at the San Francisco Bay Mussel Watch sites (ng/g dry weight)**

<b>Compound</b>	<b>Emeryville</b>	<b>Yerba Buena</b>	<b>Dumbarton Bridge</b>	<b>San Mateo Bridge</b>
Acetaminophen	<RL	<RL	<RL	<RL
Albuterol	<RL	<RL	<RL	<RL
Alprazolam	<RL	<RL	<RL	<RL
<b>Amitriptyline</b>	<b>6.21</b>	<RL	<b>5.38</b>	<b>5.96</b>
Amlodipine	<RL	<RL	<RL	<RL
<b>Amphetamine</b>	<RL	<RL	<b>19.60</b>	<RL
<b>Atenolol</b>	<b>7.63</b>	<RL	<RL	<b>12.97</b>
Atorvastatin	<RL	<RL	<RL	<RL
Azithromycin	<RL	<RL	<RL	<RL
Benzoyllecgonine	<RL	<RL	<RL	<RL
Benztropine	<RL	<RL	<RL	<RL
Bisphenol A	<RL	<RL	<RL	<RL
Caffeine	<RL	<RL	<RL	<RL
Carbamazepine	<RL	<RL	<RL	<RL
Cimetidine	<RL	<RL	<RL	<RL
Clarithromycin	<RL	<RL	<RL	<RL
Clinafloxacin	<RL	<RL	<RL	<RL
Clonidine	<RL	<RL	<RL	<RL
Cloxacillin	<RL	<RL	<RL	<RL
<b>Cocaine</b>	<RL	<b>0.63</b>	<RL	<b>1.16</b>
Codeine	<RL	<RL	<RL	<RL
Cotinine	<RL	<RL	<RL	<RL
Dehydronifedipine	<RL	<RL	<RL	<RL
Desmethyldiltiazem	<RL	<RL	<RL	<RL
Diazepam	<RL	<RL	<RL	<RL
Digoxigenin	<RL	<RL	<RL	<RL
Digoxin	<RL	<RL	<RL	<RL
<b>Diltiazem</b>	<b>1.54</b>	<RL	<RL	<RL
<b>Diphenhydramine</b>	<b>11.28</b>	<b>1.62</b>	<b>9.68</b>	<b>9.82</b>

Compound	Emeryville	Yerba Buena	Dumbarton Bridge	San Mateo Bridge
Enalapril	<RL	<RL	<RL	<RL
<b>Enrofloxacin</b>	<RL	<b>11.35</b>	<RL	<RL
<b>Erythromycin-H2O</b>	<b>2.05</b>	<RL	<RL	<RL
Flumequine	<RL	<RL	<RL	<RL
Fluocinonide	<RL	<RL	<RL	<RL
<b>Fluoxetine</b>	<b>5.35</b>	<RL	<b>6.16</b>	<b>5.56</b>
Fluticasone propionate	<RL	<RL	<RL	<RL
Furosemide	<RL	<RL	<RL	<RL
Gemfibrozil	<RL	<RL	<RL	<RL
Glipizide	<RL	<RL	<RL	<RL
Glyburide	<RL	<RL	<RL	<RL
Hydrocodone	<RL	<RL	<RL	<RL
Hydrocortisone	<RL	<RL	<RL	<RL
Ibuprofen	<RL	<RL	<RL	<RL
<b>Lomefloxacin</b>	<RL	<b>89.73</b>	<RL	<RL
Meprobamate	<RL	<RL	<RL	<RL
Metformin	<RL	<RL	<RL	<RL
<b>Methylprednisolone</b>	<RL	<RL	<b>45.81</b>	<RL
Metoprolol	<RL	<RL	<RL	<RL
Naproxen	<RL	<RL	<RL	<RL
Norfloxacin	<RL	<RL	<RL	<RL
Norfluoxetine	<RL	<RL	<RL	<RL
Norverapamil	<RL	<RL	<RL	<RL
Octachlorostyrene	<RL	<RL	<RL	<RL
<b>Ofloxacin</b>	<RL	<b>12.59</b>	<RL	<RL
Ormetoprim	<RL	<RL	<RL	<RL
Oxacillin	<RL	<RL	<RL	<RL
Oxolinic Acid	<RL	<RL	<RL	<RL
Oxycodone	<RL	<RL	<RL	<RL
Paroxetine	<RL	<RL	<RL	<RL
Penicillin G	<RL	<RL	<RL	<RL

Compound	Emeryville	Yerba Buena	Dumbarton Bridge	San Mateo Bridge
Penicillin V	<RL	<RL	<RL	<RL
Perthane	<RL	<RL	<RL	<RL
Prednisolone	<RL	<RL	<RL	<RL
Prednisone	<RL	<RL	<RL	<RL
Promethazine	<RL	<RL	<RL	<RL
Propoxyphene	<RL	<RL	<RL	<RL
<b>Propranolol</b>	<RL	<RL	<b>8.23</b>	<RL
Ranitidine	<RL	<RL	<RL	<RL
Roxithromycin	<RL	<RL	<RL	<RL
Sarafloxacin	<RL	<RL	<RL	<RL
<b>Sertraline</b>	<RL	5.46	<RL	<RL
Sulfachloropyridazine	<RL	<RL	<RL	<RL
Sulfadiazine	<RL	<RL	<RL	<RL
Sulfadimethoxine	<RL	<RL	<RL	<RL
Sulfamerazine	<RL	<RL	<RL	<RL
<b>Sulfamethazine</b>	<RL	<b>88.65</b>	<RL	<RL
Sulfamethizole	<RL	<RL	<RL	<RL
Sulfamethoxazole	<RL	<RL	<RL	<RL
Sulfanilamide	<RL	<RL	<RL	<RL
Sulfathiazole	<RL	<RL	<RL	<RL
<b>Tecnazene</b>	<RL	<RL	<b>0.51</b>	<RL
Thiabendazole	<RL	<RL	<RL	<RL
Trenbolone acetate	<RL	<RL	<RL	<RL
Triamterene	<RL	<RL	<RL	<RL
Trimethoprim	<RL	<RL	<RL	<RL
Tylosin	<RL	<RL	<RL	<RL
<b>Verapamil</b>	<b>0.95</b>	<RL	<RL	<RL
Warfarin	<RL	<RL	<RL	<RL

**Bold type indicates detected compounds; RL=reporting limit**

**Table C2. Alkylphenol concentrations in resident mussels at the San Francisco Bay Mussel Watch sites (ng/g dry weight)**

<b>Compound</b>	<b>Emeryville</b>	<b>Yerba Buena</b>	<b>Dumbarton Bridge</b>	<b>San Mateo Bridge</b>
4-Nonylphenol	<RL	<RL	222.58	<RL
4-Nonylphenol monoethoxylate	299.85	225.46	<RL	96.94
4-Nonylphenol diethoxylate	58.94	66.65	<RL	13.96
4-n-Octylphenol	<RL	<RL	<RL	<RL

RL=reporting limit

**Table C3. Flame retardant concentrations in resident mussels at the San Francisco Bay Mussel Watch sites (ng/g dry weight)**

<b>Compound</b>	<b>Emeryville</b>	<b>Yerba Buena</b>	<b>Dumbarton Bridge</b>	<b>San Mateo Bridge</b>
ΣPBDEs	131.00	36.80	15.00	12.60
BDE-47 + BDE-99	90.80	27.50	13.00	11.20
BDE-209	<RL	0.90	<RL	<RL
Hexabromocyclododecane	<RL	1.3	<RL	<RL
1,2-bis(2,4,6-tribromophenoxy)ethane	<RL	<RL	<RL	<RL
2-ethylhexyl 2,3,4,5-tetrabromobenzoate	<RL	<RL	<RL	<RL
Bis(2-ethylhexyl)-tetrabromophthalate	<RL	<RL	<RL	<RL
Tris(1,3-dichloro-2-propyl) phosphate	<RL	<RL	<RL	<RL
Tris(2-chloroisopropyl) phosphate	<RL	<RL	<RL	<RL
Tris(2-chloroethyl) phosphate	<RL	<RL	<RL	<RL

RL=reporting limit

**Table C4. Concentrations of perfluorinated chemicals in resident mussels at the San Francisco Bay Mussel Watch sites (ng/g dry weight)**

<b>Compound</b>	<b>Emeryville</b>	<b>Yerba Buena</b>	<b>Dumbarton Bridge</b>	<b>San Mateo Bridge</b>
Perfluorobutanesulfonate	<0.85	<0.85	<0.85	<0.85
Perfluorobutanoate	NA	NA	NA	NA
Perfluorodecanoate	<0.8	<0.8	<0.8	<0.8
Perfluorododecanoate	<1.1	<1.1	2.23	<1.1
Perfluoroheptanoate	<1.0	<1.0	<1.0	<1.0
Perfluorohexanesulfonate	<2.25	<2.25	<2.25	<2.25
Perfluorohexanoate	<0.95	<0.95	<0.95	<0.95
Perfluorononanoate	<1.05	<1.05	<1.05	<1.05
Perfluorooctanesulfonamide	<0.85	<0.85	<0.85	<0.85
Perfluorooctanesulfonate	<1	<1	<1	<1
Perfluorooctanoate	<1	<1	<1	<1
Perfluoropentanoate	NA	NA	NA	NA
Perfluoroundecanoate	<0.95	<0.95	<0.95	<0.95
Perfluorodecane sulfonate	<0.95	<0.95	<0.95	<0.95

RL=reporting limit

**Table C5. Current use pesticide concentrations in resident mussels at the San Francisco Bay Mussel Watch sites (ng/g dw)**

<b>Compound</b>	<b>Emeryville</b>	<b>Yerba Buena</b>	<b>Dumbarton Bridge</b>	<b>San Mateo Bridge</b>
Atrazine	<RL	<RL	<RL	NA
Chlorothalonil	<RL	<RL	<RL	NA
<b>Chlorpyrifos</b>	<RL	<b>1.66</b>	<RL	NA
Chlorpyrifos, methyl	<RL	<RL	<b>0.76</b>	NA
Chlorpyrifos, oxon	<RL	<RL	<RL	NA
<b>Chlorpyrifos, oxy</b>	<RL	<b>0.14</b>	<RL	NA
Cyanazine	<RL	<RL	<RL	NA
Cypermethrin (total)	<RL	<RL	<RL	NA
<b>Dacthal</b>	<b>0.64</b>	<b>0.16</b>	<b>0.52</b>	NA
Desethylatrazine	<RL	<RL	<RL	NA
Diazinon	<RL	<RL	<RL	NA
Diazinon, oxon	<RL	<RL	<RL	NA
Dimethoate	<RL	<RL	<RL	NA
Ethion	<RL	<RL	<RL	NA
Fenitrothion	<RL	<RL	<RL	NA
Fonofos	<RL	<RL	<RL	NA
Hexazinone	<RL	<RL	<RL	NA
Malathion	<RL	<RL	<RL	NA
Metribuzin	<RL	<RL	<RL	NA
Parathion, ethyl	<RL	<RL	<RL	NA
Parathion, methyl	<RL	<RL	<RL	NA
Permethrin (total)	<RL	<RL	<RL	NA
Phosmet	<RL	<RL	<RL	NA
Pirimiphos, methyl	<RL	<RL	<RL	NA
<b>Quintozene</b>	<RL	<RL	<b>1.06</b>	NA
Simazine	<RL	<RL	<RL	NA
Terbufos	<RL	<RL	<RL	NA

**Bold type indicates detected compounds; RL=reporting limit; NA=not analyzed**

**Appendix D – Site-specific CEC concentrations in 2010 RMP deployed mussel samples analyzed as part of the NOAA Mussel Watch California CEC Pilot Study**

**Table D1. Pharmaceutical and personal care product concentrations in 2010 RMP deployed mussel samples (ng/g dry weight)**

<b>Compound</b>	<b>Bodega Head (T-0)</b>	<b>Coyote Creek (BA10)</b>	<b>Yerba Buena (BD10)</b>	<b>San Pablo Bay (BD20)</b>	<b>Red Rock (BC61)</b>
1,7-Dimethylxanthine	<RL	<RL	<RL	<RL	<RL
10-hydroxy-amitriptyline	<RL	<RL	<RL	<RL	<RL
2-Hydroxy-ibuprofen	<RL	<RL	<RL	<RL	<RL
Acetaminophen	<RL	<RL	<RL	<RL	<RL
Albuterol	<RL	<RL	<RL	<RL	<RL
Alprazolam	<RL	<RL	<RL	<RL	<RL
<b>Amitriptyline</b>	<RL	<b>2.76</b>	<b>0.80</b>	<RL	<b>1.21</b>
Amlodipine	<RL	<RL	<RL	<RL	<RL
<b>Amphetamine</b>	<RL	<RL	<RL	<b>30.92</b>	<RL
Atenolol	<RL	<RL	<RL	<RL	<RL
Atorvastatin	<RL	<RL	<RL	<RL	<RL
Azithromycin	<RL	<RL	<RL	<RL	<RL
Benzoylcegonine	<RL	<RL	<RL	<RL	<RL
Benztrapine	<RL	<RL	<RL	<RL	<RL
Betamethasone	<RL	<RL	<RL	<RL	<RL
Bisphenol A	<RL	<RL	<RL	<RL	<RL
Caffeine	<RL	<RL	<RL	<RL	<RL
Carbadox	<RL	<RL	<RL	<RL	<RL
Carbamazepine	<RL	<RL	<RL	<RL	<RL
Cefotaxime	<RL	<RL	<RL	<RL	<RL
Cimetidine	<RL	<RL	<RL	<RL	<RL
Ciprofloxacin	<RL	<RL	<RL	<RL	<RL
Clarithromycin	<RL	<RL	<RL	<RL	<RL
Clinafloxacin	<RL	<RL	<RL	<RL	<RL
Clonidine	<RL	<RL	<RL	<RL	<RL
Cloxacillin	<RL	<RL	<RL	<RL	<RL
Cocaine	<RL	<RL	<RL	<RL	<RL
Codeine	<RL	<RL	<RL	<RL	<RL
Cotinine	<RL	<RL	<RL	<RL	<RL

<b>Compound</b>	<b>Bodega Head (T-0)</b>	<b>Coyote Creek (BA10)</b>	<b>Yerba Buena (BD10)</b>	<b>San Pablo Bay (BD20)</b>	<b>Red Rock (BC61)</b>
<b>DEET</b>	<b>2.09</b>	<b>1.61</b>	<b>1.63</b>	<b>4.92</b>	<b>1.02</b>
Dehydronifedipine	<RL	<RL	<RL	<RL	<RL
Desmethyldiltiazem	<RL	<RL	<RL	<RL	<RL
Diazepam	<RL	<RL	<RL	<RL	<RL
Digoxigenin	<RL	<RL	<RL	<RL	<RL
Digoxin	<RL	<RL	<RL	<RL	<RL
<b>Diltiazem</b>	<RL	<b>1.40</b>	<RL	<RL	<RL
<b>Diphenhydramine</b>	<RL	<b>41.94</b>	<b>1.97</b>	<b>5.91</b>	<b>2.80</b>
Enalapril	<RL	<RL	<RL	<RL	<RL
Enrofloxacin	<RL	<RL	<RL	<RL	<RL
Erythromycin-H2O	<RL	<RL	<RL	<RL	<RL
Flumequine	<RL	<RL	<RL	<RL	<RL
Fluocinonide	<RL	<RL	<RL	<RL	<RL
<b>Fluoxetine</b>	<RL	<b>7.15</b>	<RL	<RL	<RL
Fluticasone propionate	<RL	<RL	<RL	<RL	<RL
Furosemide	<RL	<RL	<RL	<RL	<RL
Gemfibrozil	<RL	<RL	<RL	<RL	<RL
Glipizide	<RL	<RL	<RL	<RL	<RL
Glyburide	<RL	<RL	<RL	<RL	<RL
Hydrochlorothiazide	<RL	<RL	<RL	<RL	<RL
Hydrocodone	<RL	<RL	<RL	<RL	<RL
Hydrocortisone	<RL	<RL	<RL	<RL	<RL
Ibuprofen	<RL	<RL	<RL	<RL	<RL
Lincomycin	<RL	<RL	<RL	<RL	<RL
<b>Lomefloxacin</b>	<b>35.47</b>	<b>35.44</b>	<b>14.06</b>	<b>25.04</b>	<b>22.00</b>
Meprobamate	<RL	<RL	<RL	<RL	<RL
Metformin	<RL	<RL	<RL	<RL	<RL
Methylprednisolone	<RL	<RL	<RL	<RL	<RL
Metoprolol	<RL	<RL	<RL	<RL	<RL
Miconazole	<RL	<RL	<RL	<RL	<RL

<b>Compound</b>	<b>Bodega Head (T-0)</b>	<b>Coyote Creek (BA10)</b>	<b>Yerba Buena (BD10)</b>	<b>San Pablo Bay (BD20)</b>	<b>Red Rock (BC61)</b>
Naproxen	<RL	<RL	<RL	<RL	<RL
Norfloxacin	<RL	<RL	<RL	<RL	<RL
Norfluoxetine	<RL	<RL	<RL	<RL	<RL
Norgestimate	<RL	<RL	<RL	<RL	<RL
Norverapamil	<RL	<RL	<RL	<RL	<RL
Ofloxacin	<RL	<RL	<RL	<RL	<RL
Ormetoprim	<RL	<RL	<RL	<RL	<RL
Oxacillin	<RL	<RL	<RL	<RL	<RL
Oxolinic Acid	<RL	<RL	<RL	<RL	<RL
Oxycodone	<RL	<RL	<RL	<RL	<RL
Paroxetine	<RL	<RL	<RL	<RL	<RL
Penicillin G	<RL	<RL	<RL	<RL	<RL
Penicillin V	<RL	<RL	<RL	<RL	<RL
Prednisolone	<RL	<RL	<RL	<RL	<RL
Prednisone	<RL	<RL	<RL	<RL	<RL
Promethazine	<RL	<RL	<RL	<RL	<RL
Propoxyphene	<RL	<RL	<RL	<RL	<RL
Propranolol	<RL	<RL	<RL	<RL	<RL
<b>Ranitidine</b>	<RL	<RL	<b>23.83</b>	<b>23.19</b>	<b>13.42</b>
Roxithromycin	<RL	<RL	<RL	<RL	<RL
Sarafloxacin	<RL	<RL	<RL	<RL	<RL
<b>Sertraline</b>	<RL	<b>18.54</b>	<b>17.14</b>	<b>7.00</b>	<b>8.00</b>
Simvastatin	<RL	<RL	<RL	<RL	<RL
Sulfachloropyridazine	<RL	<RL	<RL	<RL	<RL
Sulfadiazine	<RL	<RL	<RL	<RL	<RL
Sulfadimethoxine	<RL	<RL	<RL	<RL	<RL
Sulfamerazine	<RL	<RL	<RL	<RL	<RL
Sulfamethazine	<RL	<RL	<RL	<RL	<RL
Sulfamethizole	<RL	<RL	<RL	<RL	<RL
Sulfamethoxazole	<RL	<RL	<RL	<RL	<RL
Sulfanilamide	<RL	<RL	<RL	<RL	<RL

<b>Compound</b>	<b>Bodega Head (T-0)</b>	<b>Coyote Creek (BA10)</b>	<b>Yerba Buena (BD10)</b>	<b>San Pablo Bay (BD20)</b>	<b>Red Rock (BC61)</b>
Sulfathiazole	<RL	<RL	<RL	<RL	<RL
Theophylline	<RL	<RL	<RL	<RL	<RL
Thiabendazole	<RL	<RL	<RL	<RL	<RL
Trenbolone	<RL	<RL	<RL	<RL	<RL
Trenbolone acetate	<RL	<RL	<RL	<RL	<RL
<b>Triamterene</b>	<RL	<b>9.13</b>	<RL	<RL	<RL
Triclocarban	<RL	<RL	<RL	<RL	<RL
Triclosan	<RL	<RL	<RL	<RL	<RL
Trimethoprim	<RL	<RL	<RL	<RL	<RL
Tylosin	<RL	<RL	<RL	<RL	<RL
Valsartan	<RL	<RL	<RL	<RL	<RL
Verapamil	<RL	<RL	<RL	<RL	<RL
<b>Virginiamycin</b>	<b>12.58</b>	<b>13.50</b>	<RL	<RL	<RL
Warfarin	<RL	<RL	<RL	<RL	<RL

**Bold type indicates detected compounds; RL=reporting limit**

**Table D2. Alkylphenol concentrations in 2010 RMP deployed mussel samples (ng/g dry weight)**

<b>Compound</b>	<b>Bodega Head (T-0)</b>	<b>Coyote Creek (BA10)</b>	<b>Yerba Beuna (BD10)</b>	<b>San Pablo Bay (BD20)</b>	<b>Red Rock (BC61)</b>
<b>4-Nonylphenol</b>	<b>307.03</b>	<b>287.38</b>	<b>344.57</b>	<b>1294.12</b>	<b>658.06</b>
<b>4-Nonylphenol monoethoxylate</b>	<b>19.69</b>	<b>105.83</b>	<b>135.43</b>	<b>68.07</b>	<b>101.29</b>
<b>4-Nonylphenol diethoxylate</b>	<b>4.98</b>	<b>17.09</b>	<b>12.46</b>	<b>8.57</b>	<b>9.74</b>
4-n-Octylphenol	<RL	<RL	<RL	<RL	<RL

**Bold type indicates detected compounds; RL=reporting limit**

**Table D3. Perfluorinated compound concentrations in 2010 RMP deployed mussel samples (ng/g dry weight)**

<b>Compound</b>	<b>Bodega Head (T-0)</b>	<b>Coyote Creek (BA10)</b>	<b>Yerba Buena (BD10)</b>	<b>San Pablo Bay (BD20)</b>	<b>Red Rock (BC61)</b>
Perfluorobutanesulfonate	<0.85	<0.85	<0.85	<0.85	<0.85
Perfluorobutanoate	<0.8	<0.8	<0.8	<0.8	<0.8
Perfluorodecanoate	<1.1	<1.1	<1.1	<1.1	<1.1
Perfluorododecanoate	<1.0	<1.0	<1.0	<1.0	<1.0
Perfluoroheptanoate	<2.25	<2.25	<2.25	<2.25	<2.25
Perfluorohexanesulfonate	<0.95	<0.95	<0.95	<0.95	<0.95
Perfluorohexanoate	<1.05	<1.05	<1.05	<1.05	<1.05
<b>Perfluorononanoate</b>	<0.85	<b>6.63</b>	<0.85	<0.85	<0.85
<b>Perfluorooctanesulfonamide</b>	<1	<b>34.5</b>	<1	<1	<1
Perfluorooctanesulfonate	<1	<1	<1	<1	<1
Perfluorooctanoate	<0.95	<0.95	<0.95	<0.95	<0.95
Perfluoropentanoate	<0.95	<0.95	<0.95	<0.95	<0.95
Perfluoroundecanoate	<0.85	<0.85	<0.85	<0.85	<0.85
Perfluorodecane sulfonate	<0.8	<0.8	<0.8	<0.8	<0.8

**Bold type indicates detected compounds**

**Appendix E – Site-specific CEC concentrations in passive samplers deployed in San Francisco Bay as part of the NOAA Mussel Watch California CEC Pilot Study. These samples were deployed in 2010.**

**Table E1. CEC concentrations in POCIS samplers (ng/L; USGS pharmaceutical method)**

<b>Compound</b>	<b>Petaluma River</b>	<b>Napa River</b>	<b>Yerba Buena Island</b>	<b>South Bay</b>
1,7-Dimethylxanthine	<1.7	<1.7	<1.7	<1.7
Acetaminophen	<0.5	<0.5	<0.5	<0.5
Albuterol	<1.3	<1.3	<1.3	<1.3
Azithromycin	<0.3	<0.3	<0.3	<0.3
Bupropion	<1.4	<1.4	<1.4	<1.4
<b>Caffeine</b>	<0.6	<0.6	<b>4.75</b>	<0.6
<b>Carbamazepine</b>	<b>1.1</b>	<b>0.63</b>	<b>0.92</b>	<b>21</b>
Cimetidine	<1.3	<1.3	<1.3	<1.3
Citalopram	<1.6	<1.6	<1.6	<b>3.9</b>
Codeine	<0.2	<0.2	<0.2	<0.2
<b>Cotinine</b>	<b>1.9</b>	<b>1.3</b>	<b>2.1</b>	<b>3.5</b>
<b>Dehydronifedipine</b>	<1.5	<1.5	<1.5	<b>9.1</b>
<b>Diltiazem</b>	<1.7	<1.7	<1.7	<b>6.4</b>
<b>Diphenhydramine</b>	<b>0.03</b>	<0.1	<b>0.08</b>	<b>0.51</b>
Duloxetine	<1.5	<1.5	<1.5	<1.5
Erythromycin	<0.3	<0.3	<0.3	<0.3
Fluoxetine	<0.4	<0.4	<0.4	<0.4
Fluvoxamine	<1.6	<1.6	<1.6	<1.6
Miconazole	<1.7	<1.7	<1.7	<1.7
Norfluoxetine	<1.5	<1.5	<1.5	<1.5
Norsertaline	<1.5	<1.5	<1.5	<1.5
Paroxetine	<0.1	<0.1	<0.1	<0.1
Ranitidine	<1.5	<1.5	<1.5	<1.5
Sertraline	<0.1	<0.1	<0.1	<0.1
<b>Sulfamethoxazole</b>	<0.2	<0.2	<b>0.215</b>	<b>1.3</b>
<b>Thiabendazole</b>	<0.3	<0.3	<b>0.03</b>	<0.3
<b>Trimethoprim</b>	<0.2	<0.2	<b>0.43</b>	<b>2</b>
<b>Venlafaxine</b>	<0.2	<0.2	<b>0.55</b>	<b>14</b>
Warfarin	<1.4	<1.4	<1.4	<1.4

**Bold type indicates detected compounds; RL=reporting limit**

**Table E2. CEC concentrations in POCIS samplers (ng/L; USGS wastewater method)**

<b>Compound</b>	<b>Petaluma River</b>	<b>Napa River</b>	<b>Yerba Buena Island</b>	<b>South Bay</b>
<b>1,4-Dichlorobenzene</b>	<3.3	<3.3	<3.3	<b>53</b>
4-Octylphenol	<0.5	<0.5	<0.5	<0.5
<b>Acetophenone</b>	<b>7</b>	<0.8	<b>4.8</b>	<b>7</b>
Anthraquinone	<0.9	<0.9	<0.9	<0.9
<b>Benzophenone</b>	<0.9	<b>0.8</b>	<0.9	<0.9
Bromacil	<4.8	<4.8	<4.8	<4.8
<b>Bromoform</b>	<b>5.3</b>	<b>77</b>	<b>26</b>	<b>37</b>
Camphor	<0.9	<0.9	<0.9	<0.9
Carbaryl	<0.9	<0.9	<0.9	<0.9
Carbazole	<0.9	<0.9	<0.9	<0.9
Celestolide (ADBI)	<1.2	<1.2	<1.2	<1.2
Chlorpyrifos	<1.2	<1.2	<1.2	<1.2
<b>d-Limonene</b>	<b>0.53</b>	<b>26</b>	<b>18.5</b>	<b>5.8</b>
Diazinon	<0.1	<0.1	<0.1	<0.1
Dichlorvos	<3	<3	<3	<3
<b>Diethyl phthalate</b>	<b>240</b>	<b>46</b>	<b>16.5</b>	<b>450</b>
<b>Diethylhexyl phthalate (DEHP)</b>	<1.5	<b>70</b>	<b>118</b>	<b>670</b>
<b>Ethyl citrate</b>	<0.2	<0.2	<b>1.1</b>	<b>66</b>
<b>Galaxolide (HHCB)</b>	<0.3	<0.3	<b>4.55</b>	<b>1300</b>
<b>Indole</b>	<0.7	<b>48</b>	<b>39.5</b>	<0.7
Isophorone	<0.2	<0.2	<0.2	<0.2
Isopropylbenzene (cumene)	<0.8	<0.8	<0.8	<0.8
Isoquinoline	<3.8	<3.8	<3.8	<3.8
Menthol	<1	<1	<1	<1
Metalaxyl	<1.2	<1.2	<1.2	<1.2
N-butyl benzenesulfonamide	<1	<1	<1	<1
<b>N,N-diethyltoluamide (DEET)</b>	<b>12</b>	<b>6.8</b>	<b>7.75</b>	<b>69</b>
p-tert-Octylphenol	<0.5	<0.5	<0.5	<0.5

Compound	Petaluma River	Napa River	Yerba Buena Island	South Bay
Phantolide (AHMI)	<1.2	<1.2	<1.2	<1.2
<b>Phenol</b>	<3.2	<3.2	<b>8</b>	<3.2
Prometon	<0.1	<0.1	<0.1	<0.1
Salicylate, methyl	<0.8	<0.8	<0.8	<0.8
<b>Tonalide (AHTN)</b>	<0.3	<0.3	<0.3	<b>39</b>
Traseolide (ATII)	<1.2	<1.2	<1.2	<1.2
<b>Tributyl phosphate</b>	<0.4	<0.4	<b>1.95</b>	<b>25</b>
Triclosan	<0.2	<0.2	<0.2	<0.2
Triclosan, methyl	<1.1	<1.1	<1.1	<1.1
<b>Triphenyl phosphate</b>	<1.3	<1.3	<b>0.85</b>	<1.3
<b>Tris(2-chloroethyl)phosphate (TCEP)</b>	<0.2	<0.2	<b>11.5</b>	<b>56</b>
<b>Tris(1-chloro-2-propyl)phosphate (TCPP)</b>	<b>160</b>	<b>82</b>	<b>105</b>	<b>3100</b>
<b>Tris(1-chloro-2-propyl)phosphate isomer (TCPP isomer)</b>	<1.2	<1.2	<b>115</b>	<b>8900</b>
<b>Tris(1,3-dichloro-2-propyl)phosphate (TDCPP)</b>	<1.2	<1.2	<1.2	<b>340</b>
Tris(2-butoxyethyl)phosphate (TBEP)	<2.8	<2.8	<2.8	<2.8
Tris(2-ethylhexyl)phosphate (TEHP)	<1.7	<1.7	<1.7	<1.7

**Bold type indicates detected compounds; RL=reporting limit**

**Table E3. CEC concentrations in POCIS samplers (ng/POCIS; USGS pesticide method)**

<b>Compound</b>	<b>Petaluma River</b>	<b>Napa River</b>	<b>Yerba Buena Island</b>	<b>South Bay</b>
3,4-DCA	<10	<10	<10	<10
3,5-DCA	<10	<10	<10	<10
Alachlor	<5	<5	<5	<5
Allethrin	<10	<10	<10	<10
Atrazine	<5	<5	<5	<5
Azinphos methyl	<10	<10	<10	<10
Azinphos, methyl oxon	<10	<10	<10	<10
Azoxystrobin	<5	<5	<5	<5
Bifenthrin	<5	<5	<5	<5
Boscalid	<5	<5	<5	<5
Bromuconazole	<10	<10	<10	<10
Butylate	<5	<5	<5	<5
Captan	<10	<10	<10	<10
Carbofuran	<5	<5	<5	<5
Chlorothalonil	<10	<10	<10	<10
Chlorpyrifos, oxon	<10	<10	<10	<10
Clomazome	<5	<5	<5	<5
Cycloate	<5	<5	<5	<5
Cyfluthrin	<5	<5	<5	<5
Cyhalothrin	<5	<5	<5	<5
Cypermethrin	<5	<5	<5	<5
Cyproconazole	<10	<10	<10	<10
Cyprodinil	<10	<10	<10	<10
DCPA	<5	<5	<5	<5
Deltamethrin	<5	<5	<5	<5
Diazinon, oxon	<10	<10	<10	<10
Difenoconazole	<10	<10	<10	<10
Dimethomorph	<10	<10	<10	<10
Disulfoton	<10	<10	<10	<10
EPTC	<5	<5	<5	<5
Esfenvalerate	<5	<5	<5	<5
Ethalfuralin	<5	<5	<5	<5

Compound	Petaluma River	Napa River	Yerba Buena Island	South Bay
Etofenprox	<5	<5	<5	<5
Famoxadone	<10	<10	<10	<10
Fenarimol	<10	<10	<10	<10
Fenbuconazole	<10	<10	<10	<10
Fenhexamide	<10	<10	<10	<10
Fenpropathrin	<5	<5	<5	<5
Fipronil	<5	<5	<5	<5
Fipronil desulfinyl	<5	<5	<5	<5
Fipronil sulfide	<5	<5	<5	<5
Fipronil sulfone	<5	<5	<5	<5
Fludioxinil	<10	<10	<10	<10
Fluoxastrobin	<10	<10	<10	<10
Flusilazole	<10	<10	<10	<10
Flutriafol	<10	<10	<10	<10
Fluvalinate, tau	<5	<5	<5	<5
Hexazinone	<10	<10	<10	<10
Imazalil	<10	<10	<10	<10
Iprodione	<10	<10	<10	<10
Kresoxim, methyl	<10	<10	<10	<10
Malathion	<5	<5	<5	<5
Metconazole	<5	<5	<5	<5
Methidathion	<5	<5	<5	<5
Methoprene	<10	<10	<10	<10
Metolachlor	<5	<5	<5	<5
Molinate	<5	<5	<5	<5
Myclobutanil	<5	<5	<5	<5
Napropamide	<10	<10	<10	<10
Oxyflurofen	<10	<10	<10	<10
p,p'-DDD	<5	<5	<5	<5
p,p'-DDE	<5	<5	<5	<5
p,p'-DDT	<5	<5	<5	<5
Parathion, methyl	<5	<5	<5	<5
PCA	<5	<5	<5	<5

<b>Compound</b>	<b>Petaluma River</b>	<b>Napa River</b>	<b>Yerba Buena Island</b>	<b>South Bay</b>
PCNB	<5	<5	<5	<5
Pebulate	<5	<5	<5	<5
Pendimethalin	<5	<5	<5	<5
Permethrin	<5	<5	<5	<5
Phenothrin	<10	<10	<10	<10
Phosmet	<5	<5	<5	<5
Piperonyl butoxide	<5	<5	<5	<5
Prometryn	<5	<5	<5	<5
Propanil	<10	<10	<10	<10
Propiconazole	<10	<10	<10	<10
Propyzamide	<5	<5	<5	<5
Pyraclostrobin	<10	<10	<10	<10
Pyrimethanil	<5	<5	<5	<5
Resemethrin	<10	<10	<10	<10
Simazine	<10	<10	<10	<10
Tebuconazole	<10	<10	<10	<10
Tefluthrin	<10	<10	<10	<10
Tetraconazole	<10	<10	<10	<10
Tetramethrin	<5	<5	<5	<5
Thiobencarb	<5	<5	<5	<5
Triadimefon	<10	<10	<10	<10
Triadimenol	<10	<10	<10	<10
Trifloxystrobin	<10	<10	<10	<10
Triflumizole	<10	<10	<10	<10
Trifluralin	<5	<5	<5	<5
Triticonazole	<10	<10	<10	<10
Vinclozolin	<10	<10	<10	<10
Zoxamide	<10	<10	<10	<10

**Bold type indicates detected compounds; RL=reporting limit**

Table E4. CEC concentrations in solid-phase microextraction (SPME) fiber samplers

Compound	Unit	Petaluma River	Napa River	Yerba Buena Island	South Bay
BDE-15	pg/fiber	<2.05	<2.05	<2.05	<2.05
<b>BDE-28</b>	pg/fiber	<b>0.53</b>	<b>0.93</b>	<0.8	<b>1.42</b>
BDE-33	pg/fiber	<0.6	<0.6	<0.6	<0.6
<b>BDE-47</b>	pg/L	<b>2.53</b>	<b>2.07</b>	<b>1.12</b>	<b>21.9</b>
<b>BDE-49</b>	pg/fiber	<b>0.3</b>	<b>0.45</b>	<b>0.115</b>	<b>2.24</b>
<b>BDE-66</b>	pg/fiber	<b>0.29</b>	<b>2.77</b>	<0.9	<b>0.48</b>
<b>BDE-75</b>	pg/fiber	<0.3	<0.3	<0.3	<b>0.33</b>
<b>BDE-99</b>	pg/fiber	<b>0.44</b>	<b>0.62</b>	<b>0.265</b>	<b>2.96</b>
<b>BDE-100</b>	pg/fiber	<b>0.11</b>	<b>2.29</b>	<0.3	<b>0.82</b>
BDE-119	pg/fiber	<0.4	<0.4	<0.4	<0.4
<b>BDE-153</b>	pg/fiber	<0.1	<b>0.41</b>	<0.1	<b>0.1</b>
<b>BDE-154</b>	pg/fiber	<0.1	<0.1	<0.1	<b>0.14</b>
<b>BDE-155</b>	pg/fiber	<0.2	<b>2.29</b>	<0.2	<0.2
BDE-183	pg/fiber	<0.4	<0.4	<0.4	<0.4
<b>Bifenthrin</b>	pg/L	<5.28	<b>4.18</b>	<5.28	<b>5.5</b>
<b>Chlorpyrifos</b>	pg/L	<41.50	<41.50	<41.50	<b>51.282</b>
Cyfluthrin	pg/L	<8.69	<8.69	<8.69	<8.69
Cyhalothrin, lambda	pg/L	<1.17	<1.17	<1.17	<1.17
Cypermethrin	pg/L	<6.68	<6.68	<6.68	<6.68
Deltamethrin	pg/L	<13.10	<13.10	<13.10	<13.10
<b>Esfenvalerate</b>	pg/L	<0.45	<b>0.5</b>	<0.45	<0.45
Fenpropathrin	pg/L	<3.97	<3.97	<3.97	<3.97
<b>Fipronil</b>	pg/fiber	<0.79	<b>0.83</b>	<0.79	<b>0.52</b>
<b>Fipronil desulfinyl</b>	pg/fiber	<0.17	<b>2.03</b>	<0.17	<b>0.72</b>
<b>Fipronil sulfide</b>	pg/fiber	<0.11	<b>5.56</b>	<0.11	<b>0.31</b>
<b>Fipronil sulfone</b>	pg/fiber	<0.21	<b>4.93</b>	<0.21	<b>2.33</b>
Permethrin, cis	pg/L	<16.10	<16.10	<16.10	<16.10
Permethrin, trans	pg/L	<28.20	<28.20	<28.20	<28.20

**Bold type indicates detected compounds; RL=reporting limit**

**Table E5. CEC concentrations in polyethylene device (PED) samplers (pg/L)**

<b>Compound</b>	<b>Petaluma River</b>	<b>Napa River</b>	<b>Yerba Buena Island</b>	<b>South Bay</b>
<b>ΣPBDEs</b>	<b>5.51</b>	<b>7.94</b>	<b>1.31</b>	<b>36.73</b>
<b>BDE-15</b>	<6.8	<6.8	<6.8	<b>9.14</b>
<b>BDE-28</b>	<1.6	<b>3.19</b>	<1.6	<b>5.62</b>
BDE-33	<2.7	<2.7	<2.7	<2.7
<b>BDE-47</b>	<b>0.77</b>	<b>0.41</b>	<b>0.64</b>	<b>7.47</b>
<b>BDE-49</b>	<b>4.15</b>	<b>2.31</b>	<b>0.47</b>	<b>11.13</b>
<b>BDE-66</b>	<b>0.24</b>	<b>0.38</b>	<0.07	<b>0.16</b>
<b>BDE-75</b>	<0.5	<0.5	<0.5	<b>1.55</b>
<b>BDE-99</b>	<b>0.10</b>	<b>0.10</b>	<b>0.14</b>	<b>0.76</b>
<b>BDE-100</b>	<b>0.06</b>	<b>0.26</b>	<b>0.04</b>	<b>0.34</b>
BDE-119	<0.2	<0.2	<0.2	<0.2
<b>BDE-153</b>	<b>0.01</b>	<b>0.04</b>	<b>0.008</b>	<b>0.02</b>
<b>BDE-154</b>	<b>0.004</b>	<b>0.01</b>	<b>0.003</b>	<b>0.02</b>
<b>BDE-155</b>	<b>0.18</b>	<b>1.23</b>	<0.04	<b>0.54</b>
<b>BDE-183</b>	<0.005	<b>0.005</b>	<b>0.004</b>	<b>0.005</b>
Bifenthrin	<0.63	<0.63	<0.63	<0.63
Cyfluthrin	<2.73	<2.73	<2.73	<2.73
Cyhalothrin, lambda	<0.45	<0.45	<0.45	<0.45
Cypermethrin	<1.62	<1.62	<1.62	<1.62
Deltamethrin	<2.71	<2.71	<2.71	<2.71
Esfenvalerate	<0.20	<0.20	<0.20	<0.20
Fenpropathrin	<0.49	<0.49	<0.49	<0.49
Permethrin, cis	<13.90	<13.90	<13.90	<13.90
Permethrin, trans	<9.24	<9.24	<9.24	<9.24

**Bold type indicates detected compounds; RL=reporting limit**

## **Appendix F – Site-specific concentrations of select CECs in mussels collected from Mussel Watch sites in 2010 as part of the National Mussel Watch California CEC Pilot Study**

The following figures were generated by Nathan Dodder (Southern California Coastal Water Research Project) for the NOAA Mussel Watch CEC California Pilot Study. The figures include only data from the four San Francisco Bay Mussel Watch sites (i.e., not the RMP mussel deployment sites). Only CECs detected at 10 or more of the study sites are included.

SFEM=San Francisco Bay-Emeryville

SFYB=San Francisco Bay-Yerba Buena

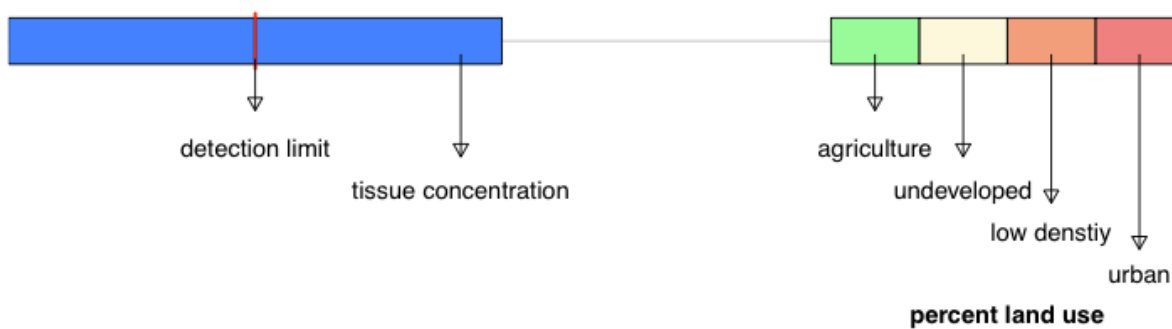
SFSM=San Francisco Bay-San Mateo Bridge

SFDB=San Francisco Bay-Dumbarton Bridge

## Analyte Report: Detects $\geq 10$ , Sorted by Compound Class

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Explanation of the colors and symbols used in the plots:



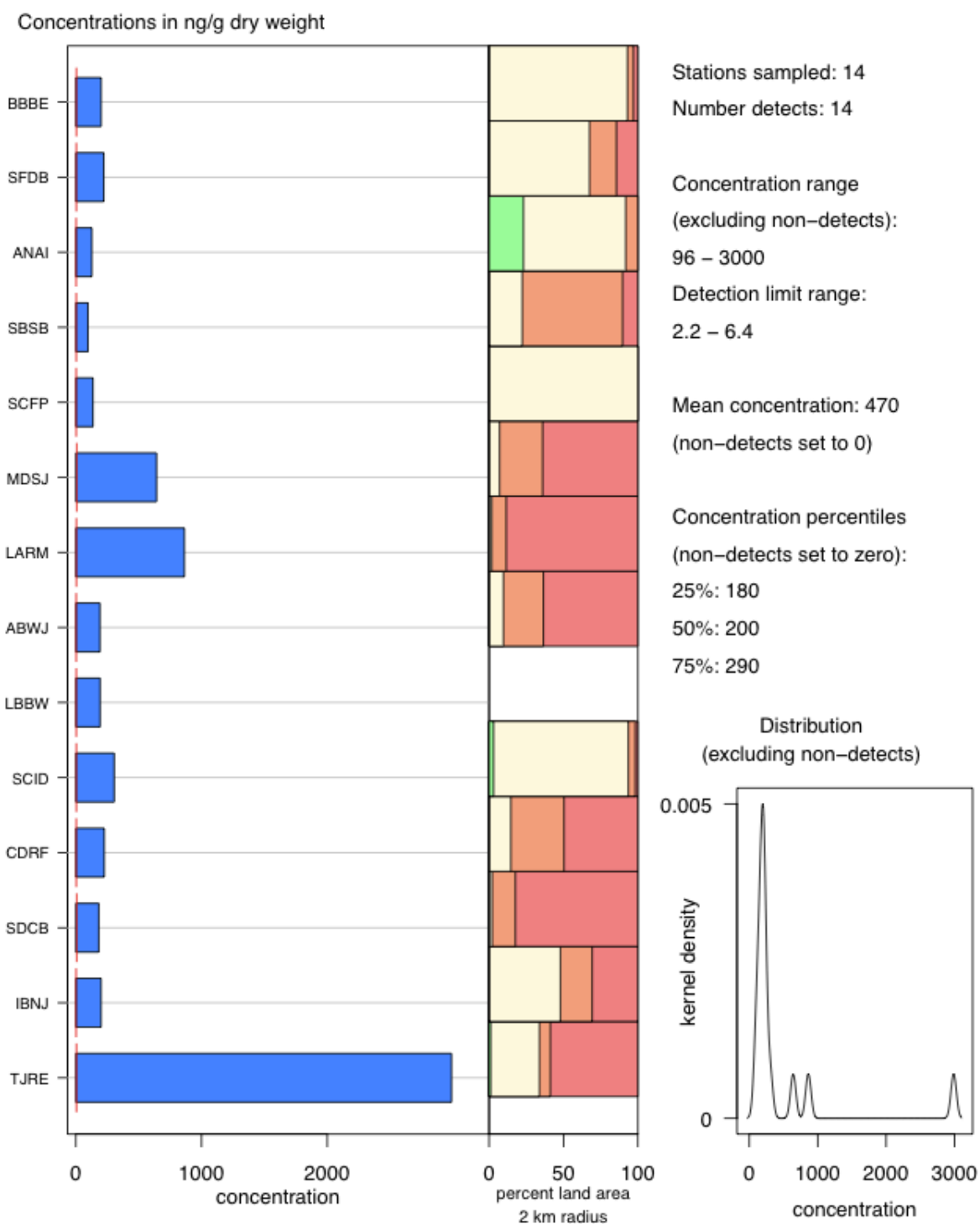
Development Version

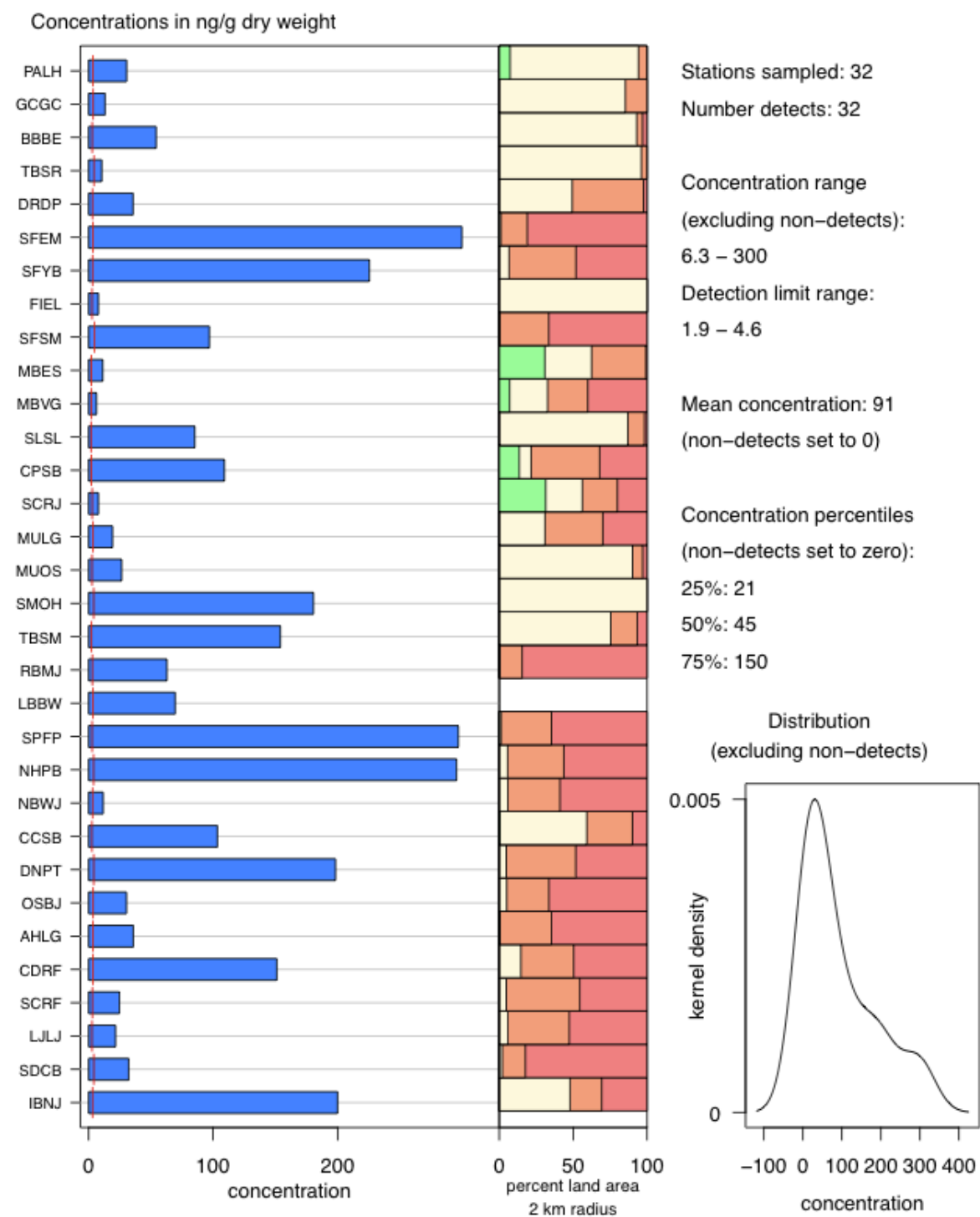
Prepared: 2012-03-07 20:55:55 by Nathan Dodder, SCCWRP

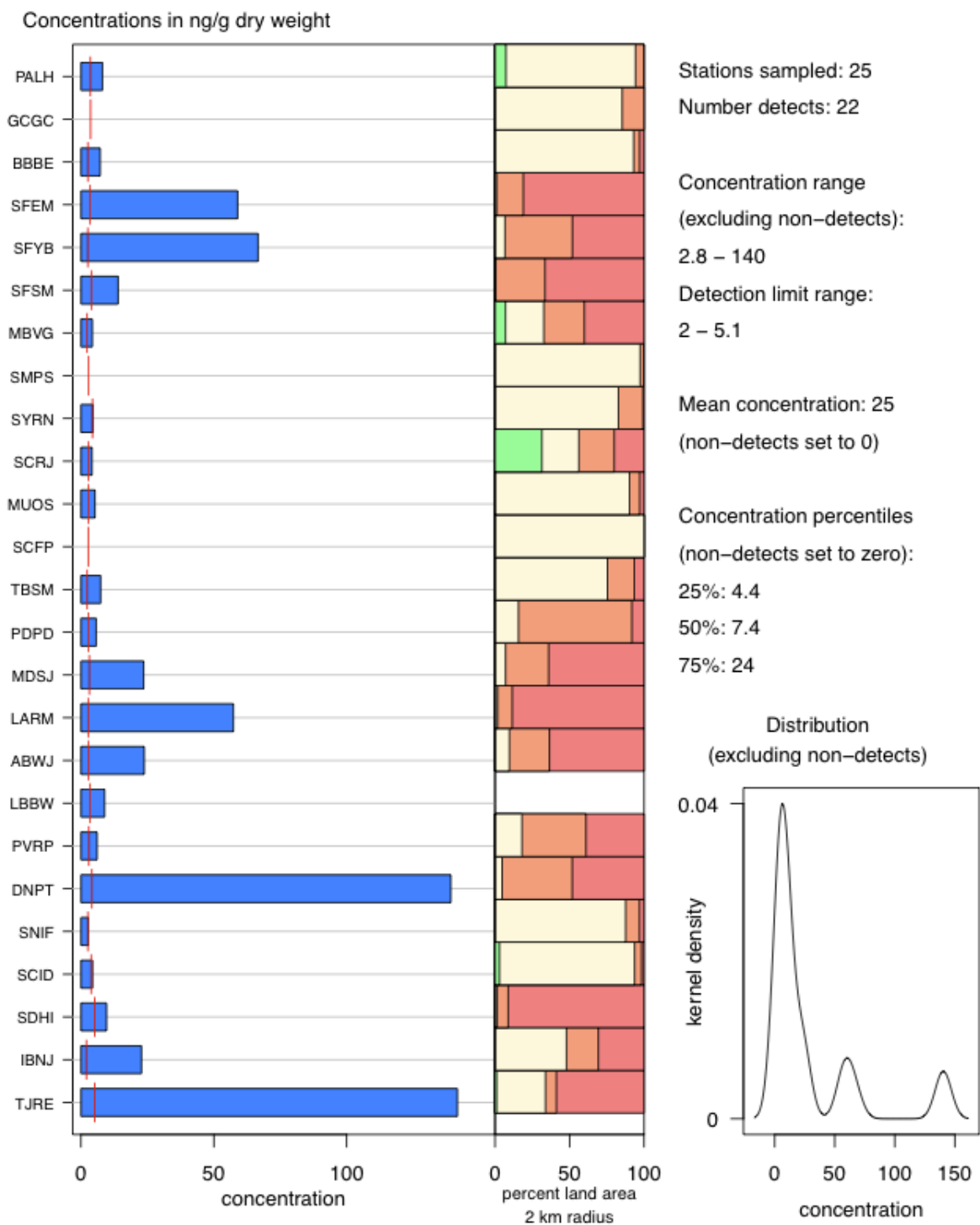
---

Compound: 4-Nonylphenol

Class: AP

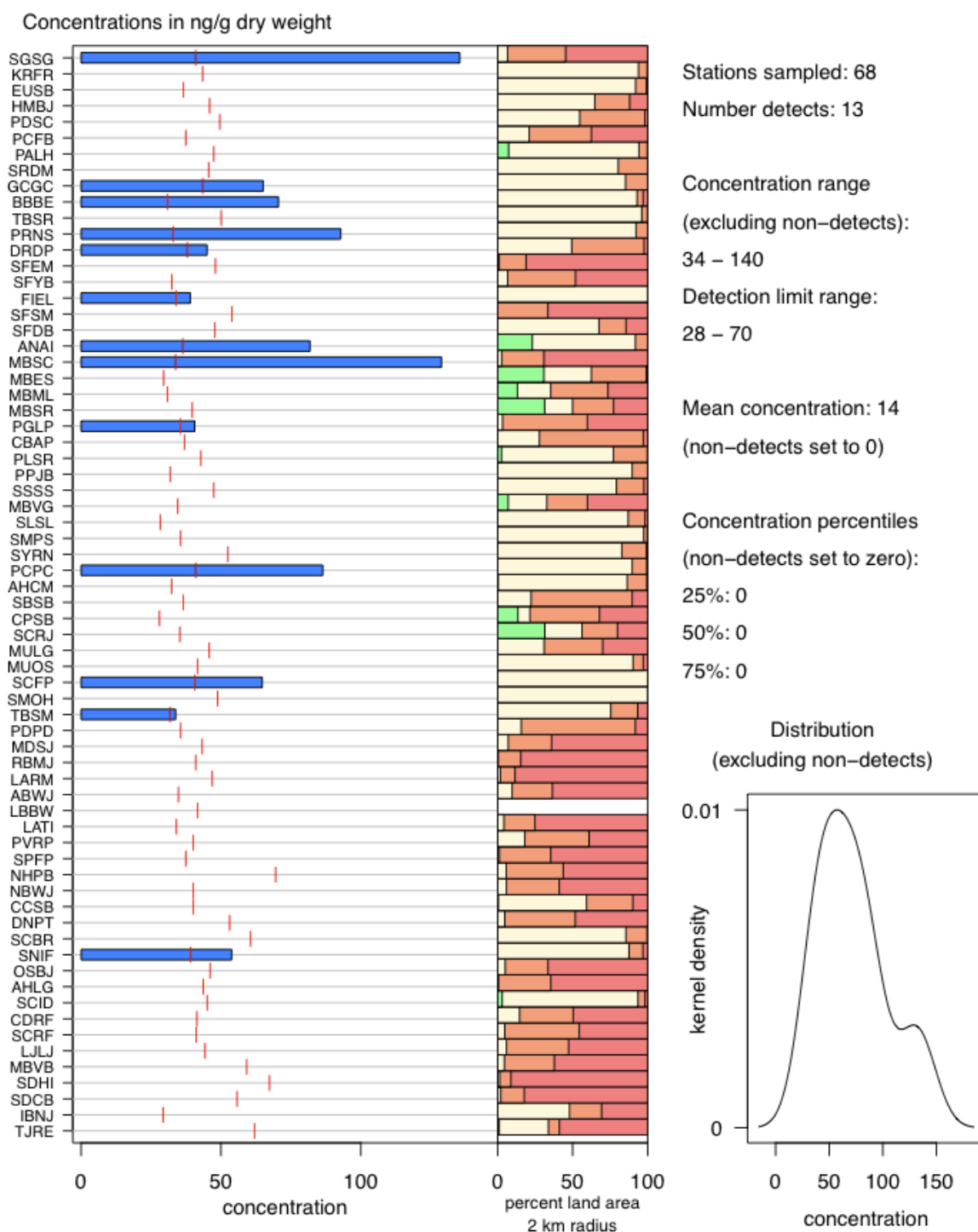






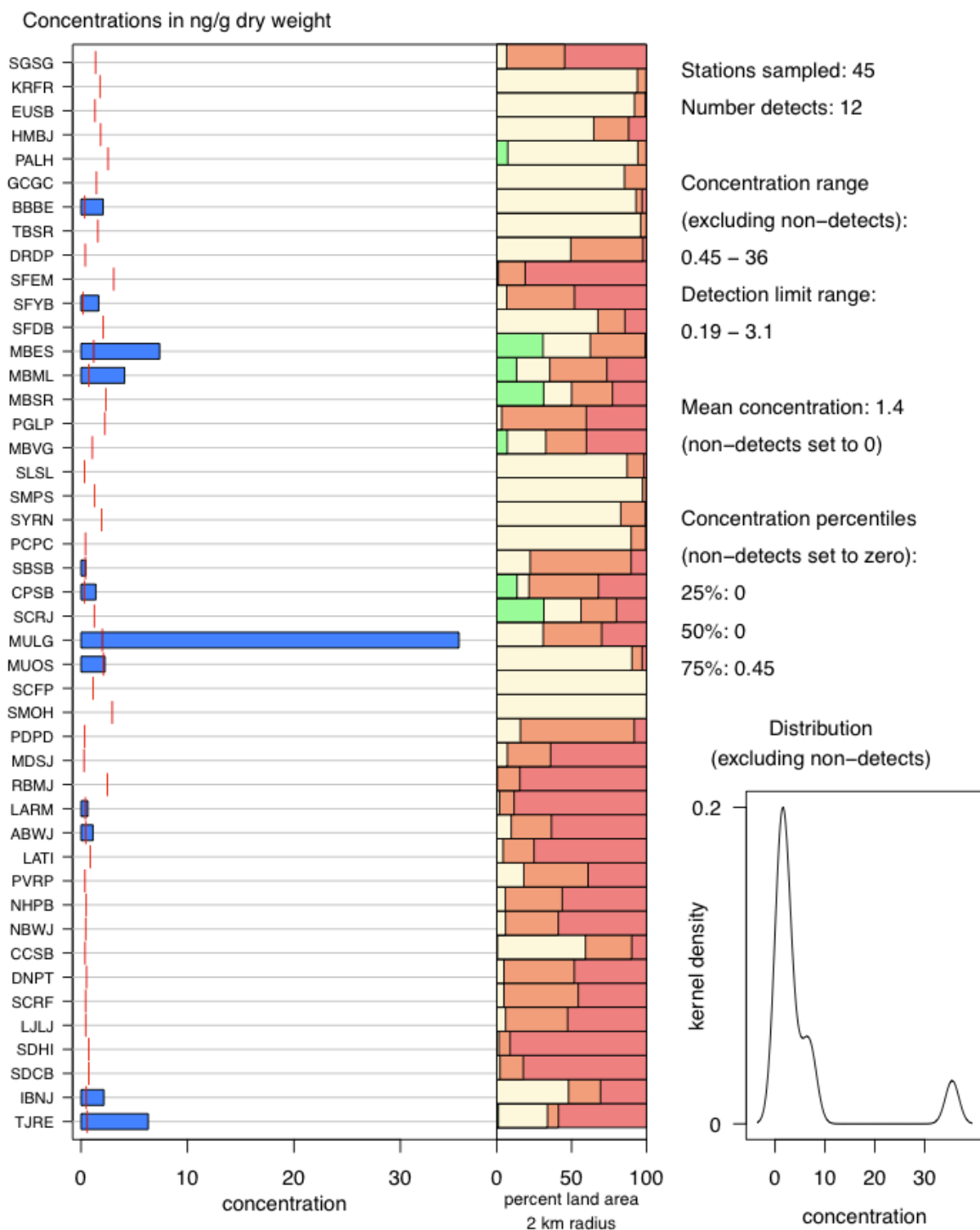
Compound: Caffeine

Class: PPCP



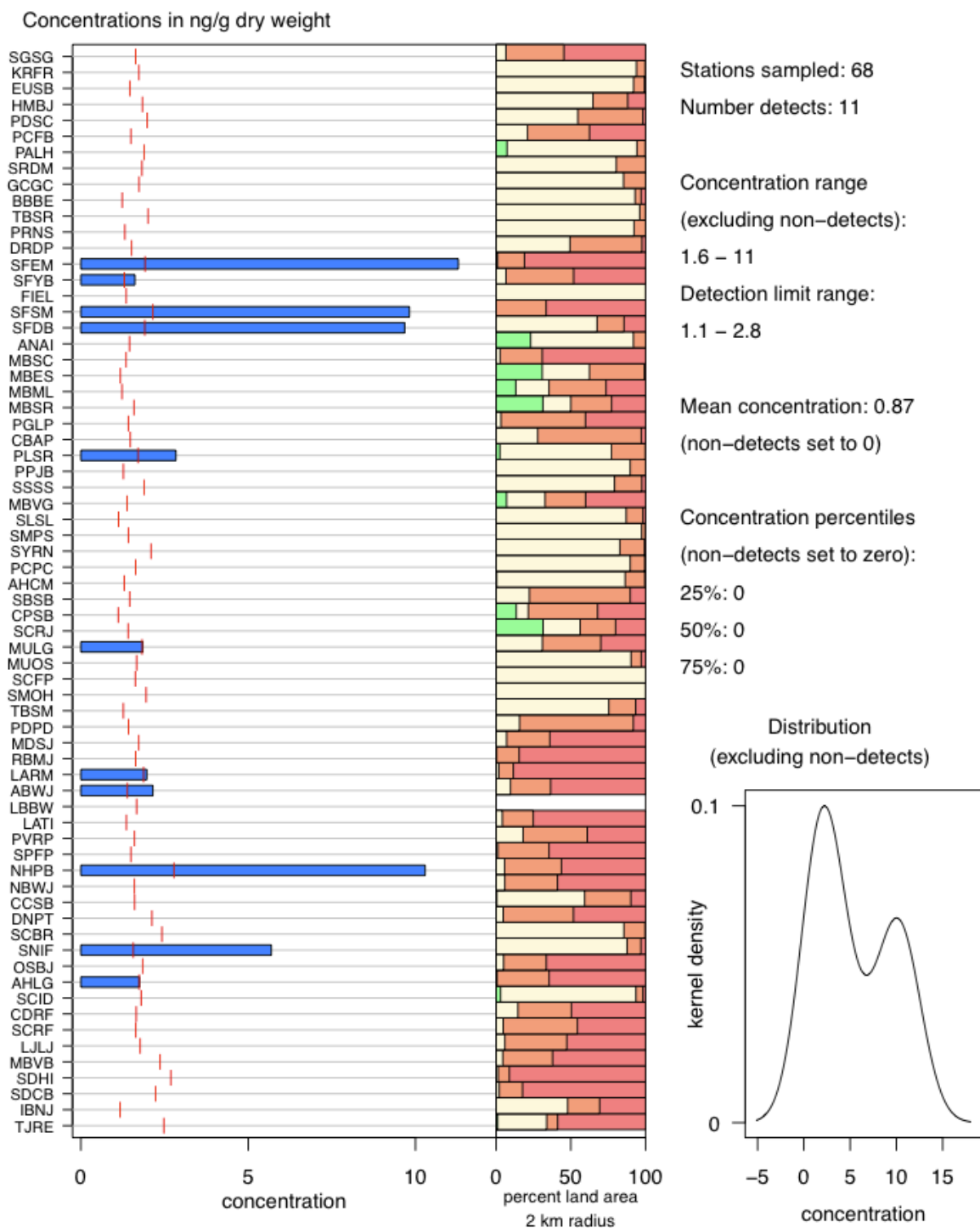
Compound: Chlorpyrifos

Class: CUP



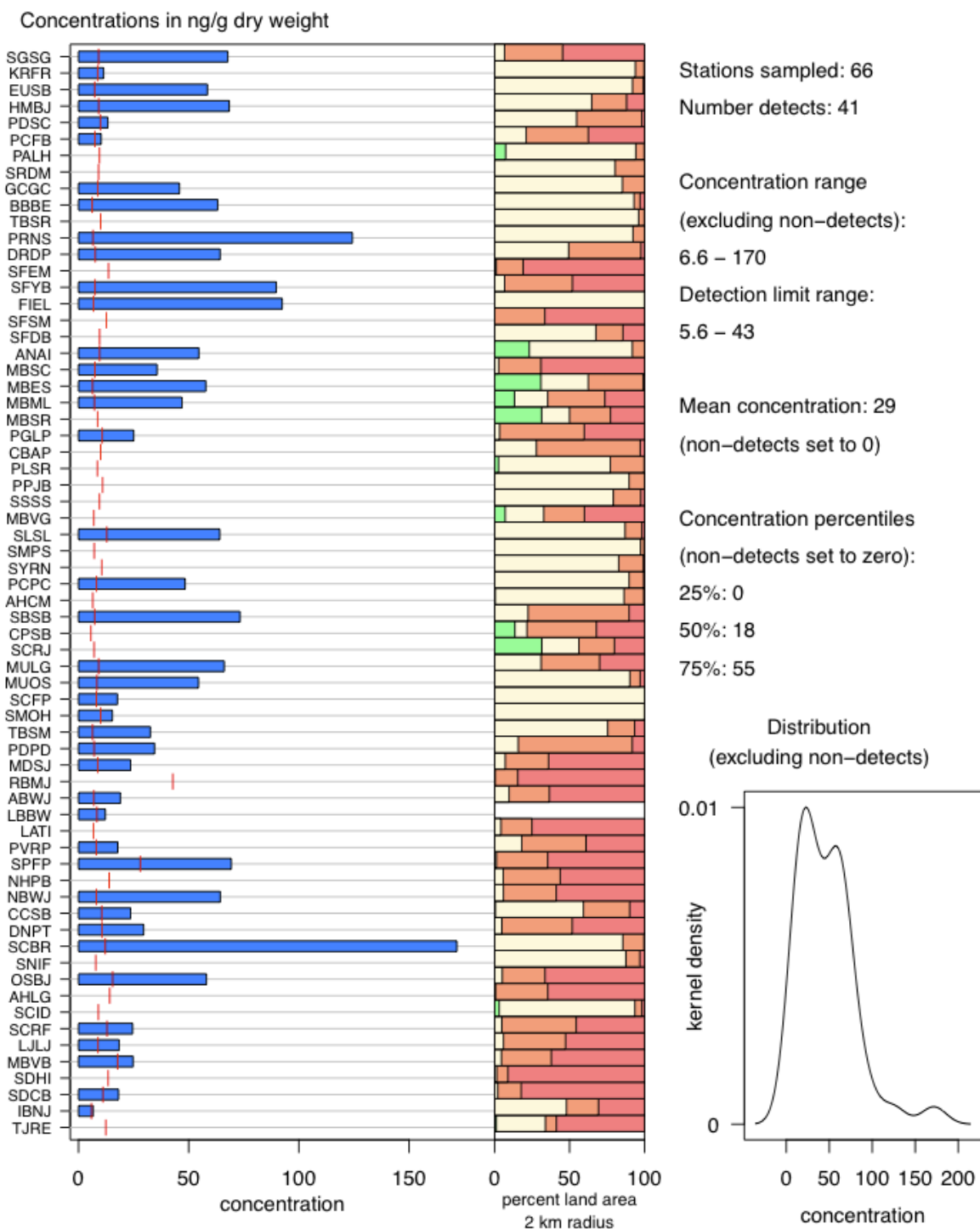
Compound: Diphenhydramine

Class: PPCP



Compound: Lomefloxacin

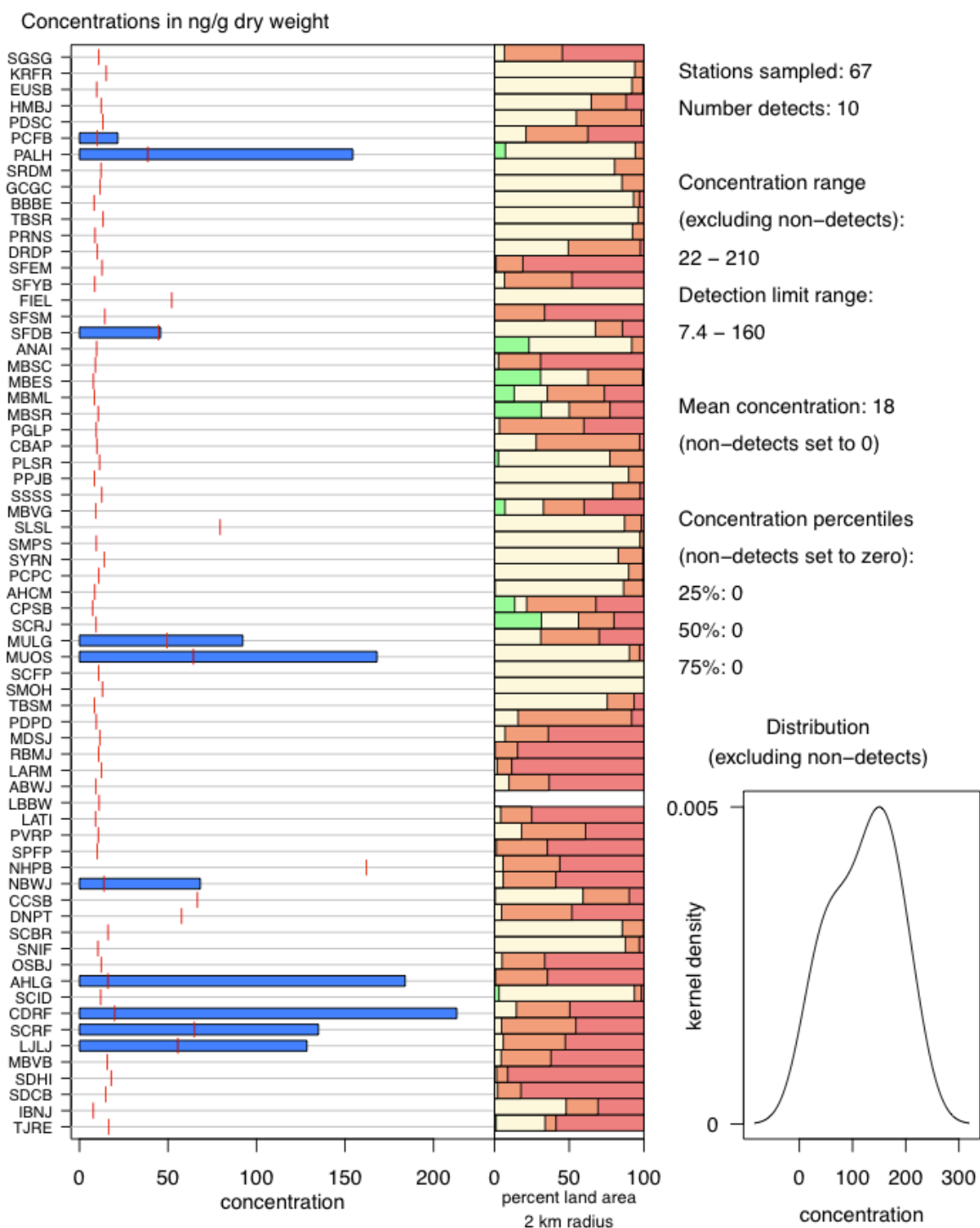
Class: PPCP



Go to next page

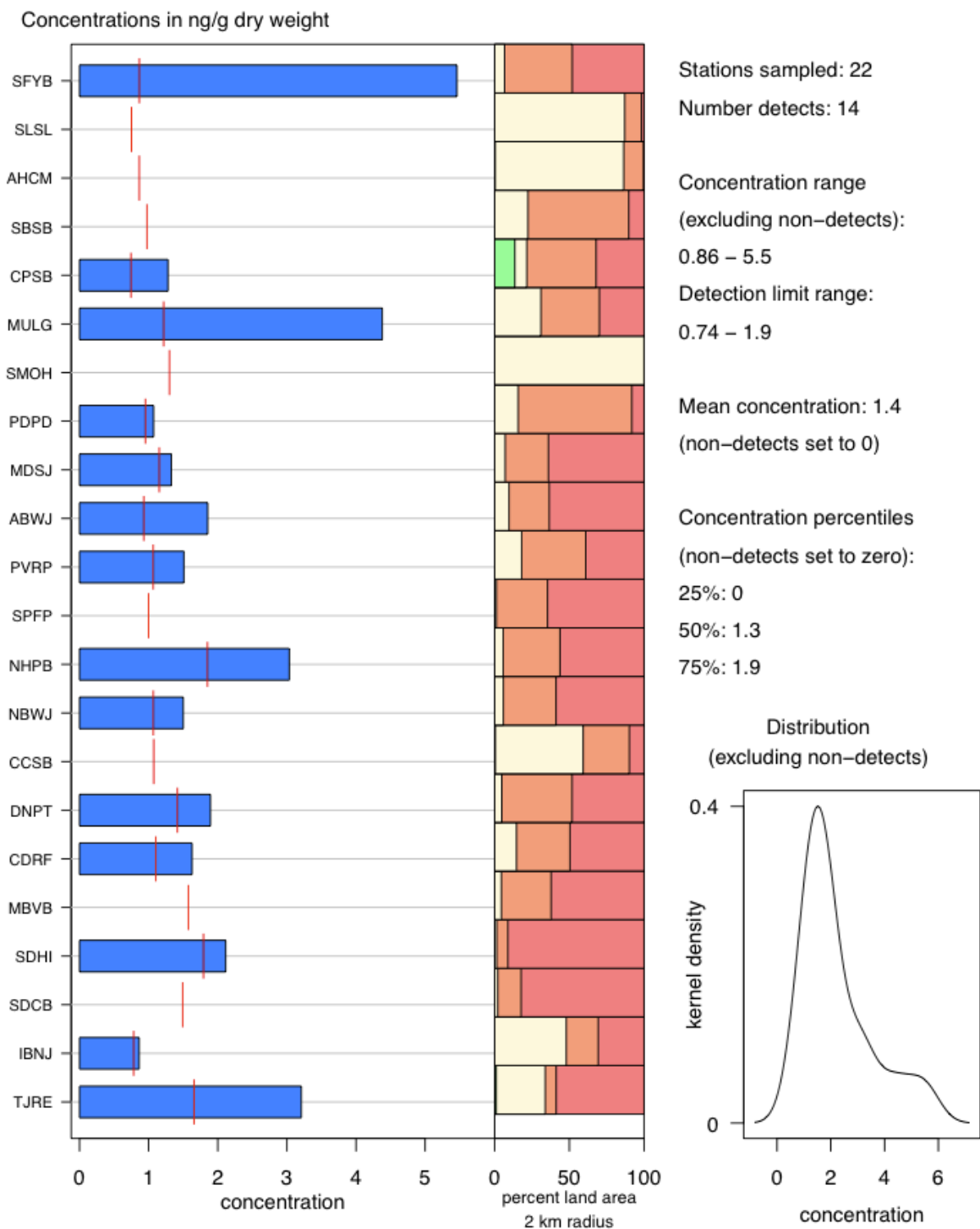
Compound: Methylprednisolone

Class: PPCP



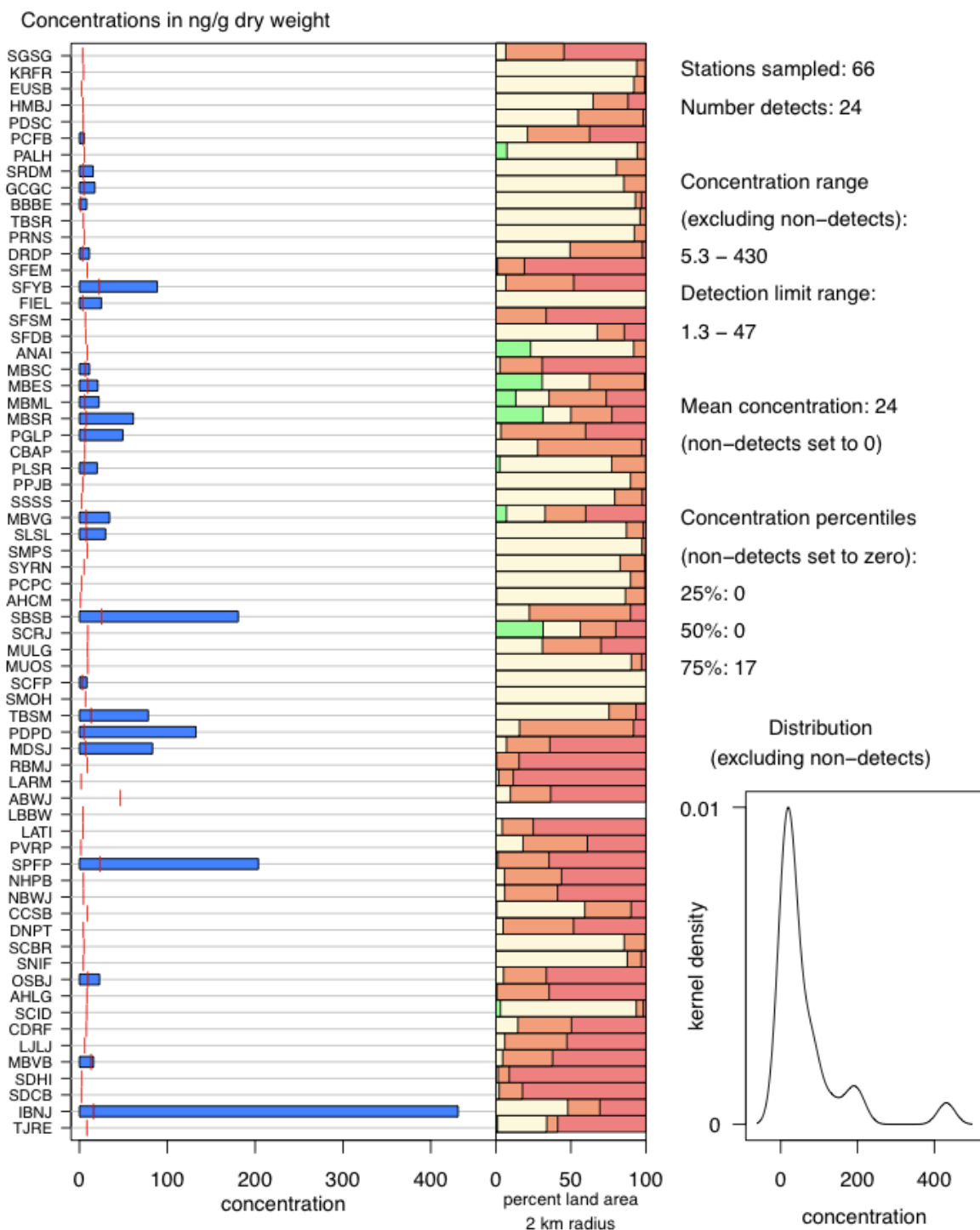
Compound: Sertraline

Class: PPCP



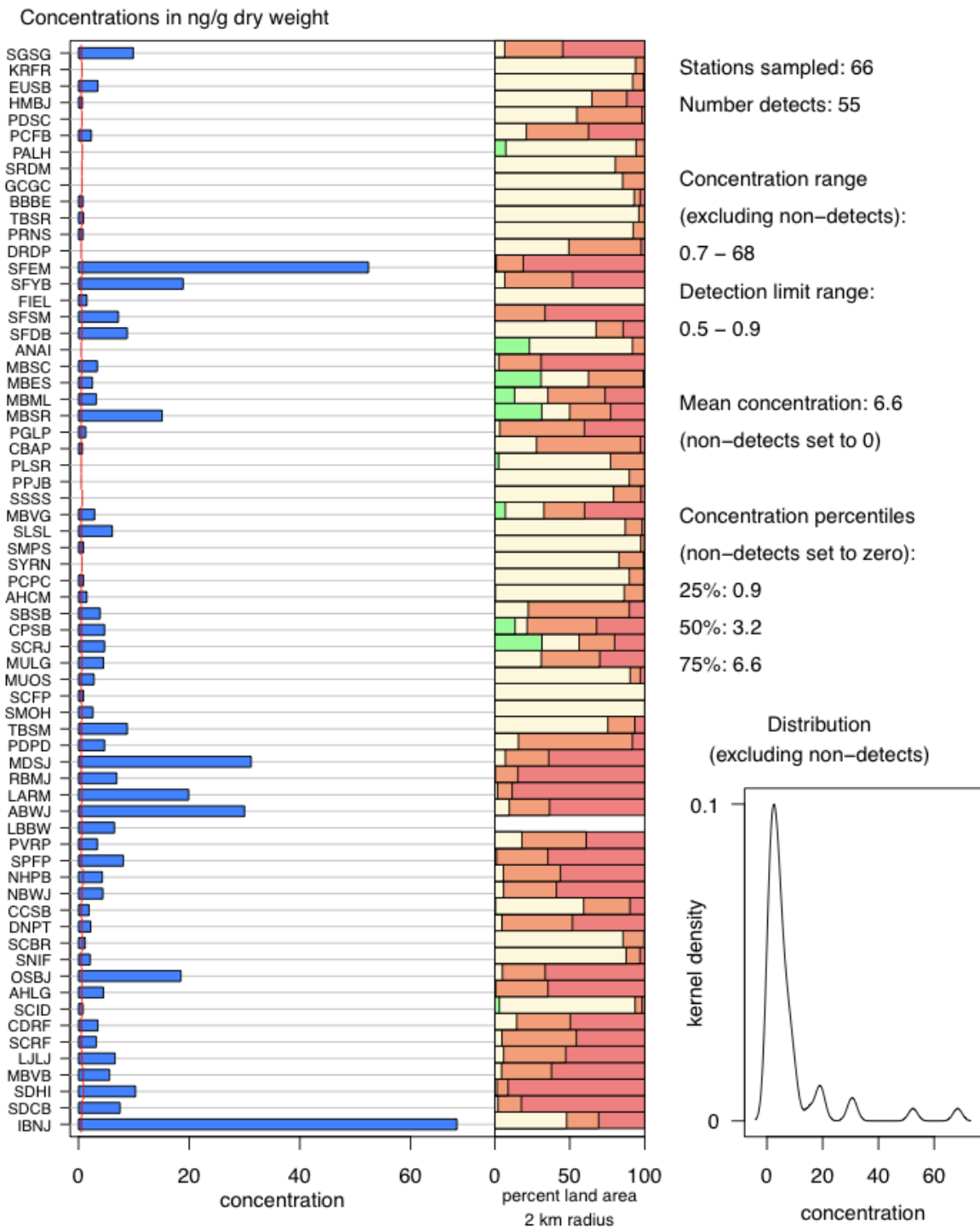
Compound: Sulfamethazine

Class: PPCP



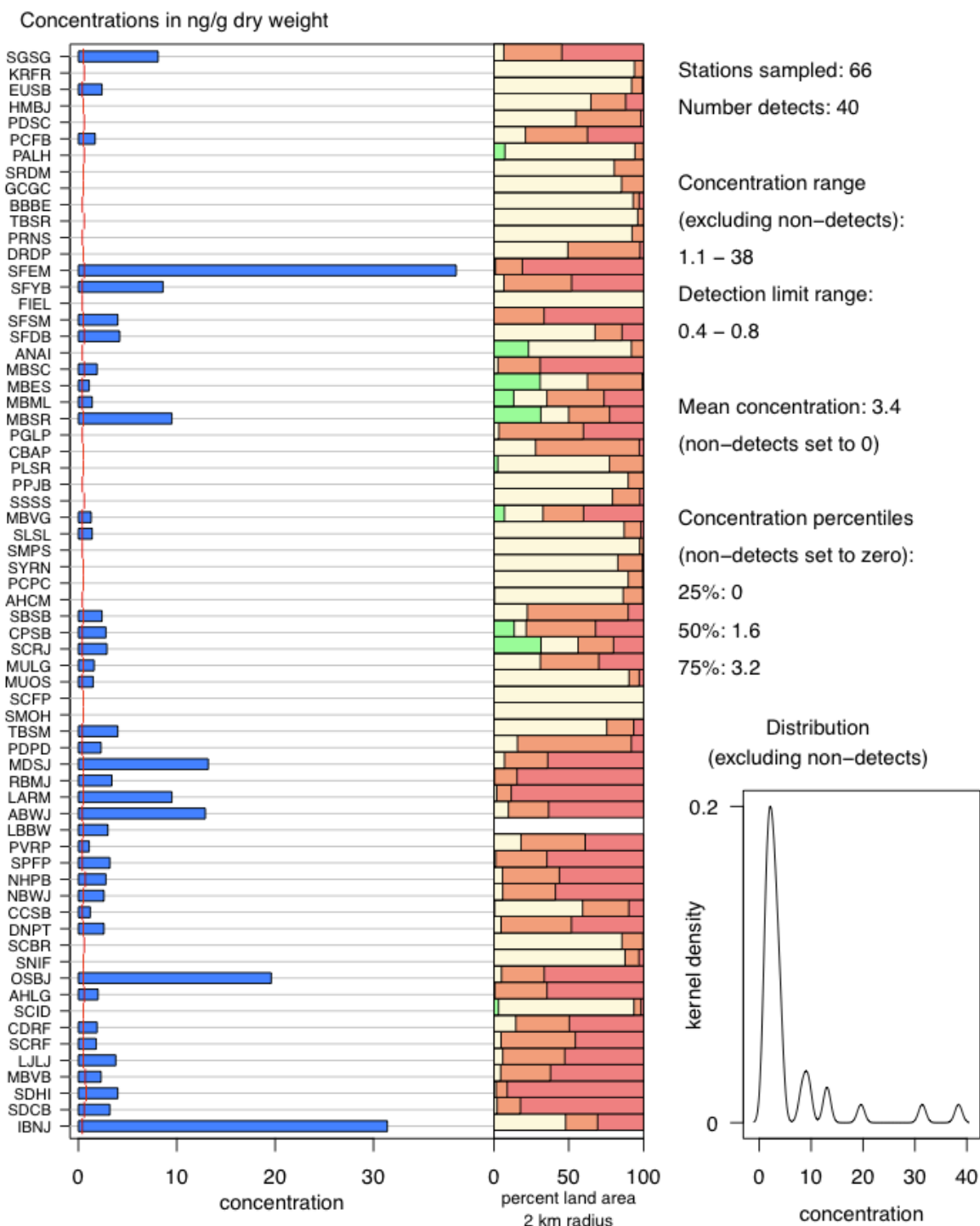
Compound: BDE-47

Class: PBDE



Compound: BDE-99

Class: PBDE



Compound: HBCD, gamma

Class: AFR

