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FINAL REPORT
MULTIYEAR REPORT
WADEABLE STREAMS BIOASSESSMENT
SANTA ANA REGION
REGION 8
SITES SAMPLED: 2006 - 2011

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Stream Ecology and Assessment Laboratory

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Executive Summary

The Santa Ana Regional Water Quality Control Board contracted California State University Long Beach's Stream Ecology and Assessment Laboratory, through the Institute for Integrated Research in Materials Environments and Society, to conduct a six year study (2006-2011) of the waterways within the Santa Ana River watershed. This study was designed to address the federal Environmental Protection Agency-mandated requirement (EPA requirement 305(b)) for an assessment of the integrity of surface waters in the watersheds of the Santa Ana and San Jacinto Rivers by sampling the biological (benthic macroinvertebrates), physical (in-stream habitat, surrounding riparian habitats), and chemical (water quality measurements) attributes at each sampling location. Over the six year period, 182 sites were sampled following standard protocols set by the Surface Water Ambient Monitoring Program, which included data on the physical habitat, the collection of *in situ* water chemistry data, the collection of water for laboratory analysis, and the collection of benthic macroinvertebrates. Annual reports detailing these data have been filed and are available online at the SWAMP website (http://www.swrcb.ca.gov/water_issues/programs/swamp/). This report is a synthesis of the data collected over the entire six-year period.

Initially, this study sought to answer one question: What is the extent of stream kilometers within the Region that fell into one of five biological conditions (Very Poor, Poor, Fair, Good, and Very Good)? This question is answered in a separate report "*Extent of Biological Condition in Region 8, 2006-2011.*" The data required to answer this initial question allowed us to further explore relationships between biological condition and a myriad of physical and chemical parameters as a first step to understanding potential drivers of biological condition. This report sought to answer four questions.

Question 1: Across the Region, what was the distribution of biological condition over the six year period?

Question 2: Given the heterogeneity of the Region, could we identify biologically relevant subregions for further analyses, and if so, what are they?

Question 3: What were the putative drivers of biological condition within each subregion?

Question 4: Within each subregion, which specific sites warranted further study because they were either significantly worse than the average condition or significantly better than the average condition?

Answer to Question 1: Across the Region, what was the distribution of biological condition over the six year period? Over the six-year period 182 sites were described with regard to physical habitat, water chemistry, and benthic macroinvertebrate communities. These sites ranged from high elevation forested areas to highly urbanized and hydro-modified channels in low gradient settings. Over the entire Region, the mean Index of Biological Integrity (IBI) score for all years was 33.0 ("Poor") with a minimum of zero and a high of 80. There was one site in the "Very Good" category, 14 were in the "Good" category, 44 were "Fair", 74 were "Poor" and 58 were "Very Poor."

Answer to Question 2: Given the heterogeneity of the Region, is it possible to identify biologically relevant subregions for further analyses, and if so, what are they? In addition to this Regional characterization of biological health, we used non-parametric multivariate statistics to identify four biologically relevant subregions. They are as follows: low elevation Santa Ana (elevation 0-350 meters), mid-elevation Santa Ana (elevation 351-700 meters), high elevation Santa Ana (above 700 meters), and San Jacinto.

Answer to Question 3: What were the putative drivers of biological condition within each subregion? Using the four subregions identified in Question 2, we conducted a correlational study to further investigate the relationships between environment and biological condition. Multiple regression analyses revealed that each subregion had different drivers of biological condition.

> The low elevation Santa Ana sites' (SA_0-350) biological condition was negatively associated with Channel Alternation and indicators of Human Influence (taken from the field forms) and positively associated with the mean width of the stream (wider streams had higher IBI scores than narrower streams). However, there were many physical habitat parameters (discussed below) and water chemistry analytes that co-varied with Channel Alteration and alkalinity and these should not be dismissed. Conductivity and pH showed a threshold relationship where the lowest scoring sites had relatively high values, but the average and high IBI scoring sites did not differ in their values.
>
> The mid-elevation Santa Ana (SA_350-700) streams were negatively associated with alkalinity; however, conductivity was highly correlated with alkalinity so both of these variables should be considered as potentially important.
>
> The high elevation Santa Ana (SA_700+) sites' IBI scores were best explained by the mean of the densiometer readings (positive influence, where the greater the canopy cover, the higher the IBI score) and alkalinity (negative influence).
>
> The San Jacinto (SJ) biological condition was negatively associated with water temperature and turbidity; however, epifaunal substrate availability and percent sand were also correlated with these two variables.

Answer to Question 4: Within each subregion, which specific sites warranted further study because they were either significantly worse than the average condition or significantly better than the average condition? We statistically categorized sites within each subregion by comparing them to the mean Index of Biological Integrity within each subregion to identify specific waterways that were exceptionally poor (scoring at least one standard deviation below the mean and denoted as "red sites") or exceptionally good (scoring at least one standard deviation above the mean and denoted as "green sites"). There were a total of 37 sites exceptionally poor and 30 sites exceptionally good with the low elevation Santa Ana subregion (SA_0-350) having 14 red sites and 12 green sites, mid-elevation Santa Ana (SA_350-700) having 5 red sites and 3 green sites, high elevation Santa Ana (SA_700+) having 14 red sites and 9 green sites, and the San Jacinto subregion (SJ) having 4 red sites and 6 green sites. All 67 sites were slated for resampling during the 2012 and 2013 field seasons to detect changes across time in biological condition.

Introduction

Freshwater is an important natural resource. Understanding the health of rivers, streams, and other water resources is essential for the development of management plans that protect the nation's vital water resources. One approach that has been advocated for improving water quality is the development of biological objectives, which provide the narrative or numeric benchmarks that describe the conditions necessary to protect aquatic life beneficial uses. These bioassessment tools utilize direct measurements of biological assemblages occupying various trophic levels and can include plants, macroinvertebrates, fish, and periphyton (diatoms and algae), as direct methods for assessing the biological health of a waterway's ecosystem. Direct measurements of biological communities, when used in conjunction with other relevant measurements of watershed health (e.g. watershed characteristics, land-use practices, in-stream habitat and water chemistry), are effective ways to monitor long-term trends of a watershed's condition (Davis and Simon 1995). Biological assessments, which integrate the effects of water quality over time, are sensitive to many aspects of both habitat and water chemistry and provide a more familiar representation of ecological health to those who are unfamiliar with interpreting the results of chemical or toxicity tests (Gibson 1996). When integrated with physical habitat assessments and chemical test results, biological assessments describe the health of a waterway and provide an *in vivo* means of evaluating the anthropogenic effects (e.g. sediments, temperature and habitat alteration) on a waterway. As defined by the 2006 EPA Wadeable Streams Assessment (WSA) document, *"biological integrity represents the capability of supporting and maintaining a balanced, integrated, adaptive community of organisms having a species composition, diversity and functional organization comparable to that of the natural habitat of the region."* Bioassessment is a proxy for determining stream water quality and habitat quality based on the types and numbers of organisms living there.

The monitoring of water quality using benthic macroinvertebrates (BMIs) is the most utilized bioassessment method when compared with similar assessments that use fish or periphyton. BMIs are not only ubiquitous, but are relatively stationary and highly diverse. These traits can provide a variety of predictable responses to a number of environmental stresses (Rosenberg and Resh 1993). Depending on the length of time an individual BMI taxon resides in an aquatic environment (a few months to several years), the sensitivity to physical and chemical alterations to its environment will vary. BMIs are an excellent indicator group in assessing the health of a waterway (Resh and Jackson 1993) and function as a significant food resource for both aquatic and terrestrial organisms. In addition, herbivorous BMIs aid in the control of periphyton populations and many BMI taxa contribute to the breakdown of detritus. Furthermore, the diversity of BMI taxa also plays an important role in the overall ecology and biogeography of a region (Erman 1996).

Biological assessments are often based on multimetric techniques. These techniques use a number of biologic measurements (metrics), each representing a particular aspect of the biological community, to assign a water quality value to the location under study. Locations can then be ranked by these values and classified into qualitative categories of "very good," "good," "fair," "poor," and "very poor." This system of ranking and categorizing biological conditions is referred to as an Index of Biotic Integrity (IBI), and is currently the recommended method for the development of biocriteria by the United States Environmental Protection Agency (USEPA; Davis and Simon 1995). This method may also be used in the development of Tiered Aquatic Life Uses (TALU). The current IBI used for southern California is the Southern Coastal California Index of Biological Integrity (SCC-IBI; Ode et al. 2005), developed by the California Department of Fish and Game's Aquatic Bioassessment Laboratory (Cal/DFG-ABL).

Until the initiation of this project, water quality information for the streams in the Santa Ana and San Jacinto watersheds (Region 8) was based mostly on discharger data from NPDES permits, and volunteer monitoring efforts of selected streams. This information focused on problem areas within the region or areas where permits have been issued. Consequently, there were a large number of streams in the region that lacked water quality information. Due to lack of available funding to implement a fully comprehensive "multiple biological assemblage model" to assess the biotic integrity, a decision was made by the Santa Ana Regional Water Quality Control Board (SARWQCB) to initially focus on using a macroinvertebrate bioassessment tool to assess the biotic integrity of the wadeable streams (perennial and ephemeral) in Region 8 of California.

In 2005, with funding provided by the Surface Water Ambient Monitoring Program (SWAMP), the SARWQCB contracted California State University Long Beach (CSULB) Stream Ecology and Assessment Laboratory (SEAL), through the Institute for Integrated Research in Materials Environments and Society (IIRMES), to conduct a six-year study within Region 8 of California waterways utilizing a probabilistic sampling design. IIRMES, a multifaceted organization was designed to promote and enhance educational and research opportunities for faculty, graduate and undergraduate students, and the greater community at large by embracing and integrating all scientists who study historical and temporally changing phenomena from the solid earth to organisms, landscapes, and societies. By collaborating with interdisciplinary faculty, scientists within the organization are able to bring common research perspectives, techniques, and instrumentation to bear their research.

Each year an annual report was made available to the public on the SWAMP website that detailed the physical habitat, the composition of macroinvertebrates, and the water chemistry of each random site. The number of sites sampled each year varied from 30 to 35 depending on available levels of funding. *This report is a synthesis and analysis of the data collected over the six years to uncover relationships among physical habitat parameters, water chemistry analytes and the biological condition of the benthic macroinvertebrate community as well as to estimate the percentage of wadeable stream kilometers in the region that fall within the five categories of stream health.*

Methods

Site Selection

Region 8 contains three hydrologic units (HU): San Gabriel River, San Jacinto River, and the Santa Ana River. Using a probabilistic design, Tony Olsen (US EPA, Corvalis, Oregon) generated 750 sites weighted by Strahler stream order (Figure 1). As sampling was to occur over a number of years, we decided to divide the Region into five strata to ensure that sites would be sampled every year across the Region and not clumped in one area due to chance draws of sites. The seven sites within the San Gabriel River HU were combined with the Santa Ana River HU sites (Figure 2). The sites in these two remaining HUs were then divided into one of three elevation strata: 0 to 350 meters, 351 – 700 meters, and greater than 700 meters. These strata were chosen using best professional judgment based on biology and to ensure an adequate sample size of each stratum. The San Jacinto River HU did not have any sites in the lowest elevation stratum. This resulted in five strata: Santa Ana, 0-350 meters (SA_0-350), Santa Ana, 350-700 meters (SA_350-700), Santa Ana, greater than 700 meters (SA_700+), San Jacinto, 350-700 meters (SJ_350-700), San Jacinto, greater than 700 meters (SJ_700+).

Physical Habitat Characterization

At each site, standard Surface Water Ambient Monitoring Program (SWAMP) field protocols were used. In 2006 and 2007, the BASIC physical habitat protocols and field forms were used, while 2008 through 2011, the FULL protocols and field forms were used. Details can be found in the annual reports available on the SWAMP website.

Water Chemistry

Standard *in situ* water parameters were measured at each site using a multiprobe and included: pH, temperature, dissolved oxygen, and conductivity. Additionally one-liter of water was collected and returned to the lab within 36 hours for the determination of the following analytes:

Constituent	Units	Constituent	Units	Constituent	Units
Ammonia-N	mg/L	Nitrite-N	mg/L	Turbidity	NTU
Conductivity	MS	Orthophosphate as P	mg/L	Alkalinity	
Nitrate-N	mg/L	Total Suspended Solids	mg/L		

Benthic Macroinvertebrate (BMI) Sampling and Processing

Samples of BMIs were collected from each site following SWAMP protocols and taken to the lab for processing. Field alcohol was rinsed and replaced with 70% ethanol. Samples were then subsampled using a Caton tray such that at least five grids were selected to obtain the required number of BMIs (500 or 600 organisms, depending upon the current SWAMP protocols at the time). These BMIs were then identified to either Level 1 or Level 2 (depending upon SWAMP requirements at the time) of the Standard Taxonomic Effort produced by the Southwestern Association of Freshwater Invertebrate Taxonomists (SAFIT). An Index of Biotic Integrity (IBI) was generated following Ode et al. 2005. This IBI was built on a 500 count and Level 1 taxonomy, which required statistical subsampling from 600 to 500 organisms and “rolling up” taxonomic identifications from Level 2 to Level 1 for all samples processed between 2008 and 2011. The IBI is a species community measure that uses seven metrics: the number of beetle taxa, the number of mayfly, stonefly, and caddisfly taxa, the number of predator taxa, the percent of individuals that are collectors, the percent of intolerant individuals, the percent non-insect taxa, and the percent of tolerant taxa. Each of these metrics are valued between 0 and 10 with 0 being the worst case and 10 being the best case. For each site, the sum of the metrics is scaled to a value between 0 and 100 by dividing the raw IBI score by 7 thus producing an adjusted score. The adjusted scores are then placed in one of five categories of health; Very poor = 0-20, poor = 21-40, fair = 40-59, good = 60-79, and very good = 80-100.

Quality Control and Interlab Calibration

Field duplicates for water samples were collected at a rate of 5% and for BMIs, at a rate of 10%. Ten percent of the BMI samples underwent external quality control via the Aquatic Bioassessment Laboratory, Chico, CA. Stringent internal quality control was applied to both sorting and taxonomy whereby subsamples had to pass at a 95% BMI recovery level and all taxonomy was double-checked by at least one other taxonomist.

Beginning in 2009, field crews participated in annual interlab calibration exercises hosted by the Storm Water Monitoring Coalition (SMC) and the Southern California Coastal Water Research Project (SCCWRP). Field audits were also conducted by a SMC member annually.

Statistical Analyses Used in the Study

Overview of analyses

In addition to obtaining the biological condition of each site, we also wanted to use this information to characterize the physical habitat and chemical correlates of biological condition and to identify groups of sites that were statistically either better or worse than their population average. This strategy would allow for the generation of specific hypotheses regarding the drivers of biological condition in these streams. We analyzed the data over four stages described below.

Stage 1: Identification of biologically relevant subregions

In order to identify biologically relevant subregions or populations of sites within Region 8, we formatted the BMI taxonomy data such that all sites were identified to Level 1 taxonomy. We then standardized the data to account for differences in sample size by assigning abundances of each taxon as a percentage that it represented within its sample. We down-weighted the importance of the common species by transforming the data using a square root. Finally we calculated Bray-Curtis community dissimilarity indices for each pair of sites within the data set. We tested specific hypotheses of natural structure in the data using Analysis of Similarity (ANOSIM) within the statistical package PrimerV6. An ANOSIM is a non-parametric multivariate statistics test analogous to an ANOVA, but not requiring the data to satisfy the assumptions of an ANOVA. The ANOSIM produces a test statistic called "Global R" that is analogous to the F-statistic of an ANOVA. Pairwise comparisons use a Pairwise R to test for significant differences. If our hypothesized groupings produce subsets of sites that reflect similarities of BMI species compositions, then we can compare these sites with regard to their other attributes with the assurance that we are comparing “apples with apples.”

Stage 2: Determining correlates between IBI scores and physical habitat and water chemistry

Once we had determined the groupings of sites into subregions, we ran Pearson correlations between IBI scores and the physical habitat parameters and the water chemistry values. Firstly, much of the physical habitat data was summarized to obtain a single number for each site per parameter. The mean width of the stream was calculated by averaging all width measurements and the variance of the width was obtained by calculating the variance of all width measurements. Substrate was summarized by obtaining the percentage of points that fell into each of seven categories: smooth bedrock, concrete/asphalt, small boulder, cobble, coarse gravel, sand, and other. The mean of the densiometer readings and the variance of this value were obtained by averaging all densiometer readings and calculating the variance, respectively. Densiometer readings range from zero (no canopy cover) to 17 (completely covered by canopy). The percent human influence was determined by counting the number of “present” were at a site divided by the number possible (this value was different between the BASIC and FULL physical habitat protocols). The following variables did not require summarization prior to use: pH, water temperature (C), conductivity (ms/cm), turbidity (NTU), dissolved oxygen (mg/l), alkalinity (T), dissolved orthophosphate (mg/l), nitrate-N (mg/l), nitrite-N (mg/l), Epifaunal Substrate, Sediment Deposition, Channel Alteration, and elevation.

Next, Pearson correlation coefficients were obtained for each stratum for IBI and the variables described above. All values with a $p<0.01$ were plotted to determine if the relationship was linear or not; for all non-linear relationships a transformation was applied to obtain linearity. Relationships whose significance was driven by a few outlying points were not used.

Stage 3: Multiple regression models

For each stratum, we ran multiple regressions (forward addition, with entry F of $p < 0.05$) using the transformed and coded variables described above.

Stage 4: Categories of biological condition and graphical analyses

For each stratum, a mean and standard deviation (SD) of IBI scores was generated and sites were categorized into one of three types: "Red Sites" those scoring at least one SD below the stratum mean, "Yellow Sites" those scoring within one SD, either plus or minus, from the mean, and “Green Sites” those scoring greater than one SD from the mean. For each of the variables identified as being correlates with IBI scores, plots with means and standard errors were generated for each stratum and maps were produced to display the spatial distribution of these three types of sites.

Results

Summary of sampling events

Between 2006 and 2011, 182 sites were sampled (Table 1). The yearly number of sites sampled varied from 22 to 35 due to variable funding levels over the years. The distribution of sites sampled across the five strata was similar to the original distribution of the 750 sites (Table 2) except that the San Jacinto 350-700 (SJ_350-700) stratum was markedly underrepresented due to the arid conditions of this stratum.

Stage 1: Identification of biologically relevant subregions

The strongest support was found for the hypothesis that the species communities of BMIs within Region 8 are best structured using the original stratification scheme modified such that the sites in SJ_350-700 and SJ_700+ are combined to form a single stratum, SJ. The ANOSIM for this grouping yielded a Global R of 0.277, p = 0.0001 with 9999 permutations (the number of permuted statistics that were greater than equal to the Global R was 0). All groups were significantly different from each other using pairwise tests (Table 3). While several of the other hypothesized groupings also garnered statistical support, we decided to use the original strata (revised) as this ensured we had sufficient sampling effort across years and groups.

Stage 2: Correlates between IBI scores and physical habitat and water chemistry

A word of caution regarding interpreting correlations: The Pearson correlation coefficient is a measure of the linear dependence or correlation between two variables. It ranges between +1 and −1, where 1 is total positive correlation, 0 is no correlation, and −1 is total negative correlation. It does not mean that one variable necessarily drives or is responsible for the value of its correlated variables; they merely change together in a linear way (either positive or negative). Although it may be true that one variable is in fact driving the behavior of another variable, this can only be determined using manipulative experiments.

Table 4 reports the Pearson correlation coefficients between IBI scores and various physical habitat summarized variables and water chemistry for each stratum. All correlates with p values less than 0.01 were plotted against the stratum IBI scores to check for linearity. The following transformations were made to correct for non-linearity:

> *SA_0-350:* dissolved orthophosphate (natural log), variance of width (natural log of x+1), and %RC (1/natural log of x+2).
>
> SA_350-700: conductivity (natural log of x+1) and alkalinity (natural log). The variable %RS was excluded because one data point was driving the correlation (See Figure 3 below).

SA_700+: no transformations, but nitrate-N was excluded because a few data points were driving the correlation (Figure 4 below).

SJ: Turbidity (natural log of x+1).

Stage 3: Multiple regression models

Multiple regressions were run for each stratum using IBI scores as the dependent variable and the correlated and transformed variables identified in Table 4 with $p < 0.01$.

For SA_0-350, the simplest model to explain IBI scores within this stratum was Channel Alteration (Table 5, Excluded variables: pH, dissolved orthophosphate (natural log), Epifaunal Substrate, variance of width (natural log of x+1), % RC (concrete), % SA (sand), elevation, %RC (1/natural log of x+2). A second model that included both Channel Alteration and mean width of the stream was also identified, but this second model did not contribute much explanatory power over the first. Because many of the variables included in the model were co-correlated (Table 6) and specifically, Channel Alteration correlated with nearly all of the remaining variables, we ran another multiple regression without Channel Alternation in the model. This produced three models with significant explanatory power (Table 7). Percent Human Influence was the simplest model, with mean width and alkalinity as additional variables in models two and three.

For the mid-elevation stratum SA_350-700, the best multiple regression model included only one variable, alkalinity (natural log) and excluded the other variable, conductivity (natural log + 1) (Table 8). However, these two variables have a Pearson correlation coefficient of 0.801 ($p < 0.01$), which suggests that both variables should be considered as potentially important in explaining the biological condition of this stratum.

For the high-elevation stratum SA_700+, two models were identified, one with the single variable mean densiometer and another that also included alkalinity (Table 9). Table 10 shows the Pearson correlation coefficients for the variables identified in Table 4.

Finally, multiple regression yielded two models for the stratum SJ (Table 11). One model included the single variable turbidity (natural log +1), and the other included turbidity (natural log +1) and water temperature. However, Table 12 shows that all of the variables were significantly co-correlated at $p < 0.01$.

In summary, multiple regressions found that for the stratum SA_0-350, wider streams and those with few indicators of human influence had the greater IBI scores as compared to sites with lower IBI scores (Table 13). This was not the case for mid-elevation Santa Ana sites where only alkalinity had a negative influence on IBI scores. At the high-elevation Santa Ana sites, IBI scores were positively influenced by the mean value of densiometer (indicating the presence of a canopy cover over the stream) and negatively by alkalinity. In the San Jacinto HU, water temperature and turbidity both had negative influences on that stratum's IBI scores.

Stage 4: Categories of biological condition and graphical analyses

The mean IBI score with the standard deviation (SD) for each stratum is shown in Table 14. The mean of the low elevation SA_0-350 was 18.8 putting it in the "Very Poor" category of biological health. The mid-elevation Santa Ana sites had a mean of 28.8 ("Poor"), while the high elevation Santa Ana sites had a mean of 45.6 ("Fair"). The San Jacinto sites had a mean of

35.5 (“Poor”). The distributions of these scores are depicted in Figure 5. While it is good to know the absolute biological condition of Region 8’s streams, it is unclear how to use this information most effectively. We decided to use our biologically relevant subregions as a way to statistically identify the worst and best sites within groups of sites that share biology and physical habitat and water chemistry parameters. We used the mean IBI of each of the four strata and designated sites within one SD of this mean as being “Yellow Sites”, while sites at least one SD below the mean IBI were designated as “Red Sites”. Sites at least one SD greater than the stratum mean IBI were designated as “Green Sites.” We then generated standard error plots of IBI versus the parameters identified as potentially being important (Table 4) as a method of visualizing the multiple regression results.

SA_0-350: The most important variable explaining IBI scores in the low elevation Santa Ana sites was Channel Alteration (Figure 6A). Because Channel Alteration was highly correlated with many of the other parameters, we also generated plots with these parameters. Alkalinity (Figure 6B) had a positive relationship with IBI score as did mean stream width. The red and yellow streams were similar in width, while the green sites had twice an average width (Figure 7A). Percent human influence showed a strong clear negative effect on IBI scores even though the means varied only from 5.5 to 1.5% (Figure 7B). A threshold, above which biological impairment is evident, was clear for both pH (Figure 8A) and conductivity (Figure 8B) with red sites having greater values than the yellow and green sites, and the yellow and green were not different from one another.

SA_350-700: In contrast to the low Santa Ana sites, alkalinity was negatively associated with IBI (Figure 9A). Figure 9B is an example of a plot where the parameter is not associated with IBI, in this case, pH. Similarly to the low elevation Santa Ana sites, conductivity showed a negative threshold effect with IBI (Figure 10A). Interestingly, the mean values for the low elevation green sites (Figure 10B) were approximately 1000 mS/cm while the green sites at the mid-elevation had a mean conductivity of 400 mS/cm, suggesting that the BMI communities at the low elevation sites are highly adapted to these high conductivity conditions.

SA_700+: Substrate had a positive threshold effect on IBI in the high elevation Santa Ana stratum, with the red sites having nearly zero small boulders (Figure 11A) and only a small percentage of cobble (Figure 11B). The yellow and green sites had approximately 10% of the substrate as small boulders and cobbles. Alkalinity and water temperature both showed clear negative associations with IBI at these high elevation sites (Figure 12A and 12B). The greater the canopy cover (mean densiometer) and the least amount of variation of this cover (variance of densiometer), was positively correlated with IBI score.

SJ: In San Jacinto, Epifaunal Substrate had a clear positive relationship with IBI (Figure 13A), while the opposite was true regarding water temperature (Figure 13B). Turbidity and pH were both negatively associated with IBI (Table 14). Percent sand also had a clear negative association with IBI (Figure 15).

Maps: The remaining figures are maps where sites were color-coded as red, yellow, and green. The entire Region 8 is shown in Figure 16. Detailed maps were generated to include spatially clustered sites and are as follows:

Figure 17 - Cajon Canyon area
Figure 18 – City Creek area
Figure 19 – Upper Santa Ana River area
Figure 20 – North Orange County
Figure 21 – Prado Flood Control area

Figure 22 – San Timoteo area
Figure 23 – Mill Creek area
Figure 24 – Southern Orange County
Figure 25 – Lakes Elsinore and Matthews areas
Figure 26 – Lake Hemet area.

Table 15 provides a summary of the sites sampled with the red and green sites color-coded and the yellow sites appearing as non-shaded rows.

Conclusions

Between 2006 and 2011, 182 stream sites were described with regard to physical habitat, water chemistry, and benthic macroinvertebrate communities (one site was not analyzed because the sample was lost and there was no IBI for that site). These sites ranged from high elevation forested areas to highly urbanized and hydro-modified channels in low gradient settings. Over the entire Region, the mean IBI score for all years was 33.0 ("Poor") with a minimum of zero and a high of 80. There was one site in the "Very Good" category, 14 were in the "Good" category, 44 were "Fair", 74 were "Poor" and 58 were "Very Poor." In addition to this Regional characterization of biological health, we also identified four biologically relevant subregions and conducted a correlational study to further investigate the relationships between environment and biological condition.

The low elevation Santa Ana subregion (SA_0-350) had mean IBI score of 18.8 that ranged from 0 to 46. It had warm, basic waters with high conductivity and alkalinity, little epifaunal substrate and high degrees of channel alteration. Many of these environmental parameters co-varied and this could be interpreted as the "urban condition." This subregion was also highly variable, so it may be best in future studies to further subdivide this stratum to refine our understanding of the driving forces in this subregion.

The mid-elevation Santa Ana stratum (SA_350-700) IBI scores were on average ten points higher than the lower elevation sites (Mean 28.8, range 0 to 60). These sites had moderately basic and warm waters and intermediate values for epifaunal substrate and channel alteration.

The high elevation Santa Ana stratum (SA_700+) was characterized by cool waters with low conductivity, high levels of epifaunal substrate and low levels of channel alteration. The mean IBI score of 45.6, very far from 80, the cutoff for "Very Good." The highest IBI score was 80. We wondered why the mean IBI was so low and why there was only one site scoring in the "Very Good" range. Possible reasons include a sample bias that differentially excluded the "Very Good" sites due to physical barriers such as rugged terrain, impacts of recreation, and fish stocking.

The San Jacinto subregion (SJ) is an extremely arid part of Region 8. The original draw contained 160 sites. Over the six-year period of this study, we either sampled or rejected all of these. The primary reason for rejecting sites was lack of water; the next reason was inaccessibility due to extreme terrain. The last reason involved closures due to the presence of the Mountain Yellow-legged Frog, a Federally endangered species. The streams that we did sample were cool, low conductive waters with high levels of epifaunal substrate and low levels of channel alteration. The mean IBI was 35.5 with a range of 4 to 74. Similar to the high elevation Santa Ana stratum, we thought it odd that the subregion scored so low on average. Sample bias could also play a role here where "Very Good" sites were differentially not sampled due to rugged terrain and the presence of an endangered species.

Overall, we suggest that using this strategy will be very helpful in identifying specific waterways that need further study. The maps clearly show anomalous sites, reds sites nestled amongst green sites along the same stream (e.g. Strawberry Creek in Figure 26) or entire streams dominated by red sites (e.g. Cajon Wash in Figure 17).

Future Directions

The study provides fodder for future studies to increase our understanding of the driving forces that shape the biological communities in the streams of Region 8. We recommend that all of the red and green sites be resampled to determine if their biological condition has changed or not. For those sites whose condition has remained unchanged, causal assessments can be conducted. Furthermore, because the IBI was built using reference sites with perennial streams and many of the streams included in the study were not perennial, a study on non-perennial streams within the Region is warranted. This study also sets the groundwork for establishing trend sites that would be sampled every year that will enable us to detect changes across time. The establishment of trend sites at reaches scoring the highest (best available) IBI within each subregion would provide information on natural variability in biological condition that is unlikely driven by anthropogenic causes, but by natural causes like changes in precipitation.

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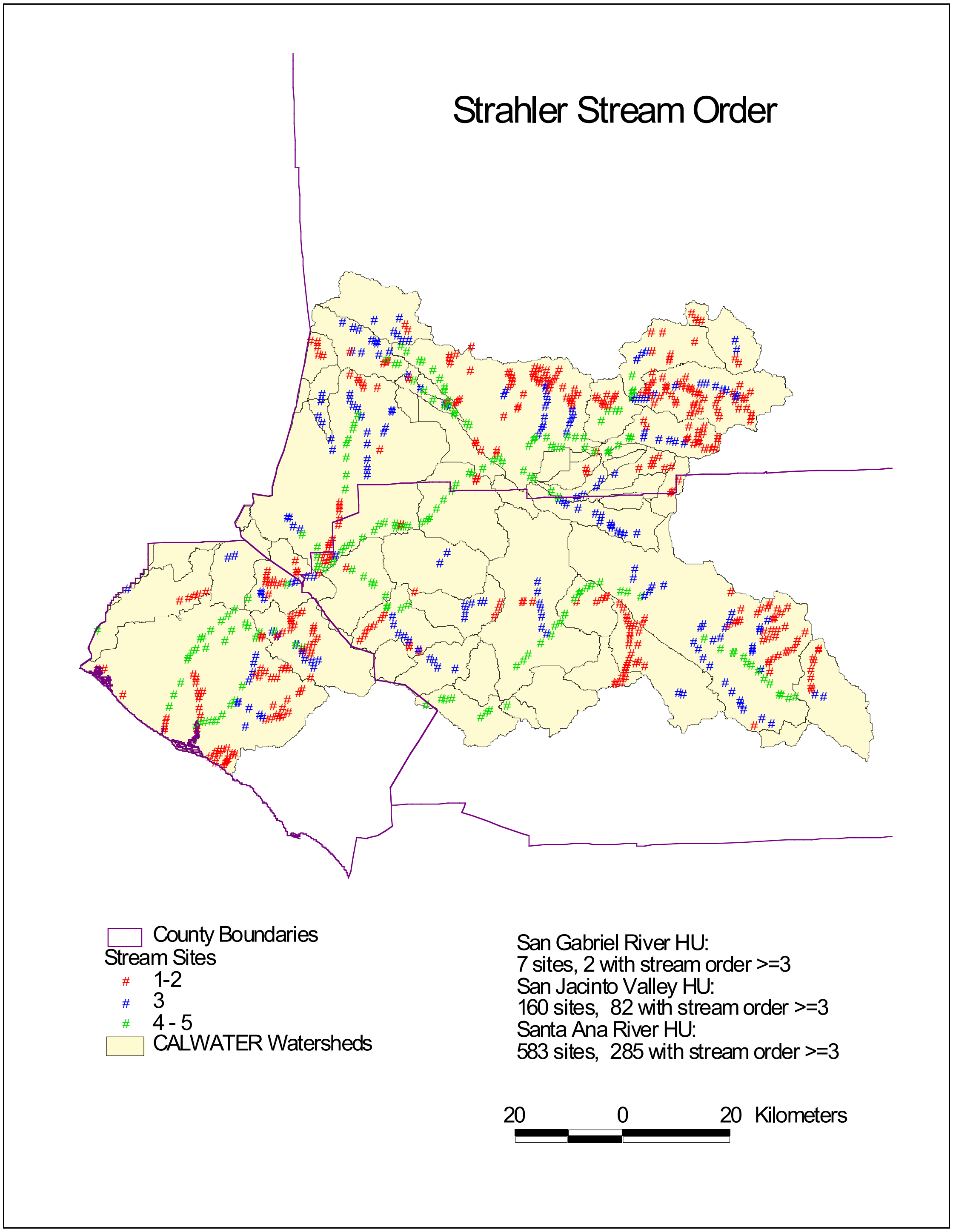


Figure 1. Map of region 8 showing the 750 sites drawn at random and weighted by Strahler stream order. Red marks are first and second order streams, blue marks are third order streams and green marks are fourth and fifth order streams. Purple lines denote county lines.

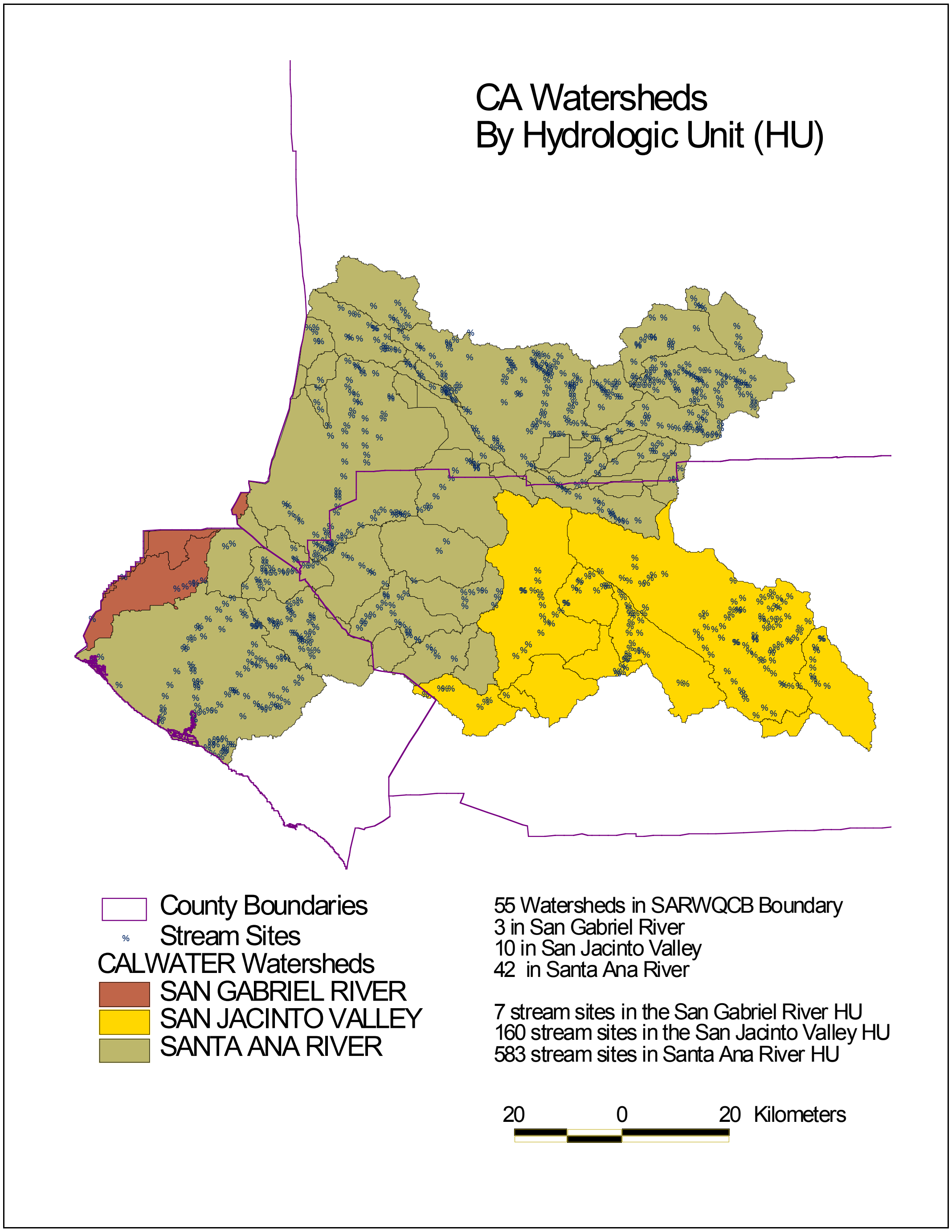


Figure 2. Map showing the three hydrologic units that comprise Region 8 and the number of stream sites by watershed.

Table 1. The distribution of sites sampled from 2006 to 2011 within the five elevation/hydrologic unit categories (Strata). "Original" is the number of sites in the 750 site draw.

Stratum	Original	2006	2007	2008	2009	2010	2011	Total
SA_0-350	237	7	2	14	14	9	12	58
SA_350-700	127	8	3	4	3	9	2	29
SA_700+	226	7	16	12	13	9	8	65
SJ_350-700	93	3	3	0	0	0	0	6
SJ_700+	67	5	6	4	5	4	0	24
Total	**750**	**30**	**30**	**34**	**35**	**31**	**22**	**182**

Table 2. Comparison of the distribution of sites sampled versus the distribution of the original 750 sites across the five strata.

Stratum	Total	Original Distribution	Percent Sampled
SA_0-350	237	32%	24%
SA_350-700	127	17%	23%
SA_700+	226	30%	29%
SJ_350-700	93	12%	6%
SJ_700+	67	9%	36%
	750		

Table 3. Results of the pairwise tests of the analysis of similarity (ANOSIM).

Groups	Pairwise R statistic	P value
SA_0-350 & SA_350-700	0.303	0.0001
SA_0-350 & SA_700+	0.439	0.0001
SA_350-700 & SA_700+	0.142	0.0008
SJ & SA_0-350	0.198	0.0001
SJ & SA_350-700	0.351	0.0001
SJ & SA_700+	0.163	0.0001

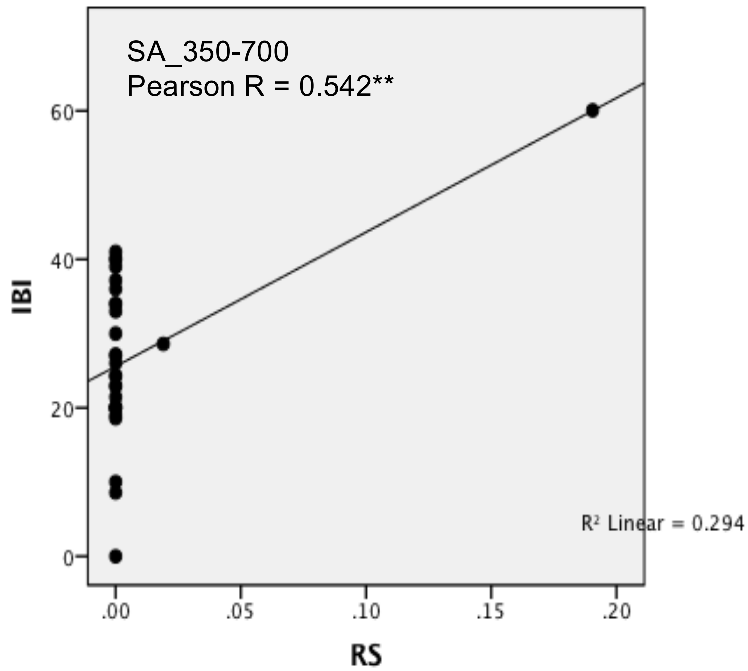


Figure 3. Correlation between IBI and % RS (smooth bedrock at stratum SA_350-700 being driven by a single point.

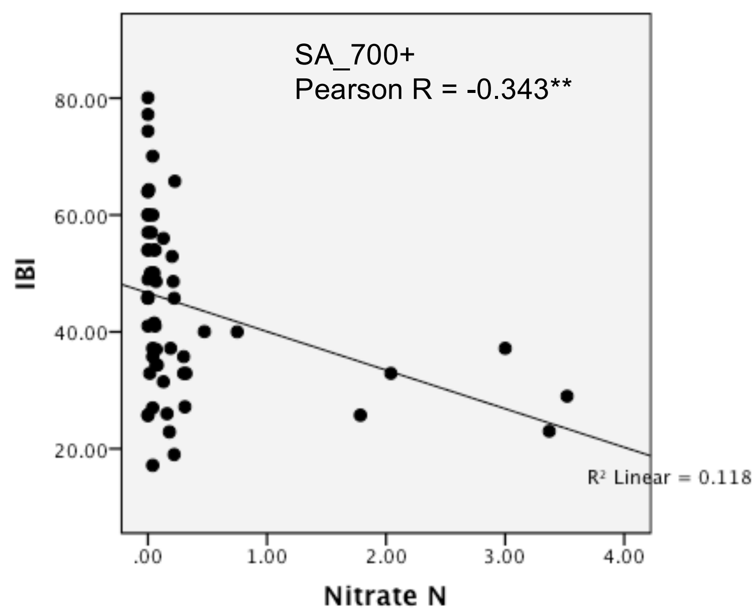


Figure 4. Correlation between IBI and nitrate-N being driven by a few points.

Table 4. Pearson correlation coefficients between IBI scores and physical habitat and water chemistry parameters for each of the four strata (revised stratification).

Variable	SA 0-350	SA 350-700	SA 700+	SJ 350+
pH	-0.416**	0.121	-0.304*	-0.483**
Water Temp C	-0.099	-0.186	-0.483**	-0.581**
Conductivity (mS/cm)	-0.246	-0.571**	-0.176	-0.283
Turbidity NTU	0.002	-0.102	0.077	-0.574**
Dissolved O2 (mg/L)	-0.059	0.15	0.156	0.436*
Alkalinity T	0.345**	-0.517**	-0.412**	-0.481*
Dissolved Orthophosphate (mg/L)	0.407**	-0.022	0.168	-0.205
Nitrate-N (mg/L)	0.294*	0.035	-0.343** (few)	-0.053
Nitrite-N (mg/L)	-0.302*	-0.074	-0.235	0.005
Epifaunal Substrate	0.332**	0.201	0.460**	0.552**
Sediment Deposition	-0.276*	0.184	0.239	0.116
Channel Alteration	0.605**	-0.039	0.227	0.322
Mean width	0.482**	0.093	-0.101	-0.411*
Variance Width	0.359**	-0.031	0.055	-0.357*
% RS (smooth bedrock)	0.101	0.542** (one)	0.034	0.312
% RC (concrete/asphalt)	-0.462**	-0.173	-0.187	--NA--
% SB (small boulder)	-0.073	0.381*	-0.013	0.335
% CB (cobble)	0.081	0.388*	-0.044	-0.093
% GC (coarse gravel)	0.091	0.17	-0.265*	0.079
% SA (sand)	0.331**	-0.232	-0.005	-0.564**
% OT (other)	-0.217	-0.222	0.268*	-0.022
Mean Densiometer	0.173	-0.117	0.581**	0.212
Variance of Densiometer	0.218	-0.02	-0.365**	-0.139
Percent Human Influence	-0.504**	-0.137	-0.138	0.097
Elevation (m)	0.452**	0.161	0.228	0.433*

* = $p < 0.05$, ** = $p < 0.01$

Table 5. Regression results for SA_0-350 with all correlated variables

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3050.369	1	3050.369	25.410	.000[a]
	Residual	6002.312	50	120.046		
	Total	9052.681	51			
2	Regression	4412.541	2	2206.271	23.298	.000[b]
	Residual	4640.139	49	94.697		
	Total	9052.681	51			

a Predictors: (Constant), Channel Alteration
b Predictors: (Constant), Channel Alteration, Mean Width

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	10.157	2.420		4.198	.000
	Channel Alteration	0.958	.190	.580	5.041	.000
2	(Constant)	5.917	2.423		2.442	.018
	Channel Alteration	.840	.172	.509	4.891	.000
	Mean width	.332	.088	.394	3.793	.000

Excluded variables: pH, Dissolved orthophosphate (natural log), Epifaunal Substrate, Variance of width (natural log of x+1), % RC (concrete), % SA (sand), Elevation, %RS (1/natural log of x+2)

Table 6. Correlations among physical habitat and water chemistry variables for the stratum SA_0-350. Only variables showing a significant correlation with IBI scores (Table 4) are shown.

	pH	Alkalinity	Epifaunal Substrate	Channel Alteration	Mean width	Variance of width	% RC (concrete)	% SA (sand)	Percent Human Influence
Alkalinity	0.625**								
Epifaunal Substrate	-0.507**	0.467**							
Channel Alteration	-0.456**	0.502**	0.596**						
Mean width	-0.145	0.042	-0.203	0.181					
Variance of width	-0.256*	0.170	-0.025	0.149	0.756**				
% RC (concrete)	0.634**	-0.589**	-0.565**	-0.665**	-0.223	-0.252*			
% SA (sand)	-0.260*	0.531**	0.007	0.361**	0.456**	0.378**	-0.548**		
Percent Human Influence	0.330**	-0.270*	-0.393**	-0.604**	-0.242	-0.092	0.408**	-0.300*	
Elevation	-0.180	-0.034	0.302*	0.522**	0.130	0.062	-0.251*	-0.130	-0.483**

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 7. Regression results for SA_0-350 with all correlated variables except Channel Alternation

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	2595.771	1	2595.771	20.101	.000[a]
	Residual	6456.910	50	129.138		
	Total	9052.681	51			
2	Regression	3727.016	2	1863.508	17.146	.000[b]
	Residual	5325.664	49	108.687		
	Total	9052.681	51			
3	Regression	4440.975	3	1480.325	15.408	.000[c]
	Residual	4611.706	48	96.077		
	Total	9052.681	51			

a Predictors: (Constant), Percent Human Influence
b Predictors: (Constant), Percent Human Influence, Mean width
c Predictors: (Constant), Percent Human Influence, Mean width, Alkalinity

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	27.729	2.394		11.583	.000
	Percent Human Influence	-2.193	.489	-.535	-4.483	.000
2	(Constant)	21.160	2.995		7.066	.000
	Percent Human Influence	-1.780	.467	-.434	-3.813	.000
	Mean width	.310	.096	.368	3.226	.002
3	(Constant)	8.695	5.370		1.619	.112
	Percent Human Influence	-1.406	.460	-.343	-3.057	.004
	Mean width	.323	.090	.383	3.568	.001
	Alkalinity	.055	.020	.294	2.726	.009

Table 8. Regression results for SA_350-700 with all correlated variables from Table 4.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	1223.564	1	1223.564	11.364	.003[a]
	Residual	2368.648	22	107.666		
	Total	3592.211	23			

a Predictors: (Constant), Alkalinity (natural log)

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	119.862	27.833		4.306	.000
	Alkalinity (natural log)	-17.862	5.298	-.584	-3.371	.003

Table 9. Regression results for SA_700+ with all correlated variables from Table 4.

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4232.137	1	4232.137	28.128	.000[a]
	Residual	9177.994	61	150.459		
	Total	13410.131	62			
2	Regression	5206.546	2	2603.273	19.040	.000[b]
	Residual	8203.585	60	136.726		
	Total	13410.131	62			

a Predictors: (Constant), Mean Densiometer
b Predictors: (Constant), Mean Densiometer, Alkalinity

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	31.212	2.974		10.496	.000
	Mean Densiometer	1.296	.244	.562	5.304	.000
2	(Constant)	40.192	4.399		9.137	.000
	Mean Densiometer	1.120	.242	.486	4.628	.000
	Alkalinity	-.061	.023	-.280	-2.670	.010

Table 10. Correlations among physical habitat and water chemistry variables for the stratum SA_700+. Only variables showing a significant correlation with IBI scores (Table 4) are shown.

	Water Temp C	Alkalinity	Epifaunal Substrate	Mean Densiometer
Alkalinity	0.469**			
Epifaunal Substrate	-0.525**	-0.533**		
Mean Densiometer	-0.632**	-0.272*	0.556**	
Variance of Densiometer	0.211	0.423**	-0.237	-0.201

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 11. Regression results for SJ with all correlated variables from Table 4.

Model		**Sum of Squares**	**df**	**Mean Square**	**F**	**Sig.**
1	Regression	3863.794	1	3863.794	15.486	.001[a]
	Residual	5489.174	22	249.508		
	Total	9352.968	23			
2	Regression	4883.074	2	2441.537	11.471	.000[b]
	Residual	4469.895	21	212.852		
	Total	9352.968	23			

a Predictors: (Constant), Turbidity (natural log +1)
b Predictors: (Constant), Turbidity (natural log +1), Water Temperature

Model		**Unstandardized Coefficients**		**Standardized Coefficients**	**t**	**Sig.**
		B	Std. Error	Beta		
1	(Constant)	50.786	4.558		11.142	.000
	Turbidity (natural log +1)	-15.310	3.891	-.643	-3.935	.001
2	(Constant)	67.873	8.871		7.651	.000
	Turbidity (natural log +1)	-10.337	4.252	-.434	-2.431	.024
	Water Temperature	-1.328	.607	-.391	-2.188	.040

Table 12. Correlations among physical habitat and water chemistry variables for the stratum SJ. Only variables showing a significant correlation with IBI scores (Table 4) are shown.

	pH	Water Temp C	Turbidity NTU	Epifaunal Substrate
Water Temp C	0.462**			
Turbidity NTU	0.552**	0.582**		
Epifaunal Substrate	-0.496**	-0.676**	-0.634**	
% SA (sand)	0.598**	0.635**	0.608**	-0.689**

** Correlation is significant at the 0.01 level (2-tailed).

Table 13. Summary of multiple regressions between IBI scores and physical habitat and water chemistry parameters.

	SA_0-350	SA_350-700	SA_700+	SJ
Positive influence	Mean Width		Mean Densiometer	
Negative influence	Percent Human Influence Channel Alteration	Alkalinity	Alkalinity	Water Temp Turbidity

Table 14. Classification of sites into three levels of biological health for each stratum, "red sites" are more than one standard deviation (SD) from the stratum mean, "yellow sites" are average (within one SD, plus or minus of the stratum mean, and "green sites" are greater than one SD from the stratum mean.

	Mean IBI	Standard deviation (SD) of IBI	Mean IBI – 1 SD	Average	Mean IBI + 1SD
SA_0-350	18.8	11.9	6.9	7.0-30.6	30.7
SA_350-700	28.8	10.7	18.1	18.0-39.4	39.5
SA_700+	45.6	15.8	29.9	30.0-61.3	61.4
SJ	35.5	19.0	16.4	16.3-54.4	54.5

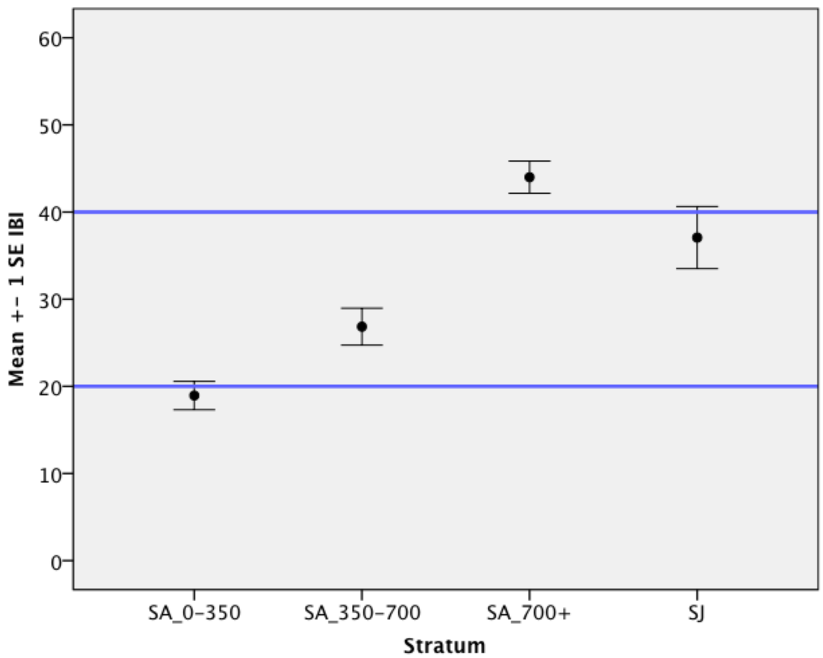


Figure 5. Summary of IBI scores (means and standard errors) of the four strata. Lines represent the categories of biological health, Very Poor (0-20), Poor (21-40), and Fair (41-60).

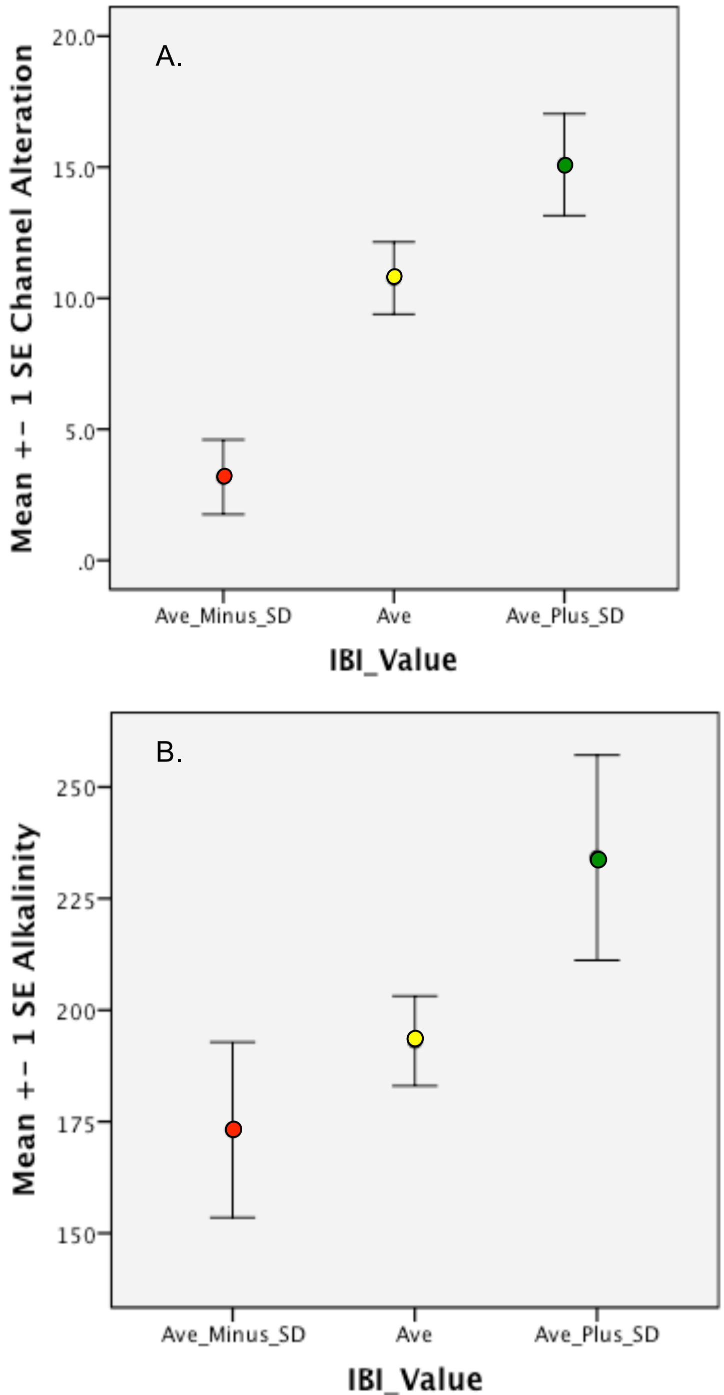


Figure 6. Means with standard errors for the stratum SA_0-350 of (A) Channel Alteration and (B) alkalinity for sites in each of the three categories of biological health (see Table 14 and text).

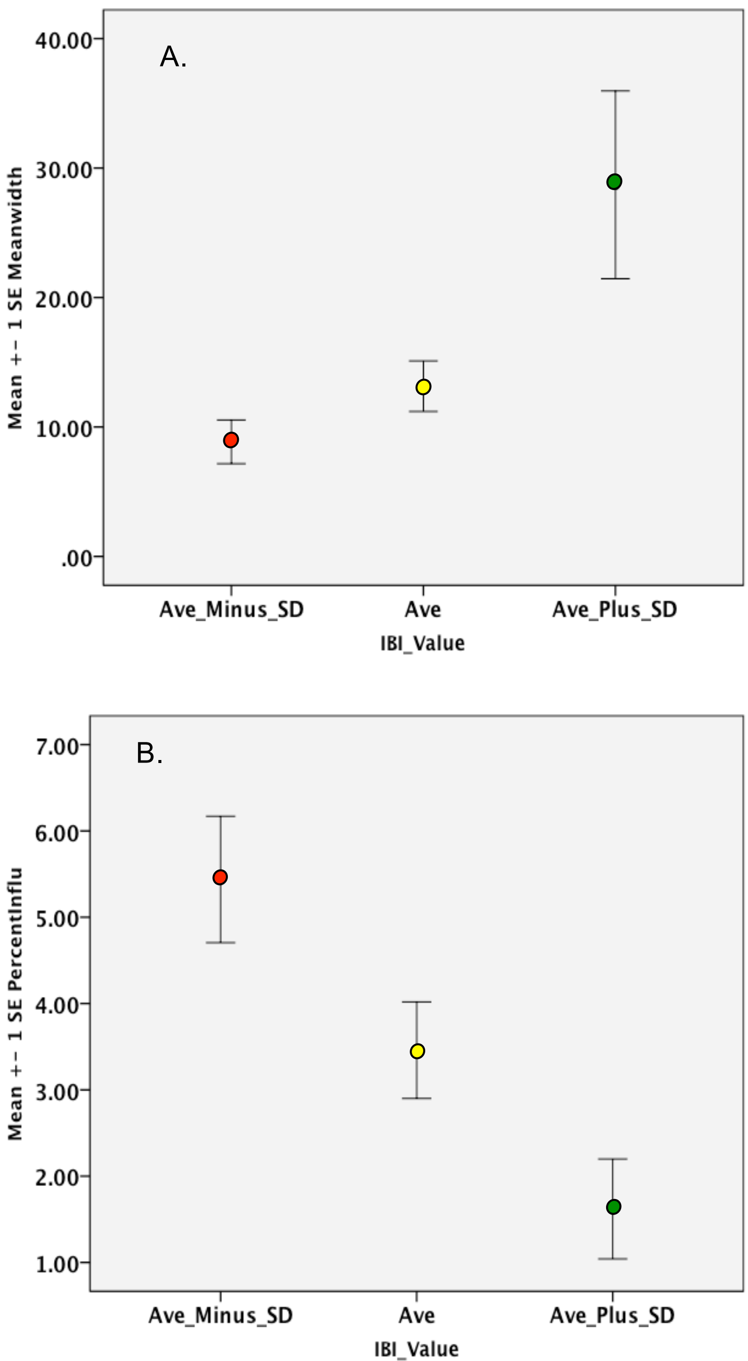


Figure 7. Means with standard errors for the stratum SA_0-350 of (A) Mean width and (B) Percent Human Influence for sites in each of the three categories of biological health (see Table 14 and text).

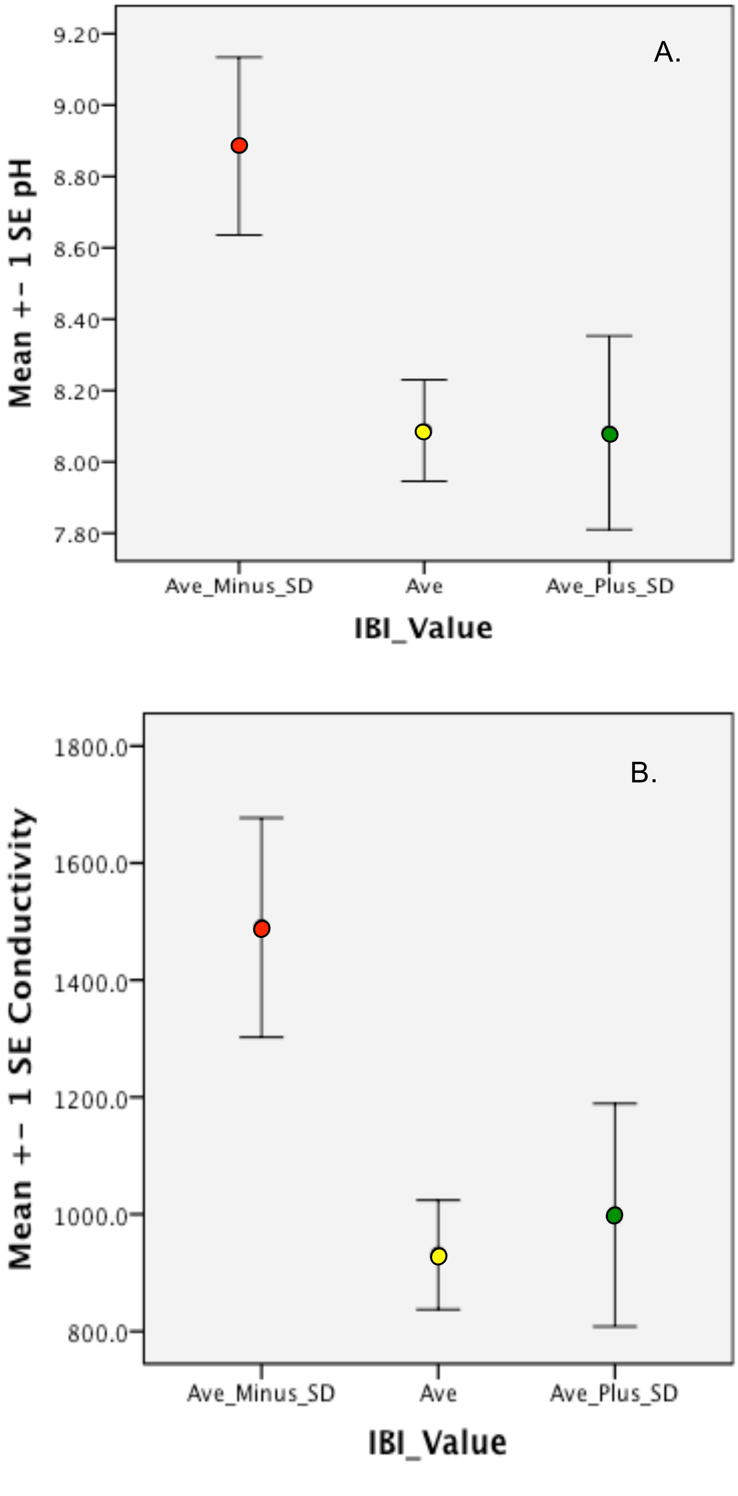
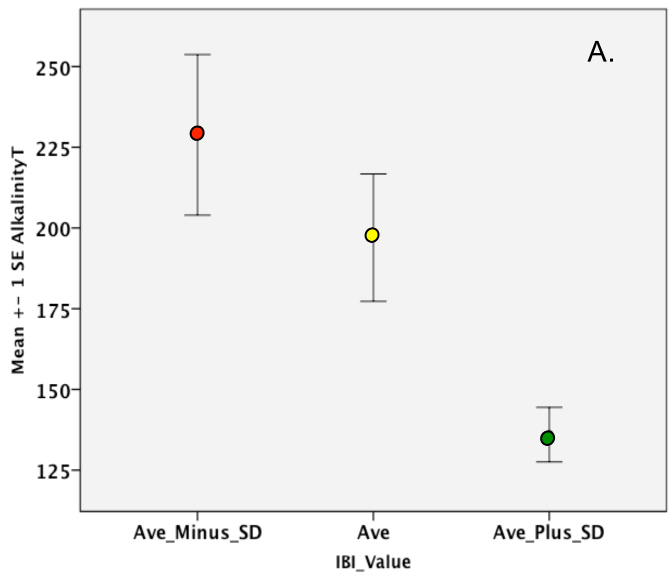


Figure 8. Means with standard errors for the stratum SA_0-350 of (A) pH and (B) conductivity for sites in each of the three categories of biological health (see Table 14 and text).



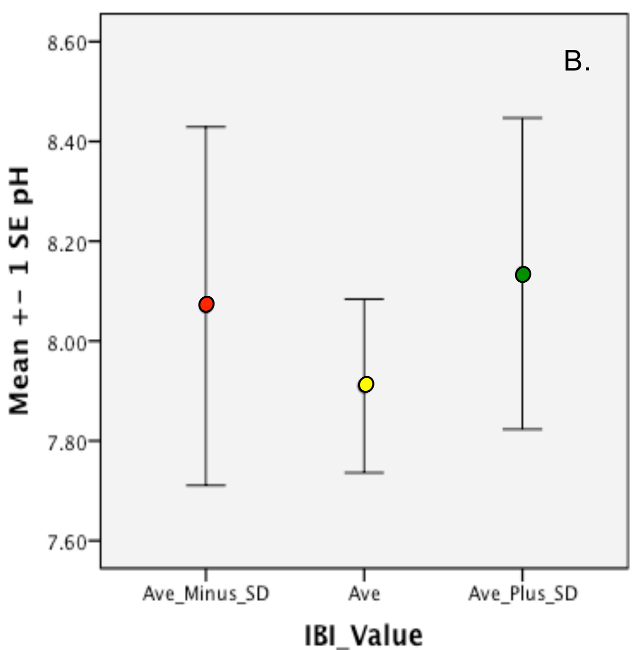


Figure 9. Means with standard errors for the stratum SA_350-700 of (A) alkalinity and (B) pH for site in each of the three categories of biological health (see Table 14 and text).

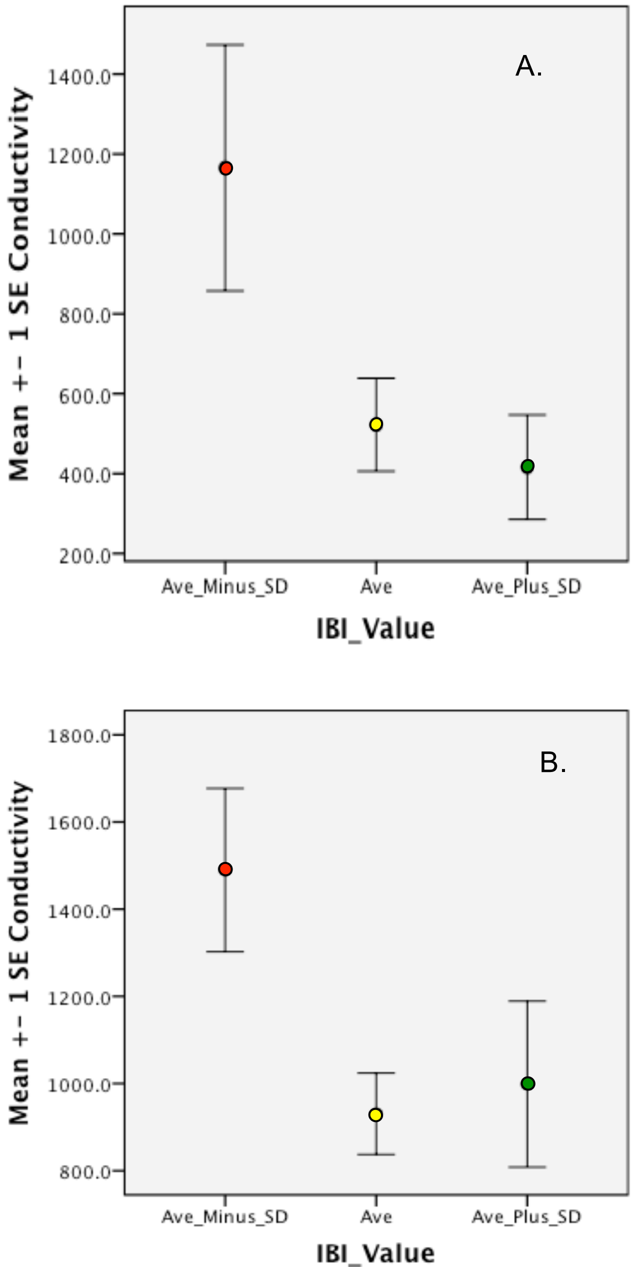


Figure 10. Means with standard errors for conductivity for the stratum SA_350-700 (A) and (B) the stratum SA_0-350 for comparison in each of the three categories of biological health (see Table 14 and text).

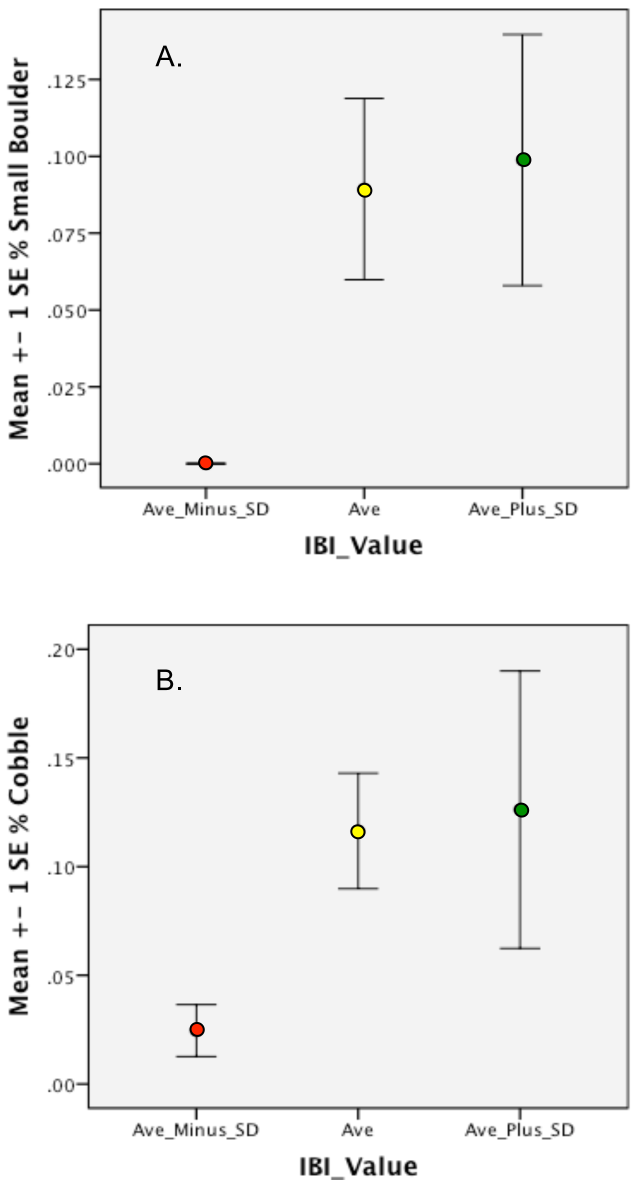
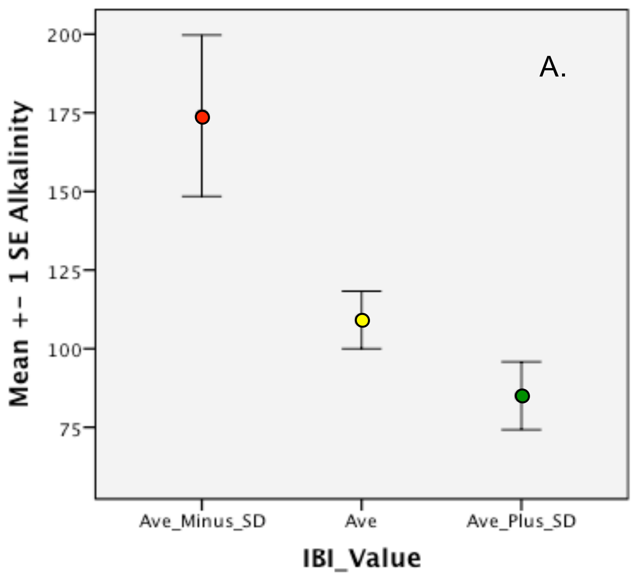


Figure 11. Means with standard errors for the stratum SA_700+ of (A) % Small Boulder and (B) % Cobble for site in each of the three categories of biological health (see Table 14 and text).



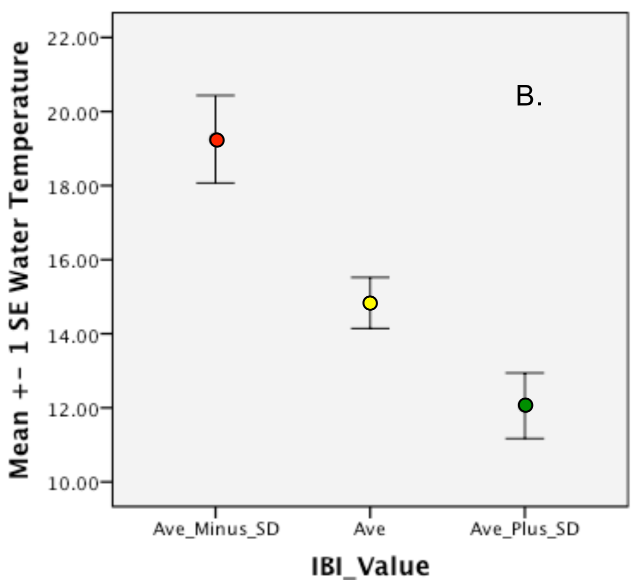
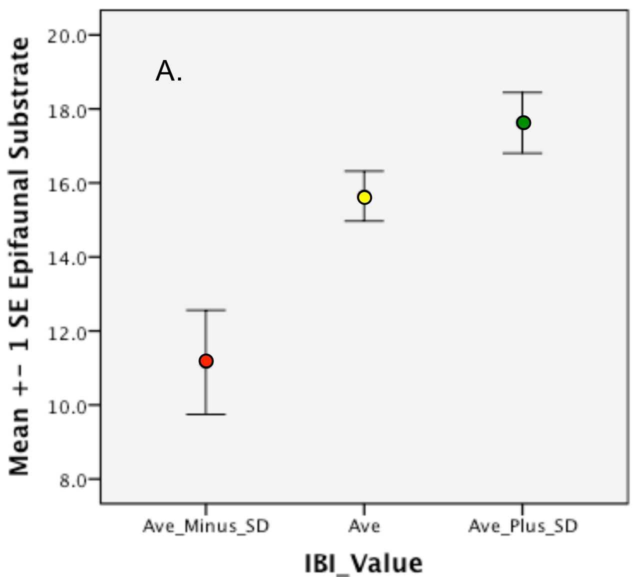


Figure 12. Means with standard errors for the stratum SA_700+ of (A) alkalinity and (B) water temperature for site in each of the three categories of biological health (see Table 14 and text).



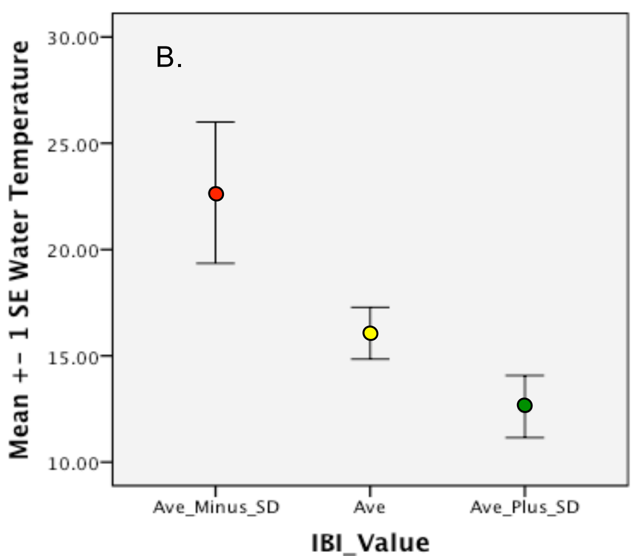


Figure 13. Means with standard errors for the stratum SJ of (A) alkalinity and (B) water temperature for site in each of the three categories of biological health (see Table 14 and text).

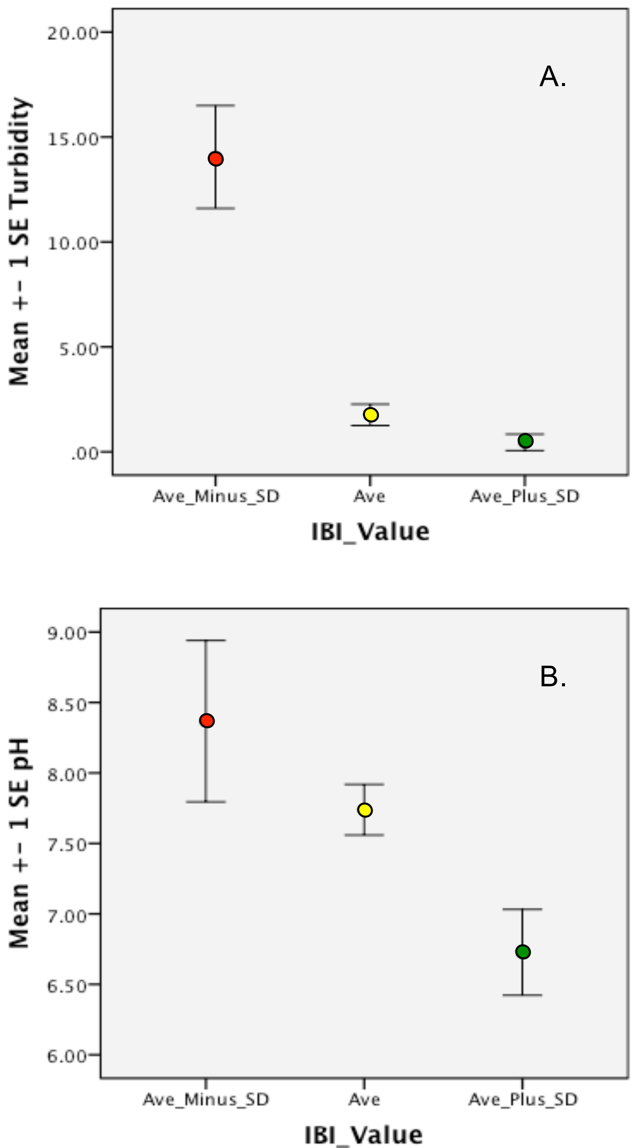


Figure 14. Means with standard errors for the stratum SJ of (A) turbidity and (B) pH for site in each of the three categories of biological health (see Table 14 and text).

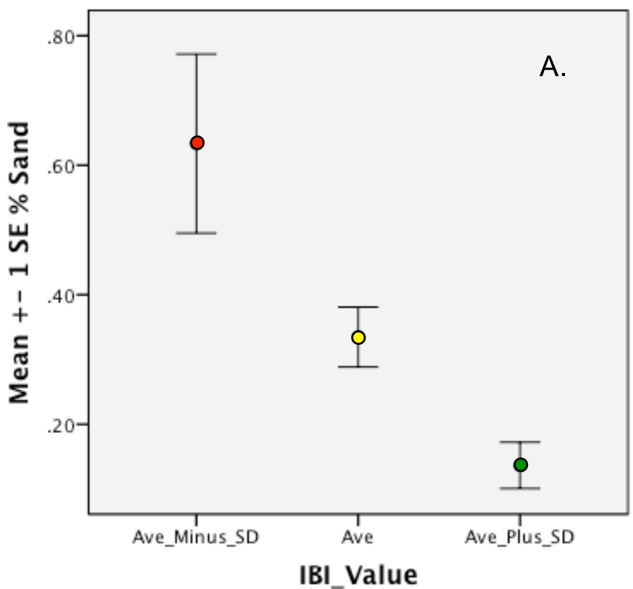


Figure 15. Means with standard errors for the stratum SJ of (A) % Sand for site in each of the three categories of biological health (see Table 14 and text).

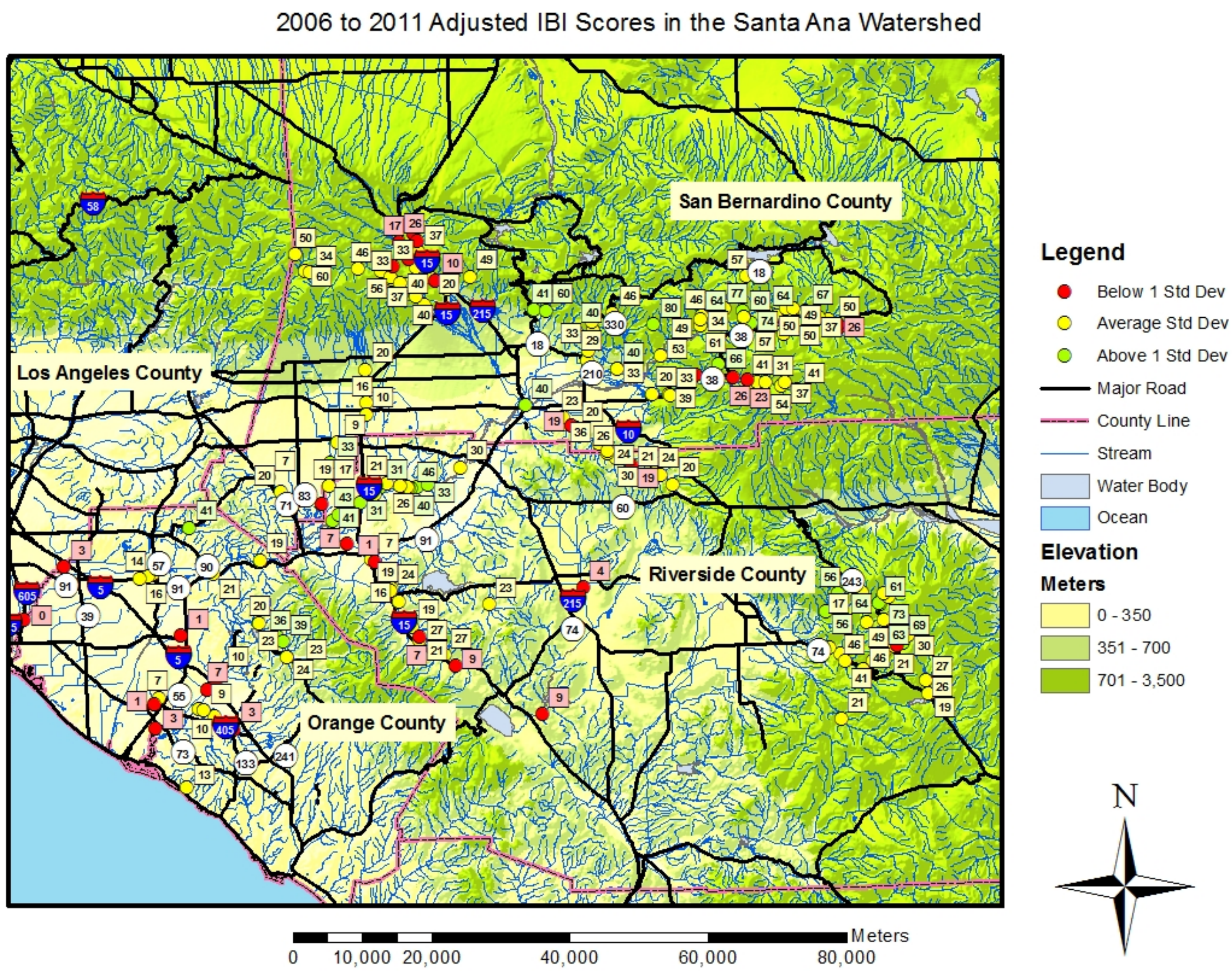


Figure 16. Overview map of Region 8 with all sites sampled 2006 to 2011. Sites in red were at least one standard deviation (SD) below the mean IBI of their respective strata. Sites in yellow were within one SD of the stratum mean and sites in green were at least one SD greater than the stratum mean IBI.

2006 to 2011 Adjusted IBI Scores in the Cajon Canyon Area

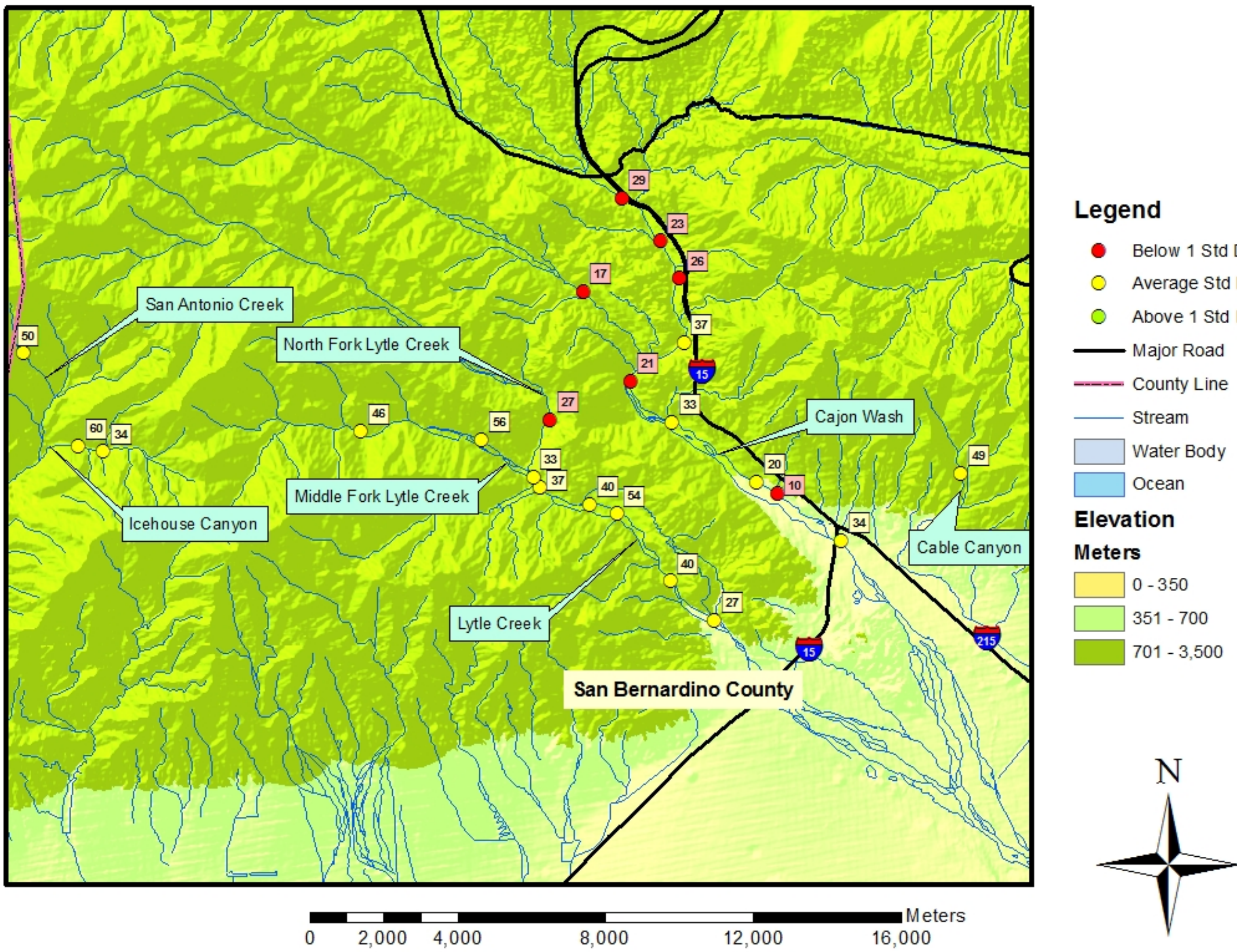


Figure 17. Map of the Cajon Canyon area of Region 8 with all sites sampled 2006 to 2011. Sites in red were at least one standard deviation (SD) below the mean IBI of their respective strata. Sites in yellow were within one SD of the stratum mean and sites in green were at least one SD greater than the stratum mean IBI.

2006 to 2011 Adjusted IBI Scores around City Creek

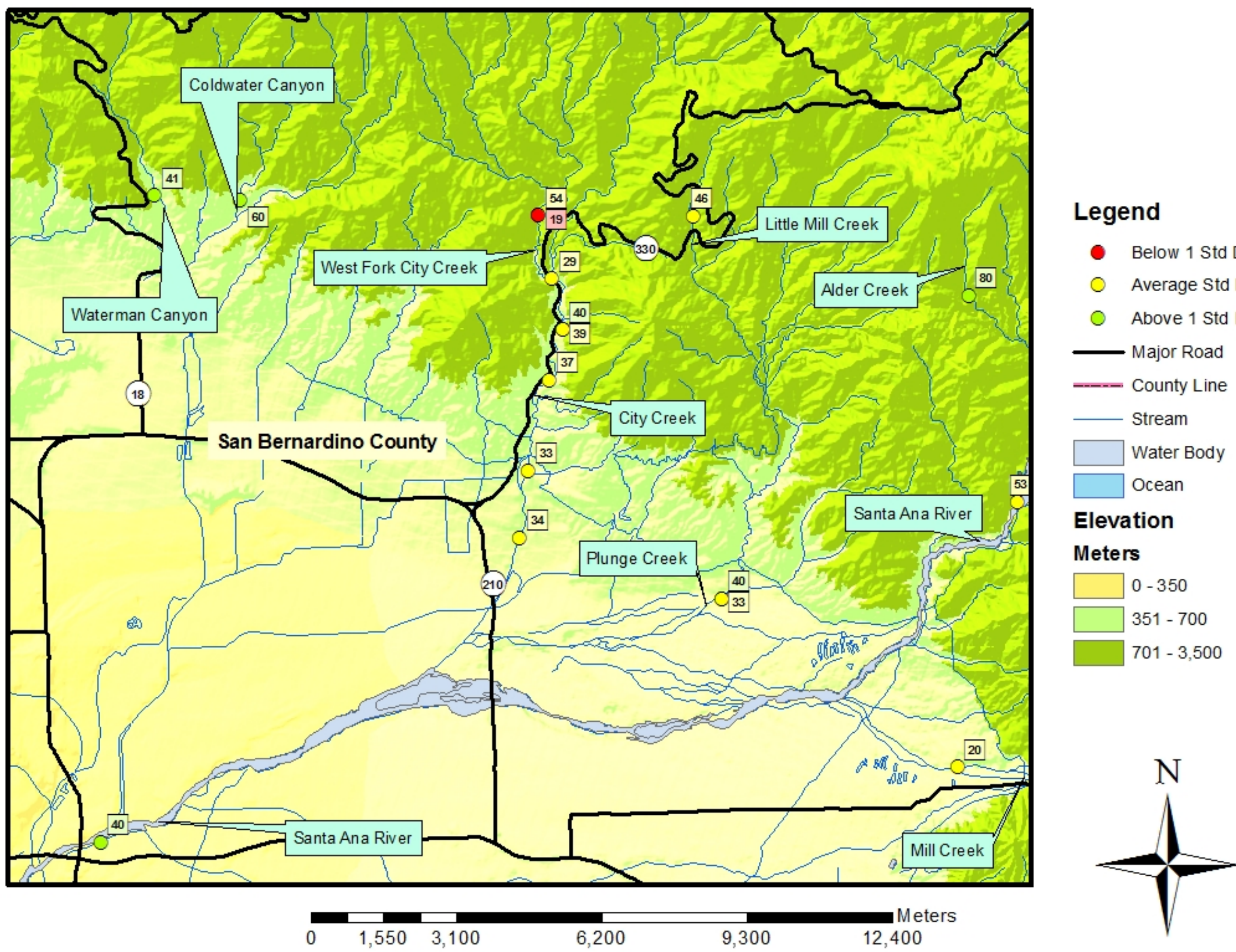


Figure 18. Map of the City Creek area of Region 8 with all sites sampled 2006 to 2011. Sites in red were at least one standard deviation (SD) below the mean IBI of their respective strata. Sites in yellow were within one SD of the stratum mean and sites in green were at least one SD greater than the stratum mean IBI.

2006 to 2011 Adjusted IBI Scores in the Upper Santa Ana River Area

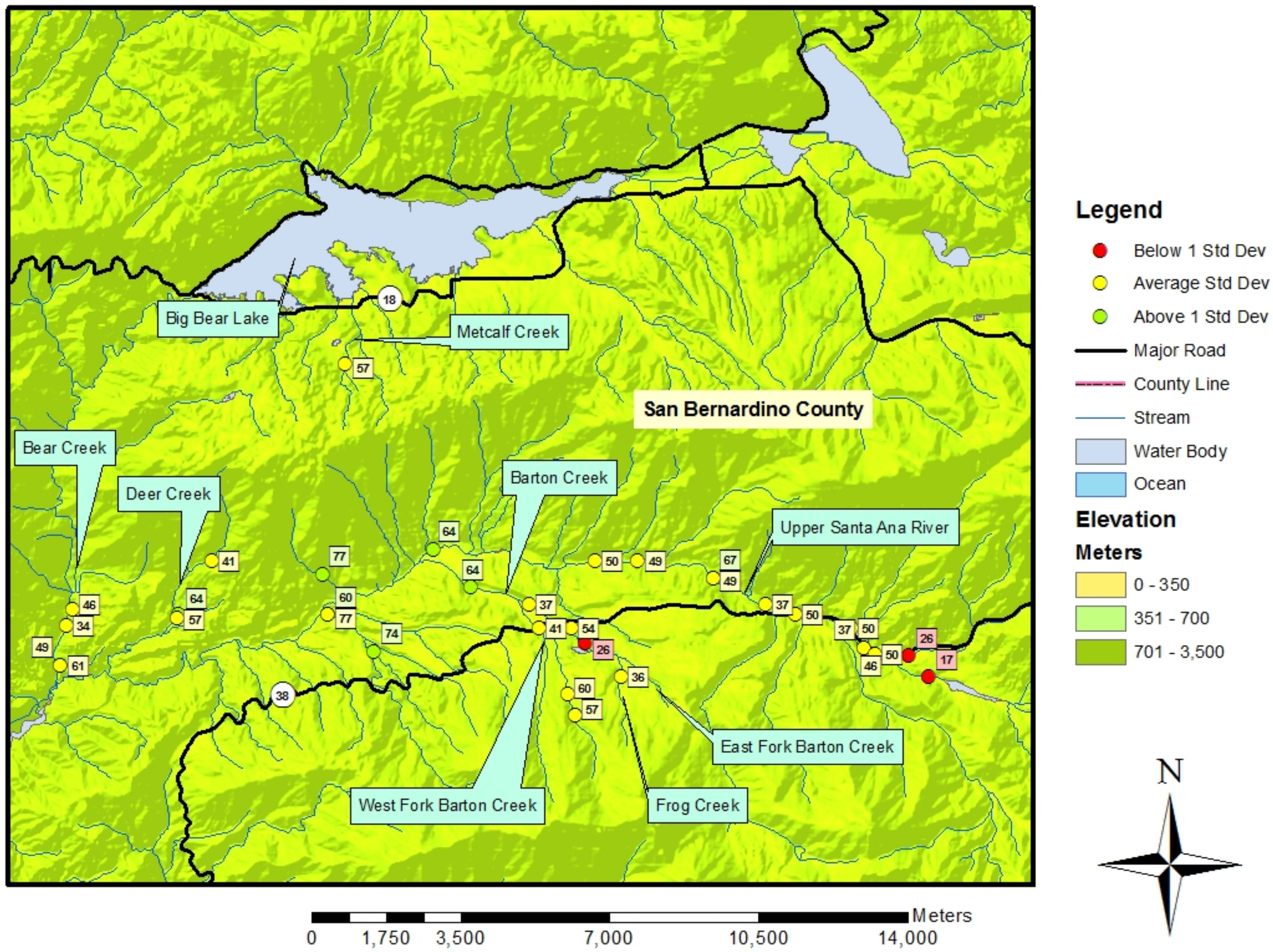


Figure 19. Map of the Upper Santa Ana area of Region 8 with all sites sampled 2006 to 2011. Sites in red were at least one standard deviation (SD) below the mean IBI of their respective strata. Sites in yellow were within one SD of the stratum mean and sites in green were at least one SD greater than the stratum mean IBI.

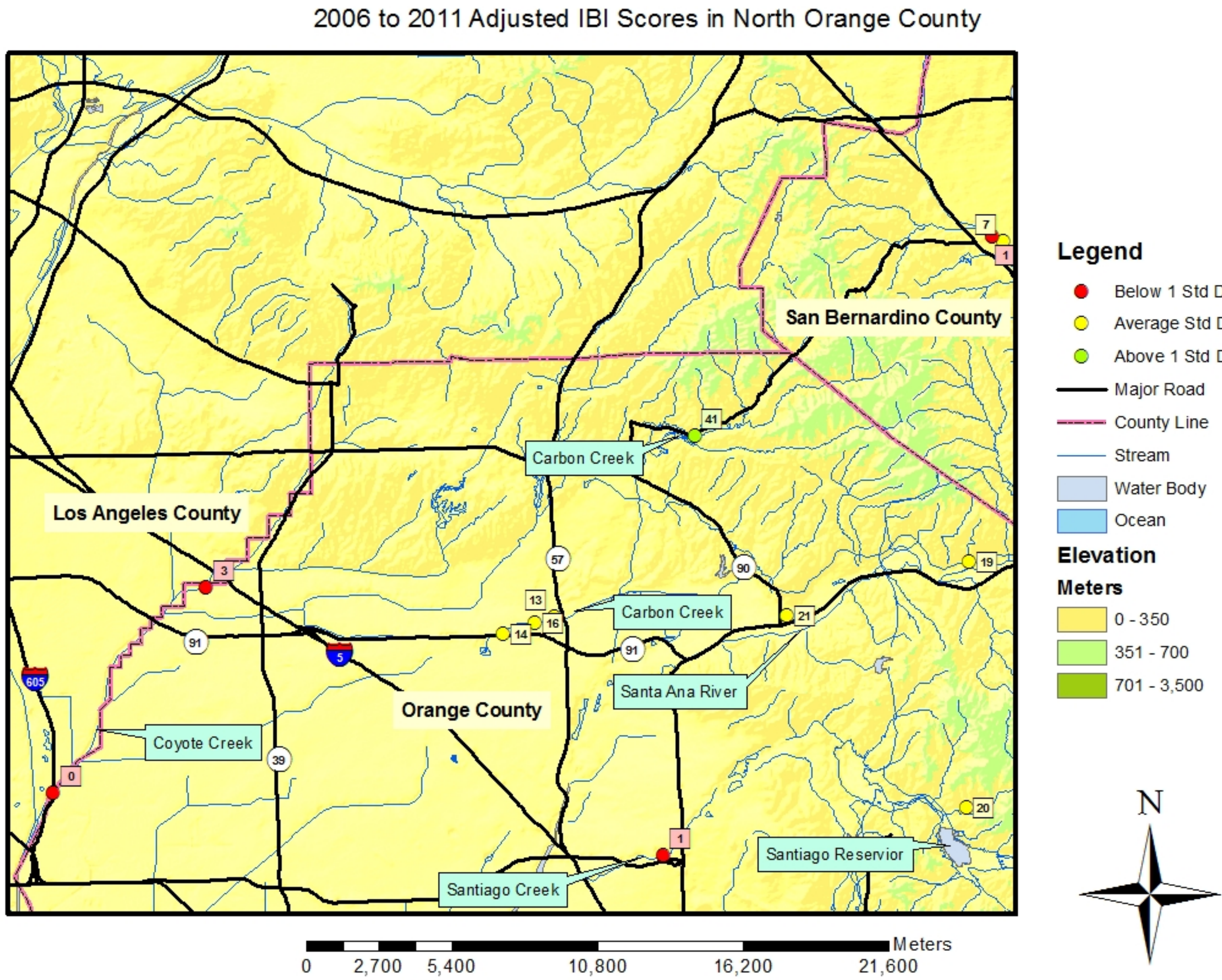


Figure 20. Map of the North Orange County area of Region 8 with all sites sampled 2006 to 2011. Sites in red were at least one standard deviation (SD) below the mean IBI of their respective strata. Sites in yellow were within one SD of the stratum mean and sites in green were at least one SD greater than the stratum mean IBI.

2006 to 2011 Adjusted IBI Scores upstream of the Prado Flood Control Basin

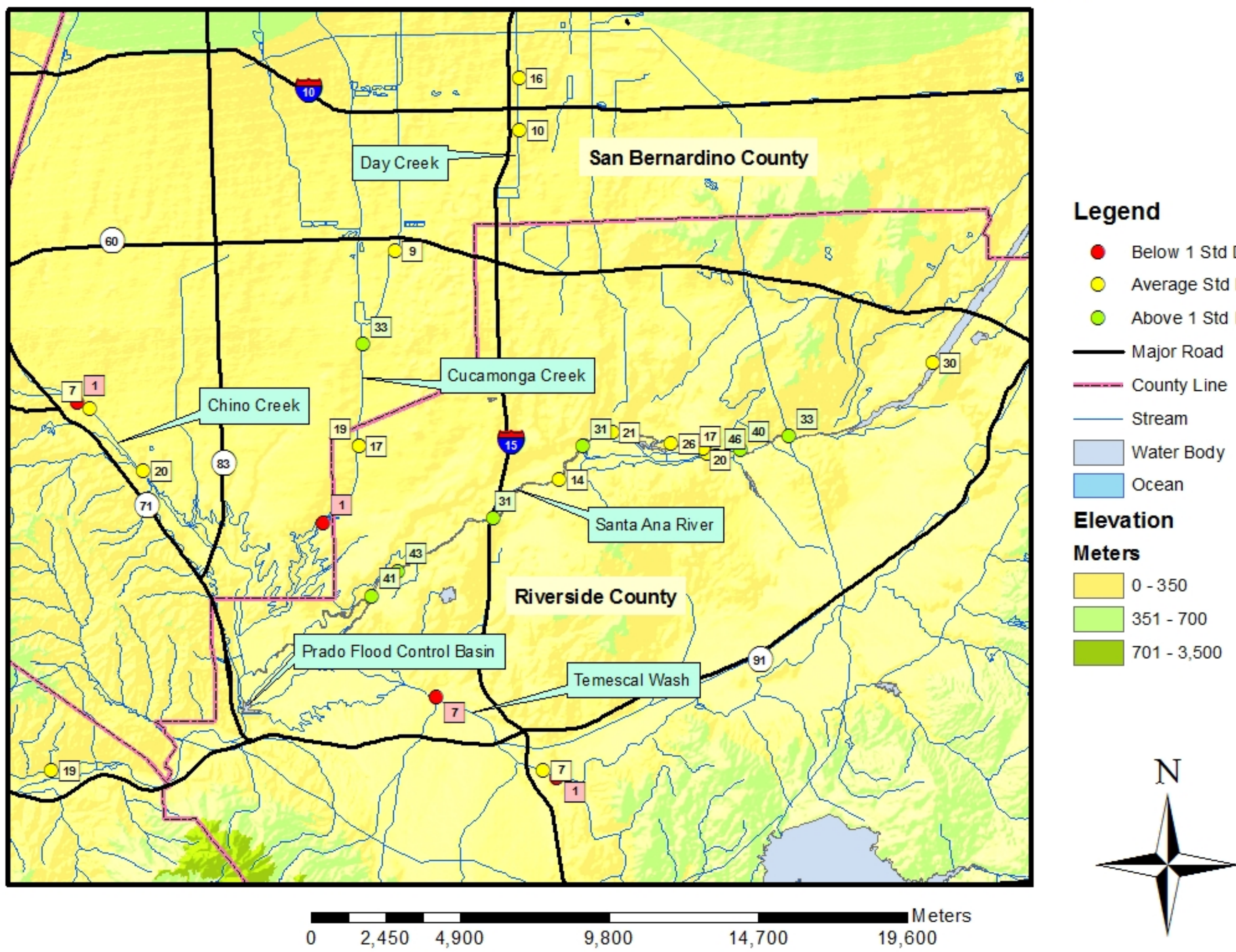


Figure 21. Map of the Prado Flood Control area of Region 8 with all sites sampled 2006 to 2011. Sites in red were at least one standard deviation (SD) below the mean IBI of their respective strata. Sites in yellow were within one SD of the stratum mean and sites in green were at least one SD greater than the stratum mean IBI.

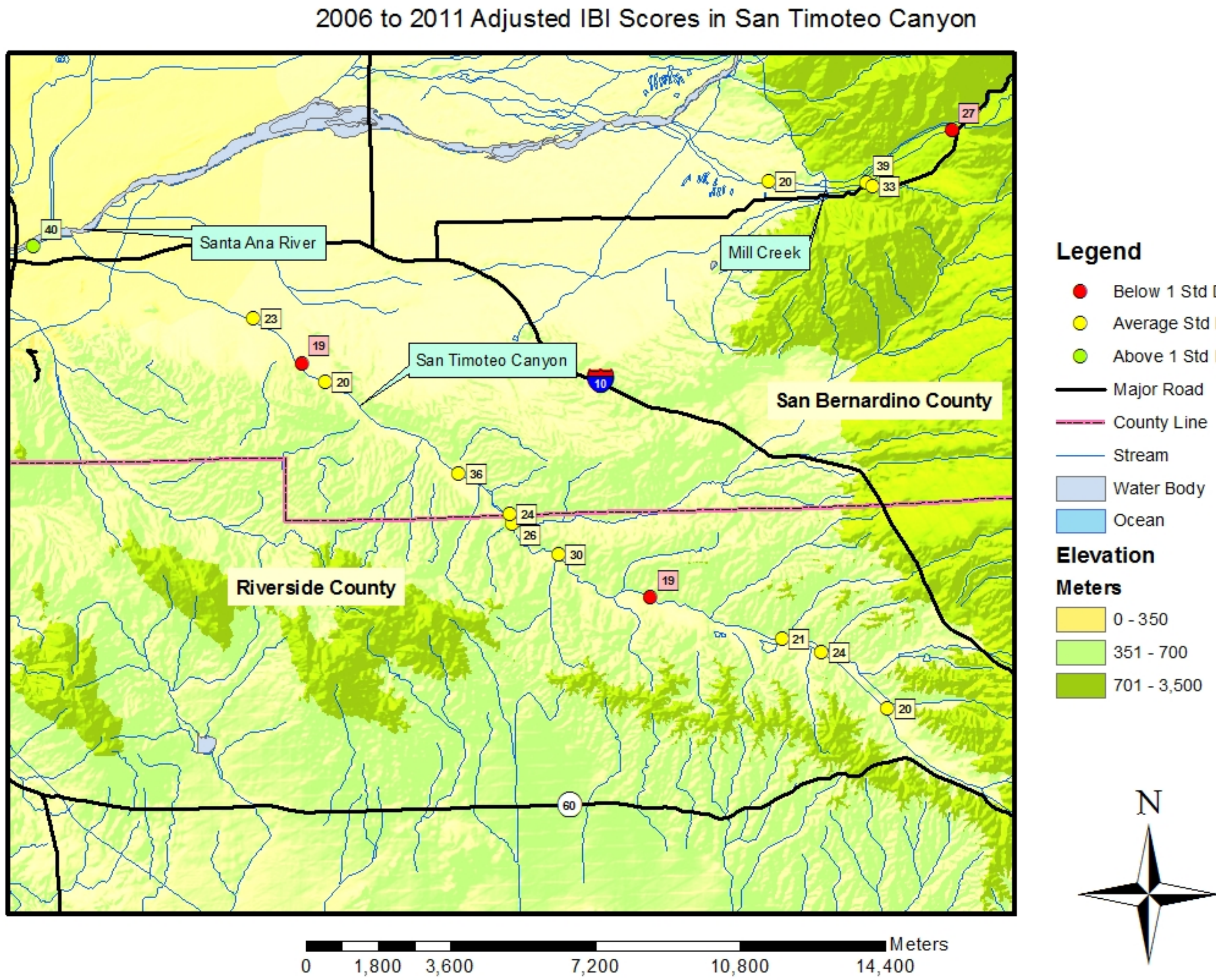


Figure 22. Map of the San Timoteo area of Region 8 with all sites sampled 2006 to 2011. Sites in red were at least one standard deviation (SD) below the mean IBI of their respective strata. Sites in yellow were within one SD of the stratum mean and sites in green were at least one SD greater than the stratum mean IBI.

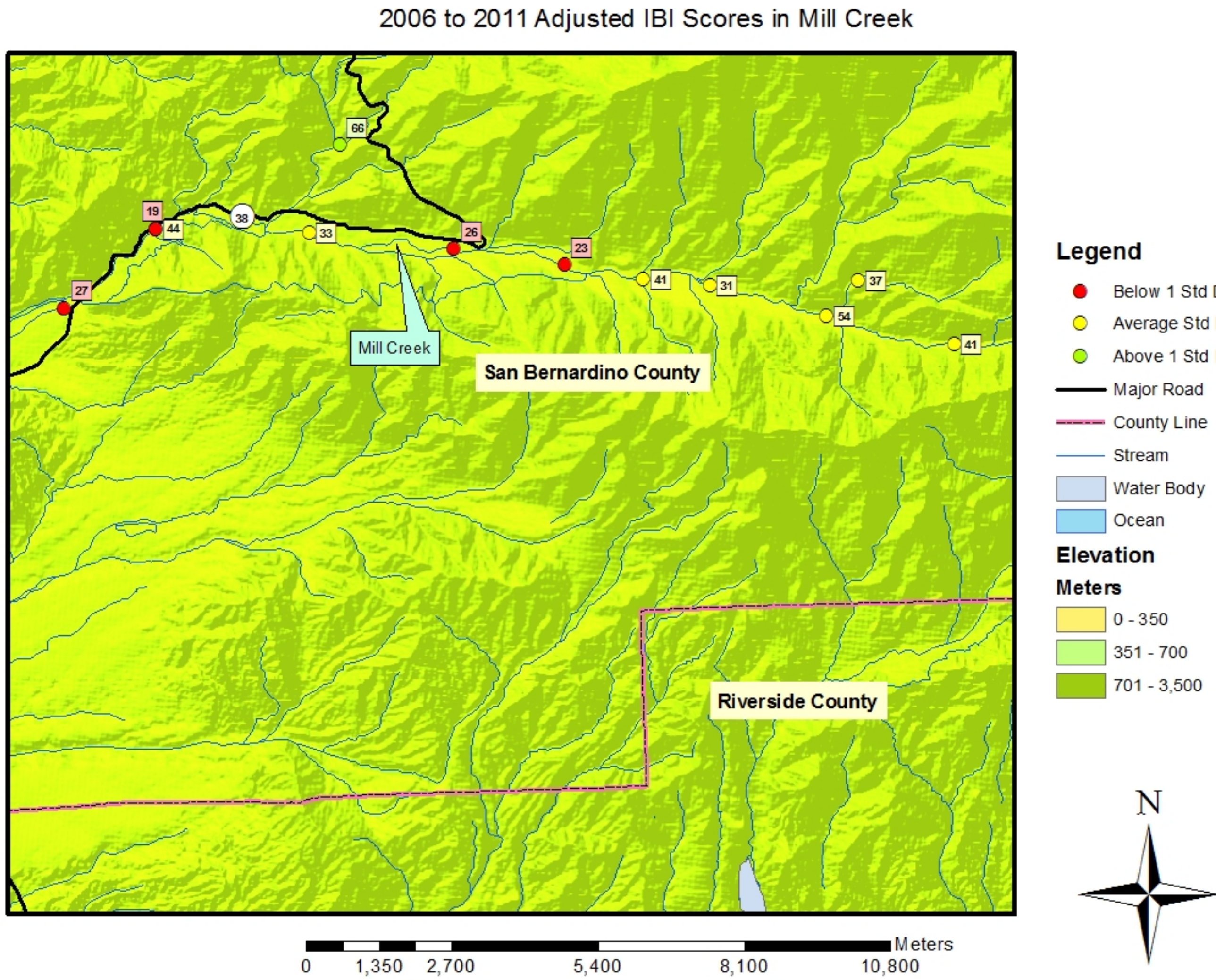


Figure 23. Map of the Mill Creek area of Region 8 with all sites sampled 2006 to 2011. Sites in red were at least one standard deviation (SD) below the mean IBI of their respective strata. Sites in yellow were within one SD of the stratum mean and sites in green were at least one SD greater than the stratum mean IBI.

2006 to 2011 Adjusted IBI Scores in Orange County

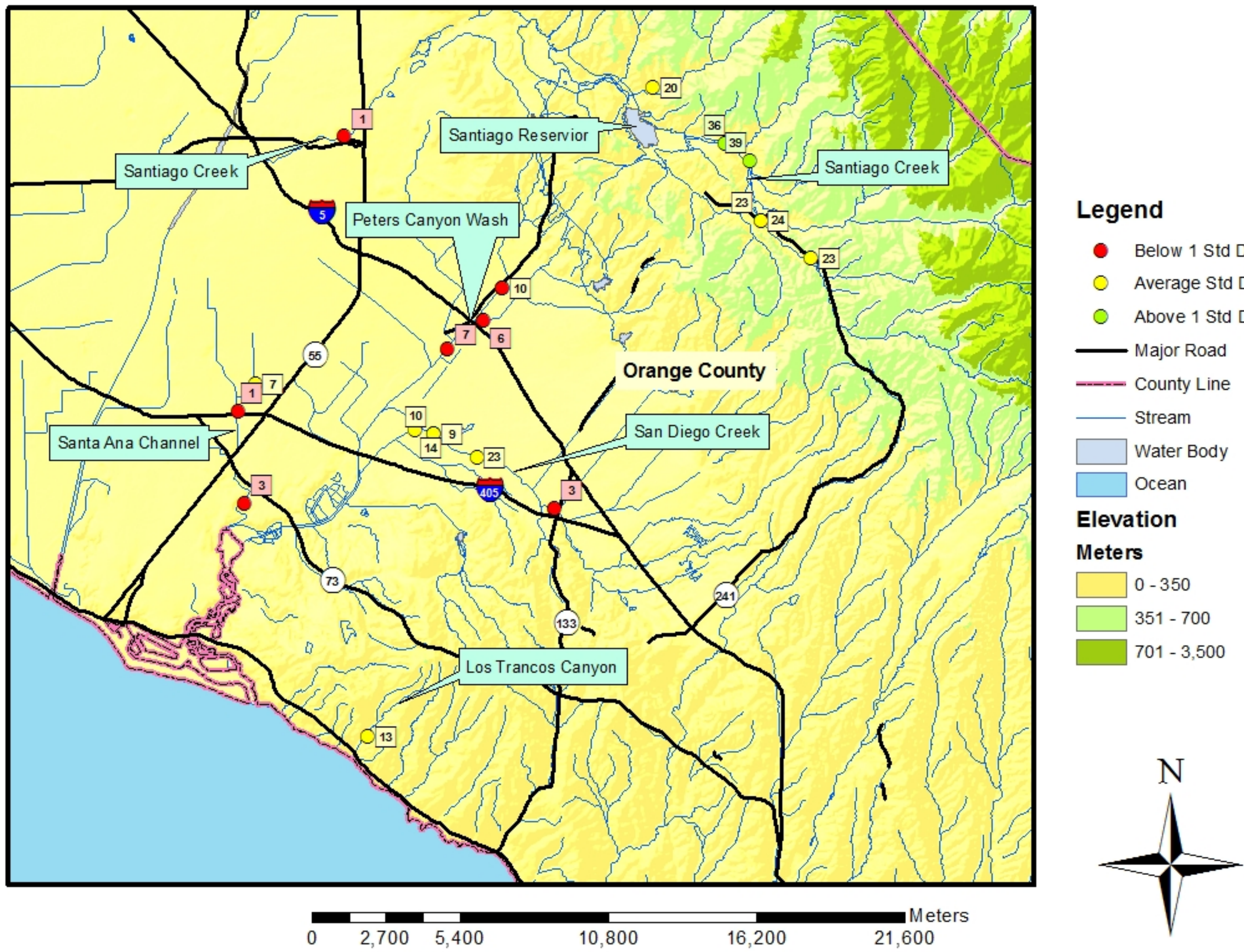


Figure 24. Map of the Southern Orange County area of Region 8 with all sites sampled 2006 to 2011. Sites in red were at least one standard deviation (SD) below the mean IBI of their respective strata. Sites in yellow were within one SD of the stratum mean and sites in green were at least one SD greater than the stratum mean IBI.

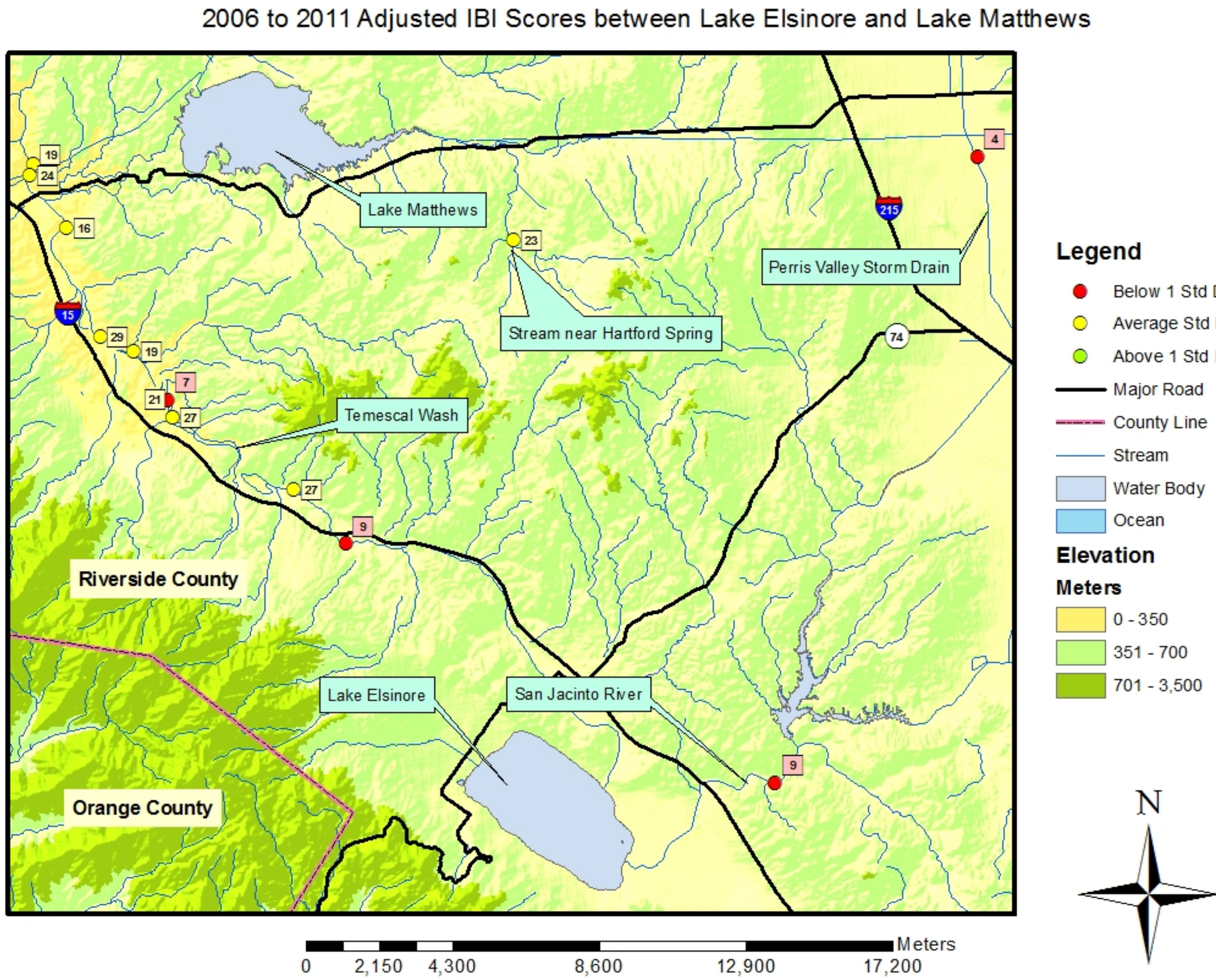


Figure 25. Map of the Lake Elsinore and Lake Matthews area of Region 8 with all sites sampled 2006 to 2011. Sites in red were at least one standard deviation (SD) below the mean IBI of their respective strata. Sites in yellow were within one SD of the stratum mean and sites in green were at least one SD greater than the stratum mean IBI.

2006 to 2011 Adjusted IBI Scores in the Lake Hemet Area

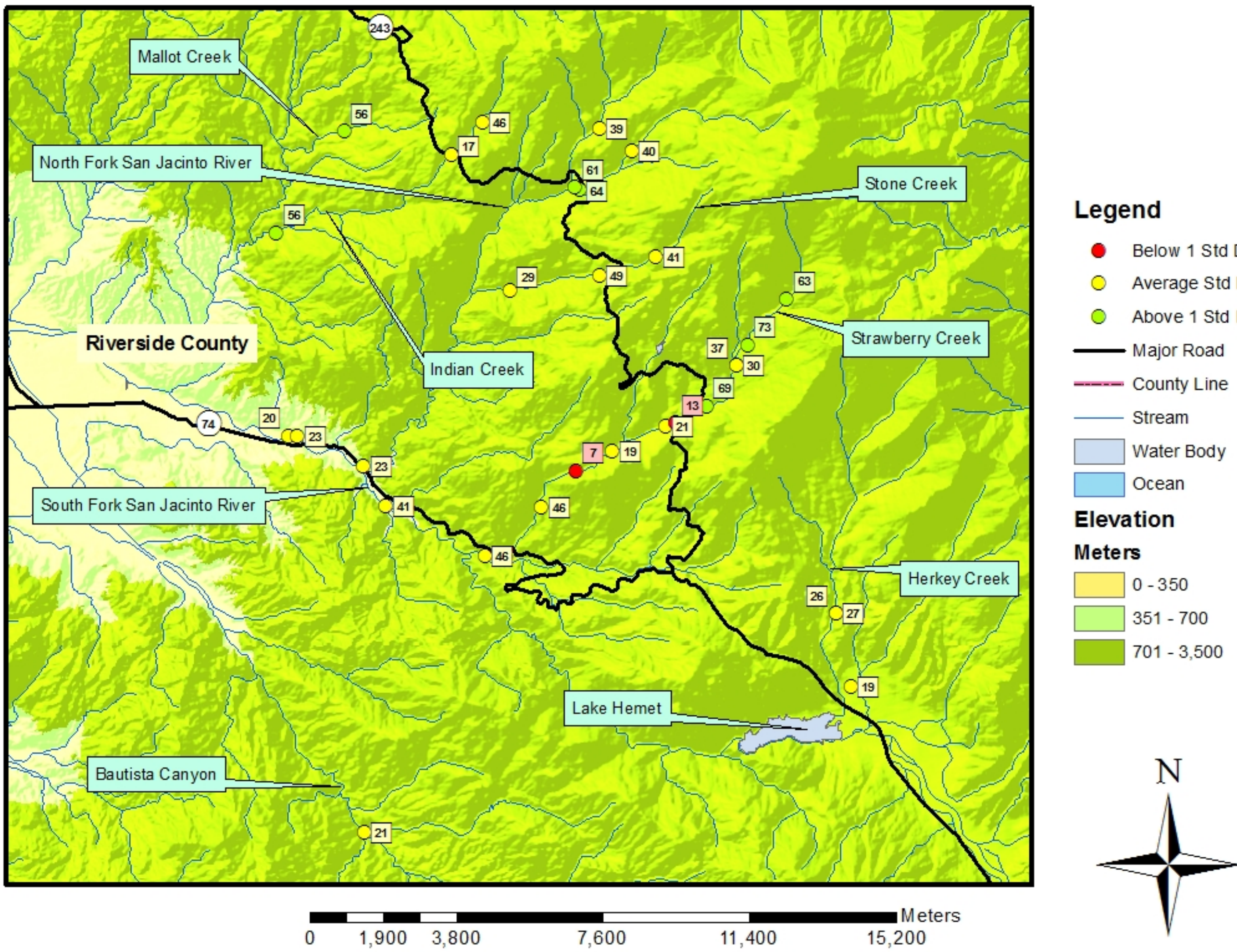


Figure 26. Map of the Lake Hemet area of Region 8 with all sites sampled 2006 to 2011. Sites in red were at least one standard deviation (SD) below the mean IBI of their respective strata. Sites in yellow were within one SD of the stratum mean and sites in green were at least one SD greater than the stratum mean IBI.

Table 15. Summary of sites sampled in Region 8 2006-2011. Red and green sites are identified; non-shaded rows are the yellow sites. Latitudes and Longitudes are field values and actual locations, not targeted locations.

Site Code	Adjusted IBI	Collection Date	Latitude	Longitude	Elevation (m)	Elevation Strata (m)	Stream Name	County
7	26	22-Jun-06	34.09520	-116.96447	1293	700 +	Mill Creek Canyon	San Bern
11	21	15-Jun-06	33.85815	-117.78667	85	0 -350	Santa Ana River	Orange
12	41	31-May-06	33.91909	-117.82201	138	0 -350	Carbon Canyon	Orange
19	41	15-Jun-06	33.92417	-117.59778	156	0 -350	Prado Flood Control Basin	Riverside
20	63	16-Jun-06	33.76698	-116.69020	1890	700 +	Strawberry Creek	Riverside
27	29	23-Jun-06	34.30610	-117.46970	917	700 +	Cajon Canyon	San Bern
28	27	4-Jun-06	34.20260	-117.44583	726	700 +	Lytle Creek	San Bern
32	39	3-Jun-06	34.07629	-117.06626	729	700 +	Mill Creek	San Bern
34	41	22-Jun-06	34.08909	-116.92669	1600	700 +	Mill Creek Canyon	San Bern
35	54	22-Jun-06	34.08193	-116.89027	1819	700 +	Mill Creek Canyon	San Bern
41	23	23-Jun-06	34.29543	-117.45882	849	700 +	Cajon Canyon	San Bern
42	1	31-May-06	33.94623	-117.61423	166	0 -350	Mill Creek	San Bern
51	30	3-Jun-06	33.99512	-117.15212	484	350 -700	San Timoteo Canyon	Riverside
55	36	3-Jun-06	34.03960	-117.21973	384	350 -700	San Timoteo Canyon	San Bern
62	40	23-Jun-06	34.21257	-117.45844	730	700 +	Lytle Creek	San Bern
70	29	17-Jun-06	33.77122	-116.76750	1385	700 +	Stone Creek	Riverside
79	23	4-Jun-06	34.22123	-117.40798	622	350 -700	East Kimbark Canyon	San Bern
85	19	4-Jun-06	34.04990	-117.23238	352	350 -700	San Timoteo Canyon	San Bern
110	40	15-Jun-06	33.96468	-117.46518	207	0 -350	Santa Ana River	Riverside
116	9	21-Jun-06	33.66396	-117.27870	410	350 -700	San Jacinto River	Riverside
160	23	7-Jun-06	33.73134	-116.81020	647	350 -700	North Fork San Jacinto	Riverside
172	56	16-Jun-06	33.78651	-116.8320	814	700 +	Indian Creek	Riverside

Site Code	Adjusted IBI	Collection Date	Latitude	Longitude	Elevation (m)	Elevation Strata (m)	Stream Name	County
180	23	20-Jun-06	33.67263	-117.78944	23	0 -350	San Diego Creek	Orange
206	19	15-Jun-06	33.73283	-116.74047	1546	700 +	Strawberry Creek	Riverside
226	34	26-Jun-06	34.19146	-117.27421	597	350 -700	East Twin Creek	San Bern
243	4	7-Jun-06	33.82798	-117.20878	440	350 -700	Perris Valley Storm Drain	Riverside
258	41	26-Jun-06	34.01399	-117.17834	443	350 -700	San Timoteo Canyon	San Bern
267	19	27-Jun-06	33.67606	-116.67871	1321	700 +	Herkey Creek	Riverside
532	1	20-Jun-06	33.77896	-117.83864	64	0 -350	Santiago Creek	Orange
713	60	23-Jun-06	34.24908	-117.63127	1557	700 +	Icehouse Canyon	San Bern
25	57	16-Jun-07	34.1739	-116.9839	1365	700 +	Deer Creek	San Bern
69	56	1-Jun-07	34.2481	-117.51276	1007	700 +	Lytle Creek	San Bern
87	46	30-May-07	34.16287	-116.80945	1990	700 +	Santa Ana River	San Bern
93	54	20-May-07	34.16891	-116.88367	1942	700 +	Frog Creek	San Bern
100	57	28-May-07	34.22644	-116.93895	2241	700 +	Metcalf Creek	San Bern
105	27	2-Jun-07	34.25265	-117.4925	967	700 +	Lytle Creek (North Fork)	San Bern
106	60	16-Jun-07	34.15508	-116.88528	2109	700 +	Barton Creek	San Bern
121	34	9-Jun-07	34.12372	-117.19213	400	350 -700	City Creek	San Bern
147	64	19-May-07	33.79427	-116.74714	1655	700 +	San Jacinto River	Riverside
151	30	10-Jun-07	33.98873	-117.39614	232	0 - 350	Santa Ana River	Riverside
159	20	20-Apr-07	33.73904	-116.83089	598	350 -700	San Jacinto River	Riverside
163	61	19-May-07	33.79478	-116.74829	1635	700 +	San Jacinto River	Riverside
168	49	16-Jun-07	34.17865	-116.84726	1846	700 +	Santa Ana River	San Bern
203	64	29-May-07	34.18658	-116.91801	1600	700 +	Hamilton Creek	San Bern
208	26	17-Jun-07	34.0023	-117.16428	476	350 -700	San Timoteo	Riverside
247	NA	9-Jun-07	34.18771	-117.18359	751		City Creek	San Bern
271	54	2-Jun-07	34.22931	-117.47362	799	700 +	Lytle Creek	San Bern
346	37	2-Jun-07	34.23613	-117.49604	880	700 +	Lytle Creek (South Fork)	San Bern

Site Code	Adjusted IBI	Collection Date	Latitude	Longitude	Elevation (m)	Elevation Strata (m)	Stream Name	County
361	33	10-Jun-07	33.96825	-117.44789	210	0 - 350	Santa Ana River	Riverside
370	19	17-Jun-07	34.10015	-117.02393	983	700 +	Mill Creek	San Bern
375	73	19-Apr-07	33.75657	-116.70164	1755	700 +	Strawberry Creek	Riverside
398	33	15-Jun-07	34.13646	-117.18965	441	350 -700	City Creek	San Bern
419	69	19-Apr-07	33.74266	-116.71364	1640	700 +	Strawberry Creek	Riverside
446	54	9-Jun-07	34.18543	-117.18567	723	700 +	City Creek	San Bern
453	23	20-Apr-07	33.73882	-116.82834	606	350 -700	San Jacinto River	Riverside
530	64	29-May-07	34.17834	-116.90881	1706	700 +	Barton Creek	San Bern
543	40	19-May-07	33.80281	-116.73208	1774	700 +	San Jacinto River	Riverside
587	41	18-May-07	33.72206	-116.80423	677	350 -700	San Jacinto River	Riverside
635	17	20-May-07	33.80349	-116.78271	1645	700 +	Indian Creek	Riverside
686	41	30-May-07	34.16918	-116.89195	1932	700 +	Halfway Creek	San Bern
168R2	67	16-Jun-07	34.17865	-116.84726	1846	700 +	Santa Ana River	San Bern
370R2	44	17-Jun-07	34.10015	-117.02393	983	700 +	Mill Creek	San Bern
446R2	19	9-Jun-07	34.18543	-117.18567	723	700 +	City Creek	San Bern
87R2	37	30-May-07	34.16287	-116.80945	1990	700 +	Santa Ana River	San Bern
801FGC022	36	23-May-08	34.16055	-116.86775	2125	700 +	Frog Creek	San Bern
801XXX046	20	5-May-08	33.79096	-117.71949	200	0 - 350	Feeder to Irvine Lake	Orange
801PCW048	6	11-May-08	33.71756	-117.78945	28	0 - 350	Peters Canyon Wash	Orange
801HBC050	17	23-Jun-08	34.15651	-116.79441	2047	700 +	Heart Bar Creek	San Bern
801MLC057	46	18-May-08	34.25033	-117.54376	1295	700 +	Middle Fork Lytle Creek	San Bern
801SAN068	50	10-Jun-08	34.2575	-117.64123	1575	700 +	San Antonio Creek Channel	San Bern
801STC071	23	5-Jun-08	33.75347	-117.67887	241	0 - 350	Santiago Creek	Orange
801STC071R2	24	5-Jun-08	33.75347	-117.67887	241	0 - 350	Santiago Creek	Orange
801MIC074	37	25-May-08	34.08167	-116.88870	1862	700 +	Mill Creek	San Bern
801EBC080	56	24-Jun-08	34.15840	-116.88742	2078	700 +	East Fork Barton Creek	San Bern

Site Code	Adjusted IBI	Collection Date	Latitude	Longitude	Elevation (m)	Elevation Strata (m)	Stream Name	County
801EBC080R2	57	24-Jun-08	34.15840	-116.88742	2078	700 +	East Fork Barton Creek	San Bern
801XXX112	21	11-Jun-08	34.26148	-117.46974	780	700 +	Cajon Wash	San Bern
801CYC114	37	7-Jul-08	34.13646	-117.18970	443	350 - 700	City Creek	San Bern
801XXX118	17	11-Jun-08	34.27906	-117.47566	880	700 +	Swarthout Canyon	San Bern
801EBC126	37	23-Jun-08	34.17491	-116.89616	1844	700 +	East Fork Barton Creek	San Bern
801STC142	36	8-Jul-08	33.77361	-117.68839	247	0 - 350	Santiago Creek	Orange
801STC149	39	8-Jul-08	33.76593	-117.67927	257	0 - 350	Santiago Creek	Orange
801TMW153	16	16-Jun-08	33.82397	-117.50602	241	0 - 350	Temescal Wash	Riverside
802INC155	46	30-Jun-08	33.80703	-116.77699	1671	700 +	Indian Creek	Riverside
801TMW162	9	16-Jun-08	33.73786	-117.41730	360	350 - 700	Temescal Wash	Riverside
801SAR165	17	6-Jul-08	33.96358	-117.47533	198	0 - 350	Santa Ana River	Riverside
801PCW171	6	4-Jun-08	33.72398	-117.78003	37	0 - 350	Peters Canyon Wash	Orange
801PCW171R2	10	4-Jun-08	33.72398	-117.78003	37	0 - 350	Peters Canyon Wash	Orange
801SDC178	14	11-May-08	33.68240	-117.81066	19	0 - 350	San Diego Creek	Orange
801XXX259	20	29-Jun-08	34.07638	-117.09505	622	350 - 700	Mill Creek	San Bern
802SWC270	7	30-Jun-08	33.72944	-116.74809	1536	700 +	Strawberry Creek	Riverside
801MIC272	31	25-Jun-08	34.08788	-116.91434	1662	700 +	Mill Creek	San Bern
801XXX305	7	4-Jun-08	33.70892	-117.80066	13	0 - 350	Peters Canyon Wash	Orange
801SAR334	50	25-Jun-08	34.18308	-116.87802	1732	700 +	Santa Ana River	San Bern
801SAR351	31	19-Jun-08	33.97295	-117.51806	189	0 - 350	Santa Ana River	Riverside
801PLC362	33	17-Jun-08	34.23904	-117.49896	902	700 +	Lytle Creek	San Bern
801PLC469	40	7-Jul-08	34.11160	-117.14689	448	350 - 700	Plunge Creek	San Bern
801PLC469R2	33	7-Jul-08	34.11160	-117.14689	448	350 - 700	Plunge Creek	San Bern
405CTC480	0	8-Jul-08	33.80402	-118.08385	2	0 - 350	Coyote Creek	Orange
802HYC496	26	1-Jul-08	33.68738	-116.68416	1371	700 +	Herkey Creek	Riverside

Site Code	Adjusted IBI	Collection Date	Latitude	Longitude	Elevation (m)	Elevation Strata (m)	Stream Name	County
802HYC496R2	27	1-Jul-08	33.68738	-116.68416	1371	700 +	Herkey Creek	Riverside
801SDC504	3	8-Jul-08	33.65657	-117.76426	45	0 - 350	San Diego Creek	Orange
801SAR528	19	25-May-08	33.87273	-117.71305	83	0 - 350	Santa Ana River	Orange
802SWC535	13	2-Jul-08	33.73919	-116.72374	1597	700 +	Strawberry Creek	Riverside
SMCR8_026	13	31-May-09	33.57734	-117.83974	11	0 - 350	Los Trancos Canyon	Orange
SMCR8_124	53	24-Jun-09	34.12656	-117.07716	699	350 - 700	Upper Santa Ana River	San Bern
SMCR8_131	41	16-Jun-09	34.18485	-116.97868	1514	700 +	Deer Creek	San Bern
SMCR8_175	13	9-Jun-09	33.85884	-117.87957	57	0 - 350	Carbon Creek	Orange
SMCR8_179	7	1-Jun-09	33.77052	-117.46747	297	0 - 350	Temescal Wash	Riverside
SMCR8_184	49	7-Jul-09	34.16546	-117.01553	1080	700 +	Bear Creek	San Bern
SMCR8_191	20	2-Jun-09	33.96461	-117.47637	201	0 - 350	Middle Santa Ana	Riverside
SMCR8_196	41	24-May-09	33.77593	-116.73138	1897	700 +	Stone Creek	Riverside
SMCR8_197	1	4-Jun-09	33.98315	-117.7007	180	0 - 350	Chino Creek	Riverside
SMCR8_207	21	7-Jun-09	33.97496	-117.09231	593	350 - 700	San Timoteo Creek	Riverside
SMCR8_218	39	23-Jun-09	33.80978	-116.7403	1780	700 +	Fuller Mill Creek	Riverside
SMCR8_219	66	6-Jul-09	34.11105	-116.99195	1265	700 +	Mountain Home Creek	San Bern
SMCR8_229	19	1-Jun-09	33.83826	-117.51148	227	0 - 350	Temescal Wash	Riverside
SMCR8_254	64	16-Jun-09	34.1043	-116.59037	1363	700 +	Deer Creek	San Bern
SMCR8_262	7	7-Jun-09	33.89382	-117.57668	170	0 - 350	Temescal Wash	Riverside
SMCR8_275	16	9-Jun-09	33.85796	-117.8917	52	0 - 350	Carbon Creek	Orange
SMCR8_289	26	3-Jun-09	34.28415	-117.45549	843	700 +	Cajon Creek	San Bern
SMCR8_299	1	9-Jun-09	33.68481	-117.88348	8	0 - 350	Santa Ana Channel	Orange
SMCR8_312	14	14-Jun-09	33.95582	-117.53091	181	0 - 350	Middle Santa Ana	Riverside
SMCR8_317	49	3-Jun-09	34.23158	-117.3728	812	700 +	Cable Canyon	San Bern
SMCR8_327	10	28-Jun-09	34.23294	-117.42894	678	350 - 700	Cajon Creek	San Bern

Site Code	Adjusted IBI	Collection Date	Latitude	Longitude	Elevation (m)	Elevation Strata (m)	Stream Name	County
SMCR8_333	41	17-Jun-09	34.07909	-116.88055	1940	700 +	Mill Creek	San Bern
SMCR8_339	21	8-Jun-09	33.76355	-117.46544	298	0 - 350	Temescal Wash	Riverside
SMCR8_344	50	15-Jun-09	34.16708	-116.81406	1968	700 +	South Fork Santa Ana	San Bern
SMCR8_376	50	17-Jun-09	34.17238	-116.83539	1885	700 +	South Fork Santa Ana	San Bern
SMCR8_415	33	8-Jul-09	34.07681	-117.06621	738	700 +	Mill Creek	San Bern
SMCR8_418	10	8-Jun-09	33.68077	-117.8069	19	0 - 350	San Diego Creek	Orange
SMCR8_474	34	5-Jul-09	34.24826	-117.62775	1631	700 +	Icehouse Canyon	San Bern
SMCR8_513	46	22-Jun-09	33.71777	-116.76274	1034	700 +	Strawberry Creek	Riverside
SMCR8_572	40	30-Jun-09	34.0772	-117.29323	294	0 - 350	Middle Santa Ana	San Bern
SMCR8_600	40	28-Jun-09	34.23092	-117.48291	815	700 +	Lytle Creek	San Bern
SMCR8_601	9	24-Jun-09	34.02789	-117.58527	247	0 - 350	Feeder to Cucamonga Ck	Riverside
SMCR8_605	21	1-Jul-09	33.73776	-116.72825	1586	700 +	Strawberry Creek	Riverside
SMCR8_613	19	29-Jun-09	33.98574	-117.13166	523	350 - 700	San Timoteo Creek	Riverside
SMCR8_688	37	1-Jul-09	33.75289	-116.70609	1700	700 +	Strawberry Creek	Riverside
107	21	24-May-10	33.64736	-116.81468	827	700 +	Bautista Canyon	Riverside
167	40	16-Jun-10	34.16605	-117.18051	641	350 - 700	Tributary of City Creek	San Bern
201	16	20-May-10	34.07375	-117.54105	308	0 - 350	Day Creek	San Bern
236	27	18-May-10	33.7424	-117.42849	352	350 - 700	Temescal Wash	Riverside
240	80	23-Jun-10	34.17036	-117.08748	1217	700 +	Alder Creek	San Bern
274	29	17-Jun-10	34.17237	-117.18072	662	350 - 700	City Creek	San Bern
277	60	27-May-10	34.18826	-117.25566	573	350 - 700	Coldwater Canyon	San Bern
293	29	18-May-10	33.78716	-117.48953	273	0 - 350	Temescal Wash	Riverside
294	26	20-May-10	33.96896	-117.48849	200	0 - 350	Santa Ana River	Riverside
297	56	25-May-10	33.80939	-116.81646	1115	700 +	Mallot Creek	Riverside
304	46	16-Jun-10	34.18234	-117.14996	1043	700 +	Little Mill Creek	San Bern

Site Code	Adjusted IBI	Collection Date	Latitude	Longitude	Elevation (m)	Elevation Strata (m)	Stream Name	County
309	37	14-Jun-10	34.27111	-117.45356	823	700 +	Cajon Canyon	San Bern
322	46	24-May-10	33.70977	-116.78127	764	700 +	Dry Creek	Riverside
356	43	10-Jun-10	33.93057	-117.59215	166	0 - 350	Santa Ana River	Riverside
380	26	21-Jun-10	34.16693	-116.88300	2004	700 +	Frog Creek	San Bern
387	24	19-May-10	34.00549	-117.16881	458	350 - 700	San Timoteo Canyon	San Bern
395	19	10-Jun-10	33.96633	-117.60172	184	0 - 350	Cucamonga Creek	Riverside
395R2	17	10-Jun-10	33.96633	-117.60172	184	0 - 350	Cucamonga Creek	Riverside
396	20	27-May-10	34.23503	-117.43389	686	350 - 700	Cajon Creek	San Bern
400	24	29-Jun-10	33.82915	-117.51021	233	0 - 350	Temescal Wash	Riverside
403	20	15-Jun-10	33.96441	-117.68029	198	0 - 350	Chino Creek	San Bern
405	49	26-May-10	33.77527	-116.74025	1773	700 +	Stone Creek	Riverside
407	26	21-Jun-10	34.16082	-116.79883	2025	700 +	Cienaga Seca Creek	San Bern
436	46	23-Jun-10	34.17451	-117.01276	1142	700 +	Bear Creek	San Bern
441	14	25-May-10	33.85435	-117.90249	49	0 - 350	Carbon Creek	Orange
445	74	24-Jun-10	34.16632	-116.93562	1632	700 +	Forsee Creek	San Bern
448	77	22-Jun-10	34.18071	-116.94460	1555	700 +	Mile Creek	San Bern
450	21	29-Jun-10	33.97123	-117.51147	192	0 - 350	Santa Ana River	Riverside
478	60	22-Jun-10	34.1799	-116.94904	1464	700 +	Forsee Creek	San Bern
478R2	77	22-Jun-10	34.1799	-116.94904	1464	700 +	Forsee Creek	San Bern
559	20	19-May-10	34.03477	-117.21236	386	350 - 700	San Timoteo Wash	San Bern
567	24	15-Jun-10	33.97268	-117.08493	606	350 - 700	San Timoteo Creek	Riverside
598	20	15-Jun-10	34.11909	-117.54105	394	350 - 700	Day Creek	San Bern
802SWC020	74	12-Jul-11	33.76705	-116.69019	1896	700 +	Strawberry Creek	Riverside
801NLC105	36	14-Jul-11	34.25153	-117.49409	982	700 +	Lytle Creek	San Bern
802SJR116	0	25-Jul-11	33.66458	-117.27673	402	350 - 700	Temescal Wash	San Bern

Site Code	Adjusted IBI	Collection Date	Latitude	Longitude	Elevation (m)	Elevation Strata (m)	Stream Name	County
801RB8197	21	11-Jul-11	33.9827	-117.69921	179	0 - 350	Chino Creek	San Bern
801RB8254	70	19-Jul-11	34.17388	-116.98386	1366	700 +	Deer Creek	San Bern
801RB825R2	48	19-Jul-11	34.17388	-116.98386	1366	700 +	Deer Creek	San Bern
801RB8312	46	6-Jul-11	33.95507	-117.5329	183	0 - 350	Santa Ana River	Riverside
801RB8339	27	25-Jul-11	33.76385	-117.46571	304	0 - 350	Temescal Wash	Riverside
801RB8404	10	15-Jun-11	34.05885	-117.54179	298	0 - 350	Day Creek	San Bern
801RB8418	13	13-Jul-11	33.68088	-117.80756	21	0 - 350	San Diego Creek	Orange
801RB8439	27	8-Jun-11	33.86946	-117.53536	193	0 - 350	Temescal Wash	Riverside
802SJC453	34	12-Jul-11	33.73663	-116.8252	620	350 - 700	San Jacinto River	Riverside
801RB8467	19	9-Jul-11	33.78296	-117.47984	278	0 - 350	Temescal Wash	Riverside
801RB8483	33	6-Jun-11	34.25191	-117.45967	745	700 +	Cajon Wash	San Bern
801RB8494	46	20-Jun-11	33.96319	-117.47569	208	0 - 350	Santa Ana River	Riverside
801RB8501	23	14-Jun-11	34.09206	-116.94312	1449	700 +	Mill Creek	San Bern
801RB8511	23	9-Jun-11	33.73577	-117.65975	317	0 - 350	Herkey Creek	Orange
801RB8512	34	19-Jul-11	34.17054	-117.01403	1111	700 +	Bear Creek	San Bern
801RB8512R2	31	19-Jul-11	34.17054	-117.01403	1111	700 +	Bear Creek	San Bern
801RB8521	7	6-Jul-11	33.98065	-117.69542	182	0 - 350	Chino Creek	San Bern
801SAR528	20	11-Jul-11	33.87267	-117.71284	114	0 - 350	Santa Ana River	Orange
801RB8533	27	7-Jul-11	34.08833	-117.04308	858	700 +	Mill Creek	San Bern
801RB8549	3	13-Jun-11	33.66026	-117.88094	7	0 - 350	Delhi Channel	Orange
801RB8558	7	8-Jun-11	33.8715	-117.53907	190	0 - 350	Temescal Wash	Riverside
801RB8566	33	15-Jun-11	33.99743	-117.59924	216	0 - 350	Cucamonga Creek	San Bern
801RB8566R2	21	15-Jun-11	33.99743	-117.59924	216	0 - 350	Cucamonga Creek	San Bern
801RB8575	33	7-Jun-11	34.09854	-116.99293	1146	700 +	Mill Creek	San Bern
801RB8590	37	20-Jul-11	34.17328	-116.83667	1886	700 +	Santa Ana River	San Bern
801RB8593	7	13-Jun-11	33.69763	-117.87672	5	0 - 350	Delhi Channel	Orange
801RB8594	31	20-Jun-11	33.94695	-117.55388	175	0 - 350	Santa Ana River	Riverside
801RB8607	49	19-Jul-11	34.18322	-116.86449	1768	700 +	Santa Ana River	San Bern
801RB8618	50	19-Jul-11	34.16035	-116.80533	2006	700 +	Santa Ana River	San Bern

Site Code	Adjusted IBI	Collection Date	Latitude	Longitude	Elevation (m)	Elevation Strata (m)	Stream Name	County
801RB8622	23	16-Jun-11	33.80933	-117.35716	574	350 - 700	Stream near Hartford Spring	Riverside
801RB8629	20	14-Jul-11	33.95681	-117.0647	650	350 - 700	San Timoteo	Riverside
845RB8633	3	26-Jul-11	33.87168	-118.0235	8	0 - 350	Coyote Creek	Orange