Newport Bay Watershed Monitoring Evaluation

Kenneth C. Schiff
A. Elizabeth Fetscher
Marlene M. Hanken

Southern California Coastal Water Research Project

Technical Report 815 - April 2014

Newport Bay Watershed Monitoring Evaluation

Kenneth C. Schiff, A. Elizabeth Fetscher, Marlene M. Hanken

Southern California Coastal Water Research Project, Costa Mesa, CA 92626

April 1, 2014

Technical Report 815

ACKNOWLEDGEMENTS

This project would not have been possible without the dedicated effort of the Project Stakeholder Advisory Committee:

Amanda Carr	City of Irvine
Wanda Cross	Santa Ana Regional Water Quality Control Board
Stuart Goong	Orange County Public Works
Ray Hiemstra	Orange County Coast Keeper
Larry Honeybourne	Orange County Health Care Agency
Adam Fischer	Santa Ana Regional Water Quality Control Board
Darren Haver	University of California Extension
John Kappeler	City of Newport Beach
Dean Kirk	The Irvine Company
Kathy Nakase	Orange County Farm Bureau
Carla Navarro	California Department of Fish and Wildlife
Jian Peng	Orange County Public Works
Ken Schiff	Southern California Coastal Water Research Project
Doug Shibberu	Santa Ana Regional Water Quality Control Board
Jack Skinner	Citizen Member
Katie Zeeman	US Fish and Wildlife Service

Appreciation is also extended to Brock Bernstein and Susan Paulsen who contributed to the technical elements and provided valuable comment to this report.

EXECUTIVE SUMMARY

The Newport Bay Watershed is a valuable ecological resource containing over 300 km of stream miles and the largest estuary in Southern California. Water bodies within the watershed are also a valuable human resource for fishing, swimming, and non-contact recreation. However, water bodies within the Newport Bay Watershed are also potentially at risk of pollution from urban runoff, boating activities, historical inputs, agricultural legacy inputs, and alterations in groundwater hydrology. As a result, a number of regulatory management programs have been instituted including NPDES discharge permits and TMDLs. Associated with these management programs are monitoring requirements to assess the magnitude of the water quality impact and track improvements as management actions are implemented. Some of these monitoring programs have existed for decades while others have just begun, but old and new monitoring requirements are rarely integrated with one another. As a result, there is concern about inefficiencies once management questions have been addressed.

The goal of this project was to evaluate the effectiveness and efficiency of monitoring programs in the Newport Bay Watershed, and then make recommendations for improvement. This evaluation followed a four step process to:

- Develop the list of management questions,
- Create an inventory of existing monitoring efforts,
- Assess the effectiveness of the current monitoring elements to address the questions of interest, and
- Redesign selected monitoring elements for improved effectiveness and efficiency to address the questions of interest.

This process was implemented using an Advisory Committee that included regulatory, regulated, advocacy, and academic stakeholders from throughout the watershed.

Five management questions were identified for which monitoring data would help make decisions. These five questions included:

- Is the ecosystem protected?
- Is it safe to eat the seafood?
- Is it safe to swim?
- Are we in attainment of water quality standards?
- What are the sources of pollutants?

Embedded within each question is also an element of trends.

The inventory of monitoring effort indicated that there is a tremendous quantity of effort expended on monitoring in the Newport Bay Watershed, the likes of which is rarely seen in California. In total, 13 long-term monitoring programs were identified that sample 139 sites for 399 different constituents. The net result was over 32,000 sample analyses per year.

After a series of one-on-one interviews with many of the Stakeholder Advisory Committee members, the assessment of current monitoring effort fell into one of four categories:

- Monitoring that was effective and efficient
- Monitoring that was effective, but inefficient
- Monitoring where effectiveness and efficiency was uncertain
- Monitoring that does not currently exist

The most ***effective and efficient*** monitoring programs were the regional-based programs that incorporated the Newport Bay Watershed within the greater Southern California region. These regional programs, such as the Southern California Bight regional marine monitoring program that samples the bay or the Stormwater Monitoring Coalition regional stream monitoring program, effectively addressed the "ecosystem protection" question. Well-developed assessment tools and monitoring infrastructure, plus placing the Newport Bay Watershed within the context of other Southern California watersheds, provided scientifically sound answers at watershed scales.

A second effective monitoring program worthy of continued investment was the beach monitoring program conducted by the Orange County Health Care Agency for assessing the "safe to swim" question. This monitoring program is highly valued by the public and has documented water quality improvements as management actions have been implemented to clean beach water quality.

Mass loading monitoring programs, whereby sampling stations are located at the end of major tributaries to Newport Bay to answer questions about "attainment of water quality standards" and "sources of pollutants," was deemed ***effective, but not efficient***. These mass loading sites are sampled weekly, sometimes for decades, and concentrations are compared to receiving water standards or TMDL load allocations. In many cases, the monitoring has shown a decrease in concentrations and loads that correspond to management actions ameliorating upstream pollutant sources. Re-answering the questions on such a frequent basis was no longer necessary. Statistical power analysis, based on the results from 2002-2012, indicated that sampling could be reduced to quarterly in dry weather for individual mass loading stations. Selecting optimal sampling frequencies based on power analysis for answering trends questions is recommended, particularly should concentrations begin to increase. The power analysis also confirmed that an optimized sampling effort for trends will provide sufficient data to make statistically sound conclusions about attainment of regulatory thresholds.

The TMDL monitoring programs for selenium and pesticides have only recently been designed and few data have been collected to address their questions regarding "attainment of water quality standards". As a result, monitoring ***effectiveness and efficiency was uncertain***. Therefore, revisiting the design of these monitoring programs after additional data has been collected is recommended.

There currently is ***no ongoing monitoring*** program for assessing the "safe to eat the seafood" question in Newport Bay. Angler warnings for seafood consumption exist along the open coast of Newport Beach, but there is insufficient data within the Bay to make conclusions about whether similar warnings are needed. Two individual monitoring projects have collected samples of seafood tissues from within the Bay, but these projects are not recent and the sparse results were mixed. However, the RWQCB has recently completed a tissue sampling program that included bioaccumulation through several trophic levels including sport fish. Waiting until these data are fully analyzed before making a decision about designing and implementing an ongoing seafood monitoring program is recommended.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

INTRODUCTION

The Newport Bay Watershed is a valuable ecological resource. The watershed is approximately 390 km^2 with roughly 300 stream km, originating in the Santa Ana Mountains and ending at the Newport Bay. The watershed includes approximately 4 km^2 of protected estuary, the largest estuary in Southern California. The estuary is a primary stop on the Pacific Flyway, the major bird migration route from North to South America along the pacific coastline. The estuary supports at least two threatened or endangered species, and is important nursery habitat for many fish species. The Newport Bay Watershed is also a valuable human resource. It contains 44 beaches, amongst the largest small boat harbors in Southern California, and an extensive creek-side trail network. As a result, human uses include swimming, fishing, and non-contact recreation.

Newport Bay Watershed faces a number of possible ecological threats. The watershed is extensively developed and includes the cities of Irvine, Tustin, Santa Ana, Costa Mesa and Newport Beach. This urbanization produces municipal and industrial runoff in both wet and dry weather. While there are no treated wastewater discharges in the watershed, recycled water is widely used for irrigation. There are also a number of dewatering discharges, especially in the flat portions of the watershed where a historical marsh once existed (Grossinger et al. 2011). Some of these discharges contain groundwater high in selenium and nutrients, which also exfiltrates into the storm sewer system (Hibbs et al., 2000). Over 10,000 recreational boats berth in Newport Bay, most with copper-based antifouling paint designed to leach into the surrounding bay water column. Finally, dredging activities to maintain navigable waterways occurs on a periodic basis.

As a result of the unique beneficial uses of the Newport Bay Watershed and the potential pollutant inputs from the various watershed activities, a number of regulatory management actions have occurred. These include either state and/or federal permits for pollutant discharges or dredging activities. An example of discharge permits includes National Pollutant Discharge Elimination System (NPDES) permits for municipal separate stormwater (MS4), industrial stormwater, or dewatering activities. Regulatory management actions also include Total Maximum Daily Loads (TMDLs) that lead to strict limits on the quantities of pollutants that can be discharged to Newport Bay Watershed stream reaches or to the Bay. A number of TMDLs exist for the Newport Bay Watershed including sediment, bacteria, nutrients (i.e., total inorganic nitrogen or TIN), pesticides, and selenium.

With each new NPDES permit or TMDL, monitoring environmental conditions are required to track the effectiveness of each management action. However, the monitoring requirements are generally not integrated among management actions and this has led to a perceived web of tangled monitoring requirements by stakeholders. Specifically, the monitoring efforts in the Newport Bay Watershed have not been thoroughly and independently reviewed for monitoring needs or effectiveness. Stakeholders are concerned that the lack of integration can lead to duplicative effort, conflicting objectives, and inefficient resource allocation. Most importantly, stakeholders are concerned that monitoring requirements are not feeding the management decision-making process.

The goal of this project is to evaluate the environmental monitoring that is being conducted in the Newport Bay Watershed relative to key monitoring questions asked by managers, evaluate its effectiveness and efficiency, and then make recommendations for improvement. This project does not compile all of the historical data from the watershed nor is it intended to create a state-of-the-watershed report.

METHODS

Key to the success of this project was the use of a Stakeholder Advisory Committee. The Advisory Committee consisted of decision makers at each of the agencies currently conducting monitoring in the watershed. The committee was comprised of multiple sectors including regulated agencies, regulatory agencies, environmental advocacy groups, and academia. Most of the group members not only had monitoring responsibility within their own organization, but also were the primary person who would be using the information from the monitoring program for making decisions. Finally, many of the individuals on the committee had many years' experience, and were quite aware of the history in the watershed, providing invaluable insight into changes (or lack of changes) in monitoring requirements and monitoring results over time.

This project utilized a four-step process for evaluating the effectiveness and efficiency of monitoring in the Newport Bay Watershed:

- Develop the list of monitoring questions
- Create an inventory of existing monitoring efforts
- Assess the effectiveness of the current monitoring elements to address the questions of interest, and
- Re-design the monitoring elements for improved effectiveness and efficiency to address the questions of interest

Monitoring questions are fundamental to the development of any monitoring program. The monitoring questions drive the study design elements including what, when, where, and how to monitor. However, there are several key pieces of information for defining an appropriate monitoring question in order to translate it into a management decision-making tool. These key pieces of information include:

- Spatial and temporal scales
- Indicators to be measured
- Benchmarks, guidelines, or thresholds for evaluation
- Data products
- Management action after answering the question

For this project, the Advisory Committee helped develop the list of monitoring questions, including a matrix that filled in each monitoring question attribute.

The second step was to create an inventory of current monitoring effort. The goal of the monitoring inventory was to assess not only what monitoring was currently being conducted, but how well it addressed the monitoring questions of interest. Several criteria were used for selecting the monitoring programs in the inventory including:

- A long-term monitoring program defined as ongoing (or will continue) for at least five years
- Located in the Newport Bay Watershed, including both the upper and lower Bay and ending at the jetty mouth, therefore excluding any monitoring along the open coast in Newport Beach
- Monitoring that collects data (including water, sediment or tissue) to support water quality based decision making

- Program has some form of documentation (i.e., work plan, quality assurance plan, data availability, etc.)

The third step, evaluating monitoring effectiveness, was conducted based upon one-on-one interviews. Because this project was lucky to have so many involved stakeholders, many of whom have a long history with monitoring in the watershed, the interviews served as a tremendous focal point for which data are (or could be) used for decision making.

The fourth step identified improvements in monitoring design that would be useful for increasing effectiveness. This process focused on power analysis utilizing historical data. Power analysis is a tool that scientists use to evaluate the robustness of sampling designs for making statistically significant statements. Power analysis quantifies the underlying variance structure of the data set, and then helps define the probability of making false negative and false positive conclusions. For conducting power analysis, we obtained historical data collected between Jul 2002 and Sep 2012. The underlying variance structure was quantified by calculating the residuals from the de-trended historical data using a best-fit polynomial equation. Power analysis for detecting trends was based on the relative change from the mean using a two-tailed test. For all power analyses it was assumed $\beta = 0.08$ and $\alpha = 0.05$.

RESULTS AND DISCUSSION

Monitoring Questions and Design Elements

The Advisory Committee helped identify the five management questions of greatest interest in the watershed (Table 1). These questions included:

- Is the ecosystem protected?
- Is it safe to eat the seafood?
- Is it safe to swim?
- Are we in attainment of water quality standards?
- What are the sources of pollutants?

These questions drive management decision making in this watershed and are not dissimilar to the monitoring questions asked by managers in other watersheds (Mazor et al. 2011, Council for Watershed Health and Aquatic Bioassay & Consulting Laboratories 2012).

The “ecosystem protection” question includes freshwater, estuarine, and marine habitats. Focusing on an index period when indicators such as chemistry and biology are in quasi-steady state is preferable in order to reduce variation that may lead to erroneous results. Moreover, pre-existing assessment tools such as the Benthic Response Index (BRI), the California Stream Condition Index (CSCI), and the California Rapid Assessment Method (CRAM) will be the benchmark for measuring ecosystem status. Finally, any ecosystem health monitoring should occur at sufficient frequencies so that trends in condition can be evaluated. Additional indicators and benchmarks (i.e., amphibians and reptiles in streams, eelgrass extent in estuaries) are optional monitoring elements, if desired.

The “seafood safety” question was limited spatially to where anglers catch and consume fish, largely in the lower Bay and lower San Diego Creek. Most of the upper Bay consists of an ecological reserve and Marine Conservation Area where no fishing is allowed. The temporal scale can be flexible, being more frequent when tissue concentrations are close to thresholds of concern and less frequent when distant from thresholds (either well above or well below). Ultimately, seafood safety decisions are made by the California Office of Environmental Health Hazard Assessment (OEHHA), but some management actions are available to the Orange County Department of Environmental Health. These decisions should be made based on concentrations in species and tissues most consumed by anglers, and compared to fish contaminant guidelines published by OEHHA (Klasing and Brodberg 2008, 2011).

The “safe to swim” question, with its focus on public health, is spatially focused in three areas: 1) a primary emphasis on swimming beaches; 2) historical sites used for tracking trends, and; 3) major tributaries to the Bay such as San Diego Creek or Costa Mesa Channel that are potential sources of pollutants to the Bay. Temporal scales have historically been weekly year-round assuming that water contact recreation occurs both in the summer and winter. Fecal indicator bacteria (*Enterococcus*, fecal coliform/*E. coli*, and total coliform) are measured and compared to regulatory thresholds established by AB 411. The management decisions are made with these monitoring data by the Orange County Health Care Agency including whether to post/remove signs warning swimmers about polluted swimming beaches. Ideally, confirmation sampling would trigger source-tracking strategies for identifying the sources of fecal pollution.

The “attainment of water quality standards” question is critical since the repercussions of exceeding standards can be severe. The spatial and temporal scales are set forth in the numerous regulatory actions established in this watershed including NPDES permit limitations often established by the California Toxics Rule, TMDL numeric targets, and sediment quality objectives (Table 2). Elements of this question are reflected in previous questions including “safe to swim” and “ecosystem protection.” Consequently, the monitoring locations are often in receiving waters such as upper and lower Newport Bay, at the mouth of large tributaries to the Bay, and along the main stem of San Diego Creek. A wide variety of indicators are measured including suspended sediments, nutrients, trace metals, toxicity, and fecal indicator bacteria. Indicators may be used in combination, such as chemistry, toxicity and biological communities to assess attainment of sediment quality objectives. While the data are often evaluated relative to regulatory benchmarks, trend information is also valuable to assess the probability of exceeding the benchmarks into the future. The management actions based on inability to attain water quality standards are typically named in the regulation, but may include triggers to conduct source identification or toxicity identification evaluations, examine effluent data to assess contributions from permitted discharges, or consider listing/delisting decisions for the State’s list of impaired water bodies (§303d).

The “pollutant source” question is perhaps the most difficult to characterize because the Advisory Committee had differing perspectives of appropriate spatial and temporal scale. These scales varied from individual parcels to subwatershed scales or from point source to nonpoint source comparisons. Their perspectives were influenced by the spatial scale of their relative management authority; agencies with more global missions thought at larger scales and local agencies thought at smaller scales. Subwatershed scales were selected for this project because this scale most closely aligns to the “attainment of water quality standards” question and subwatershed scales can most easily differentiate natural variability relative to anthropogenic impacts (i.e., stream reaches or upper/lower Bay segments). Temporal scales were seasonal to annual, once again to distinguish natural from anthropogenic loading. The indicators mirrored those in the “attainment of water quality standards” question since source tracking was a management outcome of this regulatory–based question. The management actions resulting from source identification included ranking of sources for remediation and prioritization of BMPs for treatment.

Monitoring Inventory

The monitoring inventory indicated that the Newport Bay Watershed is one of the most intensely monitored in Southern California (Tables 3). There were 13 different long-term monitoring programs in the watershed. Some of these programs have been collecting data for decades. A total of 139 unique monitoring sites were identified (Table 3, Appendix A). These programs monitor the water column, sediments, and tissues (Figure 1).

The monitoring inventory identified 399 unique analytes that fell into one of 19 different analyte groups (Table 4). These analyte groups included categories such as biology, chemistry, toxicity, physical habitat, and chemistry. Even within chemistry, there are many groups including nutrients, metals, and different types of pesticides. The final result is an estimated 32,206 individual analyses per year.

Monitoring Design Evaluation and Design Recommendations

A critical evaluation of current monitoring designs identified four categories of effectiveness and efficiency: 1) Currently effective monitoring; 2) Current monitoring is effective, but inefficient; 3) Current monitoring design remain untested; and 4) No current monitoring design.

Currently Effective Monitoring

A number of monitoring elements were very effective for managers in the Newport Bay Watershed. The most effective elements were associated with the regional-based monitoring programs. These included the Stormwater Monitoring Coalition's (SMC) regional watershed monitoring or the Southern California Bight (Bight) regional marine monitoring programs. The success of the regional programs was a function of their question-focused design, their ability to bring regulators and regulated communities together to obtain consensus on the conclusions, placing local Newport conditions in context of the spectrum of all watersheds, and their focus on training to achieve high quality monitoring (Figure 2).

Both the regional stream and bay/ocean monitoring programs address the management question on "ecosystem protection." Both programs use a multiple indicator approach for site assessment that includes chemistry, toxicity, and biological community (i.e., invertebrate communities, algal biomass and composition) information, because there is uncertainty associated with any single indicator. Both the regional stream and bay/ocean monitoring programs use a probability based design (Stevens and Olsen 2003), which allows an unbiased assessment of overall condition. If managers are interested in a specific location, then this design is not optimal. However, the Advisory Committee preferred to assess the water body or watershed as a whole, for which there is no better study design. Both regional stream and bay/ocean monitoring occurs during an index period, but streams are sampled annually while bay/ocean sampling occurs every five years. All of these elements coincide with the spatial and temporal, indicator selection, benchmarks, and data products expressed in Table 2.

Beach monitoring in the Newport Bay Watershed was also considered an effective monitoring program for answering the "safe to swim" management question. Sampling at 31 beaches and four creek mouths baywide occurs between once and five times per week. Data products on fecal indicator bacteria (FIB) concentrations relative to regulatory thresholds is generated rapidly providing the most up-to-date information to the public for making informed decisions regarding swimming risk (Figure 3). Although not optimized for tracking trends, the frequent monitoring also provides very useful information for assessing changes in bacterial contamination over time.

Because of their utility and effectiveness, keeping the regional monitoring programs largely as they are currently conceived and implemented is recommended.

Current Monitoring Is Effective, but Inefficient

A number of monitoring elements had been very effective, but the basic management questions had been answered with many years of data. As a result, analysis to optimize the sample design to increase efficiency was recommended. The optimization fell into one of three categories: sampling frequency, indicator selection, utilization of new monitoring design technology.

The most critically evaluated monitoring program was the dry weather mass loading monitoring, which is focused on answering the "attainment of water quality standards" and "sources of pollutants" monitoring questions. The mass loading monitoring collects water samples at the end of major tributaries, typically on a weekly basis, for measurements of suspended sediment, nutrients, and bacteria. The primary tributaries include San Diego Creek (SDMF05), Costa Mesa Channel (CMCG02), and Santa Ana-Delhi Channel (SADF01).

Managers had two important findings after years of monitoring. First, there had been a tremendous reduction in loads and concentrations of the regulated parameters over many years of management actions. For example, nutrient loads had decreased by two orders of magnitude since 1978 (Figure 4). Reductions have been observed for suspended sediment loads and bacteria concentrations, but to a lesser degree. Second, attainment of management benchmarks has increased dramatically over the same period. For example, estimates of average algal density had decreased from approximately 2 kg/m^2 to less than 0.5 kg/m^2 in the Bay between 1996 and 2012 (Figure 5). Similarly, the geomean fecal coliform concentrations at swimming beaches in the Bay have decreased over time and the frequency of exceedences decreased from nearly 50% of samples in 1986 to less than 10% of samples in 2012 during dry weather (Figure 6).

Changes in Sampling Frequency

As a result of the management action investment, and the improvements in attaining water quality standards reflected by the historical monitoring, analyzing whether continued mass loading monitoring during dry weather at the same level of effort was warranted. To optimize sampling effort, power analysis was conducted to determine the optimal number of samples required to detect trends and to detect differences from a water quality threshold. Power analysis to detect trends is a function of the amount of change managers wish to detect, the amount of time to detect the trend, and the underlying variability in the data.

The underlying variability in the data for each channel and indicator was determined by de-trending the 10 years of data (2002-2012) at the three mass loading stations (SDMF05, CMCG02, SADF01) (Figure 7). Results show that SDMF05 generally had the highest concentrations of suspended sediments, TIN, and *Enterococcus* of the three stations. Although trends in TIN were observed, there was little trend in sediments or *Enterococcus* at any of the channels.

Power analysis indicated that optimal sampling frequency for total inorganic nitrogen (TIN) was near the inflection point of the curve, or approximately 100 samples to detect a 30% change in concentration (Figure 8). Additional samples brought little additional power to detect trends, but fewer samples rapidly lost power. For example, an additional 50 samples (n=150) would only detect a 25% change in concentration (a 5% improvement), but 50 fewer samples would only be able to detect a 40% change in concentration (a 10% deterioration). The Advisory Committee agreed that the period for trend detection was four years, or approximately the time from when a new NPDES permit begins to when analysis for the next NPDES permit begins. Therefore, the optimal sampling frequency for TIN in SDMF05 is 100 samples over 4 years, or 25 samples per year, compared to 52 samples per year currently stipulated in the NPDES permit.

The power curve for detecting TIN concentrations that are significantly different from a regulatory threshold is similar in shape to the trend detection curves, but with greater power for fewer samples (Figure 8). Since the statistical comparison is strictly a function of the underlying variability in the data (calculated from the 10-year data set), the actual threshold does not matter. Optimal sampling frequencies of 80 samples can detect a 25% difference in concentration from the threshold. In this case, fewer samples provided greater power for threshold evaluation than trend detection. Therefore, optimizing sampling frequency for trend detection will capture the necessary frequency for threshold exceedence detection.

The power curves for different channels and indicators indicated a range of optimal sampling frequencies (Table 5, Appendix B). Optimal sampling frequencies for detecting trends in TIN concentrations during dry weather ranged from 20 to 35 per year across the three channels. This is due to the differences in variability in the 10-year data set from CMCG02 and SADF01 compared to SDMF05. The range of optimal sampling frequencies in TSS (20 to 50 per year) or *Enterococcus* (10 to 25 per year) were due to the differences in variability in the 10-year data set among the different constituents (note: *Enterococcus* concentrations were log-transformed prior to analysis). Optimal TSS frequencies were greater than TIN or *Enterococcus*, mostly due to increased variability resulting from a small number (N=2) of extraordinarily large concentrations at CMCG02 and SADF01. Removing these potentially anomalous samples reduced variability in the 10-year data set, and subsequently optimal sampling frequencies decreased by at least 50%. Therefore, the frequencies in Table 5 are considered very conservative.

Optimal sampling frequencies for detecting a difference from a water quality threshold in dry weather were universally lower than the optimal frequency for detecting trends (Table 5, Appendix B). For example, the range of sampling frequencies for the TIN threshold was 7 to 15 samples per year across the three channels. Similarly, the range of sampling frequencies for the *Enterococcus* single sample threshold was 10 to 20 samples per year across the three channels.

While power analysis was utilized to describe optimal sampling frequency, it should be noted that managers can always use the power curves to estimate the required number of samples if specific changes in concentration over time or relative to a threshold is recommended. In addition, power analysis should be repeated on a periodic basis, or anytime a change in variability is expected. The Executive Officer of the RWQCB can alter sampling frequencies dictated in NPDES permits.

Changes in Indicator Selection

The options for changes in indicator selection were very limited. Reductions in nutrient indicators were unappealing since a suite of nutrients is important for understanding biogeochemical cycling. Reductions in TSS were illogical because it is only a single indicator. Reductions in the different FIB did have some appeal, and additional data analysis to estimate correlations among FIB and decision matrix for false positive and false negatives was conducted.

There are three FIB monitored at mass loading stations SDMF05, CMCG02, and SADF01; *Enterococcus*, fecal coliform, and total coliform. All three FIB were highly correlated based on the 10-year data set, indicating that sampling multiple indicators yields information (Figure 9). When comparing FIB to regulatory thresholds to address the “attainment of water quality standards” question, contingency analysis indicated that *Enterococcus* provided the same information as fecal coliforms (Table 6). Ninety-one percent (91%) of samples for *Enterococcus* and fecal coliforms over the 10-year data set at SDMF05 were in agreement relative to their specific thresholds. Of the remaining 9% of samples, *Enterococcus* exceeded its regulatory threshold twice as often as fecal coliforms, and only 3% of samples exceeded fecal coliform thresholds when *Enterococcus* did not. Therefore, sample-for-sample, *Enterococcus* provided a more conservative estimate of water quality. CMCG02 and SADF01 also showed *Enterococcus* to be a conservative indicator of FIB contamination.

Based on this analysis, eliminating or reducing the frequency of analysis for fecal coliforms is recommended. There are a number of opportunities and challenges for implementing this recommendation. Focusing solely on *Enterococcus* makes sense for two reasons. First, the Orange County Health Care Agency utilizes *Enterococcus* as their primary indicator for making beach management decisions. This is consistent with the US Environmental Protection Agency's new policy to exclusively use *Enterococcus* for beach regulatory decisions (EPA 2012). Eliminating the redundant fecal coliform analysis will save 50% on monitoring program analytical costs. However, the bacteria TMDL for Newport Bay stipulates fecal coliforms in the RWQCB's Basin Plan. Changing from fecal coliforms to *Enterococcus* in the Basin Plan requires a public process. This process, even under the best of circumstances, requires months of effort.

Utilization of New Monitoring Design Technology

Dry weather illicit connection/illegal discharge (IC/ID) monitoring is used to answer the "sources of pollutants" question. The goal of this monitoring is to identify and remove highly preventable pollutant sources including sanitary sewer cross-connections to the storm drain system or non-stormwater discharges (i.e., restaurant wash down, mobile car washing, etc.). The current monitoring design is focused on deploying a relatively expensive mobile laboratory to pre-selected locations on a routine monthly schedule. Unfortunately, this design identifies only a small subset of offenders, constrained largely to chronic discharges. However, there are potentially many more IC/ID that are highly transient either in space or time, which the current routine monitoring design will not identify.

An improved sampling design to focus on what appears to be almost random and short-lived IC/ID sources, would be to incorporate a more spatially dispersed census of storm drain flows and then repeat at an increased frequency. The key would be to use rapid screening level information for the increased spatial and temporal scale necessary to detect possible IC/ID, which would then trigger the appropriate time and location for the detailed follow-up sampling and analysis procedure utilized by the mobile laboratory. The biggest challenge to this design is the labor necessary to survey large numbers of stream-miles on a regular basis for the screening level information.

An opportunity exists to overcome the labor requirements by linking existing programs through new information technology. Currently, the Orange County Coastkeeper uses citizen monitoring to survey stream channels for flowing storm drains. Some screening level information is collected each time a flowing storm drain is encountered. Orange County Public Works maintains an online reporting form for flowing storm drains (http://ocwatersheds.com/wphotline/reporting). A new monitoring design would link the Coastkeeper and OCPW monitoring programs. Coastkeeper has the volunteer labor to walk many stream-miles and OCPW has the follow up capability to investigate and enforce IC/ID regulations.

An effective monitoring alliance between Coastkeeper and OCPW will rely upon new information technology. The design would require screening level information transmitted in a near-real time, standardized format. This can be accomplished through hand-held devices such as a cell phone app. Cell phones have the capacity to automatically include all of the currently required information from the OCPW online form: contact information, drain location GPS coordinates, written (or voice recorded) information about the drain. Cell phones can also produce a variety of new and useful information: still or video imaging, temperature, and Bluetooth connectivity to associated water probes such as conductivity, pH, flow, light transmittance, fluorometry, and others. This technology is currently available and requires a competent programmer working with the scientists and managers who will want to utilize the information. Additional elements of the program will need to be created of course, including documentation, training, quality assurance/quality control procedures, reporting formats, trigger levels, and alike.

Current Monitoring Designs Remain Untested

There were two monitoring designs that are just being developed and implemented: selenium and pesticide TMDL monitoring. These monitoring designs focus on the “attainment of water quality standards” and “sources of pollutants” monitoring questions. The selenium TMDL monitoring was approved in December 2013 and it includes many of the concepts expressed in this report. For example, the monitoring design is specifically question driven to maintain effectiveness. The monitoring design is also tiered to increase efficiency. For example, relatively routine and inexpensive screening level information is provided on a more frequent basis (e.g., quarterly BMP monitoring). Whereas, more intensive and costly information is conducted on a less frequent basis (e.g., annual tissue monitoring). Intermediate tiers link the two ends of the spectrum (e.g., mass loading, sediment). The monitoring design, including site locations and measurement methods, is integrated with existing monitoring efforts in the watershed. Finally, adaptive monitoring concepts are incorporated into the monitoring design to react to new information including increasing (or decreasing) the level of effort, or special studies to investigate unique results or fill data gaps. The pesticide TMDL monitoring design is using similar strategies, but the monitoring design has yet to be completed and approved.

The selenium and pesticide monitoring designs have not been fully implemented yet. In fact, sampling for the selenium TMDL has only recently begun and even initial results are currently unavailable. Therefore, the recommendation for these untested monitoring designs is to wait until additional data are collected prior to evaluating effectiveness or efficiency.

No Current Monitoring Design

There was one monitoring question that had no monitoring design and virtually no data collected; “safe to eat the seafood.” Angler warnings for seafood consumption exist along the open coast of Newport Beach, but no warnings exist within the Bay. The lack of warnings is not because seafood is uncontaminated, but largely due to lack of data. Two individual monitoring projects (and therefore not in our inventory) have collected samples of seafood tissues from within the Bay. The first was a project conducted in 2000–02 that measured bioaccumulation through the food web, assessing both wildlife and human health risk (Allen et al. 2004). Results indicated the accumulation of DDT in sport fish at levels that exceeded Advisory Tissue Levels. However, the Advisory Committee was concerned that the data were a bit outdated, collected more than 12 years prior.

The next project to collect fish tissue data from Newport Bay occurred in 2009 during the Bight Regional Monitoring Program as part of the Statewide Coastal Fish Survey (Davis et al. 2012). Concentrations in edible tissues exceeded Advisory Tissue Levels for PCB and mercury, but not for DDT (Table 7). Although the samples were composites of multiple fish, there were only five samples representing two species. Despite being more recent data, there are concerns about the limited quantity of data.

The only tissue-monitoring program in our inventory was conducted by the RWQCB. Like Allen et al. (2004), the RWQCB collected multiple trophic levels to examine bioaccumulation to assess wildlife and human health risk. Edible fish tissues from at least three species were sampled at several sites in the Bay. Unlike Allen et al. (2004), these data are much more recent (collected between 2006 and 2012). In fact, these data are so new, that the samples are not completely analyzed by the laboratory and data analysis is just beginning.

It is recommended to wait until these data are fully analyzed before making a decision about the need for, and the design of, an ongoing seafood-monitoring program. Scientists at California State University, Long Beach are currently analyzing these data. Moreover, the analysis will include an assessment relative to the SWRCB’s newest models for predicting the contribution of sediment contamination, based on the next phase of Sediment Quality Objectives. If the concentrations in fish exceed Advisory Tissue Levels, and especially if the Sediment Quality Objectives analysis indicates a potential nexus to contaminated sediments, a new monitoring element should be designed and implemented to protect anglers of the Bay.

CONCLUSIONS

- **There is a tremendous amount of monitoring in the Newport Bay Watershed**

  Our inventory of monitoring effort identified 13 long-term monitoring programs, sampling 139 unique stations in the Newport Bay Watershed. Cumulatively, 399 individual parameters were measured, totaling 32,206 different analyses per year.

- **Current monitoring to address ecosystem protection and human health is most effective when the effort has been coordinated with others**

  The most effective monitoring elements were those associated with regional monitoring programs for streams (through the Southern California Stormwater Monitoring Coalition) or bay/ocean (through the Southern California Bight Regional Monitoring Program). The success of integrating with the regional monitoring programs was a function of their question-focused design, their ability to bring regulators and regulated communities together to obtain consensus on the conclusions, placing local Newport conditions in context across the spectrum of all watersheds, and their focus on training and audits to achieve high quality monitoring. Similarly, integrating water quality monitoring with the Orange County Health Care Agency has led to an effective public health warning system.

- **Current monitoring to address attainment of water quality standards has been effective at illustrating the positive outcomes from previous management actions, but updated analysis identified monitoring design inefficiencies that could be improved**

  Weekly monitoring at mass loading sites, or large tributaries that discharge to Newport Bay, are used to answer monitoring questions about pollutant sources and attainment of water quality standards in regulations such as NPDES requirements or TMDL targets. For example, reductions of algal blooms and severe eutrophication in the Bay have coincided with significant reductions in nutrient concentrations at mass loading sites. Data analysis from a decade's worth of monitoring indicated that answering these same questions could be achieved by optimizing the frequency of sampling for trend detection and exceedence of threshold values or reducing some parameters that give duplicative information.

RECOMMENDATIONS

- **Continue with the effective monitoring elements**

  Regional monitoring to assess ecosystem health was found to be one of the best monitoring designs and this monitoring should be continued. Similarly, continued beach monitoring is also recommended.

- **Reduce frequency of sampling at mass loading (i.e., end of watershed) sites to more efficiently address trend questions**

  Use table 5 to help select optimal frequencies for detecting trends or threshold exceedences. These reductions may reduce frequency from weekly to quarterly for some analytes at certain channels. Implementation logistics may dictate deviations from the optima listed in the table, such as field efforts to collect multiple samples or laboratory sample batches. However, frequencies less than those listed run the risk of losing information necessary for managers to quickly and appropriately respond to monitoring questions with confidence.

- **Consider dropping parameters that are duplicative and provide no additional information**

  Statistical analysis identified that *Enterococcus* was the most conservative indicator of fecal pollution, and that laboratory analysis of both fecal coliforms and total coliforms from the same sample at mass loading sites provided very little extra information. *Enterococcus* was highly correlated to fecal coliforms and total coliforms, and virtually every time fecal or total coliforms exceeded a water quality threshold, so did *Enterococcus*. Moreover, the County Health Care Agency focuses on *Enterococcus* for their health warning system, consistent with recent recommendations from the US EPA. However, fecal coliforms are specifically named in the bacteria TMDL for Newport Bay, so further policy action may be required to reduce the redundancies and inefficiencies in bacterial sampling and analysis.

- **Evaluate changes to specific monitoring elements after additional data collection and data analysis have been completed**

  There were two monitoring elements that were evaluated for improvements, but recommendations for changes were premature. The first was the TMDL monitoring for selenium and pesticides. These two monitoring elements address monitoring questions about attainment of water quality standards and sources of pollutants, and are still in early stages of implementation. Additional data are required before the data can be queried for refinements to study design. Second, there is no routine sampling effort for answering the monitoring question about seafood safety. There are currently no warnings to anglers about consuming seafood caught in the Bay, but results from individual projects indicated that DDTs, PCBs and mercury may be an issue. However, these data are either more than a decade old or lack sufficient sample size for making robust decisions. Bioaccumulation sampling for a seven-year study by the RWQCB was recently completed and it is recommended to wait until this information on the risk of seafood consumption is available prior to developing an appropriate monitoring design.

- **Create a State of the Watershed report**

  The Newport Bay watershed is one of the most intensely monitored watersheds in Southern California. The tremendous effort invested in this monitoring should be compiled and evaluated for answers to the monitoring questions asked in Table 1. This will provide the information managers need, and the public deserves, for determining if and what further management actions are necessary to improve the Newport Bay watershed.

Table 1. Monitoring questions for the Newport Bay Watershed, developed with the assistance of the Stakeholder Advisory Committee.

Question	Spatial Scale	Temporal Scale	Indicators	Benchmark	Data Product	Management Action
Safe to eat the seafood?	Where people catch fish: - 4 upper bay locations - lower bay - lower SD Ck	Relative to threshold: - annual when close to thresh - 5 yr when far	Species that are consumed (TBD), skin-off filets, no inverts	OEHHA advisory levels for pesticides, PCBs, mercury	Bar chart of concentration by species, Graph of species concentration over time	Conduct additional confirmatory sampling, provide data to OEHHA, conduct angler survey to improve risk estimates, DEH Press release if high risk, implement Sediment Quality Objectives
Safe to swim?	Where people swim (beaches), existing sites for historical continuity, secondary priority for mid-channel samples to support non-contact recreation (SUP, kayak)	Minimum of weekly	Fecal indicator bacteria (Ent, FC, TC)	AB411 thresholds Fecal indicator bacteria Water Quality Objectives	Estimate of Beach-mile days that exceed AB411, Bar chart or table of AB411 exceedence frequency by site, graph of exceedence frequency over time per site	Post/close beach by DEH, adaptive trigger for human marker sampling, Source tracking study, initiate BMP/source control measures
Are we in attainment of water quality standards?	Receiving waters: - 4 major tributaries - SD Ck mainstem - Upper and lower Bay	Dry weather Wet weather	Nutrients, Metals, Suspended sediments, Toxicity, Fecal indicator bacteria	TMDL targets, CTR, SQO	Table listing average concentration and frequency of attainment by site for each parameter, thematic map by site, trends plots of concentration or compliance frequency	Triggers: - review of effluent monitoring - TIE - Source ID Listing/delisting evaluation
What are the sources of pollutants?	Ranges from: - IC/ID - Land use - Jurisdictional - Point vs. nonpoint - Natural vs. anthropogenic - Subwatershed	Dry weather Wet weather Annual	Chemistry, bacteria Nutrients Sediment	TMDL target, Relative contributions	Graph of total load per year over time, pie or bar chart of relative load by source	Triggers: Upstream monitoring Ranking/prioritization of BMPs

Table 2. Regional Water Quality Control Board actions in the Newport Bay Watershed

Regulatory Permits	Order No.
Waste Discharge Requirements for the County of Orange, Orange County Flood Control District and the Incorporated Cities of Orange County within the Santa Ana Region - Area-wide Urban Storm Water Runoff - Orange County	Order No. R8-2009-0030 as amended by R8-2010-0062
General Waste Discharge Requirements for Discharges to Surface Waters that Pose an Insignificant (*De Minimus*) Threat to Water Quality	Order No. R8-2009-0003
General Discharge Permit for Discharges to Surface Waters of Groundwater Resulting from Groundwater Dewatering Operations and/or Groundwater Cleanup Activities at Sites Within the San Diego Creek/Newport Bay Watershed Polluted by Petroleum Hydrocarbons, Solvents, Metals and/or Salts	Order No. R8-2007-0041, as amended by R8-2009-0045
General Waste Discharge Requirements for the Re-injection/percolation of Extracted and Treated Groundwater Resulting from the Cleanup of Groundwater Polluted by Petroleum Hydrocarbons, Solvents and/or Petroleum Hydrocarbons Mixed with Lead and/or Solvents within the Santa Ana Region	Order No. R8-2002-0033, as amended by R8-2003-0085 and R8-2013-0020
Waste Discharge Requirements for City of Irvine, Groundwater Dewatering Facilities, Irvine, Orange County	Order No. R8-2005-0079
Waste Discharge Requirements for Nakase Bros. Wholesale Nursery, Orange County	Order No. R8-2005-0006
NPDES Statewide Storm Water Permit Waste Discharge Requirements (WDRS) for State of California Department of Transportation	Order No. 2012-0011-DWQ
Total Maximum Daily Loads	**Adoption Action**
Newport Bay/San Diego Creek Watershed Sediment	Resolution No. 98-69, as amended by Resolution No. 98-101
Newport Bay/San Diego Creek Watershed Nutrients	Attachment to Resolution No. 98-9, as amended by Resolution No. 98-100
Newport Bay Fecal Coliform	Attachment to Resolution No. 99-10
Newport Bay and San Diego Creek Diazinon and Chlorpyrifos	Resolution No. R8-2003-0039
San Diego Creek and Upper and Lower Newport Bay Organochlorine Compounds	Attachment 2 to Resolution No. R8-2011-0037, modifying Resolution No. R8-2007-0024
Newport Bay Watershed Metals	TMDLs for Toxic Pollutants, San Diego Creek and Newport Bay, California; U.S. Environmental Protection Agency, Promulgated June 2002
Newport Bay Watershed Selenium	TMDLs for Toxic Pollutants, San Diego Creek and Newport Bay, California; U.S. Environmental Protection Agency, Promulgated June 2002
Rhine Channel Chromium and Mercury	TMDLs for Toxic Pollutants, San Diego Creek and Newport Bay, California; U.S. Environmental Protection Agency, Promulgated June 2002

Table 3. List of long-term monitoring programs, monitoring agency, number of years monitoring, and number of monitoring sites in the Newport Bay Watershed circa 2013

Program Name	Agency[a]	Number of Years Monitoring	Number of Stations by Matrix: water	sediment	habitat	fish tissue	bivalve tissue	Total Unique Stations
Assembly Bill 411-Beach Water Quality Monitoring Program	OCHCA	15	41					41
Southern California Bight Project 1998, 2003, 2008, 2013	SCCWRP	19	31	31		2		33
Irvine Ranch Water District-Wetlands NTS	IRWD	?	5					5
John Wayne Airport General Industrial Permit Monitoring	JWA	15	1		2			3
Mass Emissions Monitoring Program	OCPW	11	9	9				9
Metal Recyclers BMP Monitoring Program	OCCK	?	1					1
Newport Bay Post Dredging Monitoring	OCCK	?	13	13				13
Newport Bay Toxic and Bioaccumulative Trend Monitoring	RWQCB	7	7	7		7	7	7
Stream Pollutions Trend Monitoring	SWRCB	6		1				1
Regional Watershed SMC	SCCWRP	5	8					8
Total Maximum Daily Load Program	OCPW	15	10	10	10			10
USGS Climate Change Study	UCLA	18	1		2			3
Wildlife Monitoring (Birds)	DFW	34			5			5
	TOTAL		127	71	19	9	7	139

[a] OCHCA = Orange County Health Care Agency, SCCWRP = Southern California Coastal Water Research Project, IRWD=Irvine Ranch Water District, JWA=John Wayne Airport, OCPW=Orange County Public Works, OCCK=Orange County Coast Keeper, RWQCB=Regional Water Quality Control Board, SWRCB=State Water Resources Control Board, UCLA=University of California Los Angeles, DFW=California Department of Fish and Wildlife

Table 4. Analyte groups and monitoring frequency in the Newport Bay Watershed circa 2013

Analyte Group	# Different Analytes per Group[a]	# Analyses With Varying Monitoring Frequency[b]									Cumulative # Analyses per Year
		5 Yr	2 Yr	1 Yr	6 mo	4 mo	3 mo	2 mo	1 mo	1 wk	
Bacteria	4			1	30	30	12			150	7999
Biology	8	21		45							49
Toxicity	11	44		3	40	40	1				216
Debris	1	6		8							9
Physical Habitat	9			16			2				24
Grain Size	35	571		8						9	590
Chemistry											
General Parameters	27	31		134	202	86	21	12	40	98	6534
Metals	63	525		353	522	50	14		7	153	9748
Nutrients	16	27		107	80	24	8	3	5	56	3366
Antifouling Pesticides	2	16									3
Fipronil Pesticides	6			95							95
Organochlorine Pesticides (OCPs)	47	295	3	112	23	10	8			27	1685
Organophosphorus Pesticides (OPPs)	2				15	10	4		6	9	616
Pyrethroid Pesticides	22	28		238							244
Herbicides	3	8			10	10	4			9	536
Polynuclear Aromatic Hydrocarbons (PAHs)	27	557		28							139
Flame retardants (PBDEs)	56	208		50							92
Polychlorinated Biphenyls (PCBS)	58	964		35	8		4				260
Other Organics	2			1							1
TOTAL	399										32206

[a] Number of different analytes within that group. Not all analytes within a group are measured at all stations
[b] Analyte specific per site

Table 5. Results of power analysis to describe optimal sampling frequency to detect trends in concentrations or concentration difference from a threshold from Newport Bay Watershed mass loading stations

Indicator	Optimal Sampling Frequency Based on Power Curve					
	# Samples Per Year for Trend Detection (% change per 4 years)			# Samples Per Year for Detecting Difference from Threshold (% distance from threshold after 4 years)		
	SDMF05	**CMCG02**	**SADF01**	**SDMF05**	**CMCG02**	**SADF01**
Enterococcus	25 (20)	20 (10)	15 (20)	15 (15)	8 (10)	15 (12)
Total Inorganic Nitrogen	25 (30)	35 (40)	20 (20)	20 (25)	10 (8)	20 (20)
Total Suspended Sediment	20 (30)	50 (125)	30 (100)	-[a]	-	-

[a] no threshold for evaluation

Table 6. Contingency tables (% of samples) for fecal indicator bacteria relative to single sample thresholds of concern at three mass loading stations (SDMF05, SADF01, CMCG01) in the Newport Bay Watershed for wet and dry weather 2002-2012 (Ent=*Enterococcus*, FC = Fecal Coliform, Ent threshold = 104 MPN/100 mL, FC threshold = 400 MPN/100 mL)

SDMF05	FC>400	FC<400
Ent>104	21	6
Ent>104	3	69

SADF01	FC>400	FC<400
Ent>104	42	20
Ent>104	15	21

CMCG01	FC>400	FC<400
Ent>104	71	27
Ent>104	1	2

Table 7. Tissue concentrations in edible sport fish tissues from Newport Bay collected during the Statewide Coastal Fish Survey (Davis et al. 2012, Advisory Tissue Levels from OEHHA (2008), "-" indicates no data)

Common Name	Replicate Number	DDTs ng/wet g	PCBs ng/wet g	Hg ug/wet g	Se ug/wet g
Advisory Tissue Level	Safe to eat, Do Not Consume	<520, >2100	<21, >120	<0.07, >0.44	<2.5, >15
White Croaker	1	61.7	69.8	0.232	0.35
White Croaker	2	56.0	55.0	0.221	0.34
White Croaker	3	40.4	53.1	0.227	0.38
Spotted Sand Bass	1	83.1	95.5	-	0.67
Spotted Sand Bass	2	34.4	55.4	-	1.24

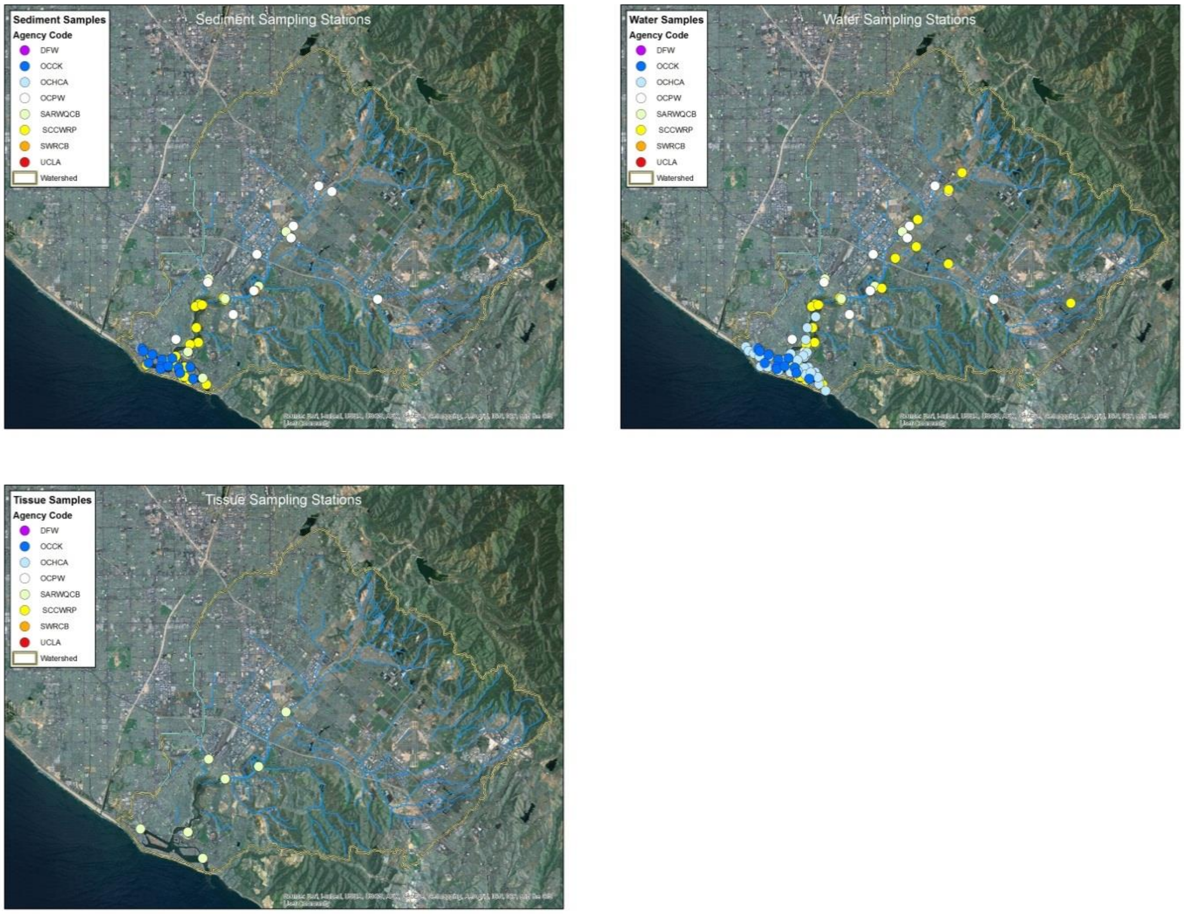
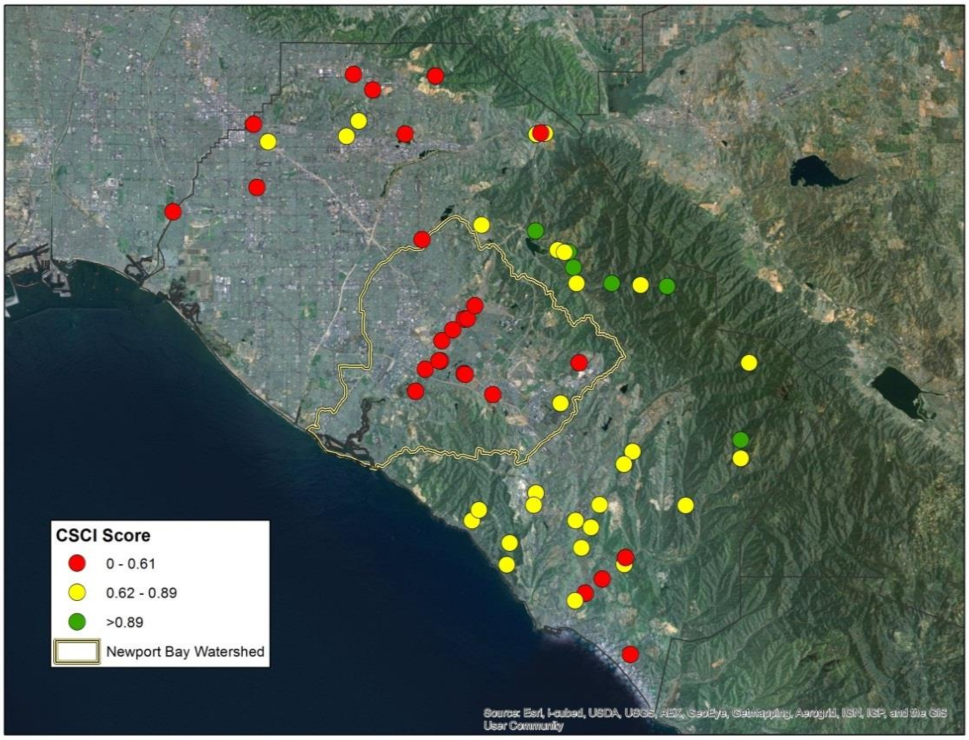


Figure 1. Map of monitoring locations in the Newport Bay Watershed by matrix



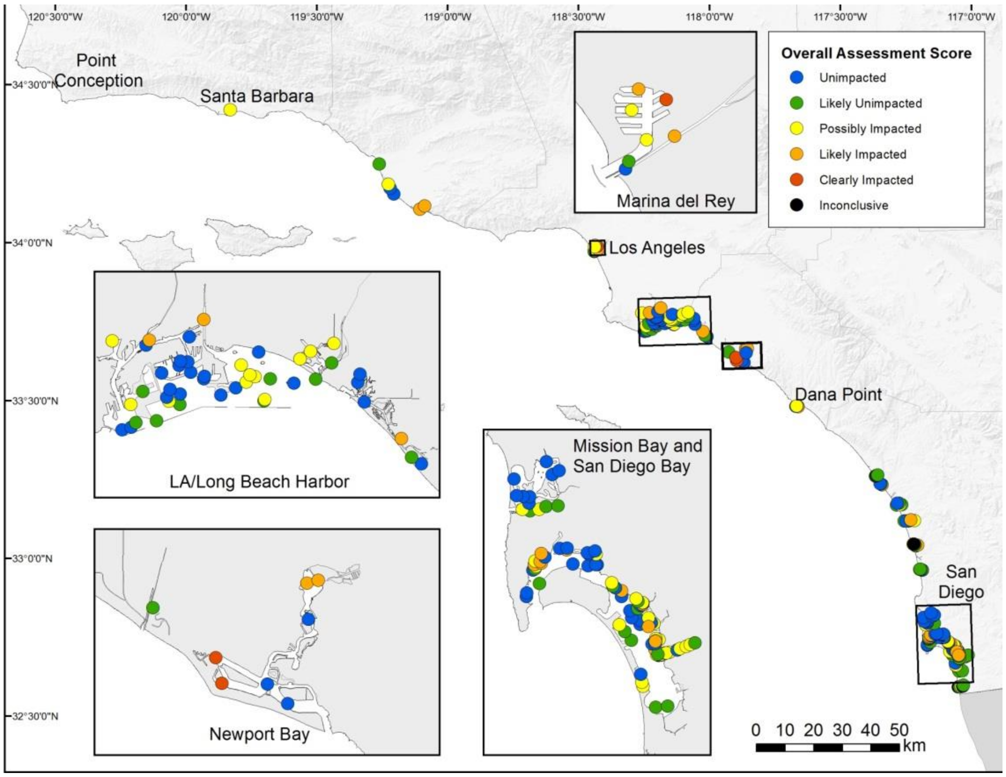


Figure 2. Summary of results from regional stream monitoring (top, Mazor et al. 2009) and regional bay/ocean monitoring (bottom, Coastal Ecology Committee 2012)

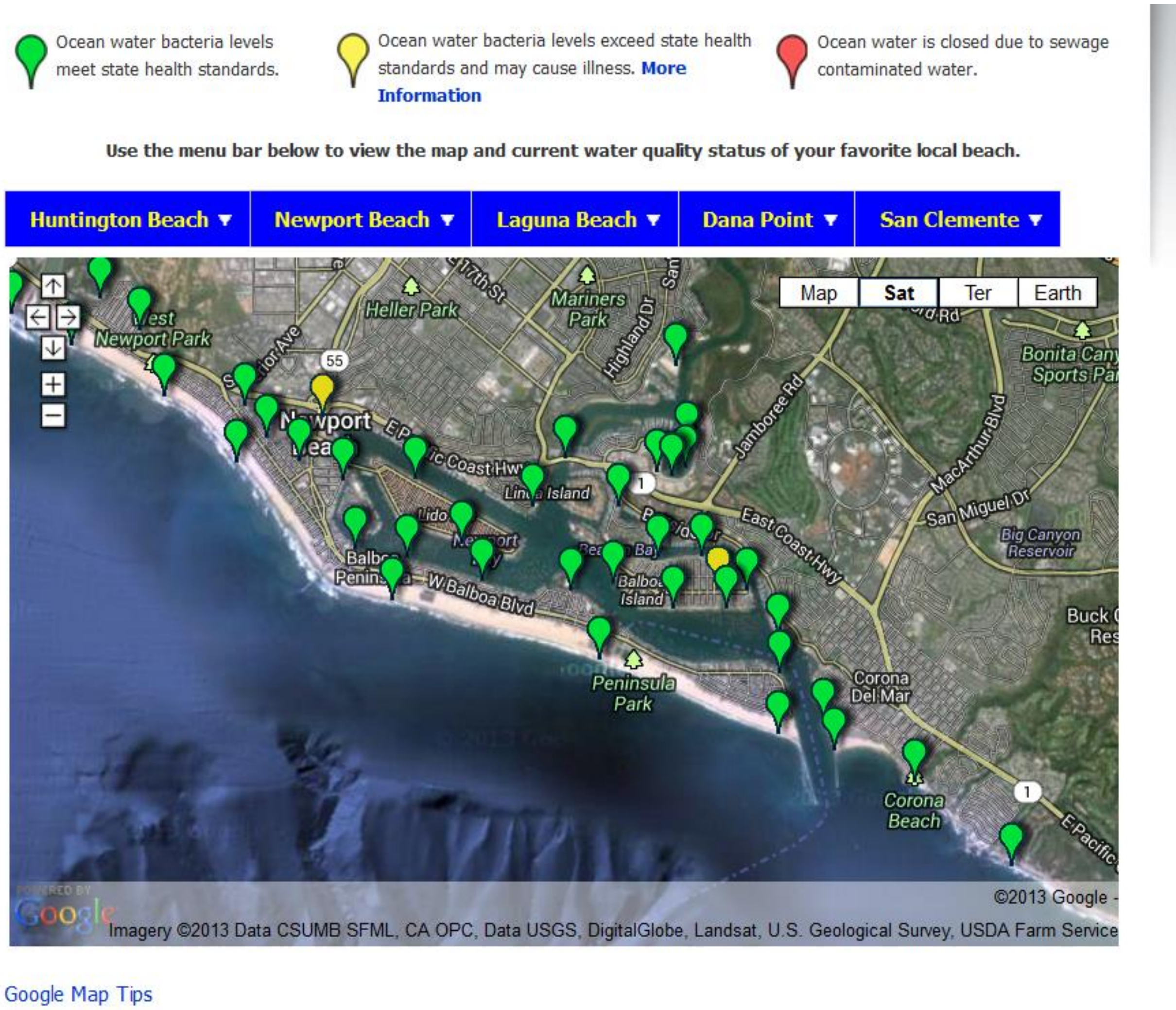


Figure 3. Example of data output from the Newport Bay beach monitoring program (http://ocbeachinfo.com/)

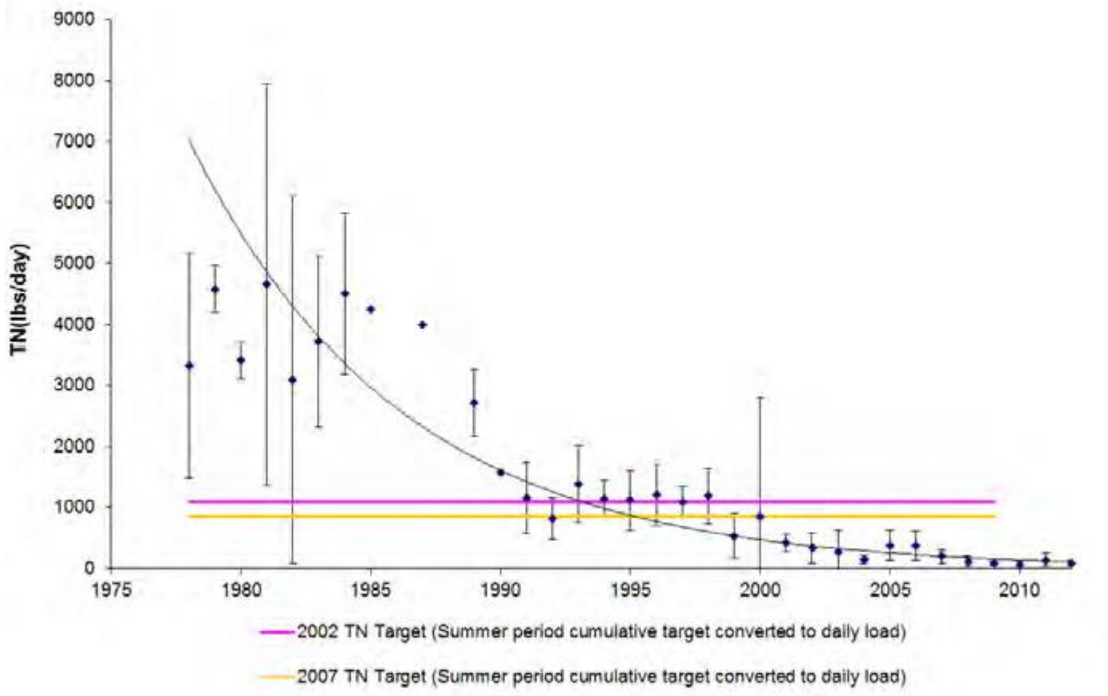


Figure 4. Trends in nutrients loads since 1978 (from OCPW 2013)

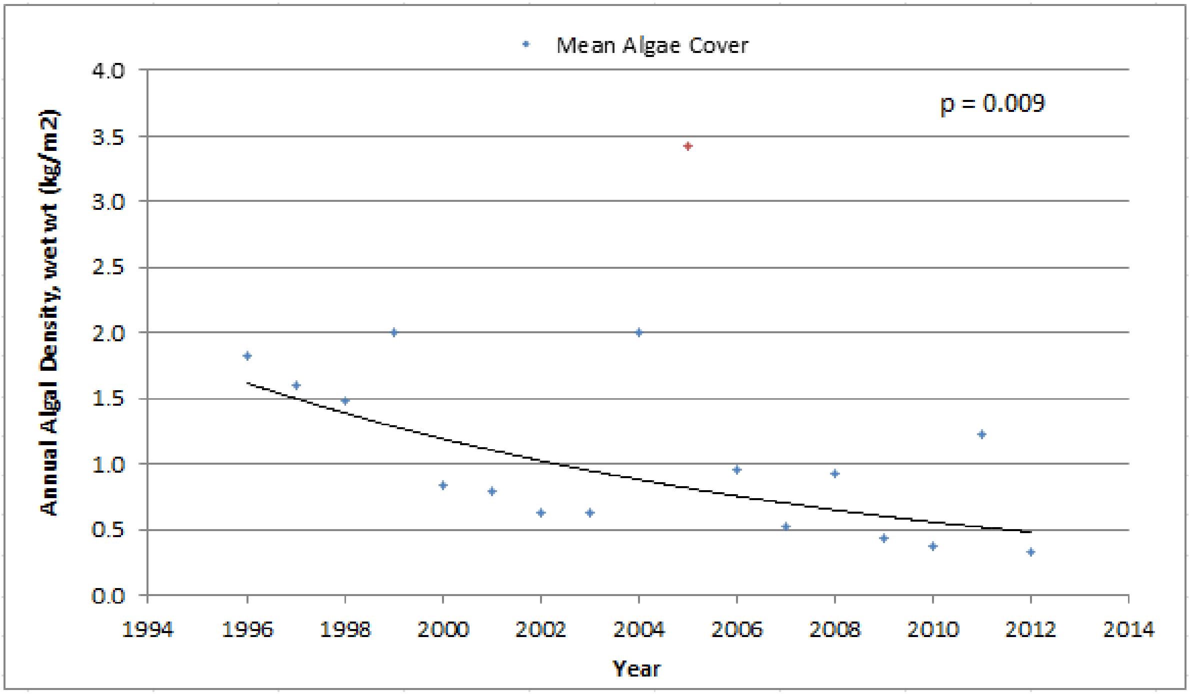


Figure 5. Trends in algal biomass since 1996 (OCPW 2013)

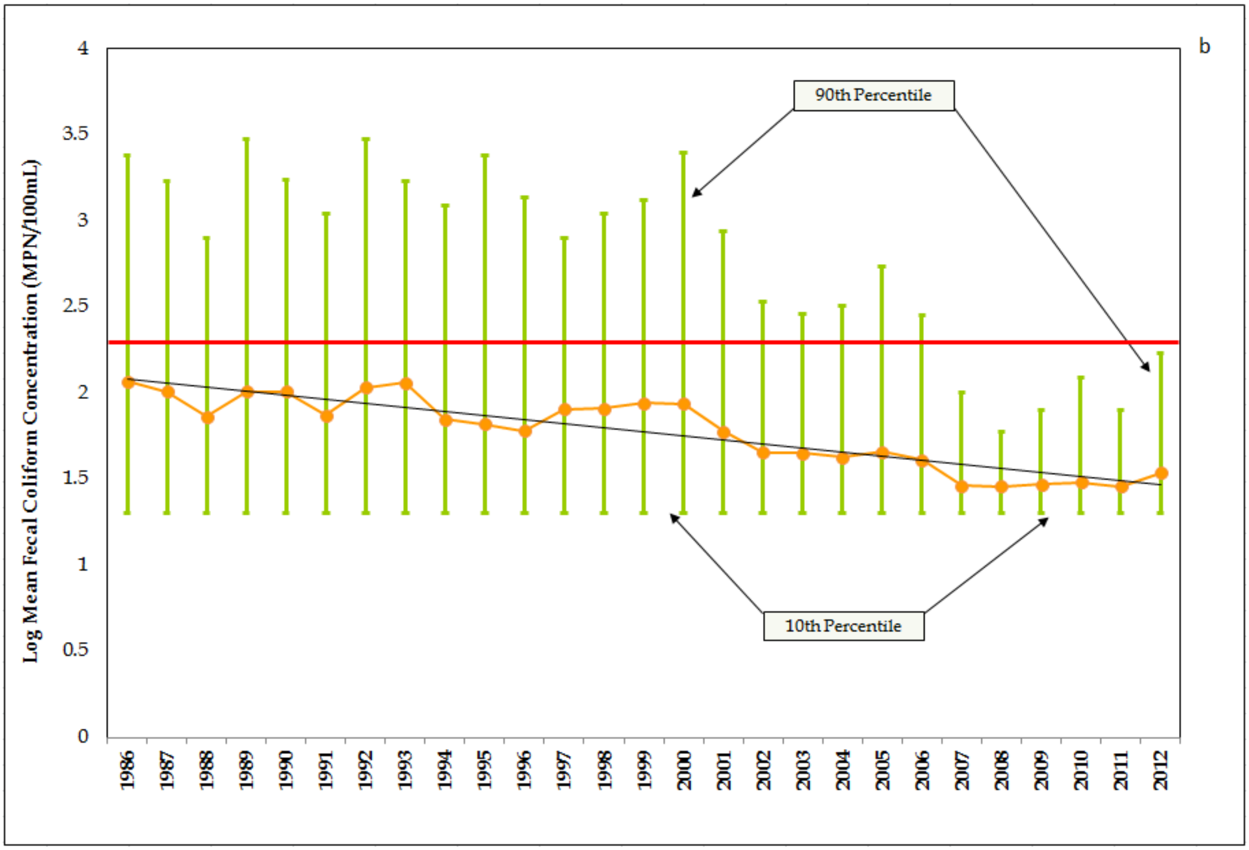


Figure 6. Frequency of FIB exceedence at Bay beaches during AB411 (OCPW 2013)

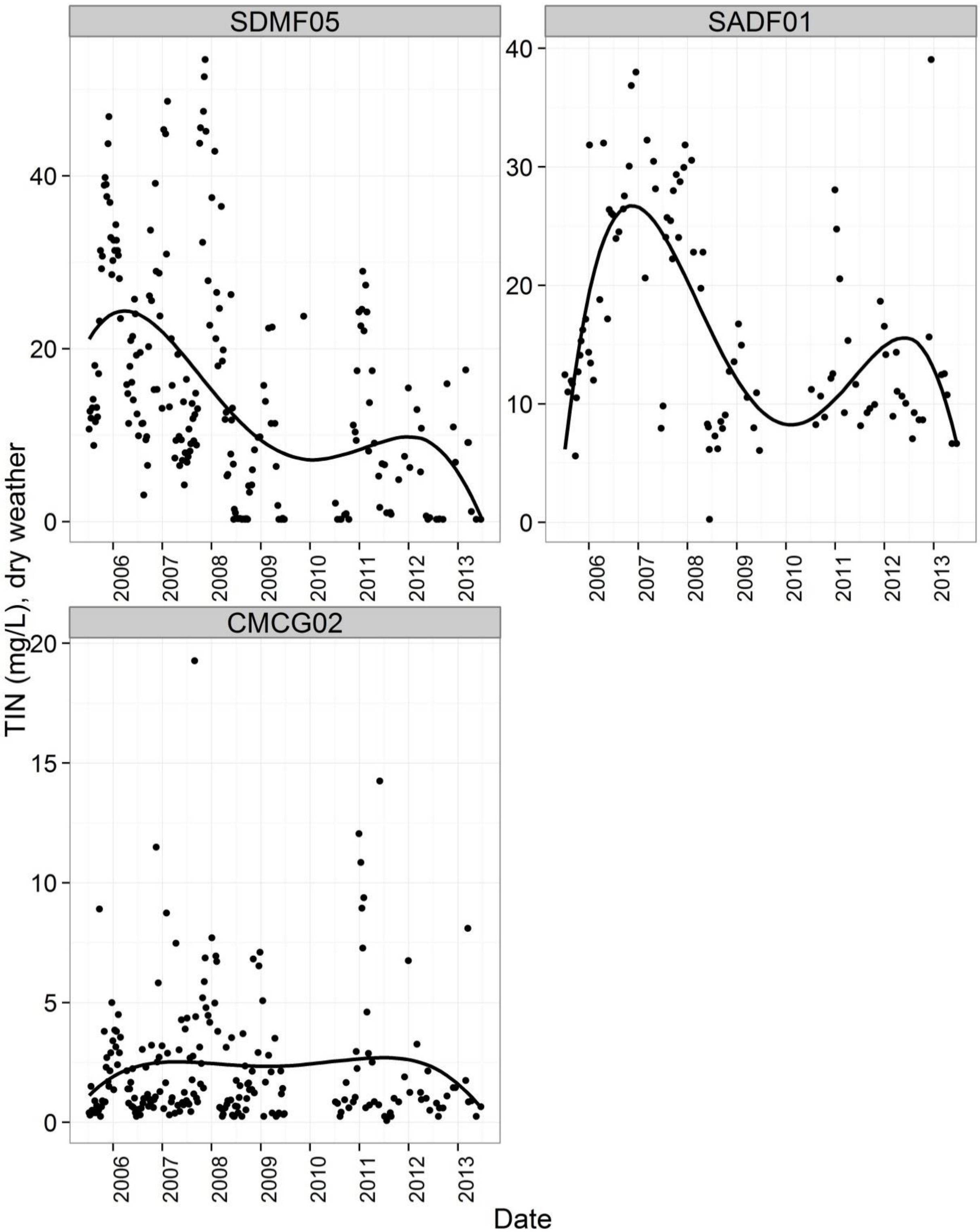
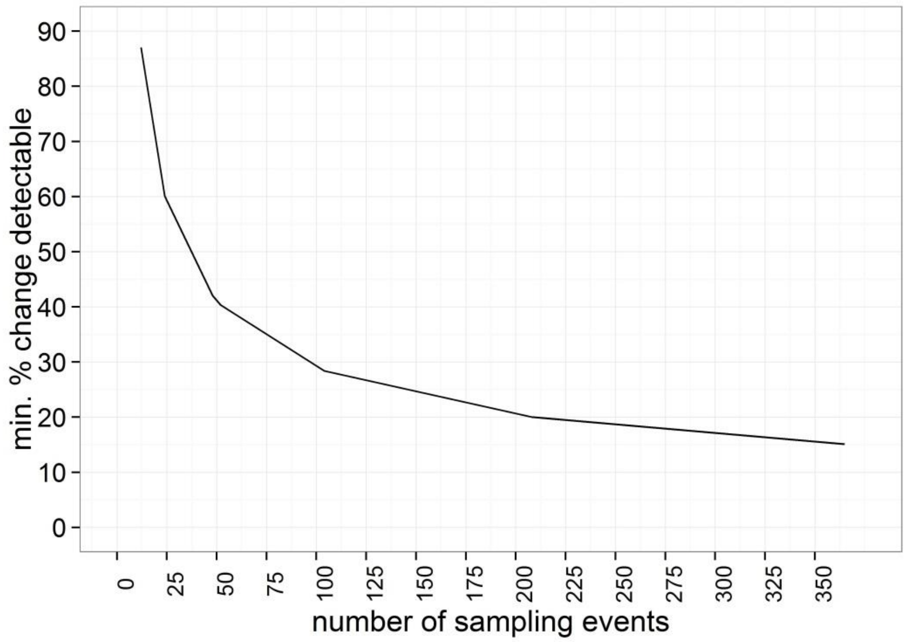


Figure 7. Trend information for three mass loading stations tributary to Newport Bay (data from OCPW)

a)



b)

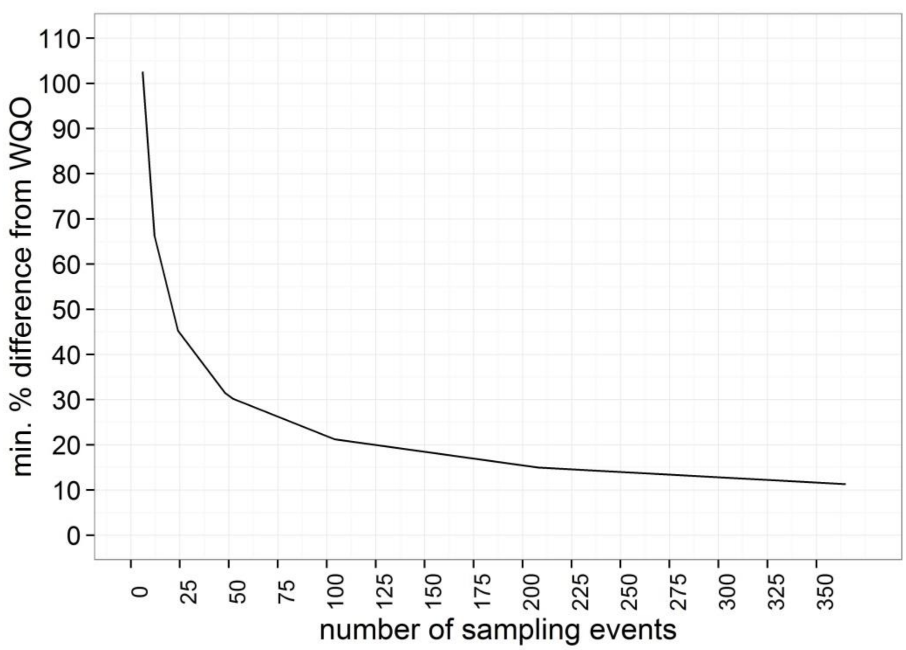


Figure 8. Power analysis for (a) trend detection and (b) percent difference from a threshold for nutrients (Total Inorganic Nitrogen) at mass loading station SDMF05

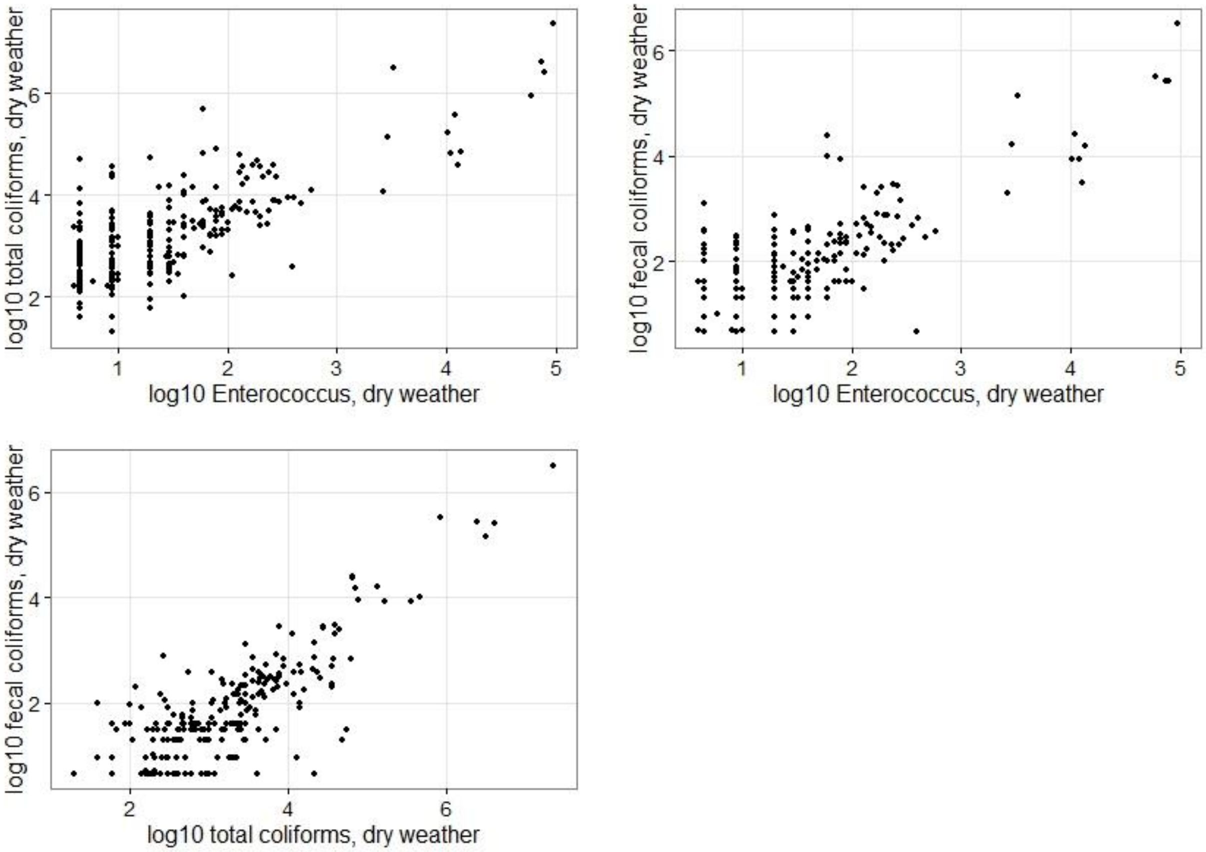


Figure 9. Correlations between *Enterococcus*, fecal coliform, and total coliform from the SDMF05 mass loading station, 2000-2011

LITERATURE CITED

Allen, M.J., D.W. Diehl and E.Y. Zeng. 2004. Bioaccumulation of contaminants in recreational and forage fish in Newport Bay, California in 2000-2002. Technical Report 436. Southern California Coastal Water Research Project. Westminster, CA.

Coastal Ecology Committee, 2008 Southern California Bight Regional Monitoring Program. 2012. Coastal Ecology Synthesis Report. Southern California Coastal Water Research Project. Costa Mesa, CA.

Council for Watershed Health and Aquatic Bioassay & Consulting Laboratories. 2012. San Gabriel River Regional Monitoring Program: 2011 Annual Report. Council for Watershed Health. Los Angeles, CA.

Davis, J.A., J.R.M. Ross, S.N. Bezalel, J.A. Hunt, A.R. Melwani, R.M. Allen, G. Ichikawa, A. Bonnema, W.A. Heim, D. Crane, S. Swenson, C. Lamerdin, M. Stephenson and K. Schiff. 2012. Contaminants in fish from the California coast, 2009-2010: Summary report on a two-year screening survey. Surface Water Ambient Monitoring Program. Sacramento, CA.

Environmental Protection Agency (EPA). 2012. Recreational Water Quality Criteria. Office of Water 820-F-12-058. US Environmental Protection Agency. Washington, DC.

Grossinger, R.M., E.D. Stein, K.N. Cayce, R.A. Askevold, S. Dark and A.A. Whipple. 2011. Historical wetlands of the Southern California coast: An atlas of US coast survey T-sheets, 1851-1889. Contribution 586. San Francisco Estuary Institute. Richmond, CA. Technical Report 589. Southern California Coastal Water Research Project.

Hibbs, B., M. Lee and J. Walker. 2000. Selenium remobilization due to destruction of wetlands in the Irvine subbasin, Orange County, California. *Environmental Geosciences* 7:211.

Klasing, S. and R. Brodberg. 2008. Development of fish contaminant goals and advisory tissue levels for common contaminants in California sport fish: Chlordane, DDTs, dieldrin, methylmercury, PCBs, selenium and toxaphene. Prepared for the California Office of Environmental Health Hazard Assessment. Oakland, CA.

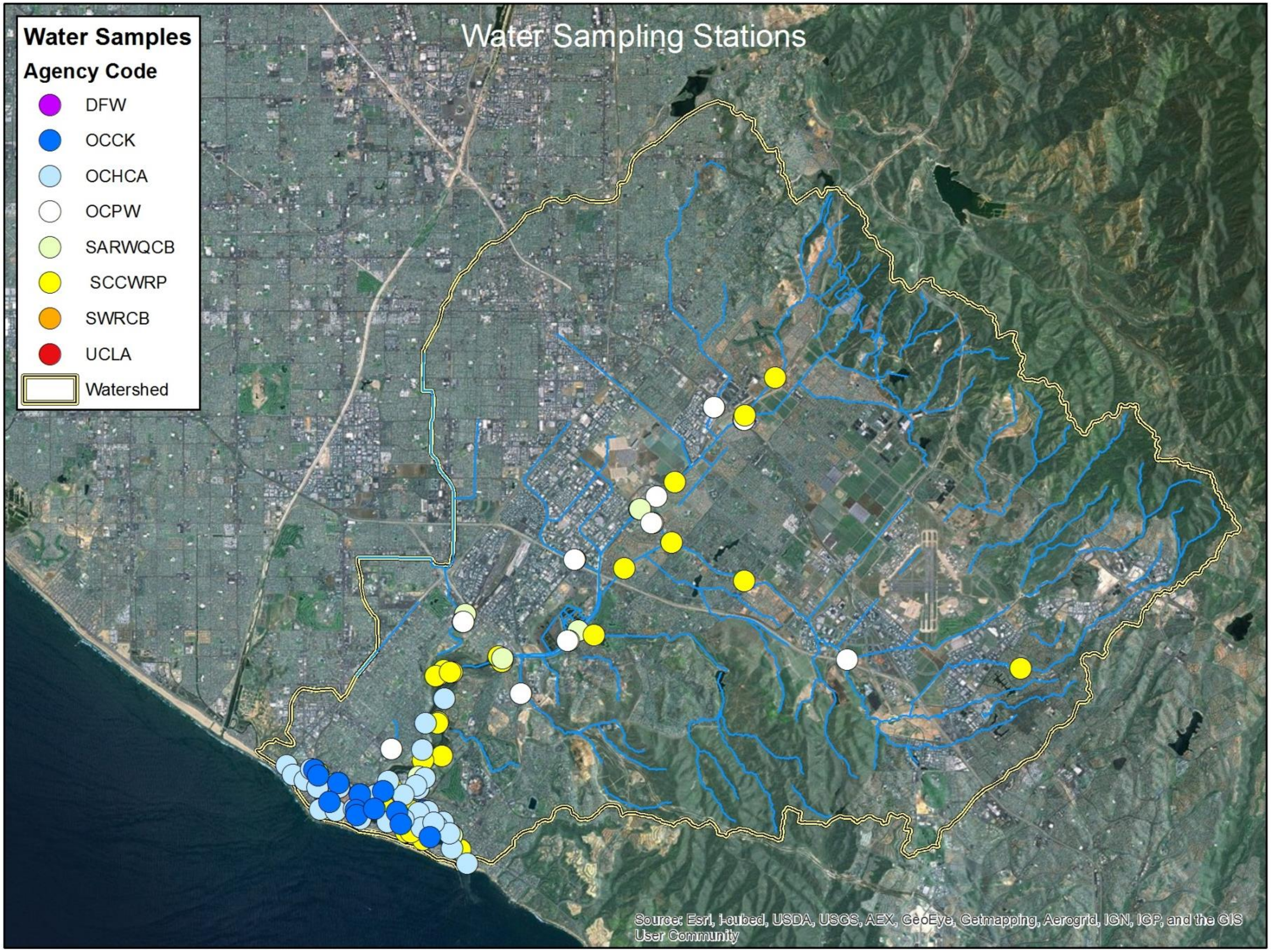
Klasing, S. and R. Brodberg. 2011. Development of fish contaminant goals and advisory tissues levels for common contaminants in California sport fish: Polybrominated diphenyl ethers (PBDEs). Prepared for the California Office of Environmental Health Hazard Assessment. Oakland, CA.

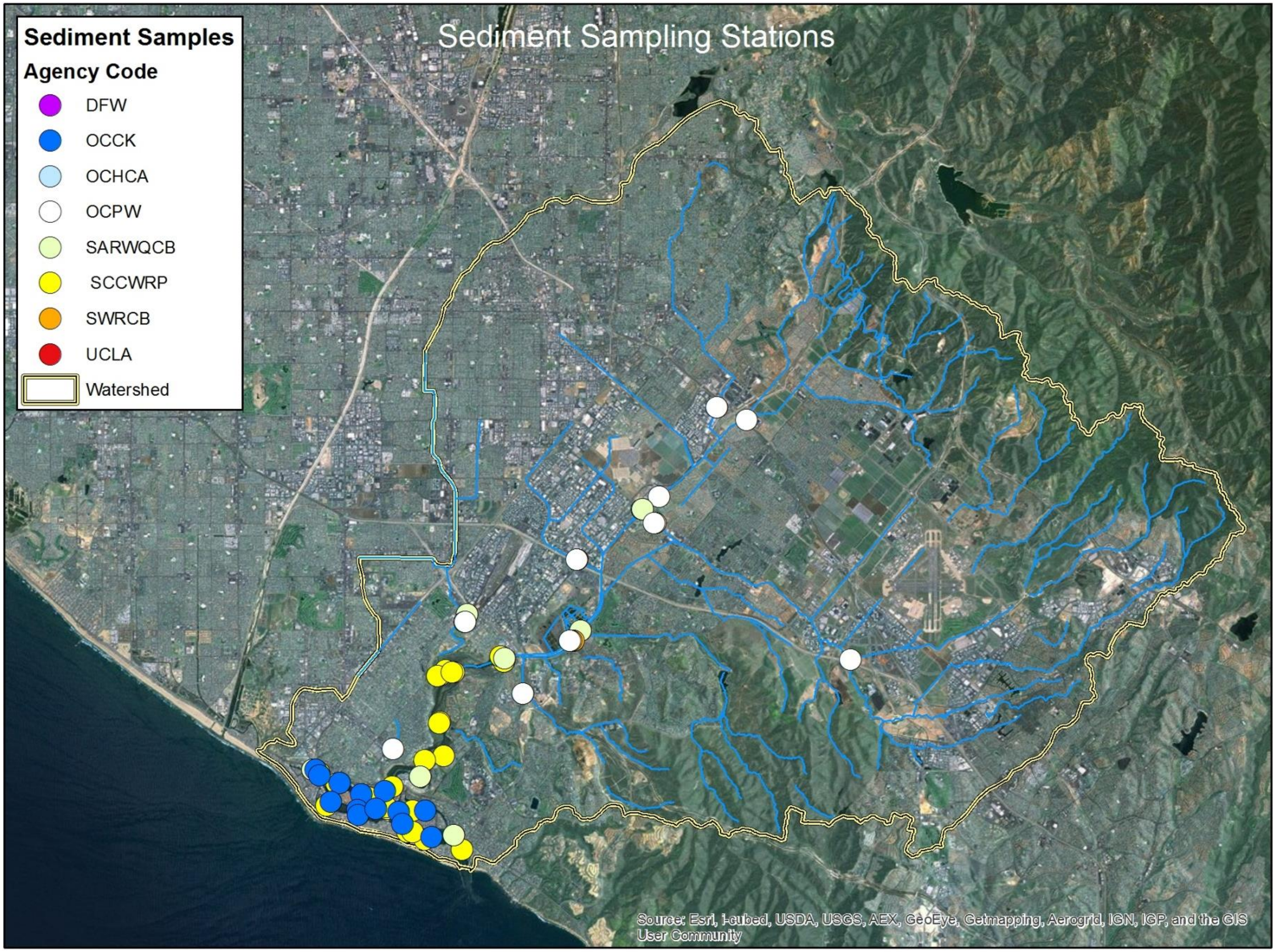
Mazor, R.D., D.J. Gillett, K. Schiff, K. Ritter and E. Stein. 2011. Ecological condition of watersheds in coastal Southern California: Progress report of the Stormwater Monitoring Coalition's stream monitoring program first year (2009). Technical Report 639. Prepared for the Stormwater Monitoring Coalition Bioassessment Workgroup. Southern California Coastal Water Research Project. Costa Mesa, CA.

Orange County Public Works (OCPW). 2013. Report of waste discharge. Prepared for the Santa Ana Regional Water Quality Control Board. Orange County Public Works. Santa Ana, CA.

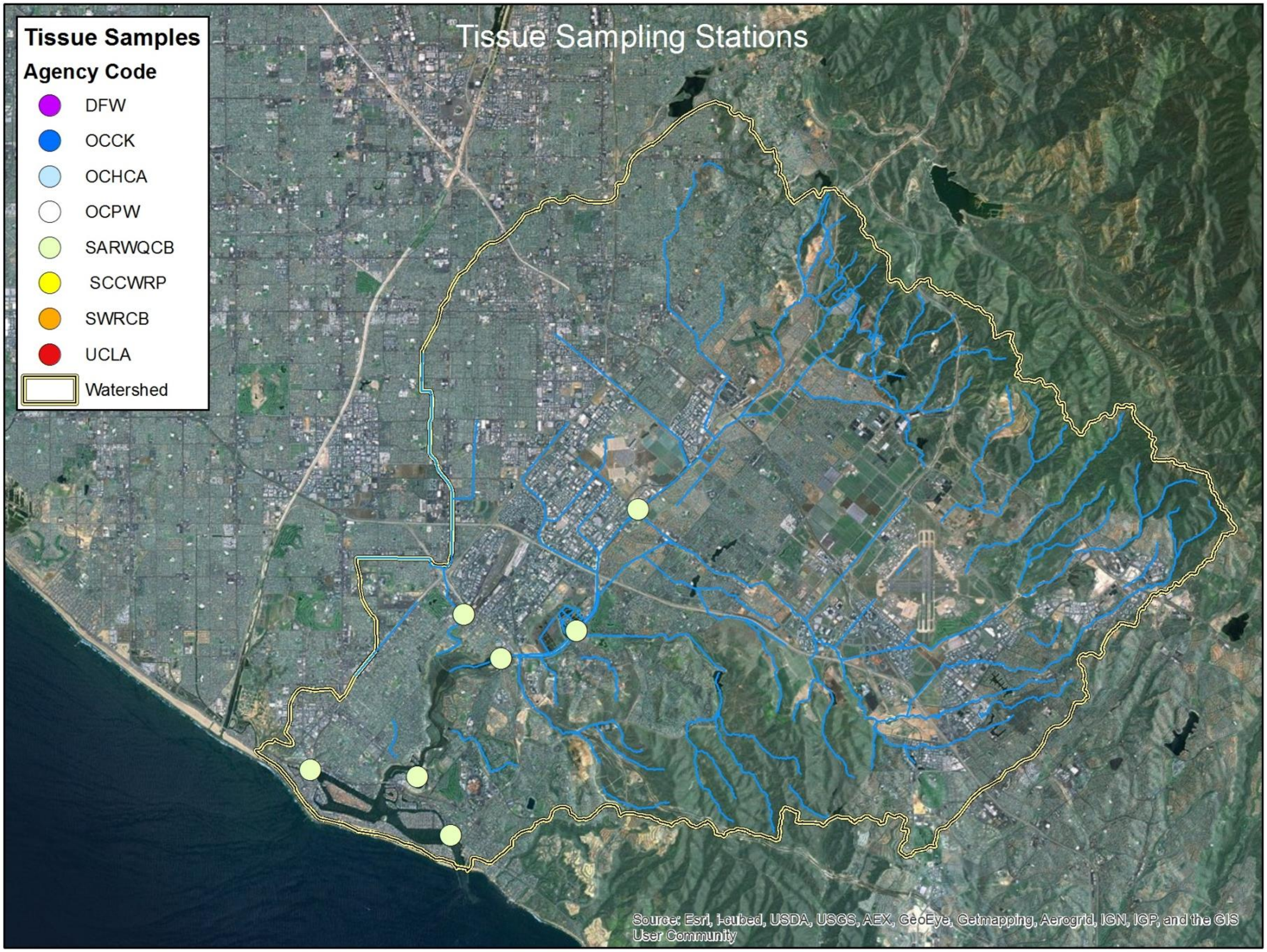
Stevens, D. and A. Olsen. 2003. Variance estimation for spatially balanced samples of environmental resources. *Envirometrics* 14:593-610

APPENDIX A: MAPS OF STATION LOCATIONS FROM THE MONITORING INVENTORY BY SAMPLE MATRIX (WATER, SEDIMENT, TISSUE)

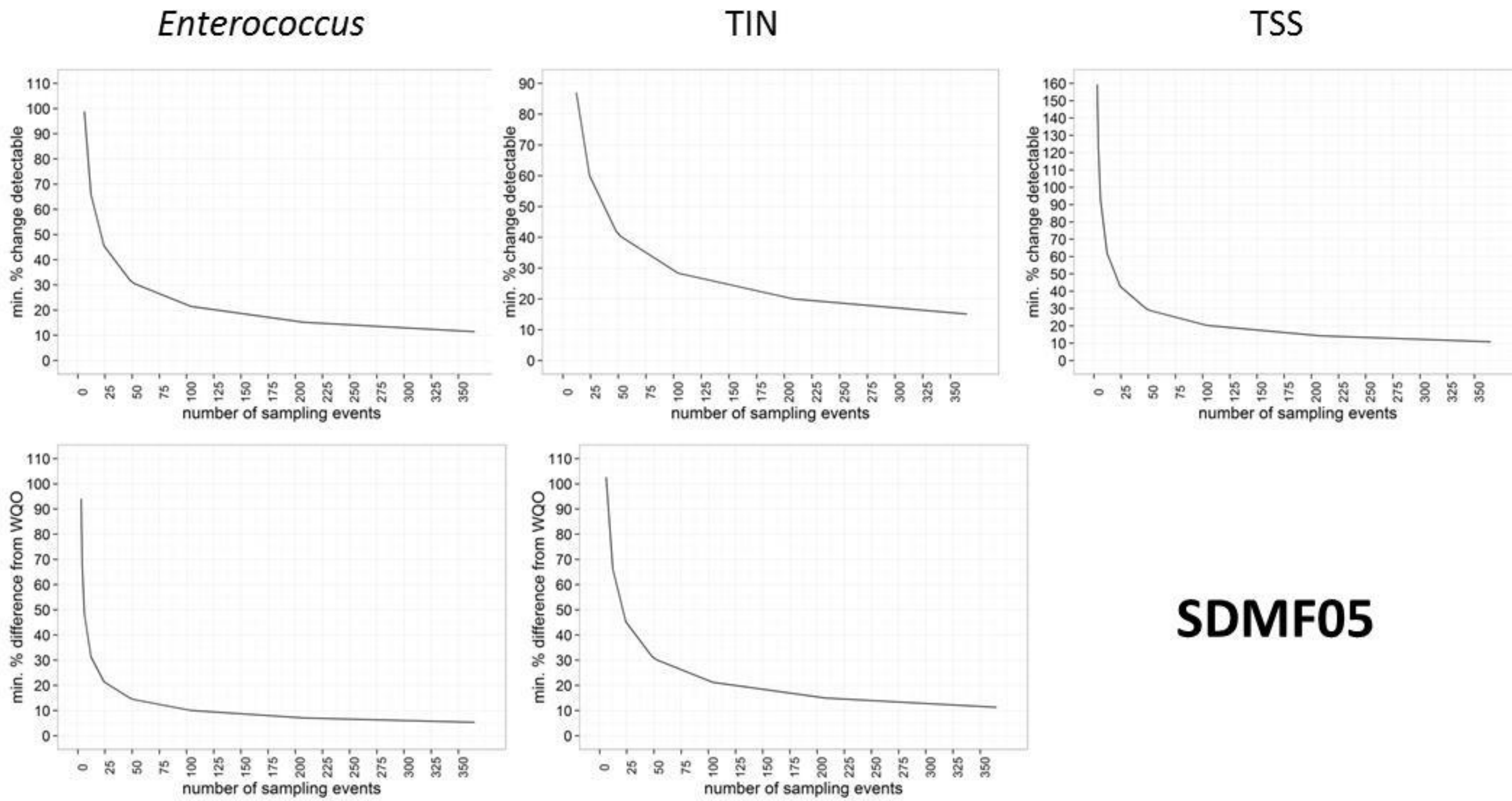

Water Sampling Stations
Water Samples
Agency Code
DFW
OCCK
OCHCA
OCPW
SARWQCB
SCCWRP
SWRCB
UCLA
Watershed
Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

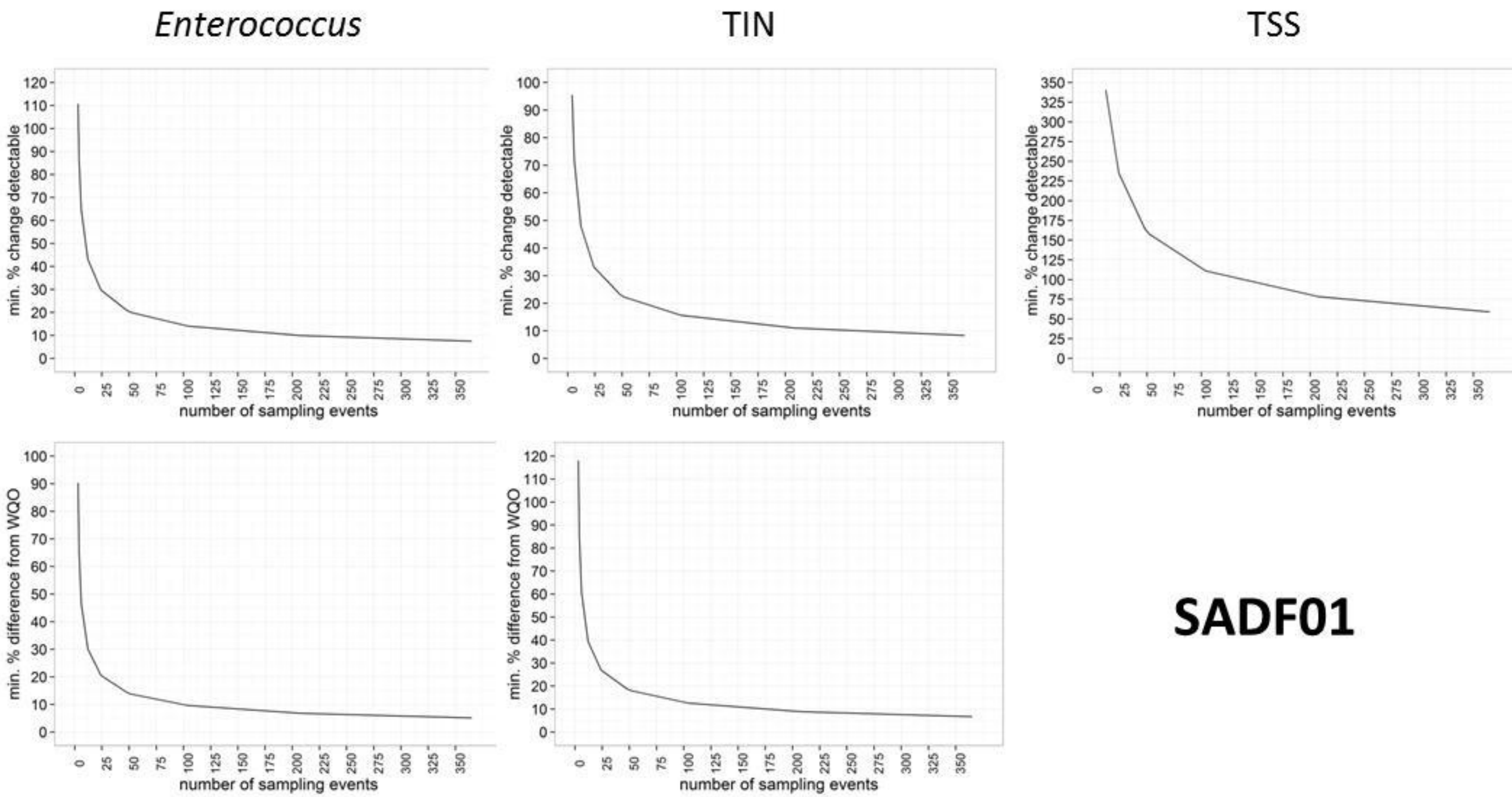


Sediment Samples
Agency Code
DFW
OCCK
OCHCA
OCPW
SARWQCB
SCCWRP
SWRCB
UCLA
Watershed
Sediment Sampling Stations
Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

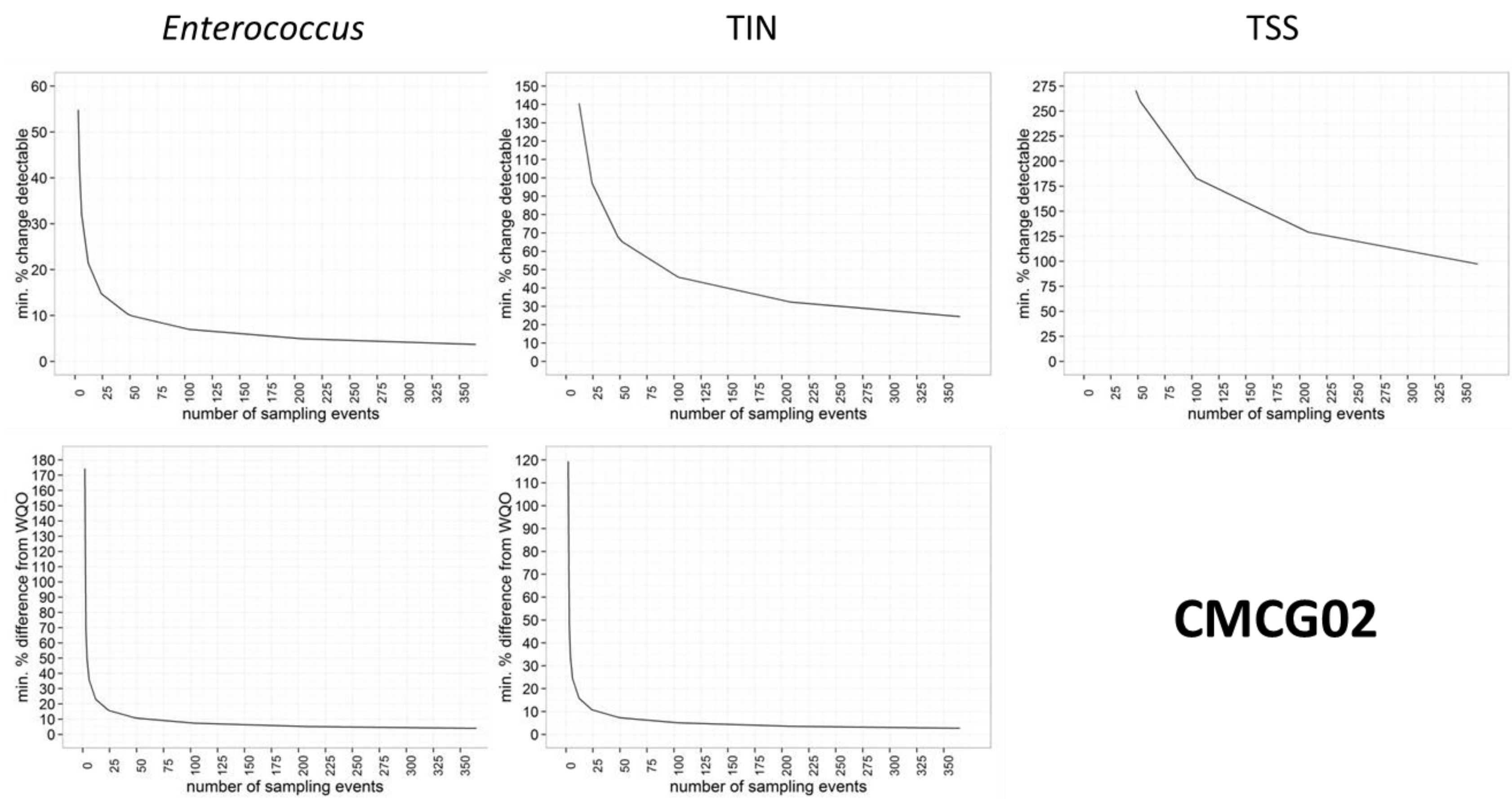

Tissue Sampling Stations
Tissue Samples
Agency Code
DFW
OCCK
OCHCA
OCPW
SARWQCB
SCCWRP
SWRCB
UCLA
Watershed
Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, and the GIS User Community

APPENDIX B: POWER CURVES FOR TOTAL SUSPENDED SOLIDS (TSS), TOTAL INORGANIC NITROGEN (TIN), *ENTEROCOCCUS* FROM THE THREE MASS LOADING SITES (SDMF05, CMCG02, SADF01)


Enterococcus
TIN
TSS
min. % change detectable
min. % difference from WQO
number of sampling events
SDMF05



Enterococcus
TIN
TSS
min. % change detectable
min. % difference from WQO
number of sampling events
SADF01


Enterococcus
TIN
TSS
min. % change detectable
number of sampling events
min. % difference from WQO
CMCG02