C-11-V.0 URBAN STREAM BIOASSESSMENT MONITORING

C-11-V.1 Introduction

This section reviews results and findings of the Urban Stream Bioassessment Monitoring Program, which consisted of field monitoring during the spring and summer of 2017 by the Permittees. Bioassessment monitoring is a means of assessing the biological quality of aquatic habitat by evaluating the assemblage of benthic macroinvertebrates (BMIs). Each site is rated on its ecological structure and taxonomic completeness by using the California Stream Condition Index (CSCI), which is a scoring tool that evaluates the biological condition of a site based on a statistical distribution of the conditions for reference sites in California (see the following link for the CSCI Fact Sheet and technical memo: http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/883_CSCI-StatewideBioScoringTool.pdf).

The CSCI is calibrated so that the 50th percentile of reference sites is 1, and sites that approach 0 demonstrate a significant departure from reference conditions. **Section C-11-V.2** presents the CSCI scores for 2017 monitoring locations. BMI collection is one of the multiple lines of evidence performed at each site. Physical habitat condition, algae assemblages, and water chemistry are analyzed as well. The 2017 chemistry data for the bioassessment program can be referenced at the following link: https://ocgov.box.com/v/2016-17-SAR-PEA-C-11-Datasets.

C-11-V.2 Regional Monitoring

In 2009, the Permittees began participating in a regional bioassessment monitoring program sponsored by the Southern California Stormwater Monitoring Coalition (SMC) and managed by the Southern California Coastal Water Research Project (SCCWRP). This program was designed to assess stream health using the resident stream BMIs to determine the water quality conditions within a stream reach. The "SMC Program," as it is known, is based on a probabilistic sampling design that allows the ambient condition of streams in southern California to be assessed and compared to stream systems in watersheds with similar conditions and land use. The original five-year study spanned 2009 through 2013 with 2014 being a transitional year. The goal of this multi-agency program is to:

1. Determine the status of BMI conditions across southern California streams;
2. Identify key stressors that affect stream BMI conditions; and,
3. Monitor receiving water stressors over time.

Stream monitoring sites are stratified by urban, open space, and agricultural land uses to provide a better assessment across stressor gradients from chemical, biological, and physical influences.

The 2014 sampling effort was the sixth year of the original five-year study to assess stream macroinvertebrate conditions across southern California, which represented a transitional year for the regional program by expanding the original five-year period and preparing the program for its next five year monitoring cycle. The report on the first 5 years of the SMC Program can be found at the following link:
http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/844_SoCalStrmAssess.pdf

The second SMC Program five-year study began in 2015 and will span through 2019. The core questions from the original study have carried over with modifications to the program that reflect what was learned and what still needs additional understanding from the first five years. There has been a reduction in water quality analysis by eliminating metals, pesticides, and toxicity since these have not been correlated to the health of BMI assemblages. The new study emphasizes nutrients and elevated major ions as these have statistically shown to be drivers of impaired biology. The technical report for the current five-year study can be found at the following link:
http://ftp.sccwrp.org/pub/download/DOCUMENTS/TechnicalReports/849_SMCWorkplan2015.pdf

Several new methods have been introduced to quantify effects on biological integrity since 2015. New field components include channel modification, hydromodification, vertebrate identification, and flow regime, which are reported to SCCWRP through the SMC Stream Data Submission webpage. Furthermore, a new experimental procedure was introduced in 2016 to assess algae taxonomy. DNA extractions were performed in coordination with SCCWRP and California State University, San Marcos as a potentially new taxonomic method. Contaminants of emerging concern (CECs) were sampled at trend sites in 2015 and 2016 as a SCCWRP special study, but this effort was discontinued in 2017.

SCCWRP has also generated a new probabilistic site draw to use for this study. For the first time, non-perennial and first order streams have been included in the site draw. The SMC Program requires three condition sites to be sampled every year in the Santa Ana Region, with a new set of three sites changing each season. There is also a requirement for two developed trend sites and one open trend site to be revisited each year of the study. These sites are intended to be static and not change unless there are undesirable flow conditions or accessibility issues. It is important to note that trend sites are not necessarily limited to the Santa Ana Region of Orange County as the probabilistic site draws for trend sites are shared with the San Diego Region of the SMC Program. For 2017, the Santa Ana Region had the one open trend site (station SMC00105, see **Table C-11-V.1** and **Figure C-11-V.1** below). Conversely, both developed trend sites were in the San Diego Region for 2015 through 2017, and likely will be for the remainder of the five-year study based on the seasonal flow conditions and accessibility.

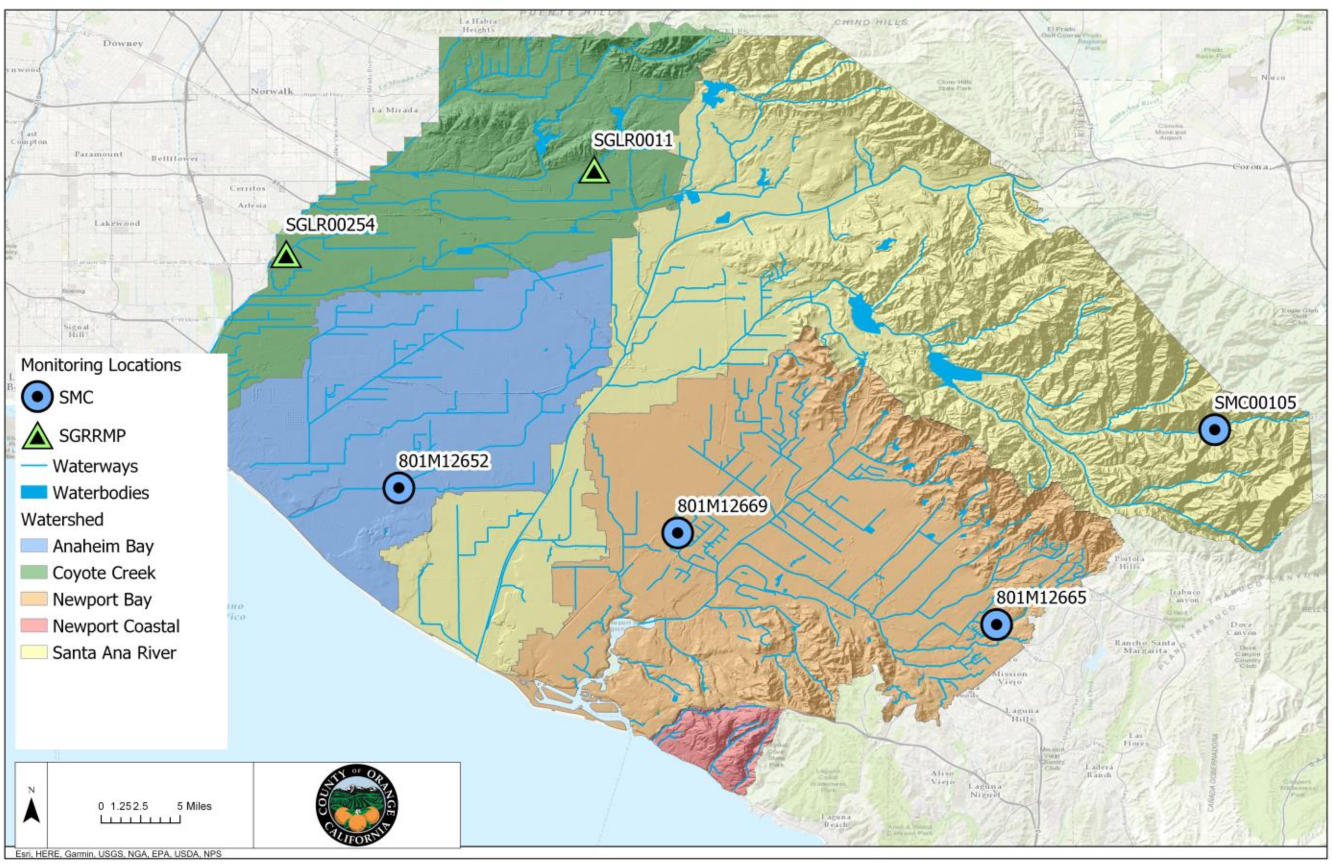
In addition to the SMC Program, the Permittees also participate in the San Gabriel River Regional Monitoring Program (SGRRMP). This program is designed to assess and improve the water quality impairments in the San Gabriel River Watershed, and contains a bioassessment component that follows both SWAMP and SMC protocols. One station on Fullerton Creek (SGLR0011) has been a revisit site since 2015 and will be revisited on an annual basis. SGLR00254 is a random site and will change in the 2018 sampling season. A third site (SGLR00894) was a non-perennial location and was dry during the sampling period, however the SGRRMP still required a physical habitat assessment using CRAM. Since infauna data could not be collected at this site, it will not be used in the subsequent data analysis. In addition to the SMC suite for water chemistry, the SGRRMP also monitors for heavy metals, pyrethroids, and organic carbon. Toxicity has historically been monitored and tested for *Ceriodaphnia dubia*, however this analysis was removed in 2017 due to issues with the *Ceriodaphnia dubia* reproduction test identified through an SMC toxicity intercalibration study. This issue is discussed in greater detail in **Section C-11.0**.

Table C-11-V.1 and **Figure C-11-V.1** below describe the bioassessment monitoring sites sampled during the April to June 2017 index period. A total of six sites were visited in 2017: four as part of the SMC Program, and two sites (SGLR0011, SGLR00254) as part of the Permittees participation in the SGRRMP.

Table C-11-V.1: Receiving Water Locations for Bioassessment Monitoring Program Table. The table displays 2017 monitoring stations, stream name, coordinates, and sample date.

Station	Station Description	Sample Date	Latitude	Longitude
801M12652	EGG Wintersburg Channel	18-May-17	33.71786	-117.99700
801M12665	Serrano Creek	18-May-17	33.64869	-117.69431
801M12669	Lane Channel	29-Jun-17	33.69506	-117.85581
SGLR0011	Fullerton Creek	29-Jun-17	33.88029	-117.89814
SGLR00254	Moody Creek	29-Jun-17	33.83744	-118.05412
SMC00105	Silverado Creek	12-Apr-17	33.74733	-117.58385

Figure C-11-V.1: Receiving Water Locations for Bioassessment Monitoring Program Map. The map depicts 2017 monitoring stations in the Santa Ana Region within each watershed boundary.

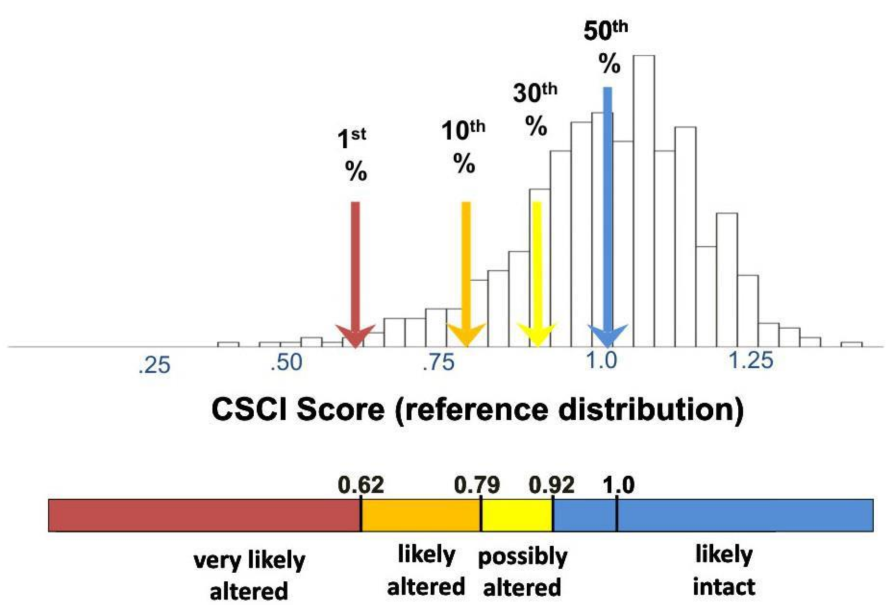


Biological integrity data analysis was conducted for the 2017 monitoring activities by using the CSCI. The following section details the CSCI scores for the stations monitored as part of the Regional SMC Program and SGRRMP in 2017. **Attachment C-11-I** includes additional information on the methods used to develop this analysis.

CSCI Results

The CSCI was created to address some of the limitations of previous biological indices, such as the Southern California Index of Biotic Integrity (SoCal IBI). Several stream types exist within California, and regional indices like the SoCal IBI did not accurately represent the wide variation of reference conditions and climate regions. The CSCI was developed with a robust dataset of these reference locations and conditions to allow for representative biological benchmarks. Two indices are combined to create the CSCI, each quantifying different biological conditions of a stream: a multi-metric index (MMI) that measures ecological structure and function, and an observed-to-expected (O/E) index that measures taxonomic completeness. These indices are averaged to provide more comprehensive lines of evidence. Scoring of reference conditions has been calibrated to 1, and sites that begin to approach 0 demonstrate a significant departure from reference condition. A minimum threshold has not been established. **Figure C-11-V.2** displays the CSCI scoring distribution with thresholds and condition categories. A SWAMP technical memo is available detailing the creation, scoring, and calculations of the CSCI at the following link:
http://www.waterboards.ca.gov/water_issues/programs/swamp/bioassessment/docs/csci_tech_memo.pdf

Figure C-11-V.2: CSCI Scoring Distribution. This figure displays the scoring distribution of reference sites that were used to create the CSCI. Scoring thresholds and condition categories are included.



The CSCI score, observed-to-expected (O/E) index, and the multi-metric index (MMI) scores for the six sites collected in 2017 are presented in **Table C-11-V.2** and **Figure C-11-V.3**. **Table C-11-V.3** explains the six metrics that constitute the MMI, as well as their relative response to impairment.

CSCI scores ranged from 0.16 at station 801M12669 located in a highly modified concrete-lined flood control channel (Lane Channel) to 0.79 at station SMC00105 located in Silverado Creek in Silverado Canyon, which is a natural riparian area in a near reference location. Other than station 801M12665 in a restored section of Serrano Creek (CSCI score 0.75), each of the other sites were located in a heavily modified flood control channel, and CSCI scores did not exceed 0.66 (SGLR0011, Fullerton Creek).

An examination of the MMI and O/E indices provides greater detail, and O/E values are consistently higher than the MMI with the exception of 801M12669, which is an extremely impaired site and can be considered an outlier. One noteworthy station is 801M12665, which scored poorly on the MMI at 0.49 (0.00 percentile), but had much better biological condition given the comparator sites with an O/E score of 1.01 (52^{nd} percentile). The habitat is also relatively complex for an urban stream, and this is captured in the physical habitat section below in **Figure C-11-V.4**. Also of interest is the highest scoring station (SMC00105), which had the best benthic diversity. It is also the only station that was identified with intolerant species (1%), as well as the relatively intolerant order Coleoptera (beetles). Conversely, Lane Channel had very poor diversity and was dominated by the very tolerant amphipod *Hyalella*. These stations are good examples that the individual indices and sub-metrics should be examined to better understand the dynamic biological environment

It is interesting that the highest scoring urban station with the MMI was a trapezoidal concrete section of Fullerton Creek (SGLR0011). It is not clear what conditions allowed for the improved benthic community at this station, especially the 39% EPT taxa sub-metric. This station was also sampled in 2015 and 2016, and scored 0.56 (0.52 MMI) and 0.59 (0.53 MMI), respectively. The localized flow conditions are characterized by a fairly evenly distributed mix of riffles, runs, and glides. Perhaps these microhabitats are providing sufficient variety to promote relatively diverse benthic assemblages.

It is important to stress there is not an established minimum disturbance threshold for the CSCI, however low values should be considered indicative of degradation. Furthermore, the CSCI percentiles show how similar the biological condition is for a given site compared to the distribution of reference sites it was compared against. For example, station SMC00105 was similar in biological condition to the 10^{th} percentile of sites in the reference distribution to which it was compared. In contrast, four of the other five stations were located in heavily shored or concrete lined channels and fell outside the reference distribution (percentile scores ≤ 0.01). The exception was station 801M12665, which was comparable to 6% of the reference distribution and has a relatively complex habitat for an urban stream.

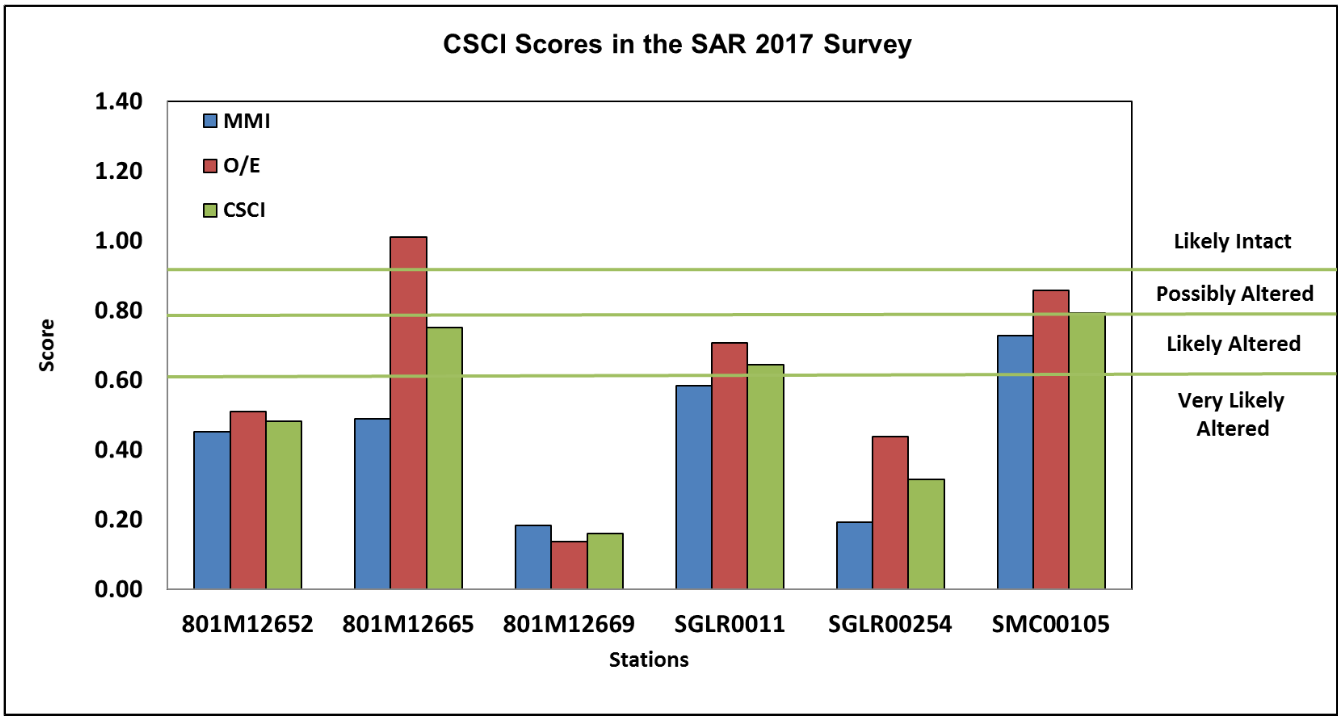
Table C-11-V.2: CSCI Scores and Metrics for Sites Monitored in the Santa Ana Region, 2017. The CSCI is the average of the O/E and MMI indices. The percentile of the CSCI scores is relative to the reference distribution sites they were compared to for the analysis. Station SMC00105 along Silverado Creek had a CSCI score of 0.79, which was the highest score for the stations monitored in 2017; it is located in a more natural riparian area in a near reference location.

CSCI Scores and Metrics 2017						
CSCI	801M12652 EGG Wintersburg Channel	801M12665 Serrano Creek	801M12669 Lane Channel	SGLR0011 Fullerton Creek	SGLR00254 Moody Creek	SMC00105 Silverado Creek
CSCI						
CSCI Score	**0.48**	**0.75**	**0.16**	**0.64**	**0.31**	**0.79**
CSCI Percentile	**0.00**	**0.06**	**0.00**	**0.01**	**0.00**	**0.10**
CSCI Category	**Very Likely Altered**	**Likely Altered**	**Very Likely Altered**	**Likely Altered**	**Very Likely Altered**	**Possibly Altered**
MMI Metric						
% Clinger Taxa	25	25	0	25	0	17
% Coleoptera Taxa	0	0	0	0	0	14
Taxonomic Richness	11	15	6	13	5	14
% EPT Taxa	18	20	0	39	0	34
Shredder Taxa	0	0	1	0	0	1
% Intolerant	0	0	0	0	0	1
MMI Score	**0.45**	**0.49**	**0.18**	**0.58**	**0.19**	**0.73**
MMI Percentile	**0.00**	**0.00**	**0.00**	**0.01**	**0.00**	**0.06**
O/E						
Mean Observed Taxa	4	8	1	8	3	7
Expected Taxa	8	8	7	11	7	8
O/E	**0.51**	**1.01**	**0.14**	**0.71**	**0.44**	**0.86**
O/E Percentile	**0.00**	**0.52**	**0.00**	**0.06**	**0.00**	**0.23**

Table C-11-V.3: Descriptions of the Six MMI Metrics. The MMI's six metrics represent different aspects of BMI assemblage composition and function. All of the taxa associated with each metric respond poorly to impaired habitat.

MMI Metric	Description	Response to Impairment
% Clinger Taxa	Percent of taxa that are adapted for attachment to surfaces in flowing water.	Decrease
% Coleoptera Taxa	Percent taxa from the insect order coleoptera.	Decrease
Taxonomic Richness	Total number of individual taxa.	Decrease
% EPT Taxa	Percent taxa in the orders Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly).	Decrease
Shredder Taxa	Number of taxa that shreds coarse particulate matter.	Decrease
% Intolerant Individuals	Percent of organisms in the sample that are highly intolerant to impairment as indicated by a tolerance value of 0, 1, or 2.	Decrease

Figure C-11-V.3: CSCI, O/E and MMI Scores for Sites Monitored in the Santa Ana Region, 2017. This figure displays the tabular data for O/E, MMI, and CSCI from **Table C-11-V.2**. Green lines denote scoring thresholds at the 1st, 10th, and 30th percentiles.



Research and usage of the CSCI scoring system is expected to increase in the future as it has become the standard scoring index used by the SMC as well as other State bioassessment programs, such as SWAMP's Perennial Streams Assessment (PSA). Additional context and historical analysis of the Santa Ana Region bioassessment program using the CSCI can be found in **Section C-11-V.3 Spatial Pattern Analysis**.

Physical Habitat and CRAM Methods

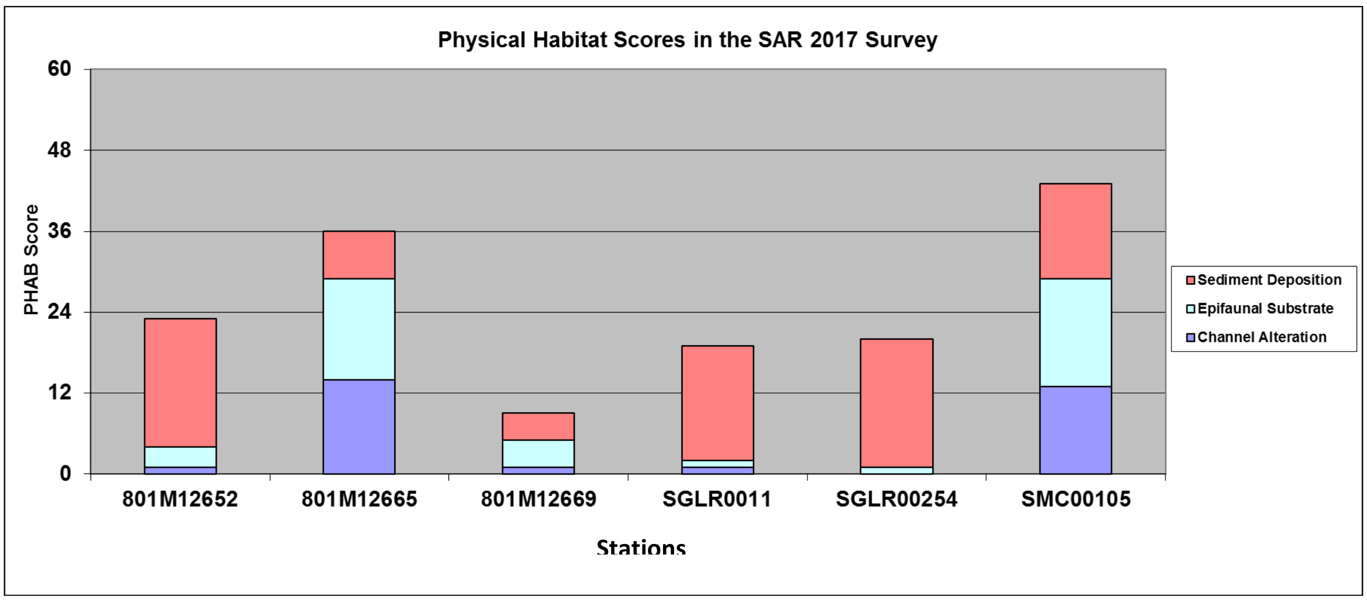
The bioassessment field data collection (benthic macroinvertebrates, algae, physical habitat) were conducted according to SWAMP protocols which can be found at the following link: http://www.waterboards.ca.gov/water_issues/programs/swamp/bioassessment/docs/combined_sop_2016.pdf

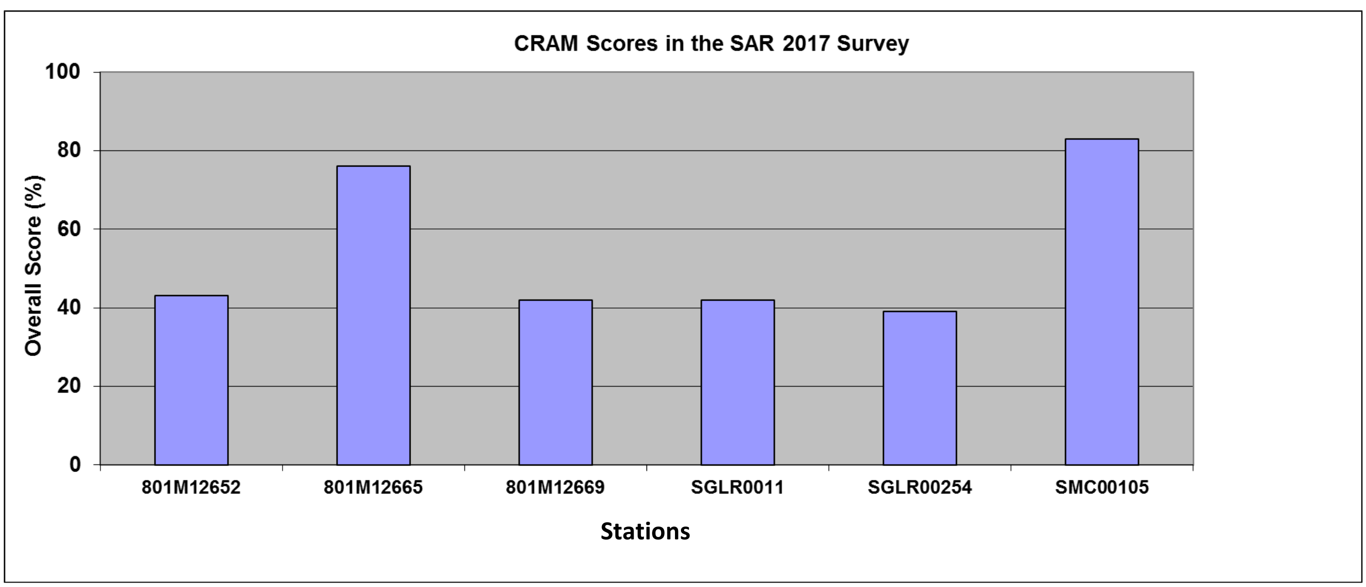
In addition to the SWAMP in-stream physical habitat condition measurements, the SMC Program also specifies that the California Rapid Assessment Method (CRAM) be conducted at each site. This protocol provides an assessment of not only the instream habitat condition, but also of hydrology and the buffer zone surrounding the site, including the biotic structure of the riparian zone. Details of the protocols for CRAM assessments can be found at the following link: http://www.cramwetlands.org/

Physical Habitat and CRAM Scoring

Monitoring results are presented in **Figure C-11-V.4** below.

Figure C-11-V.4: Physical Habitat and CRAM Scores in 2017. The first chart includes physical habitat condition, which is important to the biological condition. Physical habitat is assessed at each site by determining how much sediment deposition there is in the stream bed (more sediment yields a lower score), the amount of epifaunal substrate cover (more cover yields a higher score), and the amount of channel alteration that has occurred (more alteration yields a lower score). Site SMC00105 had the best overall physical habitat condition which was reflected in a higher CSCI score. As portrayed in the site location map (**Figure C-11-V.1**), this site is located in the upper watershed where habitat conditions are the most favorable. The other sites had poor physical habitat conditions, although not as severe at 801M12665 which had a modest score despite moderate sediment deposition. California Rapid Assessment Method (CRAM) scores are included in the second chart. CRAM provides a measure of streambed, riparian, buffer zone, hydrologic, and biotic condition, thus providing a wider assessment of physical habitat. The trend for this measure was slightly different than the physical habitat assessment, but still tracked with the CSCI scores.





The physical habitat conditions for each of the SMC Program and SGRRMP sites were assessed using three attribute scores (sediment deposition, epifaunal substrate, channel alteration) that are summed together to a total score ranging from zero (poorest condition) to 60 (best condition). SMC00105 had the highest score of 43. Despite being an upper watershed station, it is located next to single family homes and a parking lot at the lower end of the sampling reach. These factors are somewhat suppressing the physical habitat score, and are likely driving the relatively low CSCI score of 0.79. The 801M12665 score of 36 is relatively high for an urban site, which correlates to the CSCI score of 0.75. The California Department of Fish and Wildlife is currently creating an Index of Physical Habitat Integrity (IPI), which is a predictive index with similar structure to the CSCI. Next year's reporting cycle will include IPI analysis if it is ready for use.

CRAM scores for each site were somewhat consistent with the CSCI and physical habitat scores. Of note is that site SMC00105 had a CRAM score of 83, which is within the excellent range and indicates very good habitat condition. The rest of the CRAM scores scored in the poor range, with the exception of 801M12665 (CRAM score of 76). These other locations share similar characteristics due to their channel engineering and/or flood control influences. CRAM assessment is important in determining stream health since it evaluates not only the condition of the stream bed habitat, but also the condition of the buffer zones surrounding the riparian zone out to 250 meters on either side of the stream. The higher CRAM score for Silverado Canyon coincided with a moderate CSCI score, which is consistent with an upper watershed location.

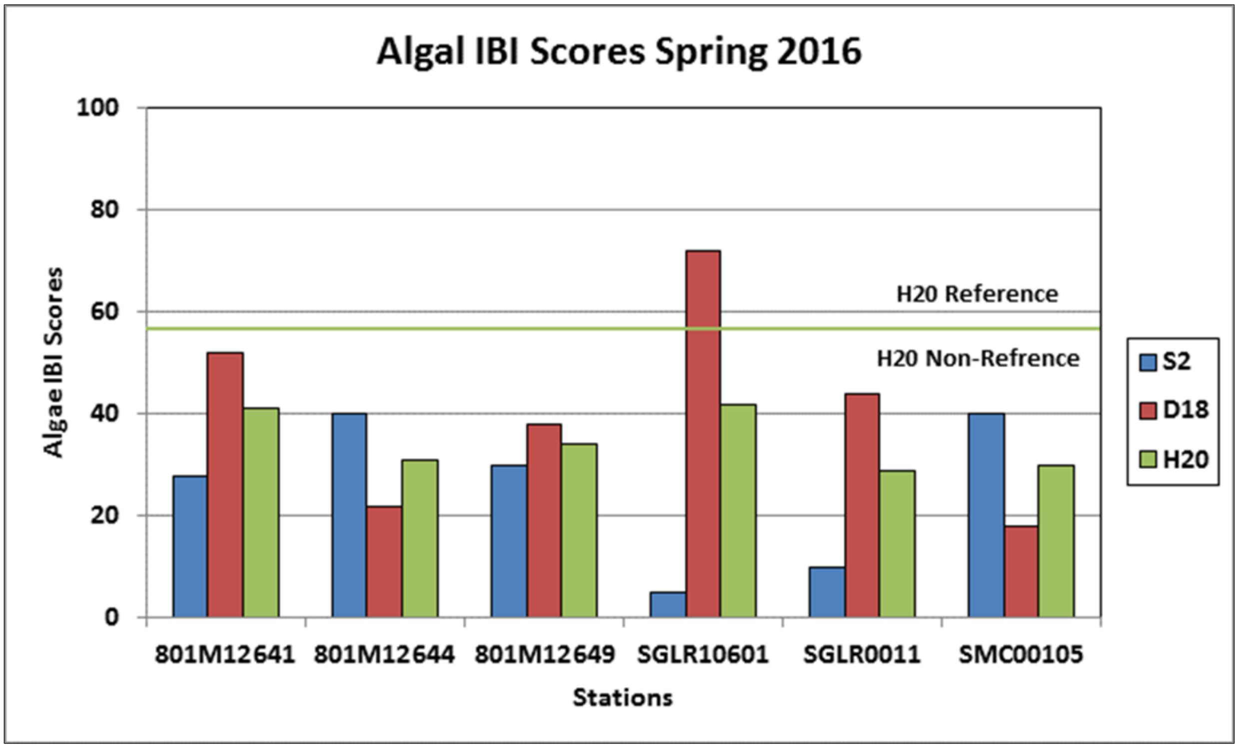
Attached Algae

Soft-bodied algae and diatom community structure can be used to assess many aspects of stream water quality including the effects of nutrient loading and other contaminants, such as dissolved metals and trace organics. The Southern California Coastal Water Research Project (SCCWRP) scientists have created the Southern California Algae Index of Biotic Integrity (SoCA Algal IBI) which is similar to the index used for BMIs by using algal taxonomy to assess anthropogenic impacts. Algae samples were collected from 2007 through 2010 at a total of 451 distinct southern California stream reaches to develop the IBI scoring system. The SoCA Algal IBI is composed of three indices: 1) a diatom IBI (D18) is based solely on diatom metrics; 2) a soft algae IBI (S2) is based solely on non-diatom (soft) algae metrics; and 3) a hybrid (H20) of both diatom and soft bodied algae metrics. IBIs are composed of metrics chosen for their ability to differentiate between reference and non-reference stream conditions. The SoCA Algal IBI metrics, IBI score, and quality control results were calculated using the SCCWRP SoCA Algal IBI calculator and its underlying R script. SCCWRP is currently in development of a new algal scoring tool called the Algal Stream Condition Index (ASCI). Modeled after the CSCI, this will be an additional line of evidence to assess biological stream health. It is anticipated that the next reporting cycle will include ASCI analysis.

Figure C-11-V.5 below contains algae data from the three indices for the bioassessment sites sampled in 2016. The 2017 data is still being analyzed and quality controlled by the State and should be completed in early 2018. The H20 boundary chosen to delineate between reference and non-reference condition (57 on a scale from 0 to 100) was based purely on statistical grounds, and was calculated as two standard deviations below the mean distribution of reference sites. As a result, it does not represent an ecologically meaningful change point in community composition and cannot be used in a regulatory framework. An H20 score above 57 is considered reference condition, and below 57 is considered non-reference. The S2 and D18 indices do not have accepted scoring thresholds to date.

The figure demonstrates that both reference location sites (SMC00105, Silverado Creek) and urban locations can score poorly with the H20 index and sub-indices. However, reference and urban stations in the Santa Ana Region have also scored above the 57 threshold for the H20 index, as was the case with the 2015 stations. Further study and trend analysis should be completed before any conclusions can be made from these assessments. The aforementioned ASCI could assist with this effort in the future.

Figure C-11-V.5: Algal IBI Scores, Spring 2016. The figure displays the 2016 SoCA Algal IBI and the three indices for the six monitored stations. 2017 results should be available in early 2018.



C-11-V.3 Spatial Pattern Analysis

In addition to describing patterns and trends in benthic macroinvertebrates, a further purpose of the SMC Program is to evaluate the triad of monitoring indicators to determine whether physical habitat, aquatic chemistry, and algae are correlated with CSCI scores. If strong correlations exist, then this would suggest the presence of a causal relationship between the various stressors and biological integrity. Previous analysis conducted by the SMC Program has shown that water chemistry and toxicity data does not have a strong correlation with impaired biology, thus the suspension of metals, pesticides, and toxicity collection (except with the SGRRMP, which has retained metals and pesticides). Impaired and/or degraded physical habitat remains the strongest driver of lower CSCI scores.

The spatial pattern analysis of biotic integrity consists of five elements:

1. Spatial Distribution;
2. Relationship to Aquatic Chemistry;

3. Biological Cluster Analysis;
4. Correlation with Algae; and,
5. Correlation with Metrics and Parameters

Spatial Distribution

Broad patterns exist in 2017 for interrelated indicators (i.e., CSCI and CRAM) and were mapped in **Figure C-11-V.6** below. As with other years, impaired physical habitat is linked with undesirable benthic assemblages. **Figure C-11-V.7** historically shows consistently low CSCI scores across the urbanized portion of the County (CSCI < 0.79). Some sites in the upper watershed, especially those around and east of Irvine Lake, had CSCI scores that were ≥ 0.79 indicating the health and diversity of biological communities at these locations were similar to those found at reference sites in the CSCI dataset. The physical habitat and surrounding riparian zones tend to be of better quality in these areas. This trend in more diverse and complex habitat is also captured in **Figure C-11-V.8**, which displays historical CRAM scores throughout the SMC Program.

Figure C-11-V.6: Summary of Overall Conditions in 2017. This map depicts overall conditions observed at sites monitored in 2017. For this analysis, physical habitat was measured using the comprehensive California Rapid Assessment Method (CRAM).

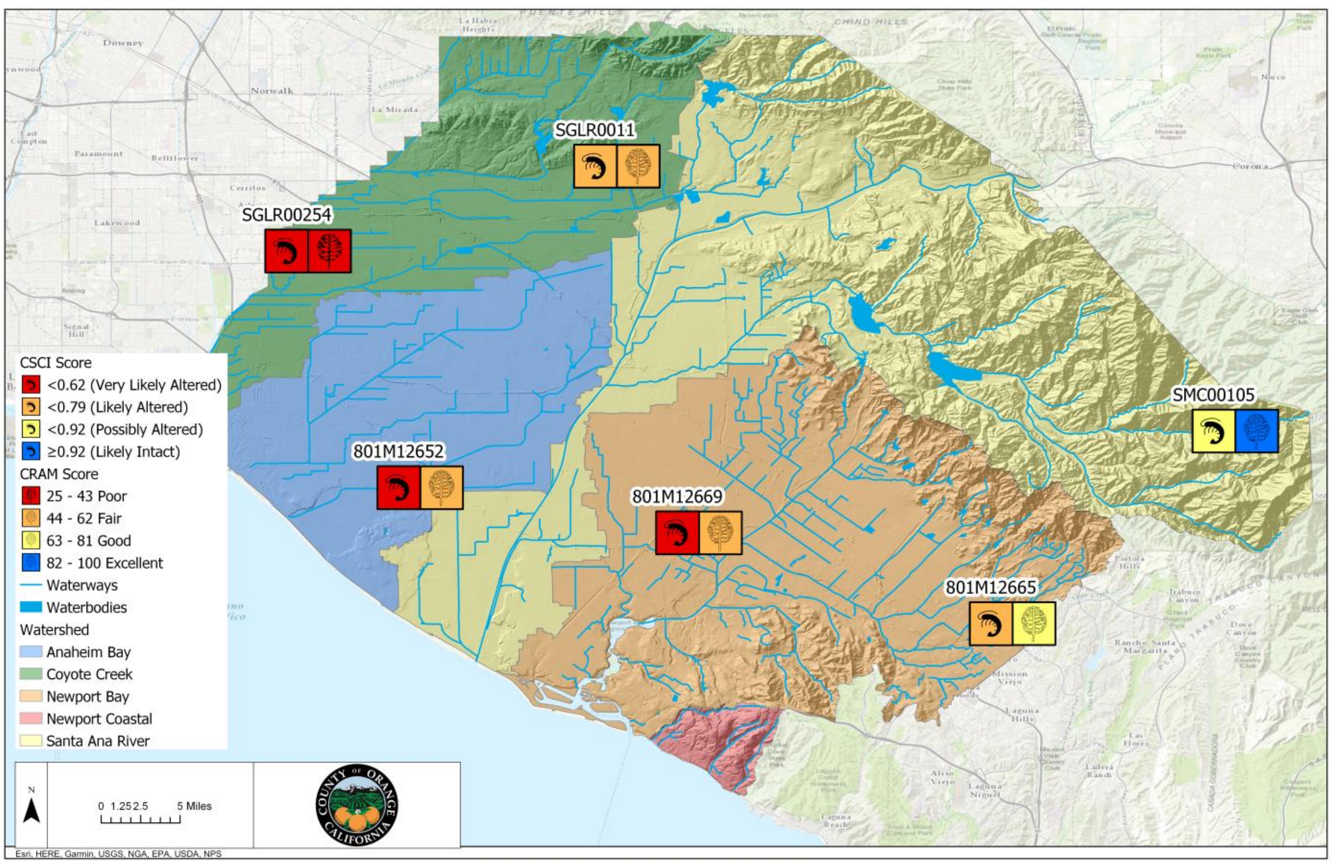
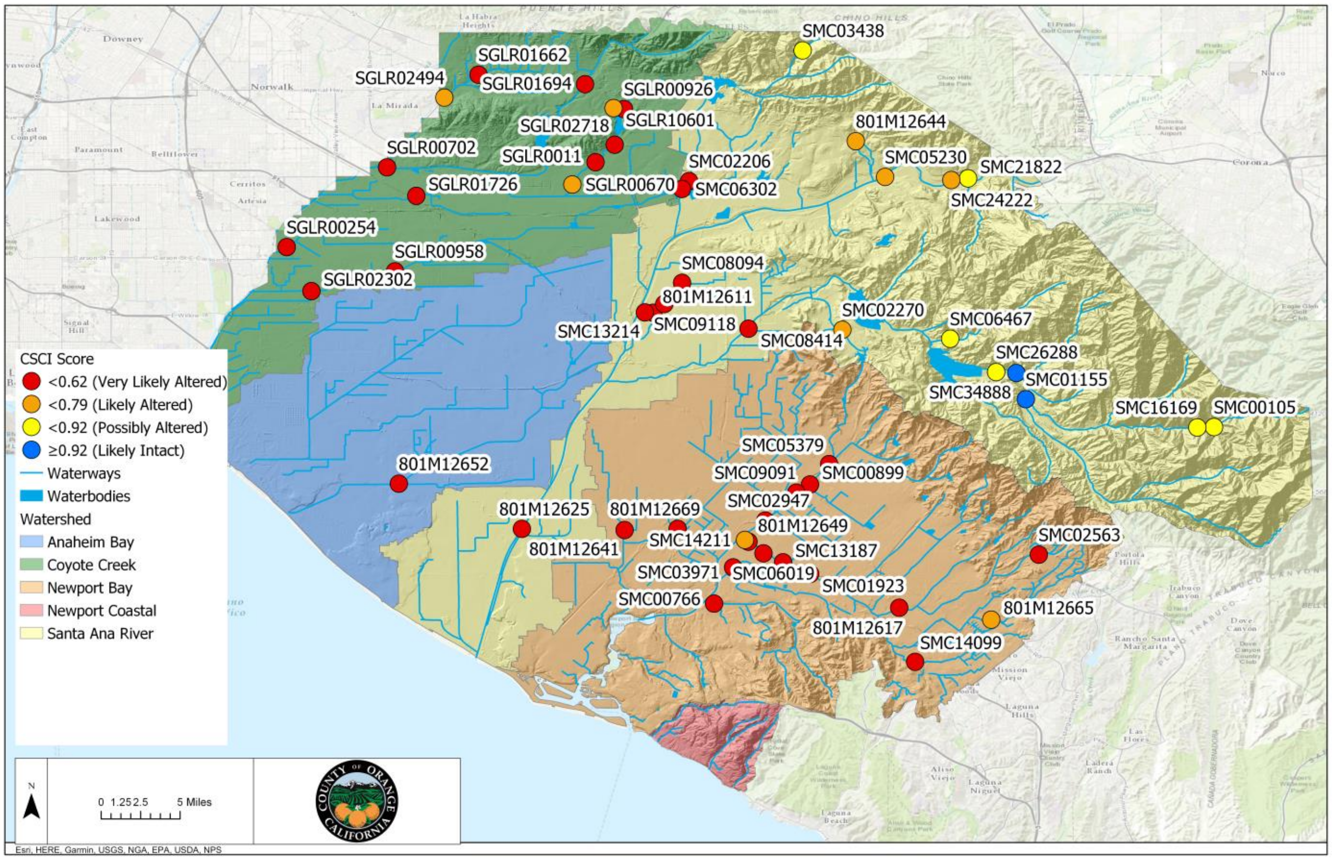


Figure C-11-V.7: Patterns of CSCI Scores for the SMC Program, 2009 - 2017. This map shows regional CSCI scores observed as part of the SMC Program since its inception in 2009. The color scheme for the scores has been adjusted from **Figure C-11-V.2** to match the CSCI scale and condition categories used in the referenced SWAMP technical memo. Stations that have been sampled more than once during this period show the average CSCI score.



The CRAM scores perform much better in the upper Santiago Creek sub-watershed, especially in Santiago and Silverado Creeks as shown in **Figure C-11-V.8**. These stations often have physical habitats that are dominated by strong canopy cover to keep the water temperature cooler, and to provide fallen debris in the stream for increased habitat complexity. Various woody debris and cobble rocks also provide habitats for BMIs that are more sensitive to impairments. CRAM scores for lower watershed locations consistently score poorly due to extensive channel alteration and the consequential loss of habitat. Between 2009 and 2017, there was a relatively strong association between CSCI and CRAM scores ($R^2 = 0.5322$) in these watersheds as shown in **Figure C-11-V.9**. Another trend with these locations is that groundwater sources are not as prominent, aiding in keeping the dissolved solids (especially chloride) relatively lower in these locations.

Figure C-11-V.8: Patterns of CRAM Scores for the SMC Program, 2009 - 2017. This map shows overall CRAM scores observed in the SMC monitoring program since its inception in 2009. Stations that have been sampled more than once during this period show the average CRAM score.

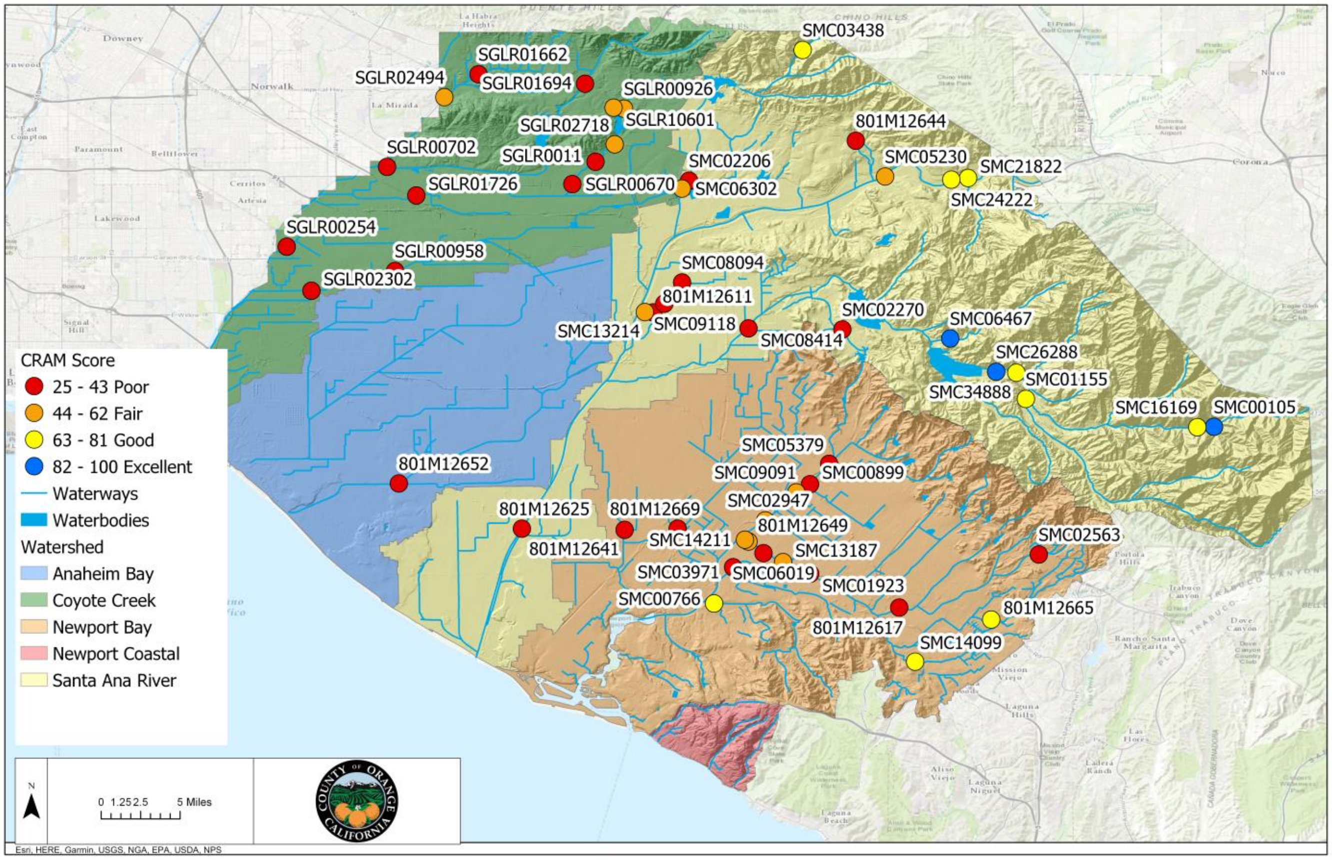
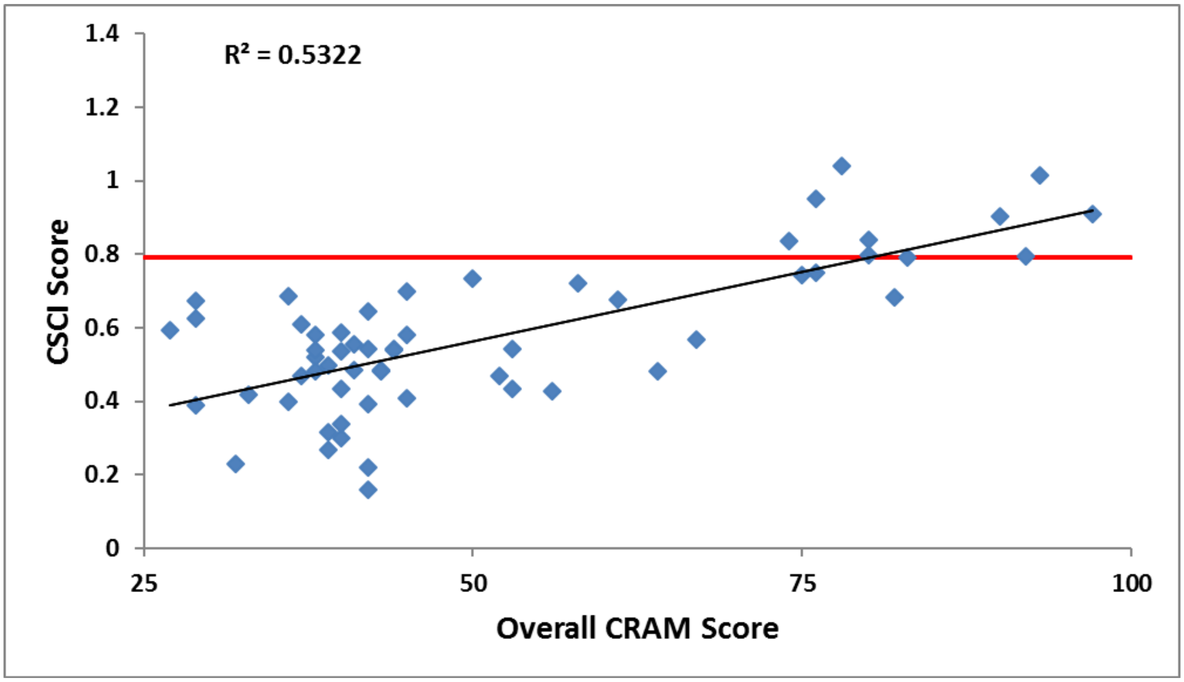


Figure C-11-V.9: CSCI Score versus Overall CRAM Score. This graph shows the correlation between CRAM scores of the riparian and buffer zones surrounding a stream reach and the biological condition (CSCI score) through the 2017 sampling season. Correlations with biological condition of 0.4 or greater ($R^2 = 0.5322$) are considered to be reasonably strong for this assessment. The red horizontal line indicates the 30th percentile of the CSCI, and scores below this line either fall in the likely or very likely altered condition categories.



Relationships to Aquatic Chemistry

Detailed monitoring data for aquatic chemistry were examined to determine whether there are any clear relationships to biotic integrity at a finer level of detail. No definitive relationships could be made between chemical concentrations and CSCI scores. However, urban streams are typically characterized by elevated nutrients, which are known to impair benthic communities. Furthermore, stations on streams with known groundwater sources (801M12669) have elevated dissolved solids and chloride, which more than likely contribute to the lower CSCI score at these stations. It should be mentioned that these stations are also in highly modified flood control channels. Therefore, the physical habitat is also significantly impaired and certainly driving down the biotic integrity. Trying to determine the extent to which these factors have contributed to impaired biology is difficult to assess. Causal analysis could be considered to attempt to tease out the sources of the impairments in these types of stream habitats. At the two SGRRMP stations, CTR exceedances of metals were not observed for the dissolved fraction for both acute and chronic concentrations.

A more detailed analysis of the individual parameters monitored with a historical perspective can be seen in the Correlation with Metrics and Parameters section with **Figure C-11-V.14** through **Figure C-11-V.19**.

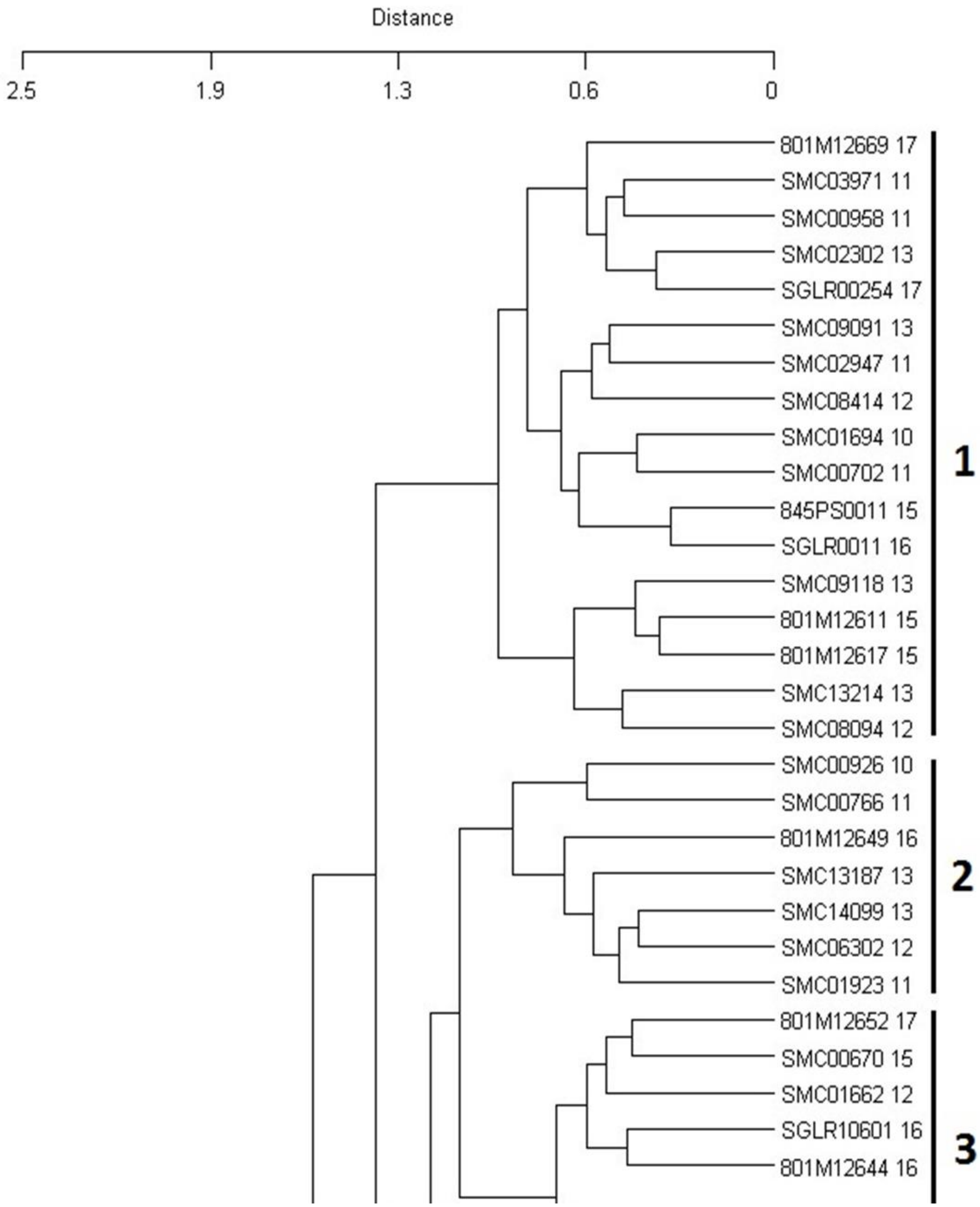
Biological Cluster Analysis

A more powerful set of analyses were used to discern relationships between the biological patterns in the benthic community and patterns in potential explanatory variables in the physical habitat and aquatic chemistry.

As a first step, the species data from all surveys were clustered to identify groupings of sites that were similar in terms of their community composition. The dendrogram in **Figure C-11-V.10** below shows the cluster analysis and groupings of all sites during surveys conducted from 2009 to 2017. Cluster analysis arranges sites that are similar to one another based on species composition and abundances. Sites that are near one another on a dendrogram node are similar to one another in terms of the BMIs collected at those locations. The clusters have years fairly evenly spread between them indicating that annual variation (i.e., drought vs. wet years) was not as great a factor as location and habitat condition. The sites in cluster Group 6 were located in the upper watershed (especially Santiago Creek sub-watershed) and have some of the best CSCI scores.

Figure C-11-V.11 is the two-way coincidence table of the relative distribution of species at each site during each monitoring event. Horizontal and vertical lines on the two-way coincidence table identify major groupings of species and site locations, respectively. Sites are identified by their station number and year of sampling. Relative species abundances are shown as symbols in the table. Smaller symbols represent a lesser proportion of maximum abundance and larger symbols a greater proportion. The abundance of each species was standardized in terms of its maximum at each site over all surveys. Again, cluster Group 6 is dominated by upper watershed site locations.

Figure C-11-V.10: Dendrogram Analysis of Sites Surveyed in the Santa Ana Region, 2009 – 2017 (continued on the next page). Cluster analysis arranges sites that have similar BMI assemblages. Six cluster groups represent the nine years of the SMC Program. Data were square root transformed and distances between groups were calculated using the Bray-Curtis Similarity Index. Groups were defined by cluster analysis using a trimmed species list that excluded rare species.



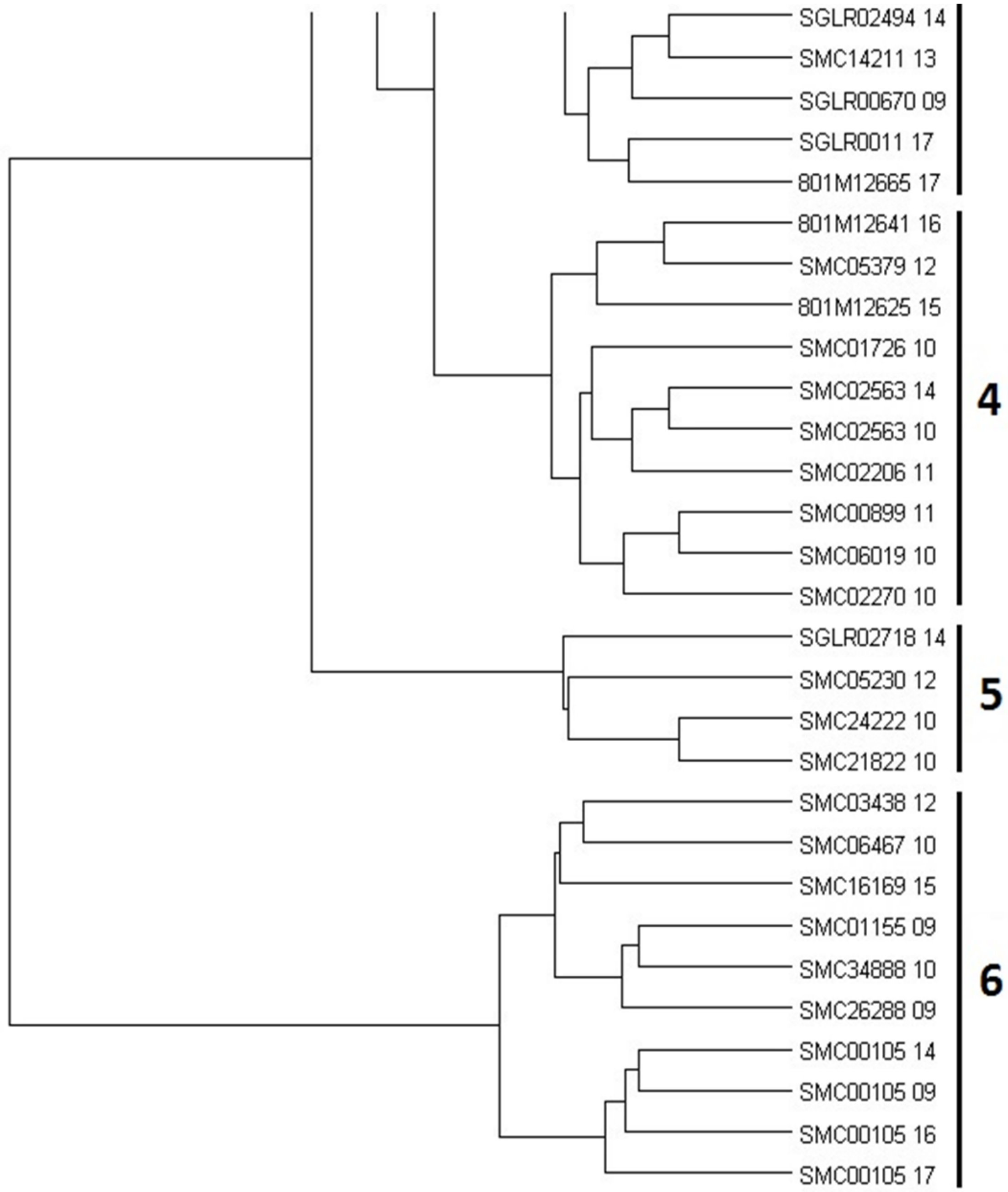
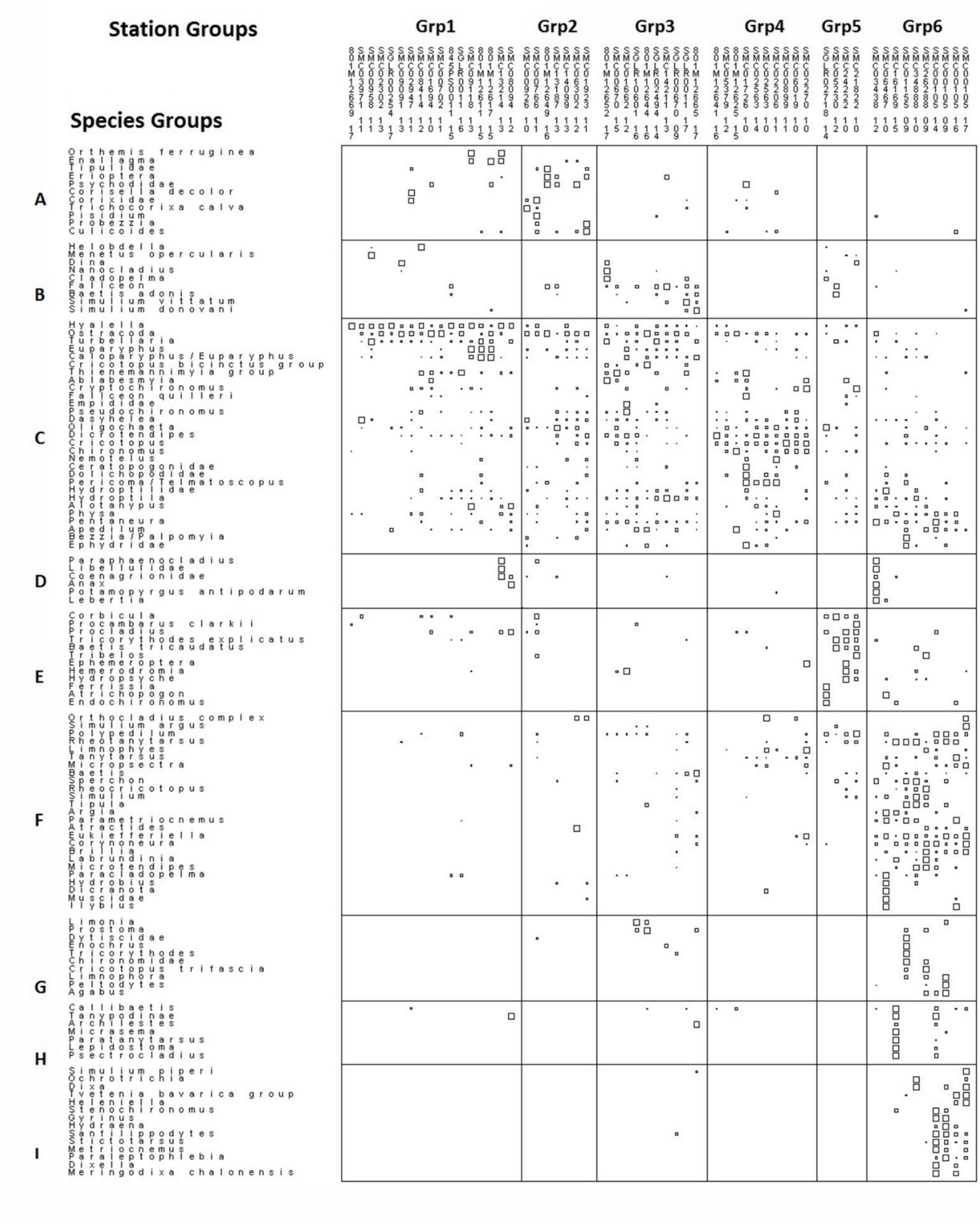


Figure C-11-V.11: Two-Way Coincidence Table of Sites Surveyed in the Santa Ana Region, 2009 – 2017 (see next page). The two-way coincidence table is simply a different way of looking at the cluster analysis. The same six cluster groups of stations are depicted along the horizontal axis, while the species clusters are depicted along the vertical axis. The symbols in the graph show the relative abundance of each species and how important they are at a given site. Group I includes species that are more sensitive to pollution and impaired habitat, and are dominant in sites in the upper watershed (Upper Santiago and Silverado Creeks).

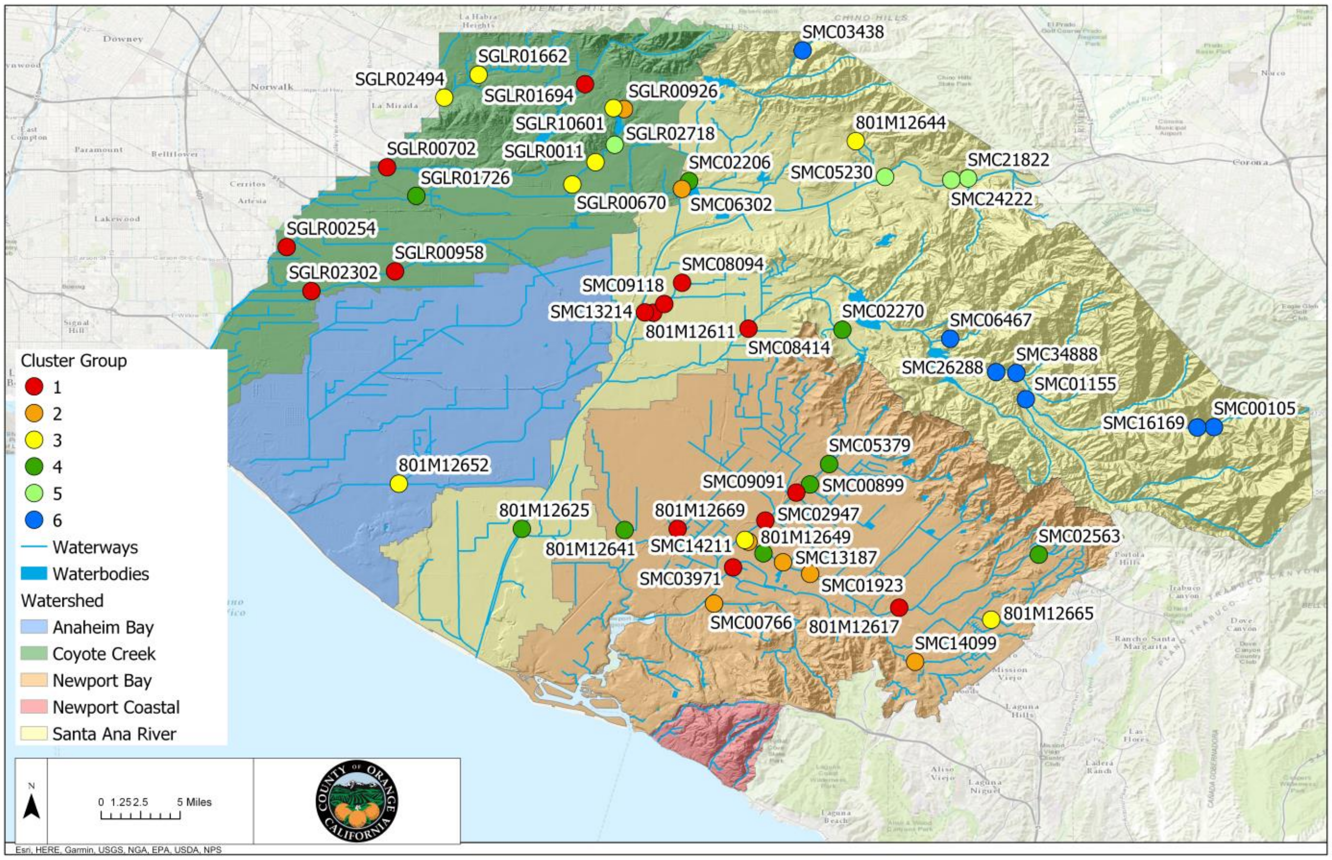

Station Groups
Grp1
Grp2
Grp3
Grp4
Grp5
Grp6
Species Groups
A
B
C
D
E
F
G
H
I
Orthemis ferruginea
Enallagma
Tipulidae
Erioptera
Psychodidae
Corisella decolor
Corixidae
Trichocorixa calva
Pisidium
Probezzia
Culicoides
Helobdella
Menetus opercularis
Dina
Nanocladius
Cladopelma
Fallceon
Baetis adonis
Simulium vittatum
Simulium donovani
Hyalella
Ostracoda
Turbellaria
Euparyphus
Caloparyphus/Euparyphus
Cricotopus bicinctus group
Thienemannimyia group
Ablabesmyia
Cryptochironomus
Fallceon quilleri
Empididae
Pseudochironomus
Dasyhelea
Oligochaeta
Dicrotendipes
Cricotopus
Chironomus
Nemotelus
Ceratopogonidae
Dolichopodidae
Pericoma/Telmatoscopus
Hydroptilidae
Hydroptila
Alotanypus
Physa
Pentaneura
Apedilum
Bezzia/Palpomyia
Ephydridae
Paraphaenocladius
Libellulidae
Coenagrionidae
Anax
Potamopyrgus antipodarum
Lebertia
Corbicula
Procambarus clarkii
Procladius
Tricorythodes explicatus
Baetis tricaudatus
Tribelos
Ephemeroptera
Hemerodromia
Hydropsyche
Ferrissia
Atrichopogon
Endochironomus
Orthocladius complex
Simulium argus
Polypedilum
Rheotanytarsus
Limnophyes
Tanytarsus
Micropsectra
Baetis
Sperchon
Rheocricotopus
Simulium
Tipula
Argia
Parametriocnemus
Atractides
Eukiefferiella
Corynoneura
Brillia
Labrundinia
Microtendipes
Paracladopelma
Hydrobius
Dicranota
Muscidae
Ilybius
Limonia
Prostoma
Dytiscidae
Enochrus
Tricorythodes
Chironomidae
Cricotopus trifascia
Limnophora
Peltodytes
Agabus
Callibaetis
Tanypodinae
Archilestes
Micrasema
Paratanytarsus
Lepidostoma
Psectrocladius
Simulium piperi
Ochrotrichia
Dixa
Tvetenia bavarica group
Heleniella
Stenochironomus
Gyrinus
Hydraena
Sanfilippodytes
Stictotarsus
Metriocnemus
Paraleptophlebia
Dixella
Meringodixa chalonensis

These two figures clearly show several dominant patterns. First, sites that are at or near reference conditions based on the CSCI are concentrated at the lower end of the dendrogram, which is equivalent to station Groups 5 and 6, located on the right side of the two-way coincidence table. These sites are mostly located in the upper watershed above and east of Irvine Lake (see **Figure C-11-V.11** above and **Figure C-11-V.12** below).

Secondly, there is no clear clustering of sites based on the sample year. This suggests that annual variability in weather conditions is not driving the composition and abundances of taxa in the watersheds. Rather, it is predominantly based on habitat conditions (**Figure C-11-V.9**), as well as some geographic correlations as well (**Figure C-11-V.12**). Cluster Groups 1 through 4 tend to be gathered in highly urbanized geographical areas. Therefore, similar habitat conditions are found in each of the respective cluster groups, such as armored flood control channels. Groups 5 and 6 are gathered in tighter geographical areas, especially along the Santa Ana River (Group 5) and Upper Santiago Creek watershed (Group 6). It can be inferred that taxa in these groups have more specific habitat requirements that are limited or do not exist in urbanized regions.

Lastly, species with broader spatial and temporal distributions are concentrated in the upper three species groups (Groups A, B, and C) on the two-way coincidence table. Species with such extensive distributions tend to be more pollution and/or habitat disturbance tolerant. In contrast, species in the lower two species groups (Groups H and I) have much more restricted distributions, and are found primarily at the upper Santiago Creek watershed and upper Santa Ana River sites where anthropogenic impact is relatively minimized. A closer examination of the species groups in the two-way coincidence table shows that species Group I contains a diverse assemblage of several sensitive types of organisms, such as the coleopteran (beetle) *Gyrinus spp*., or the trichopteran (caddisfly) *Ochrotrichia*. Species Groups A, B and C (at the top of the two-way table) include moderate to very tolerant species characteristic of disturbed sites such as the amphipod *Hyalella azteca*. Moreover, many of the dominant taxa at the upper and lower vertical ends of the two-way coincidence table are characterized by larger symbols, thus a larger proportion of species abundance. **Figure C-11-V.12** is effective at spatially capturing these patterns.

Figure C-11-V.12: Map of the Cluster Group Distribution across the Santa Ana Region, 2009 - 2017. This map includes historical and current year bioassessment data and is intended to show the locations of cluster group sites. As indicated above, Group 6 is found in the upper watersheds, particularly in the Santiago Creek watershed east of Irvine Lake.

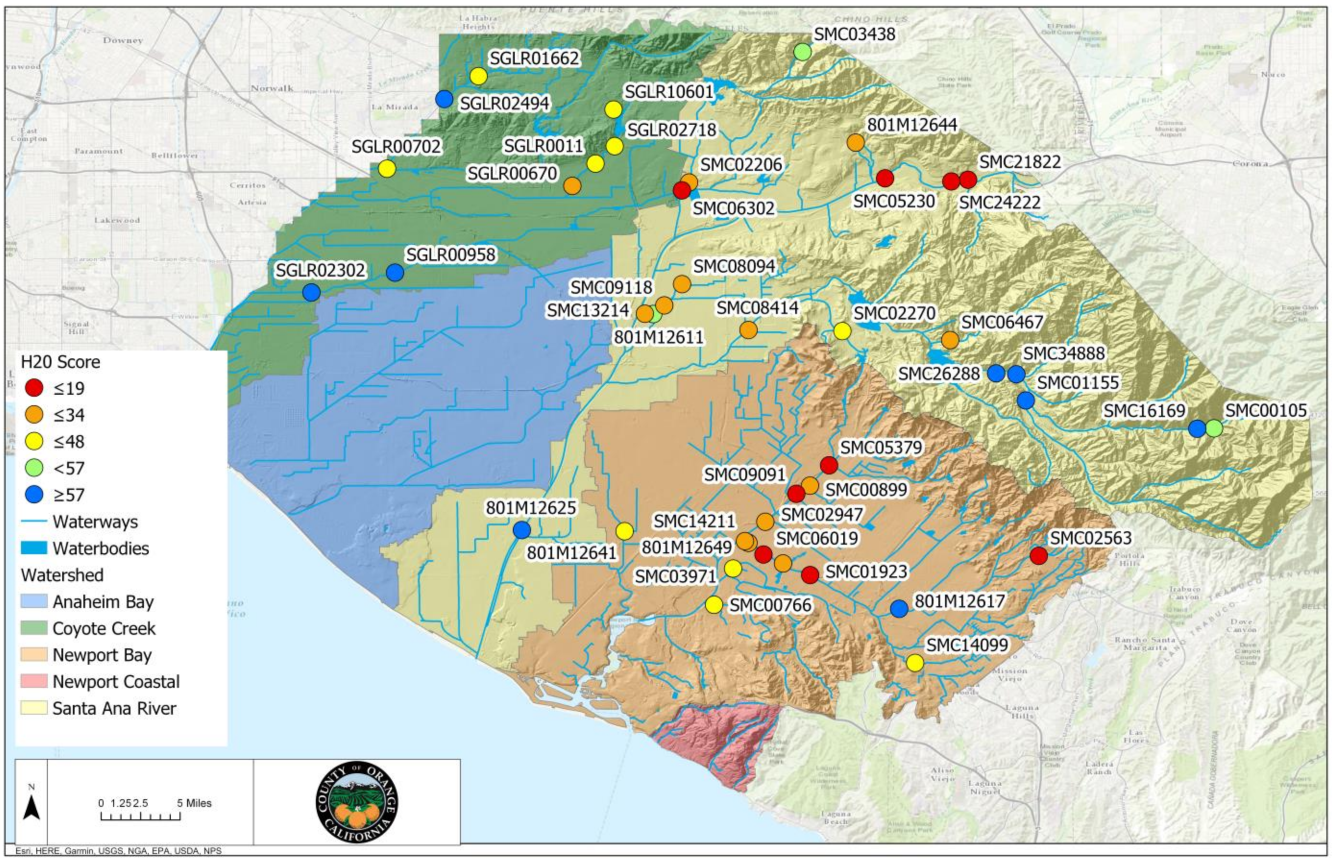


Correlation with Algae

Historical spatial analysis was completed for algae using the soft algae and diatom hybrid H20 index. **Figure C-11-V.13** shows the H20 scores for all SMC stations through 2016. A score ≥ 57 indicates reference condition and less than 57 is considered non-reference. The rest of the scoring range is arbitrary without corresponding condition categories, but it assists in providing some spatial context. H20 scores do not always reflect the CSCI scores for the six cluster groups, especially in urban site locations. Conversely, sites in the Santiago Creek watershed east of Irvine Lake regularly score 57 or higher. It is interesting that despite known legacy nutrient issues in the Newport Bay watershed, the H20 scores demonstrate impairment despite this abundant food source. Also of note is that some of the highly modified urban sites (e.g., 801M12625) score very well with the H20 index. It has been observed throughout southern California that diatoms specifically can score well in urban environments, even in concrete channels. For example, in 2016, SGLR10601 scored 72 on the diatom D18 index. Even though the D18 is lacking a scoring threshold, it is still indicative of the diatom community being in good condition. Despite elevated nutrients in these urban streams, several sensitive soft algae taxa thrive in conditions of low nutrient concentrations and cooler temperatures, as is evidenced by upper watershed locations.

The 2016 SMC algal scores should be available by spring 2017 once they are analyzed and quality controlled by the State. 2016 marked the beginning of a DNA extraction method, which is intended to assist in future algal taxonomy studies and analysis. However, greater study and analysis is needed to understand algal taxonomy in urban watersheds. To date there is not an accepted scoring threshold for the soft algae (S2) and diatom (D18) indices. There is currently an Algal Stream Condition Index (ASCI) in production at SCCWRP which is scheduled to be launched in the beginning of 2018. Next year's reporting period will include this new algal index if it is ready for use.

Figure C-11-V.13: Historical Algal H20 Index, 2009 – 2016. This map shows the historical stations with their corresponding H20 scores. Stations sampled more than once during this period show the average H20 score. The scoring range is arbitrary, but 57 or greater is considered reference. 2017 SMC algae data should be available in spring 2017.



Correlation with Metrics and Parameters

Variables measured during the surveys conducted from 2009 to 2017 were then grouped into biotic condition (e.g. CSCI scores), physical habitat parameters (e.g. channel alteration), water quality physical measurements (e.g. pH, dissolved oxygen), nutrients (e.g. nitrate), potential pollutant parameters (e.g. dissolved metals) and ions (e.g. sulfate). The median values of each parameter were then plotted for each cluster group using box and whisker plots. "Cluster Group" on the x-axis of the box and whisker plots refers to the site groupings based on taxa from the dendrogram and two-way coincidence table.

The box and whisker plots below show the condition of each cluster group as determined by the scoring mechanism for the respective analysis (**Figures C-11-V.14** to **C-11-V.19** below). Median CSCI scores (**Figure C-11-V.14**) were just below the "likely intact" condition category threshold of 0.92 for Group 6 (median CSCI 0.87), which were the sites located in the upper watershed east of Irvine Lake. Median CSCI scores were below the 0.79 threshold in Groups 1 through 5, placing these groups in the "likely altered" or "very likely altered" condition categories. Groups 1 through 5 are largely, although not completely, characterized by highly engineered sites located in the lower watershed. CSCI scores were somewhat better in Group 5, but this is a small sample size and trends cannot be definitively made.

Figure C-11-V.14: CSCI Score versus Cluster Group, 2009 - 2017. This boxplot shows how the median biological condition (CSCI score) is expressed for each of the station groups derived from the cluster analysis. There is a clear gradient of generally improving CSCI scores from cluster Group 1 through 6. Group 6 includes sites located mainly in the upper watershed where physical habitat conditions are relatively beneficial.

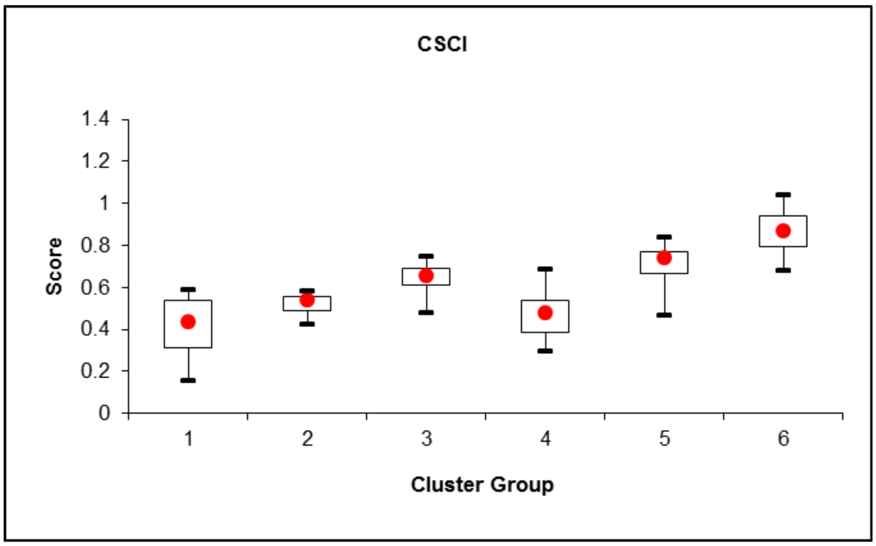


Figure C-11-V.15: Algal H20 Index versus Cluster Group, 2009 - 2016. This boxplot shows algal condition using the SoCA Algal IBI (H20 score), and is expressed for each of the station groups derived from the cluster analysis. There does not appear to be a clear trend in cluster Group 1 through 5. Group 6 likely has site specific factors providing relatively higher scores such as desirable nutrient concentrations as well as ambient surfaces for diatoms. 2017 algae data is not included in this analysis.

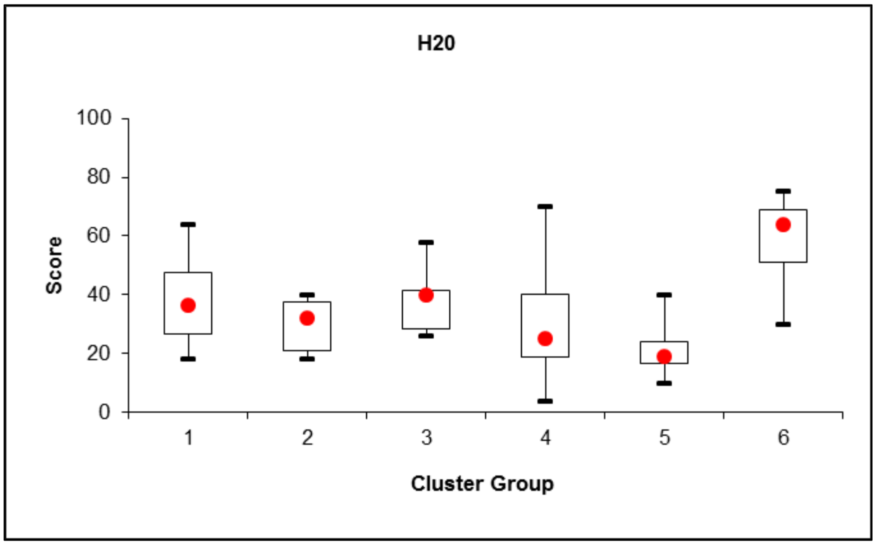
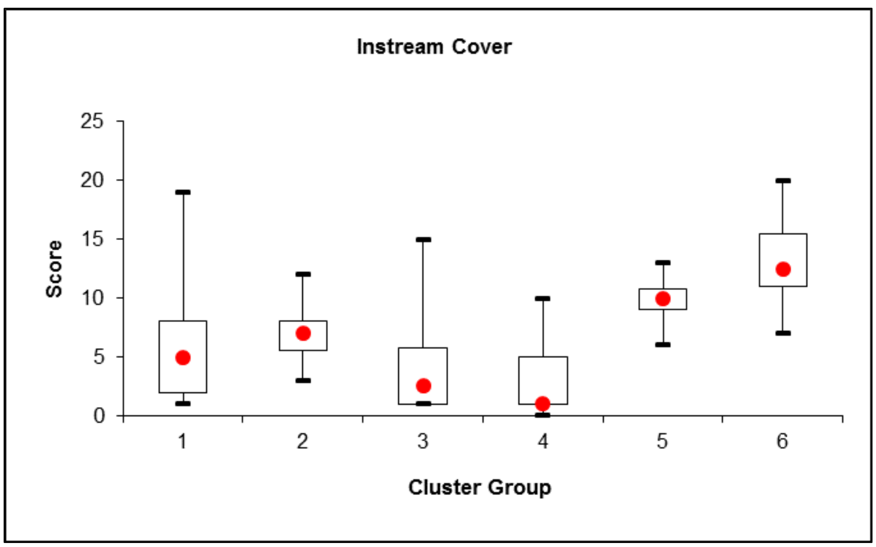
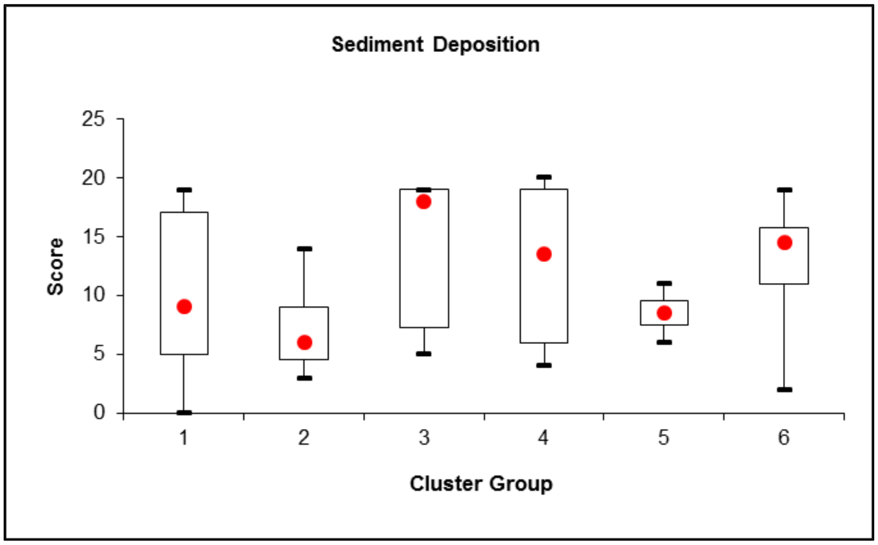


Figure C-11-V.16: Physical Habitat Condition versus Cluster Group as it relates to Instream Cover, Sediment Deposition, and Channel Alteration, 2009 – 2017 Continued on Next Page). These graphs show the three key physical habitat measures by station cluster groups. Instream cover and channel alteration show the strongest trends.




Sediment Deposition
Score
25
20
15
10
5
0
1
2
3
4
5
6
Cluster Group

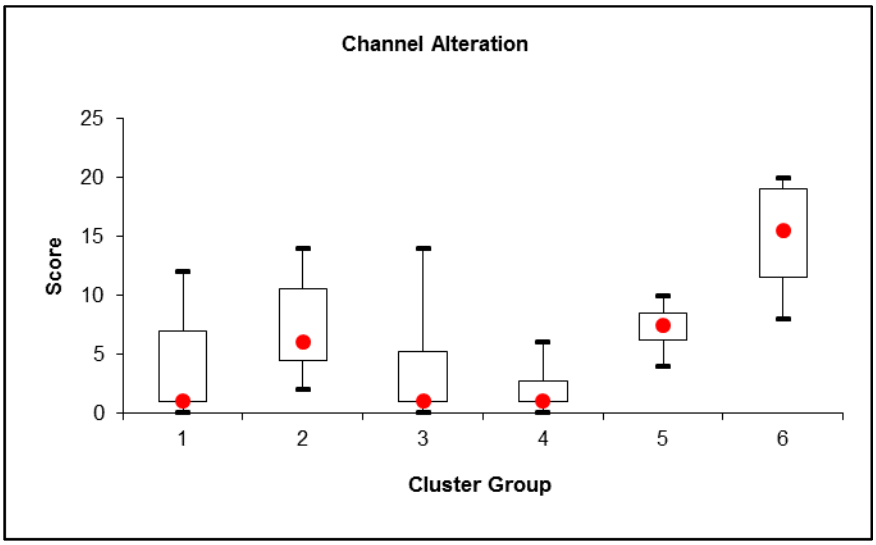
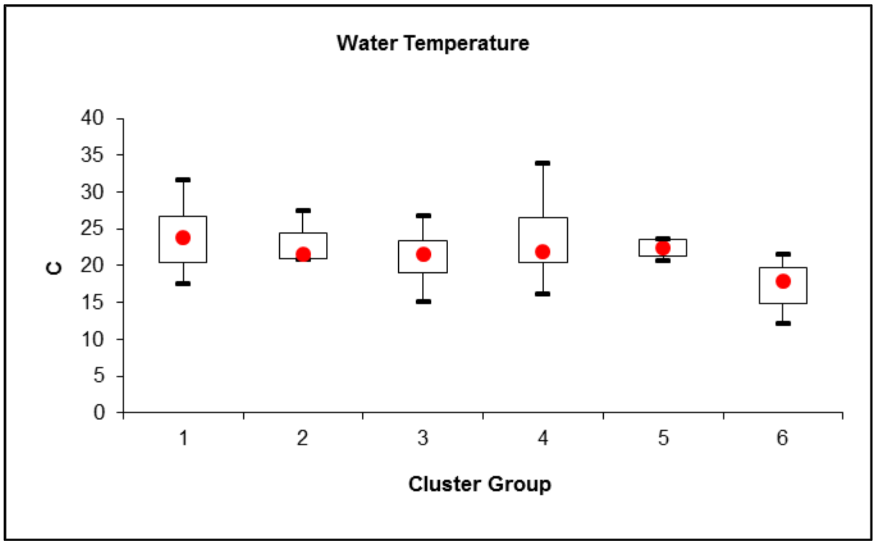
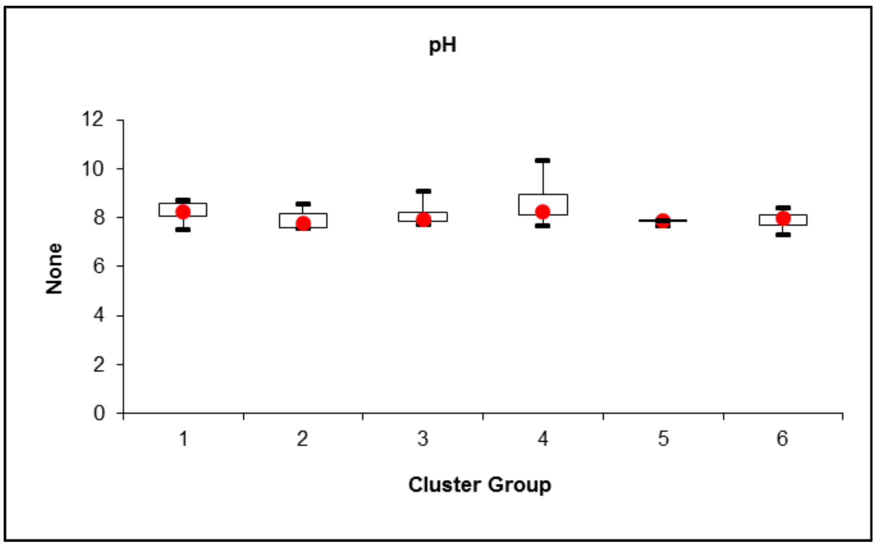
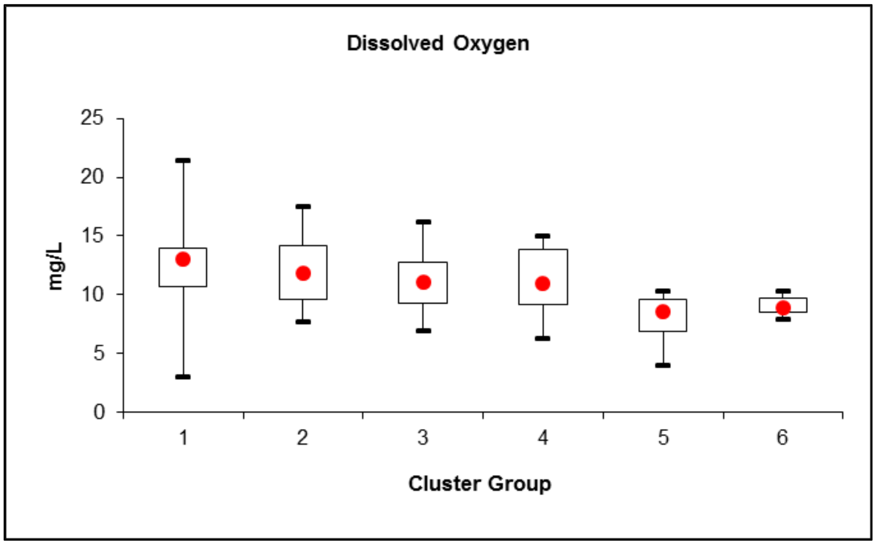
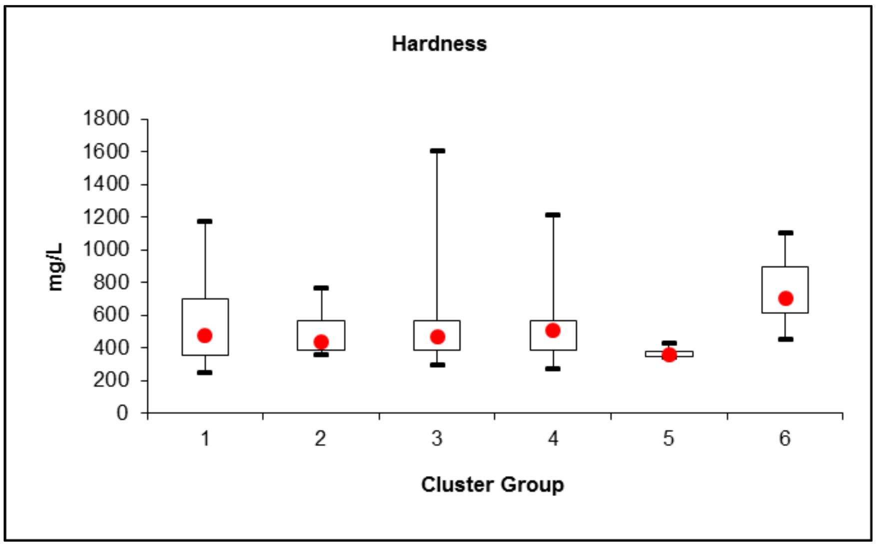

Channel Alteration
Score
25
20
15
10
5
0
1
2
3
4
5
6
Cluster Group

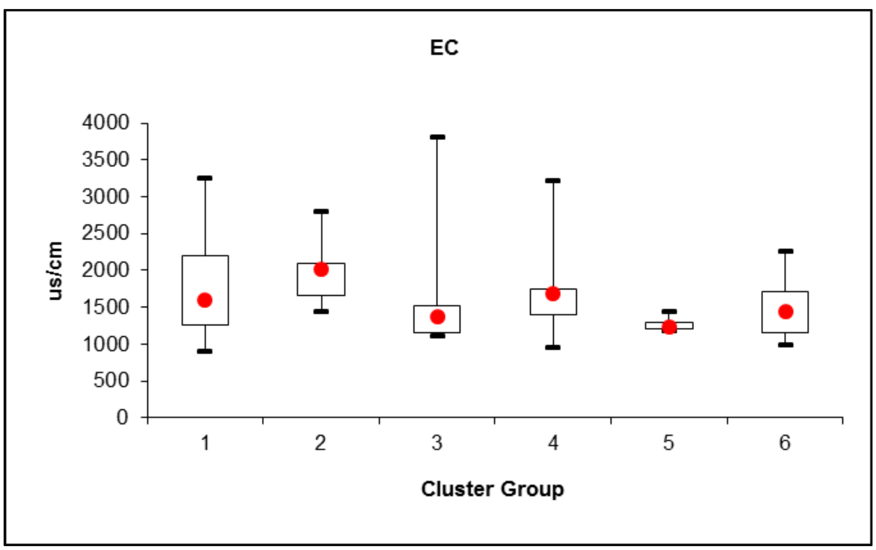
Figure C-11-V.17: Physical Parameters versus Cluster Group, 2009 – 2017 (Continued on Next Two Pages). Water quality conditions were generally similar across cluster groups indicating these results probably do not have a strong influence on the biological condition, whereas the CSCI condition categories do not follow the same pattern. The exception is cooler water temperature in cluster Group 6, which is more desirable for sensitive taxa and reflects better instream cover. Note the elevated suspended solids in Group 5.






Dissolved Oxygen
mg/L
25
20
15
10
5
0
1
2
3
4
5
6
Cluster Group


Hardness
mg/L
1800
1600
1400
1200
1000
800
600
400
200
0
1
2
3
4
5
6
Cluster Group


EC
us/cm
4000
3500
3000
2500
2000
1500
1000
500
0
1
2
3
4
5
6
Cluster Group

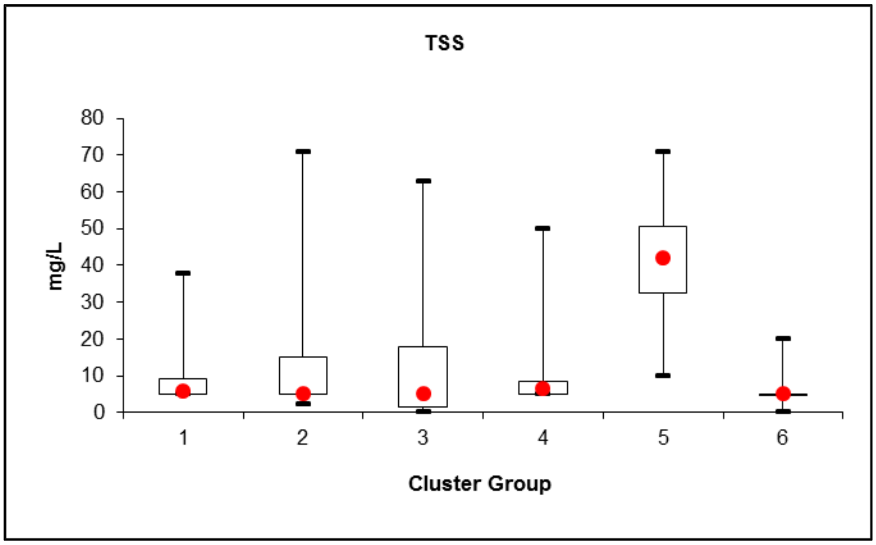
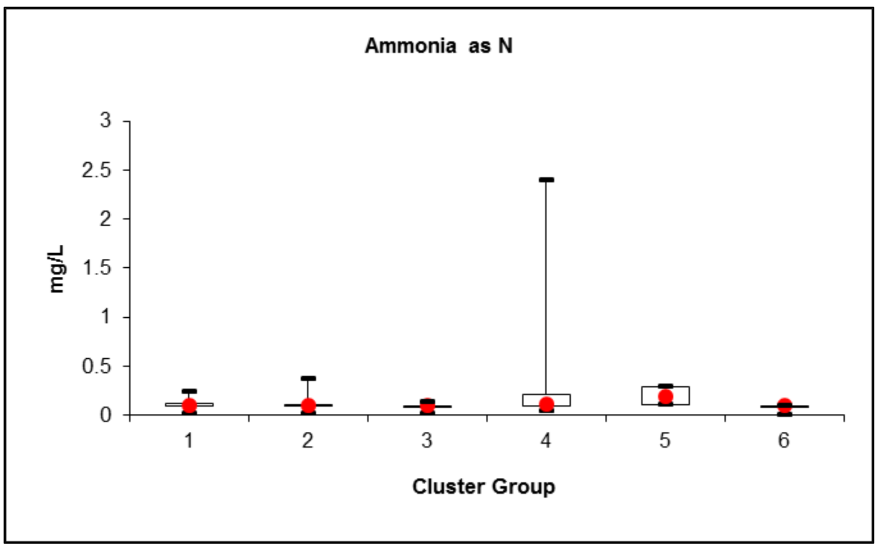
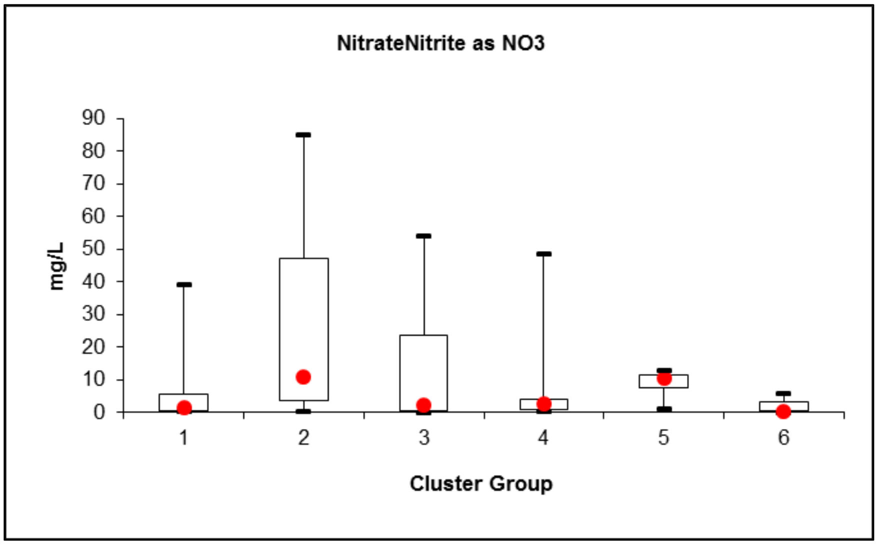
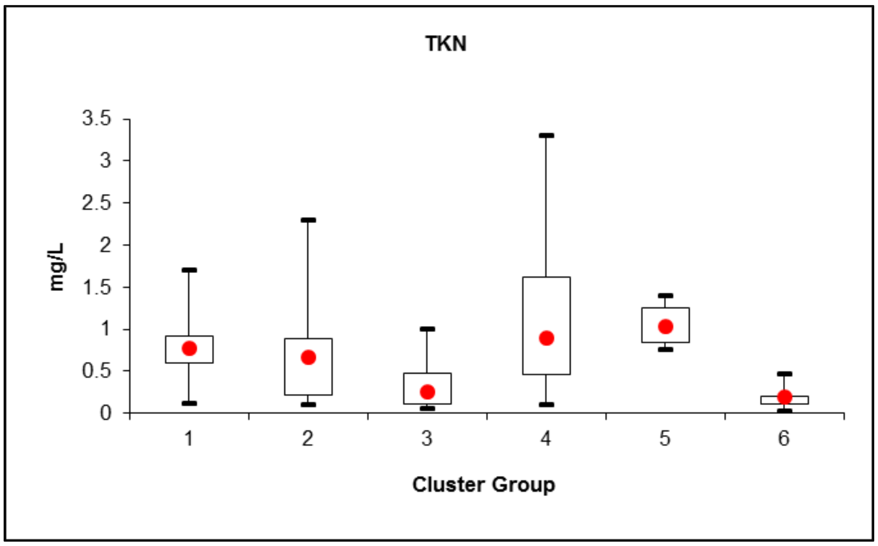
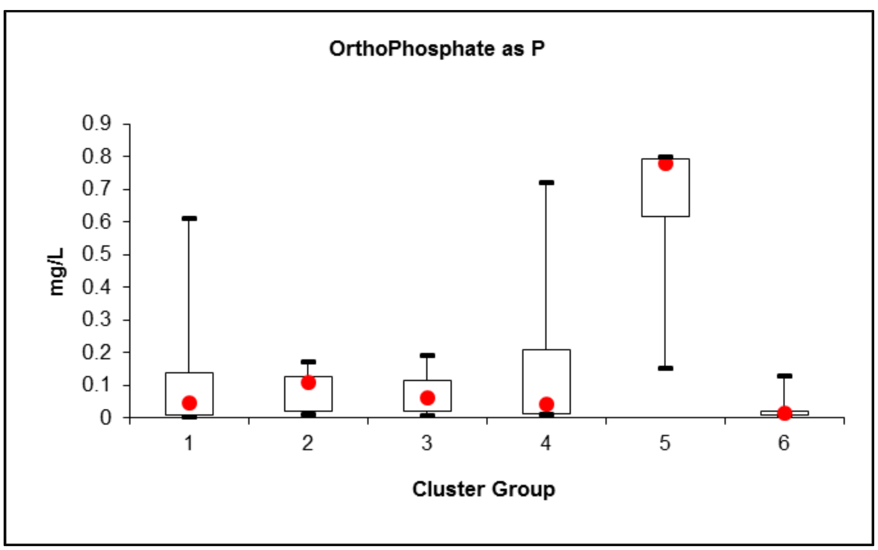


Figure C-11-V.18: Nutrient Parameters versus Cluster Group, 2009 – 2017 (Continued on Next Two Pages). Nutrient conditions across the cluster groups also do not show an obvious pattern. There are occasional instances of elevated nitrate/nitrite in Groups 1 through 4, as well as nitrogen in organic compounds (TKN). However, these are probably site specific and are just one potential factor in regards to undesirable CSCI scores for these cluster groups. Note the elevated orthophosphate concentrations at sites in Group 5.




NitrateNitrite as NO3
mg/L
90
80
70
60
50
40
30
20
10
0
1
2
3
4
5
6
Cluster Group


TKN
mg/L
3.5
3
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
Cluster Group


OrthoPhosphate as P
mg/L
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
2
3
4
5
6
Cluster Group

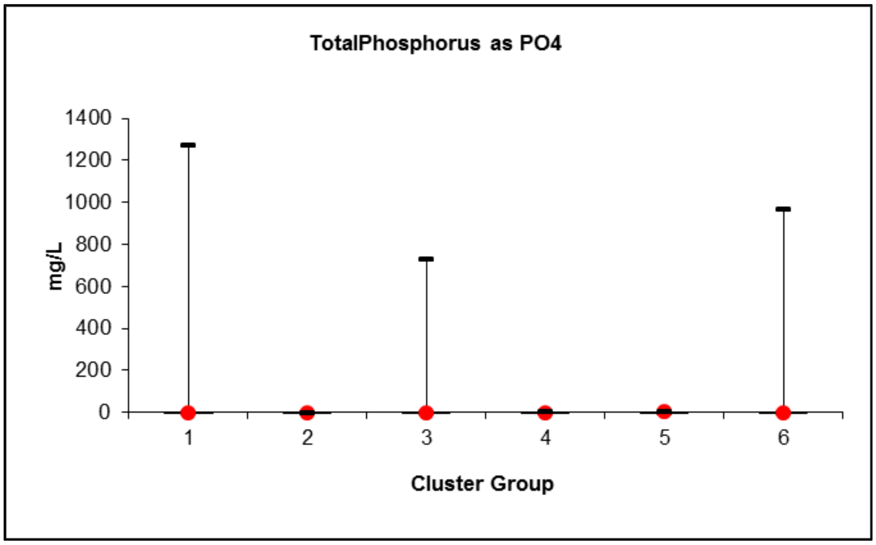
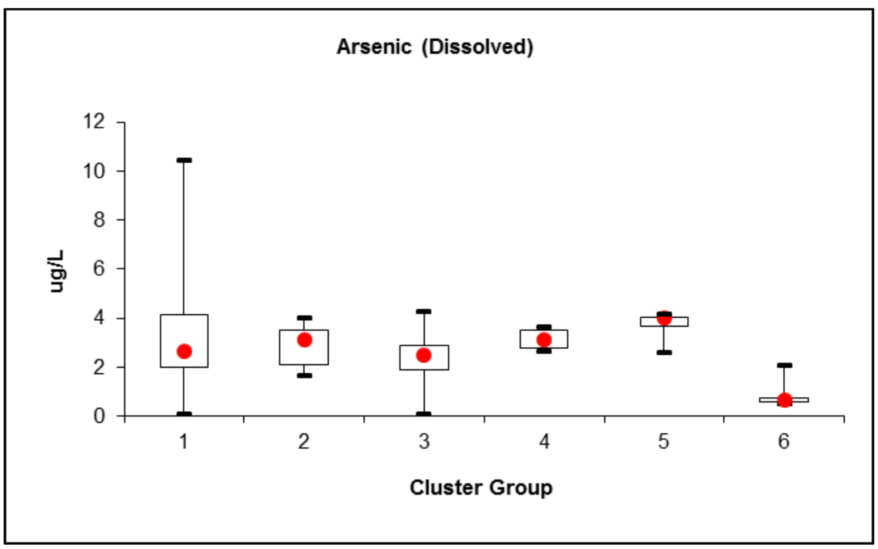
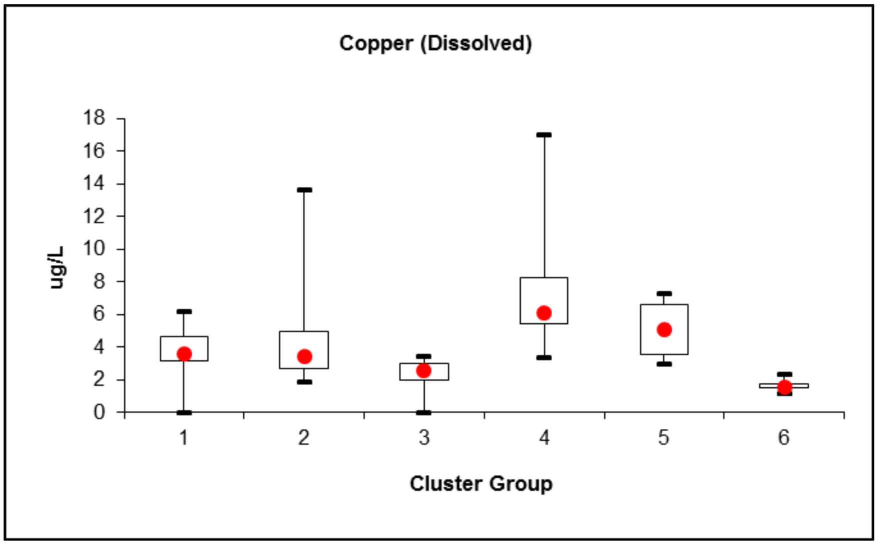
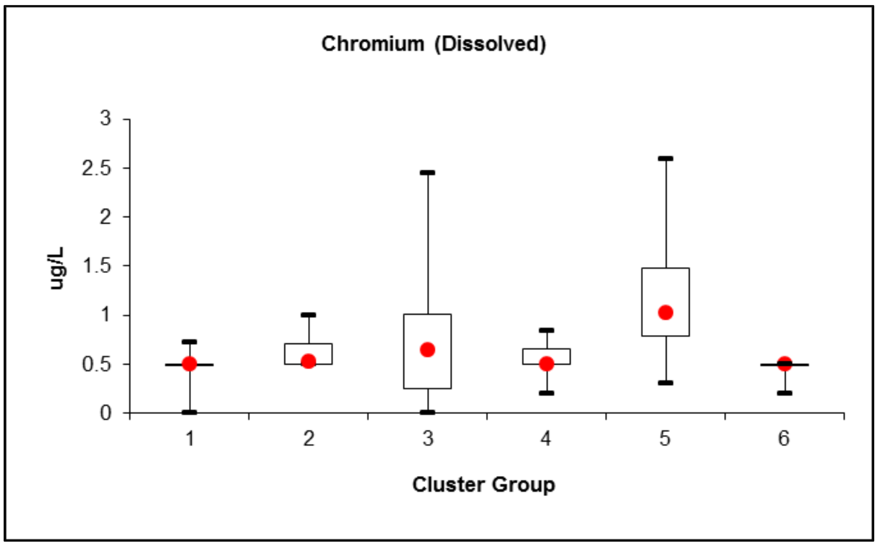
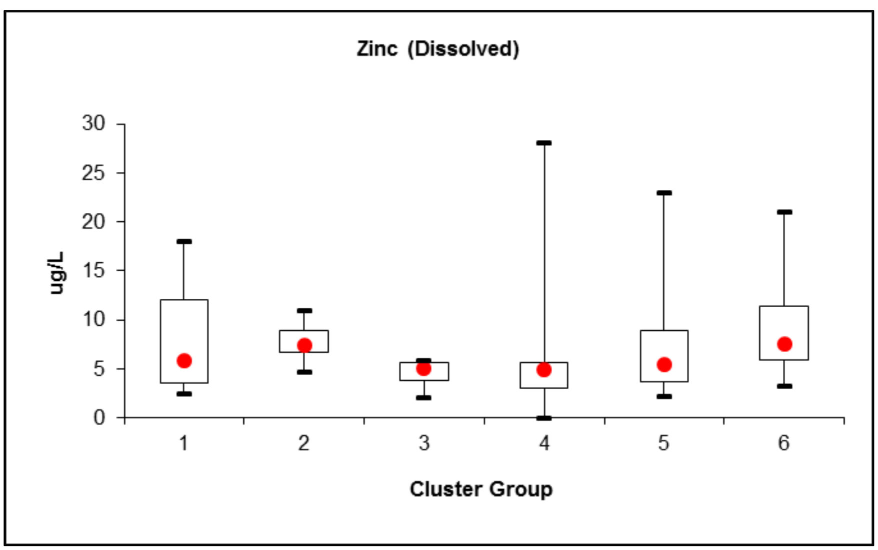


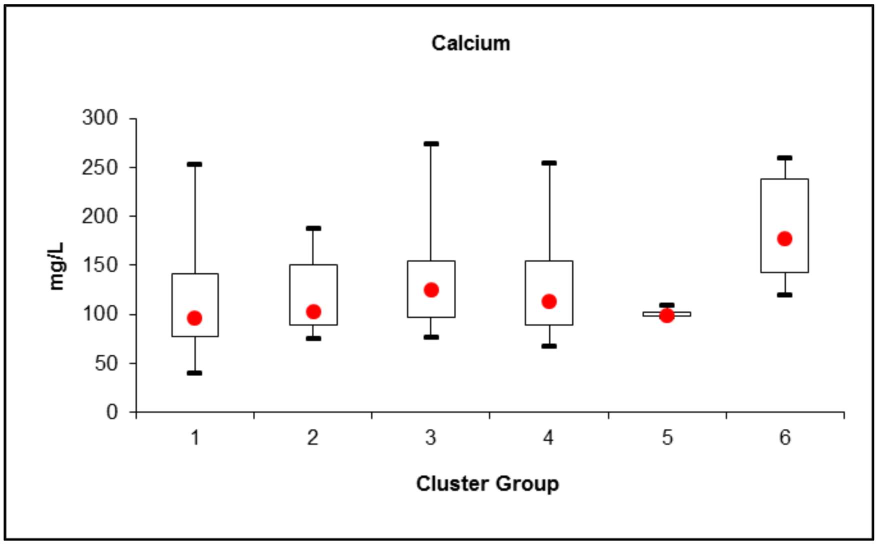
Figure C-11-V.19: Box and Whisker Plots of Dissolved Metals and Major Ions versus Cluster Groups, 2009 – 2017 (Continued on Next Three Pages). No clear dissolved metal trends are observed between the cluster groups outside of occasional elevated single outliers. Note that beginning in 2015, metals are no longer collected at SMC sites, but are continued at SGRRMP sites. Chloride generally decreases with increasing cluster group order.

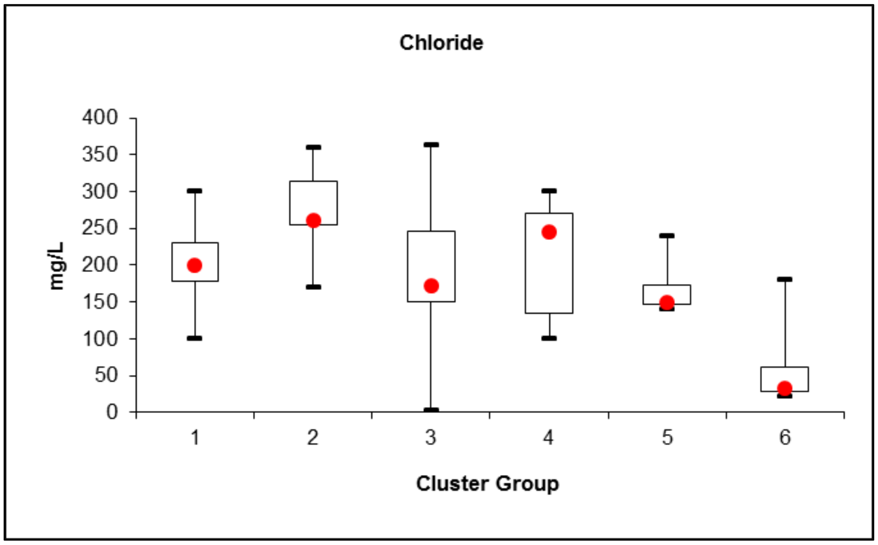


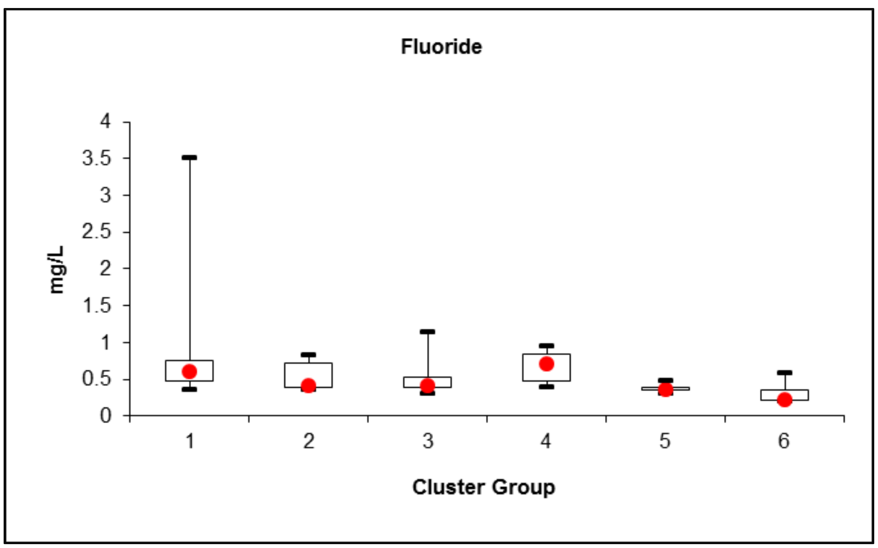

Copper (Dissolved)
ug/L
0
2
4
6
8
10
12
14
16
18
1
2
3
4
5
6
Cluster Group

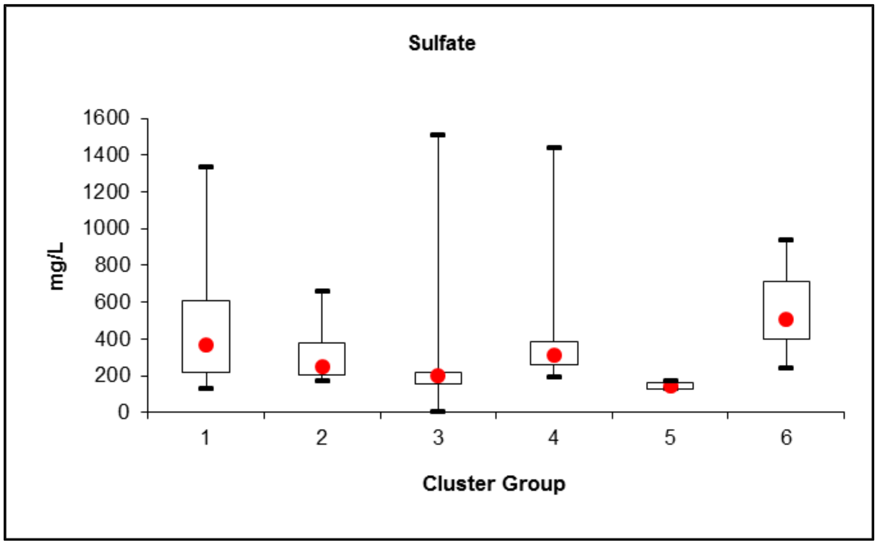

Chromium (Dissolved)
ug/L
0
0.5
1
1.5
2
2.5
3
1
2
3
4
5
6
Cluster Group


Zinc (Dissolved)
ug/L
0
5
10
15
20
25
30
1
2
3
4
5
6
Cluster Group


Calcium
mg/L
300
250
200
150
100
50
0
1
2
3
4
5
6
Cluster Group


Chloride
mg/L
400
350
300
250
200
150
100
50
0
1
2
3
4
5
6
Cluster Group


Fluoride
mg/L
4
3.5
3
2.5
2
1.5
1
0.5
0
1
2
3
4
5
6
Cluster Group



Physical habitat parameters differed markedly across the station groups. In general, physical habitat scores for channel alteration, in stream cover, and to a lesser extent sediment deposition, were in better condition at near reference location sites and worse in the lower watershed urban sites (**Figure C-11-V.16**). This is expected because diverse and more sensitive biological communities, such as those found in the upper watershed reference sites, require undisturbed and relatively complex instream habitat, coupled with good vegetative cover on the banks. These relationships are consistently reflected with the CSCI scores. The sites with the greatest median scores (Group 6) had the least amount of alteration. The lower watershed sites, in Groups 1 through 5 were moderately to substantially altered.

Values for physical chemistry parameters such as water temperature and dissolved oxygen were slightly elevated at the lower watershed site groups which is most likely associated with the reduction in canopy cover and nuisance algal growth in highly urbanized areas. Several parameters were relatively similar across cluster groups including pH, hardness, and conductivity (EC). The exception was the elevated total suspended solids (TSS) in Group 5. These are mostly Santa Ana River sites where there is an earthen bottom being stirred up by relatively high flow rates, often around 100 cubic feet per second (cfs).

Clear patterns or trends in nutrients and metals results were difficult to discern, although elevated orthophosphate was present in the upper reaches of the Santa Ana River (Group 5). Nitrate and TKN were elevated in the upper levels of the data distribution for some of the lower watershed groups as compared to the upper watershed sites (**Figure C-11-V.18**). Dissolved arsenic and copper trend lower at the reference sites than in the urban areas, while the median chromium and zinc levels are more or less consistent, suggesting there could be a geological source (**Figure C-11-V.19**). Increased metals and nutrients in the lower watershed are presumably the result of urban and agricultural runoff from the surrounding watersheds. It should be noted that the SMC Program discontinued metals analysis in 2015, although this data is still collected as a part of the SGRRMP.

The evaluation of nine years of SMC Program monitoring data in the Santa Ana Region shows that there is a robust relationship between the biological community patterns and physical habitat. This relationship has been observed in a number of other bioassessment programs, including the County's bioassessment monitoring in the San Diego Region. On the other hand, strong relationships between biological patterns and water chemistry have not been typically observed in these programs, with the exception of elevated ions and potentially nutrients. The relationships observed here may be causal, or it may simply be due to the fact that chemical concentrations and physical habitat alteration are highly correlated in urbanized environments. These issues will be evaluated further as more data become available and the scoring metrics for biotic health can more accurately model a complex and dynamic environment.

C-11-V.4 Special Studies

Urban Stream Bioassessment field monitoring efforts for 2017 included a special study that examined sediment toxicity and chemistry. Out of the six stations sampled, stations 801M12652, 801M12665, 801M12669, and SMC00105 contained sediment that could be sampled. Toxicity was not sampled at 801M12652 due to insufficient quantity, as well as SMC00105 due to its near reference location and the unlikelihood of present toxicity.

For the toxicity component, the standard sediment test for *Hyalella azteca* at 23 °C was performed as well as testing the same organism at 15 °C. Previous studies conducted by SWAMP's Stream Pollution Trends (SPoT) Monitoring Program have found that fipronil and pyrethroid pesticides can be significantly more toxic at colder temperatures due to slower metabolic breakdown of trace organics at colder temperatures, as well as increased nerve sensitivity of the organism. Furthermore, cooler temperatures more accurately reflect the ambient average surface water temperature in California streams where sediment is present. Sediment chemistry was analyzed for fipronil, pyrethroids, organic carbon, nitrogen, and phosphorus. Acute toxicity was not observed at either of the two stations. However, the mean survival of *Hyalella azteca* at 15 °C was only 70%. While this does not definitely indicate toxicity, it is worth noting that bifenthrin was observed at 2.19 ng/g. While this is a low concentration, bifenthrin is known to cause effects in the low range. Coupled with the bioassay at the colder temperature, it gives possible cause to the relatively low mean survival. In previous special studies, the colder temperature test has also revealed issues with acclimation of the organism to the lower temperature. It should be noted that the 23°C test demonstrated a 95% mean survival. More study will be needed to better understand the differences in the two tests in regards to temperature variation.

Proposed special studies for the 2018 sampling season include a continuation of the sediment chemistry and toxicity in conjunction with an examination of the presence of sediment pyrethroids and fipronil. Special studies will be discussed amongst the SMC Bioassessment Workgroup, and potential study design should be completed by early 2018.