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The Reference Site Study and the Urban Gradient Study Conducted in Selected San Francisco Bay Region Watersheds in 2008-2010

June 2012

SWAMP
Surface Water Ambient Monitoring Program

SAN FRANCISCO BAY REGIONAL WATER QUALITY CONTROL BOARD

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SURFACE WATER AMBIENT MONITORING PROGRAM (SWAMP)

SAN FRANCISCO BAY REGION

THE REFERENCE SITE STUDY AND THE URBAN GRADIENT STUDY CONDUCTED IN SELECTED SAN FRANCISCO BAY REGION WATERSHEDS IN 2008-2010

(Years 8 to 10)

Final Report

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SAN FRANCISCO BAY REGIONAL WATER QUALITY CONTROL BOARD

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Executive Summary

This report analyzes data collected by the Surface Water Ambient Monitoring Program (SWAMP) in two related monitoring projects in the San Francisco Bay Area, commonly referred to as Region 2 of the State Water Resources Control Board (hereafter referred to as "the Region"). One project, the Reference Site Study, involved sampling six *a priori* defined reference streams: three perennial (i.e. having flowing water year-round) and three non-perennial (seasonally going dry each year), which were located throughout the Region. The study examined seasonal and annual variability in biological communities (algae and benthic macroinvertebrates [BMI]) and water chemistry, in addition to in-stream and riparian physical habitat conditions. Samples were collected multiple times during the year in 2008 and 2009 and once in 2010. The second project, the Urban Gradient Study, focused on examining two streams which flow through an urban gradient from non-developed headwaters to moderately-developed portions of the watershed. SWAMP monitored algae and macroinvertebrate communities as well as water chemistry along this urban gradient.

The SWAMP Bioassessment Protocol (2007) and associated algae protocol (2009) were used to successfully collect usable data at both the reference streams and the urban gradient streams. The six reference sites were not affected by common anthropogenic stressors (e.g., roads, urbanization, bank stabilization, and bank channelization) and thus provided a good representation of stream conditions under a minimally disturbed state.

The results showed strong seasonal and inter-annual variation in biological communities (algae and BMI, water chemistry (e.g., nutrients and dissolved oxygen), and algae biomass (chlorophyll *a* and ash-free dry mass [AFDM]). Assessed characteristics (a.k.a. water quality parameters) showed more inter-site, seasonal, and annual variation in non-perennial streams than in perennial streams. In particular, BMI taxonomy and index of biotic integrity (IBI) scores based on the community structure showed considerable variation in two of the three non-perennial streams. IBI scores from these streams dropped from mostly good condition (range 58-85) in 2008 and 2009 to poor condition (range 27-35) in 2010. Perennial sites did not decrease in biotic integrity during this year and consistently had scores in or near the 'good' range (54-93).

IBI scores from these reference sites were similar to reference monitoring data collected by the Statewide SWAMP Reference Condition Monitoring Program, which is an external validation of the quality of these regional reference sites. Perennial streams scored higher than non-perennial streams in both the Southern California and North Coast IBIs, which provides evidence that biological indicators developed specifically for perennial streams – although they may still be useful assessment tools for non-perennial streams – are slightly biased against them. Because of the natural variation in benthic macroinvertebrate communities at perennial and non-perennial reference sites, SWAMP recommends developing different bioassessment tools (e.g., IBIs) for perennial and non-perennial streams in this region.

Algae communities in reference streams also reflected seasonal and annual variation. Although seasonal changes in diatom community structure were observed in sites that were sampled 2-3 times within a single wet season, there was no consistent shift in community structure. The seasonal variation between algae community samples suggests the need for an index period, i.e.,

a specified time of year to sample for metrics and indices of condition based on community structure. In addition, the diatom community assemblage differed between perennial and non-perennial streams.

Algal biomass increased substantially throughout spring and summer. Non-perennial streams reached peak biomass in summer (May-June) before drying out, while perennial streams reached peak algae biomass in late summer (August-September). Monitoring programs designed to document peak algae production should sample streams in this region accordingly. The algae biomass, measured as benthic chlorophyll *a*, typically fell below the NNE Beneficial Risk Use Classification (BURC I) benchmarks developed for COLD (100 mg/m^2) and WARM (150 mg/m^2) beneficial uses, in both perennial and non-perennial streams. Only one WARM and two COLD exceedances were observed in the reference data, which together make up a small fraction (4.4%) of the total data. Although over half of the samples collected at reference sites (59.6%) contained phosphorous at concentrations higher than 0.03 mg/L total P (which is the EPA Nutrient Ecoregion III, Omernik Level III ecoregion 6 benchmark), high levels were not consistently associated with algal biomass above the BURC guidelines. Only 4.3% of the samples exceeded the EPA total nitrogen benchmark of 0.518 mg/L.

The Urban Gradient Study was helpful in identifying important contrasts between reference and urban sites and between different urban watersheds. Saratoga Creek appears to represent an example of best-attainable biological conditions in urban settings, with high IBI scores (i.e. 65-83) even in the more urbanized stream sections. In contrast, Las Trampas Creek exhibited poor biological conditions based on BMI (IBI range 16-51), despite the similar urban development levels in the two watersheds. Algae taxonomy indicators were not responsive to increasing degradation along the urban gradient in Saratoga Creek (the only urban creek with algae data). However, algae taxonomy could prove to be a more useful indicator of urbanization when an algae IBI is developed for this region.

List of Acronyms

Acronym	**What it means**
AFDM	Ash-Free Dry Mass
BASMAA	Bay Area Stormwater Management Agencies Association
BMI	Benthic Macroinvertebrates
BURC	Beneficial Use Risk Categories
CAMLnet	California Aquatic Macroinvertebrate Laboratory Network
CHDI	Combined Human Disturbance Index
CSBP	California Stream Bioassessment Procedure
CTR	California Toxics Rule
DFG	Department of Fish and Game
DFG-ABL	Department of Fish and Game, Aquatic Biology Laboratory
DFG-WPCL	Department of Fish and Game, Water Pollution Control Laboratory
DO	Dissolved Oxygen
EMAP	Environmental Monitoring and Assessment Program
EPA, or U.S. EPA	United States Environmental Protection Agency
EPT	Ephemeroptera, Plecotera, Trichoptera (BMI taxa)
IBI	Index of Biological Integrity; a.k.a Index of Biotic Integrity
MDL	Minimum Detection Limit
MLML	Moss Landing Marine Laboratory
MPSL	Marine Pollution Studies Laboratory
MQO	Measurement Quality Objective
MWAT	Maximum Weekly Average Temperature
NMS	Non-metric Multidimensional Scaling
NNE	Nutrient Numeric Endpoints
PHAB	Physical Habitat
QAPP	Quality Assurance Project Plan
QMP, or QAMP	Quality Management Plan
RB2	Regional Board 2 (SF Bay Regional Board)
RBP	Rapid Bioassessment Protocol
RL	Reporting Limit
RWB	Reachwide Benthos
SAFIT	Southwest Association of Freshwater Invertebrate Taxonomists
SFBRWQCB	San Francisco Bay Regional Water Quality Control Board
SOP	Standard Operating Procedure
STE	Standard Taxonomic Effort
SWAMP	Surface Water Ambient Monitoring Program
SWRCB	State Water Resources Control Board
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TRL	Target Reporting Limit
WPCL	Water Pollution Control Laboratory

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1 Introduction

1.1 Overview of the Surface Water Ambient Monitoring Program (SWAMP) in California

California Assembly Bill 982 (Water Code Section 13192; Statutes of 1999) required that the State Water Resources Control Board (SWRCB) assess and report on State water monitoring programs and prepare a proposal for a comprehensive surface water quality monitoring program. The SWRCB proposed to restructure the existing water quality monitoring programs into a new program, the Surface Water Ambient Monitoring Program (SWAMP). This program consists of statewide environmental monitoring focused on providing the information needed to effectively manage the State's water resources. SWAMP is designed to be consistent, cooperative, adaptable, scientifically sound, and to meet clear monitoring objectives. It also facilitates reporting and categorizing of the State's water quality under Sections 305 (b) and 303 (d) of the federal Clean Water Act.

SWAMP conducts statewide monitoring through the SWRCB and regional monitoring through the Regional Water Quality Control Boards. Statewide programs include the Perennial Stream Assessment, the Reference Condition Monitoring Program, and Bioaccumulation of pollutants in sport fish and wildlife (http://www.waterboards.ca.gov/water_issues/programs/swamp/reports.shtml#bmp_assess). SWAMP has revised previous sampling protocols for ambient freshwater stream assessments to incorporate comprehensive collection of benthic macroinvertebrates, algae, physical habitat, and water chemistry data (http://swamp.mpsl.mlml.calstate.edu). SWAMP is currently using the large bioassessment dataset developed over the past 10 years to develop Biological Objectives for perennial streams (http://www.swrcb.ca.gov/plans_policies/biological_objective.shtml).

1.2 Overview of the San Francisco Bay Region SWAMP Monitoring Program

There are five components to SWAMP monitoring in the San Francisco Bay Region, which include the following:

1. Monitoring watersheds throughout Region 2 to assess water quality impacts and to establish regional reference sites;
2. Monitoring edible fish and shellfish for tissue contaminant levels in reservoirs and coastal areas where people catch and consume fish;
3. Developing and reviewing tools related to water quality standards (e.g., an index of biotic integrity);
4. Conducting special studies to answer critical management questions (e.g., studying the effects of ammonia on limiting primary production in Suisun Bay); and
5. Collecting data to support the total maximum daily load (TMDL) process (e.g., Water Quality Attainment Strategies) developed for impaired water bodies, and to support monitoring to assess improvement in water quality.

Five years of watershed monitoring based on the rotating basins design were completed in 2006. Data were reported and interpreted in three previous documents collectively titled "Water Quality Monitoring and Bioassessment in San Francisco Bay Region Watersheds": (a) **The Years 1&2 Report** (SFBRWQCB 2007a), (b) **The Year 3 Report** (SFBRWQCB 2007b), and (c) **The Years 4&5 Report** (SFBRWQCB 2008). San Francisco Bay Region SWAMP personnel also pioneered trash assessment efforts, which are summarized in the report "A Rapid Trash Assessment Method Applied to Waters of the San Francisco Bay Region: Trash Measurement in Streams" (SFBRWQCB 2007c). The watersheds, fish tissue, and trash reports are available on the SWAMP websites at (http://www.waterboards.ca.gov/sanfranciscobay/water_quality.shtml) and (http://www.waterboards.ca.gov/water_issues/programs/swamp/reports.shtml).

1.3 Objectives of the Watershed Component of SWAMP in the San Francisco Bay Region

The component of the Surface Water Ambient Monitoring Program (SWAMP) in the San Francisco Bay Region designed to monitor and assess watersheds in the Region has eight objectives:

1. Use a weight-of-evidence approach, based on measurement of physical, chemical, and biological water quality characteristics, for the assessments;
2. Use the data for evaluating watersheds for 305b reporting and 303d listing;
3. Evaluate beneficial use protection;
4. Measure water quality indicators and stressors to characterize spatial and temporal trends;
5. Determine relationships between water quality indicators, specific stressors and land use, including water management;
6. Identify regional reference sites;
7. Develop and evaluate monitoring tools; and
8. Coordinate and collaborate with other watershed monitoring programs such as the BAASMA Regional Monitoring Coalition.

1.4 Reference Study Rationale

Reference sites form the foundation of a reasonable expectation for biological, physical, and chemical conditions in aquatic ecosystems in the absence of human-created stressors. Between 2001 and 2005, San Francisco Bay Region SWAMP used a rotating basin sampling design to perform year-long surveys of water quality conditions in a select number of watersheds around the Region. Some of the conclusions of those studies were that, in order to better interpret ambient monitoring data, more information was needed on (1) long-term trends and annual variability, especially the effects of climate change and other regional and local factors affecting minimally-disturbed reference sites; and (2) minimally-disturbed ("reference") conditions for benthic macroinvertebrates, nutrients, and basic water quality (e.g., dissolved oxygen) (SFBRWQCB 2007a, 2007b, 2008). An additional finding of those studies was that benthic macroinvertebrate assemblages were usually quite degraded in urban areas, raising questions about the "best attainable" biological conditions in urban areas. To address these data gaps and questions raised by the initial studies, San Francisco Bay Region SWAMP initiated studies described in this report.

Monitoring Objectives and Questions

Listed below are objectives and questions for SWAMP monitoring of reference and urban sites at the regional level that will be addressed in this report. Although this report has been compiled using three years of data, answers to some questions posed in this report will require future monitoring to generate very long datasets (e.g., > 10 years), and a more comprehensive examination of existing monitoring data within the Bay Area.

I. Describe water quality conditions and biotic assemblages, and the spatial and temporal variability of those conditions, at minimally-disturbed reference sites.
   - I.1. What is the seasonal and annual variability in benthic macroinvertebrate and algae (periphyton) assemblages, and how do they vary between perennial and non perennial (intermittent) streams?
   - I.2. What is the seasonal and annual variability in basic water quality?
   - I.3. What are the interrelationships among dissolved nutrients, algae assemblages, primary productivity, and dissolved oxygen?
   - I.4. What are the long-term trends in biology, chemistry, and physical habitat at reference sites?

II. Document how biological (macroinvertebrate, algae) communities, water chemistry, and physical habitat change along an urban gradient from open space into urbanized areas.
   - II.1. Document the longitudinal gradient of biological conditions in two urban watersheds.
   - II.2. Examine if the observed urban gradient responses are consistent between years.
   - II.3. Identify the water quality and habitat conditions that are associated with better-than-expected assemblages of benthic macroinvertebrates in Saratoga Creek.

Minimally-disturbed reference sites

Characterization of water quality, physical habitat, and biota at reference sites can be used to identify best attainable condition. This information can be used by SWAMP and other water quality programs to set expectations for these conditions in the Bay Area. For example, the BASMAA Regional Monitoring Coalition will perform ambient monitoring in Bay Region watersheds including the collection of bioassessment data. This bioassessment data requires interpretive tools such as an index of biotic integrity (IBI) to evaluate whether biologically-based beneficial uses are supported. Reference site data collected from this study and past SWAMP monitoring will be essential to support the development of numeric tools, such as an IBI for non-perennial streams. In addition to supporting regional efforts, the annual sampling of biological assemblages at minimally-disturbed reference sites outlined in this study will contribute to data used by the State Water Board to develop state-wide biological objectives for perennial streams (http://www.swrcb.ca.gov/plans_policies/biological_objective.shtml).

The focus on both long-term trends and temporal variability at minimally-disturbed reference sites (i.e. "minimally-disturbed condition" of Stoddard *et al.* 2006) will serve the purpose of identifying the effects of climate change at sites where this is presumed to be the primary anthropogenic stressor. In doing this, expectations for other sites may be modified so that the effects of other anthropogenic stressors (land use, water withdrawals, toxics, etc.) can be identified.

1.5 Scope of the Report

This report provides a data summary for the Reference Site Study monitoring and the Urban Gradient Study monitoring conducted from 2008 to 2010. Data were compared with published water quality benchmarks and reviewed to identify spatial and/or temporal trends. Data analysis was also geared to document the biological, chemical, and physical qualities of reference streams in the Bay Area. In addition, we examined the physical habitat data and algae data produced by the new SWAMP monitoring tools (Ode 2007, Fetscher *et al.* 2009) in order to evaluate the applicability of these new protocols. This report does not provide an evaluation of beneficial use support, nor does it assess watershed impairment; however, data provided herein can be used in support of such determinations.

The authors of this report hope that all the basic information a reader will find essential to understanding the report has been provided. However, this report leans heavily on rationale, discussions, and details contained in six previously-released documents, and the reader is advised to have these documents accessible:

- SF Bay Region SWAMP interpretive report for years 1 and 2 (SFBRWQCB 2007a);
- SF Bay Region SWAMP interpretive report for year 3 (SFBRWQCB 2007b);
- SF Bay Region SWAMP interpretive report for years 4 and 5 (SFBRWQCB 2008);
- SWAMP Quality Management Plan (Puckett 2002) and SWAMP Quality Assurance Program Plan (QAPrP) (2008), along with their corresponding appendices and SOPs;
- SWAMP SOPs for algae and macroinvertebrate bioassessment (Ode 2007; Fetscher *et al*. 2009); and
- SF Bay Region SWAMP FY07-08 work plan (http://www.waterboards.ca.gov/sanfranciscobay/water_quality.shtml).

Section 2 (Methods) of this report provides summary information on the watersheds sampled, and shows the sampling locations. It also describes the study design, the logistics of field operations, and the laboratory methodology. Section 3 (Results) shows highlights of the results, arranged for each group of indicators collected at a site (Section 3.1 to 3.6); these are followed by a discussion of general trends and relationships between indicators (Section 3.7). Section 4 (Discussion) provides discussion of all results and places the results in the context of other monitoring in the Bay Area. Section 5 (Recommendations) lays out the conclusions and the recommendations, and Section 6 provides the references for the articles cited throughout the report. The body of this report (Sections 1 through 6) is followed by a set of appendices which contain the individual monitoring results and are an integral part of the reporting effort.

2 Methods

2.1 Watershed and Site Descriptions

2.1.1 Watershed and site selection criteria

The watersheds selected for years 2008-2010 monitoring represented a variety of terrains and microclimates in different geographic regions of the SF Bay Area.

Establishing reference sites is of utmost importance. The criteria for establishing reference sites for a watershed have been a long-debated issue, but general requirements are that the sites are accessible, are found in geographic and geologic conditions similar to those of impacted sites, and are as close to pristine historical conditions as is available in the watershed. The need for urban land use reference sites (i.e., urban sites that have the best attainable conditions for urban land use) has also been identified, but selection of such sites will be based on a different set of criteria.

For the reference sites study described in this report, the criteria for identifying minimally-disturbed sites included: (1) minimal upstream human land use (> 1.5% urban land use, and light grazing or limited timber harvest) based upon semi-quantitative assessments of watershed land use from land use maps, aerial photos, and field reconnaissance; (2) minimal local habitat disturbance based upon previous physical habitat (PHAB) assessments and field reconnaissance; and (3) excellent water quality based upon existing water quality and bioassessment data. The six reference sites were also chosen to represent the pool of perennial and non-perennial streams and the variety of conditions and watershed sizes across the region.

2.1.2 Years 2008-2010 sampling stations

Table 2.1-1 shows the lat/long coordinates for the 14 sites monitored by SWAMP in the watersheds selected for the Reference Site Study and the Urban Gradient Study. Station elevations were taken from the SWAMP database (which includes values gleaned from topographic maps), and flow regime information was obtained from reconnaissance summaries, where available. Reconnaissance data sheets and summaries are available from SWAMP personnel at the SF Bay Region office. **Table 2.1-2** provides watershed land use information about each monitoring site as gleaned from various GIS layers, including area covered by agricultural and urban land uses, as well as road density. The extent of each land use is provided in Table 2.1-2 both at the local level, i.e. in a radius of 1 km up-drainage-area from the site, and also at the watershed level, i.e. as a percentage of the entire watershed area that drains to that point in the river network. Road density is calculated as km/km^2. The designated beneficial uses for each of the watershed segments in which our reference sites are located are shown in **Table 2.1-3**.

Figure 2.1-1 shows the six Reference Sites and the two clusters of Urban Gradient sites in Saratoga Creek and Las Trampas Creek (4 stations in each) as located throughout the San Francisco Bay Region. Reference sites were selected from a pool of candidate sites to provide good representation of terrains, microclimates, marine influences (coastal vs. inland), geographical areas, etc., and span six different Bay Area counties. Urban gradient sites were sought in least-impacted urban streams.

Urban Gradient Study Sites

Previous monitoring by the Santa Clara Valley Urban Runoff Pollution Prevention Program (SCVURPPP) indicated that benthic macroinvertebrate (BMI) assemblages in urban portions of Saratoga Creek had very high biological integrity relative to other urban watersheds. For example, 8 to 15 EPT (Ephemeroptera, Plecoptera, and Trichoptera; indicators of good water quality) taxa were collected during BMI sampling (at site S-4 in the City of Saratoga between 2004-2005 (SCVURPPP 2005) using the 2003 CSBP high gradient field protocol and 500 organism laboratory count). This site is in an urban area approximately 2 miles downstream of the urban-rural boundary, where 18 to 23 EPT taxa were collected. In contrast, few EPT taxa are found in other urban streams. For example, only 2-5 EPT taxa were collected at site LT-5 in Las Trampas Creek by the Contra Costa Clean Water Program (CCCWP 2004). These samples were collected in 2003 and 2004 using the 2003 CSBP high gradient field protocol and 500 organism laboratory count. This site is also approximately 2.0 miles downstream of the urban-rural boundary, and has a similar watershed size and level of urbanization as the Saratoga Creek site. Above the urban-rural boundary, benthic macroinvertebrate assemblages in Las Trampas Creek were diverse (22 EPT taxa) and similar to minimally-disturbed conditions elsewhere in the Bay Area (SFBRWQCB 2007a).

2.2 Sampling design summary

The strategy used for the Reference Sites Study and the Urban Gradient Study focused on a number of site visits each year, conducted over three years. Bioassessment visits were conducted during the spring, summer, and fall, to capture the time of base flows (as separate from the rainy season). Storm runoff events were avoided; in fact, one of the criteria for algae collection was that sampling should not be performed within a month of a major flow event. Sonde and Hobo-Temp deployments for time-series data for ‘vital signs’ (dissolved oxygen, specific conductance, pH, temperature and turbidity) were also limited to periods of base flow. However, water samples for nutrient analyses were collected during the winters as well as during base flow periods.

Table 2.2-1 shows a summary of monitoring activities performed in years 2008-2010. This information is elaborated on in Appendix A-1.

2.3 Field operations

Field operations were conducted by the SWAMP Region 2 crew. The crew developed its own logistics over time and mostly kept a consistent order of sampling activities to assure shipping of samples as soon as all were collected, often using a crew member as the designated courier.

2.3.1 Bioassessment and physical habitat assessments

BMI samples were collected as instructed in the Standard Operating Procedures (SOP) developed for SWAMP, "Standard Operating Procedures for Collecting Macroinvertebrate Samples and Associated Physical and Chemical Data for Ambient Bioassessments in California" (Ode 2007). The crew collected benthic macroinvertebrate (BMI) and algae samples at the beginning of the monitoring day. Each BMI sample represents a collection of organisms captured with a D-frame dipnet (0.5 mm mesh size) from eleven sampling squares that were systematically located by each transect within a 150 m Reach. Each square had an area of $1ft^2$ and was sampled to the depth of 4-6 inches. The eleven sub-samples were pooled together, elutriated if needed, and preserved in 95 percent ethanol in the field to a final ethanol concentration of 70 percent or higher.

Algae samples were collected per the SOPs developed for SWAMP, "Standard Operating Procedures for Collecting Stream Algae Samples and Associated Physical Habitat and Chemical Data for Ambient Bioassessments in California" (Fetscher *et al.* 2009). Algae samples were collected, at the same time as BMI samples, from eleven small sampling plots that were systematically located by each transect within a 150 m Reach, 25 cm upstream of each BMI plot. Algae sub-samples were collected by scraping from a variety of streambed substrates using specialized devices for erosional or depositional habitats. The size of most algal sampling plots was 12.6 cm^2 – these were collected with a rubber delimiter or a PVC delimiter – while the size of plot collected with the syringe scrubber was 5.3 cm^2. The algal suspensions from all sub-samples were composited into one container and homogenized thoroughly. The composite sample was then used as a source for four aliquots. Two aliquots of 25 mL each were filtered and the filters were immediately frozen in dry ice to be used for analyses of chlorophyll *a* and ash-free dry mass (AFDM), which represents the quantity of organic matter. Two additional aliquots of 45 mL each were transferred into 50 mL tubes and preserved with glutaraldehyde for diatom and for soft-bodied algae taxonomic identification and enumeration. The crew also collected a qualitative unpreserved composite sample of all the types of live algae they were able to find in the Reach.

The crews also conducted physical habitat assessments at the full level of effort following the SWAMP SOP (Ode 2007) with the algal cover characteristics added per the algae SOP (Fetscher *et al.* 2009). Each season they used the current version of the SWAMP Data Sheets, and replaced the Data Sheets as they were updated over time.

2.3.2 Field measurements and sampling of water for chemical analyses

Grab water samples for analysis of nutrients and a number of other conventional characteristics were collected per the SWAMP protocols (i.e., the original Appendices to Puckett 2002), using, at each site visit, the prescribed array of pre-cleaned plastic containers to accommodate all required analytes and protect the integrity of each "sub-sample." All grab water samples were collected at stream locations that represent the bulk of the flow, about 10 cm below the surface. The crews were also responsible for collection of field duplicates per SWAMP QAMP (Puckett 2002) and QAPrP (SWAMP 2008). At the time of sampling, the crew also recorded field observations (e.g., weather, flow conditions, sample color or odor, presence of algae, etc.) and conducted field measurements (temperature, pH, dissolved oxygen, and specific conductance) to support lab data.

2.3.3 Time-Series (continuous) monitoring

Time-series (continuous) field measurements site visits to deploy and retrieve data logging sondes and Hobo-Temps were conducted at all six Reference sites by the SF Bay Region SWAMP crews. The YSI 6600 sondes were programmed to measure pH, dissolved oxygen, temperature, specific conductance, and turbidity every 15 minutes, and the HOBO Water Temp Pro v2 (HoboTemps) measured and logged the temperature every hour.

Deployment episodes ranged from 2 to 25 weeks (sondes) and 13 to 24 weeks (HoboTemps), with one exceptional sonde deployment of two days. Detailed deployment information is provided in Appendix F. The crews were also responsible for pre-deployment calibrations, accuracy checks with a reference instrument during deployments, mid-deployment calibrations in the field (if necessary), and post-deployment accuracy checks at the lab. During deployment and retrieval visits, crews recorded location attributes (e.g., vegetation, depth of stream, flow, visual turbidity, and substrate type) on data sheets and took photographs of sondes and HoboTemps in deployment locations.

2.4 Laboratory analyses

Table 2.4-1 shows the groups of analytes and other characteristics that were analyzed, tested, or counted in various laboratories using a variety of methods. A brief description, plus additional information on selected laboratory activities, is provided below.

2.4.1 Benthic macroinvertebrates

All samples were sorted and identified by the Department of Fish and Game Aquatic Bioassessment Laboratory (DFG ABL) (http://www.dfg.ca.gov/abl/) in accordance with the Standard Taxonomic Effort (STE) Level II developed by the Southwest Association of Freshwater Invertebrate Taxonomists (SAFIT) (Richards and Rogers 2006),. Six hundred individual organisms were randomly sub-sampled from each sample for identification and enumeration.

2.4.2 Algae taxonomy

The algae samples collected for laboratory taxonomic identification at each site included the soft-bodied algae sample, which consisted of the sample in the 50 mL centrifuge tube and the qualitative sample used by the lab to aid in taxonomic identification, and the 50 mL centrifuge tube containing the diatom sample. The diatom samples were shipped to the University of Colorado Boulder (UCOB) Museum of Natural History, where 600 organisms from each sample were identified to the species level. The soft-bodied algal taxonomic identification samples were sent to California State University San Marcos (CSUSM). The lab at CSUSM performed quantitative analysis to identify as many taxa (usually species) present in the sample as possible, and to provide an accurate and uniform estimate of algal taxon richness and quantity in terms of biovolumes.

2.4.3 Algal biomass indicators

Samples for analyses of chlorophyll *a* and ash-free dry mass (AFDM) were delivered to the Department of Fish and Game Water Pollution Control Laboratory (DFG-WPCL) on glass-fiber filters. The filters were incinerated (i.e., pre-ashed) at 500^{o}C for 30 minutes by the lab before field sampling. The lab determined the concentration of chlorophyll *a* by extracting the photosynthetic pigments from the filter directly and measuring the absorbance of the extract at various wavelengths. Chlorophyll *a* data were not corrected for pheophytin. AFDM was determined gravimetrically, by weighing each filter before and after ignition at >500^{o}C, which burned all the organic matter (i.e., the dry mass that is not inorganic ash).

2.4.4 Chemical analyses

Nutrients and other conventional constituents were analyzed at the DFG-WPCL laboratory. The DFG-WPCL was able to deliver the low detection levels required by SWAMP. Table 2.4-1 shows the actual ranges of detection limits and reporting limits achieved for each analyte in water.

2.5 Data analysis and interpretation

The term "data analysis" often refers to several types of formal activities, including but not limited to the following: **(a) endpoint derivation** for individual samples (e.g., BMI metrics, algae metrics, etc.), which often involves the use of special software programs; **(b)** computation of **summary statistics** (e.g., median, geometric mean, MWAT, etc.) for data sets comprised of multiple measurements; **(c)** comparisons of constituent concentrations or conditions to **water quality benchmarks**, either individually or in compilations (e.g., weekly minimum); **(d)** derivation of **correlation** coefficients to detect **relationships** between pairs of characteristics or factors; **(e)** application of **multivariate analyses** of individual results data to detect associations, or similarity, between characteristics or assemblages, and to explore variability within result values (e.g., non-metric multidimensional scaling (NMS) ordination of algal taxa); and **(f)** application of statistical tests to detect significant differences between groups of results or calculated endpoints (e.g., ANOVA). Another common "data analysis" activity refers to **(g)** creation of result presentation items such as **tables and figures,** and conducting **observations** of these items.

Note that the data verification and validation process is an essential but a totally separate part of the data handling process.

Data analyses (activity type "a") for BMI were initially performed by the laboratory according to their Standard Operating Procedures. As the SWAMP database developed and reporting modules were created, SWAMP data management team and RB2 team members used the new modules to generate BMI metrics. For algae metrics, an RB2 team member staged the raw algal data (i.e., counts of each taxon) and calculated algal metrics using spreadsheets. Physical habitat (PHAB) endpoints were calculated using the FlexiGrid templates (Katznelson 2008) with formulae adapted from EPA's Environmental Monitoring and Assessment Program (EMAP, Kaufmann *et al.* 1999). Summary statistics (activity type "b") for time-series field measurements were calculated following procedures established for year 1&2 (SFBRWQCB 2007a Sections 4.6.2 and 4.6.5). The NMS ordination software was used by two team members to generate NMS plots (activity type "e") for BMI and algae assemblages. Statistical software was used for analysis of variance (activity type "f"). The authors of this report conducted all comparisons to quality benchmarks (activity type "c"), as well as conducting exploratory correlation plots (activity type "d") and tabulating and plotting the results for the report (activity type "g"). The following sub-sections provide further description of selected data analysis activities conducted with years 2008-2010 data.

2.5.1 Calculation of Index of Biological Integrity (IBI) values

Benthic macroinvertebrate (BMI) index of biological integrity (IBI) values can currently be calculated using one of two algorithms. The first has been developed for Southern California (SC-IBI, Ode *et al.* 2005) and the second was developed for the California North Coast (NC-IBI, Rehn *et al.* 2005). An IBI for diatoms is currently under development for Southern California but could not be implemented for this report. The IBI calculations were run using the SWAMP reporting module, which randomly selects a fixed number of 500 individual invertebrates from a pool of 600 identified per sample. Rarifying the data from 600 counts used in the current SWAMP protocol was necessary because the two IBIs are based on 500 count samples. Because IBI values vary depending on which observations were included, the calculation was done in 20 iterations for each sample's data, and the values were averaged for the report. The mean, minimum, and maximum values are shown in Appendix B.

2.5.2 Analysis of Variance (ANOVA)

The NC-IBI and SC-IBI scores across the perennial and non-perennial reference sites were compared using ANOVA in JMP (v. 8, SAS Inc., Corey NC).

2.5.3 Ordination plots for biotic assemblages

<u>Background</u>

Ordination is a technique whereby multiple variables are reduced and expressed in a small number of dimensions. For this analysis, sites were graphed in a three-dimensional ordination space based on the abundance of taxa present at each site. Sites that are close together in ordination space exhibit similar benthic assemblages; increasing distance between sites indicates that a greater number of different taxa were present at the sites. Non-metric multidimensional scaling (NMS) is the most generally effective ordination technique for evaluating patterns in ecological community data and identifying site differences (McCune and Grace 2002).

NMS ordination has been a useful analytical approach for benthic macroinvertebrate data in previous SWAMP monitoring studies in the San Francisco Bay region. The NMS plot from the years 1&2 studies showed clear relationships between BMI assemblages and three land use groups that represented (a) open space and rural residential; (b) grazing, agriculture and mixed; and (c) urban (SFBRWQCB 2007a, Section 6). Although no resources were available to conduct a similar review of watershed land use for year 3 and years 4&5 watersheds, the same NMS ordination process was used in order to explore similarities in benthic macroinvertebrate assemblages among sites and watersheds in year 3 and years 4&5. These ordination plots reinforced the conclusion that there is a clear separation between open space and urban sites with regards to benthic macroinvertebrate assemblages (SFBRWQCB 2007b, 2008). The selection of minimally disturbed sites for the 2008-2010 Reference Site Study relied on these observations.

Years 2008-2010 Report

Multivariate analyses of the taxonomic data using non-metric multidimensional scaling (NMS) ordinations were performed to determine if the macroinvertebrate and algae communities differed because of flow status (perennial vs. non-perennial) and across urban gradients. NMS ordinations were run in PC-ORD (per McCune and Mefford 2006) with the following settings: ≤ 6 axes; 250 runs of real data; 20 iterations to evaluate stability; 100 maximum iterations; and Sorenson distance metric. Relative abundance (out of 600 individuals identified per sample) counts were transformed prior to ordination, using the natural log with a correction factor for zero count data (*ln* (1 + count)).

- **BMI taxa** present at 2 or more of the 34 sites (> 5%) were included in the analysis (n = 113 taxa included). BMI taxonomic data were originally identified to SAFIT Level 2 but the ordination was conducted at SAFIT Level 1 (Richards and Rogers 2006) with the inclusion of taxa identified as Heptageniidae and Chironomidae identified to subfamily. This operational taxonomic unit (OTU) level is most similar to SAFIT1_OTUa used by the Department of Fish and Game Aquatic Bioassessment Lab.
- **Diatom taxa** present at 2 or more of the 38 samples (> 5%) were included in the analysis (n = 86 taxa included). Diatom taxa were identified to species according to SWAMP master taxa list (http://www.cad-twg.org/Resources/tabid/439/Default.aspx).

The overall taxonomic differences among the three groups identified in the reference selection process were compared using multi-response permutation procedures (MRPP) (McCune and Grace 2002).

2.5.4 Summary statistics and box plots for time-series field measurement (continuous monitoring) episodes

Each sonde file, generated from one deployment episode, usually contained several thousand individual measurements for each water quality characteristic (pH, temperature, dissolved oxygen, specific conductance and turbidity). The minimum and maximum values within each data set were easily identified by an Excel function, and so were the median, the 25th percentile, and the 75th percentile values used to construct a box-plot presentation for each episode. This type of “box and whisker” plot is widely used to explore the distribution of independent data points (e.g., Helsel and Hirsch 2005), but it has often been used for presentation of the general tendencies of continuous monitoring data as well.

The continuous temperature data were used to compute one endpoint: the maximum weekly average temperature (MWAT), also described as the "7-day mean." Dissolved oxygen (DO) data were used to calculate a similar endpoint: the 7-day average minimum. These endpoints, calculated separately for each season, were used for comparison to water quality benchmarks as described below. In reality, the MWAT benchmark applies to data collected for a whole year, but it was necessary to do a theoretical extrapolation of each monitoring season to the entire year to generate an endpoint that enables checking for exceedances.

2.5.5 Comparison of monitoring results to water quality benchmarks.

The phrase "water (or sediment) quality benchmark" is a catch-all term to include objectives, guidelines, limits, targets, standards, and other types of values for concentrations of constituents that should not be exceeded in a given water body. There may be a profound difference between each sub-set of benchmarks, for example, objectives are used as regulatory tools, while guidelines are used for evaluation but are not legally binding. The term "threshold" is often used in this report to convey the same meaning as "benchmark". For constituent concentrations, the word "exceedance" means that the sample value was above the benchmark (and that this was not "good"). However, dissolved oxygen values are "good" if they are above the benchmark, and "good" pH values are those that fall within a defined range (usually 6.5 to 8.5), above and below which the conditions are considered "not good", i.e., an "exceedance."

Table 2.5-1 shows the water quality benchmarks used in this report. These values are also shown in Appendix Tables E-1 (nitrogen and phosphorus), E-2 (benthic chlorophyll *a*), and F-2 (temperature, DO and pH), as part of the results summary. The benchmarks were selected from a variety of sources, such as the regional Basin Plan for protection of aquatic life, the Nutrient Numeric Endpoints (Tetra Tech 2006) benchmarks for nutrients and chlorophyll *a*, the U.S. EPA criteria, and a peer reviewed literature article.

2.6 Data quality

Field and lab operators followed the SWAMP field procedures and the internal lab SOPs, as required to assure generation of data of known and documented quality. With some exceptions, the data reported in Section 3 and in the Appendix Tables are SWAMP-compliant. This means the following:

(a) Sample container, preservation, and holding time specifications of all measurement systems have been applied and were achieved as specified;
(b) All the quality checks required by SWAMP were performed at the required frequency;
(c) All measurement system runs included their internal quality checks and functioned within their performance/acceptance criteria; and
(d) All SWAMP measurement quality objectives (MQOs) were met.

Operators performed an array of actions to **affect** (i.e., act to influence the outcome) and **check** (test to evaluate or verify) the different aspects of data quality in field measurements, sampling and shipping, and lab analyses. Quality checks were conducted in years 2008-2010 as relevant to the six data quality indicators mentioned in the U.S. EPA Quality Assurance Project Plan guidance, the SWAMP Quality Assurance Program Plan (SWAMP 2008), the SWAMP Quality Assurance Project Plan for Bioassessments (SCCWRP 2009), and the SWAMP Quality Management Plan (Puckett 2002). Some of the data did not meet all the conditions stated above. However, most of these data are still usable if the flaw or omission was not considered detrimental, and these were flagged as “estimated” by the SWAMP Quality Assurance Team. The reader is referred to RB2 SWAMP Years 2008-2010 archive for spreadsheets that provide all the data as well as the data quality flags for each Result.

Table 2.1-1: Location of 2008-2010 monitoring stations

	Station	Waterbody Name	Watershed Name	Station Name/Location	Station Code	Latitude	Longitude	Elevation (ft)
Reference sites								
Non-perennial	COY610	Coyote Creek	Coyote Creek	Coyote approx 1.5 miles upstream of Gilroy Hot Springs Rd. bridge	205COY610	37.11770	-121.48111	992
Non-perennial	IND200	Indian Creek	Indian Creek	Indian approx 1.8 miles upstream of San Antonio Reservoir	204IND200	37.56223	-121.79820	619
Non-perennial	MTD117	Mitchell Canyon	Mt. Diablo Creek	Mitchell Canyon approx 250 m upstream of bridge at Mt. Diablo SP entrance	207MTD117	37.91847	-121.94421	615
Perennial	PES162	Pescadero Creek	Pescadero Creek	Pescadero approx 150 m upstream of Towne Fire Road crossing	202PES162	37.26914	-122.26395	240
Perennial	RDW080	Redwood Creek	Redwood Creek	Redwood at ped bridge in Frank Valley - approx 1 mile upstream of Hwy 1	201RDW080	37.87717	-122.58114	62
Perennial	RIC100	Ritchie Creek	Napa River	Ritchie above gabion wall in Napa-Bothe State Park	206RIC100	38.55078	-122.52137	384
Urban Gradient								
Perennial	SAR057	Saratoga Creek	Saratoga Creek	Saratoga above Congress Springs Park	205SAR057	37.27781	-122.01132	309
Perennial	SAR060	Saratoga Creek	Saratoga Creek	Saratoga behind Lutheran school - Saratoga Ave and Braemar	205SAR060	37.27220	-122.01630	331
Perennial	SAR070	Saratoga Creek	Saratoga Creek	Saratoga inside SCVWD gate - below Walnut Ave	205SAR070	37.26150	-122.02960	412
Perennial	SAR080	Saratoga Creek	Saratoga Creek	Saratoga near Hakone Gardens	205SAR080	37.25410	-122.04200	513
Perennial	WAL410	Las Trampas Creek	Walnut Creek	Las Trampas above dirt bike jumps	206WAL410	37.86781	-122.09793	366
Perennial	WAL412	Las Trampas Creek	Walnut Creek	Las Trampas above St. Mary's Road bridge	206WAL412	37.86103	-122.10192	417
Perennial	WAL415	Las Trampas Creek	Walnut Creek	Las Trampas below St. Mary's and Bollinger Canyon Roads	206WAL415	37.84789	-122.10840	532
Perennial	WAL420	Las Trampas Creek	Walnut Creek	Las Trampas at 900 Bollinger Canyon Road	206WAL420	37.83922	-122.09908	579

Note: Elevation values were gleaned from topo map. All coordinates use WGS 84

Table 2.1-2: Drainage area information for reference and urban sites

Station	Percent Agriculture		Percent Urban		Road Density (km/km^2)	
	1K	WS	1K	WS	1K	WS
COY610	0.0	0.0	0.0	0.0	0.1	0.2
IND200	0.0	0.0	0.0	0.0	0.0	1.2
MTD117	1.4	0.2	0.0	0.0	0.3	1.1
PES162	0.0	0.0	0.0	0.0	2.7	3.2
RDW080	0.0	0.0	0.0	1.0	0.8	2.0
RIC100	0.0	0.0	0.0	0.0	2.0	1.1
SAR057	0.0	0.1	84.6	6.8	12.1	4.0
SAR060	0.0	0.1	64.9	5.5	10.7	3.9
SAR070	0.0	0.1	58.8	3.1	12.2	3.6
SAR080	0.0	0.1	7.5	0.6	5.6	2.9
WAL410	0.0	0.0	21.2	5.3	5.9	2.2
WAL412	0.0	0.0	9.6	4.2	3.3	1.9
WAL415	0.0	0.0	24.4	4.0	6.0	2.0
WAL420	0.0	0.0	0.0	0.1	2.3	1.2

All sites are Omernik L 3 Ecoregion #6 except PES162 which is #1
1K – local vicinity, area spans 1 km radius above site
WS – entire watershed area upstream of the site

Table 2.1-3: Listed beneficial uses for reference sites

Station	AGR	MUN	FRSH	GWR	COMM	SHELL	COLD	MIGR	RARE	SPWN	WARM	WILD	REC-1	REC-2
COY610				E	E		E	E	E	E	E	E	E	E
IND200			E				E		E	E	E	E	E*	E
MTD117							E	E	E	E	E	E	E	E
RDW080	E	E	E			E	E	E	E	E	E	E	E	E
RIC100							E	E	E	E	E	E	E	E
PES162	E	E					E	E	E	E	E	E	E	E

E = Existing
E* = Water quality objectives apply; water contact recreation is prohibited or limited to protect public health

Agricultural Supply (AGR); Municipal and Domestic Supply (MUN); Freshwater Replenishment to Surface Waters (FRSH); Groundwater Recharge (GWR); Ocean, Commercial and Sport Fishing (COMM); Shellfish Harvesting (SHELL); Cold Freshwater Habitat (COLD); Fish Migration (MIGR); Preservation of Rare and Endangered Species (RARE); Fish Spawning (SPWN); Warm Freshwater Habitat (WARM); Wildlife Habitat (WILD); Water Contact Recreation (REC-1); Noncontact Water Recreation (REC-2)

Table 2.2-1: Summary of 2008-2010 monitoring activities included in this report.

Characteristic group	Medium	Activity Category	Field Activity type	Laboratory work	Activity Frequency	Season & Timing *(Note 1)*	Total # of Stations	*Total # of StationVisits or Samples or deployments (Note 2)*
Local conditions *(Note a)*	All	Evaluative	Categorical Observations	None	up to 14/yr	All	14	152
"Vital signs" *(Note b)*	Water	Measured	Discrete Field Measurements	None	up to 14/yr	All	14	152
Benthic macroinvertebrate assemblages	Biota	Collected	Biota Sample	BMI Taxonomy (ID and count)	1/yr	Spring	14	30
Benthic algae assemblages	Biota	Collected	Biota Sample	Diatoms and Soft Algae Taxonomy	up to 3/yr	Spring, summer	10	38
Benthic algae biomass	Biota	Collected	Biota Sample	Analyses	up to 3/yr	Spring, summer	10	38
Physical habitat attributes	All	Evaluative and Measured	Categorical Observations, Numeric-range estimates, Morphology surveys, Discharge	None	up to 3/yr	Spring, summer, fall	9	37
Conventional WQ characteristics (including salts & nutrients)	Water	Collected	Sample (abiotic media)	Analyses	up to 6/yr	All	14	69
Sonde probes suite *(Note c)*	Water	Measured	Time-series Field Measurements	Calibrations and accuracy checks	up to 4/yr	Spring, summer, fall	6	28
HoboTemps *(Note d)*	Water	Measured	Time-series Field Measurements	Accuracy checks	up to 2/yr	Spring, summer, fall	6	29

Note 1 Station visits occurred any time of day (not directed to a specific time). Trip scheduling was directed to non-rainy weather, i.e., base flow conditions.
Note 2 Activities done at specific stations are shown in Appendix Table A-1 and in the data appendix tables (B-1, C-1, and F-1).
Note a Local conditions include estimated flow, weather, Station appearance & odors, water color, and presence of special features
Note b The “vital signs” are: temperature, pH, dissolved oxygen, specific conductance, and turbidity; these were measured during sample collection to support lab data.
Note c The YSI 6600 Sonde probe suite included temperature, pH, dissolved oxygen, specific conductance, and turbidity, measured every 15 min. for 1-19 weeks.
Note d The HoboTemps were deployed along horizontal and vertical gradients, measuring the temperature every hour for 1-24 weeks.

Table 2.4-1: Laboratory analyses performed with water and benthic algae samples in 2008-2010

Group	Analyte w Fraction & Unit	Laboratory	Method	Preparation	MDLs Min	MDLs Max	RLs Min	RLs Max
Nutrients								
	Ammonia as N,Total mg/L	DFG-WPCL	QC 10107061G	LabFiltered, LabAcidified	0.0050	0.01	0.0100	0.02
	Nitrate + Nitrite as N mg/L	DFG-WPCL	QC 10107041B	LabFiltered, LabAcidified	0.0050	0.01	0.01	0.02
	Nitrate as N mg/L	DFG-WPCL	QC 10107041B	LabFiltered, LabAcidified	0.0050	0.0050	0.0100	0.01
	Nitrite as N mg/L	DFG-WPCL	QC 10107041B	FieldFiltered	0.0020	0.0020	0.0050	0.0050
	Nitrite as N mg/L	DFG-WPCL	QC 10107041B	LabFiltered	0.0020	0.0020	0.0050	0.0050
	Nitrogen, Total mg/L	DFG-WPCL	QC 10107044B	LabAcidified	0.010	0.025	0.0500	0.05
	Nitrogen, Total Kjeldahl mg/L	DFG-WPCL	QC 10107062E	LabAcidified	0.050	0.1	0.100	0.5
	OrthoPhosphate as P,Dissolved mg/L	DFG-WPCL	QC 10115011M	FieldFiltered	0.0020	0.004	0.0050	0.01
	OrthoPhosphate as P,Dissolved mg/L	DFG-WPCL	QC 10115011M	LabFiltered	0.0020	0.002	0.0050	0.005
	Phosphorus as P,Total mg/L	DFG-WPCL	QC 10115012B	LabAcidified	0.0050	0.02	0.0100	0.04
Other Conventional Characterisitcs								
	Alkalinity as CaCO3 mg/L	DFG-WPCL	QC 10303311A	LabFiltered	3.0	12	10.0	40
	Alkalinity as CaCO3,Total mg/L	DFG-WPCL	QC 10303311A	LabFiltered	3.0	12	10.0	40
	Chloride mg/L	DFG-WPCL	EPA 300.0	LabFiltered	0.20	5	0.5	12.5
	Dissolved Organic Carbon mg/L	DFG-WPCL	EPA 415.1M	LabFiltered, LabAcidified	0.50	0.5	1	1
	Silica as SiO2,Dissolved mg/L	DFG-WPCL	QC 10114271A	FieldFiltered	1.0	1	2.00	2
	Silica as SiO2,Dissolved mg/L	DFG-WPCL	QC 10114271A	LabFiltered	1.0	2	2.00	4
	Suspended Sediment Concentration mg/L	DFG-WPCL	ASTM D3977	None	2	2	4	4
Benthic algal biomass indicators								
	Ash Free Dry Mass mg/L	DFG-WPCL	WRS 73A.3	FieldFiltered, FieldFrozen	50	50	150	150
	AFDM_Algae,Particulate g/m^2	DFG-WPCL	WRS 73A.3	FieldFiltered, FieldFrozen	1.26	2.08	3.79	6.24
	Chlorophyll *a* ug/L	SFL	SM 10200 H-2b	FieldFiltered, FieldFrozen	0.500	0.500	40	40
	Chlorophyll *a* ug/L	DFG-WPCL	SM 10200 H-2b	FieldFiltered, FieldFrozen	50	100	150	300
	Chlorophyll *a* ,Particulate mg/m^2	DFG-WPCL	SM 10200 H-2b	FieldFiltered, FieldFrozen	1.11	1.83	3.79	6.24

MDL - minimum detection limit; RL - reporting limit; NA - not applicable
DFG-WPCL: Department of Fish and Game Water Pollution Control Laboratory; SFL: Sierra Foothill Laboratory

Table 2.5-1: Water quality benchmarks for protection of aquatic life

Characteristic	Description of Benchmark	Numeric Limit	Units	Reference
Temperature	Max, salmonids	24	° C	USEPA, 1977
	7-day Mean for Coho	14.8	° C	Sullivan *et al* , 2000
	7-day Mean for steelhead	17	° C	Sullivan *et al* , 2000
Oxygen, dissolved	Instantaneous Min, WARM	5	mg/L	Region 2 Basin Plan
	Instantaneous Min, COLD	7	mg/L	Region 2 Basin Plan
Oxygen, dissolved	rolling 7-day average of Min values, WARM	5	mg/L	2004 303(d) Listing Policy Sec 3.2 *(Note 1)*
	rolling 7-day average of Min values, COLD	7	mg/L	2004 303(d) Listing Policy Sec 3.2*
pH	Range	6.5 to 8.5	S.U.	Region 2 Basin Plan
Ammonia, unionized	Annual median	0.025	mg/L	Region 2 Basin Plan
Nitrogen, total as N	Maximum	0.518	mg/L	EPA Nutrient ecoregion III, sub-region 6, 2000
Phosphorus, total as P	Maximum	0.03	mg/L	EPA Nutrient ecoregion III, sub-region 6, 2000
Chlorophyll *a* (benthic)	BURC 1 Presumptive unimparied COLD	<100	mg/m^2	TetraTech 2006 *(Note 2)*
	BURC 2 Potentially imparied COLD	100-150	mg/m^2	TetraTech 2006
	BURC 3 Presumptive imparied COLD	>150	mg/m^2	TetraTech 2006
	BURC 1 Presumptive unimparied WARM	<150	mg/m^2	TetraTech 2006
	BURC 2 Potentially imparied WARM	150-200	mg/m^2	TetraTech 2006
	BURC 3 Presumptive imparied WARM	>200	mg/m^2	TetraTech 2006

Note 1: 2004 303(d) Listing Policy Sec 3.2 Numeric Water Quality Objectives for Conventional or Other Pollutants in Water says
"When continuous monitoring data (DO) are available, the seven-day average of daily minimum measurements shall be assessed."
Note 2: BURC = Beneficial Use Risk Categories

Figure 2.1-1: SF Bay Area monitoring locations used for the Reference Sites and Urban Gradient studies

3 Results

This section presents the results obtained at the six reference sites and eight urban sites selected for the Reference Site Study and the Urban Gradient Study of 2008-2010. Unlike the previous monitoring years, in which each year focused on characterization of a different set of watersheds, the years 2008-2010 study focused on sites that were visited multiple times over three years to document seasonal and inter-annual variability, as well as long-term trends. The results are organized by subject matter, with separate sections for various biological characteristics, physical habitat conditions, and water quality. The figures are shown at the end of each sub-section.

This Results section shows only highlights of the results, whereas the entire data set is presented in an array of appendices, which constitute an integral part of this report. The appendix tables are organized by subject matter, in the same internal order as the subjects in each of the subsections. This order is as follows: benthic macroinvertebrate (BMI) taxonomy, algae (periphyton) taxonomy, physical habitat, algal biomass indicators, nutrients, and water quality (including continuous field measurements). The appendices also contain a list of station visits and all activities conducted during each visit (Appendix A), as well as sample or sonde-file inventories at the beginning of each subject appendix (for Appendices B, C, and F). The six reference sites were visited several times per year for a variety of monitoring activities, yielding a total of 140 visits. The four sites at each of the two urban streams were visited less frequently; all urban sites were visited in 2008, but monitoring at Las Trampas Creek was then discontinued due to logistical constraints. Thus, the total number of site visits to urban streams was 19.

3.1 BMI Communities

Benthic macroinvertebrate (BMI) communities have been assessed in SF Bay Area streams by a variety of agencies since the early 1990s. The Region 2 SWAMP efforts included BMI assessments since 2000. Our 2008-2010 studies introduced monitoring at eight new urban sites and repeated sampling at six new reference sites over three years; the resulting data are presented in Appendix B. Four sites were sampled along each of the two urban streams, moving from minimal urbanization to moderate urbanization in the drainage area. Reference sites were selected to represent the streams that were least impacted by anthropogenic activities in the Region.

In total, SWAMP collected 30 BMI samples from these 14 sites over the three years of monitoring (Appendix A); 18 samples were collected in the reference sites and 12 in the urban sites.

SWAMP has monitored for BMI at 204 sites since 2000. **Figure 3.1-1** panels show overall conditions observed in these streams as indicated by the number of Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa, a common indicator that responds negatively to anthropogenic stress (Rosenberg and Resh 1993). The EPT taxa metric was divided into four categories (Excellent, Good, Fair, or Poor) based on an analysis of the data (Cover 2010, personal communication).

The six Reference Study sites monitored in 2008-2010 are shown in purple; panel a (North Bay) shows two perennial stream sites (Ritchie and Redwood Creeks) and one non-perennial site (Mitchell Canyon), while panel b (South Bay) shows one perennial site (Pescadero Creek) and two non-perennial sites, on Indian and Coyote Creeks (source: map prepared for Pulse of the Estuary 2010).

BMI communities showed distinct responses to both natural gradients and stressor gradients across the Bay Area. Streams with higher diversity of EPT taxa were common in the steeper, more open-space portions of the watersheds, whereas streams with lower EPT taxa counts were common in the low-gradient urbanized areas downstream (Figures 3.1-1a and 3.1-1b). Four of the six average EPT taxa values for the Reference Study sites (purple highlights) were categorized in the "Excellent" category (green points), and two of the reference sites – Redwood Creek, with a three-year average EPT value of 18, and Mitchell Canyon, with a three-year average EPT value of 10 – were categorized as "Good" (see values in Appendix B). These six reference sites scored better or similar to other sites in open space areas. When considering all bioassessment data collected by SWAMP to date, mean EPT taxa richness was 10.8 (n=204) across the Bay Area, with streams receiving higher scores in the North Bay (mean=13.1, n=71) than in the South Bay (mean=9.5, n=133).

The Reference Site Study

Benthic macroinvertebrate communities showed distinct patterns based on sample location and hydrologic regime **(Figure 3.1-2).** A three-axis non-metric multidimensional scaling (NMS) ordination was the optimal solution for the 18 samples collected at the six reference sites (stress = 11.8, instability < 0.00001, total R^2 = 85.9%). The stress and instability of this ordination were set within optimal levels. The plot is based on the taxonomic composition of benthic macroinvertebrate assemblages. The sites are color-coded by hydrologic regime (i.e. perennial or non-perennial stream flow). An ordination plot consists of two to six axes on which individual site-visit samples are plotted. The axes represent the most important multivariate gradients in the data set, which in turn represent the most variation in relative abundance of taxa between the samples. The axes may be correlated to physical habitat variables, but are solely based on the invertebrate community structure. Most importantly, the distance between sites on the ordination plot is an indication of their similarity. For example, sites close to one another support similar biological communities, whereas sites farthest away from one another on the plot indicate that they have quite different biological communities.

Perennial streams supported different biological communities than non-perennial streams. The ordination shows a clear separation between the perennial (solid blue dots) and non-perennial (red squares) stream sites (Figure 3.1-2). Multi-response permutation procedures (MRPP) analysis confirmed that the difference in ordination space between the perennial and non-perennial streams was a significant difference (Sørenson distance measurement, *A* statistic = 0.27, $p < 0.00001$).

The non-perennial sites showed more inter-annual variability than the perennial sites. For example, the size of the ellipses in Figure 3.1-2 demonstrates the amount of variation in BMI communities observed over the three years. Coyote Creek (COY610), a non-perennial inland stream, exhibited the most variation whereas the two perennial coastal streams (PES162, RDW080) exhibited the least.

There was a marked similarity among the biological communities observed at the same sample stations over time. For example, the three years of data from each site tended to cluster together (as shown by ellipse shapes) and away from other sites. This result indicates that low-stress sites have similar BMI communities over time, but they the communities are not identical every year.

Benthic macroinvertebrate communities at Indian Creek (IND200) seem to be more similar to perennial sites than to other non-perennial sites. Reasons for this could include the fact that IND200 has the longest hydroperiod of the non-perennial streams and/or a more permanent hyporheic zone. This result suggests that there may not be a clear-cut dichotomy in the biological response to perennial and non-perennial flow regimes. In other words, we can expect to see a gradient of response based on how many months a stream has flow or on the depth of the local groundwater table.

The inter-annual variation in the BMI assemblages showed some similarities between sites. For example, the communities at the non-perennial sites all shifted in the same direction in ordination space in 2010 (Figure 3.1-2). Thus, the change in community structure was similar in this year for all three sites. The value for Ritchie Creek (RIC100) in 2010 also followed the non-perennial community trend; however, the other perennial sites did not. RIC100 is the “least perennial” of all the perennial sites. It has a different geology and climate, being situated inland where it is drier and with hillside vegetation being dominated by oak savannah, grasses and shrubs. There is also some pumping and discharge modification upstream of the site. Because of these variable flow conditions, RIC100 experiences more changes in the wetted width of the stream. This variation in flow might have some impact on the BMI communities present at this site.

The same benthic macroinvertebrate data used in the NMS ordinations were also used to derive a variety of BMI metrics that provide insight into the composition of the community and other aspects of its richness and abundance (Appendix B). A number of these BMI metrics were then used to calculate an index of biological integrity (IBI) for each sample. IBI scores reflect the overall condition, or “health,” of the BMI community. IBI scores are then used to categorize the overall condition as very good, good, fair, poor, or very poor.

Figure 3.1-3 shows the BMI-based index of biological integrity (IBI) scores calculated for each of the reference site samples. IBI scores were calculated based on the formula developed for the North Coast for all sites. The southern California IBI was also calculated for Omernik Level 3 ecoregions where the tools were applicable, i.e., for all the reference streams except for Pescadero Creek. Each bar represents the arithmetic mean of 20 IBI calculation iterations, each performed with a random draw of 500 organisms out of the whole sample of 600 organisms. The minimum and maximum values of the 20 iterations of IBI scores are shown in Appendix B, and the differences between them are as high as 10 points in some cases. Most IBI scores indicate that the reference sites are in very good, good, or fair conditions, the main exceptions being the 2010 COY610 and MTD117 values. The North Coast and SoCal IBI values mostly follow the same trends over time, indicating that the indices are both responsive to the differences between sites and differences observed over time. The Southern California IBI gives generally higher scores than the North Coast IBI, by an average of 9 IBI points in reference sites.

Overall, four of the reference sites showed moderate inter-annual variability (<10 points over three years). On the other hand, Coyote Creek (COY610) and Mitchell Canyon (MTD117) showed very high variability, with both sites dropping approximately 35 IBI points in 2010. Both of these sites are non-perennial, which shows that the variation observed in the NMS ordination was also reflected in substantial differences in IBI scores. The 2010 Water Year had an unusual distribution of storm events, and some events created high-energy flows that may have affected the BMI communities.

The Urban Gradient Study

Beyond studying the conditions in the six reference sites, the 2008-2010 monitoring effort included an Urban Gradient Study in which a number of urban sites along the mainstems of two urban creeks were monitored. Las Trampas Creek, a tributary of Walnut Creek in the East Bay, was monitored in 2008. Saratoga Creek, in the South Bay, was monitored in 2008 and 2009. Saratoga Creek was selected based on previously-collected data which indicated that it represents the upper end of habitat quality in the Bay Area urban environment; i.e., it was considered to represent best-attainable conditions for an urban stream. In contrast, Las Trampas Creek was selected because previous data indicated that it was heavily impacted even though it was not intensely urbanized, and one of the original study questions was "why are these two streams behaving so differently?" **Figure 3.1-4** panels show some of the BMI metrics and IBI results obtained from the Urban Gradient Study.

We observed a significant decrease in biological condition along the urban gradient in Saratoga Creek in both 2008 and 2009. **Figure 3.1-4** shows the values of selected BMI metrics in Saratoga Creek in two panels (a, for 2008 and b, for 2009). The values of taxa richness, the number of EPT taxa, and the % EPT metrics decrease as one moves downstream (Figure 3.1-4). The % Sensitive EPT metric exhibited a threshold response, with low values at the three downstream urban sites and higher values in the least-urban Saratoga Creek site (SAR080). In contrast, the % Collectors metric showed an inverse threshold response: collectors were dominant in the three downstream urban sites. The dominance of collectors is considered a good indicator for disturbance, potentially resulting from increased organic debris (more food for collectors) and diminished representation of the more sensitive taxa in other feeding groups. These patterns were consistent for both years of monitoring in Saratoga Creek.

Figure 3.1-5 panels **a&b** show the BMI-based index of biological integrity (IBI) scores for the Urban Gradient Study sites in Las Trampas Creek and Saratoga Creek. Urban site scores are generally lower than those calculated for the reference sites (Figure 3.1-3 above). All scores were at or below 50 at the Las Trampas sites and in the three downstream stations of Saratoga Creek. As expected from past data, IBI scores were higher at Saratoga than at Las Trampas. This result is interesting considering that Saratoga Creek has greater amounts of urbanization and road densities in the local (1 km) drainages and in the overall watershed. The 1 km local urban gradient at Las Trampas does not show a consistent increase (Table 2.1-2). In particular, the IBI scores for WAL420 were lower than expected based on GIS stressors.

Flow regime: perennial vs. non-perennial flows

The 2008-2010 Reference Study addressed another important question regarding the differences between perennial and non-perennial sites. Figure 3.1-2 above showed a clear separation in BMI assemblages between perennial and non-perennial streams. However, we cannot conclude that non-perennial streams are in worse condition, because both NC and SC IBIs were specifically designed for perennial streams. Therefore, we investigated how selected BMI metrics were different in these two stream types by averaging the scores of the three non-perennial reference sites (Coyote, Indian, and Mitchell) and comparing that to the average for perennial reference sites (Pescadero, Redwood, and Richie).

Figure 3.1-6 shows the average values of selected BMI metrics for the two groups of reference sites. The BMI metrics that are indicators of high-quality streams (e.g., taxa richness and high percentage of EPT groups) are higher in perennial streams. In contrast, the relative abundance of collectors, which are more tolerant to degradation and therefore indicate less favorable conditions, is higher in non-perennial streams.

Similar comparisons between perennial and non-perennial reference sites were performed using the IBI scores. **Figure 3.1-7** shows the box plots created for the 18 IBI values (6 sites x 3 site visits) obtained in our 2008-2010 Reference Site Study, grouped by stream type. Also shown are box plots with Bay Area reference site data collected by others as part of the Bay Area Macroinvertebrate Bioassessment Information Network (BAMBI) study (Lunde 2011). A fifth box plot includes data collected by BAMBI in 2000-2007 in non-reference sites (both non-perennial and perennial). These “box and whisker” plots are useful for showing the distribution, the range, and the central tendency of the data.

The distribution of IBI scores in SWAMP non-perennial reference site samples is much wider than in perennial sites. This is a very small dataset, comprised of three sites in each group. In the larger dataset of reference sites identified for the BAMBI study by Lunde (2011), non-perennial streams had lower median IBI scores than perennial streams (58 and 79, respectively). The dataset of Bay Area reference sites indicates that there are significant differences in the biological communities associated with these two hydrologic regimes. As expected, the IBI scores of samples from a variety of non-perennial and perennial urban and non-urban sites were much lower, with a median score of 26 (Lunde 2011).

3.2 Algae Taxonomy Results

Algae bioassessment was incorporated into the Region 2 SWAMP monitoring effort in 2008, while the protocol was still under development. The field crews collected a total of 34 algae samples in reference sites. They also collected 4 samples in urban sites at Saratoga Creek in 2009 (Appendix A). Algal metrics based on diatom taxonomy data are still under development as this report is being written, so we examined several experimental metrics that proved to be useful indicators in Southern California (Fetscher, personal communication). Algae IBIs for Southern California are also in development, and will be published soon after this report is submitted to

SWAMP. Thus, the analysis in this report was limited to multivariate analyses through NMS ordination and examination of selected algae metrics. All algal metric data are presented in Appendix C.

Figure 3.2-1 shows the NMS ordination of the 38 diatom assemblages sampled for this study. Reference sites cluster by hydrologic regime; the perennial group is fairly distinct from the non-perennial group, although there is overlap among groups along both Axis 1 and Axis 2. The urban sites from perennially-flowing Saratoga Creek cluster more closely as a group within the perennial reference stream cluster. Non-perennial stream sites show higher total variability (wider scatter within cluster) – the same trend observed in the BMI data (Figure 3.1-2 above). MRPP analysis confirmed the visual trends in the NMS ordination showing that diatom assemblages were significantly different in perennial and non-perennial reference streams (Figure 3.2.1, *A* statistic = 0.11, $p < 0.003$).

Few explanatory variables were associated with differences in diatom composition besides flow status. Among the fifteen explanatory variables examined, only % canopy cover and the Combined Human Disturbance Index showed moderate association (mean $R^2 > 0.1$) with changes in diatom community structure. The lack of association between explanatory variables and diatom community structure might be due to the limited range of condition in this dataset. Four urban gradient sites were included in the ordination; these are from Saratoga Creek, a stream that was known to be in very good biological condition (according to its benthic macroinvertebrates) despite the urban surroundings.

Selected algal metrics showed consistent trends based on hydrologic regime (perennial vs. non-perennial) or season. **Figure 3.2-2** shows the results of four algal metrics at non-perennial streams (3.2-2a) and perennial streams (3.2-2b) during the spring and summer seasons of 2008-2010. High values for the two richness metrics indicate high diversity. It is expected that the dominance of motile diatoms would indicate rapid changes in the streambed substrate, and that presence of *Achnanthidium minutissimum* (a very sensitive diatom species) would indicate good conditions. As shown in figure 3.2-2, diatom genera richness was the most stable metric (i.e. there was little variation over time), whereas % diatoms of motile genera and % *A. minutissimum* were more variable within a year and between years. The effects of seasonal variation were more pronounced in non-perennial streams than in perennial streams.

The scores of selected algal metrics at perennial streams differed from those at the non-perennial streams (Appendix C and Figure 3.2-2). Diatom genera richness and % diatoms of motile genera were both higher overall in the perennial streams, whereas % *A. minutissimum* was lower. The soft algae genera richness was slightly higher on average in perennial streams, although this pattern is obscured by the high genera richness levels observed in non-perennial streams in 2009. Perhaps this outlier was affected by the high spring runoff during 2009.

Figure 3.2-3 shows the seasonal variation in the values of six diatom metrics at the reference sites. The first three bars in each group (lighter fill) represent the non-perennial streams; those did not have any flow in late summer (third group in each panel). The last three bars show results from the perennial streams. Again, diatom genera richness (panel a) appears to be the most stable metric and shows little seasonal variation. The percentage of motile diatom genera was highly variable in Coyote Creek (COY) and Mitchell Canyon (MTD). Percent nitrogen fixing diatoms (panel d) was generally very low (e.g., <2%), except at two sites during the summer (COY and PES) and at one of the same sites (PES) during late summer.

The algae community showed some responses to the urban gradient, but often contrary to expectation. **Figure 3.2-4** shows the same selection of algal metrics obtained for samples collected along Saratoga Creek in 2009. There was a gradient in the percentage of motile diatoms, with the higher percentages found further upstream. This result is unexpected, because the dominance of motile diatom species is considered to be an indicator of high silt deposition. Diatoms with motile capabilities tend to have an ecological advantage to non-motile species in these conditions, and will presumably dominate in the downstream stations where, it is assumed, more of the stream bed is composed of fines and sand that move frequently (and cover algal mats). There is also a gradient in the percentage of *A. minutissimum*, again in an inverse direction to our expectation; it is assumed that the relative abundance of this sensitive diatom species should increase as conditions improve when we move upstream. The other two metrics did not show any noticeable responses to the urban gradient. It is important to emphasize that it is possible that the algae community is extremely sensitive to stress, and so even the least-urban site on Saratoga Creek might exhibit effects of urban stress. This is a very small dataset and the value of algae taxonomy still needs more investigation.

3.3 Physical Habitat Assessments

Physical habitat (PHAB) assessments have often accompanied bioassessments to support BMI data, but the level of effort has changed over time. The EPA's Rapid Bioassessment Protocol (RBP), which has been used for decades (Plafkin *et al.* 1989), supports a qualitative assessment of several physical habitat characteristics based on visual observations. The RBP was implemented in California in various versions of the California Stream Bioassessment Procedures (CSBP) (Harrington 1999), which was predominantly evaluative (i.e., qualitative). In years 2004-2005 SWAMP implemented an interim protocol with a medium level of effort as a transition from the CSBP to EPA's rigorous Environmental Monitoring and Assessment Program (EMAP) protocol, and in 2007 the official SWAMP physical habitat assessments protocol was introduced (Ode *et al.* 2007). Assessment of algal cover characteristics was added in 2008. The current SWAMP protocols for BMI and algae sampling and for PHAB assessment involve measurements of multiple characteristics and can be implemented at two major levels of effort (Basic or Full); Region 2 crews performed the full protocol with some exceptions. The full suite of endpoints (including metrics, summary statistics, and indices) for years 2008-2010 PHAB assessments is shown in Appendix D.

The assessment of human influence is done by noting human-related features in the channel and on the banks around each transect, and calculating a proximity-weighed index for the entire reach for each disturbance feature. Indices from all features are then added up to form the Combined Human Disturbance Index (CHDI) for the assessment reach (see calculation information in Appendix D). Reference Study sites were intentionally selected in areas thought to be least disturbed, and indeed the human influence, as exerted by structures such as roads, hydromodifications, riparian vegetation removal, and various land use activities, is very minimal in those sites. **Figure 3.3-1** shows a summary “box and whiskers” plot of the CHDI values for all 2008-2010 Reference sites assessments, and compares it to the plot obtained for SWAMP’s Yrs 4&5 assessment data. The distribution of CHDI values ranges between zero and 1.87 in the reference sites, with 15 of the 18 values below 0.38 and the three higher values due to pipes and roads in Richie Creek (Appendix D). CHDI values in Yrs 4&5 sites, which represented a mixture of urban and non-urban sites, ranged between zero and 4.53 (SFBRWQCB 2008) with a median of 1.4, considerably higher than the median of 0.2 observed in the reference sites.

PHAB assessments included a variety of other observations and measurements. The PHAB Endpoints calculated for the six reference reaches (Appendix D) all indicate a high-quality aquatic environment, with intact riparian canopy, good mix of habitat types, ample shelter elements for fish, and minimally-embedded streambed substrate. However, three (RDW080, PES162, RIC100) of the six sites did not meet the criteria currently proposed for reference sites as part of state-wide Biological Objectives (http://www.swrcb.ca.gov/plans_policies/biological_objective.shtml). In most of these cases, road density > 1.5 km/km^2 was the excluding criteria. These state-wide reference criteria were more stringent than the reference criteria used for development of previous IBIs or for the reference sites in the BAMBI study (Ode *et al.* 2005, Rehn *et al.* 2005, Lunde 2011).

3.4 Benthic Algae Biomass and Chlorophyll *a*

Algae growing in lotic (flowing) aquatic systems must be attached to the stream substrate in order to remain in place when flow energy is high, and the most common algal taxa are present as filaments attached to substrate particles or as biofilms adhering to particles in microlayers. Both of these forms are referred to as “benthic algae” and the estimation of their biomass is of utmost importance for understanding the processes of primary production and nutrient cycling in streams. The 2008-2010 Reference Site Study implemented the SWAMP protocols to assess three aspects of benthic algae development:

(a) The substrate assessment, a.k.a. the “Pebble Count”, included five algal cover characteristics, reported either as presence/absence or as microlayer thickness;
(b) The habitat complexity assessment included estimates of filamentous algae cover as percentage of a given area; and
(c) The benthic algae sampling and analysis included measuring the concentrations of chlorophyll *a* and organic matter on substrate particles.

Sample collection involved scraping the benthos from a known area of the streambed substrate to form a slurry, along with the wash-water, of a known volume. Benthic particles (=algae and detritus) were then separated on glass fiber filters by filtration of aliquots of known volumes of the slurry; chlorophyll *a* was determined by extraction of pigments from one loaded filter. Ash-free dry mass (AFDM), which represents all organic matter (living organisms plus organic debris), was determined by weight difference before and after incineration of the other loaded filter. (Note: aliquots of the same sample slurries were preserved and used for taxonomic analyses of benthic diatoms and soft algae assemblages described in Section 3.2 above).

Figure 3.4-1 shows the relationship between two algal biomass indicators – chlorophyll *a* and AFDM (organic matter) – in reference sites. The chlorophyll *a*:AFDM ratio is expected to be approximately 2.5 according to the Nutrient Numeric Endpoints (NNE) model (Tetra Tech 2006) and the average ratio was 3.1 in this dataset. The correlation is relatively weak, probably due to the difference between what each characteristic represents: chlorophyll *a* is found only within living algal cells, while AFDM can include other forms of organic matter as well (e.g., decaying animals and plant detritus). The amount of AFDM from sources other than living algae (i.e., allocthonous organic material), is variable depending on flow energy, seasonal inputs, and degradation rates among other factors. Thus, chlorophyll *a* provides a better representation of the current photosynthetic potential in a streambed.

The relationship between chlorophyll *a* concentrations and other characteristics (e.g., Total nitrogen or phosphorus, Total Kjeldahl nitrogen, % algae-covered pebbles, and others) as examined in plots similar to Figure 3.4-1 did not reveal any significant correlations. This result may have occurred because algae levels in this study were limited to the low end of the spectrum due to being in reference condition**.** There was only one outlier of 169 mg/m^2, detected in the June 11, 2009 sample from IND200, which is within the NNE BURC III presumed impairment class > 150 mg/m^2 for coldwater salmonid streams (Appendix E).

Table 3.4-1 shows the benthic chlorophyll *a* averages and standard deviations for the six reference sites, broken down by site and by season and grouped by stream type. Algae biomass levels appear low in the spring season in both perennial and non-perennial streams. Non-perennial streams reach peak biomass in summer, which is earlier than perennial streams. Rapid growth in diatoms and filamentous algae can result from decreasing flow and increasing temperatures (Tetra Tech 2006).

Temporal variation in chlorophyll *a* concentrations at each site were very large and often showed no consistent trends (Appendix E), probably due to natural factors (e.g., patchiness and variety of substrate types) in combination with sampling and measurement error. Other measures of algal development, such as the extent of filamentous algae cover, revealed a more consistent seasonal trend, particularly when the assessment was done at the same fixed plots over time.

Figure 3.4-2 shows changes in filamentous algae cover in the habitat complexity plots assessed at each transect in Redwood Creek during the 2008 and 2009 seasons. Each group of bars shows the four observations (2008, panel a) or three observations (2009, panel b) done at a given transect plot over the season; the same plots were assessed in both years but there was no October visit in 2009. Cover of filamentous algae increased markedly through the summer of 2008 in some transects but not in others. Transect plots that were not covered with filamentous algae in 2008 were also not covered in 2009. There was no obvious relation between algal cover in each transect-plot and the extent of shade and canopy above it.

It must be noted that the extensive cover seen in some transects in Redwood Creek (and in many transects in the other reference streams [not shown],) indicates a considerable standing crop of primary producers, a situation equivalent to algal blooms in ponds or lakes. In low-flow or drying streams these blooms can lead to extreme pH and dissolved oxygen conditions associated with rigorous photosynthesis (when alive) or with mass mortality, oxygen depletion, odors, and other “nuisance” situations (Tetra Tech 2006, literature summary), but such occurrences were not observed at reference sites.

3.5 Nutrients

Water samples for analyses of selected nutrients were collected 1-2 times a year in non-perennial reference sites and 1-5 times a year in perennial sites, concomitantly with every benthic algae sample if collected. All results are shown in Appendix E, with comparisons to the EPA Nutrient ecoregion III, Omernik ecoregion 6 benchmarks (U.S. EPA 2000); these benchmarks represent the 25th percentile of concentrations measured in reference streams in these ecoregions. Although some analytical methods evolved over the span of the study, the total nitrogen and total phosphorous concentrations could be calculated from any of the analyte configurations.

Figure 3.5-1 shows the concentrations of total nitrogen (N) and total phosphorus (P) in 2008-2010 samples collected at non-perennial (a) and perennial (b) reference sites. The number of samples collected in **non-perennial** streams (14, panel a) was limited due to cessation of flow in May or June. Total P concentrations in non-perennial streams were in the range of ‘not detected’ (<0.005) to 0.04 mg/L (Table 3.7-1 below), and 7.1% of the samples exceeded the EPA 25th percentile reference benchmark of 0.03 mg/L (Figure 3.5-1a and Appendix E-1). Total N concentrations in these streams ranged between ‘not detected’ (<0.05) and 0.7 mg/L, and 7.1% of the samples exceeded the EPA benchmark of 0.518 mg/L (Figure 3.5-1a and Appendix E).

Sampling for nutrients in **perennial** streams spanned the entire seasons of 2008 and 2009, with 5 samples per year collected between late April and mid-December (Figure 3.5-1b). There were fluctuations in total N and total P concentrations with no seasonal pattern; however, decreasing concentrations of N over the season were observed in Redwood and Ritchie Creeks in 2008. There were no similarities between years, no consistent relationships between sites, and no sites with consistently high concentrations. A total of 27 out of 33 perennial stream samples (81.8%) exceeded the EPA benchmark of 0.03 mg/L for total P, but only 1 of 33 samples (3%) exceeded the EPA benchmark of 0.518 mg/L for total N (Figure 3.5-1b and Appendix E).

Nutrient data show severe nitrogen limitation in both perennial and non-perennial reference streams and nutrients levels differ based on hydrology. Of the 46 samples with total nitrogen (TN) and total phosphorus (TP) data, 45 were nitrogen-limited according to the Redfield Ratio. The Redfield Ratio (RR) is the molar ratio of nitrogen to phosphorous; a ratio of < 17 is N-limited and a ratio of > 17 is P-limited. The mean RR for all data points was 2.5 (range 0.03 to 21.4). The non-perennial streams were generally less N-limited (RR=6.8) than the perennial streams (RR=1.2) (Table 3.7-1). However, the clear trend for N-limitation suggests that reference Bay Area streams have high P levels which appear to be natural (i.e. background). Perennial reference streams had 4.5 times higher TP levels (0.09 mg/L) than non-perennial reference streams (0.02 mg/L), which indicates that nutrient levels may be affected by stream hydrology.

Water samples from the two urban gradient creeks had a mean TP of 0.09 mg/L (not shown), which is considered low for urban streams. The SWAMP Yrs 4&5 sites had a mean TP of 0.10 mg/L (Table 3.7-1), with concentrations that ranged between 0.03 mg/L in the pristine creeks of

West Marin County and 0.41 mg/L in the densely urbanized creeks of the East Bay (SFBRWQCB 2008). The mean TP values from Years 4&5 data are only slightly higher than at reference sites, but the maximum values are two times higher. In contrast, TN levels were ten fold higher in the Yrs 4&5 data compared to the reference streams, which indicates that nitrogen addition may be occurring in many non-reference watersheds. More extensive nutrient data from reference streams and streams specifically impacted by urbanization and agriculture are needed to confirm these initial trends and to explain the difference between perennial and non-perennial streams.

3.6 Time-Series Field Measurements

Region 2 crews used six data-logging sondes (model YSI 6600) for unattended time-series (continuous) monitoring of dissolved oxygen, specific conductance, pH, temperature, and turbidity. The instruments were deployed numerous times during the base flow seasons of 2008, 2009, and 2010 for variable durations, yielding datasets of about 1,000 to 13,000 data points (Appendix F). The logged data files were processed to yield a variety of endpoints and summary statistics.

Figure 3.6-1 shows plots of daily minima and maxima in dissolved oxygen (DO) concentrations over time. Data from 2009 and 2010 were aligned by date; 2008 data (not shown) were very similar to 2009 data. The vertical distance between lines of identical color/shape represents the daily amplitude. In 2009, DO levels at Indian Creek decreased during late June while the daily amplitude increased dramatically. The field crew observed a significant decrease in flow (noted on 6/29/09 field sheets) that coincided with the sudden drop in DO concentrations. Within two weeks of that visit, the majority of flow had dried up or moved underground and the creek contained surface water only in isolated pools. On the other hand, the 2010 rain year provided for prolonged flow period and more stable DO concentrations at least until early August. The DO conditions in the other two non-perennial streams were essentially similar.

In all three perennial reference streams, DO remained fairly consistent throughout and between years, as shown for Pescadero Creek (Figure 3.6-1), except for several DO excursions below 7 mg/L in Redwood Creek (not shown).

The summary statistics for all water quality characteristics (median, 25th and 75th percentiles, minimum, and maximum) were calculated for each deployment and are shown in Appendix F tables, along with exceedances of a variety of water quality benchmarks (Methods Table 2.5-1). The summary statistics were also used to generate a “box and whisker” plot that shows the data distribution for each dataset. In some cases, the amplitude of daily fluctuation in values can be gleaned from these box plots.

Figure 3.6-2 shows the box plot **s**ummaries of time-series field measurements of temperature, dissolved oxygen, and pH in reference sites in 2008-2010. Data from the three non-perennial reference sites (panel a) indicate some annual differences (e.g., dissolved oxygen median in Mitchell Canyon was lowest in 2008) and some differences between streams (e.g., temperatures appear to be slightly elevated in Coyote Creek). DO benchmarks were not met very often in

Mitchell Canyon (most values were lower than 7 mg/L), but there were very few DO excursions below 7 mg/L in the other two non-perennial streams. There were few exceedances of temperature and pH benchmarks set for individual measurements among non-perennial streams (Figure 3.6-2a).

The overall variability in temperature, dissolved oxygen, and pH values was much lower in perennial streams (Figure 3.6-2b). This could be due to the stable flows which minimized the daily fluctuations. **The difference between streams was generally more pronounced than the inter-annual differences within each site**. Of all characteristics measured in perennial streams, there were exceedances only of the high-pH benchmark, in Pescadero Creek.

The water quality benchmarks shown in Figure 3.6-2 above are suitable for comparison with individual measurement results, i.e., instantaneous conditions. However, some of the water quality benchmarks for protection of aquatic life have been developed for comparison with calculated endpoints (e.g., daily or weekly averages) that reflect a general tendency rather than short-lived peaks or troughs. This is based on the assumption that exceedance of 'protective' values for a short time does less damage than sustained exposure to these values. The endpoint-based benchmarks applicable to temperature and dissolved oxygen are shown in Methods Table 2.5-1 above.

Figure 3.6-3 shows the box-plots of **7-day means** calculated from time-series field measurements of temperature and dissolved oxygen measured in reference sites in 2008-2010, in conjunction with four water-quality benchmarks. The first panel (Figure 3.6.-3a) shows the box plots obtained for **non-perennial** streams. All the 7-day means of temperature values at Coyote Creek exceeded the maximum 7-day mean temperature for Coho (14.8^{o}C); more than 50% of these mean values exceeded that benchmark in Indian Creek; and in Mitchell Canyon these values exceeded the benchmark in 2010 but not in 2009. The other temperature benchmark – maximum 7-day mean for Steelhead (17.0^{o}C) – was exceeded by most 7-day mean values in Coyote Creek, but there were very few exceedances in Indian Creek and no exceedances in Mitchell Canyon. The dissolved oxygen box plots show a somewhat different pattern: there were no drops below 7 mg/L (the minimum 7-day mean for cold freshwater habitat) in Coyote Creek and very few drops in Indian Creek, while in Mitchell Canyon most of the 7-day mean values did not meet this benchmark, i.e., dropped below 7 mg/L. In fact, all 7-day means in Mitchell Canyon dropped below 5 mg/L (the minimum 7-day mean for warm freshwater habitat) in 2008, as did many in subsequent years.

As shown above for individual measurements (Figure 3.6-2), temperature and dissolved oxygen 7-day means in **perennial** streams were less variable than in non-perennial streams, and the exceedances of water quality benchmarks were fewer and less severe (Figure 3.6-3b). There were only a few dissolved oxygen exceedances of the cold freshwater habitat benchmark of 7 mg/L and no drops below 5 mg/L. Temperatures in Redwood Creek were always adequate for Coho and Steelhead (i.e., the majority of 7-day means did not exceed 14.8^{o}C). In Pescadero and Ritchie Creeks, less than 50% of the 7-day means exceeded the steelhead benchmark of 17.0^{o}C in 2009 and 2010, but the median values of 7-day mean temperature exceeded the steelhead benchmark in 2008 in both of these streams. .

Region 2 crews also used a collection of data logging temperature sensors, called HoboTemps or HOBOs. These could be deployed for longer durations than the sondes, as they do not require frequent calibration adjustments, and they could be deployed in groups to track vertical and longitudinal temperature gradients. The temperature datasets generated from HoboTemp deployments were reported in Appendix F. Selected datasets are also presented in the box plot format as described above.

Figure 3.6-4 shows the box plot summaries of time-series field measurements of temperature along a vertical and a longitudinal gradient in 2008 and 2009. The datasets used for these box plots represent the same time period, i.e., the same interval of calendar dates, for each panel. Vertical gradients will develop if a pool is thermally stratified during summer, and this will be reflected in different values at different depths. The magnitude of daily fluctuations in temperature may also be different at different depths, and indeed this appears to have been the case in both years; surface temperatures show wider variability (Figure 3.6-4a). However, the figure shows very similar median values at the three depths in 2008, and very similar values for 2009. There was a difference between years: the last two weeks of July 2009 were warmer then the same time period in 2008.

HoboTemps deployed along a longitudinal gradient for 10 weeks over late summer collected similar temperature data at the three locations, during both years (Figure 3.6-4b). Here too, the median values were very similar for all three locations, but the magnitude of daily amplitude values was variable. There were a number of exceedances of the Salmonid lethal limit of 24^{o}C over these periods, both at Coyote Creek and Indian Creek.

3.7 Relationships between Indicators

<u>Selected Indicators Summary</u>

Table 3.7-1 shows a summary comparison of non-perennial and perennial reference sites as reflected in a variety of indicators spanning physical habitat, algae, water chemistry, and stress factors. Data from the three non-perennial reference sites collected during all visits was averaged and compared to averages calculated for the three perennial reference sites; the mean and (range) are shown for each stream type. Averaged values from Years 4&5 samples, collected at a mixture of 41 urban and non-urban sites, was added to Table 3.7-1 as a third column where available.

The differences between perennial and non-perennial streams are most pronounced in macroalgae cover, with non-perennial streams averaging 23% and perennial streams only 10%. However, the benthic algal biomass expressed in chlorophyll *a* concentrations was higher in perennial streams. BMI IBIs were higher in perennial streams.

A number of differences between reference sites and non-reference sites are also evident in Table 3.7-1: reference sites had generally lower proportions of fine sediments, more natural shelter elements, and less channel alterations than non-reference sites.

Human disturbance and BMI Taxa

Figure 3.7-1 shows the relationship between the extent of human disturbance (as reflected in the Combined Human Disturbance Index – CHDI) and selected BMI taxa. Data from the Reference Site Study, shown in filled (blue) dots, are clustered in the lower CHDI values range, with the exception of two points; these correspond to the Richie Creek assessments and are due to presence of an old pipe along the reach. Data from years 4&5 assessments, shown in filled (orange) triangles, span the entire range of CHDI values. The percentage of oligochaetes, one of the most tolerant taxa, can be considerably high even in highly disturbed sites (top panels). On the other hand, the number of individuals from the sensitive EPT taxa shows a marked decline in more disturbed sites. In other words, sensitive taxa are not found in highly disturbed streams.

Table 3.4-1: Benthic chlorophyll *a* concentrations (mg/m^2) at six reference sites monitored between 2008 and 2010

	Spring (April-May)	Summer (June-July)	Late Summer (August-Sept.)
COY610	20 ±3	36 ±2	
IND200	16 ±21	94 ±**106**	
MTD117	5 ±1	9 ±n/a	
Non-perennial average	**14 ±14**	**54 ±66**	
PES162	11 ±2	23 ±17	40 ±13
RDW080	17 ±14	21 ±14	41 ±41
RIC100	49 ±31	53 ±4	73 ±39
Perennial average	**26 ±24**	**32 ±19**	**51 ±31**
Reference sites average	**19 ±19**	**40 ±41**	**51 ±31**

Notes: Each number represents the average and the standard deviation of several samples, usually 3 or more for perennial sites. The total number of samples analyzed in 2008-2010 was n=33.

Table 3.7-1: Descriptions of physical habitat, water chemistry, algae, invertebrates, and stress characteristics at reference and non-reference sites

	Non-perennial reference	Perennial reference	Yrs 4&5
Physical structure			
Hydroperiod (months)	9	12	
Slope of 150m or 250m reach (%)	2.4	1.4	
Mean depth (cm)	16.5	15.7	16.4
Flow (m^3/s, ft^3/s)	0.047, 1.7	0.044, 1.6	0.083, 2.9
Natural shelter cover (XFC_NAT)	43	59	29
% cover (densiometer readings)	64%	91%	
Median particle size: D50 (mm)	51	47	
% Cobble embeddedness *(Note 1)*	39	35	37
% (all) Sediment particles <16 mm	28	32	48
% Sand-Silt-Clay <2 mm	11	21	27
Epifaunal substrate score *(Note 2)*	17.4	17.8	12.5
Water chemistry			
pH	8.14 (7.7-8.4)	7.85 (7.2-8.4)	
Specific conductance (µS/cm)	448 (330-537)	385 (107-876)	
Total phosphorous (mg/L)	0.02 (ND-0.04)	0.09 (0.016-0.20)	0.10 (0.03-0.41)
Total nitrogen (mg/L)	0.18 (ND-0.7)	0.12 (ND-0.57)	1.7 (0.17-8.5)
Redfield Ratio (N:P molar ratio)	6.8 (0.8-21.4)	1.2 (0.03-8.3))	8.6 (1.8-61.8)
Algae and invertebrate data			
Chlorophyll *a* (mg/m^2)	28.5 (2-170)	35.8 (7-100)	
Ash-free dry mass (g/m^2)	10.0 (2-25)	12.1 (3-32)	
Microalgae average thickness (mm)*	0.18 (0.02-0.80)	0.20 (0.02-1.0)	
% Macroalgae cover	23 (0-64)	10 (0-26)	
Southern California IBI (invertebrates)	65 (24-84)	78 (64-93)	
North Coast IBI (invertebrates)	59 (28-88)	66 (54-82)	
Stress metrics			
Human disturbance index (W1_Hall)	0.09	0.6	1.85 (0–4.5)
% Stable banks	45	28	
Sediment deposition score *(Note 2)*	17.5	16	10.4
Channel alteration score *(Note 2)*	18.4	17.4	12.9

* Two outlier points were removed from the perennial streams dataset due to inability to identify the material on pebbles at Richie Creek

Note 1: Cobbles are defined as substrate particles larger that 64 mm and smaller than 250 mm.
Note 2: These evaluative metrics scored between 0 and 20, with 20 being the most optimal condition (i.e., high epifaunal substrate, low sediment deposition, and low channel alteration).

Table 3.7-1 Legend: Numbers shown represent the mean and the range, in parentheses, where relevant. Mean values were calculated from all available data in each category, with maximum numbers as follows: non-perennial (n=18), perennial (n=34), and Years 4&5 (n=59). However, in many cases fewer than this number of total data points were available because of dry stream conditions in non-perennial streams and because some physical habitat values were only recorded once a year instead of during each visit.

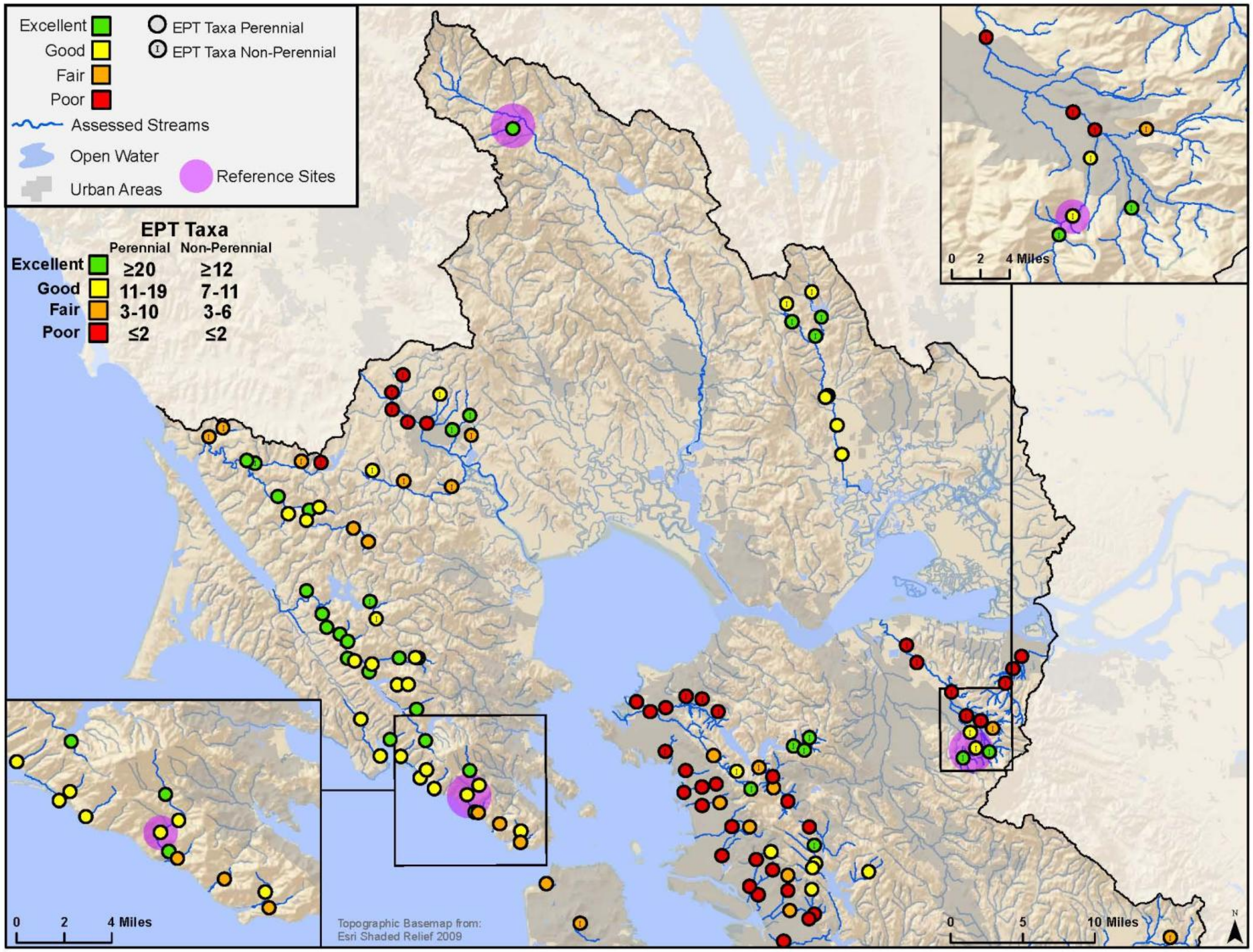


Figure 3.1-1a: BMI conditions in North Bay streams monitored by SWAMP

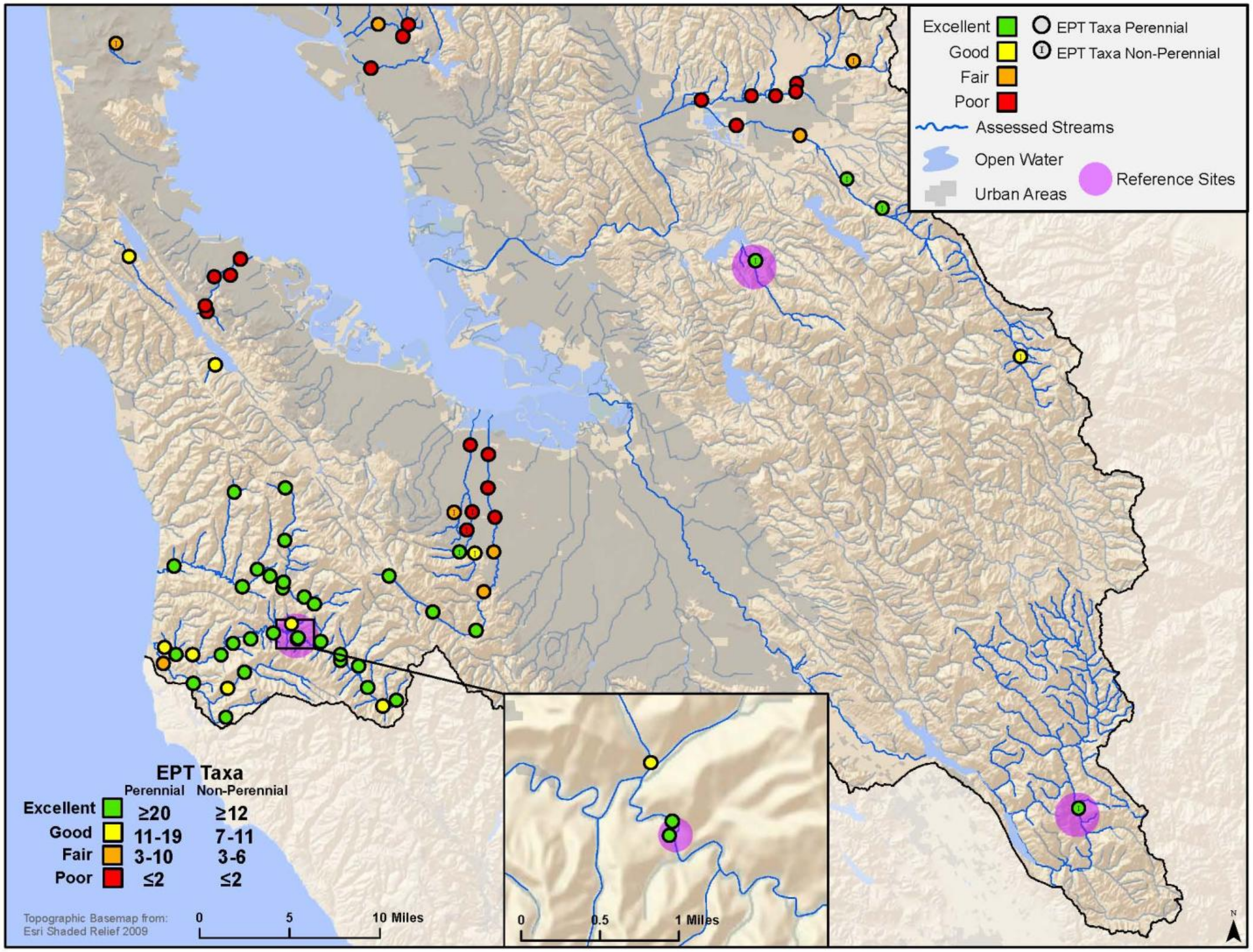


Figure 3.1-1b: BMI conditions in South Bay streams monitored by SWAMP

Figure 3.1-1 Legend:
The two maps show the conditions in 204 stream reaches SWAMP sampled between 2001 and 2010 in Region 2. Each point shows the location of a monitoring site as perennial or non-perennial. The point's color shows the result obtained for a selected indicator (number of EPT taxa) as one of four stream-health categories (Cover 2010). Sites monitored during 2001-2005 were selected based on rotating-basin design and each point represents the category derived from one sample result (n=1). The Reference Study sites monitored during 2008, 2009, and 2010 are highlighted in purple and their EPT taxa categories were derived from values that represent the average of three samples collected at each site, one for each year (n=3). The sites used in 2008-09 for the Urban Gradient study are not shown.

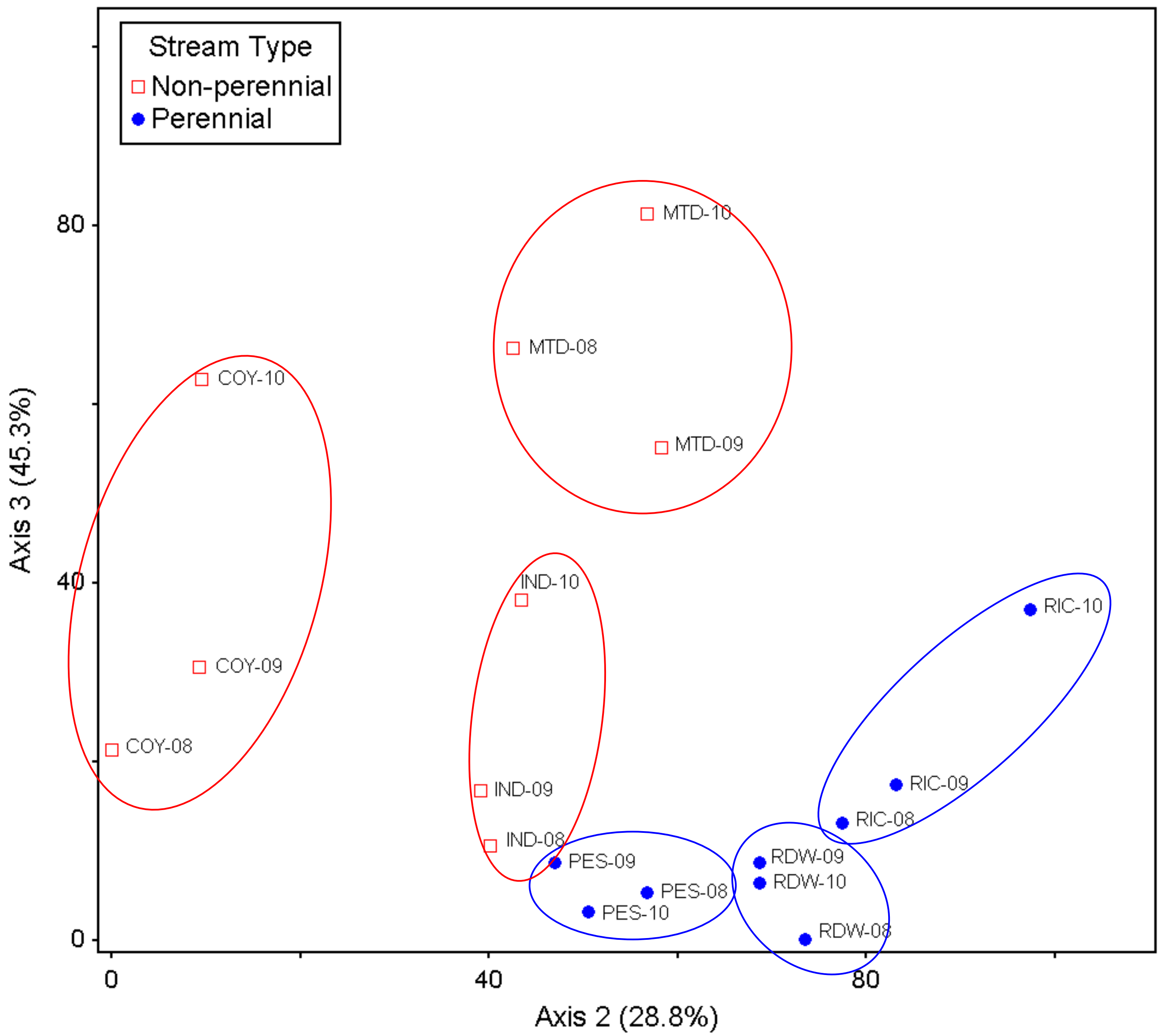


Figure 3.1-2: Non-metric multidimensional scaling (NMS) ordination of benthic macroinvertebrate assemblages at reference sites over three years

Legend: NMS ordination with a 3-axis solution (2 axes shown) (stress = 11.8, instability < 0.00001, total R^2 = 85.9%). This figure shows 3 non-perennial and 3 perennial reference sites with data collected annually from 2008-2010 (n=18). Percentages in axis labels indicated the percent of total variability represented by the axis. MRPP analysis confirmed that flow status was a significant environmental variable affecting the biological community (Sørenson distance measurement, *A* statistic = 0.27, $p < 0.00001$). Circles encompass all three sites from a given location across the three years.

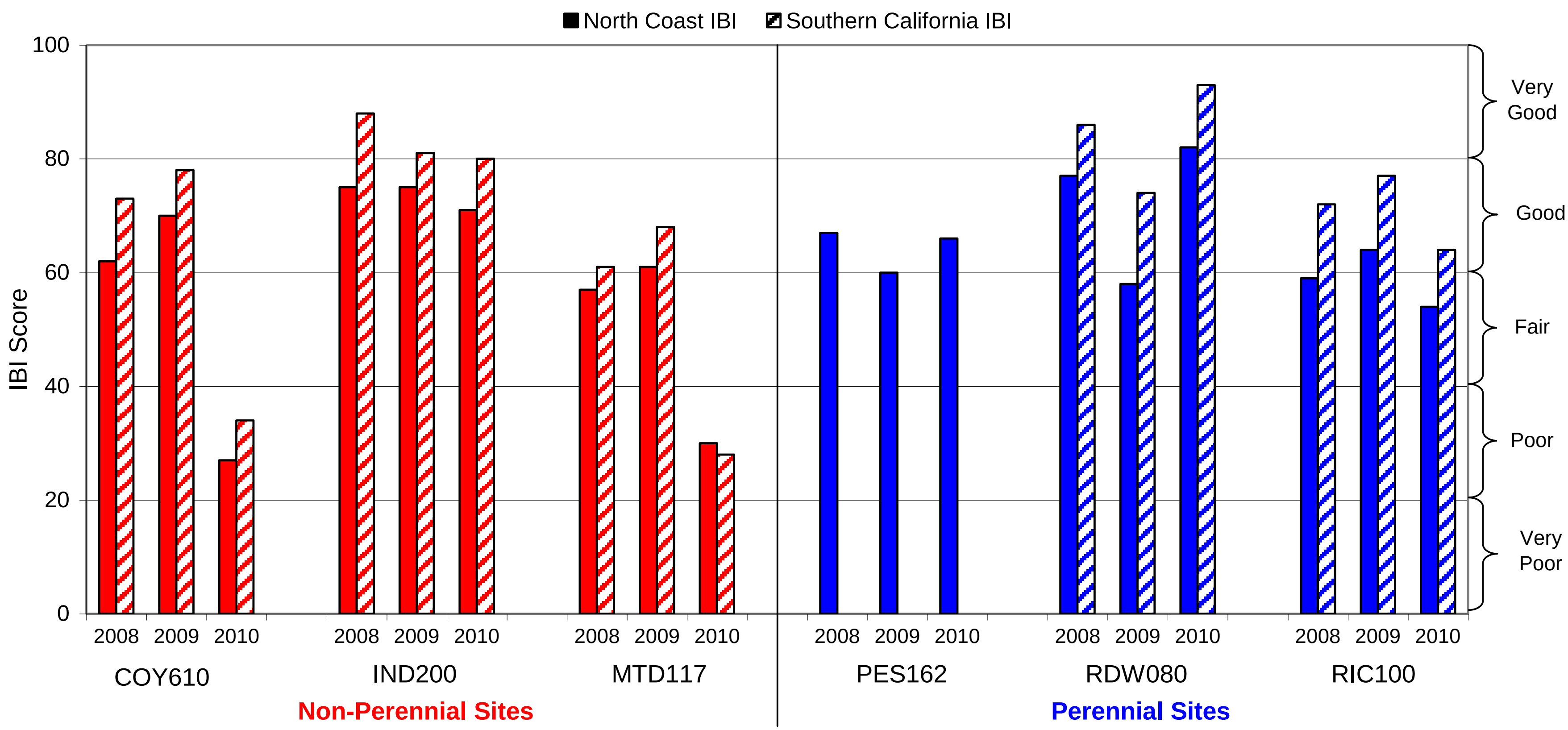


Figure 3.1-3: BMI index of biological integrity (IBI) scores for reference site data

Legend: Each bar represents the arithmetic mean of 20 calculation iterations. The Southern California IBI could not be calculated for PES162 because Pescadero Creek is not in the ecoregion for which the IBI was developed.

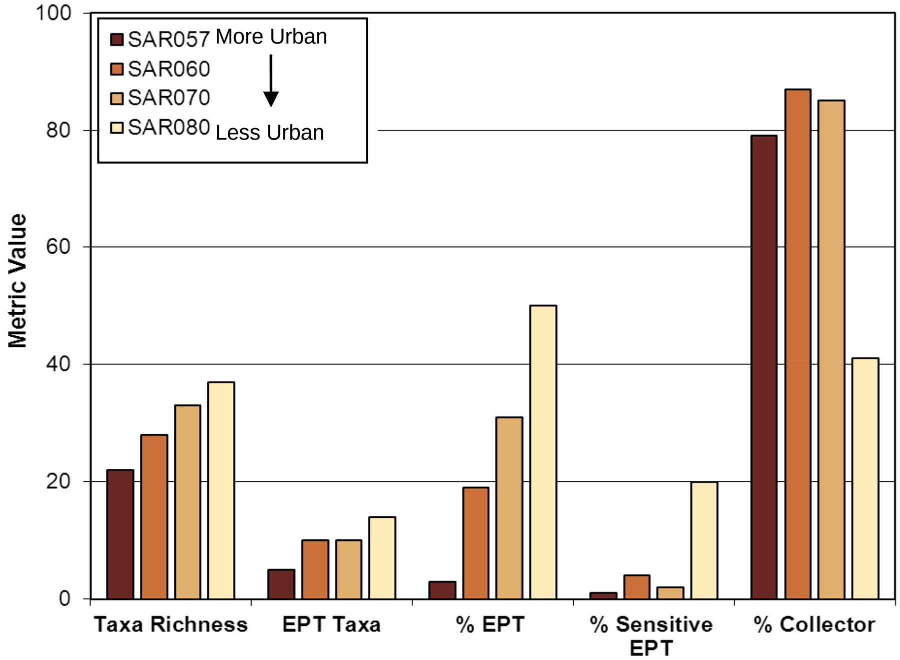


Figure 3.1-4a: Selected BMI metrics along the urban gradient from Saratoga Creek in 2008

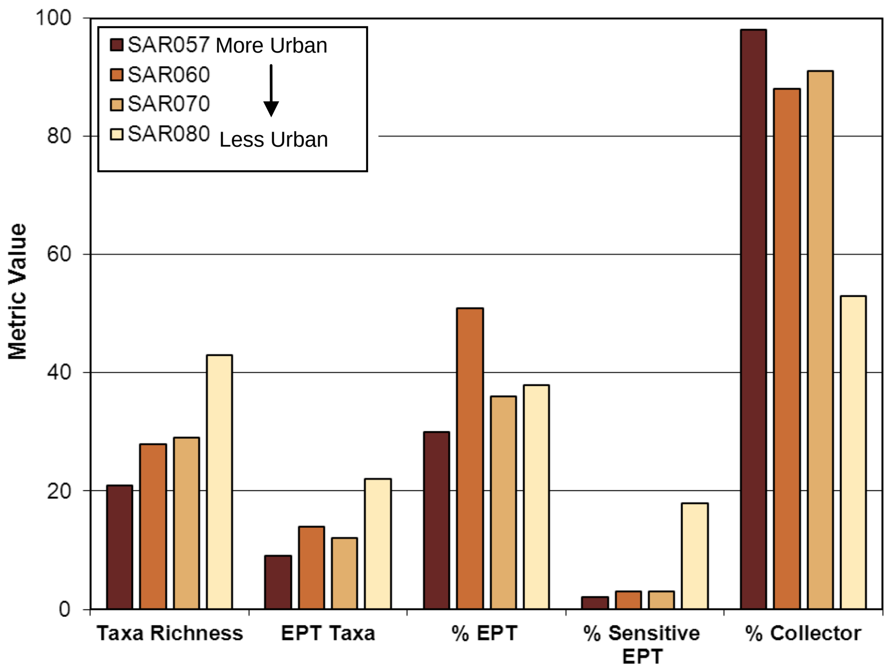


Figure 3.1-4b: Selected BMI metrics along the urban gradient from Saratoga Creek in 2009

Legend: Each bar represents one sample. Sites are organized in order of diminishing urban influence. For example, SAR057 is downstream in a more urbanized area and SAR080 is in a less urbanized area slightly upstream of the urban boundary.

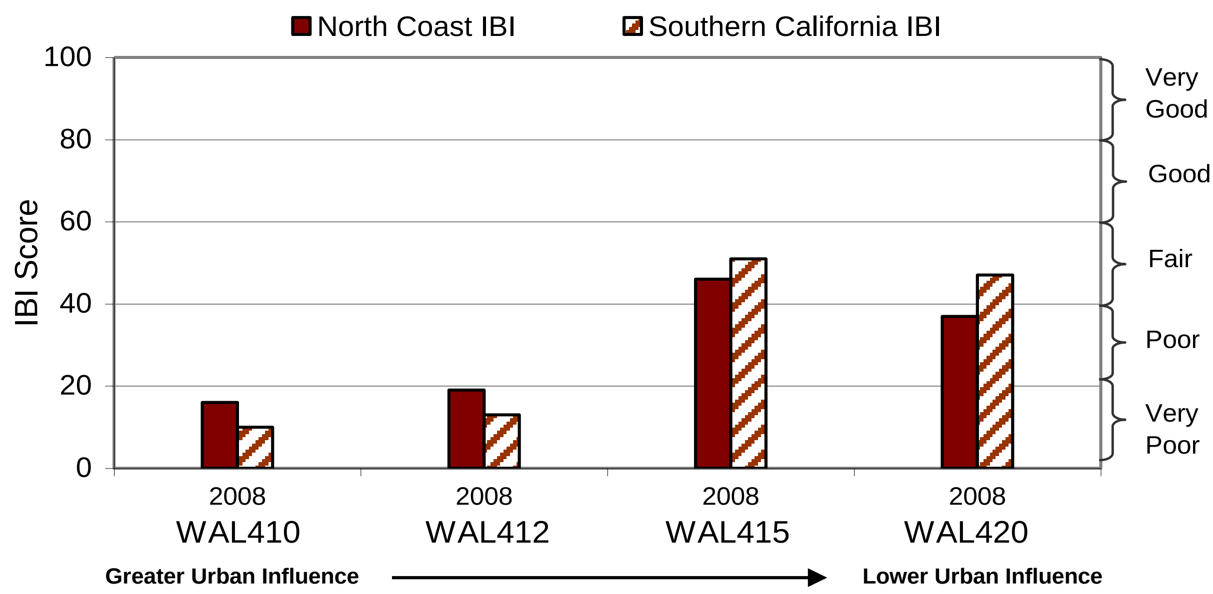


Figure 3.1-5a: **BMI index of biological integrity (IBI) scores for Las Trampas Creek, 2008**

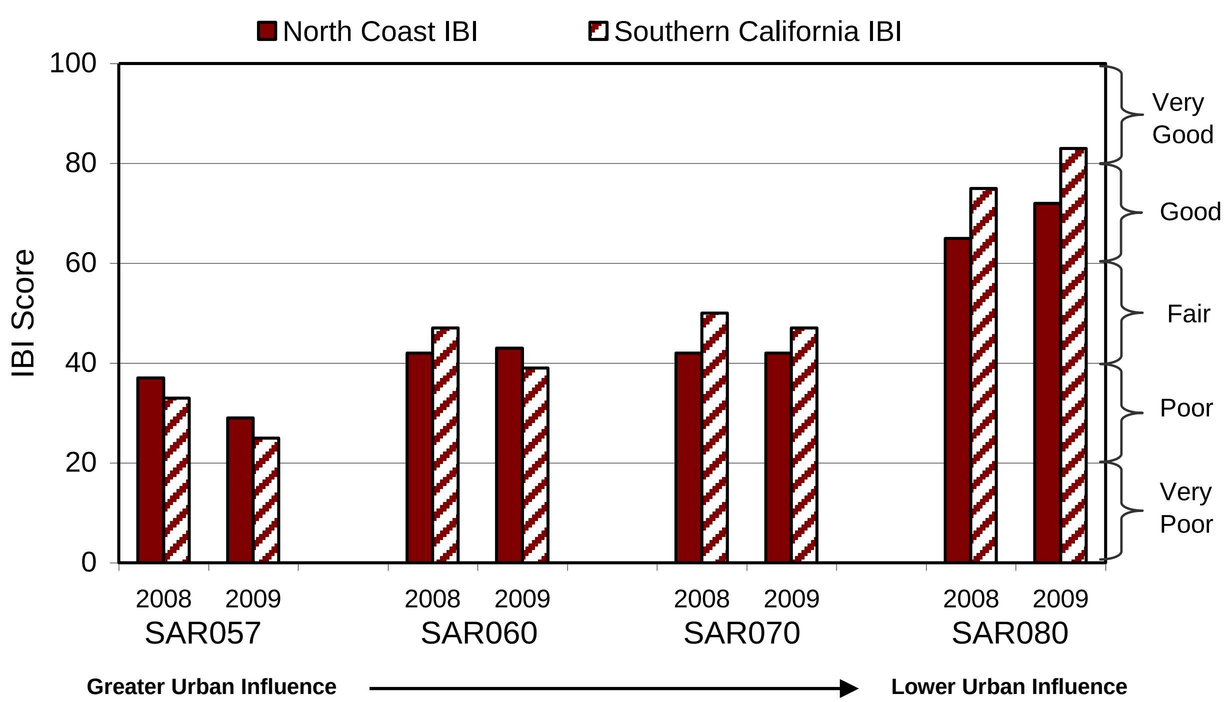


Figure 3.1-5b: **BMI index of biological integrity (IBI) scores for Saratoga Creek, 2008-2009**

Legend: Each bar represents the arithmetic mean of IBI scores from 20 rarification iterations.

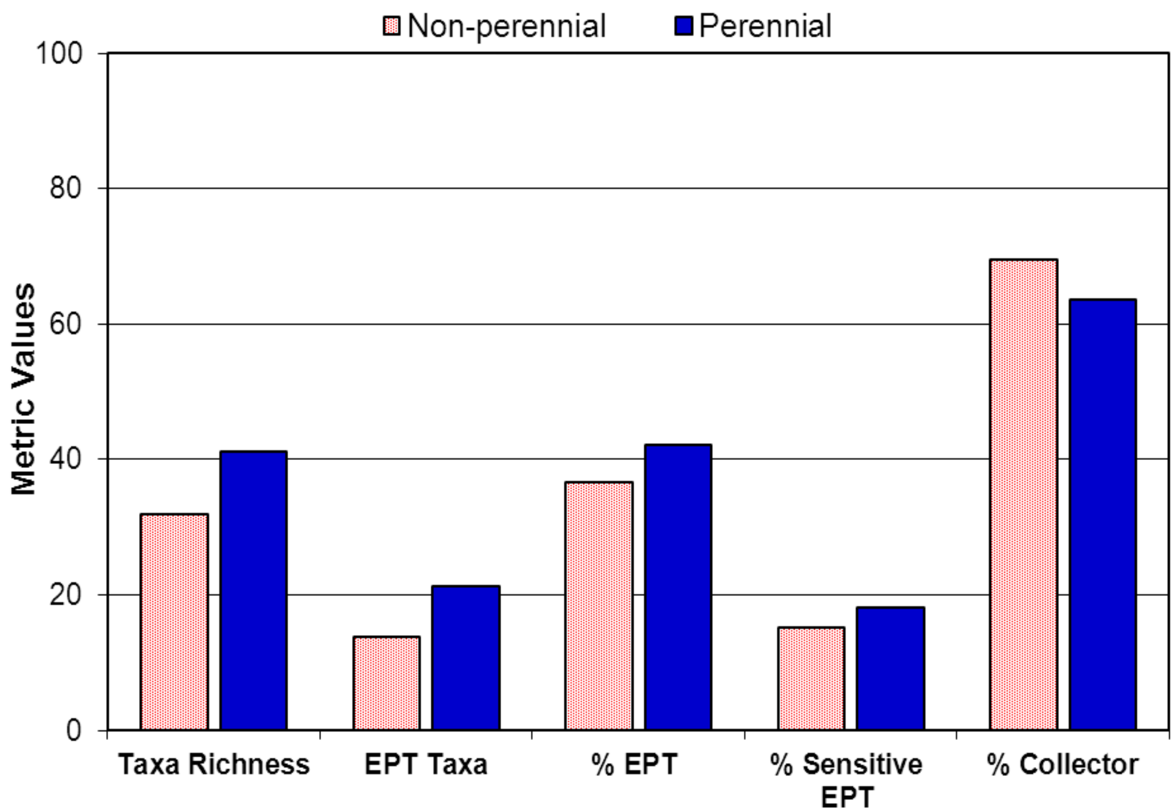


Figure 3.1-6: **Values of BMI metrics from 2008-2010 samples, averaged for each stream type**

Legend: The BMI metric values shown by each bar are arithmetic means of the 2008, 2009, and 2010 reference site data (n=18). The averages for each stream type, non-perennial (light red bars) or perennial (blue bars), were calculated from results of three annual samples per site for three sites (n=9). Taxa Richness and EPT Taxa metrics were calculated from the number of taxa identified, while the Percent EPT, Percent Sensitive EPT, and Percent Collector metrics were calculated from the number of individuals within these classes out of the 600 organisms identified.

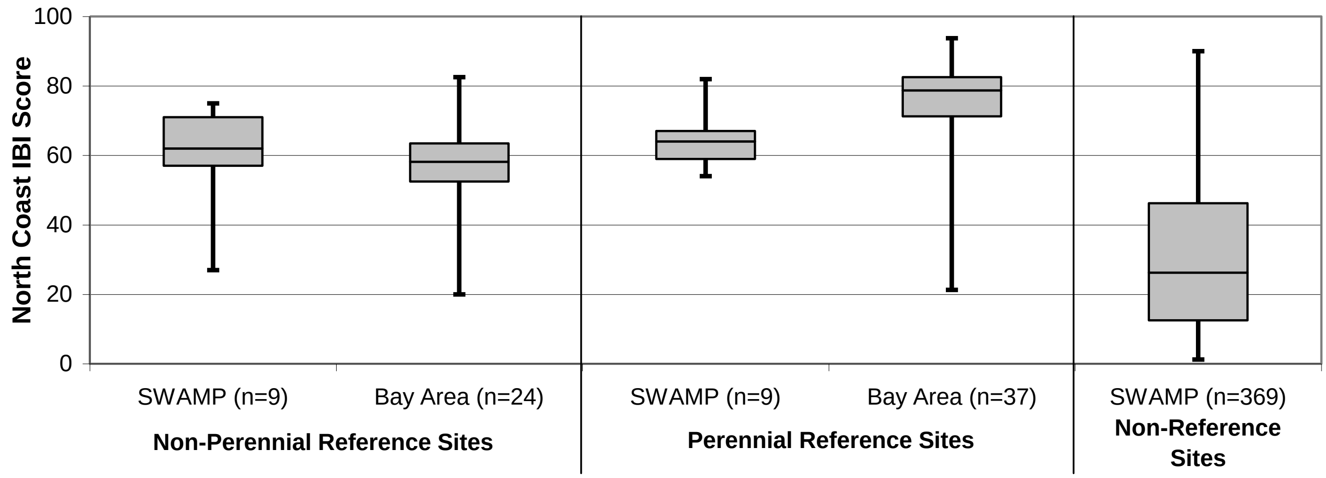


Figure 3.1-7: **Distribution of North Coast BMI index of biological integrity (IBI) scores in SWAMP and Bay Area non-perennial and perennial reference sites, and in SWAMP non-reference sites**

Legend: SWAMP BMI data were grouped into the perennial and non-perennial Reference Study sites (2008-2010, main panels) and non-reference sites (2000-2005, right panel). SWAMP data are compared to data from the general Bay Area (Region 2) reference sites selected by Lunde (2011). These sites were vetted as reference according to a GIS screen and local stressor identification process and represent general reference conditions in the Bay Area. The box-plot presentation for each dataset shows minimum, 25th percentile, median, 75th percentile and maximum values of that dataset.

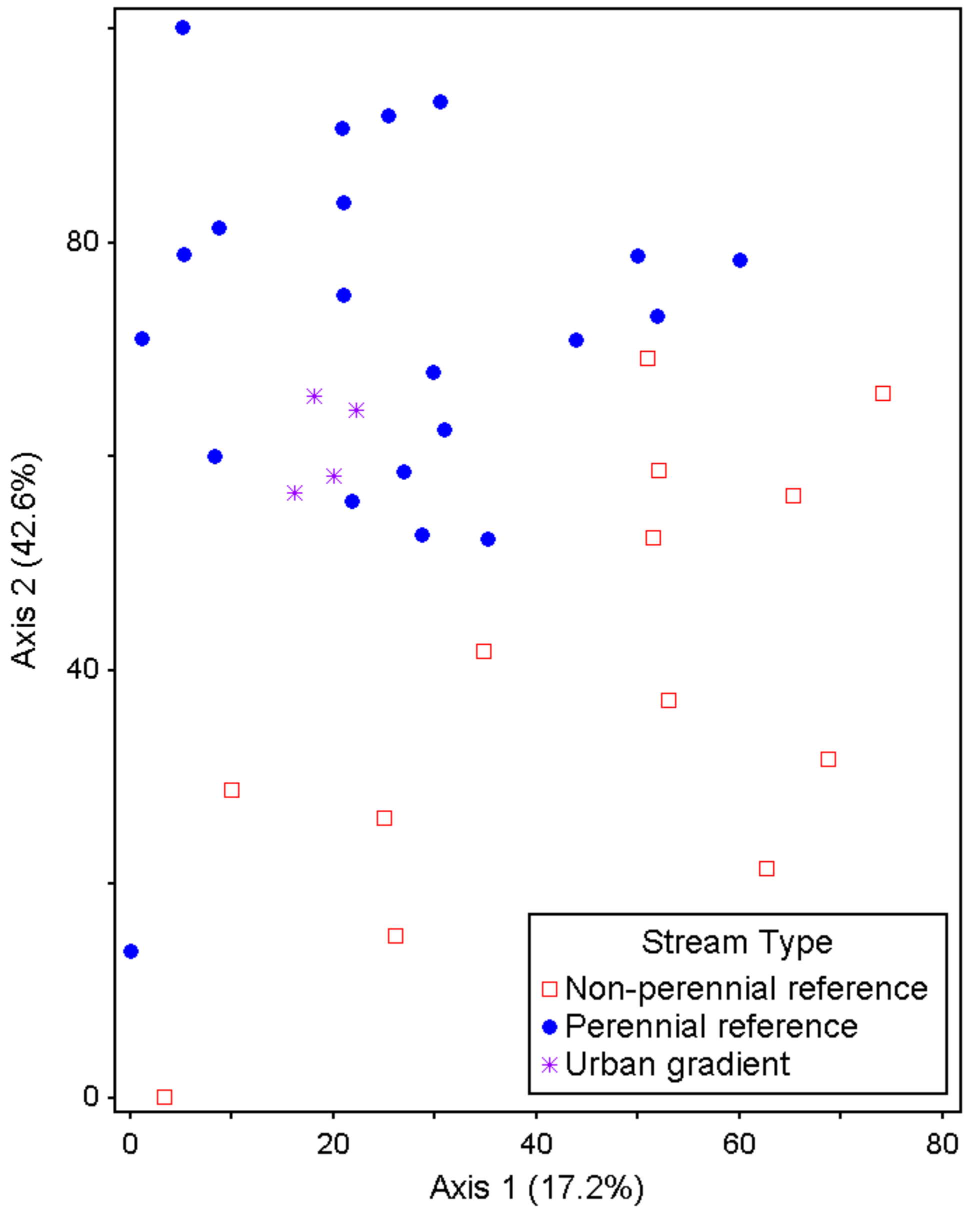


Figure 3.2-1: Nonmetric Multidimensional Scaling (NMS) ordination of diatom assemblages

Legend: The figure shows 3 non-perennial and 3 perennial reference sites with data collected annually for three years and up to three times per year (n=34). Additionally, the ordination shows 4 sites from a perennial urban stream (Urban Gradient Study sites). The most optimal ordination was a 3-axis solution (stress = 13.7, instability < 0.00001, coefficients of determination R^2 = 82.7%). Percentages in axis labels indicate the percent of total variability represented by the axis. MRPP analysis confirmed that hydrologic regime (perennial vs. non-perennial) was a significant environmental variable affecting the biological community (Sørenson distance measurement, *A* statistic = 0.11, $p < 0.003$).

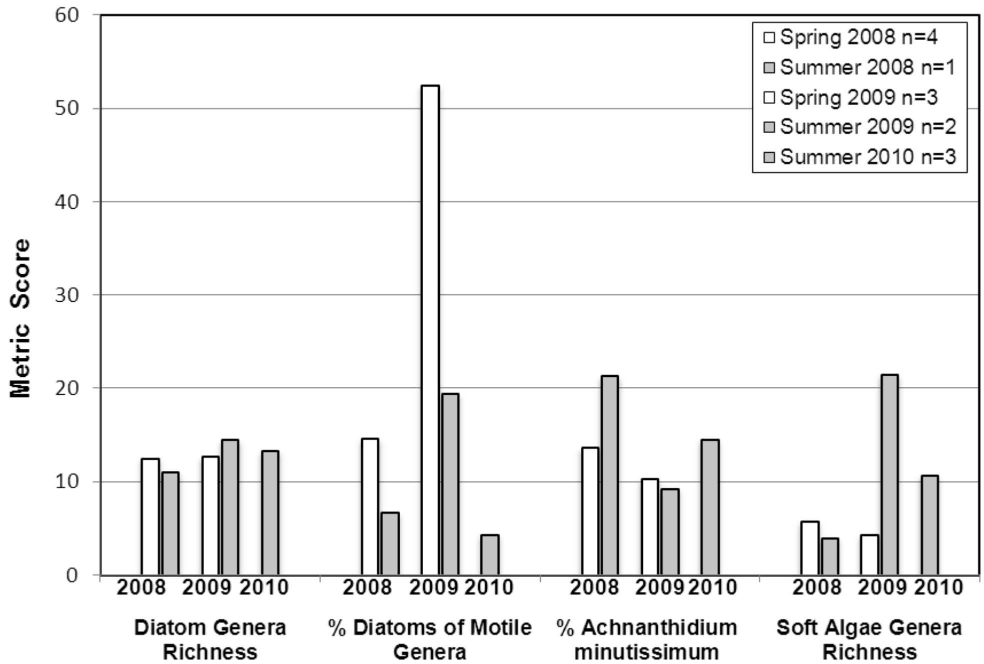


Figure 3.2-2a: Seasonal and annual variation in selected algal metrics at non-perennial reference sites

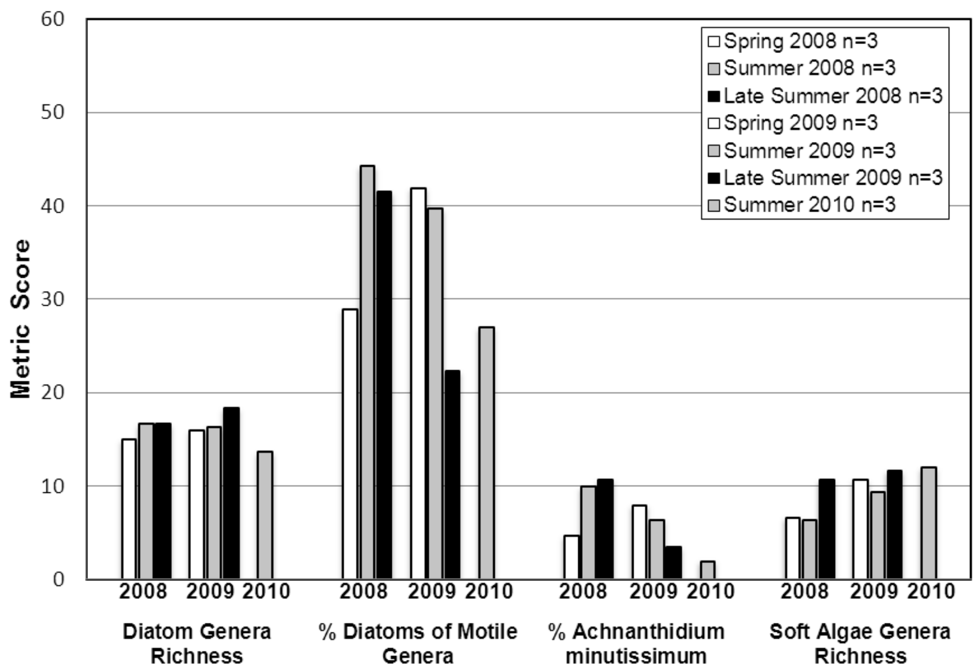


Figure 3.2-2b: Seasonal and annual variation in selected algal metrics at perennial reference sites

Legend: The bars represent the average metric value at sites in 2008, 2009, and 2010. The number of samples averaged is shown by n=x in the plot legend. In general, each bar represents an average of three samples. However, some non-perennial sites went dry resulting in one or two samples within a season, and at Indian Creek there was an extra sample taken three weeks after the first sample in May.

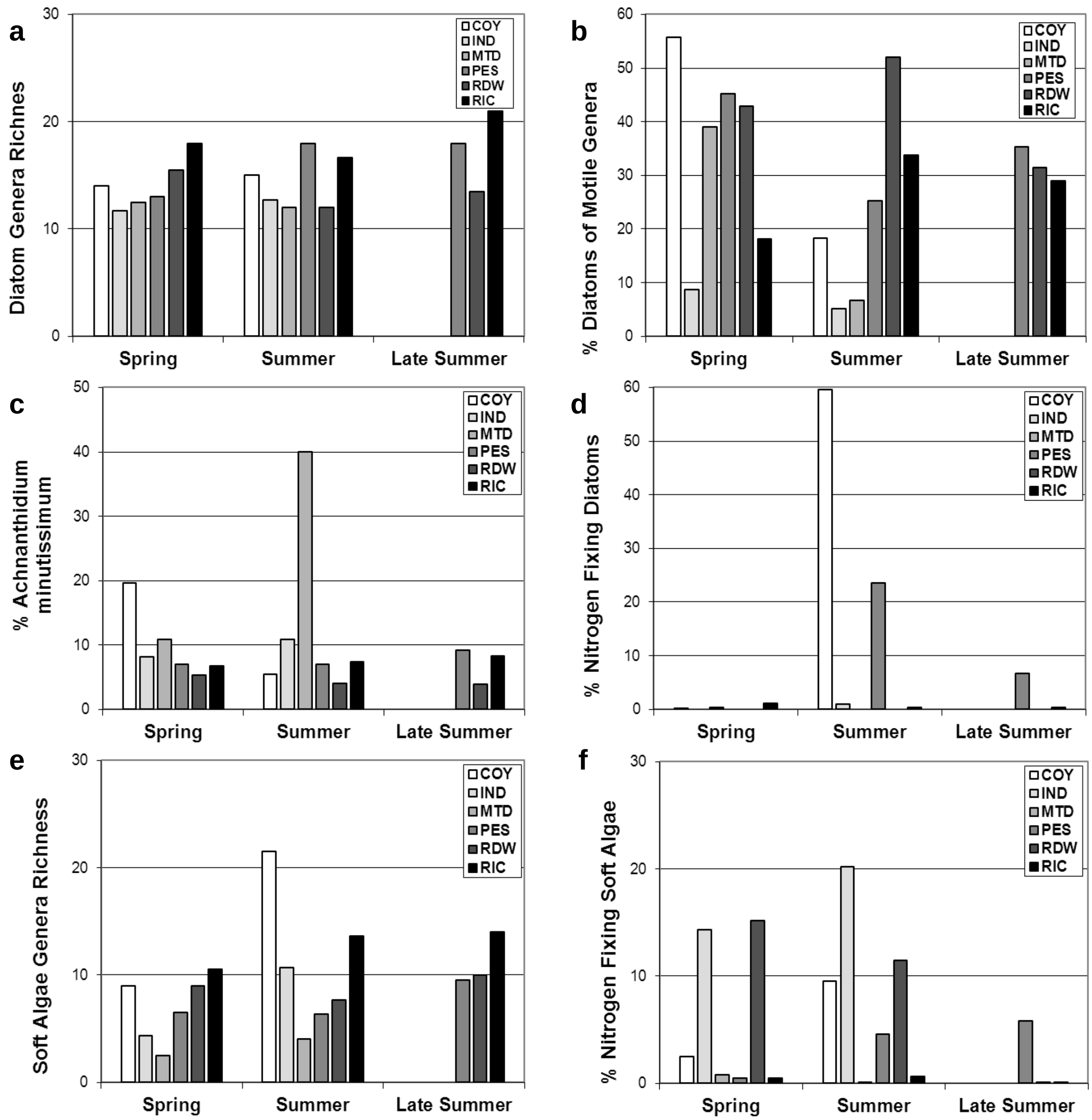


Figure 3.2-3a-f: Selected metrics at reference sites during spring, summer, and late summer sampling events

Legend**:** Each bar represents the average metric value of all 2008-2010 samples collected at that reference sites during the season shown: spring, summer, or late summer. The number of samples averaged for each bar varies for various sites and seasons (see Appendix C). The first three bars in each group (lighter shade) represent non-perennial streams, and the last three bars show results for perennial streams.

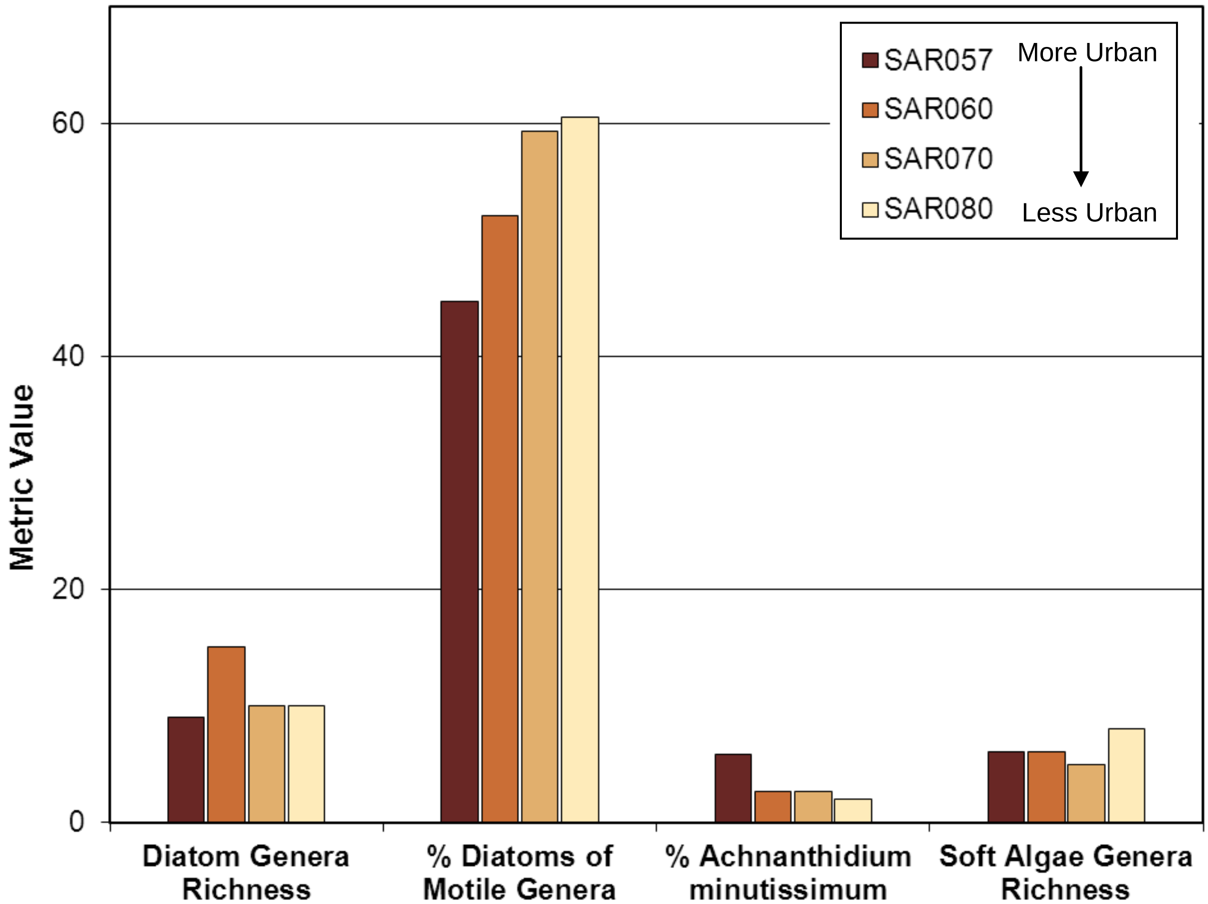


Figure 3.2-4: Selected algal metrics along Saratoga Creek in 2009

Legend: Each bar represents one sample. Sites are organized in order of diminishing urban influence: SAR057 downstream in a more urbanized area, and SAR080 in a less urbanized area slightly upstream of the urban boundary.

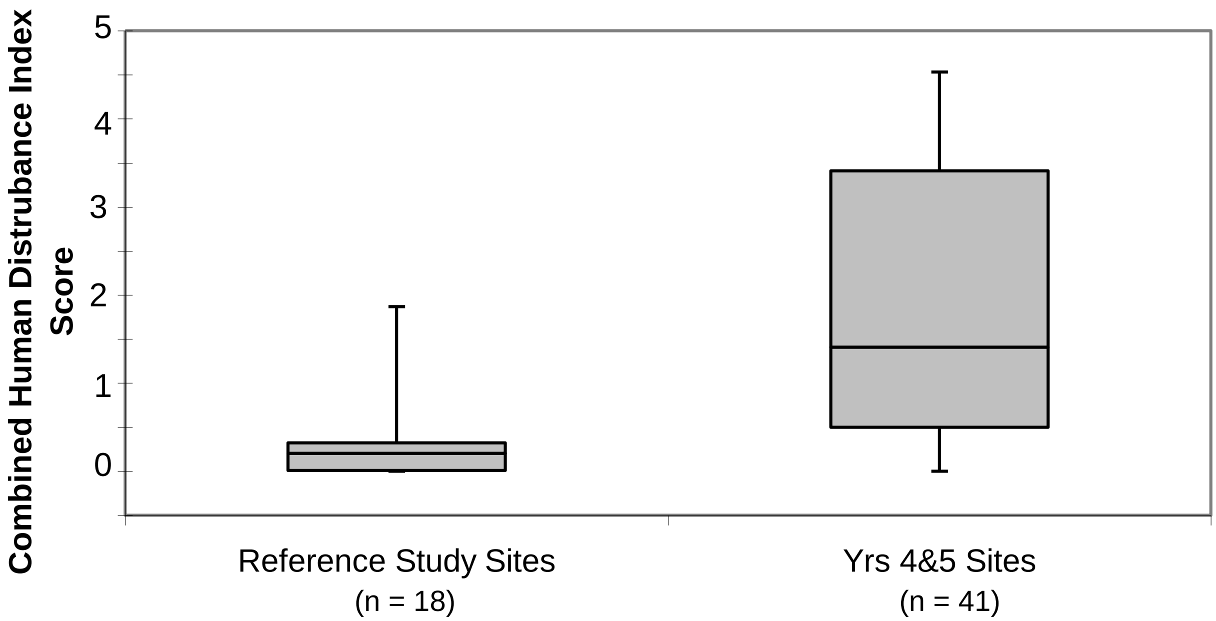


Figure 3.3-1: Combined Human Disturbance Index (CHDI) comparison between Reference Study sites and Yrs 4&5 sites

Legend: The 25th percentile, median, and 75th percentile values were used to create the boxes and the minimum and maximum values were used to create the whiskers. The median value was 0.2 for the Reference Study sites and 1.4 for Yrs 4&5 sites.

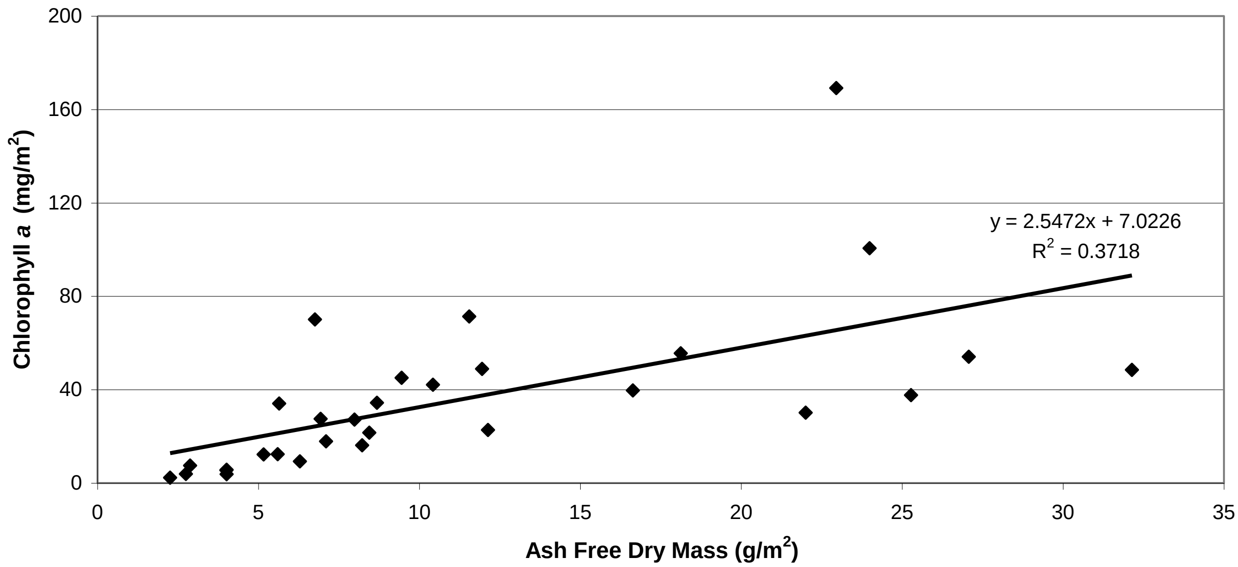


Figure 3.4-1: Relationship between two algal biomass indicators – chlorophyll *a*, and ash free dry mass (organic matter) – in reference sites, 2008-2010 (n=29)

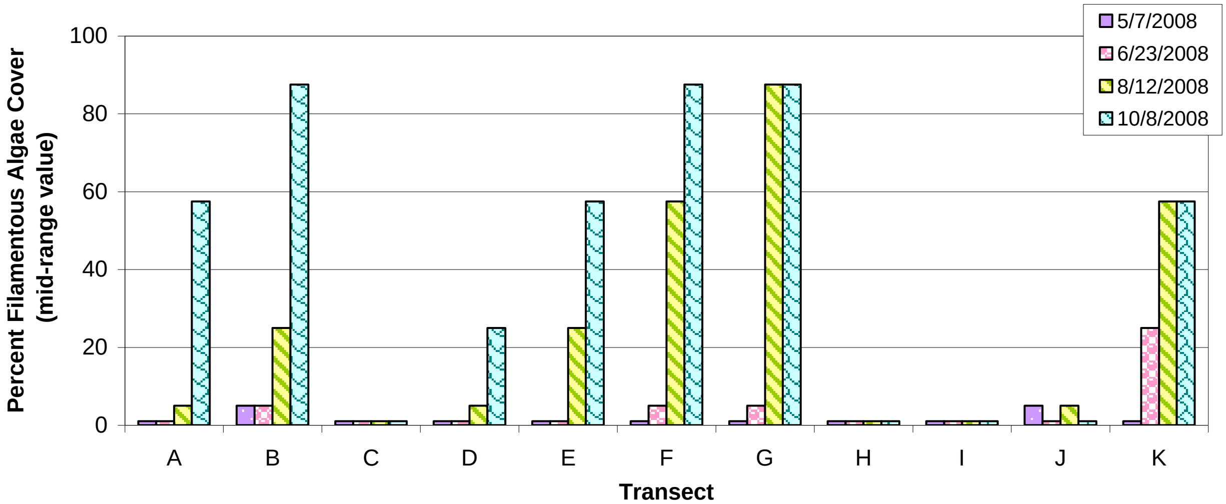


Figure 3.4-2a: Changes in filamentous algae cover in individual habitat complexity plots over the 2008 season at RDW080

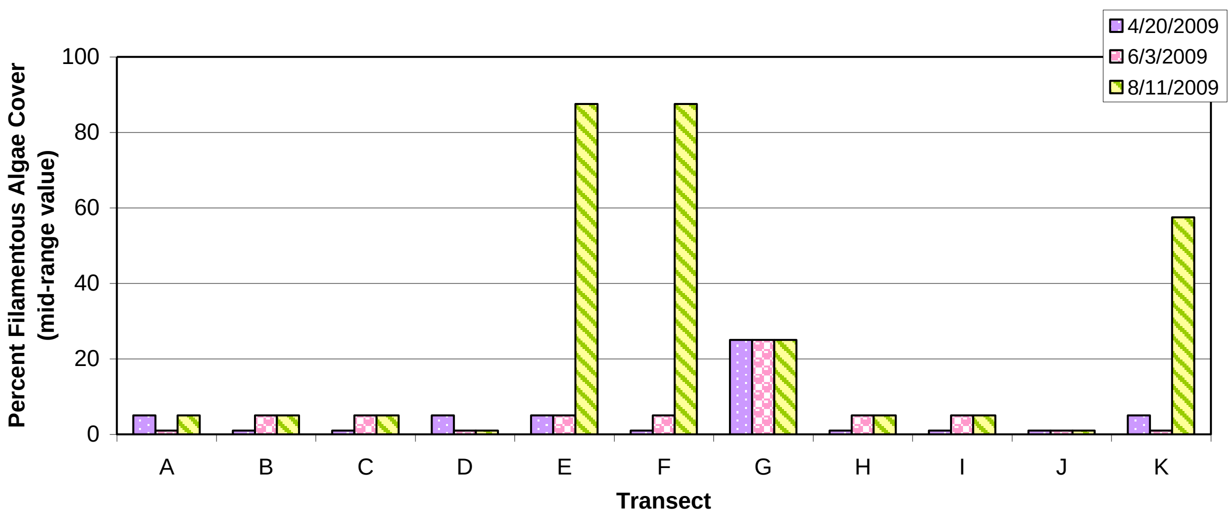


Figure 3.4-2b: **Changes in filamentous algae cover in individual habitat complexity plots over the 2009 season at RDW080**

Legend: Each bar represents one observation done at a given Transect Plot extending across the wetted channel from five meters downstream to five meters upstream of the transect. Percent cover was reported in one of five numeric-range categories, and the bar height shows the mid-range value of the reported category (for example, the range category of 10-40% cover is shown as 25% cover).

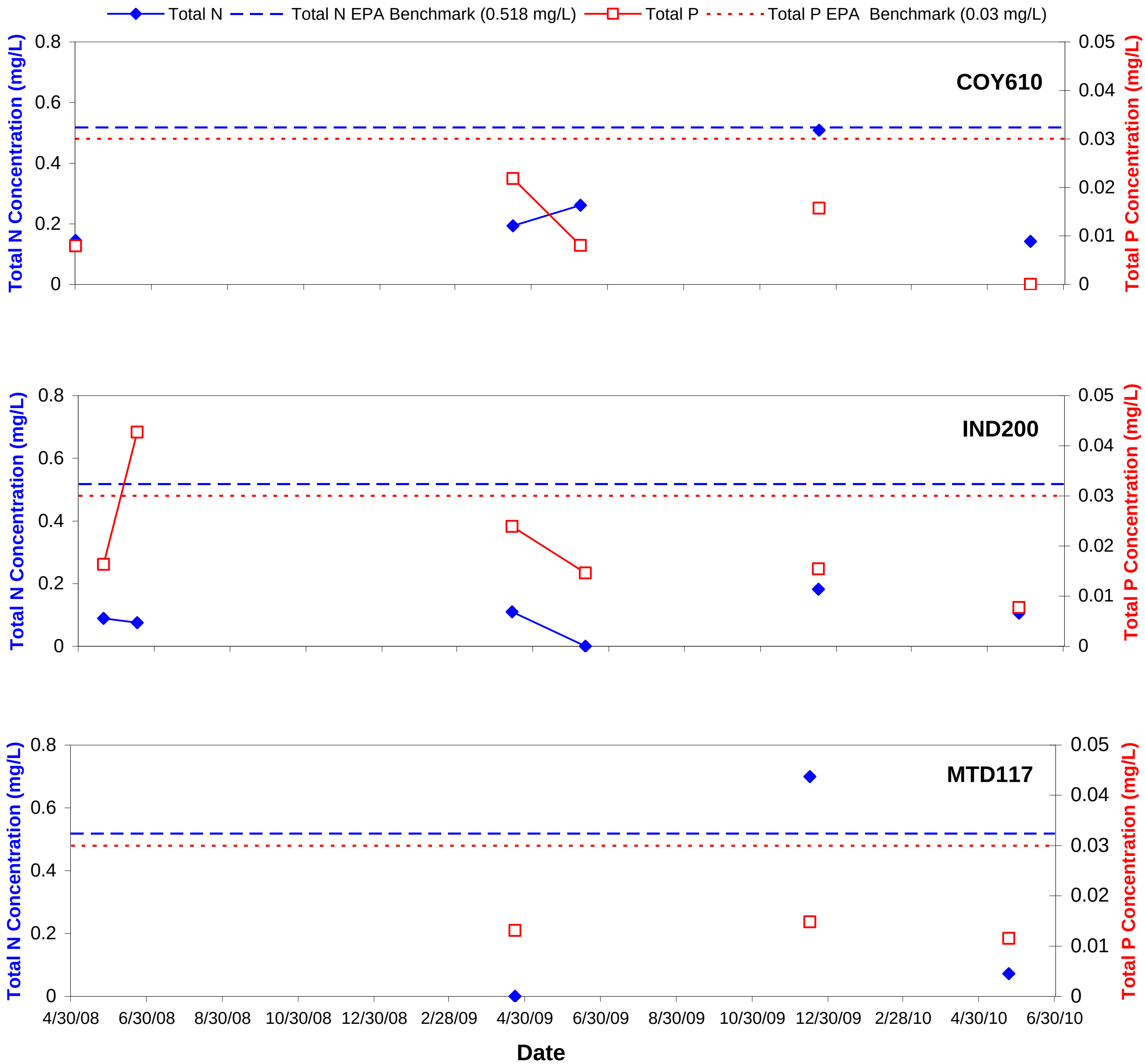


Figure 3.5-1a: **Total phosphorus and total nitrogen in non-perennial reference sites in 2008-2010**

Legend: Each point represents one sample. Points connected by a line were collected in the same wet season. Water quality benchmarks for Total N and Total P were developed for Nutrient Ecoregion III, sub-ecoregion 6 (EPA 2000).

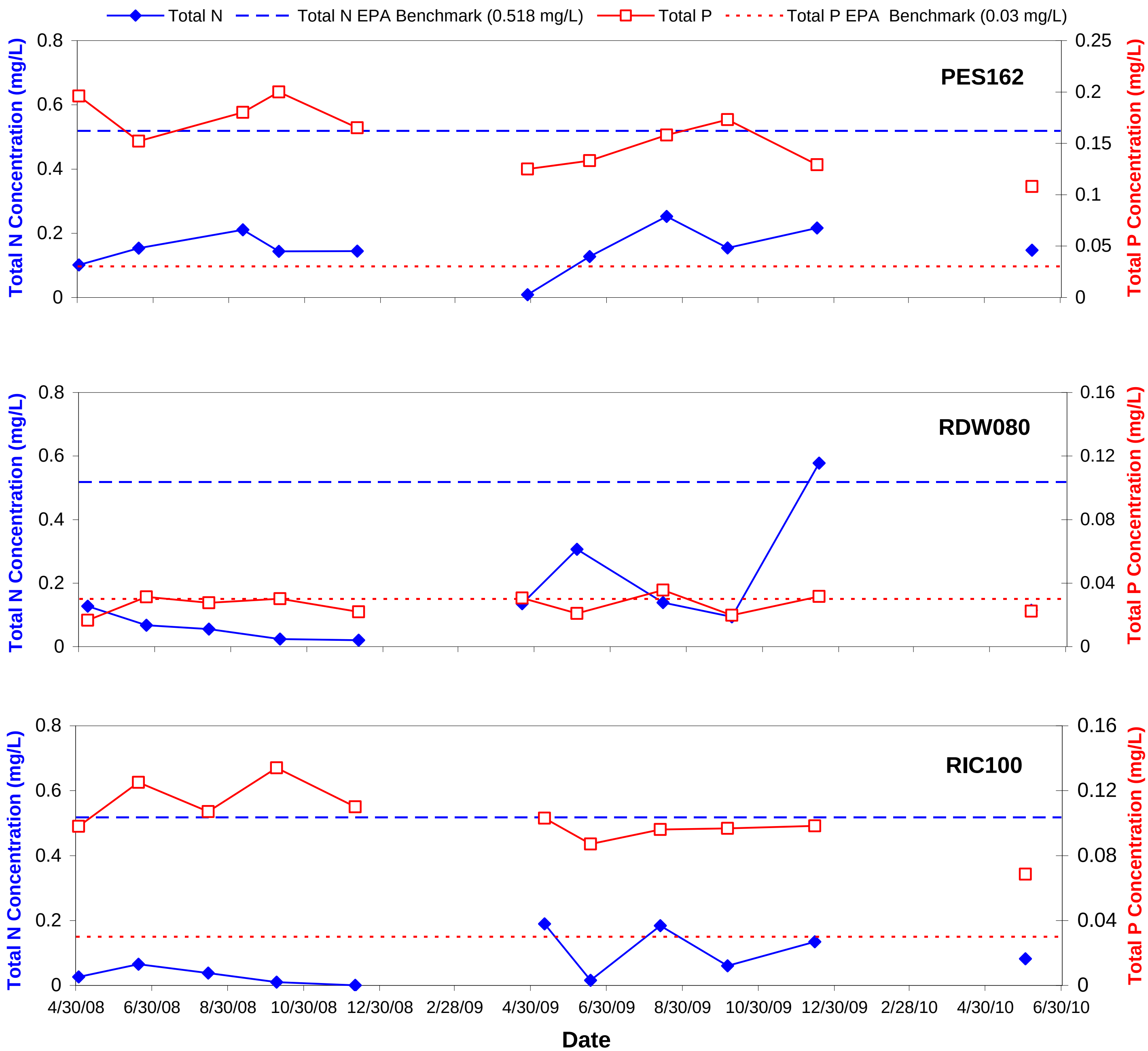


Figure 3.5-1b: **Total phosphorus and total nitrogen in perennial reference sites in 2008-2010**

Legend: Each point represents one sample. Total phosphorus axis was scaled to match data. Water quality benchmarks for Total N and Total P were developed for Nutrient Ecoregion III, sub-ecoregion 6 (EPA 2000).

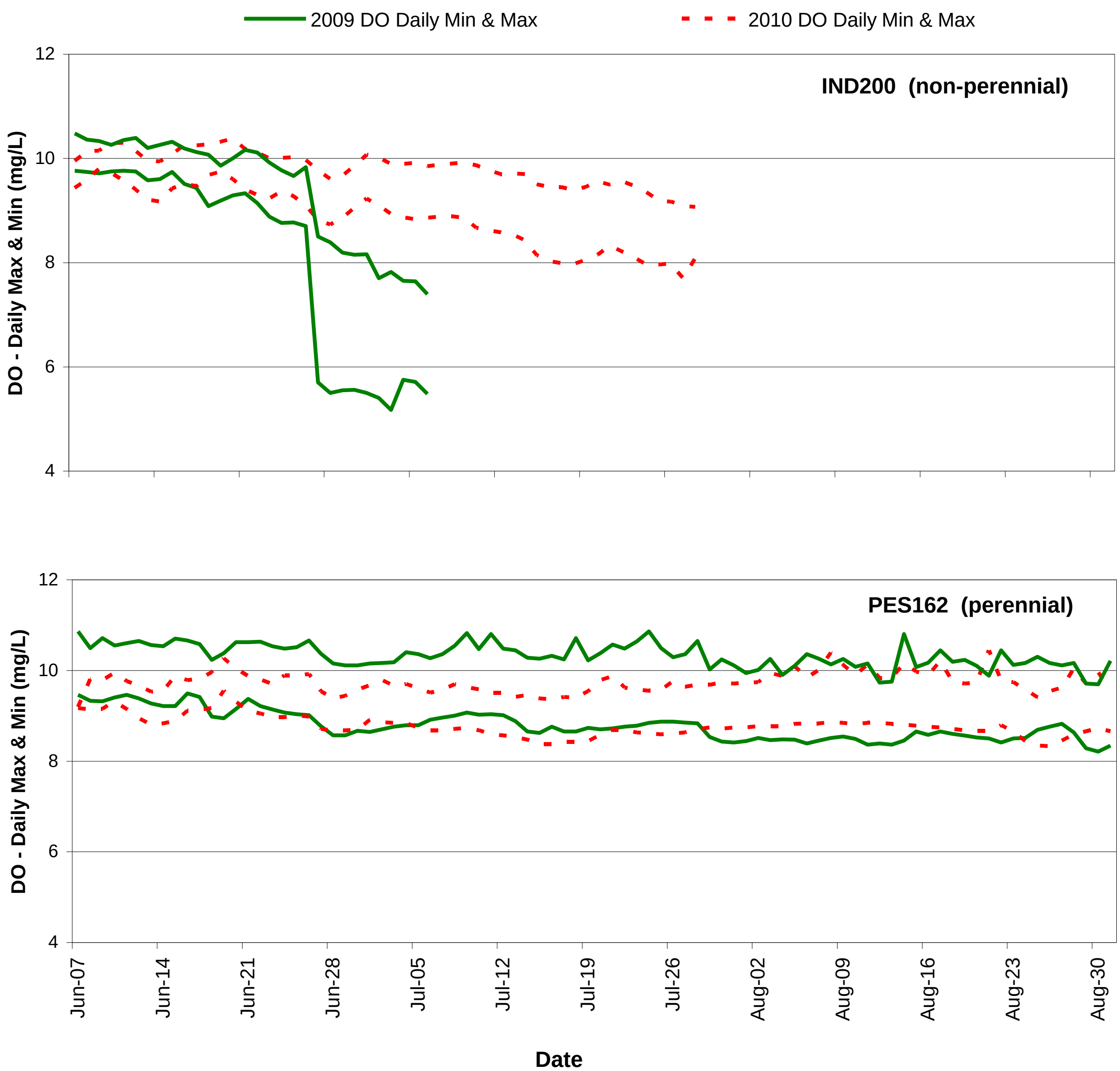


Figure 3.6-1: Daily minimum and maximum concentrations of dissolved oxygen in selected reference sites during the summers of 2009 and 2010

Legend: Daily minima and maxima were extracted from time-series field measurements taken at 15-minute intervals. Values for one non-perennial stream (top panel) and one perennial stream (bottom panel) were plotted for the same time period each year.

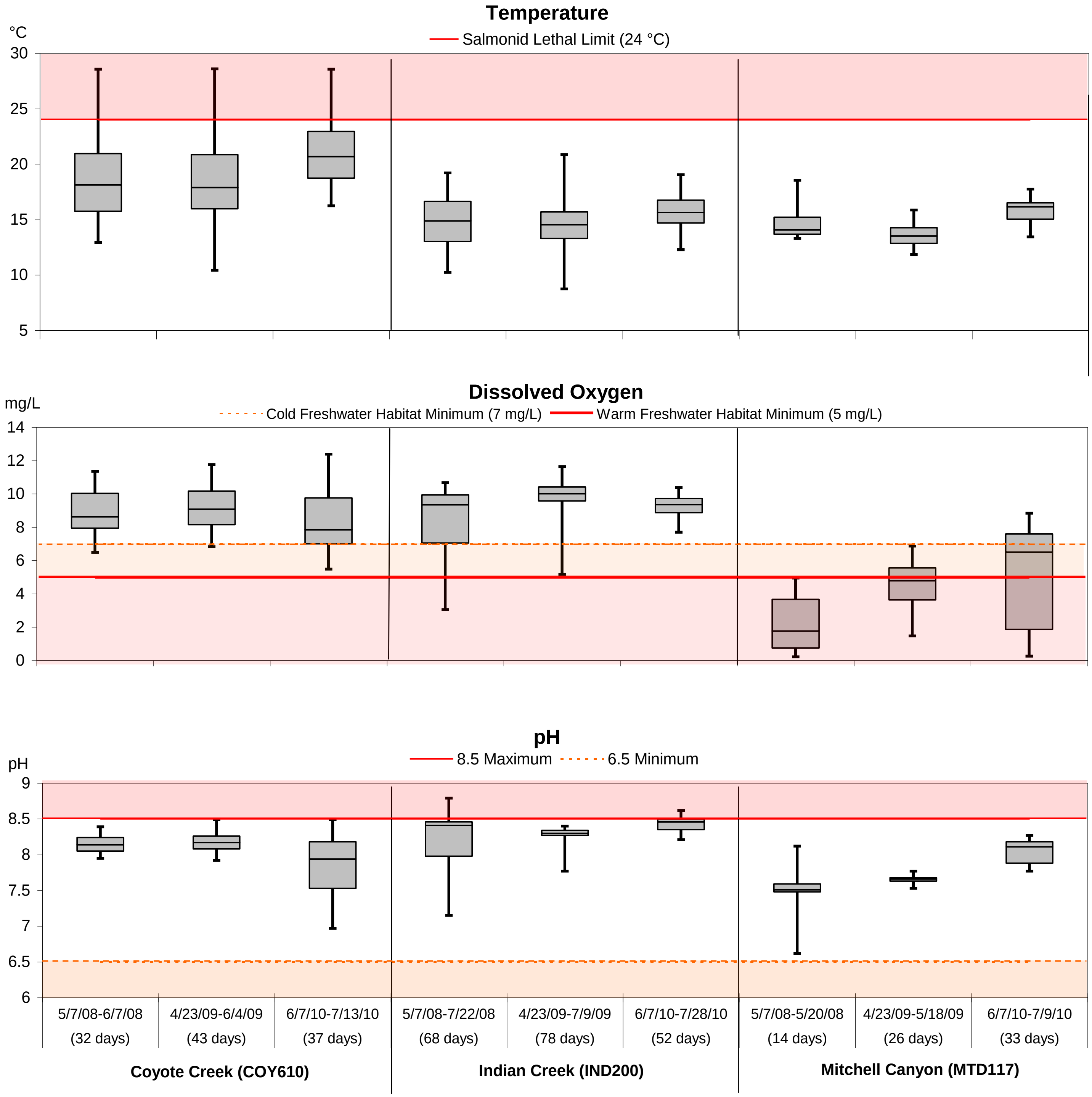


Figure 3.6-2a: Summaries of time-series field measurements of temperature, dissolved oxygen, and pH in non-perennial reference sites in 2008-2010

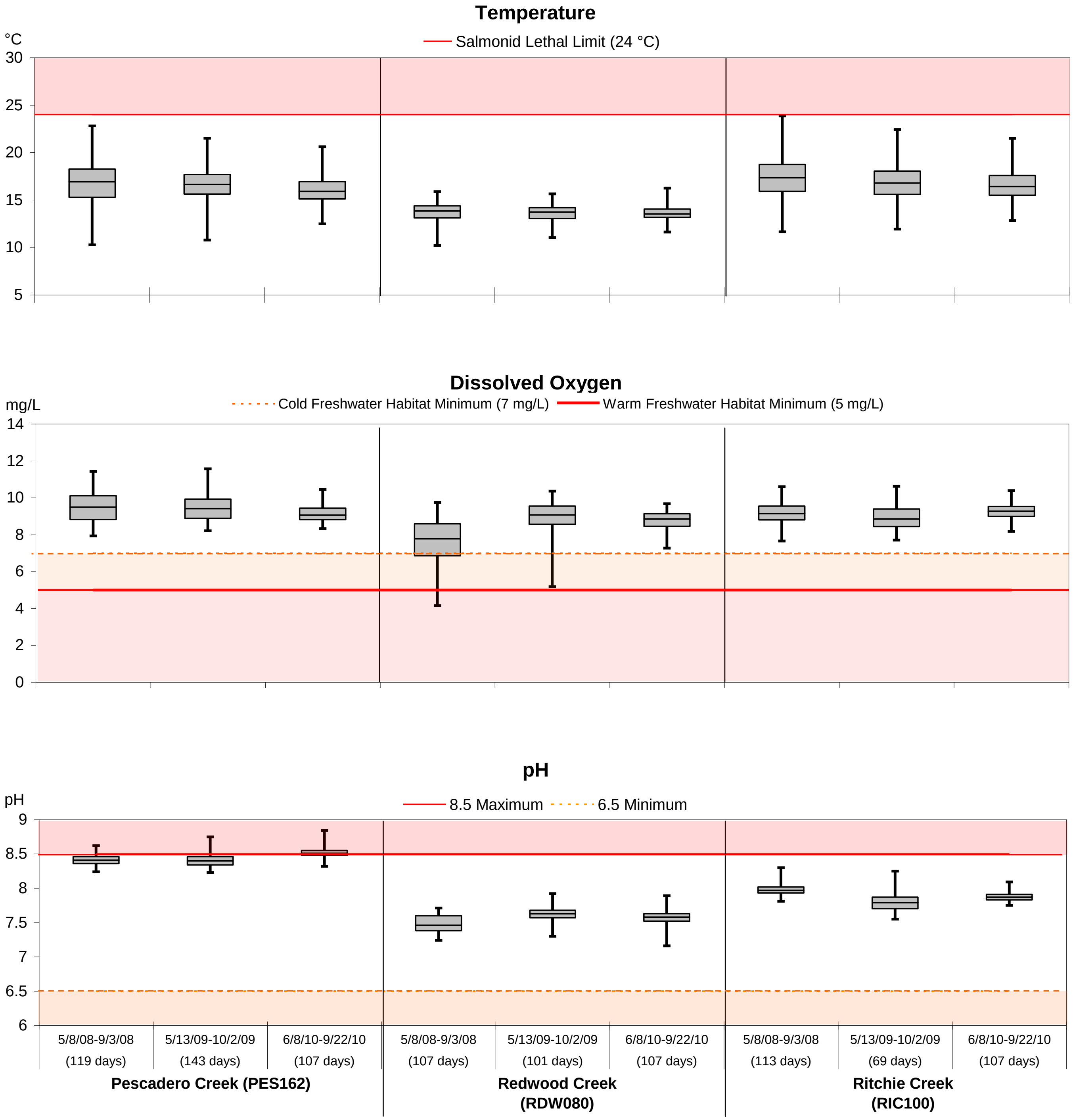


Figure 3.6-2b: Summaries of time-series field measurements of temperature, dissolved oxygen, and pH in perennial reference sites in 2008-2010

Figure 3.6-2 Legend: Time-series individual measurements were collected at 15-minute intervals. The Salmonid lethal limit maximum temperature benchmark is from USEPA, 1977. The pH minimum and maximum benchmarks are from SF RWQCB Basin Plan, 2005.

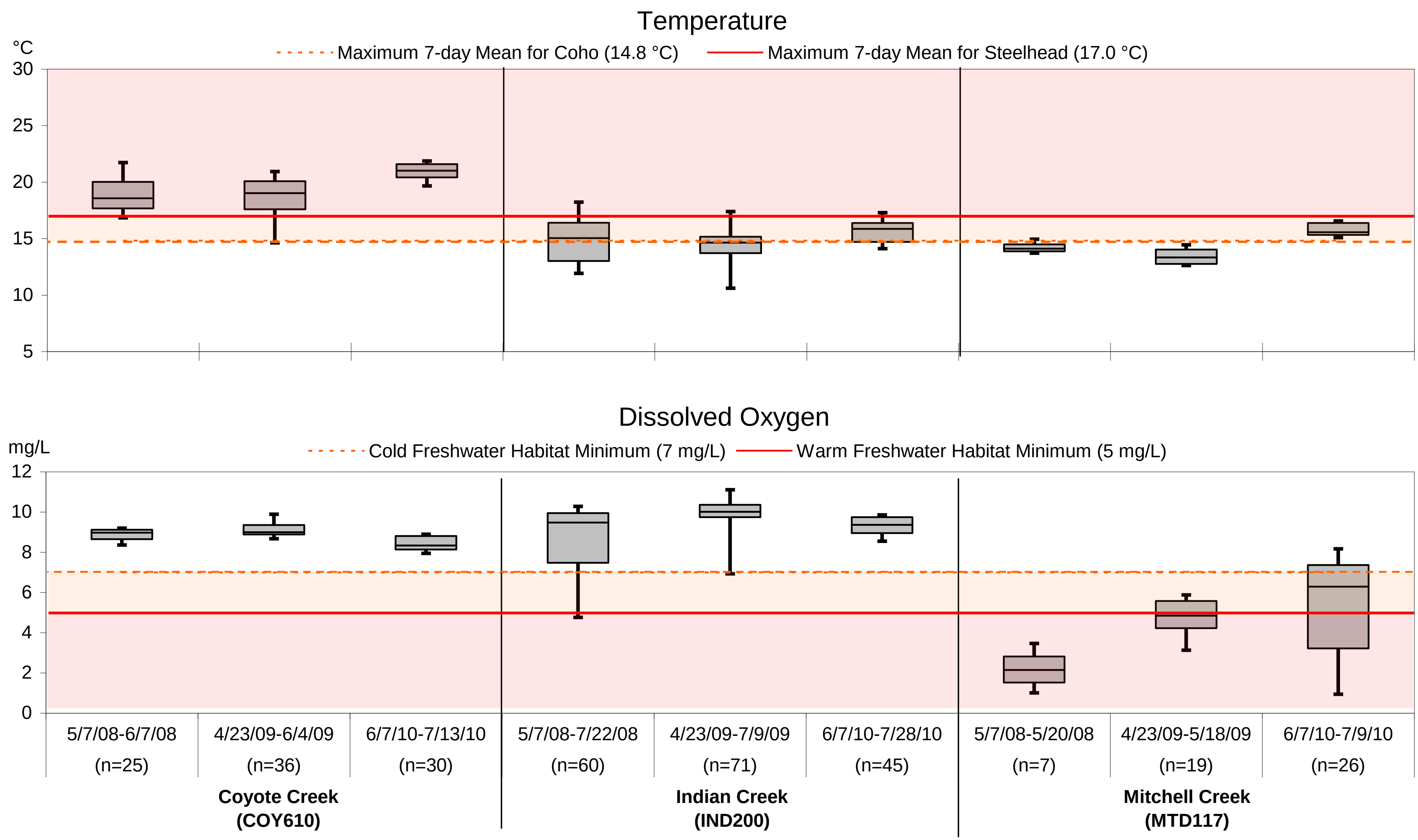


Figure 3.6-3a: Box-plots of 7-day averages calculated from time-series field measurements of temperature and dissolved oxygen in non-perennial reference sites in 2008-2010

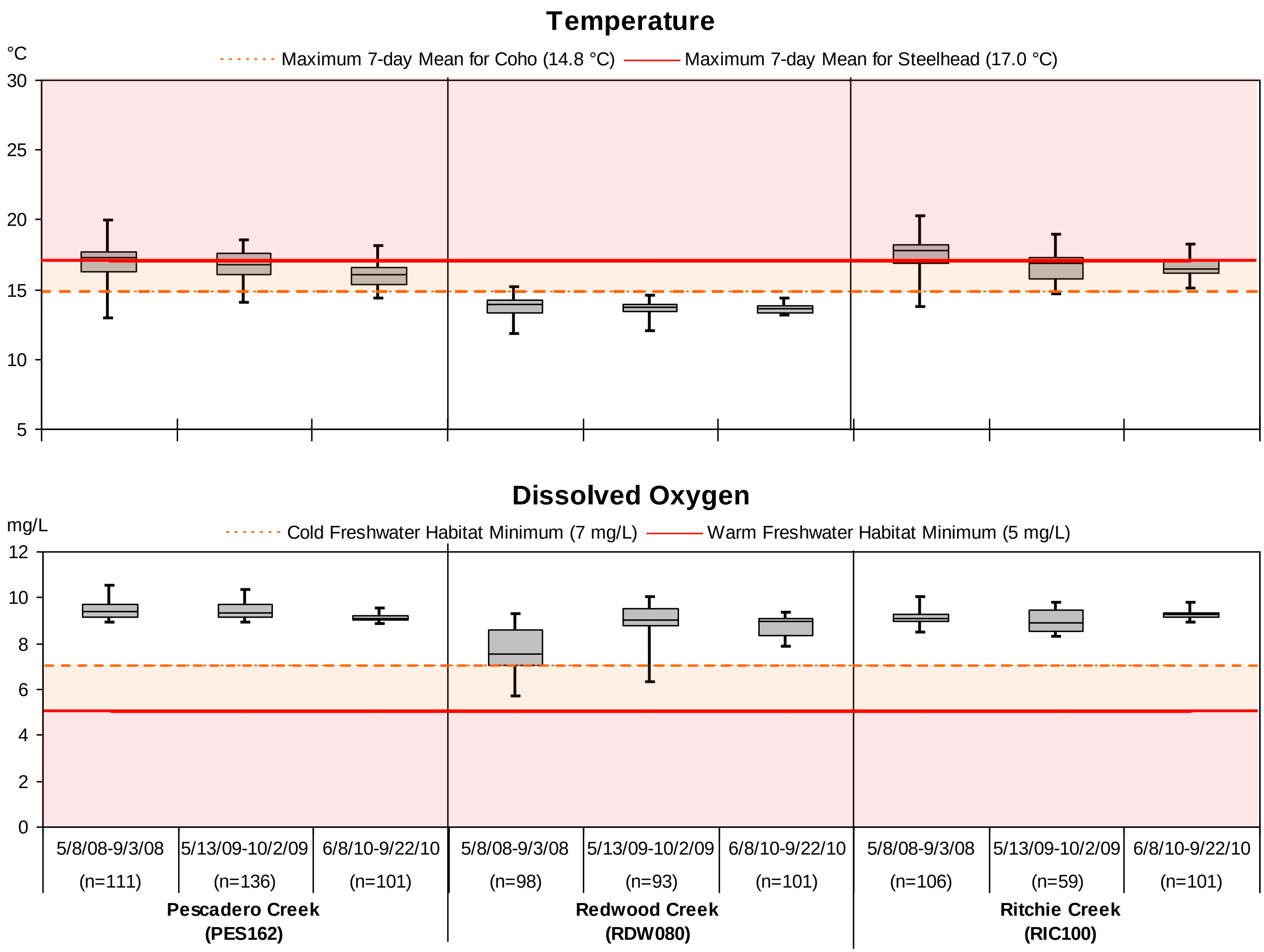


Figure 3.6-3b: Box-plots of 7-day averages calculated from time-series field measurements of temperature and dissolved oxygen in perennial reference sites in 2008-2010

Figure 3.6-3 Legend: The 7-day averages were calculated from continuous individual point measurements collected at 15-minute intervals. The 25th percentile, median and 75th percentile values were used to create the boxes and the minimum and maximum values were used to create the whiskers. The Coho and Steelhead maximum 7-day mean temperature benchmarks are from Sullivan et al, 2000. The COLD and WARM freshwater habitat minimum benchmarks compared to 7-day mean dissolved oxygen are from the SF RWQCB Basin Plan, 2005.

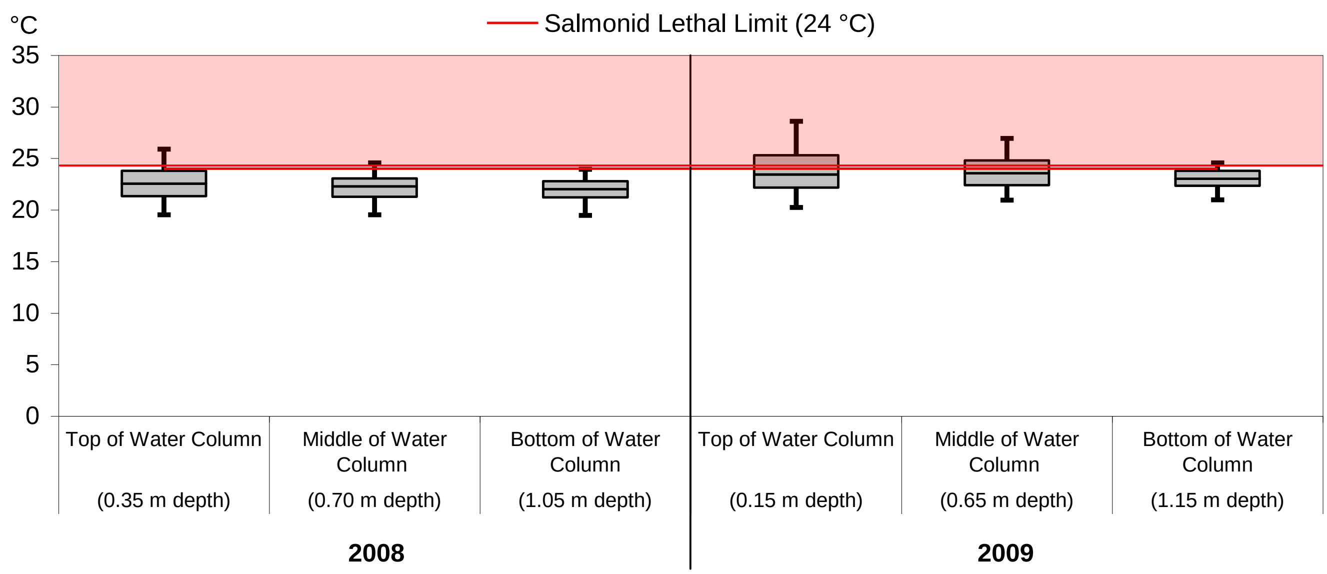


Figure 3.6-4a: HOBO time-series field measurements along a vertical depth gradient at COY610 in 2008 and 2009

Legend: Plots show descriptive statistics of time-series individual point measurements, collected at 60-minute intervals at the same time period each year (7/16 - 7/27).

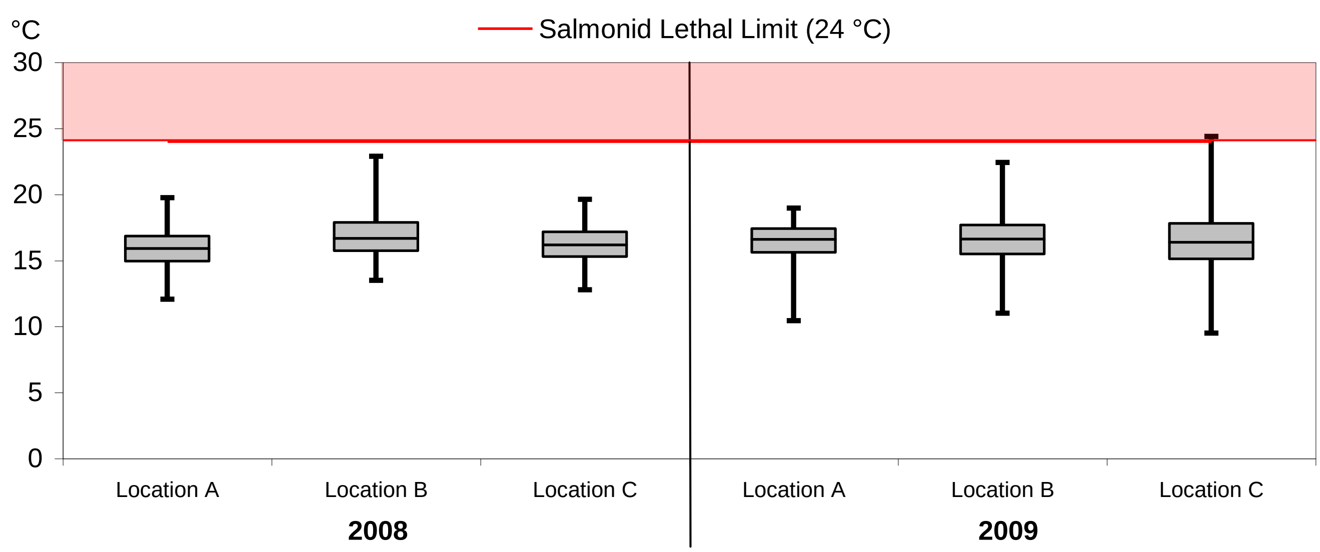
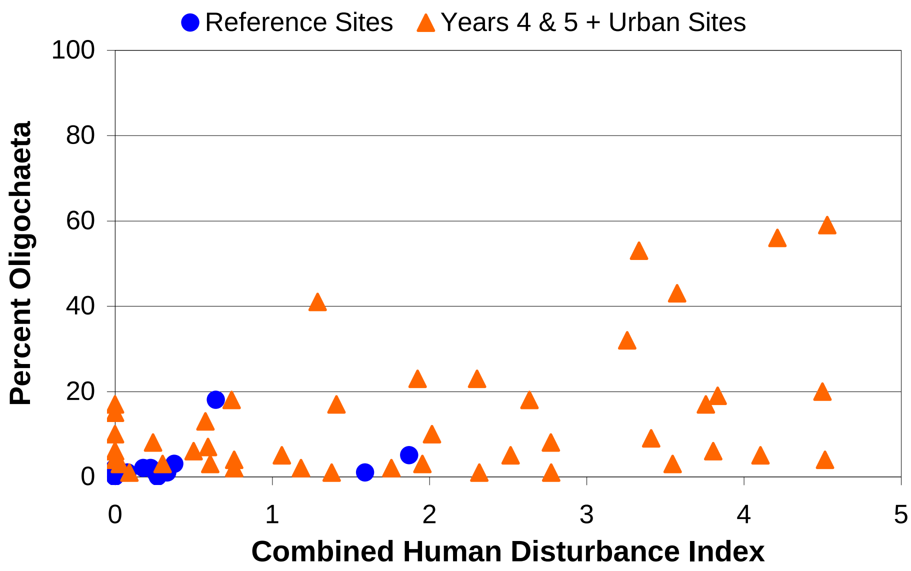


Figure 3.6-4b: HOBO time-series field measurements along a longitudinal gradient at IND200 in 2008 and 2009

Legend: Three HoboTemps were deployed at locations along the stream spaced a few meters apart. Datasets shown are comprised of individual measurements collected at 60-minute intervals between July 22 and October 9 (same time period for both years).



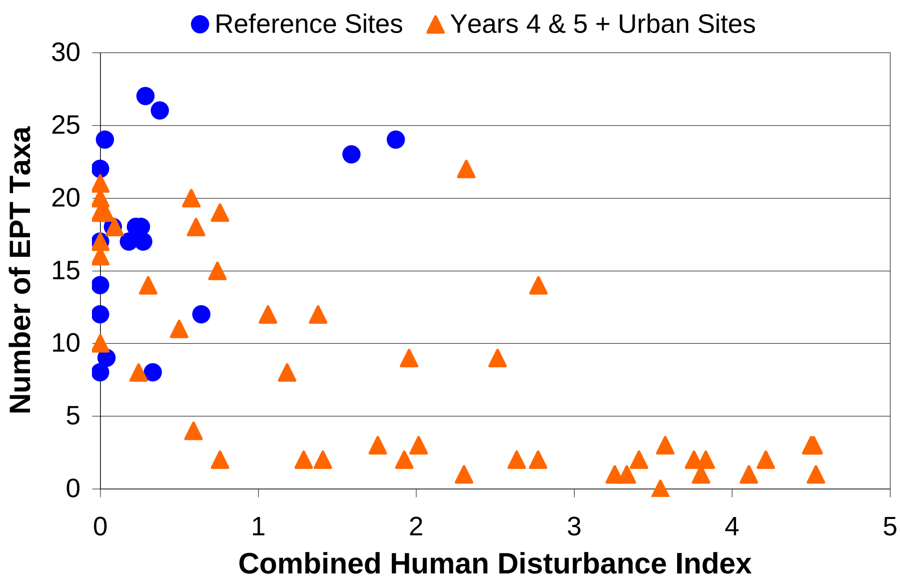


Figure 3.7-1: Relationship between the extent of human disturbance and selected benthic macroinvertebrate taxa in 2004-2006 and 2008-2010 samples

Legend: Each point represents one station visit. Human disturbances observations were used to generate a proximity-weighed index for each disturbance feature. Indices from all features are then added up to form the Combined Human Disturbance Index (CHDI) for the assessment reach.

4 Discussion

Years 2008-2010 biological, physical, and chemical data are discussed in this section by grouping them under topics that pertain to the main study questions. The summary of reference site characteristics (Sub-Section 4.1) is followed by a detailed comparison of perennial to non-perennial sites, using an array of stressors and condition indicators (4.2). Urban sites are discussed next (4.3). The study methods and design section (4.4) highlights the main insights about the usefulness of various indicators, and the timing of site visits, as an introduction to the discussion of natural variability (4.5) and our ability to detect long-term trends (4.6). The benefits of Years 2008- 2010 studies, as well as the potential uses of the data, are discussed in closing (4.7).

4.1 Reference Site Characterization

4.1.1 Attributes of reference sites

The six reference sites sampled in this study were minimally-disturbed by human stressors, supported good biological assemblages, and had good water quality conditions. Temperature, dissolved oxygen, and pH values did not fluctuate radically, and the majority did not exceed water quality benchmarks for protection of aquatic life. According to the physical habitat data (e.g., low Human Disturbance Index scores for most features), most of these sites were minimally disturbed (Table 3.7-1, Figure 3.3-1) and had intact riparian zones with multiple layers of vegetation and good canopy cover (Appendix D). Most of the physical habitat endpoints showed higher impact at the Yrs 4&5 sites than at the reference sites. In particular, reference streams had less fine sediment, more natural shelter cover, better epifaunal substrate, less sediment deposition, and less channel alteration (Table 3.7-1). The mean Combined Human Disturbance Index (CHDI) score at the six reference sites (mean=0.33, s.d.=0.03) was about half of the mean score calculated for the four urban sites at Saratoga Creek (mean=0.68, s.d.=0.14).

According to both the North Coast IBI and Southern California IBI, the biological integrity of the macroinvertebrates at reference sites was similar to that observed at other reference sites in a larger study in the Bay Area (Figure 3.1-7), which is additional evidence that these sites were good reference sites. Most of the samples scored as ‘good’ with a few ‘very good’ (or ‘Excellent’) and two ‘poor’ conditions (Figure 3.1-1, 3.1-3). The two poor scores were from non-perennial streams and highlight the value in calibrating an IBI to non-perennial conditions. In addition, the IBI scores at the reference sites were much higher than scores from non-reference sites monitored in other studies (Figure 3.1-7). IBI scores at the six regional reference sites did not differ from reference sites identified by SWAMP as part of the statewide Reference Condition Monitoring Program (RCMP), which monitors perennial streams. Southern California IBI scores from the 34 RCMP sites in Region 2 and Region 3 ranged from 29 to 95 with a mean score of 72, compared to a mean score of 71 for RIC100 and 84 for RDW080. An IBI score for Pescadero was not calculated because it is in a ecoregion that was not included in index calibration.

Because the SWAMP algae methods are relatively new and there are no established tools to analyze the data, we were not able to compare our algae taxonomy data to other reference sites in our region or other regions.

Reference sites were selected based on criteria that required continued access for future sampling and thus all sites are on public property such as local and state parks. Reference sites also had to be accessible by car to allow the multiple visits per year needed to document intra-annual variation. The nature of these criteria resulted in the selection of sites with some local stressors. In particular, two reference sites, Ritchie Creek (RIC) and Mitchell Canyon Creek (MTD), might not represent the best-attainable condition in the Bay Area. RIC was close to a campground and might have historical effects of water diversions for a mill, and current impacts from campers and potential effluent from outhouses. At MTD, there is direct anthropogenic impact from a dirt road that runs parallel to the creek, 35 - 40 meters from the stream channel. MTD117 has some other anthropogenic stressors near the site, but not within the drainage area of the site: a building near the downstream end of the reach, and a bridge and gravel parking lot downstream of the site. Additionally, there is a large gravel mine a few hundred yards downstream of the study reach. The GIS layer shows some human influence in the 1 km watershed-area that drains into the site (Table 2.1-2), which could contribute to local impacts. In regard to unique natural flow conditions at MTD, the creek has very low flow in the spring months, and a substantial proportion of the total creek flow is actually underground. In the summer the creek still flows, but there is no surface water for long stream segments. These conditions do not provide much, if any, habitat for aquatic species that are captured using the bioassessment protocol. Because of the flow patterns, dissolved oxygen values drop significantly in the dry season, creating an instream environment very different from that of the other non-perennial sites.

4.1.2 Prevailing conditions in the reference sites in 2008-2010

Despite choosing as reference sites those which, to the best of our knowledge, represented the least-disturbed sites in the Bay Area, some water quality measurement results did exceed the water quality benchmarks for temperature, dissolved oxygen and pH. In addition, total phosphorus concentrations very often exceeded the EPA benchmark of 0.03 mg/L, but there were few exceedances of the EPA total nitrogen benchmark (0.518 mg/L). However, we found no correlation between high nutrient concentrations and high benthic chlorophyll *a* concentrations. It must be emphasized that the sources of nutrients at the six reference sites are believed to be natural rather than human-induced, and this raises a question about the applicability of the EPA 25th percentile nutrient benchmarks in Region 2. Actually, the EPA document suggests collecting local reference data, such as those collected for this study, to develop more applicable benchmarks. However, this dataset is too small to set percentile-based standards at this time; therefore SWAMP intends to sample new reference sites so such an approach can be taken.

IBI scores for benthic macroinvertebrates were above the impairment thresholds in all cases except COY610 and MTD117 in 2010. It is important to highlight that the 39-point threshold for the Southern California IBI and 52-point threshold for the North Coast IBI were developed using data from those regions, so these thresholds may not be suitable for Region 2. However, the decrease in scores in 2010 at these two non-perennial streams was indicative of a drastic change in biota composition. We assume that this change was due to natural factors that ordinarily contribute to variation in biological communities (e.g., precipitation and/or temperature), but it is possible that unobserved anthropogenic stress that occurred earlier in the season might have played a role.

One goal of this monitoring was to examine reference conditions across the Region to see if best-attainable conditions varied spatially. However, the sampling design prevents us from answering this question because there is only one independent site in each region. This question is still important to examine to ensure that reference thresholds based on biological communities are appropriate for all areas within the region, but doing so will require a larger dataset such as the Bay Area Macroinvertebrate Bioassessment Indicator network (BAMBI) dataset. Previous work on the BAMBI dataset indicated that minor biological differences occurred between the two major ecoregions of the Bay Area (e.g., Coast Range vs. Southern and Central California Chaparral and Oak Woodlands), and that these differences were minor compared to the association with hydrology (Lunde 2011).

4.2 Effects of Hydrologic Regime on Reference Condition (perennial vs. non-perennial)

There were a number of significant differences between perennial and non-perennial streams. The most prominent was the difference in variability of the biological, chemical, and physical habitat characteristics: perennial streams had less inter-site variability and seasonal/annual variability than non-perennial streams. This difference is corroborated by analysis of a larger dataset from Bay Area reference sites (Lunde 2011), and is apparent throughout the interpretation of the results as discussed below.

4.2.1 Hydrology and water quality

The non-perennial streams chosen for this study, although they dried out each year, did in fact stay wet for 8 to 10 months during the water year. We selected non-perennial streams with a long hydroperiod because the SWAMP SOP requires that the sampling of benthic macroinvertebrates take place between April and July, and the stream needs to have flowing water for the sampling to be effective.

Water quality conditions– such as daily amplitudes in temperature and dissolved oxygen – were more variable and more extreme in non-perennial streams than in perennial streams (Figure 3.6-2). Nitrogen concentrations also exceeded the NNE benchmark more often in non-perennial streams, although the range of concentrations was similar. Strong variation in water chemistry has also been observed in other studies of non-perennial streams and wetlands. This result is expected, as water evaporates during the drying phase – a process which concentrates nutrients, salts, and other solutes. However, total phosphorous (and orthophosphate) concentrations were remarkably higher in perennial streams, which appears to result from natural conditions (Table 3.7-1).

4.2.2 Bioassessment data

A clear distinction was observed between the benthic macroinvertebrate (BMI) and algae (diatom) assemblages found in perennial and non-perennial reference streams (Figures 3.1-2, 3.2-1). For BMI assemblages, the differences observed between perennial and non-perennial sites could have to do with (a) prevalence of “non-perennial specialist” taxa in the non-perennial sites but not in perennial sites. These “specialists” may be refuge-seeking taxa (such as organisms adapted to burrowing into the hyporheic zone, or migrating to perennial waters) and/or taxa adapted to surviving desiccation; (b) absence of taxa with a long life cycle in the non-perennial sites; and/or (c) absence of “non-perennial specialists” in the perennial sites because they lack a competitive edge**.**

The differences in BMI assemblages at perennial and non-perennial streams were also reflected in average values of several BMI metrics (Figure 3.1-6) and in substantial differences in average IBI scores, with perennial sites scoring 7 (North Coast) or 13 (Southern CA) points higher than non-perennial sites (Table 3.7-1). While the median scores are only slightly different in Figure 3.1-7, the IBI scores for non-perennial sites were much lower according to the range differences and means. A study of the 61 BAMBI reference sites located throughout the Bay Area (Lunde 2011) also discovered that perennial sites score higher than non-perennial sites across the Bay Area (Figure 3.1-7). This finding has important implications for bioassessment interpretive tools (e.g., IBIs or O/E models). IBIs calculated in this report were developed using perennial stream samples, and it appears they are biased against non-perennial streams. Therefore, bioassessment data interpreted with a tool developed only for perennial streams should be used with caution in other stream types.

Data presented in the report show the value of using an IBI developed in another region, but also show that results might be affected by the development dataset. The North Coast IBI was developed using reference data from a small part of Region 2 (a portion of Marin County) but most of the data came from the Coast Range ecoregion, which encompasses less than 25% of the Bay Area. In contrast the Southern California IBI was developed with reference sites from the Southern and Central California Chaparral and Oak Woodland ecoregion, which encompasses over 75% of the Bay Area, but no data from the Bay Area were used in the development dataset. The North Coast IBI scored the same reference samples 9 points lower than the Southern California IBI. The difference between the two indicators highlights the need for using reference data in the SF Bay Area to develop separate numeric tools specifically for perennial and non-perennial streams in our region. We are not aware of other states that have developed separate IBIs based on hydrology, but California is relatively unique in having a Mediterranean climate which results in a large proportion of non-perennial stream miles.

Another important distinction based on hydrology was that non-perennial streams had much greater inter-annual variation in BMI communities than did perennial streams. The NMS ordination and IBI scores confirmed this trend. Similar results were also identified in the BAMBI dataset (Lunde 2011). The greater variation in non-perennial streams is likely caused by the dispersal, emergence or death of aquatic organisms as water temperatures increase, flows decrease, and diurnal fluctuations in temperature and dissolved oxygen become more prominent.

Inter-annual and seasonal variation in macroinvertebrate bioassessment data from non-perennial streams can be minimized by restricting the index period for sampling to shorter than three months (e.g., 1.5 months), and by associating the onset of the index period to important weather conditions. The SWAMP SOPs already state that sampling cannot begin until 30 days after the last significant rain event, but more information regarding the changes in biological communities during the drying cycle could help field crews identify the date past which non-perennial streams cannot be reliably sampled. A study designed to examine this question is being undertaken by the Southern California Coastal Water Resources Project (http://www.sccwrp.org).

The differences between algae (diatom) communities found at perennial and non-perennial streams were significant (although not as distinct as the differences between invertebrates). However, this study is small and we currently lack supporting data needed to reliably determine if separate indicators should be developed for algae for the two hydrologic regimes in Region 2, and recommend exploring this question as additional data become available. Similar to the differences among invertebrates, non-perennial diatom communities varied more than at perennial sites. Therefore, the signal-to-noise ratio will be lower for non-perennial streams (thus weakening the responsiveness of the indicator).

4.3 The Effect of Urbanization

BMI communities in both urban watersheds responded negatively to urbanization, and the IBI was an effective tool to describe this degradation. However, the algae community in Saratoga Creek (for which we have data) did not show such a consistent response. Urban sites clustered together in the algae NMS plot (Figure 3.2-1), but were not distinct from the perennial reference sites that have little to no urbanization in the watershed. Metrics of algae composition did not show consistent changes related to the urban gradient, in contrast to what we had expected from the literature (Figure 3.2-4).

Benthic macroinvertebrate IBI scores were better at Saratoga Creek than at Las Trampas Creek (Figure 3.1-5), confirming observations from previous monitoring data collected at these creeks.. This difference in BMI conditions between the two streams could not be explained by land-use data: Las Trampas Creek is less urbanized and has lower road density than Saratoga Creek (Table 2.1.2). Due to a lack of physical habitat data from Las Trampas Creek in 2008-2010, we were unable to determine the cause of the difference in biological potential at these sites, but recent physical habitat assessments conducted at the two downstream stations in Las Trampas Creek (WAL410 and WAL412) indicated that habitat conditions there are similar to the conditions at Saratoga Creek. However, Saratoga Creek had larger median sediment size and a smaller proportion of the stream bed is covered in fines and sands (data not shown), which could be a factor. Thus, it is still not clear why BMI communities score low at Las Trampas and we need to look at other measurable stressors in both watersheds.

In addition, we recommend using ambient regional monitoring data (e.g., BAMBI dataset) to look at the current best-attainable biological condition in urban streams to see these to watersheds in a broader context.

4.4 Methodology and sampling design

4.4.1 Implementation of the algae protocol developed for SWAMP

This report shows one of the first algal assessment datasets collected in the SF Bay Area per the SWAMP protocol (Fetscher *et al.* 2009). The sampling method described in the SOP worked well to collect data in all stream types sampled in this study. It is too early to determine whether the algae taxonomy data is a useful biological indicator for the Region. The field crew successfully collected a small number of samples from a very specialized set of sites; these sites do not represent the entire array of Bay Area's streams, especially streams in agricultural and urban areas. Algae metrics did not appear to be useful in this study. For example, individual algae metrics in the Urban Gradient Study either showed no response or a response opposite to the expected prediction based on previous studies of algal communities. Individual metrics and the NMS ordination showed substantial seasonal and inter-annual variation in the algae assemblage, which means that IBIs based on metrics may be subject to the effects of natural variation and weaken the signal-to-noise ratio. None of the diatom metrics we calculated proved to be a good indicator of urban stress.

4.4.2 Implementation of North Coast and Southern California Indices of Biological Integrity (IBIs)

Both the North Coast and Southern California IBIs were developed in different geographic areas and were not developed using BMI data from this Region (except for the small set of Marin County data used for the NC IBI). Thus, while we found it useful to calculate scores with these indices, the specific score values and thresholds should be interpreted with caution. Also, they were developed specifically for perennial streams, while we are calculating scores using BMI data from non-perennial streams as well. We did observe a consistent trend whereby the Southern California IBI scores were higher than the North Coast IBI scores for the same samples. There is no gold standard for bioassessment data in this region; thus we cannot say which IBI is more applicable. Efforts are underway to use the BAMBI dataset to develop separate benthic macroinvertebrate IBIs for perennial and for non-perennial streams in this Region so we can evaluate local bioassessment data with more appropriate tools.

4.4.3 Usefulness of biological, chemical, and physical characteristics

Benthic macroinvertebrate (BMI) communities appear to be very good integrative indicators for assessing stream conditions, but the diatom communities did not show predictive responses to urban stress. According to both ordination analyses and the IBI scores, BMI were very responsive to the stress factors they may have encountered (e.g., urbanization, stream channelization, bank stabilization, riparian disturbance)). BMI communities were less variable between years than were diatom communities, which makes them more suitable for our purpose, because the lower the inter-annual variation in reference sites, the better the biological indicator. Macroinvertebrate communities were more responsive to flow regime than diatom communities, i.e., the difference between perennial and non-perennial sites was more pronounced.

In contrast, diatom assemblages were not responsive to urban stress according to ordination analyses, but the small sample size of urban sites (only 4 samples) is a severe limitation. Because there is no approved tool to analyze algae data at this time, we could not make a more direct comparison between the two bioassessment indicators. Preliminary observations of diatom metrics show that genera richness appears to be most stable over time, meaning that it can be a good indicator for our purpose (Figure 3.2-2). In contrast, % *Achnanthidium minutissimum* and % motile genera are the most variable metrics over time, and if these metrics are used for IBI development, the timing of sampling will become very important.

The current SWAMP bioassessment protocol involves collecting benthic macroinvertebrates, algae, water chemistry, and physical habitat characteristics. In general, the physical habitat assessment requirements were adapted from the Environmental Monitoring and Assessment Program under US EPA (http://www.epa.gov/emap/). The physical habitat endpoints that were most useful were numeric metrics with a known directional response to anthropogenic stress. In particular, the Combined Human Disturbance Index (CHDI) was useful in describing the low degree of human influence at our reference sites. However, a major limitation of the current physical habitat data is the frame of reference for the habitat endpoints. The collection of data at reference sites is the first step in documenting the range of conditions as observed with the new physical habitat metrics, but we will also need to assess impacted sites so we can document the response to physical habitat stressors with the same methods. Inclusion of Years 4&5 data highlighted the usefulness of Human Disturbance Indices; adding them created a combined dataset that spanned a wide range of values, from minimally disturbed to highly disturbed, and this stressor-gradient correlated with the abundance of several indicator BMI species (Figure 3.7-1). Other PHAB characteristics were very responsive to seasonal changes; for example, the cover of filamentous algae in habitat complexity plots increased during the season (Figure 3.4-2).

Nutrient concentrations were measured by a variety of methods over the 2008-2010 study period, but all analytical suites supported the use of the data for comparison with water quality objectives and for testing the current NNE model. For example, we obtained concentrations of the phosphorus species (Total and inorganic) needed for the various NNE models (Tetra Tech 2006 and DWQ 2007), and the nitrogen species (Total, organic, inorganic, toxic as NH_3, etc.) needed for all uses. The new method for measuring total nitrogen with a single test, introduced in 2010, worked well in conjunction with measurements of ammonia and total Kjeldahl nitrogen on the same sample.

The results of benthic algae biomass indicators (chlorophyll *a* and ash-free dry mass [AFDM]) spanned a wide range and showed no spatial or temporal trends. They also did not match the prediction of the NNE model when we plugged the ambient nutrient data into the model. As we mentioned earlier, the protocol was in development while the crews were in the field. The accuracy and precision of these measurement systems have not yet been quantified. Measurement error can be greatly reduced by adjusting the volume of composite-sample liquid filtered to assure that the amount of material on each filter is adequate.

Currently the SWAMP protocol recommends filtering 25 mL of a 500 mL-900 mL composite sample. Sub-sampling such a small fraction of the total sample can lead to additional error. Therefore, if chlorophyll *a* or AFDM are critical variables in a study, the field crew can filter more water through the same filter if algae levels are low. If diatom or sediment levels are high in the stream, the filter may not be able to pass more than 25 mL. In those cases, multiple 25 mL subsamples could be collected to filter a larger total volume of the algae sample. Lastly, larger-diameter filters than 47 mm could be used, while keeping the 0.7 mm pore size constant, to filter a greater volume of the composite water if field filtering equipment can use that larger filter diameter.

4.4.4 Index period, length of sampling season, and station-visit intervals

Ambient monitoring programs usually visit sites only once a year. In contrast, this study involved repeated visits during the same season to see how characteristics change over time and to examine how the index period could affect the data collected. The index period for perennial streams in this Region is May to July (per SWAMP Perennial Streams Assessment guidance), but many of our non-perennial streams dry out before the end of that index period. Therefore, we recommend trying to sample all sites in this Region by the end of June in order to obtain comparable data for a larger number of creeks. Historically, a large number of sites were sampled in late April in this region, especially during dry years, and that time worked well to collect an adequate number of invertebrates at sizes that could be reliably identified. This study was not designed to answer how BMI communities change over the course of the season; therefore, we did not sample BMI multiple times throughout the season. However, that information would have been useful to help determine how much the intra-annual variation could alter bioassessment results and inform our Regional index period.

Diatom community taxonomy and overall algae biomass (chlorophyll *a* and AFDM) changed throughout the season. The NMS ordination of the algae did not show a consistent seasonal trend, meaning that the seasonal trends will be hard to remove from this analysis and will contribute to overall noise. The effect of season on chlorophyll *a* was clear in some stations during some years with increasing values throughout the season as flows decreased, water temperature increased and filamentous algae had time to develop. The index period for BMI does not overlap with the observed peak algae biomass in these streams. If we sample only once a year to determine peak algae levels, the May-June window will not capture potential nuisance algae levels. Studies designed to identify nuisance algae can use the SWAMP sampling protocols, but will need to sample during the seasonal window that corresponds to peak algae production in their region. In Bay Area perennial streams, this window corresponds to late summer and early fall, prior to the rainy season.

4.4.5 Use of permanent station and fixed transects for repeated assessments

This study used a fixed transect method to minimize “noise” that would blur the seasonal and inter-annual variation. Ambient monitoring studies (including the SWAMP protocol) that are based on random selection of transects (i.e. at different locations in every visit) use temporary transect markers (e.g., removable flags) for the day. However, we set up semi-permanent markers for every reach and sampled the same transects every season and every year. This approach minimized the effect of within-stream patchiness that would have otherwise contributed to apparent differences between station visits. A single 150 m reach usually contains a number of pools and riffles, so shifting the reach up or down a few meters could result in assessment of a totally different habitat plot every time. If we look at a single transect each time, such a shift will lead to the conclusions that conditions changed at that particular transect when in fact the variation was caused by a frame-shift of the entire reach. Semi-permanent transects allowed for tracking of seasonal changes at fixed plots, eliminating a major source of spatial variability and enabling (a) detection of changes over time, and (b) consistency in results from specific plots within the reach (Figure 3.4-2).

4.5 Natural (Inherent) Variability

Natural variability is inherent to all ecosystems. The same biological community is not found in every minimally-disturbed stream. The goal of using bioassessment data in water quality monitoring is to study natural variation and to find ways to constrain the analysis and sampling to minimize this variation (noise) compared to the response of the biological community to anthropogenic stress (signal). In general, ecologists look at spatial and temporal variation and use different tools in each case to minimize how this variation affects the assessment tool.

This study was not designed to measure the effects of spatial variation but to be spatially representative. Thus, the six reference sites represent perennial and non-perennial streams, of variable sizes, in various Bay Area hydrologic units. Having each site represent a unique combination of attributes (i.e., flow regime, watershed size, and hydrologic unit) makes it very difficult to "separate the variables" for the purpose of making comparisons between sites. The analysis of the historical data from SWAMP shows that sites in the North Bay have biological communities that are slightly different from those in the South Bay. A larger reference pool will be necessary to examine if there are significant differences in biological communities throughout the Bay Area.

Given that we selected sites that are very different from one another, we need to eliminate the inter-site variability by looking at a single site if we want to detect change. We can also eliminate intra-reach variability by looking at a single transect plot because transect plots can be very different from one another. Depiction of filamentous algae cover at each transect over time (Figure 3.4-2) indeed shows that spatial variation (i.e. patchiness) within an assessment reach can be considerable. This point was emphasized above in relation to the benefit of fixed transect locations (Section 4.4.5).

The effect of patchiness on water temperature within the reach was examined in two non-perennial streams by deploying HoboTemp data-loggers along horizontal and vertical axes. When the datasets were trimmed to reflect the same time period for all locations, no vertical or horizontal gradients were observed (Figure 3.6-4). This indicates that, during these time periods, water flow was sufficient to mix the stream adequately, and we infer that the time-series field measurements of other water quality characteristics, conducted with the YSI6600 sondes deployed in one spot within each reach, actually represent the quality of water in the entire reach.

As mentioned in a number of sections of this report, the temporal variations in benthic algae biomass, diatom communities, and several PHAB characteristics were considerable, with few discernable patterns. It is important to mention that the 2008-2010 dataset was collected using a new protocol that was in development during these years. Field observations/estimates and algae lab identification and counting habits may have changed over time as operators went through the learning curve of protocol development. Therefore, differences between 2008 and 2009 might be affected by clarifications in the protocol that were brought to light after the first season. Some of the inter-annual variability observed may also be related to introduction of new field operators and changes in the field crew across the three years.

4.6 Detection of Long-term Trends

We did not observe a long-term trend in any of the monitored characteristics. Three years of data were not sufficient to detect long-term changes related to climate change or changes in condition from large-scale off-site impacts. Considering the amount of natural inter-annual variation we expect, it would likely take 10-20 years to observe long-term trends within Bay Area streams. We propose studying these same reference sites every five years to examine any potential long-term trends, a study design that will free up resources to better monitor reference sites spatially throughout the region, and to focus on gathering data in non-perennial reference streams in particular.

4.7 Data Uses and Study Benefits

The years 2008-2010 data can be used to provide the following benefits and outcomes:

- Support the development of reference conditions and numeric biocriteria (e.g., IBIs) for benthic macroinvertebrate and algae (periphyton) assemblages for both perennial and non-perennial streams;
- Support the development of "best attainable conditions" (based on Stoddard *et al.* 2006) for urban areas for benthic macroinvertebrate and algae assemblages;
- Supplement the statewide Reference Condition Management Program study by providing information on natural annual variability;
- Provide water quality data to the Regional Water Board for the 305(b)/303(d) integrated report;
- Provide context for previously collected and future SWAMP water quality data;
- Provide timely and relevant water quality data to stormwater programs and over 75 volunteer watershed groups currently operating in the Region;
- Collaborate with monitoring partner organizations (e.g., BASMAA Regional Monitoring Coalition); and
- Inform the development of the Nutrient Numeric Endpoints (NNE) model and nutrient objectives for the Bay Area (e.g., highlight the prevalence of naturally-high phosphorus concentrations in reference creeks, and the lack of relationship between nutrients and secondary indicators).

5 Conclusions and Recommendations

5.1 Identify Additional Reference Sites

Reference sites were indeed different from urban and other disturbed sites; therefore, the six reference sites we chose were adequate for our purposes. However, Region 2 SWAMP needs to identify additional reference sites to better quantify what least-disturbed conditions are throughout the Region. In addition, sampling more reference sites will make the comparisons of reference conditions across important natural gradients possible in the SF Bay Area. It will also help us document how natural variation such as geography and stream type might influence stream biology, water chemistry, and physical habitat. We recommend sampling a total of 30 perennial and 30 non-perennial reference sites distributed spatially across the Bay Area to ensure an adequate reference network.

5.2 Develop Separate Biological Tools for Non-perennial and for Perennial Streams

We observed a significant separation of benthic macroinvertebrate (BMI) and algal (diatom) communities between perennial and non-perennial streams using ordination analysis. Furthermore, the BMI index of biological integrity (IBI) scores were often lower in the non-perennial streams, indicating that the biological differences in these streams can be interpreted as a less desirable condition. It is recommended to examine the need to develop separate interpretation/evaluation tools for biological data for the two types of streams.

5.3 Continue the Implementation of the SWAMP Protocols, IBI, and NNE Model

The SWAMP methodology used in this study provided a well-balanced suite of indicators, many of which proved to be very useful (i.e. relevant, responsive to stressors, and sensitive to environmental differences or change). These include many BMI metrics; IBIs; the Combined Human Disturbance Index; nutrients; water quality characteristics; and a variety of benthic algae cover characteristics. Beyond the use of established methods, we successfully implemented the new algae (periphyton) assessment protocols and its biomass indicators. Algae results were widely variable, and we still need to examine the applicability of the protocol, the metrics, and the biomass indicators to the conditions generated by all levels of disturbance in SF Bay Region streams. We recommend exploring how data collected using the SWAMP bioassessment protocol can be used to calculate predicted algae cover using the Tetra Tech (2006) Nutrient Numeric Endpoint (NNE) model.

5.4 Limit the Effects of Natural (Inherent) Variability on the Utility of Our Assessment Tools

Throughout this Report we have identified a number of ways in which natural variation can influence ambient monitoring data. Effective ways to reduce the inherent natural variability in monitoring data including the following: specifying short index periods (2 months); stratifying by stream type (perennial vs. non-perennial); following the same protocol (i.e., the SWAMP Bioassessment SOPs); and using highly trained and well-calibrated field crews (preferably the same personnel over time). If one of the study objectives is to track seasonal and annual changes over time, it is recommended to establish semi-permanent markers for the reach and its transects.

5.5 Detect Long-term Trends

There were no visible long-term trends in any of the characteristics monitored. Given the annual variability observed in this dataset, a monitoring period of 10-20 years may be required to detect significant long-term trends, if any are present. This dataset provides a good baseline for such continued monitoring. It is recommended to continue monitoring, at 5-year intervals, at the highest-quality reference sites (RDW080, PES162, IND200, COY610) for the following characteristic groups: BMI communities, algae communities and biomass, time-series dissolved oxygen, nutrients, and physical habitat.

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Appendices

To

THE REFERENCE SITE STUDY AND THE URBAN GRADIENT STUDY CONDUCTED IN SELECTED SAN FRANCISCO BAY REGION WATERSHEDS IN 2008-2010

(Years 8 to 10)

Final Report

June 15, 2012

SAN FRANCISCO BAY REGIONAL WATER QUALITY CONTROL BOARD

List of Appendix Tables

Table A-1: Summary of all monitoring activities performed in years 8-10 watersheds

Site Type	Watershed	Station	Site Name	Year	BMI Samples	Algae Samples	Full PHAB	Additional PHAB (associated with subsequent algae sampling)	Field Measurements and Habitat Observations	Water Nutrient Samples	Sonde Deployments	Total Duration of Sonde Deployments (weeks)	HOBO's Deployed at Site: Number of Instruments x Duration in Weeks
Intermittent-Reference	Coyote Creek	COY610	Coyote approx 1.5 miles upstream of Gilroy Hot Springs Rd. bridge	2008	1	1	1	1	3	1	1	6 (dry in June)	3 x 14
				2009	1	2	1	1	7	4	1	7 (dry in June)	3 x 20
				2010	1	1	1	0	4	1	1	6 (dry in July)	1 x 22
	Indian Creek	IND200	Indian approx 1.8 miles upstream of San Antonio Reservoir	2008	1	3	1	1	6	2	2	12 (dry in July)	3 x 13
				2009	1	2	1	1	9	4	2	13 (dry in July)	3 x 21
				2010	1	1	1	0	4	1	1	9 (dry in July)	1 x 24
	Mitchell Canyon	MTD117	Mitchell approx 250 m upstream of bridge at Mt. Diablo SP entrance	2008	1	1	1	0	3	1	1	2 (dry in May)	0
				2009	1	1	1	0	5	3	1	4 (dry in May)	0
				2010	1	1	1	0	3	1	1	7 (dry in July)	1 x 17
Perennial-Reference	Pescadero Creek	PES162	Pescadero approx 150 m upstream of Towne Fire Road crossing	2008	1	3	1	2	10	6	2	22	2 x 14*
				2009	1	3	1	2	13	6	2	23	1 x 21
				2010	1	1	1	0	6	1	1	17	1 x 17
	Redwood Creek	RDW080	Redwood at ped bridge in Frank Valley - approx 1 mile upstream of Hwy 1	2008	1	3	1	2	10	6	2	25	1 x 15
				2009	1	3	1	2	14	6	2	24	2 x 20
				2010	1	1	1	0	7	1	1	19	1 x 19
	Ritchie Creek	RIC100	Ritchie above gabion wall in Napa-Bothe State Park	2008	1	3	1	2	10	6	2	23	3 x 14
				2009	1	3	1	2	14	6	4	21	2 x 22
				2010	1	1	1	0	7	1	1	19	1 x 19**
Urban-Reference	Saratoga Creek	SAR057	Saratoga above Congress Springs Park	2008	1	0	partial	0	1	1	0	0	0
				2009	1	1	1	0	1	1	0	0	0
		SAR060	Saratoga behind Lutheran school - Saratoga Ave and Braemar	2008	1	0	partial	0	1	1	0	0	0
				2009	1	1	1	0	1	1	0	0	0
		SAR070	Saratoga inside SCVWD gate - below Walnut Ave	2008	1	0	partial	0	1	1	0	0	0
				2009	1	1	partial	0	1	1	0	0	0
		SAR080	Saratoga near Hakone Gardens	2008	1	0	partial	0	1	1	0	0	0
				2009	1	1	1	0	1	1	0	0	0
	Las Trampas Creek	WAL410	Las Trampas above dirt bike jumps	2008	1	0	partial	0	2	1	0	0	0
		WAL412	Las Trampas above St. Mary's Road bridge	2008	1	0	partial	0	3	1	0	0	0
		WAL415	Las Trampas below St. Mary's and Bollinger Canyon Roads	2008	1	0	partial	0	2	1	0	0	0
		WAL420	Las Trampas at 900 Bollinger Canyon Road	2008	1	0	partial	0	2	1	0	0	0

*Two HOBOs were deployed - one had been removed from the deployment site when Field Crew attempted to retrieve instruments.
** HOBO was retrieved, however no data was able to be recovered from instrument.

Table B-1: Inventory of Site-Visits for BMI sampling in years 2008-2010

2008

Station	Site Name	Date Sampled	Duplicate
COY610	Coyote approx 1.5 miles upstream of Gilroy Hot Springs Rd. bridge	4/30/2008	
IND200	Indian approx. 1.8 miles upstream of San Antonio Reservoir	4/29/2008	
MTD117	Mitchell approx 250 m upstream of bridge at Mt. Diablo SP entrance	5/6/2008	
PES162	Pescadero approx 150 m upstream of Towne Fire Road crossing	5/1/2008	
RDW080	Redwood at ped bridge in Frank Valley - approx 1 mile upstream of Hwy 1	5/7/2008	
RIC100	Ritchie above gabion wall in Napa-Bothe State Park	5/2/2008	
SAR057	Saratoga above Congress Springs Park	5/21/2008	
SAR060	Saratoga behind Lutheran school - Saratoga Ave and Braemar	5/21/2008	X
SAR070	Saratoga inside SCVWD gate - below Walnut Ave	5/21/2008	
SAR080	Saratoga near Hakone Gardens	5/21/2008	X
WAL410	Las Trampas above dirt bike jumps	5/8/2008	
WAL412	Las Trampas above St. Mary's Road bridge	5/8/2008	
WAL415	Las Trampas below St. Mary's and Bollinger Canyon Roads	5/8/2008	
WAL420	Las Trampas at 900 Bollinger Canyon Road	5/20/2008	

2009

Station	Site Name	Date Sampled	Duplicate
COY610	Coyote approx 1.5 miles upstream of Gilroy Hot Springs Rd. bridge	4/15/2009	
IND200	Indian approx. 1.8 miles upstream of San Antonio Reservoir	4/13/2009	
MTD117	Mitchell approx 250 m upstream of bridge at Mt. Diablo SP entrance	4/22/2009	
PES162	Pescadero approx 150 m upstream of Towne Fire Road crossing	4/27/2009	
RDW080	Redwood at ped bridge in Frank Valley - approx 1 mile upstream of Hwy 1	4/20/2009	X
RIC100	Ritchie above gabion wall in Napa-Bothe State Park	5/11/2009	
SAR057	Saratoga above Congress Springs Park	5/13/2009	
SAR060	Saratoga behind Lutheran school - Saratoga Ave and Braemar	5/13/2009	
SAR070	Saratoga inside SCVWD gate - below Walnut Ave	5/14/2009	
SAR080	Saratoga near Hakone Gardens	5/14/2009	

2010

Station	Site Name	Date Sampled	Duplicate
COY610	Coyote approx 1.5 miles upstream of Gilroy Hot Springs Rd. bridge	6/3/2010	X
IND200	Indian approx. 1.8 miles upstream of San Antonio Reservoir	5/25/2010	
MTD117	Mitchell approx 250 m upstream of bridge at Mt. Diablo SP entrance	5/24/2010	
PES162	Pescadero approx 150 m upstream of Towne Fire Road crossing	6/7/2010	
RDW080	Redwood at ped bridge in Frank Valley - approx 1 mile upstream of Hwy 1	6/2/2010	
RIC100	Ritchie above gabion wall in Napa-Bothe State Park	6/1/2010	

Table B-2: Summaries of BMI metrics and IBI scores in years 2008-2010 sites

Table B-2a: BMI Metrics and IBI scores calculated for reference sites in years 2008-2010

	COY610			IND200			MTD117			PES162			RDW080			RIC100		
Metric*	**4/30/08**	**4/15/09**	**6/3/10**	**4/29/08**	**4/13/09**	**5/25/10**	**5/6/08**	**4/22/09**	**5/24/10**	**5/1/08**	**4/27/09**	**6/7/10**	**5/7/08**	**4/20/09**	**6/2/10**	**5/2/08**	**5/11/09**	**6/1/10**
Coleoptera Taxa	4	3	0	3	5	6	1	1	0	4	3	3	7	4	7	3	4	2
Diptera Taxa	5	7	7	12	13	10	8	8	5	10	9	6	4	6	5	11	12	10
Ephemeroptera Taxa	9	10	5	5	10	6	5	6	3	13	10	11	6	9	5	11	11	5
Plecoptera Taxa	4	3	0	4	7	6	2	3	2	3	5	4	4	4	4	5	7	2
Trichoptera Taxa	2	5	3	9	5	5	2	3	4	10	12	9	8	5	9	8	8	6
Non-Insect Taxa	6	5	5	7	9	9	3	3	6	11	7	7	6	6	7	8	9	5
Taxa Richness	33	35	21	40	50	42	21	25	20	53	45	41	35	33	36	45	52	30
EPT Taxa	14	17	8	17	22	17	8	12	9	26	27	24	18	18	18	24	25	12
Abundance (#/Ft.^{2})	200	52	116	355	57	40	222	155	537	772	339	295	951	308	146	709	263	463
% EPT	68	43	7	50	39	27	43	39	13	62	51	76	30	23	50	32	31	24
% Sensitive EPT	7	15	1	29	15	14	26	29	1	18	19	23	15	12	33	13	15	16
% Chironomidae	16	8	35	11	23	26	49	53	79	8	20	5	40	61	12	55	57	50
% Oligochaeta	0	0	1	1	0	2	2	2	1	3	1	1	1	2	1	5	1	18
% Baetidae	12	10	1	6	18	12	15	8	10	9	9	27	4	4	8	6	4	4
% Simulidae	0	31	52	20	14	10	0	1	4	1	17	1	0	1	2	0	2	0
% COBS	28	49	89	38	55	50	66	64	94	21	47	34	45	68	23	66	64	72
% Intolerant	7	16	1	31	14	12	26	30	1	18	18	21	14	11	33	13	13	17
% Tolerant	19	13	2	1	4	23	2	1	1	6	2	4	2	1	2	3	2	2
Tolerance Value	5	5	6	3	4	6	5	4	6	4	4	4	5	5	4	5	5	5
% Predator	17	22	6	13	14	21	21	20	3	22	11	16	15	7	16	8	8	6
% Collector-filterer	0	31	54	21	15	11	0	1	4	2	19	2	0	1	3	1	3	1
%Collector-gatherer	50	31	39	32	52	42	76	75	91	61	58	49	56	76	29	71	66	75
% Scraper	33	15	0	33	17	22	2	2	1	14	8	29	22	12	330	5	7	1
% Shredder	0	1	0	1	2	3	0	1	0	1	4	3	7	5	23	3	7	8
% Other	0	0	1	0	0	1	1	1	1	0	0	1	0	0	0	12	9	9
North Coast IBI Score Minimum	58	66	24	71	71	71	51	58	25	64	56	64	74	54	80	56	62	50
North Coast IBI Score Maximum	64	72	29	78	79	71	61	64	31	68	62	68	80	61	84	60	66	56
North Coast IBI Score Arithmetic Mean	62	70	27	75	75	71	57	61	30	67	60	66	77	58	82	59	64	54
SoCal IBI Score Minimum	69	76	30	84	74	80	59	66	24	N/A	N/A	N/A	79	69	90	70	72	60
SoCal IBI Score Maximum	76	80	37	90	83	80	63	70	32	N/A	N/A	N/A	87	76	94	74	80	67
SoCal IBI Score Arithmetic Mean	73	78	34	88	81	80	61	68	28	N/A	N/A	N/A	86	74	93	72	77	64

* Metric definitions are provided with Table B-2b below

Table B-2: Summaries of BMI metrics and IBI scores in years 2008-2010 sites

Table B-2b: BMI Metrics and IBI scores calculated for urban sites in years 2008-2010

	SAR057		SAR060		SAR070		SAR080		WAL410	WAL412	WAL415	WAL420	Metric Definitions
Metric	5/21/08	5/13/09	5/21/08	5/13/09	5/21/08	5/14/09	5/21/08	5/14/09	5/8/08	5/8/08	5/8/08	5/20/08	
Coleoptera Taxa	2	1	3	3	5	3	3	4	1	N/A	4	3	Number of Coleoptera (beetle) taxa
Diptera Taxa	7	5	5	4	8	8	9	10	3	4	7	7	Number of Diptera (true fly) taxa
Ephemeroptera Taxa	4	8	4	7	7	9	7	13	2	4	4	6	Number of Epehemeroptera (mayfly) taxa
Plecoptera Taxa	N/A	N/A	2	N/A	N/A	3	2	3	1	N/A	1	3	Number of Plecoptera (stonefly) taxa
Trichoptera Taxa	1	1	4	7	3	N/A	5	7	1	1	3	N/A	Number of Trichoptera (caddisfly) taxa
Non-Insect Taxa	7	6	8	8	8	5	8	7	6	7	8	6	Number of non-insect taxa
Taxa Richness	22	21	28	28	33	29	37	43	15	16	29	24	Total number of invertebrate taxa
EPT Taxa	5	9	10	14	10	12	14	22	4	5	8	8	Number of Epehemeroptera, Plecoptera, and Trichoptera taxa
Abundance (#/Ft.^{2})	136	457	1033	637	980	151	251	142	327	1239	391	803	Estimated number of organisms collected per square foot
% EPT	3	30	19	51	31	36	50	38	14	9	15	25	Percent composition of Ephemeroptera, Plecoptera, and Trichoptera
% Sensitive EPT	1	2	4	3	2	3	20	18	1	0	2	5	Percent composition of EPT with tolerance values <3
% Chironomidae	51	55	34	30	43	51	20	24	27	54	44	60	Percent composition of Chironimidae (midges)
% Oligochaeta	20	5	13	1	6	1	6	1	12	15	20	4	Percent composition of Oligochaeta (worms)
% Baetidae	1	25	11	38	22	31	8	11	12	8	5	15	Percent composition of Baetis
% Simulidae	0	7	25	6	8	4	0	8	41	16	1	5	Percent composition of Simulium (black flies)
% COBS	72	92	83	75	79	87	34	44	52	93	70	84	Percent composition of Chironimidae, Oligochaeta, Baetis, and Simulium
% Intolerant	1	2	4	3	2	3	21	17	0	0	1	5	Percent of organisms with tolerance values <3
% Tolerant	14	3	3	5	3	2	6	3	3	1	6	5	Percent of organisms with tolerance values >7
Tolerance Value	6	6	6	6	6	6	4	4	6	6	6	6	Average tolerance value of all organisms
% Predator	3	1	4	7	4	4	10	10	1	2	14	4	Percent of organisms that feed on other organisms
% Collector-filterer	0	7	26	7	8	4	1	10	41	17	1	5	Percent of organisms that filter fine particulate organic matter
%Collector-gatherer	79	91	61	81	77	87	40	43	53	78	79	88	Percent of organisms that gather fine particulate organic matter
% Scraper	18	1	9	5	9	5	38	34	4	3	4	4	Percent of organisms that graze on periphyton
% Shredder	0	1	1	0	2	0	12	3	0	0	1	0	Percent of organisms that shred coarse particulate organic matter
% Other	0	0	0	0	0	0	0	0	1	0	1	0	Percent of organisms with other types of feeding
North Coast IBI Score Minimum	35	26	39	40	39	39	64	69	11	11	44	32	
North Coast IBI Score Maximum	40	31	44	44	44	46	66	74	18	20	48	40	
North Coast IBI Score Arithmetic Mean	37	29	42	43	42	42	65	72	16	19	46	37	
SoCal IBI Score Minimum	30	19	44	36	46	39	73	79	6	10	47	37	
SoCal IBI Score Maximum	36	32	50	42	56	54	79	84	11	17	53	52	
SoCal IBI Score Arithmetic Mean	33	25	47	39	50	47	75	83	10	13	51	47	

Table C-1: Inventory of Site-Visits for Algae sampling in years 2008-2010

2008

Station	Site Name	Date Sampled	Duplicate
COY610	Coyote approx 1.5 miles upstream of Gilroy Hot Springs Rd. bridge	4/30/2008 6/17/2008	
IND200	Indian approx. 1.8 miles upstream of San Antonio Reservoir	4/29/2008 5/20/2008 6/16/2008	X
MTD117	Mitchell approx 250 m upstream of bridge at Mt. Diablo SP entrance	5/6/2008	
PES162	Pescadero approx 150 m upstream of Towne Fire Road crossing	5/1/2008 6/18/2008 9/10/2008	 X
RDW080	Redwood at ped bridge in Frank Valley-approx 1 mile upstream of Hwy 1	5/7/2008 6/23/2008 8/12/2008	
RIC100	Ritchie above gabion wall in Napa-Bothe State Park	5/2/2008 6/19/2008 8/14/2008	

2009

Station	Site Name	Date Sampled	Duplicate
COY610	Coyote approx 1.5 miles upstream of Gilroy Hot Springs Rd. bridge	4/15/2009 6/8/2009	X
IND200	Indian approx. 1.8 miles upstream of San Antonio Reservoir	4/13/2009 6/11/2009	
MTD117	Mitchell approx 250 m upstream of bridge at Mt. Diablo SP entrance	4/22/2009	
PES162	Pescadero approx 150 m upstream of Towne Fire Road crossing	4/27/2009 6/16/2009 8/17/2009	
RDW080	Redwood at ped bridge in Frank Valley-approx 1 mile upstream of Hwy 1	4/20/2009 6/3/2009 8/11/2009	X
RIC100	Ritchie above gabion wall in Napa-Bothe State Park	5/11/2009 6/17/2009 8/12/2009	
SAR057	Saratoga above Congress Springs Park	5/13/2009	
SAR060	Saratoga behind Lutheran school - Saratoga Ave and Braemar	5/13/2009	
SAR070	Saratoga inside SCVWD gate - below Walnut Ave	5/14/2009	
SAR080	Saratoga near Hakone Gardens	5/14/2009	

2010

Station	Site Name	Date Sampled	Duplicate
COY610	Coyote approx 1.5 miles upstream of Gilroy Hot Springs Rd. bridge	6/3/2010	
IND200	Indian approx. 1.8 miles upstream of San Antonio Reservoir	5/25/2010	X
MTD117	Mitchell approx 250 m upstream of bridge at Mt. Diablo SP entrance	5/24/2010	
PES162	Pescadero approx 150 m upstream of Towne Fire Road crossing	6/7/2010	
RDW080	Redwood at ped bridge in Frank Valley-approx 1 mile upstream of Hwy 1	6/2/2010	
RIC100	Ritchie above gabion wall in Napa-Bothe State Park	6/1/2010	

Table C-2: Summaries of algae metrics in years 2008-2010 sites

Table C-2a: Algae metrics calculated for non-perennial reference sites in years 2008-2010

	COY610				IND200						MTD117		
	2008	2009		2010	2008			2009		2010	2008	2009	2010
Metric	April	April	June	June	April	May	June	April	June	May	May	April	May
Diatom Genera Richness	17	11	15	15	12	11	11	12	14	13	10	15	12
% Diatoms of Motile Genera	40.7	70.8	33.5	3.0	10.0	4.8	6.7	11.2	5.3	3.3	2.8	75.3	6.7
% Diatom of Motile Species	37.0	71.2	36.7	4.0	8.8	5.2	4.7	11.5	5.7	3.5	2.8	63.2	8.0
% Achnanthidium minutissimum	22.8	16.3	9.5	1.3	13.3	6.5	21.3	4.7	9.0	2.3	11.8	9.8	40.0
% Nitrogen Fixing Diatoms	0.2	0.0	41.5	77.8	0.0	0.0	0.0	0.0	0.0	3.0	0.0	0.7	0.0
Soft Algae Genera Richness	9	9	28	15	4	7	4	2	15	13	3	2	4
% Nitrogen Fixing Soft Algae	0.24	4.8	17.0	2.0	42.93	0.001	54.65	0.00	1.00	5.0	1.59	0.00	0.0001
Total Biovolume ($\mu m^3/cm^2$); x10^9	5.8	8.3	3.1	30.6	0.00005	1.4	0.00005	0.0000006	14.5	18.3	0.02	0.08	5.9

Metric Definitions	
Diatom Genera Richness-	The total number of diatom genera counted.
% Diatoms of Motile Genera-	The Percent of all diatoms counted that are classified as motile at the genus level.
% Diatom of Motile Species-	The Percent of all diatoms counted that are classified as motile at the species level.
% Achnanthidium minutissimum-	The Percent of all diatoms counted that are classified as Achnanthidium minutissimum.
% Nitrogen Fixing Diatoms-	The Percent of all diatoms counted that are classified as nitrogen fixing at the genus level.
Soft Algae Genera Richness-	The total number of soft algae genera observed, including genera identified during qualitative sampling.
% Nitrogen Fixing Soft Algae	The percentage of biovolume that belong to nitrogen fixing genera of soft algae.
Total Biovolume	The total volume of soft algae evaluated as $\mu m^3/cm^2$.

Table C-2: Summaries of algae metrics in years 2008-2010 sites

Table C-2b: Algae metrics calculated for perennial reference and urban sites in 2008-2010

	PES162						
	2008			2009			2010
Metric	May	June	Sept	April	June	Aug	June
Diatom Genera Richness	13	20	17	13	17	19	17
% Diatoms of Motile Genera	36.7	37.7	45.7	53.8	36.2	25.0	1.8
% Diatom of Motile Species	30.7	37.5	30.3	55.0	29.7	22.2	3.5
% Achnanthidium minutissimum	6.3	11.8	15.3	7.7	5.7	3.0	3.3
% Nitrogen Fixing Diatoms	0.0	0.8	1.8	0.0	2.0	11.7	67.8
Soft Algae Genera Richness	8	4	8	5	7	11	8
% Nitrogen Fixing Soft Algae	0.0	0.0	8.6	1.0	13.8	3.0	0.003
Total Biovolume ($\mu m^3/cm^2$); x10^9	4.3	0.00003	0.0004	2.9	0.0002	3.0	2.9

	RDW080						
	2008			2009			2010
Metric	May	June	Aug	April	June	Aug	June
Diatom Genera Richness	14	11	15	17	14	12	11
% Diatoms of Motile Genera	38.2	58.2	51.5	47.7	31.0	11.3	67.0
% Diatom of Motile Species	37.2	57.5	51.2	50.0	31.3	11.0	67.2
% Achnanthidium minutissimum	1.3	5.3	4.3	9.3	5.7	3.5	1.0
% Nitrogen Fixing Diatoms	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Soft Algae Genera Richness	5	10	13	13	5	7	8
% Nitrogen Fixing Soft Algae	30.3	0.008	0.004	0.001	0.0	0.0	34.3
Total Biovolume ($\mu m^3/cm^2$); x10^9	0.0003	2.9	3.0	2.9	0.0009	17.3	0.001

	RIC100							SAR057	SAR060	SAR070	SAR080
	2008			2009			2010	2009	2009	2009	2009
Metric	May	June	Aug	May	June	Aug	June	May	May	May	May
Diatom Genera Richness	18	19	18	18	18	24	13	9	15	10	10
% Diatoms of Motile Genera	12.0	37.0	27.3	24.3	52.0	30.7	12.2	44.7	52.0	59.3	60.5
% Diatom of Motile Species	12.0	25.8	26.3	27.5	46.0	34.7	11.8	44.7	51.5	58.8	60.7
% Achnanthidium minutissimum	6.3	12.7	12.5	7.0	7.8	4.0	1.7	5.8	2.7	2.7	2.0
% Nitrogen Fixing Diatoms	0.0	0.0	0.0	2.3	0.3	0.7	0.8	0.0	0.0	0.0	0.0
Soft Algae Genera Richness	7	5	11	14	16	17	20	6	6	5	8
% Nitrogen Fixing Soft Algae	0.0002	0.48	0.0004	1.0	1.4	0.0	0.003	2.24	0.00	0.00	20.30
Total Biovolume ($\mu m^3/cm^2$); x10^9	5.8	0.004	3.2	0.3	0.006	3.1	14.6	0.01	6.1	0.007	0.0007

Metric Definitions	
Diatom Genera Richness-	The total number of diatom genera counted.
% Diatoms of Motile Genera-	The Percent of all diatoms counted that are classified as motile at the genus level.
% Diatom of Motile Species-	The Percent of all diatoms counted that are classified as motile at the species level.
% Achnanthidium minutissimum-	The Percent of all diatoms counted that are classified as Achnanthidium minutissimum.
% Nitrogen Fixing Diatoms-	The Percent of all diatoms counted that are classified as nitrogen fixing at the genus level.
Soft Algae Genera Richness-	The total number of soft algae genera counted, including genera identified during qualitative sampling.
% Nitrogen Fixing Soft Algae	The percentage of biovolume that belong to nitrogen fixing genera of soft algae.
Total Biovolume	The total volume of soft algae evaluated as $\mu m^3/cm^2$.

Table D-1: Physical habitat characteristics assessed in years 2008-2010 Page 1 of 7

Station Type	Station	Date	Water surface gradient over Reach (%)	Slope variability (SD of % Slope)	Mean direction of reach flow (degrees)	Sinuosity	Average width of wetted channel (m)	Average water depth (cm)	flow discharge at sampling time (m^3/sec)	flow discharge at sampling time (**cfs**)	Dominant landuse /landcover	Evidence of fire	Evidence of recent rainfall	Channel conditions - estimated scores (out of 20)		
														Epifaunal Substrate/Available Cover	Sediment Deposition	Channel Alterations
I	COY610	30/Apr/2008					8.9	29.8	0.041	1.5	Forest	NO	NO			
I	COY610	17/Jun/2008	1.08	1.06	169	1.02					-	-	-	18	17	18
I	COY610	15/Apr/2009	0.51	0.80	170	1.01	9.1	28.0	0.091	3.2	Forest	NO	NO	17	18	19
I	COY610	08/Jun/2009					7.8	22.3			Forest	NO	NO			
I	COY610	03/Jun/2010	0.50	0.81	192	1.01	9.9	29.2	0.266	9.4	Forest	NO	NO	16	18	16
I	IND200	29/Apr/2008					3.2	12.9	0.015	0.5	Forest	NO	NO	19	18	20
I	IND200	16/Jun/2008	4.40	1.83	303	1.12	2.8	15.3	0.004	0.1	-	-	-			
I	IND200	13/Apr/2009	3.81	1.67	309	1.16	3.1	16.2	0.002	0.7	Rangeland	NO	NO	18	18	18
I	IND200	11/Jun/2009					4.1	11.9	0.002	0.1	Rangeland	NO	NO			
I	IND200	25/May/2010	4.53	2.46	278	1.35	4.2	13.0	0.035	1.2	Rangeland	NO	minimal	19	18	19
I	MTD117	06/May/2008					1.2	5.7			Forest	NO	NO	17	18	20
I	MTD117	08/Jan/2009	2.15	1.45	241	1.17					-	-	-			
I	MTD117	22/Apr/2009	2.35	1.53	239	1.18	1.5	4.4	0.014	0.5	Forest	NO	NO	16	16	18
I	MTD117	24/May/2010	2.45	1.28	253	1.19	2.2	8.8	0.000	0.0	Forest	NO	minimal	16	17	18
P	PES162	01/May/2008					8.9	22.4			Forest	NO	NO	18	12	17
P	PES162	18/Jun/2008	0.68	0.76	332	1.02	9.0	19.1			-	-	-			
P	PES162	10/Sep/2008					7.9				-	-	-			
P	PES162	27/Apr/2009	0.71	1.05	334	1.02	9.8	21.7	0.142	5.1	Forest	NO	NO	16	13	18
P	PES162	16/Jun/2009					8.8	20.6	0.014	0.5	Forest	NO	NO			
P	PES162	17/Aug/2009					8.1	21.2	0.033	1.2						
P	PES162	07/Jun/2010	0.36	1.00	350	1.03	9.3	25.8	0.129	4.5	Forest	NO	minimal	19	17	20
P	RDW080	07/May/2008					4.5	20.6			Forest	NO	NO	19	16	19
P	RDW080	23/Jun/2008	0.78	0.86	225	1.23	4.0	18.7	0.013	0.5						
P	RDW080	12/Aug/2008					5.0	19.5								
P	RDW080	08/Oct/2008					4.0	15.0								
P	RDW080	20/Apr/2009	0.65	0.77	214	1.22	4.8	15.5	0.042	1.5	Forest	NO	NO	18	16	16
P	RDW080	03/Jun/2009					5.1	14.7	0.025	0.9	Forest	NO	minimal			
P	RDW080	11/Aug/2009					3.9	13.1	0.009	0.3						
P	RDW080	02/Jun/2010	0.67	0.66	243	1.16	4.9	20.0	0.100	3.5	Forest	NO	minimal	19	18	19
P	RIC100	02/May/2008					3.7	9.5			Forest	NO	NO	17	18	16
P	RIC100	19/Jun/2008	3.03	2.58	56	1.04	3.0	7.5			-	-	-			
P	RIC100	14/Aug/2008					3.4	7.0			-	-	-			
P	RIC100	11/May/2009	2.87	1.60	55	1.01	3.9	10.9	0.012	0.4	Forest	NO	minimal	17	16	18
P	RIC100	17/Jun/2009					3.1	9.2	0.003	0.12	Forest	NO	NO			
P	RIC100	12/Aug/2009					2.8	7.1								
P	RIC100	01/Jun/2010	2.98	1.45	73	1.03	3.8	9.9	0.018	0.6	Forest	NO	minimal	17	18	14
U	SAR057	13/May/2009	0.59	0.58	7	1.02	3.7	8.2	0.016	0.6	Suburb/Town	NO	>10% flow increase	12	13	13
U	SAR060	13/May/2009	0.96	0.98	42	1.00	3.7	12.2	0.004	0.1	Suburb/Town	NO	>10% flow increase	14	14	12
U	SAR070	14/May/2009	1.45	1.54	126	2.028	5.0	25.8	0.038	1.4	Suburb/Town	NO	>10% flow increase	12	12	13
U	SAR080	14/May/2009	1.93	1.41	39	1.32	3.6	11.7	0.067	2.4	Forest	NO	>10% flow increase	16	16	15

Station	Date	Percent Stable Banks (%)	Percent Vulnerable Banks (%)	Percent Eroded Banks (%)	Average Bankfull Width (m)	Average Bankfull Height (m)		Flow habitat units distribution (% of total reach length)							% fast water hab	% slow water hab
							.	Cascades /falls	Rapids	Riffles	Runs	Glides	Pools	Dry channel	(Cas+Rap+ Rif+run)	(Glide+Pool)
COY610	30/Apr/2008	58	42	0				0	0	17	1	14	68	0	18	82
COY610	17/Jun/2008				17.2											
COY610	15/Apr/2009	36	59	5	21.2	1.4		0	0	22	6	57	15	0	28	72
COY610	08/Jun/2009							0	0	10	0	72	19	0	10	90
COY610	03/Jun/2010	73	27	0	14.9	0.3		0	0	29	0	47	25	0	29	72
IND200	29/Apr/2008	73	27	0	6.2	0.5		9	0	39	4	11	38	0	52	49
IND200	16/Jun/2008				7.4											
IND200	13/Apr/2009	23	73	5	8.6	0.7		5	12	27	42	6	9	0	85	15
IND200	11/Jun/2009							7	0	37	0	40	17	0	44	57
IND200	25/May/2010	77	18	5	8.0	0.4		5	2	51	9	7	18	9	67	25
MTD117	06/May/2008	27	55	18				0	0	42	0	10	41	8	42	51
MTD117	08/Jan/2009				5.8											
MTD117	22/Apr/2009	9	86	5	4.8	0.5		0	0	58	0	25	17	0	58	42
MTD117	24/May/2010	27	64	9	3.0	0.2		0	0	83	2	6	4	7	85	10
PES162	01/May/2008	50	41	9				0	9	16	10	25	41	0	35	66
PES162	18/Jun/2008				15.3	1.0		0	0	8	8	70	13	0	17	83
PES162	10/Sep/2008							0	0	20	0	71	10	0	20	81
PES162	27/Apr/2009	41	45	14	16.1	1.0		0	0	30	14	55	2	0	43	57
PES162	16/Jun/2009							0	11	20	20	40	10	0	51	50
PES162	17/Aug/2009							0	0	19	10	70	1	1	29	71
PES162	07/Jun/2010	18	82	0	13.3	0.4		0	3	34	4	50	7	3	41	57
RDW080	07/May/2008	36	36	27				0	0	24	0	13	63	0	24	76
RDW080	23/Jun/2008				7.8	0.5		0	0	15	0	48	37	0	15	85
RDW080	12/Aug/2008							0	0	21	0	48	32	0	21	80
RDW080	08/Oct/2008							0	0	31	0	25	44	0	31	69
RDW080	20/Apr/2009	9	91	0	9.2	0.6		0	0	21	1	56	22	0	22	78
RDW080	03/Jun/2009							0	0	29	5	52	16	0	33	67
RDW080	11/Aug/2009							0	0	14	0	66	18	3	14	84
RDW080	02/Jun/2010	23	73	5	7.2	0.3		0	0	35	3	38	20	5	38	58
RIC100	02/May/2008	27	50	23				0	0	51	0	17	33	0	51	50
RIC100	19/Jun/2008				6.1	0.4		0	0	35	0	52	14	0	35	66
RIC100	14/Aug/2008							0	0	52	0	36	13	0	52	49
RIC100	11/May/2009	0	100	0	6.8	1.1		6	0	27	43	14	11	0	76	25
RIC100	17/Jun/2009							1	0	51	1	44	5	0	52	49
RIC100	12/Aug/2009							0	0	46	0	44	8	3	46	52
RIC100	01/Jun/2010	45	41	14	6.7	0.4		0	1	64	19	11	5	1	83	16
SAR057	13/May/2009	0	59	41	8.5	0.7		0	0	36	43	16	5	0	79	21
SAR060	13/May/2009	27	50	23	6.8	0.8		1	0	25	23	40	12	0	49	51
SAR070	14/May/2009	9	77	14				5	2	25	43	16	10	0	74	26
SAR080	14/May/2009	14	73	14	9.2	0.8		3	0	49	29	19	1	0	81	19

Station	Date	Reach-wide substrate composition (percent, derived from 105 size-class determinations)							Reach-wide substrate composition (percent, derived from 105 size-class determinations) (continued)						number of size-class determinations (all classes)
		% Bedrock - smooth	% Bedrock - rough	% Concrete/asphalt	% Boulders- large (1000-4000mm)	% Boulders - small (250-1000mm)	% Cobble (64-250mm)	% Gravel - coarse (16-64mm)	% Gravel - fine (2-16mm)	% Sand (0.06-2mm)	% Fines (silts/clay/muck, <0.06mm)	% Hardpan	% Wood (any size)	% Other substrate	
COY610	30/Apr/2008	1	0	0	7	17	16	21	22	15	0	0	0	0	99
COY610	17/Jun/2008														
COY610	15/Apr/2009	0	0	0	10	12	17	25	18	15	2	0	0	0	105
COY610	08/Jun/2009	0	0	0	0	22	34	26	10	7	1	0	0	1	105
COY610	03/Jun/2010	1	1	0	1	12	20	30	22	13	1	0	0	0	104
IND200	29/Apr/2008	12	0	0	0	9	31	25	11	13	0	0	0	0	103
IND200	16/Jun/2008	4	0	0	2	11	33	23	15	10	3	0	0	0	103
IND200	13/Apr/2009	6	0	0	0	19	24	23	13	12	1	0	2	0	105
IND200	11/Jun/2009	10	0	0	0	18	38	28	3	2	0	0	2	0	105
IND200	25/May/2010	0	4	0	0	16	38	18	14	1	5	0	4	0	105
MTD117	06/May/2008	0	0	0	0	0	15	43	31	7	0	0	4	0	95
MTD117	08/Jan/2009														
MTD117	22/Apr/2009	0	0	0	0	1	9	53	21	8	3	0	6	0	105
MTD117	24/May/2010	0	0	0	0	0	15	45	26	2	9	0	4	0	105
PES162	01/May/2008	8	0	0	0	17	27	17	7	24	0	0	0	0	103
PES162	18/Jun/2008	3	0	0	0	0	33	18	0	39	6	0	0	0	33
PES162	10/Sep/2008														
PES162	27/Apr/2009	8	0	0	2	5	29	25	10	11	7	0	3	2	105
PES162	16/Jun/2009	8	0	0	0	7	44	14	4	18	3	0	3	0	105
PES162	17/Aug/2009	3	3	0	0	8	35	30	3	13	3	0	3	0	103
PES162	07/Jun/2010	3	4	0	0	15	21	17	15	21	3	0	1	0	105
RDW080	07/May/2008	0	1	0	0	0	10	45	24	19	0	0	1	0	104
RDW080	23/Jun/2008	1	0	0	0	0	13	38	21	19	4	0	4	0	100
RDW080	12/Aug/2008	0	0	0	0	0	7	41	13	18	15	0	7	0	96
RDW080	08/Oct/2008														
RDW080	20/Apr/2009	1	0	0	0	0	9	50	15	13	10	0	3	0	105
RDW080	03/Jun/2009	2	0	0	0	0	9	56	12	7	10	0	4	0	105
RDW080	11/Aug/2009	2	0	0	0	0	8	67	9	6	8	0	2	0	105
RDW080	02/Jun/2010	0	0	0	1	1	6	34	19	23	9	0	8	0	105
RIC100	02/May/2008	0	0	0	0	20	24	20	17	19	0	0	2	0	102
RIC100	19/Jun/2008	2	0	0	0	16	35	19	13	10	4	0	0	0	98
RIC100	14/Aug/2008	0	0	0	0	21	20	18	12	25	4	0	0	0	100
RIC100	11/May/2009	0	0	0	1	15	41	25	10	4	3	0	1	0	104
RIC100	17/Jun/2009	0	0	0	0	16	43	22	4	10	0	0	5	0	105
RIC100	12/Aug/2009	0	0	0	0	13	44	21	6	13	2	0	2	0	104
RIC100	01/Jun/2010	0	0	0	0	13	30	24	13	12	6	0	2	2	104
SAR057	13/May/2009	0	0	0	0	6	30	42	8	8	8	0	0	0	105
SAR060	13/May/2009	0	0	1	0	6	20	30	13	13	14	0	3	0	105
SAR070	14/May/2009														44
SAR080	14/May/2009	0	0	0	3	19	23	35	5	10	3	2	1	0	104

Table D-1: Physical habitat characteristics assessed in years 2008-2010

Station	Date	Percent Substrate as Bedrock	Percent Substrate larger than fine gravel (>16 mm)	Percent Substrate fine gravel or smaller (<16 mm)	Percent Substrate smaller than sand (<2 mm)	Geometric mean substrate diameter (Dgm)	Estimated geometric mean substrate diameter (mm)	total # of rock substrate class observations (n)	Geometric mean of particulate substrate size (mm)	total # of particle observations (n)	Median Particle size (measured)	total # of particle measurements (n)	Cobble embeddedness (%)	Embeddedness particle count (n)
							anti-log of LSUB_DMM		(boulders to fines)					
COY610	30/Apr/2008	1	63	37	15	36.9	39.8	99	44.0	98	28	104	39	41
COY610	17/Jun/2008													
COY610	15/Apr/2009	0	65	35	17	32.7	35.7	105	41.6	105	65	83	41	42
COY610	08/Jun/2009	0	82	17	8	56.6	71.2	104	74.4	104	90	73	38	43
COY610	03/Jun/2010	2	64	36	13	27.5	30.7	104	31.7	102	25	103	44	36
IND200	29/Apr/2008	12	77	23	13	61.9	70.8	103	41.9	91	45	93	33	41
IND200	16/Jun/2008	4	73	27	13	39.3	46.1	103	41.7	99	60	101	49	49
IND200	13/Apr/2009	6	71	27	13	45.5	60.3	103	45.8	97	70	87	35	41
IND200	11/Jun/2009	10	93	5	2	121.5	161.9	103	111.2	93	70	68	30	41
IND200	25/May/2010	4	76	20	6	45.7	67.9	101	60.0	97	85	97	44	49
MTD117	06/May/2008	0	58	38	7	15.6	17.3	91	23.1	91	20	91	39	14
MTD117	08/Jan/2009													
MTD117	22/Apr/2009	0	63	31	10	12.9	17.2	99	20.0	99	30	86	48	35
MTD117	24/May/2010	0	60	36	10	10.2	14.4	101	16.3	101	25	101	33	33
PES162	01/May/2008	8	69	31	24	42.9	52.5	103	33.2	95	55	97	40	47
PES162	18/Jun/2008	3	55	45	45	9.5	12.6	33	9.1	32	17	34	53	11
PES162	10/Sep/2008													
PES162	27/Apr/2009	8	68	28	18	24.3	38.0	100	24.1	92	50	84	46	36
PES162	16/Jun/2009	8	72	25	21	37.8	50.9	102	33.9	94	90	87	42	46
PES162	17/Aug/2009	6	79	18	16	38.1	53.0	100	38.8	94	70	87	35	35
PES162	07/Jun/2010	7	60	39	24	26.5	34.9	104	23.3	97	30	97	28	33
RDW080	07/May/2008	1	56	43	19	12.8	13.7	103	15.4	102	20	103	31	29
RDW080	23/Jun/2008	1	52	44	23	9.2	11.9	96	12.2	95	17.5	100	27	13
RDW080	12/Aug/2008	0	48	45	32	3.6	6.9	89	5.8	89	15	96	51	8
RDW080	08/Oct/2008													
RDW080	20/Apr/2009	1	59	38	23	7.6	11.5	102	10.5	101	25	94	34	34
RDW080	03/Jun/2009	2	67	30	17	9.4	15.3	101	12.9	99	30	81	28	34
RDW080	11/Aug/2009	2	76	22	13	13.8	20.4	103	17.7	101	35	85	25	8
RDW080	02/Jun/2010	0	42	50	31	4.6	7.3	97	7.1	97	12	96	12	26
RIC100	02/May/2008	0	63	35	19	28.3	35.2	100	37.1	100	45	103	38	45
RIC100	19/Jun/2008	2	72	28	14	36.0	45.5	98	42.3	96	60	103	30	52
RIC100	14/Aug/2008	0	59	41	29	18.8	25.5	100	23.3	100	27.5	104	38	42
RIC100	11/May/2009	0	83	16	7	50.7	63.0	103	68.7	103	100	94	40	62
RIC100	17/Jun/2009	0	81	14	10	50.2	69.8	100	74.1	100	90	73	30	47
RIC100	12/Aug/2009	0	78	20	14	39.2	49.3	102	52.3	102	110	91	29	47
RIC100	01/Jun/2010	0	66	30	17	20.1	29.8	100	30	100	40	101	35	34
SAR057	13/May/2009	0	77	23	15	20.2	27.4	105	27.3	105	42.5	94	48	38
SAR060	13/May/2009	0	56	41	28	6.6	12.7	102	10.5	101	30	87	48	37
SAR070	14/May/2009													
SAR080	14/May/2009	0	80	17	13	46.9	63.6	103	51.9	103	67.5	92	35	47

Table D-1: Physical habitat characteristics assessed in years 2008-2010

Station	Date	CPOM Presence frequency (%)	Micro-Algae Average Thickness (among all transect points)	Micro-Algae Average Thickness (only where detected)	Percent presence of a micro-algae layer (any thickness)	Percent points with a thick micro-algae layer (>1mm) among all points	Percent points with a thick micro-algae layer (>1mm) among micro-algae covered points	Macroalgae-Attached - Presence frequency among all points	Macrophytes Presence frequency among all points	Macroalgae-Unattached-Presence frequency among all points
COY610	30/Apr/2008	20	0.37	1.54	24		8	13	5	0
COY610	17/Jun/2008									
COY610	15/Apr/2009	45	0.14	0.33	43	0	0	25	20	2
COY610	08/Jun/2009	42	0.80	1.08	74	1	2	59	36	5
COY610	03/Jun/2010	26	0.12	0.23	52	0	0	55	14	0
IND200	29/Apr/2008	36	0.04	0.11	32		0	1	4	0
IND200	16/Jun/2008	27	0.06	0.16	39		0			
IND200	13/Apr/2009	33	0.02	0.07	25	0	0	0	3	0
IND200	11/Jun/2009	41	0.25	0.42	60	0	0	10	9	0
IND200	25/May/2010	51	0.09	0.19	48	0	0	29	19	0
MTD117	06/May/2008	35	0.15	0.44	35		3	4	1	0
MTD117	08/Jan/2009									
MTD117	22/Apr/2009	51	0.03	0.05	59	0	0	9	11	0
MTD117	24/May/2010	44	0.09	0.19	50	0	0	41	5	5
PES162	01/May/2008	24	0.13	0.34	39		0	4	6	0
PES162	18/Jun/2008	29	0.02	0.08	20		0	3	0	0
PES162	10/Sep/2008									
PES162	27/Apr/2009	50	0.06	0.09	64	0	0	10	22	0
PES162	16/Jun/2009	44	0.98	1.10	89	4	4	24	18	0
PES162	17/Aug/2009	49	0.34	0.52	64	0	0	26	23	0
PES162	07/Jun/2010	28	0.14	0.31	46	0	0	24	8	1
RDW080	07/May/2008	39	0.02	0.08	23		0	0	2	0
RDW080	23/Jun/2008	32	0.05	0.21	22		0	0	0	0
RDW080	12/Aug/2008	35	0.03	0.10	25		0	6	1	0
RDW080	08/Oct/2008									
RDW080	20/Apr/2009	59	0.03	0.07	46	0	0	9	15	1
RDW080	03/Jun/2009	55	0.16	0.20	79	0	0	5	6	0
RDW080	11/Aug/2009	62	0.14	0.26	54	0	0	17	8	0
RDW080	02/Jun/2010	53	0.05	0.17	32	0	0	3	7	0
RIC100	02/May/2008	38	0.25	0.86	29		3	4	2	0
RIC100	19/Jun/2008	34	0.05	0.16	32		0	3	0	1
RIC100	14/Aug/2008	38	0.09	0.29	30		0	8	6	0
RIC100	11/May/2009	64	0.11	0.19	58	0	0	13	13	0
RIC100	17/Jun/2009	53	3.37	3.98	85	21	25	17	0	7
RIC100	12/Aug/2009	57	3.65	5.34	68	25	37	10	3	1
RIC100	01/Jun/2010	58	0.93	1.86	50	4	8	7	8	1
SAR057	13/May/2009	66	0.12	0.13	92	0	0	13	1	0
SAR060	13/May/2009	58	0.23	0.26	88	0	0	6	13	0
SAR070	14/May/2009									
SAR080	14/May/2009	30	0.08	0.09	86	0	0	4	2	0

Table D-1: Physical habitat characteristics assessed in years 2008-2010 **Page 6 of 7**

Station	Date	Habitat & shelter value - percent cover of habitat elements (Average of numeric-range-categories mid-values from 11 Habitat Plots)										Shelter types present (count)	Natural shelter cover (sum LW, brush, overhang, boulders, undercut) (%)	Big shelters cover (sum LW, boulder, artificial, undercut) (%)
		Average Aquatic Macrophytes /Emergent Vegetation cover	Average Boulders cover	Average Filamentous Algae cover	Average Woody Debris >0.3m cover	Average Live tree roots cover	Average Overhanging vegetation cover	Average Woody Debris <0.3m cover	Average Undercut Banks cover	Average Artificial structures cover	.		[XFC_NAT]	new calculation
COY610	30/Apr/2008	8	12	23	0	1	7	3	3	0		7	25	15
COY610	17/Jun/2008													
COY610	15/Apr/2009	9	15	16	0	1	3	2	3	0		7	22	17
COY610	08/Jun/2009	27	27	27	1	4	22	3	1	0		8	53	29
COY610	03/Jun/2010	21	21	58	0	2	14	7	0	0		7	42	21
IND200	29/Apr/2008	9	24	3	0	4	1	3	2	0		8	31	27
IND200	16/Jun/2008	5		8								3		
IND200	13/Apr/2009	6	8	0	0	4	2	3	3	0		6	16	10
IND200	11/Jun/2009	17	24	14	1	18	9	6	1	0		8	41	26
IND200	25/May/2010	10	41	34	1	5	10	10	1	0		8	64	44
MTD117	06/May/2008	5	3	11	5	11	18	20	13	0		9	58	21
MTD117	08/Jan/2009													
MTD117	22/Apr/2009	5	0	2	8	7	10	34	6	0		8	58	15
MTD117	24/May/2010	9	2	48	7	5	28	22	3	0		8	61	15
PES162	01/May/2008	6	15	5	1	5	7	5	6	0		8	34	22
PES162	18/Jun/2008	4		13								2		
PES162	10/Sep/2008	5		10								3		
PES162	27/Apr/2009	10	16	0	5	23	35	12	29	0		7	98	50
PES162	16/Jun/2009	29	33	2	7	9	41	13	15	0		8	109	55
PES162	17/Aug/2009	15	16	0	4	6	23	4	11	0		8	58	31
PES162	07/Jun/2010	9	13	15	2	4	9	5	5	0		8	33	25
RDW080	07/May/2008	4	0	**1**	6	20	16	11	14	0		9	48	21
RDW080	23/Jun/2008	4		**4**										
RDW080	12/Aug/2008	7		**24**										
RDW080	08/Oct/2008	9		**42**										
RDW080	20/Apr/2009	5	0	4	10	27	13	14	33	0		9	70	43
RDW080	03/Jun/2009	10	0	5	8	24	24	21	29	0		8	81	37
RDW080	11/Aug/2009	13	0	26	6	15	14	12	14	0		8	46	20
RDW080	02/Jun/2010	4	0	2	3	4	17	20	8	0		8	48	19
RIC100	02/May/2008	3	5	3	1	9	4	4	4	1		9	19	12
RIC100	19/Jun/2008	1		3								2		
RIC100	14/Aug/2008	4		19								2		
RIC100	11/May/2009	3	14	11	0	30	15	14	7	0		8	50	21
RIC100	17/Jun/2009	3	41	34	1	7	12	16	3	8		9	73	53
RIC100	12/Aug/2009	4	31	25	1	9	8	12	1	1		9	55	35
RIC100	01/Jun/2010	8	41	28	0	11	10	14	2	0		9	68	46
SAR057	13/May/2009	5	2	0	2	3	18	6	5	0		8	33	9
SAR060	13/May/2009	6	2	9	0	36	36	8	26	8		8	72	35
SAR070	14/May/2009	2	15	10	2	14	20	13	14	26		9	65	57
SAR080	14/May/2009	1	31	0	0	33	3	6	10	8		9	51	49

Table D-1: Physical habitat characteristics assessed in years 2008-2010 Page 7 of 7

Station	Date	Average shade and canopy cover (%)	Bank vegetation percent cover on LB+RB, by cover type (Average of numeric-range-categories mid-values from11 Riparian Plots)					Riparian canopy presence (proportion of reach)		Human Disturbance Index by Activity (proximity-weighed index)														Combined Human Disturbance Index (all types)
		(densiometer)	Upper Canopy Trees and Saplings	Lower Canopy vegetation (0.5-5m)	Woody Shrubs Ground Cover	Herbs/ grasses Ground Cover	Barren, bare soil/duff Ground cover	.	.	Bridges/ Abutments	Buildings	Landfill/Trash	Logging operations	Mining activity	Orchard/Vineyard	Park/Lawn	Pasture/Range/ hayfield	Pavement/ Cleared lot	Pipes (Inlet/outlet)	Road/ Railroad	Row crops	Vegetation Management	Wall/rip-rap/Dam	W1_HALL
COY610	30/Apr/2008	25	37	23	19	27	44	1.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
COY610	17/Jun/2008																							
COY610	15/Apr/2009	39	12	19	24	16	29	0.98		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.24	0.00	0.00	0.00	0.27
COY610	08/Jun/2009	36																						
COY610	03/Jun/2010	40	22	36	23	34	64	1.00		0.00	0.00	0.15	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.33
IND200	29/Apr/2008	73	55	23	51	26	23	0.98		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IND200	16/Jun/2008																							
IND200	13/Apr/2009	92	33	33	27	49	19	1.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
IND200	11/Jun/2009	95																						
IND200	25/May/2010	97	49	26	36	19	46	1.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.18
MTD117	06/May/2008	61	29	32	36	40	27	0.77		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MTD117	08/Jan/2009																							
MTD117	22/Apr/2009	73	19	26	37	59	21	0.86		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
MTD117	24/May/2010	69	20	26	47	54	14	0.86		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.00	0.00	0.00	0.04
PES162	01/May/2008	81	60	25	39	11	43	1.00		0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.38	0.00	0.00	0.00	0.38
PES162	18/Jun/2008	85																						
PES162	10/Sep/2008	84																						
PES162	27/Apr/2009	82	44	40	39	35	47	1.00		0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.24	0.00	0.00	0.00	0.29
PES162	16/Jun/2009	89																						
PES162	17/Aug/2009	96																						
PES162	07/Jun/2010	82	55	43	31	37	46	1.00		0.00	0.00	0.03	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03
RDW080	07/May/2008	92	50	25	75	6	16	0.98		0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00	0.26
RDW080	23/Jun/2008	94																						
RDW080	12/Aug/2008	93																						
RDW080	08/Oct/2008																							
RDW080	20/Apr/2009	95	35	32	35	61	10	1.00		0.23	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.23
RDW080	03/Jun/2009	97																						
RDW080	11/Aug/2009	98																						
RDW080	02/Jun/2010	89	53	45	69	33	24	1.00		0.06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.00	0.00	0.08
RIC100	02/May/2008	82	46	28	24	10	27	1.00		0.00	0.00	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.91	0.71	0.00	0.00	0.07	1.87
RIC100	19/Jun/2008	93																						
RIC100	14/Aug/2008	93																						
RIC100	11/May/2009	94	23	45	48	21	43	1.00		0.00	0.00	0.24	0.00	0.00	0.00	0.00	0.00	0.00	1.02	0.33	0.00	0.00	0.00	1.59
RIC100	17/Jun/2009	97																						
RIC100	12/Aug/2009	96																						
RIC100	01/Jun/2010	92	56	55	43	31	27.00	1.00		0.00	0.00	0.05	0.00	0.00	0.00	0.00	0.00	0.00	0.39	0.20	0.00	0.00	0.00	0.64
SAR057	13/May/2009	95	40	29	30	64	29	1.00		0.00	0.67	0.14	0.00	0.00	0.00	0.09	0.00	0.00	0.05	0.67	0.00	0.00	0.91	2.52
SAR060	13/May/2009	88	42	29	63	25	34	0.91		0.00	0.55	0.00	0.00	0.00	0.00	0.39	0.00	0.00	0.05	0.06	0.00	0.00	1.73	2.77
SAR070	14/May/2009	94	36	35	54	26	39	0.98		0.00	0.24	0.23	0.00	0.00	0.00	0.09	0.00	0.00	0.14	0.00	0.00	0.00	0.68	1.38
SAR080	14/May/2009	97	44	32	28	14	60	1.00		0.23	0.00	1.46	0.00	0.00	0.00	0.00	0.00	0.00	0.09	0.36	0.00	0.00	0.18	2.32

Table D-2: Calculation information for physical habitat characteristics endpoints P. 1 of 3

Feature	Characteristic [Endpoint]	Components Aggregate for Endpoint	Max # of observations in aggregate (n)	Endpoint calculation protocol		Calculation comment
Flow-habitat type						
	(one of 7) habitat type Percent (of Reach)	Trans-Trans Interval	70	Cover, M. pers. comm.		Length-weighed average of all habitat typing sections (i.e., transect-to-transect intervals) evaluated in the reach
Habitat complexity						
	(one of 9) shelter element Average cover	Habitat Plots	11	Kaufmann et al 1999		Average of numeric-range-categories mid-values from all transect-based Plots. Note: The cover categories are given in codes (0 to 4), each corresponding to a numeric range category ("1" stands for 0-10% cover - mid-value is 5%; "2" stands for 10-40% - mid-value is 25%; etc.). Each observation was 'translated' to the mid-value and those 11 values were averaged.
	Big shelters cover (sum LW, boulder, artificial, undercut) (%)	Habitat Plots	44	Kaufmann et al 1999		Sum of percent-cover values of large shelter element cover. Note: this is a sum of the averages calculated for each of the characteristic above.
	Natural shelter cover (sum LW, brush, overhang, boulders, undercut) [XFC_NAT] (%)	Habitat Plots	55	Kaufmann et al 2000		Sum of percent-cover values of natural shelter element cover. Note: this is a sum of the averages calculated for each characteristic above.
	Shelter types present (count)	Habitat Plots	9	Cover, M. pers. comm.		Count of shelter element types present in the reach
Human Influence						
	(one of 14) Human Disturbance characteristic	Riparian plots & beyond	33	Kaufmann et al 1999		Proximity-weighed index based on presence or absence. Observed disturbances at each proximity level (CH, B&C, and P) were counted and expresses as a proportion of the total number of observations (i.e., 22). These proportions were than multiplied by a proximity factor (CH=1.5, B, C=1, P=0.667) and added up for the reach. (adding the proportions may be a modification from the language in Kaufmann et al 1999.
	Combined Human Disturbance Index (all characteristics)	Riparian plots & beyond	33x14			Sum of Proximity-weighed indices for all human-disturbance factors assessed (e.g., buildings, Pipes, etc.)
Notable Field Conditions						
	Dominant landuse/landcover	n/ap	n/ap	n/ap		(as observed in the field, no calculations)
	Evidence of fire	n/ap	n/ap	n/ap		(as observed in the field, no calculations)
	Evidence of recent rainfall	n/ap	n/ap	n/ap		(as observed in the field, no calculations)
Reach condition scores						
	Channel Alterations	n/ap	n/ap	Barbour et al 1999		Evaluative score, done in the field based on a list of criteria
	Epifaunal Substrate/Available Cover	n/ap	n/ap	Barbour et al 1999		Evaluative score, done in the field based on a list of criteria
	Sediment Deposition	n/ap	n/ap	Barbour et al 1999		Evaluative score, done in the field based on a list of criteria
Riparian Vegetation						
	(one of 5) Vegetation type Average cover (LB+RB)	Riparian Plots	22	Kaufmann et al 1999		Average of numeric-range-categories mid-values from all transect-based Plots. Note: The cover categories are given in codes (0 to 4), each corresponding to a numeric range category ("1" stands for 0-10% cover - mid-value is 5%; "2" stands for 10-40% - mid-value is 25%; etc.). Each observation was 'translated' to the mid-value and those 11 values were averaged.
	Riparian canopy presence (proportion of reach)	Riparian Plots	44	Kaufmann et al 1999		Proportion of riparian plots with any canopy present (Upper or Lower canopy, or both)
Shade & Canopy						
	Average Shade&Canopy cover (4 directions)	Mid-wet-channel points	44	Kaufmann et al 1999		Average of the percentages calculated for 44 observations (4 directions per transect).

Table D-2: Calculation information for physical habitat characteristics endpoints P. 2 of 3

Feature	Characteristic [Endpoint]	Components Aggregate for Endpoint	Max # of observations in aggregate (n)	Endpoint calculation protocol	Calculation comment
Slope					
	Centerline length weighed mean slope	Slope Sections	10	Kaufmann et al 1999	Length-weighed average of slope sections' percent slope; curvilinear length measurements were done on the Centerline
	Water surface gradient over Reach	Slope Sections	10		Sum of elevation increments expressed as percentage of total reach length
	Slope variability (SD of % Slope)	Slope Sections	10	Kaufmann et al 1999	Kaufmann's "Standard Deviation of water surface gradient (%)"; SD of all Slope sections' percent slope values
Stream Bearing					
	Mean direction of reach flow (degrees from magnetic N)	Bearing Segments	20	Kaufmann et al 1999	Length-weighted average of all bearing segments
	Sinuosity	Bearing Segments	20	Kaufmann et al 2000	Reach length divided by straight line distance between reach ends
Stream-Bank					
	Percent Eroded (or Vulnerable, or Stable) Banks	Bank-Plot	22	Cover, M. pers. comm.	The count of each bank stability category was expressed as a percentage of total number or observation
	Average Bankfull Height	Transect	11	Cover, M. pers. comm.	Average and SD of individual bankfull height measurements
	Average Bankfull Width	Transect	11	Cover, M. pers. comm.	Average and SD of individual bankfull width measurements
Wetted Channel					
	Average water depth (Without zeros)	Transect-Points	65 or var	Cover, M. pers. comm.	Average and SD of individual depth measurements that are different from zero.
	Average width of wetted channel	Transects	21	Kaufmann et al 1999	Average and SD of 21 width measurements
Flow					
	Flow Discharge (Q, ft)	Verticals	var	(traditional)	The channel cross-section was divided into small rectangles (with the Verticals in the centers), depth and velocity values were used to calculate volume per time for each rectangle, and the volumes per time were added up.
	Flow Discharge (Q, metric)	Verticals	var	(traditional)	The channel cross-section was divided into small rectangles (with the Verticals in the centers), depth and velocity values were used to calculate volume per time for each rectangle, and the volumes per time were added up.
Stream-bed substrate					
	(one of 13) substrate size class Percent (of Reach)	Transect-Points	105	Kaufmann P. pers. comm.	The count of each particle size class was expressed as a percentage of total particles assessed
	Percent Substrate as Bedrock	Transect-Points	105	Kaufmann P. pers. comm.	The percentages of rough and smooth bedrock were added up
	Percent Substrate fine gravel or smaller (<16 mm)	Transect-Points	105	Kaufmann P. pers. comm.	The percentages of all size fractions larger than 16 mm were added up
	Percent Substrate larger than fine gravel (>16 mm)	Transect-Points	105	Kaufmann P. pers. comm.	The percentages of all size fractions smaller than 16 mm were added up
	Percent Substrate smaller than sand (<2 mm)	Transect-Points	105	Kaufmann P. pers. comm.	The percentages of sand and fines were added up

Table D-2: Calculation information for physical habitat characteristics endpoints P. 3 of 3

Feature	Characteristic [Endpoint]	Components Aggregate for Endpoint	Max # of observations in aggregate (n)	Endpoint calculation protocol		Calculation comment
Stream-bed substrate (cont.)						
	Geometric mean substrate diameter (Dgm)	Transect-Points	105	Kaufmann P. pers. comm.		Each particle size class was assigned a nominal diameter equal to the geometric mean of its upper and lower bounds, the proportion of each size class was multiplied by the Log 10 of it nominal diameter, the products were added up, and the anti-log was derived to produce the Dgm. This calculation included only bedrock and unbound rocks (i.e., Wood, Concrete, and Other were excluded).
	mean diameter class (SUB_X)	Transect-Points	105	Kaufmann et al 1999		Each substrate size class was given a number between 1 and 6 (which is log-proportional to its size), and these numbers were averaged for the entire reach. All size classes except Wood and Other, were included . See Kaufmann et al 1999 page 42
	Estimated geometric mean substrate diameter (mm) (anti-log of LSUB_DMM)	Transect-Points	105	Kaufmann et al 1999		See Kaufmann et al 1999 page 42
	Geometric mean of particulate substrate size	Transect Points	105	(experimental endpoint)		Each size-class Result was assigned a number which is the log10 of the mid-value of that class's numeric range, these log products were averaged for all transect points (including inter-transects) in the reach, and the anti-log was derived from the average log. This calculation includes only unbound 'particulate rocks', i.e., Hardpan, Bedrock, Concrete, Wood, and Other were excluded.
	Median Particle size (measured)	Transect-points	105	(traditional)		Numeric Results from all transect points (including inter-transects) in the reach were used to calculate the median particle diameter (d50). SA and FN were given a value of **1** mm. This calculation includes only 'particulate rocks' i.e., hardpan, bedrock, concrete, wood, and Other were excluded.
	Average Cobble Embeddedness	Transect-Points	28	Cover, M. pers. comm.		Average and SD of individual cobble embeddedness estimated values
	CPOM Presence frequency (among all points)	Transect-points	105	Cover, M. pers. comm.		Present/Absence observations were used to calculate the percentage of Present; dry points were excluded
	Micro-Algae Average Thickness (among all transect points)	Transect Points	105	Cover, M. pers. comm.		Average of numeric-range-categories mid-values from all assessed transect-point, including D and UD which count as zero
	Micro-Algae Average Thickness (only where detected)	Transect Points	105	Cover, M. pers. comm.		Average of numeric-range-categories mid-values from all transect-point where algae code was >0
	Percent presence of a micro-algae layer (any thickness) among all points	Transect Points	105	Cover, M. pers. comm.		Number of wet points with any micro-algae detection (code1 and up), expressed as a percentage of all assessed transect points (including D and UD)
	Percent points with a thick micro-algae layer (>1mm) among all points	Transect Points	105	Cover, M. pers. comm.		Number of wet points with a thick micro-algae layer (definitely more than 1mm, i.e., >code3 in formula), expressed as a percentage of all assessed points (including D and UD)
	Percent points with a thick micro-algae layer (>1mm) among all micro-algae covered points	Transect Points	105	Cover, M. pers. comm.		Number of wet points with a thick micro-algae layer (definitely more than 1mm, i.e., >code3 in formula), expressed as a percentage of all wet micro-algae-covered points
	Macroalgae-Attached - Presence frequency among all points	Transect-point	105	Cover, M. pers. comm.		Number of points with observed attached Macro-filaments, expressed as a percentage of all transect points
	Macroalgae-Attached - Presence frequency among wet points	Transect-point	105	Cover, M. pers. comm.		Number of points with observed attached Macro-filaments, expressed as a percentage of all wet points
	Macroalgae-Unattached-Presence frequency among all points	Transect-points	105	Cover, M. pers. comm.		Number of points with UNattached Macro-filaments, expressed as a percentage of all points
	Macroalgae-Unattached-Presence frequency among wet points	Transect-points	105	Cover, M. pers. comm.		Presence/Absence observations were used to calculate the percentage of Present (these codes exclude all dry points)
	Macrophytes Presence frequency among all points	Transect-points	105	Cover, M. pers. comm.		Number of points with Macrophytes, expressed as a percentage of all assessed transect points

Table E-1: Water chemistry in years 2008-2010 samples and comparisons of total N, P to EPA benchmarks

Station ID	Date	Time	Phosphorus as P,Total mg/L	Ortho-Phosphate as P, Dissolved mg/L	Total N[1] (mg/L)	Nitrate + Nitrite as N (mg/L; DL=0.005)	Ammonia as N,Total (mg/L; DL=0.01)	Nitrogen, Total Kjeldahl (mg/L; DL=0.1)	Nitrite as N (mg/L; DL=0.002)	Nitrate as N (mg/L; DL=0.005)	Dissolved Organic Carbon mg/L	Silica as SiO2, Dissolved mg/L	Chloride mg/L	Alkalinity as CaCO3 mg/L	SSC[2] (mg/L; DL=2)
COY610	15/May/2008	14:45	0.0079	0.0137	0.145	ND	0.0055	0.145							
COY610	15/Apr/2009	15:13	0.0218	0.0133	0.193	ND	ND	0.193				13			
COY610	08/Jun/2009	13:00	0.008	0.0132	0.261		ND	0.261	ND	ND		11.4			
COY610	16/Dec/2009	15:10	0.0157	0.0102	0.5083		ND	0.495	ND	0.0133	7.11	12.8	8.55	135	
COY610	03/Jun/2010	13:00	0	0.0063	0.142		ND		ND	ND	2.33	7.64	12	186	ND
IND200	20/May/2008	11:45	0.0163	0.0204	0.0885	0.0065	0.0057	0.082 *							
IND200	16/Jun/2008	11:23	**0.0427**	0.0171	0.0747	0.0057	0.0105	0.069							
IND200	13/Apr/2009	12:20	0.0239	0.0184	0.11	ND	ND	0.11				12.2			
IND200	11/Jun/2009	12:17	0.0146	0.0172	0		ND	ND	ND	ND		13.6			
IND200	15/Dec/2009	11:45	0.0154	0.0149	0.182		ND	0.182	ND	ND	2.36	17	15.9	192	
IND200	25/May/2010	11:30	0.0077	**0.0386**	0.105		ND		ND	ND	1.7	13.7	10.5	158	ND
MTD117	22/Apr/2009	12:00	0.0131	0.0234	0	ND	ND	ND				24.6			
MTD117	15/Dec/2009	14:52	0.0148	**0.0319**	**0.699**		ND	0.433	ND	0.266	2.66	30	11.9	230	
MTD117	24/May/2010	11:00	0.0115	**0.0713**	0.0719		ND		ND	ND	2.04	26.3	10.1	216	ND
PES162	15/May/2008	11:00	**0.196**	**0.128**	0.101	ND	-0.005 ND	0.101							
PES162	18/Jun/2008	12:00	**0.152**	**0.147**	0.153	ND	0.0105	0.153							
PES162	10/Sep/2008	13:40	**0.18**	**0.167**	0.2106	0.0096	0.0154	0.201							
PES162	09/Oct/2008	13:19	**0.2**	**0.185**	0.1431	0.0061	ND	0.137							
PES162	11/Dec/2008	12:10	**0.165**	**0.147**	0.1441	0.0091	ND	0.135							
PES162	27/Apr/2009	11:30	**0.125**	**0.0978**	0.0083	0.0083	0.0191	ND				23.2			
PES162	16/Jun/2009	11:30	**0.133**	**0.133**	0.127		ND	0.127	ND	ND		23.9			
PES162	17/Aug/2009	13:25	**0.158**	**0.148**	0.252		0.0122	0.252	ND	ND	3.25	31.3	12.9	231	
PES162	05/Oct/2009	16:10	**0.173**	**0.164**	0.154		ND	0.154	ND	ND	3.44	26.2	76.2	255	
PES162	16/Dec/2009	11:00	**0.129**	**0.115**	0.2162		ND	0.208	ND	0.0082	4.48	27.8	22.7	172	
PES162	07/Jun/2010	12:00	**0.108**	**0.126**	0.147		ND		ND	ND	2.48	26	31.3	194	ND
RDW080	14/May/2008	9:00	0.0165	0.0281	0.1268	0.0418	0.0079	0.085							
RDW080	23/Jun/2008	10:35	**0.0313**	**0.0316**	0.0672	0.0672	0.0093	-0.05 ND							5.6
RDW080	12/Aug/2008	11:50	0.0275	**0.04**	0.0552	0.0552	ND	-0.05 ND							
RDW080	08/Oct/2008	15:10	**0.0301**	0.0276	0.0236	0.0236	ND	-0.05 ND							
RDW080	10/Dec/2008	10:58	0.0219	0.0202	0.0198	0.0198	ND	-0.05 ND							
RDW080	20/Apr/2009	13:30	**0.0305**	0.0244	0.1348	0.0308	ND	0.104				17.9			
RDW080	03/Jun/2009	12:15	0.0208	0.0236	0.3064		ND	0.277	ND	0.0294		18.5			
RDW080	11/Aug/2009	12:15	**0.0355**	**0.0323**	0.1383		0.0128	0.0977	ND	0.0406	1.4	21.7	11.4	92.1	3.9
RDW080	05/Oct/2009	12:45	0.0197	0.0211	0.0936		ND	0.065	ND	0.0286	1.2	19.5	14.1	91.3	
RDW080	14/Dec/2009	13:35	**0.0315**	0.022	**0.577**		ND	0.374	ND	0.203	4.4	18.1	16.4	83.4	
RDW080	02/Jun/2010	11:00	0.0222	0.0273	0.114		ND		ND	0.0378	1.03	22.7	15.5	87	ND

Table E-1: Water chemistry in years 2008-2010 samples and comparisons of total N, P to EPA benchmarks **Page 2 of 2**

Station ID	Date	Time		Phosphorus as P,Total mg/L	Ortho-Phosphate as P, Dissolved mg/L	Total N[1] (mg/L)	Nitrate + Nitrite as N (mg/L; DL=0.005)	Ammonia as N,Total (mg/L; DL=0.01)	Nitrogen, Total Kjeldahl (mg/L; DL=0.1)	Nitrite as N (mg/L; DL=0.002)	Nitrate as N (mg/L; DL=0.005)	Dissolved Organic Carbon mg/L	Silica as SiO2, Dissolved mg/L	Chloride mg/L	Alkalinity as CaCO3 mg/L	SSC[2] (mg/L; DL=2)
RIC100	14/May/2008	11:45		**0.098**	**0.129**	0.026	0.026	0.0089	-0.05 ND							
RIC100	19/Jun/2008	11:26		**0.125**	**0.135**	0.065	0.065	0.0124	-0.05 ND							
RIC100	14/Aug/2008	12:20		**0.107**	**0.181**	0.0374	0.0374	ND	-0.05 ND							
RIC100	08/Oct/2008	12:02		**0.134**	**0.139**	0.0096	0.0096	ND	-0.05 ND							
RIC100	10/Dec/2008	13:45		**0.11**	**0.104**	0.1	ND	ND	-0.05 ND							
RIC100	11/May/2009	13:30		**0.103**	**0.0744**	0.1892	0.0122	0.0114	0.177				64.2			
RIC100	17/Jun/2009	12:40		**0.087**	**0.102**	0.0154		ND	ND	ND	0.0154		67.9			
RIC100	12/Aug/2009	12:30		**0.096**	**0.136**	0.1839		ND	0.131	ND	0.0529	1.02	74.8	4.42	88	5.1
RIC100	05/Oct/2009	9:45		**0.0967**	**0.103**	0.0599		ND	0.0405	ND	0.0194	1.04	71	4.38	86.4	
RIC100	14/Dec/2009	9:45		**0.0982**	**0.112**	0.134		ND	0.134	ND	ND	4.14	63.8	5.55	81.6	
RIC100	01/Jun/2010	11:45		**0.0685**	**0.0951**	0.0814		0.0128		ND	0.0106	5.45	66	6.02	70.7	ND
SAR057	21/May/2008	11:45		**0.0519**	**0.0637**	**0.597**	0.418	0.0056	0.179							
SAR057	13/May/2009	12:00		**0.048**	**0.0526**	**0.552**		0.0241	0.154	ND	0.398		19.9			
SAR060	21/May/2008	11:30		**0.0603**	**0.0654**	**0.852**	0.462	0.0073	0.39							
SAR060	13/May/2009	13:30		**0.0558**	**0.0519**	**0.602**		0.0183	0.19	ND	0.412		20.1			
SAR070	21/May/2008	11:00		**0.0632**	**0.0734**	0.437	0.308	0.0072	0.129							2.3
SAR070	14/May/2009	11:30		**0.0537**	**0.0509**	0.324		ND	0.106	ND	0.218		19.2			
SAR080	21/May/2008	10:20		**0.0686**	**0.0801**	0.375	0.247	0.0057	0.128							
SAR080	14/May/2009	13:00		**0.0507**	**0.0565**	0.244		ND	0.123	ND	0.121		18			
WAL410	20/May/2008	16:00		**0.119**	**0.118**	0.214	ND	0.0085	0.214							5.6
WAL412	20/May/2008	15:20		**0.0946**	**0.102**	0.2629	0.0359	0.0083	0.227							
WAL415	20/May/2008	14:45		**0.203**	**0.183**	**0.686**	0.251	0.0341	0.435							6.8
WAL420	20/May/2008	14:15		**0.155**	**0.153**	0.457	0.209	0.0193	0.248							5.4

Notes

Note 1: Total N was calculated for 2008 and 2009. For 2010 analyses, WPCL used the new Lachat total digestion method, not calculation, to derive Total N values .

Note 2: SSC = Suspended Sediment Concentration mg/L

EPA Nutrient Ecoregion III, sub-region 6 benchmark for total nitrogen is 0.518 mg/L (exceedances shown in tan) and for total phosphorus is 0.03 mg/L (exceedances shown in yellow color)

* TKN Value of field replicate was used

Table E-2: Concentrations of benthic ash-free dry mass (AFDM) and chlorophyll *a* in years 2008-2010 samples

Station	Date	Chl a (mg/m^2)	AFDM (g/m^2)
COY610	30/Apr/2008	17.94	7.104
COY610	15/Apr/2009	22.71	12.136
COY610	08/Jun/2009	37.72	25.273
COY610	03/Jun/2010	34.38	8.679
IND200	29/Apr/2008	5.75	4.012
IND200	20/May/2008	3.89	2.742
IND200	16/Jun/2008	19.05	
IND200	13/Apr/2009	2.36	2.253
IND200	11/Jun/2009	**169.21**	22.955
IND200	25/May/2010	39.75	16.634
MTD117	06/May/2008	3.81	4.008
MTD117	22/Apr/2009	5.52	4.000
MTD117	24/May/2010	8.65	7.775
PES162	01/May/2008	9.28	6.288
PES162	18/Jun/2008	16.21	8.219
PES162	10/Sep/2008	48.92	11.948
PES162	27/Apr/2009	12.26	5.159
PES162	16/Jun/2009	42.10	10.419
PES162	17/Aug/2009	30.21	21.998
PES162	07/Jun/2010	10.83	
RDW080	07/May/2008	7.48	2.879
RDW080	23/Jun/2008	34.13	5.646
RDW080	12/Aug/2008	12.40	5.598
RDW080	29/Apr/2009	27.23	7.982
RDW080	03/Jun/2009	21.58	8.444
RDW080	11/Aug/2009	70.13	6.753
RDW080	02/Jun/2010	7.02	2.525
RIC100	02/May/2008	27.51	6.934
RIC100	19/Jun/2008	55.56	18.123
RIC100	14/Aug/2008	45.13	9.444
RIC100	11/May/2009	71.36	11.550
RIC100	17/Jun/2009	54.14	27.069
RIC100	12/Aug/2009	**100.53**	23.991
RIC100	01/Jun/2010	48.49	32.139
SAR057	13/May/2009	21.18	5.772
SAR060	13/May/2009	70.69	13.584
SAR070	14/May/2009	40.69	11.020
SAR080	14/May/2009	26.70	4.618

Shaded results indicate exceedance of Chlorophyll *a* BURC 1 (unimpaired COLD) benchmark (100 mg/m^2)

Table E-3: Field measurements and observations recorded in years 2008-2010

Table E-3a: Nutrient sampling site visits Page 1 of 2

Watershed	Station	Year	Season	Sample Date	Dissolved Oxygen (mg/L)	Oxygen Saturation (%)	pH	Specific Conductivity (µS/cm)	Temperature (°C)	Turbidity (NTU)
Coyote Creek	COY610	2008	Spring	5/15/2008	10.77		8.24	487	25.92	0.4
		2009	Spring	4/15/2009	10.88	101.5	8.22	464	12.17	-1.1
			Dry	6/8/2009	9.43	102.8	7.89	435	19.55	-3.2
			Wet	12/16/2009	11.23	98	8.36	348	9.32	0.6
		2010	Wet	3/1/2010	10.66	96.3	8.21	271	10.78	
			Spring	6/3/2010	10.16	112.4	8.22	465	20.18	~ 0
Indian Creek	IND200	2008	Spring	5/20/2008	9.29		8.14	330	14.66	-0.1
			Spring	6/16/2008	8.7	87.4	7.9	504	15.53	0.2
		2009	Spring	4/13/2009	10.65	94.2	8.28	28	9.95	-0.6
			Dry	6/11/2009	9.24	90.6	8.05	502	14.41	0.2
			Wet	12/15/2009	10.54	90.9	8.12	527	8.76	0.5
		2010	Wet	3/1/2010	11.12	97.7	8.18	231	9.59	
			Spring	5/25/2010	10.59	95.2	8.27	385	10.58	-1.6
Mitchell Canyon	MTD117	2009	Wet	2/23/2009	10.27	94.5	8.37	373	11.59	0
			Spring	4/22/2009	7.36	72.1	7.72	506	14.31	-0.5
			Wet	12/15/2009	9.75	90.3	8.11	537	11.84	0.7
		2010	Wet	2/23/2010	10.39	93.7	8.06	436	10.72	
			Spring	5/24/2010	9.66	90.7	8.23	476	12.42	-0.8
Pescadero Creek	PES162	2008	Spring	5/15/2008	10.06		8.26	679	14.69	0.1
			Spring	6/18/2008	10.74	109.3	8.34	737	16.13	-0.1
			Dry	9/10/2008	9.89	101.8	8.25	871	16.62	-0.1
			Dry	10/9/2008	10.1	95.6	8.24	876	12.76	-0.9
			Wet	12/11/2008	12.21	98	8.08	796	4.93	-1.1
		2009	Wet	2/10/2009	12.3	98.7	8.15	707	5.86	0.3
			Spring	4/27/2009	10.66	96.7	8.13	640	10.95	-1.1
			Dry	6/16/2009	9.81	97.9	8.22	714	15.22	0.6
			Dry	8/17/2009	10.75	99.2	8.23	791	15.79	-1
			Dry	10/5/2009	10.12	92.7	8.05	855	11.32	-1.4
			Wet	12/16/2009	11.72	100.4	8.35	585	8.55	2
		2010	Wet	3/9/2010	11.45	98.6	8.07	423	8.76	
			Spring	6/7/2010	9.39	96.1	8.33	613	16.38	-0.2
Redwood Creek	RDW080	2008	Spring	5/14/2008	9.38		7.48	230	11.82	0.3
			Spring	6/23/2008	8.36	79.6	7.5	235	13.09	0
			Dry	8/12/2008	7.38	71.6	7.42	243	13.97	1.9
			Dry	10/8/2008	7.59	74	7.43	244	14.28	-1.1
			Wet	12/10/2008	9.38	80.9	7.44	257	8.85	-1.1
		2009	Wet	2/11/2009	11.11	93.5	7.91	257	7.84	0.8
			Spring	4/20/2009	9.37	87	7.94	193	11.99	-1.4
			Dry	6/3/2009	9.99	94.4	7.72	219	12.76	1.9
			Dry	8/11/2009	7.97	78.3	7.41	237	14.5	-0.7
			Dry	10/5/2009	7.34	69.4	7.19	252	12.77	-1.4
			Wet	12/14/2009	10.57	93.4	7.74	240	9.87	5
		2010	Wet	2/22/2010	10.76	96.9	7.68	199	10.67	
			Spring	6/2/2010	9.85	92.7	7.59	224	12.6	-0.2
Ritchie Creek	RIC100	2008	Spring	5/14/2008	9.8		7.91	107	15.49	0.5
			Spring	6/19/2008	9.03	91.9	7.8	177	16.18	0
			Dry	8/14/2008	8.82	95.5	7.8	202	19.17	-0.1
			Dry	10/8/2008	9.74	95.6	7.93	195	14.49	-1
			Wet	12/10/2008	11.61	95.5	7.8	192	6.93	-0.9
		2009	Wet	2/11/2009	11.78	92.7	8.14	169	7.26	0.6
			Spring	5/11/2009	10.2	98.1	7.66	160	13.55	6
			Dry	6/17/2009	9.72	98.7	7.94	194	16.1	0.4
			Dry	8/12/2009	8.68	91.7	7.76	191	17.98	-0.7
			Dry	10/5/2009	9.83	88.7	7.6	193	10.78	-1.4
			Wet	12/14/2009	11.13	95.7	7.8	185	8.76	1.1
		2010	Wet	2/22/2010	11.05	97.8	7.81	145	9.95	
			Spring	6/1/2010	10.07	99	7.87	163	14.51	1.2
Saratoga Creek	SAR057	2008	Spring	5/21/2008	10.1	98.9	8.37	570	14.4	0.4
		2009	Spring	5/13/2009	10.66	102	8.46	482	13.29	
	SAR060	2008	Spring	5/21/2008	10.43		8.19	389	14.72	0.8
		2009	Spring	5/13/2009	10.54	104.2	8.24	518	14.8	
	SAR070	2008	Spring	5/21/2008	9.94		8.14	526	13.76	1.7
		2009	Spring	5/14/2009	10.12	96.2	8.02	457	13.04	
	SAR080	2008	Spring	5/21/2008	10.04		8.22	485	13.26	1.1
		2009	Spring	5/14/2009	10.16	97	8.16	401	13.2	
Las Trampas Creek	WAL410	2008	Spring	5/20/2008	11.16		8.02	964	19.53	1.1
	WAL412	2008	Spring	5/20/2008	7.35		7.97	600	17.55	0.3
	WAL415	2008	Spring	5/20/2008	8.11		7.72	979	15.56	3.8
	WAL420	2008	Spring	5/20/2008	8.65		8.06	857	18.59	4.6

Table E-3a: Nutrient sampling site visits Page 2 of 2

Station	Sample Date	Observed Flow	Water Clarity	Sky Code	Precipitation	Precipitation (last 24 hrs)	Stream Depth (m)	Stream Width (m)	Distance from Bank (m)
COY610	5/15/2008	1-5 cfs	Clear	Clear	None	None	0.5	7	3
	4/15/2009	0.1-1 cfs	Clear	Clear	None	None	0.3	6.5	2.5
	6/8/2009	0.1-1 cfs	Clear	Clear	None	None	0.15		
	12/16/2009	20-50 cfs	Clear	Partly Cloudy	None	<1 inch	0.39	10.2	5.5
	3/1/2010	5-20 cfs	Clear	Overcast	None	<1 inch	0.38	21.75	9.5
	6/3/2010	1-5 cfs	Clear	Clear	None	None	0.3	13.5	5
IND200	5/20/2008	1-5 cfs	Clear	Overcast	None	None	0.12	2.1	0.83
	6/16/2008	0.1-1 cfs	Clear	Clear	None	None	0.1	2.5	1.5
	4/13/2009	0.1-1 cfs	Clear	Clear	None	None	0.17	3.3	1
	6/11/2009	1-5 cfs	Clear	Overcast	None	None	0.13	3.2	1
	12/15/2009	1-5 cfs	Clear	Overcast	None	>1 inch	0.32	1.9	0.8
	3/1/2010	5-20 cfs	Clear	Partly Cloudy	None	<1 inch	0.37	3.8	2.9
	5/25/2010	5-20 cfs	Clear	Partly Cloudy	None	Unknown	0.15	2.2	0.8
MTD117	2/23/2009	1-5 cfs	Clear	Cloudy	Drizzle	>1 inch	0.23	3.3	
	4/22/2009	0.1-1 cfs	Clear	Clear	None	None	0.28	2.5	1.25
	12/15/2009	1-5 cfs	Clear	Overcast	None	>1 inch	0.25	2.8	1.7
	2/23/2010	1-5 cfs	Clear	Overcast	Drizzle	<1 inch	0.18	1.6	1.3
	5/24/2010	1-5 cfs	Clear	Overcast	Drizzle	<1 inch	0.22	1.2	0.7
PES162	5/15/2008	1-5 cfs	Clear	Partly Cloudy	None	None	0.7	6	2
	6/18/2008	1-5 cfs	Clear	Clear	None	None	0.15	10	10
	9/10/2008	1-5 cfs	Clear	Clear	None	None	0.25	11.2	3
	10/9/2008	1-5 cfs	Clear	Clear	None	None	0.18	14	5
	12/11/2008	1-5 cfs	Clear	Clear	None	None	0.4	4	2
	2/10/2009	5-20 cfs	Clear	Partly Cloudy	None	<1 inch		5	
	4/27/2009	1-5 cfs	Clear	Overcast	None	None	0.24	9	4
	6/16/2009	1-5 cfs	Clear	Overcast	None	None	0.3	10	3
	8/17/2009	1-5 cfs	Clear	Fog	Fog	None	0.27	5.9	2
	10/5/2009	1-5 cfs	Clear	Clear	None	None	0.27	6.1	4
	12/16/2009	5-20 cfs	Clear	Overcast	Rain	<1 inch	0.34	7	4.6
	3/9/2010	20-50 cfs	Cloudy	Clear	None	<1 inch	0.39	10	10
	6/7/2010	5-20 cfs	Clear	Overcast, Fog	None	Unknown	0.41	8	6.2
RDW080	5/14/2008	1-5 cfs	Clear	Clear	None	None	0.3	2	1.5
	6/23/2008	1-5 cfs	Clear	Overcast	None	None	0.22	3	1.5
	8/12/2008	0.1-1 cfs	Clear	Overcast, Fog	None	None	0.27	4	2
	10/8/2008	0.1-1 cfs	Clear	Clear	None	None			
	12/10/2008	0.1-1 cfs	Clear	Clear	None	None	0.2	1	0.5
	2/11/2009	5-20 cfs	Clear	Overcast	Rain	<1 inch	0.23	4.5	2
	4/20/2009	0.1-1 cfs	Clear	Clear	None	None	0.13	2.8	1.6
	6/3/2009	1-5 cfs	Clear	Partly Cloudy	Rain	Unknown	0.37	4.7	3
	8/11/2009	0.1-1 cfs	Clear	Fog	Fog	None	0.29	4.4	2.3
	10/5/2009	0.1-1 cfs	Clear	Clear	None	None	0.19	4.7	2.7
	12/14/2009	5-20 cfs	Cloudy	Overcast			0.31	3.65	1.3
	2/22/2010	5-20 cfs	Clear	Clear	None	<1 inch	0.31	5.4	3.4
	6/2/2010	5-20 cfs	Clear	Overcast	None	Unknown	0.26	3.1	1.5
RIC100	5/14/2008	1-5 cfs	Clear	Partly Cloudy	None	None	0.1	3	1
	6/19/2008	0.1-1 cfs	Clear	Clear	None	None	0.14	2	0.2
	8/14/2008	0.1-1 cfs	Clear	Clear	None	None			
	10/8/2008	0.1-1 cfs	Clear	Clear	None	None	0.25	2.5	2
	12/10/2008	0.1-1 cfs	Clear	Clear	None	None	0.2	0.8	0.5
	2/11/2009		Clear	Overcast	Rain	<1 inch	0.28	2.4	0.8
	5/11/2009	1-5 cfs	Clear	Partly Cloudy	None	None	0.1	3	0.5
	6/17/2009	0.1-1 cfs	Clear	Clear	None	None		1.6	0.7
	8/12/2009	0.1-1 cfs	Clear	Clear	None	None	0.21	1.5	0.5
	10/5/2009	0.1-1 cfs	Clear	Hazey	None	None	0.24	3.3	2.8
	12/14/2009	1-5 cfs	Clear	Fog	Fog	<1 inch	0.23	1.85	1.1
	2/22/2010	5-20 cfs	Clear	Clear	None	<1 inch	0.2	3.3	1.8
	6/1/2010	1-5 cfs	Clear	Partly Cloudy	None	None	0.27	3.2	1.2
SAR057	5/21/2008	1-5 cfs	Clear	Clear	None	None			
	5/13/2009	1-5 cfs	Clear	Partly Cloudy	None	None	0.2	2.5	1.5
SAR060	5/21/2008	1-5 cfs	Clear	Clear	None	None	0.15	3	1.5
	5/13/2009	1-5 cfs	Clear	Overcast	None	None	0.12	3	1.5
SAR070	5/21/2008	1-5 cfs	Clear	Clear	None	None	0.335	4	0.25
	5/14/2009	1-5 cfs	Clear	Clear	None	None	0.4	4.5	2.5
SAR080	5/21/2008	1-5 cfs	Clear	Clear	None	None	0.75	2.5	0.5
	5/14/2009	1-5 cfs	Clear	Clear	None	None		4	3
WAL410	5/20/2008	0.1-1 cfs	Clear	Clear	None	None	0.5	2	0.3
WAL412	5/20/2008	0.1-1 cfs	Clear	Clear	None	None	0.15	1	0.5
WAL415	5/20/2008	0.1-1 cfs	Cloudy	Clear	None	None	0.2	1.5	0.5
WAL420	5/20/2008	0.1-1 cfs	Clear	Clear	None	None	0.15	1.5	0.75

Table E-3: Field measurements and observations recorded in years 2008-2010

Table E-3b: Sonde Deployment/retrieval site visits   Page 1 of 2

Watershed	Station	Year	Deployment - Retrieval Dates	Dissolved Oxygen (mg/L)	Oxygen Saturation (%)	pH	Specific Conductivity (µS/cm)	Temperature (°C)	Turbidity (NTU)	Observed Flow
Coyote Creek	COY610	2008	4/30/2008	10.62	106.2	8.22	537	15.35	0.1	1-5 cfs
			6/17/2008							Dry Waterbody Bed
		2009	4/16/2009	10.88	99.4	7.86	464	11.25	0.5	1-5 cfs
			6/8/2009	10.47	127.9	8.23	559	25.38	-1.4	0.1-1 cfs
		2010	6/4/2010	9.02	98.2	8.01	533	19.41	-0.9	1-5 cfs
			7/13/2010	9.02	116.3	8.46	656	28.41	-1.2	0.1-1 cfs
Indian Creek	IND200	2008	4/29/2008	10.37	96.1	8.31	410	11.85	0.3	1-5 cfs
			7/22/2008							Isolated Pool
		2009	4/14/2009	10.97	96.4	8.23	394	9.63	2.4	0.1-1 cfs
			7/14/2009							Dry Waterbody Bed
		2010	5/25/2010	10.33	95.3	8.3	379	11.67	3.1	5-20 cfs
			7/28/2010	9.06	91.4	8.3	538	15.75	1.16	0.1-1 cfs
Mitchell Canyon	MTD117	2008	5/6/2008	5.26	50.9	7.61	536	13.86	0.8	0.1-1 cfs
			5/28/2008							Dry Waterbody Bed
		2009	4/22/2009	7.36	72.1	7.72	506	14.31	-0.5	0.1-1 cfs
			5/18/2009	1.44	14.4	7.56	558	15.53	-0.3	Isolated Pool
		2010	5/24/2010	9.26	88.4	8.19	465	13.19	2.8	1-5 cfs
			7/9/2010	0.5	5.1	7.4	588	16.7		Isolated Pool
Pescadero Creek	PES162	2008	5/1/2008	11.12	100.2	5.32	669	10.63	6.5	1-5 cfs
			10/28/2008							0.1-1 cfs
		2009	4/27/2009	10.66		8.14	640	10.95	-1.1	1-5 cfs
			10/5/2009	10.45	95.7	8.33	870	11.32	1.5	1-5 cfs
		2010	6/7/2010	9.66	99.7	8.45	605	16.81	3.8	5-20 cfs
			10/7/2010	9.83	92.4	8.6	733	12.56	2.9	1-5 cfs
Redwood Creek	RDW080	2008	5/7/2008	9.52	88.8	7.59	230	12.19	2.7	1-5 cfs
			10/30/2008							0.1-1 cfs
		2009	4/21/2009	9.41	88.8	7.76	227	12.77	3.5	0.1-1 cfs
			10/9/2009	7.77	72.7	7.48	248	12.31	-1	1-5 cfs
		2010	6/2/2010	9.83	94.5	7.67	219	13.54	4.3	1-5 cfs
			10/15/2010	8.04	76.8	7.54	257	13.22	1.9	0.1-1 cfs
Ritchie Creek	RIC100	2008	5/4/2008	10.18	99	7.99	177	14.09	3.8	1-5 cfs
			10/30/2008							0.1-1 cfs
		2009	5/11/2009	10.2	98.1	7.66	160	13.55	6	1-5 cfs
			10/5/2009	10	90.1	7.73	192	10.7	1.7	0.1-1 cfs
		2010	6/1/2010	9.38	94.7	7.8	164	16.67	8.8	1-5 cfs
			10/5/2010	9.72	96.4	7.92	194	14.96	3.3	0.1-1 cfs

Table E-3b: Sonde Deployment/retrieval site visits   Page 2 of 2

Station	Deployment - Retrieval Dates	Water Clarity	Sky Code	Precipitation	Precipitation (last 24 hrs)	Hydromodification	Hydromodification Location	Stream Depth (m)	Stream Width (m)	Distance from Bank (m)
COY610	4/30/2008	Clear	Clear	None	None	Pipes	US	0.08	5.9	1
	6/17/2008	NA	Clear	None	None	Culvert	US	0	0	NA
	4/16/2009	Clear	Clear	None	None	Culvert	US	0.3	4.5	2.5
	6/8/2009	Clear	Clear	None	None	Culvert	US	0.15	4	2
	6/4/2010	Clear	Clear	None	None	None	NA	0.21	12	4
	7/13/2010	Clear	Clear	None	None	Culvert	US	0.09	4	0.58
IND200	4/29/2008	Clear	Partly Cloudy	None	None	None	NA	0.25	2	0.1
	7/22/2008	Clear	Clear	None	None	None	NA	0.29	2.1	1
	4/14/2009	Clear	Overcast	None	None	None	NA	0.29	1.85	0.35
	7/14/2009	NA	Clear	None	None	None	NA	NA	NA	NA
	5/25/2010	Clear	Overcast	Rain	<1 inch	None	NA	0.34	1.5	0.3
	7/28/2010	Clear	Clear	None	None	None	NA	0.22	1	0.5
MTD117	5/6/2008	Clear	Clear	None	None	None	NA	0.3	1.5	0.3
	5/28/2008	NA	Partly Cloudy	None	None	None	NA	NA	NA	NA
	4/22/2009	Clear	Clear	None	None	None	NA	0.28	2.5	1.25
	5/18/2009	Clear	Clear	None	None	None	NA	0.24	2.5	0.5
	5/24/2010	Clear	Overcast	Drizzle	<1 inch	None	NA	0.29	2.5	0.5
	7/9/2010	Clear	Clear	None	None	None	NA	0.18	2	0.2
PES162	5/1/2008	Clear	Clear	None	None	None	NA	0.35	8.5	1.7
	10/28/2008	Clear	Clear	None	Unknown	None	NA	0.39	8	7
	4/27/2009	Clear	Overcast	None	None	None	NA	0.42	5	1
	10/5/2009	Clear	Clear	None	None	None	NA	0.29	7.2	1.5
	6/7/2010	Clear	Overcast	None	Unknown	None	NA	0.48	8	1.5
	10/7/2010	Clear	Clear	None	None	None	NA	0.29	6.75	1.5
RDW080	5/7/2008	Clear	Clear	None	None	Bridge	DS	0.4	4.5	3
	10/30/2008	Clear	Overcast	Rain	<1 inch	Bridge	DS	0.315	4	3
	4/21/2009	Clear	Clear	None	None	Bridge	DS	0.3	4	3
	10/9/2009	Clear	Fog	Fog	None	Bridge	DS	0.32	3.7	3
	6/2/2010	Clear	Partly Cloudy	None	None	Bridge	DS	0.37	3.8	0.2
	10/15/2010	Clear	Overcast	None	None	Bridge	DS	0.28	4.8	2.5
RIC100	5/4/2008	Clear	Hazy	None	None	Pipes	US, DS	0.3	3.5	
	10/30/2008	Clear	Overcast	Drizzle	None	Pipes	US, DS	0.2	1.4	0.75
	5/11/2009	Clear	Clear	None	None	Pipes	DS		2.5	1.5
	10/5/2009	Clear	Hazy	None	None	Pipes	US	0.35	2.3	1.3
	6/1/2010	Clear	Clear	None	None	Pipes	Channel	0.27	4	1.5
	10/5/2010	Clear	Clear	None	None	Pipes	US	0.22	3	1

Table E-3: Field measurements and observations recorded in years 2008-2010

Table E-3c: HoboTemp Deployment/retrieval site visits Page 1 of 2

Watershed	Station	Year	Number of Instruments Deployed	Instrument Location	Deployment - Retrieval Dates	Dissolved Oxygen (mg/L)	Oxygen Saturation (%)	pH	Specific Conductance (µS/cm)	Temperature (°C)	Turbidity (NTU)	Observed Flow
Coyote Creek	COY610	2008	3	Deep Pool at Transect K - vertically through water column	7/15/2008							Isolated Pool
					10/22/2010							Isolated Pool
		2009	3	Deep Pool at Transect K - vertically through water column	5/22/2009							0.1-1 cfs
					10/9/2009							Isolated Pool
		2010	1	Deep Pool at Transect K	6/4/2010	9.02	98.2	8.01	533	19.41	-0.9	1-5 cfs
					11/9/2010							Isolated Pool
Indian Creek	IND200	2008	3	Pool DS of Transect J	7/22/2008							Isolated Pool
					10/20/2008							Isolated Pool
				Pool DS of Transect K	7/22/2008							Isolated Pool
					10/20/2008							Isolated Pool
				Pool at Transect K	7/22/2008							Isolated Pool
					10/20/2008							Isolated Pool
		2009	3	Pool DS of Transect K	5/18/2009	10.02	102.2	8.36	446	16.25	2.7	0.1-1 cfs
					10/9/2009							Isolated Pool
				Pool ~4m US of Transect K	5/18/2009	10.02	102.2	8.36	446	16.25	2.7	0.1-1 cfs
					10/9/2009							Isolated Pool
				Pool ~8m US of Transect K	5/18/2009	10.02	102.2	8.36	446	16.25	2.7	0.1-1 cfs
					10/9/2009							Isolated Pool
		2010	1	Pool at Transect K	5/25/2010	10.33	95.3	8.3	379	11.67	3.1	5-20 cfs
					11/9/2010	5.11	45.6	7.64	876	10.16	2.5	0.1-1 cfs
Mitchell Canyon	MTD117	2010	1	Pool between InterTransect FG and Transect G	5/24/2010	9.26	88.4	8.19	465	13.19	2.8	1-5 cfs
					7/16/2010							Dry Waterbody Bed
Pescadero Creek	PES162	2008	2	Deep glide US of Transect A	7/23/2008							0.1-1 cfs
					10/28/2008							0.1-1 cfs
				Pool at Transect K	7/23/2008							0.1-1 cfs
					NA*							0.1-1 cfs
		2009	1	Pool at Transect K	5/21/2009	10.66	102	8.39	673	13.29	-0.4	1-5 cfs
					10/12/2009							1-5 cfs
		2010	1	Pool at Transect K	6/7/2010							5-20 cfs
					10/7/2010	9.83	92.4	8.6	733	12.56	2.9	1-5 cfs
Redwood Creek	RDW080	2008	1	Pool at Transect B	7/17/2008							0.1-1 cfs
					10/30/2008							0.1-1 cfs
		2009	2	Pool US of InterTransect AB	5/26/2009							1-5 cfs
					10/9/2009	7.77	72.7	7.48	248	12.31	-1	1-5 cfs
				Pool ~2m DS of Transect K	5/26/2009							1-5 cfs
					10/9/2009	7.77	72.7	7.48	248	12.31	-1	1-5 cfs
		2010	1	Pool at Transect D	6/2/2010	9.83	94.5	7.67	219	13.54	4.3	1-5 cfs
					10/15/2010	8.05	76.8	7.54	257	13.22	1.9	0.1-1 cfs
Ritchie Creek	RIC100	2008	3	US of Transect K	7/21/2008							0.1-1 cfs
					10/30/2008							0.1-1 cfs
				US of Transect G	7/21/2008							0.1-1 cfs
					10/30/2008							0.1-1 cfs
				DS of Transect A	7/21/2008							0.1-1 cfs
					10/30/2008							0.1-1 cfs
		2009	2	US of InterTransect AB	5/12/2009							1-5 cfs
					10/9/2009	10.15	93.8	7.8	190	11.79	2.1	0.1-1 cfs
				At Transect K	5/12/2009							1-5 cfs
					10/9/2009	10.15	93.8	7.8	190	11.79	2.1	0.1-1 cfs
		2010	1	Pool at InterTransect AB	6/1/2010	9.38	94.7	7.8	164	16.67	8.8	1-5 cfs
					10/15/2010	9.72	96.4	7.92	194	14.96	3.3	0.1-1 cfs

* HOBO was removed from site during deployment. Field crew was unable to recover lost HOBO.

Table E-3c: HoboTemp Deployment/retrieval site visits Page 2 of 2

Station	Deployment - Retrieval Dates	Water Clarity	Sky Code	Precipitation	Precipitation (last 24 hrs)	Water Color	Hydromodification	Hydromodification Location	Stream Depth (m)	Stream Width (m)	Distance from Bank (m)
COY610	7/15/2008	Cloudy	Clear	None	None	Green-Brown	Culvert	US	1.315		
	10/22/2010	Clear	Clear	None	None	Colorless	Culvert	US			
	5/22/2009	Clear	Clear	None	None	Colorless	Culvert	US	1.65	12	4.5
	10/9/2009	Clear	Clear	None	None	Colorless	Culvert	US	0.14	7.6	0
	6/4/2010	Clear	Clear	None	None	Colorless	Culvert	US	1.8		6
	11/9/2010	Clear	Clear	None	<1 inch	Brown	Pipes	DS	0.63	8	2
IND200	7/22/2008	Clear	Clear	None	None	Colorless	None	NA	0.54	4	1.5
	10/20/2008	Cloudy	Clear	None	None	Colorless	None	NA			
	7/22/2008	Clear	Clear	None	None	Colorless	None	NA	0.34	3	1.5
	10/20/2008	Clear	Clear	None	None	Colorless	None	NA			
	7/22/2008	Clear	Clear	None	None	Colorless	None	NA	0.29	2.1	1.5
	10/20/2008	Cloudy	Clear	None	None	Colorless	None	NA			
	5/18/2009	Clear	Clear	None	None	Colorless	None	NA	0.53	4	1.5
	10/9/2009	Cloudy	Clear	None	None	Colorless	None	NA	0.39	3	
	5/18/2009	Clear	Clear	None	None	Colorless	None	NA	0.48	3.5	2
	10/9/2009	Cloudy	Clear	None	None	Colorless	None	NA	0.14	1.7	
	5/18/2009	Clear	Clear	None	None	Colorless	None	NA	0.4	5	4.5
	10/9/2009	Cloudy	Clear	None	None	Colorless	None	NA	0.11	1.4	
	5/25/2010	Clear	Overcast	Rain	<1 inch	Colorless	None	NA	0.4	2.1	0.1
	11/9/2010	Clear	Partly Cloudy	None	<1 inch	Colorless	None	NA	0.2	2	1.7
MTD117	5/24/2010	Clear	Overcast	Drizzle	<1 inch	Colorless	None	NA	0.35	2.5	1.5
	7/16/2010	NA	Overcast	None	<1 inch	NA	Bridge	DS	Dry	Dry	Dry
PES162	7/23/2008	Clear	Clear	None	None	Colorless	None	NA	0.43	4.5	0.3
	10/28/2008	Clear	Clear	None		Colorless	None	NA	0.44	4	1
	7/23/2008	Clear	Clear	None	None	Colorless	None	NA	0.67	8	6
	NA*	Clear	Clear	None		Colorless	None	NA	0.42	14	10
	5/21/2009	Clear	Clear	None	None	Colorless	None	NA	0.75	9	6
	10/12/2009	Clear	Overcast	None	None	Colorless	None	NA	0.74	5.1	
	6/7/2010	Clear	Overcast	None	Unknown	Colorless	None	NA	1.05	12.7	3
	10/7/2010	Clear	Clear	None	None	Colorless	None	NA	0.87	11.76	3.64
RDW080	7/17/2008	Clear	Clear	None	None	Colorless	Bridge	DS	0.37	1.6	0.5
	10/30/2008	Clear	Clear	Rain	None	Colorless	Bridge	DS	0.52	2	1.5
	5/26/2009	Clear	Clear	None	None	Colorless	Bridge	DS	0.62	5	4.7
	10/9/2009	Clear	Fog	Fog	None	Colorless	Bridge	DS	0.67	3.8	
	5/26/2009	Clear	Clear	None	None	Colorless	Bridge	DS	0.9	5	4.8
	10/9/2009	Clear	Fog	Fog	None	Colorless	Bridge	DS	0.52	2.6	
	6/2/2010	Clear	Partly Cloudy	None	None	Colorless	Bridge	DS		5	0.1
	10/15/2010	Clear	Overcast	None	None	Colorless	Bridge	DS	0.78	4	1.2
RIC100	7/21/2008	Clear	Clear	Fog	None	Colorless	Culvert	DS	0.24	1.4	0.2
	10/30/2008	Clear	Overcast	Drizzle	None	Colorless	Pipes, Culvert	DS	0.25	1.1	0.9
	7/21/2008	Clear	Clear	Fog	None	Colorless	Culvert	DS	0.265	3	0.3
	10/30/2008	Clear	Overcast	Drizzle	None	Colorless	Pipes, Culvert	DS	0.26	4	3
	7/21/2008	Clear	Clear	Fog	None	Colorless	Culvert	DS	0.28	1.6	0.3
	10/30/2008	Clear	Overcast	Drizzle	None	Colorless	Culvert	DS	0.34	1.4	0.4
	5/12/2009	Cloudy	Clear	None	None	Colorless	Pipes	US	0.4	2.7	1.3
	10/9/2009	Clear	Fog	None	None	Colorless	Bridge, Pipes, Concrete	US	0.32	2.4	1.4
	5/12/2009	Clear	Clear	None	None	Colorless	Pipes	US, DS	0.12	4.2	2.6
	10/9/2009	Clear	Fog	None	None	Colorless	Bridge, Pipes, Concrete	US	0.15	4	
	6/1/2010	Clear	Clear	None	None	Colorless	None	NA	0.55	3	2.7
	10/15/2010	Clear	Clear	None	None	Colorless	Pipes	US	0.49	3.1	1.86

* HOBO was removed from site during deployment. Field crew was unable to recover lost HOBO.

Table F-1: Inventory and deployment periods of time-series field measurement events conducted in 2008-2010

Year	Watershed	Station	Site Name	Sonde Deployments	Sonde Deployment Start	Sonde Deployment End	HOBO Deployments**	HOBO Deployment Start	HOBO Deployment End
2008	Coyote Creek	COY610	Coyote approx 1.5 miles upstream of Gilroy Hot Springs Rd. bridge	***1***	4/30/2008	6/7/2008	3	7/15/2008	10/21/2008
	Indian Creek	IND200	Indian approx 1.8 miles upstream of San Antonio Reservoir	***2***	4/29/2008 7/1/2008	6/22/2008 7/22/2008	3	7/22/2008	10/20/2008
	Mitchell Canyon	MTD117	Mitchell approx 250 m upstream of bridge at Mt. Diablo SP entrance	***1***	5/6/2008	5/20/2008			
	Pescadero Creek	PES162	Pescadero approx 150 m upstream of Towne Fire Road crossing	***2***	5/1/2008 7/8/2008	7/8/2008 9/28/2008	2	7/23/2008	10/28/2008
	Redwood Creek	RDW080	Redwood at ped bridge in Frank Valley - approx 1 mile upstream of Hwy 1	***2***	5/7/2008 7/9/2008	6/26/2008 9/4/2008	1	7/17/2008	10/30/2008
	Ritchie Creek	RIC100	Ritchie above gabion wall in Napa-Bothe State Park	***2***	5/5/2008 7/7/2008	7/1/2008 10/9/2008	3	7/21/2008	10/30/2008
2009	Coyote Creek	COY610	Coyote approx 1.5 miles upstream of Gilroy Hot Springs Rd. bridge	***1***	4/16/2009	6/4/2009	3	5/22/2009	10/9/2009
	Indian Creek	IND200	Indian approx 1.8 miles upstream of San Antonio Reservoir	***2***	4/14/2009 6/29/2009	6/29/2009 7/9/2009	3	5/18/2009	10/9/2009
	Mitchell Canyon	MTD117	Mitchell approx 250 m upstream of bridge at Mt. Diablo SP entrance	***1***	4/23/2009	5/18/2009			
	Pescadero Creek	PES162	Pescadero approx 150 m upstream of Towne Fire Road crossing	***2***	4/28/2009 7/29/2009	7/29/2009 10/3/2009	1	5/21/2008	10/12/2009
	Redwood Creek	RDW080	Redwood at ped bridge in Frank Valley - approx 1 mile upstream of Hwy 1	***2***	4/21/2009 9/10/2009	7/29/2009 10/9/2009	2	5/26/2009	10/9/2009
	Ritchie Creek	RIC100	Ritchie above gabion wall in Napa-Bothe State Park	***4***	5/12/2009 6/24/2009 9/10/2009 *10/7/2009* *	6/1/2009 7/20/2009 10/5/2009 *10/13/2009* *	2	5/12/2009	10/9/2009
2010	Coyote Creek	COY610	Coyote approx 1.5 miles upstream of Gilroy Hot Springs Rd. bridge	***1***	6/4/2010	7/13/2010	1	6/4/2010	11/9/2010
	Indian Creek	IND200	Indian approx 1.8 miles upstream of San Antonio Reservoir	***1***	5/25/2010	7/28/2010	1	5/25/2010	11/9/2010
	Mitchell Canyon	MTD117	Mitchell approx 250 m upstream of bridge at Mt. Diablo SP entrance	***1***	5/24/2010	7/9/2010	1	5/24/2010	7/16/2010
	Pescadero Creek	PES162	Pescadero approx 150 m upstream of Towne Fire Road crossing	***1***	6/7/2010	10/7/2010	1	6/7/2010	10/7/2010
	Redwood Creek	RDW080	Redwood at ped bridge in Frank Valley - approx 1 mile upstream of Hwy 1	***1***	6/2/2010	10/15/2010	1	6/2/2010	10/15/2010
	Ritchie Creek	RIC100	Ritchie above gabion wall in Napa-Bothe State Park	***1***	6/1/2010	10/15/2010	1	6/1/2010	10/15/2010

*Two-day deployment only, did not include data in larger dataset for endpoint calculation.

** Number of HOBO instruments deployed - sites were monitored at multiple locations within the reach simultaneously.

Table F-2: Exceedances of water quality benchmarks and summary statistics of time-series field measurement deployments in years 2008-2010

Table F-2a: Summary statistics of time-series field measurement deployments at Non-Perennial Reference Sites, 2008-2010

Sonde Deployments

	Site		**COY610**				**IND200**				**MTD117**		**Water Quality Benchmarks (Thresholds)**
	Creek Name		**Coyote Creek**				**Indian Creek**				**Mitchell Canyon**		**Note:** Highlighted results in table indicate benchmarks were not met.
	Start Date	**4/30/2008**	**4/16/2009**	**6/4/2010**	**4/29/2008**	**7/1/2008**	**4/14/2009**	**6/29/2009**	**5/25/2010**	**5/6/2008**	**4/23/2009**	**5/24/2010**	
	End Date	**6/7/2008**	**6/4/2009**	**07/13/10**	**6/22/2008**	**7/22/2008**	**6/29/2009**	**7/9/2009**	**07/28/10**	**5/20/2008**	**5/18/2009**	**7/9/2010**	
	Location in Reach	**InterTransect AB**	**InterTransect AB**	**InterTransect AB**	**InterTransect FG**	**Transect K**	**InterTransect FG**	**InterTransect FG**	**InterTransect FG**	**Transect G**	**Transect G**	**Transect G**	
	Min	11.6	10.23	16.24	9.11	13.76	7.26	13.82	10.38	13.11	11.83	11.61	
	Median	17.63	17.8	20.855	13.31	17.03	14.15	16.38	15.36	14.06	13.515	15.56	
°C	***Max***	**28.58**	**28.61**	**28.57**	19.2	19.22	20.87	19.19	19.05	18.54	15.86	17.75	**> 24** 24 °C, Lethal Limit
	Max 7-day Mean	**21.73**	**20.93**	**21.86**	**15.83**	**18.23**	**16.31**	**16.83**	**17.29**	**14.94**	14.45	**16.56**	**>14.8 Coho, >17 Steelhead**
	Accuracy	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	
	Min	6.49	6.81	5.49	7.56	3.06	7.97	5.17	7.7	0.22	1.48	0.26	
	Median	8.84	9.11	7.87	9.86	5.85	10.16	7	9.5	1.95	4.79	7.47	
mg/L	***Max***	11.35	11.76	12.39	10.95	9.23	11.82	9.99	10.92	5.26	6.87	9.88	Coldwater and Warmwater limits
	7-day Avg. Min.	**6.67**	7.04	**5.85**	8.34	**4.04**	8.68	**5.49**	8.00	**0.59**	**2.61**	**0.40**	**<7 mg/L COLD, <5 mg/L WARM**
	Accuracy (MQO: + 0.5 mg/L)	*0.08*	*0.05*	*0.01*	*0.05*	*0.10*	*0.05*	*0.07*	*0.01*	*0.02*	*0.23*	*0.06*	
	Min	7.95	7.92	6.97	7.15	7.75	8.09	7.77	8.21	*6.62*	7.53	7.77	**< 6.5** 6.5 Basin Plan Minimum
	Median	8.16	8.17	7.98	8.44	7.89	8.31	7.86	8.4	*7.52*	7.66	8.17	
pH	***Max***	8.39	8.49	**8.72**	**8.79**	8.11	8.4	8.01	**8.57**	*8.12*	7.77	8.29	**>8.5** 8.5 Basin Plan Maximum
	Accuracy (MQO: + 0.2)	*0.16*	*0.11*	*0.50*[2]	*0.17*	*0.03*	*0.12*	*0.01*	*0.20*	*0.22*[2]	*0.08*	*0.06*	
	Min	501	463	434	409	585	390	555	359	528.8	501	445	
uS/cm	***Median***	553	495	574	454	656	451	586	441	547.25	515	516	
	Max	583	557	660	560	712	556	616	540	591.6	559	584	**>1000 μS/cm (potential pollution)**
	Accuracy (MQO: + 5%)	*0.4%*	*0.0%*	*0.5429%*	*0.5%*	*0.8%*	*0.3%*	*0.0%*	*0.1857%*	*0.3%*	*1.1%*	*0.1%*	**>2000 μS/cm (freshwater limit)**
	Min	-2.6	*-1.5*	-1.3	-5.1	-1.1	2.5	1.7	1.4	-1	*-0.8*	2.8	
NTU	***Median***	-0.4	*-0.4*	0.3	-0.7	-0.8	2.8	1.9	1.8	-0.8	*-0.6*	3.3	
	Max	16.3	*117.1*	572	13.4	10.7	5.7	7.3	8.1	47.5	*35.8*	318.7	
	Accuracy (MQO: + 0.2 NTU)	*0.20*	***3.40***	*1.8*[2]	*0.1*	*0.2*	*0.1*	*0.7*[2]	*1.1*[2]	*0.1*	*0.3*[2]	*0.1*	
	n	*3647*	*4714*	*3758*	*5206*	*2021*	*7287*	*984*	*6105*	*1356*	*2430*	*4375*	

HOBO Deployments

	Site				**COY610**							**IND200**				**MTD117**	
	Creek Name				**Coyote Creek**							**Indian Creek**				**Mitchell Canyon**	
	Start Date		**7/15/2008**			**5/22/2009**		**6/4/2010**		**7/22/2008**			**5/18/2009**		**5/25/2010**	**5/24/2010**	
	End Date	**8/11/2008**	**9/17/2008**	**10/21/2008**	**7/28/2009**	**8/23/2009**	**9/14/2009**	**11/9/2010**		**10/20/2008**			**10/9/2009**		**11/9/2010**	**7/16/2010**	
	HOBO SN	**1271565**	**1271574**	**1271561**	**1271558**	**1271559**	**1271560**	**1271566**	**1271558**	**1271567**	**1271564**	**2039008**	**2039009**	**2039010**	**1271560**	**1271559**	
	Location in Reach	**Transect K- Top of Water Column**	**Transect K- Middle of Water Column**	**Transect K- Bottom of Water Column**	**Transect K- Top of Water Column**	**Transect K- Middle of Water Column**	**Transect K- Bottom of Water Column**	**Transect K**	**Transect K**	**US of Transect J**	**DS of Transect J**	**DS of Transect K**	**4m US of Transect K**	**8m US of Transect K**	**Transect K**	**Transect G**	
	Min	18.89	8.89	9.39	15.68	15.65	15.63	10.59	7.97	10.47	8.74	9.51	11.03	10.44	9.16	11.54	
	Median	22.54	22.11	20.87	21.08	20.96	21.22	19.32	15.65	16.42	15.96	15.84	16.11	16.23	14.98	15.49	
°C	***Max***	**27.43**	**29.37**	**25.07**	**28.59**	**31.23**	**26.77**	22.99	19.77	22.90	19.65	**24.41**	22.44	19.34	21.29	22.49	**> 24**
	Max 7-day Mean	**23.00**	**23.35**	**22.81**	**24.35**	**23.89**	**23.31**	**21.61**	**17.52**	**18.52**	**18.05**	**18.26**	**17.98**	**17.80**	**17.09**	**16.94**	**>14.8, >17**
	Accuracy	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	*NR*[1]	
	n	645	1522	2357	1602	2218	2754	3787	2157	2157	2157	3454	3454	3454	4007	1266	

Notes: Color-highlighted results in table indicate that benchmarks were not met.
Red italicized font indicates that data did not meet SWAMP MQOs. **NR:** Value not recorded
1 = Post-deployment accuracy checks performed during annual lab calibration - Temp. probe met SWAMP MQO's.
2 = Instrument drift during period of deployment did not meet SWAMP MQO's but data may still be useful.

Table F-2b: Summary statistics of time-series field measurement deployments at perennial reference sites, 2008-2010

Sonde Deployments

	Site	**PES162**					**RDW080**					**RIC100**						**Water Quality Benchmarks**
	Creek Name	**Pescadero Creek**					**Redwood Creek**					**Ritchie Creek**						**(Thresholds)**
	Start Date	**5/1/2008**	**7/8/2008**	**4/28/2009**	**7/29/2009**	**6/7/2010**	**5/7/2008**	**7/9/2008**	**4/21/2009**	**9/10/2009**	**6/2/2010**	**5/5/2008**	**7/4/2008**	**5/12/2009**	**6/24/2009**	**9/10/2009**	**6/1/2010**	**Note:** Highlighted results in
	End Date	**7/8/2008**	**9/28/2008**	**7/29/2009**	**10/3/2009**	**10/7/2010**	**6/26/2008**	**9/4/2008**	**7/29/2009**	**10/9/2009**	**10/15/2010**	**7/1/2008**	**10/29/08**	**6/17/2009**	**7/20/2009**	**10/05/09**	**10/15/2010**	table indicate benchmarks
	Location in Reach	**Transect H**	**Transect H**	**Transect H**	**Transect H**	**Transect H**	**Transect E**	**Transect E**	**Transect E**	**Transect E**	**Transect E**	**Transect G**	**Transect G**	**Transect G**	**Transect G**	**Transect G**	**Transect G**	were not met.
Temp °C	***Min***	9.52	11.75	9	10.78	12.49	10.2	12.83	9.5	11.15	11.63	11.24	12.64	11.93	14.25	10.71	12.83	
	Median	15.3	16.91	16.17	16.71	15.79	13.05	14.19	13.31	13.99	13.53	15.9	17.18	15.45	17.99	17.36	16.38	
	Max	21.53	22.8	21.51	20.14	20.61	15.63	15.87	15.37	15.64	16.25	21.52	23.87	19.66	22.43	18.89	21.49	> 24 — 24 °C, Lethal Limit
	Max 7-day Mean	**18.36**	**19.9**	**18.53**	**17.96**	**18.14**	13.87	**15.13**	14.15	14.54	14.31	**18.02**	**20.2**	**16.08**	**18.94**	**17.3**	**18.19**	**>14.8 Coho, >17 Steelhead**
	Accuracy	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	
DO mg/L	***Min***	8.22	7.93	8.57	8.21	8.33	7.1	4.02	8.29	5.18	6.43	8.25	7.66	8.7	7.74	7.7	8.17	
	Median	10.02	9.13	9.8	9.01	9.05	8.66	6.87	9.4	6.6	8.78	9.55	9.13	9.68	8.71	8.55	9.29	
	Max	11.43	11.26	11.57	10.88	10.44	9.74	8.58	10.76	8.25	9.71	10.6	10.67	10.62	9.76	10.05	10.39	Coldwater and Warmwater limits
	7-day Avg. Min.	8.65	8.01	8.67	8.34	8.43	7.5	**4.92**	8.47	**5.6**	**6.82**	8.55	7.99	9.01	7.9	7.81	8.48	**<7 mg/L COLD, <5 mg/L WARM**
	Accuracy (MQO: ± 0.5 mg/L)	*0.16*	*0.16*	*0.13*	*0.11*	*0.45*	*0.13*	*0.04*	*0.26*	*0.12*	*0.22*	*0.27*	*0.07*	*0.13*	*0.07*	*0.05*	*0.13*	
pH	***Min***	8.31	8.24	8.23	8.23	8.32	7.51	7.24	7.54	7.29	7.16	7.81	*7.82*	*7.69*	7.7	7.55	7.74	**< 6.5** — 6.5 Basin Plan Minimum
	Median	8.44	8.37	8.43	8.34	8.51	7.6	7.38	7.65	7.37	7.57	7.95	*8.01*	*7.87*	7.83	7.65	7.87	
	Max	**8.62**	**8.52**	**8.71**	**8.75**	**8.92**	7.71	7.5	7.92	7.54	8.15	8.3	*8.3*	*8.25*	8.11	7.92	8.15	**>8.5** — 8.5 Basin Plan Maximum
	Accuracy (MQO: ± 0.2 pH)	*0.10*	*0.12*	*NA**	*0.08*	*0.02*	*0.14*	*0.16*	*0.10*	*0.09*	*0.05*	*0.14*	*0.25[2]*	*0.4[2]*	*0.11*	*0.08*	*0.10*	
SC uS/cm	***Min***	641	753	601	766	594	228	237	124	243	224	43	60	153	181	191	5	
	Median	696	810	691	821	661	233	242	225	246	243	186	193	170	188	196	183	
	Max	753	884	765	871	733	238	256	238	251	265	194	203	177	195	202	193	**>1000 µS/cm (potential pollution)**
	Accuracy (MQO: ± 5%)	*0.3%*	*0.0%*	*0.0%*	*0.4%*	*1.2%*	*0.6%*	*0.2%*	*0.0%*	*0.2%*	*0.3%*	*0.8%*	*0.7%*	*0.4%*	*0.1%*	*0.3%*	*0.2%*	**>2000 µS/cm (freshwater limit)**
Turbidity NTU	***Min***	-8.3	*-7.7*	-1.7	*0.3*	2.6	1.4	*0.9*	*0.6*	*-0.9*	1	2.5	1.5	*3.4*	-1.6	1.2	2.8	
	Median	-7.2	*-7.1*	-0.6	*1.7*	3.1	2.4	*2*	*2*	*-0.7*	1.7	3.2	2.2	*4.2*	-1.3	1.4	3.8	
	Max	3.4	*2.2*	2.2	*14.3*	22.6	17	*46.9*	*219.5*	*77*	87	15.8	19.1	*7.9*	2.6	7.7	31	
	Accuracy (MQO: ± 0.2 NTU)	*0.10*	*10.8*	*0.20*	*0.3[2]*	*0.9[2]*	*0.2*	*1.1[2]*	*1.2[2]*	*3.1*	*1.0[2]*	*0.1*	*0.1*	*0.7[2]*	*0.1*	*0.2*	*0.5*	
	n	*6528*	*7908*	*8816*	*6331*	*11208*	*4831*	*5493*	*9519*	*2774*	*12938*	*5440*	*9045*	*1913*	*2514*	*2384*	*10870*	

HOBO Deployments

	Site	**PES162**				**RDW080**				**RIC100**						
	Creek Name	**Pescadero Creek**				**Redwood Creek**				**Ritchie Creek**						
	Start Date	**7/23/2008**		**5/21/2009**	**6/7/2010**	**7/17/2008**	**5/26/2009**		**6/2/2010**		**7/21/2008**		**5/12/2009**		**6/1/2010**	
	End Date	**10/28/2008**	**N/A***	**10/12/2009**	**10/7/2010**	**10/30/2008**	**10/9/2009**		**10/15/2010**		**10/30/2008**		**10/9/2009**		**10/15/2010**	
	HOBO SN	**1271562**	**1271571**	**1271561**	**1271568**	**1271575**	**1271564**	**1271565**	**1271564**	**1271570**	**1271572**	**1271560**	**1271562**	**1271563**	**1271563**	
	Location in Reach	**Transect A**	**Transect K**	**Transect K**	**Transect K**	**Transect B**	**InterTransect AB**	**Transect K**	**Transect D**	**US Area of Reach**	**MidReach**	**DS Area of Reach**	**InterTransect AB**	**Transect K**	**InterTransect AB**	
Temp °C	***Min***	7.57	*N/A* **	9.36	12.07	8.02	10.57	10.54	11.52	10.74	10.12	10.47	10.47	10.81	*N/A* ***	
	Median	15.58	*N/A* **	16.51	15.63	13.55	13.88	13.88	13.45	15.29	15.29	16.75	16.89	16.87	*N/A* ***	
	Max	21.44	*N/A* **	21.60	20.53	18.51	15.84	15.34	16.23	19.41	19.75	21.01	**27.26**	**27.48**	*N/A* ***	> 24
	Max 7-day Mean	**17.98**	*N/A* **	**18.54**	**18.09**	14.48	14.58	14.37	14.23	**17.33**	**17.46**	**19.02**	**19.14**	**19.11**	*N/A* ***	**>14.8, >17**
	Accuracy	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	*NR[1]*	
	n	2323	*N/A* **	3452	2901	1991	3258	3259	3239	2421	2421	2421	3592	3592	*N/A* ***	

Notes: Color-highlighted results in table indicate that benchmarks were not met.
Red italicized font indicates that data did not meet SWAMP MQO's. **NR:** Value not recorded
1 = Post-deployment accuracy checks performed during annual lab calibration - Temp. probe met SWAMP MQO's.
2 = Instrument drift during period of deployment did not meet SWAMP MQO's but data may still be useful.
***** Probe was broken in the field during calibration check - no post-deployment calibration check data for this probe.
** HOBO was removed from site during deployment. Field crew was unable to recover lost HOBO.
*** HOBO was retrieved from site, however data could not be recovered from the instrument.

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