Bioassessment of Perennial Streams in Southern California: A Report on the First Five Years of the Stormwater Monitoring Coalition's Regional Stream Survey

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Southern California Coastal Water Research Project

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STORMWATER MONITORING
Coalition

SWAMP
Surface Water
Ambient Monitoring
Program

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Established 1969

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

Ventura Countywide
Stormwater Quality
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Stormwater Monitoring Coalition Bioassessment Workgroup

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ACRONYMS

Acronym	Definition
AFDM	Ash-free dry mass
CI	Confidence interval
CMAP	California Monitoring and Assessment Program
CRAM	California Rapid Assessment Method
CSCI	California Stream Condition Index
CTR	California Toxics Rule
D18	Diatom Index of Biotic Integrity
EMAP	Environmental Monitoring and Assessment Program
EPA	Environmental Protection Agency
IBI	Southern and Central California Index of Biotic Integrity
NHD	National Hydrography Dataset
NRSA	National Rivers and Streams Assessment
O/E	Ratio of Observed to Expected Taxa
PCT_BIGR	% large substrate (>128 mm)
PCT_CPOM	% cover by coarse particulate organic matter
PCT_FAST	% fast-water habitat
PCT_MAP	% macroalgae cover
PCT_MCP	% macrophyte cover
PCT_MIAT1	% cover by thick (>1 mm) microalgae
PCT_SAFN	% sands and fines (≤2 mm)
pMMI	Predictive Multi-Metric Index
PSA	Perennial Stream Assessment
S2	Soft Algae Index of Biotic Integrity
SD	Standard Deviation
SMC	Stormwater Monitoring Coalition
TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorous
XEMBED	Mean % cobble embeddedness
XFC_NAT_SWAMP	Natural fish cover
XMIATP	Mean microlagae thickness (where present)

EXECUTIVE SUMMARY

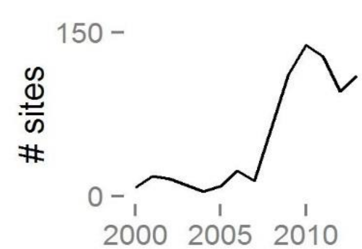
Streams are important natural resources in the South Coast of California, a region that extends from Ventura to San Diego counties. Competing needs for aquatic resources are intense and growing. Assessing the biological condition of these streams has been the focus of considerable monitoring activity. However, until 2009 these efforts were minimally coordinated and provided only limited information about the health of streams in the region, as a result of an emphasis on end-of-watershed monitoring. The Stormwater Monitoring Coalition (SMC) regional perennial stream survey was created in response to the need for a more holistic and coordinated approach. This report provides the results of a five-year probability-based bioassessment of southern California's perennial wadeable streams and represents one of the most comprehensive assessments of stream conditions in the United States.

The five-year survey was designed to answer key questions that are essential to watershed management:

1) What is the biological condition of perennial streams in the region?

2) What stressors are associated with poor condition?

3) Are conditions changing over time?



The Stormwater Monitoring Coalition has greatly increased the number of sites sampled in southern California.

Answering these questions at the regional scale provides resource managers with the ability to contextualize their programs and improve understanding of the effectiveness of management actions, prioritization of streams most in need of protection, and identification of stressors that are likely to pose the greatest risk to stream health.

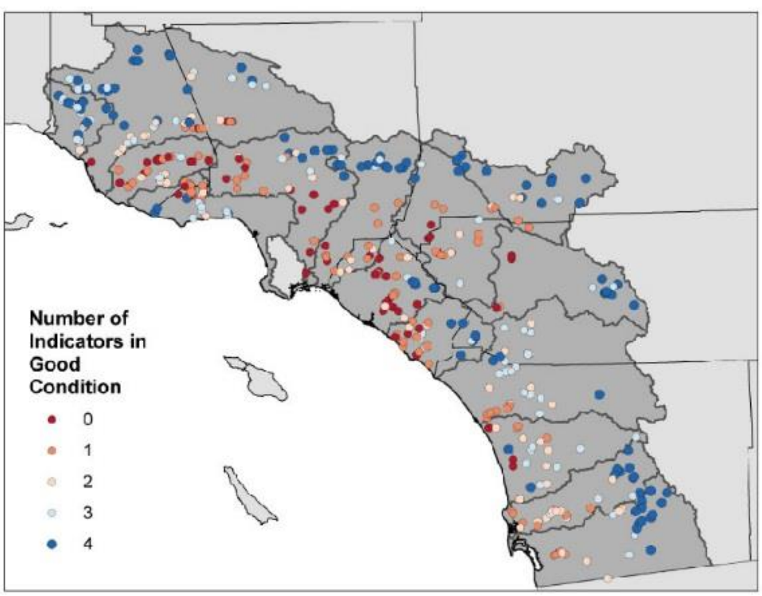
Prior to the initiation of the SMC perennial stream survey, bioassessment efforts in southern California had a limited ability to answer any of these questions. Lead monitoring agencies worked with little coordination, typically addressing site-specific problems with sometimes incomparable methodologies and rarely sharing data. Targeted monitoring mandated by permits did not provide the regional context needed to inform management decisions. Earlier probabilistic sampling efforts in southern California were limited (rarely more than a handful of sites per year), and were conducted as a small part of a statewide or national assessment.

Since the initiation of the SMC perennial stream survey in 2009, stormwater agencies have been able to coordinate their monitoring efforts with regulatory agencies, reallocate resources, and generate the needed data in a cost-neutral way, while simultaneously allowing regulated agencies to fulfill their permit obligations. This survey serves as the regional component of the statewide Perennial Stream Assessment, allowing both the SMC and the State Water Resources Control Board to leverage resources and support each other's surveys.

To answer key management questions, over 500 sites were sampled for four key indicators of biological condition: benthic macroinvertebrates, diatoms, soft algae, and riparian wetlands. These indicators were used to assess the biological health of over 7000 km of streams. In addition, water chemistry, water column toxicity, and physical habitat were examined in order to identify stressors affecting biological conditions in the region. Furthermore, because the survey spanned five years, initial estimates of regional trends are now possible.

Key Findings

Biologically healthy perennial streams are a scarce resource, comprising only 25% of perennial wadeable stream-miles in the region. Based on four biological indicators (i.e., benthic macroinvertebrates, diatoms, soft algae, and riparian wetlands), perennial streams in good biological condition (i.e., scores above the 10th percentile of reference sites) were largely confined to undeveloped portions of watersheds; most indicators identified slightly better conditions at agricultural streams relative to urban streams. Ventura, Santa Clara, Upper Santa Ana, and Southern San Diego watersheds were in better condition than other watersheds for most indicators, whereas perennial streams in poor condition (i.e., scores below the 10th percentile of reference sites) were most extensive in Calleguas, Los Angeles, San Gabriel, and Lower and Middle Santa Ana watersheds.



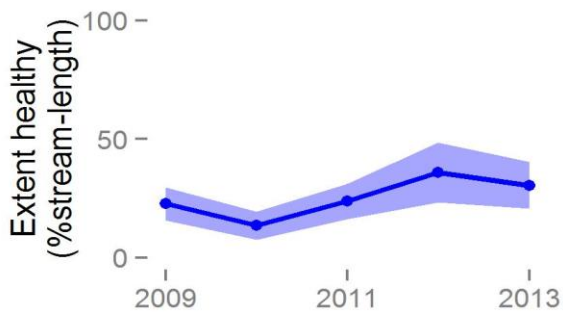
Perennial stream condition was evaluated with four biological indicators: benthic macroinvertebrates, diatoms, soft algae, and riparian condition. In general, these components of the stream community rarely indicated good health in developed portions of watersheds.

Nutrients, sulfates, and habitat degradation were extensive, high-risk stressors associated with poor biological condition. Future investigations should consider these possible candidate stressors as potential causes of poor biological condition. In contrast, metals, pyrethroids, and toxicity were either rarely above threshold or weakly associated with biological condition.

A large extent of the South Coast region was at risk from physical habitat degradation, elevated nutrients, and major ions. Pyrethroids and metals were either weakly or rarely associated with poor health.

Very high priority (Affects more than 25% of region)	High priority (Affects more than 10% of region)	Moderate or low priority (Limited extent or low risk)
Nitrogen Phosphorus Physical habitat Sulfates Dissolved solids	Chloride Suspended solids pH	Pyrethroids Metals Biomass Toxicity

No changes in biological condition were detected. Although mean condition estimates fluctuated from year to year, conditions in 2013 were similar to those observed in 2009; fluctuations were primarily driven by variability in undeveloped streams, as urban streams were consistently in poor condition, varying little from year to year. At no time during the survey were more than 35% or less than 14% of streams estimated to be intact for all indicators. Moving forward, the ability to detect trends could be improved by minor changes to the study design, such as revisiting sites over several years and by extending the survey for additional years.



Extent of perennial streams in good biological condition for all four indicators (benthic macroinvertebrates, diatoms, soft algae, and riparian condition) fluctuated from year to year, but was always limited to less than 35% of perennial stream-miles in the region. The band indicates the 95% confidence interval.

How can this survey support management decisions?

Evaluate steps to protect healthy streams and improve unhealthy streams. Given the small extent of healthy perennial stream-miles in the southern California, protecting such streams may be a priority for resource managers. Additionally, the relatively large extent of stream-miles in poor condition suggests that managers will need to prioritize actions to address stressors affecting unhealthy streams. Prioritization should focus on likelihood of success, achievability of objectives, breadth of impact, and costs associated with management activities, as well as local objectives and needs for each waterbody. Although most of the actions required will be site-specific, a regionally coordinated approach will aid in priority ranking and enable leveraging of efforts across sites or watersheds.

Use regional context in site-specific evaluations. The primary application of survey data is to provide context in evaluating site-specific questions. Comparing the condition of a specific site to conditions at sites with similar land use within the region may provide more useful benchmarks for management objectives than comparison to reference sites, which may not provide an achievable management objective.

Use survey data in causal assessments to identify candidate stressors. Because of the breadth of information collected at each site, the comparability of methods used, and the diversity of sites sampled, data from this survey are well suited to causal assessment applications. With some investment in tool development, regional watershed managers will be able to overcome the data limitations (such as difficulties in identifying comparison sites with information on stressors) that often hinder effective causal assessments.

Recommendations for future monitoring

Although this survey successfully produced preliminary answers to key questions, important knowledge gaps remain. Continuing the survey with modifications will address these gaps.

Include stream types that were previously excluded from the survey. The chief limitation of this survey is that it was restricted to perennial, wadeable streams, 2^{nd} order and higher. The condition of nonperennial and headwater streams represents the largest gap in our regional assessment. Perennial streams account for only 25% of stream-miles in the region as a whole, and as little as 5% in certain watersheds; this variation is caused by both natural factors (such as climate) and land use. Because perennial and higher-order streams are more abundant in developed regions, it is likely that the surveyed portion of the region is in worse condition than the region as a whole. Expanding the survey to include assessment of nonperennial streams (approximately 59% of stream-miles in the region), and exploring ways to map them will help fill these knowledge gaps. Existing assessment tools may be appropriate to assess condition of nonperennial streams, and new tools should be developed as needed.

Improve trend detection through site revisits. Probabilistic sites that are revisited for several years can be used to estimate the extent of improving, degrading, or stable streams in the region. Additionally, management practices associated with changes in conditions can be identified.

Use survey data and special studies to support causal assessments and investigate high-priority stressors. Stressor prioritizations are strictly associative and cannot identify with certainty causal relationships between stressors and biological condition. In some cases, stressors that were identified as high priority (e.g., nutrients) might not directly affect biological condition. Instead, the high risk may reflect a correlation with an unmeasured stressor. The frequent co-occurrence of multiple stressors can make it difficult to disentangle the relationships between individual stressors and biological condition. The SMC can address these limitations in several ways:

- Analyze existing data to explore the diagnostic potential of biological indicators to identify specific stressors.
- Enhance the stream survey with new indicators related to habitat degradation (e.g., hydromodification indicators) or nutrient enrichment (e.g., continuous water quality loggers, algae biomass), or other stressors of emerging concern (e.g., sediment pyrethroids).
- Conduct special studies to distinguish biological constraints imposed by habitat degradation, channel engineering, water chemistry, and natural factors.

SURVEY OVERVIEW

This survey provides the best estimate of the extent of perennial (e.g., Big Tujunga Creek, upper photo) and nonperennial streams (e.g., San Juan Creek, lower photo) in the South Coast region.

Introduction

Southern California's coastal watersheds contain important aquatic resources that support a variety of ecological functions and environmental values. Comprising over 7,000 stream-kilometers, both humans and wildlife depend on these watersheds for habitat, drinking water, agriculture, and industrial uses. In order to assess the health of streams in these watersheds, the Stormwater Monitoring Coalition (SMC), a coalition of multiple state, federal, and local agencies, initiated a regional monitoring program in 2009. Using multiple indicators of ecological health, including benthic macroinvertebrates, benthic algae, riparian wetland condition, water chemistry, water column toxicity, and physical habitat, the SMC has led the first comprehensive assessment of southern California's watersheds based on a probabilistic survey design. Through the re-allocation of permit-required monitoring efforts, the SMC has developed a cooperative sampling program that is efficient and cost-effective for participants. This report represents a summary of data collected in the first five years of the SMC's stream survey. Data from previous surveys, such as the Environmental Protection Agency (EPA) Environmental Monitoring and Assessment Program (EMAP) and California's Perennial Stream Assessment (PSA), are included as well.

The SMC monitoring program was designed to address three main questions:

1) What is the biological condition of perennial streams in the region?
2) What stressors are associated with poor condition?
3) Are conditions changing over time?

The first question is addressed by estimating the extent of biologically intact streams, as determined by key biological indicators. The second question is addressed by estimating the extent of streams with stressors above key thresholds, and by associating stress levels with biological indicators through correlation and relative risk analyses (Van Sickle *et al.* 2006). The third question is addressed by comparing condition across years of the survey.

Regional assessments provide critical information to complement site-specific monitoring at sites of interest. Regional surveys that use a probabilistic design provide statistically valid and unbiased assessments of large geographic areas (Gibson *et al.* 1996). Crucially, regional assessments provide context to site-specific problems and allow sites to be prioritized for protection or restoration (Barbour *et al.* 1996). Furthermore, regional assessments provide a comprehensive perspective on reference conditions (Reynoldson *et al.* 1997). Although regional programs do not replace the need for monitoring at sites of interest (such as below discharges or within sensitive wildlife areas), the context provided by a regional assessment is essential for effective watershed management (Barbour *et al.* 1996, Gibson *et al.* 1996).

Methods

Study Area

Coastal southern California (i.e., the South Coast) is a semi-arid region with a Mediterranean climate, which experiences nearly all of its precipitation as rainfall during winter months. Lower elevations are characterized by chaparral, oak woodlands, grasslands, and coastal sage scrub. The region is bordered by the Transverse Ranges to the North, and the Peninsular Ranges to the East, and continues to the Mexican border to the South. Both Transverse and Peninsular ranges contain peaks that exceed 10,000 feet and regularly experience snow, although contributions to stream flow are limited. Much of the higher elevations are undeveloped and remain protected in a network of national, state, and county parks and forests. The lower elevations have been largely urbanized or converted to agriculture. Wildfires and drought are frequent in the region, with extensive fires occurring in 2007, 2009, and 2013 throughout much of the area. By area, the overall region is 59% undeveloped open space, 28% urban, and 13% agricultural (National Oceanic and Atmospheric Administration (NOAA) 2001).

Survey Design

The target population of the survey was defined as perennial, wadeable second-order and higher streams located in the six southern California counties draining into the Southern California Bight. The study area was divided into fifteen management units (hereafter referred to as watersheds) based on a combination of hydrologic and political boundaries (Table S-1, Figure S-1). The National Hydrography Dataset Plus stream network (NHD Plus; US Geological Survey and US Environmental Protection Agency 2005) was used as the sample frame. Stream segments in the NHD Plus typically represent lengths of streams between two confluences, although particularly long reaches are often split into shorter lengths. In order to assign land-use to each segment of the NHD Plus frame, a 500-m buffer was drawn around each stream segment and overlain in a GIS onto a landcover layer (NOAA 2001). If the buffer was more than 75% natural or open land, the segment was considered open space; if not, it was considered urban or agricultural, depending on which land use was relatively more dominant. Very short segments were occasionally hand corrected if the buffers were too small to adequately capture the adjacent land use; these corrections were most typically used for segments representing individual channels in complex braided systems, such as the mainstem of the Santa Clara River.

The study employed the "master list" approach to integrate sampling efforts by multiple agencies and to facilitate collaboration with other monitoring programs (Larsen *et al.* 2008). A master list was generated, containing over 50,000 sites randomly distributed across the entire stream network using a spatially balanced generalized random-tessellation design (Stevens and Olsen 2004). Sites were then assigned to a watershed using a geographic information system (GIS). Sites were attributed with Strahler stream order from the NHD Plus dataset, and with land use based on the designation of the stream segment, as described above. Sites were then attributed with watershed, stream order, and land-use of the corresponding stream segment of the sample frame. First order streams were excluded from the survey, because these sites typically have a higher rejection rate based on nonperenniality or inaccessibility in mountainous regions. A target sample of 30 sites was selected from each watershed, with heavier representation in relatively uncommon strata (e.g., agricultural streams) to improve balance among the sampled stream types. Large oversamples (ranging from 5x to 20x) were selected as well because of high rejection rates in certain strata. Sites in the sample draw and oversamples were distributed to field crews for evaluation for sampling suitability.

Sites were evaluated for sampling using both desktop and field reconnaissance. Field crews attempted to locate a reach suitable for sampling within 300 m of the target coordinates. Sites with no nearby suitable reaches were rejected for sampling. Reasons for rejection included nonperenniality (see box below), inaccessibility (defined as sites that cannot be safely reached and sampled within one day), refusal or lack of response from landowners, map errors (e.g., no channel near the target coordinates), nonwadeability (i.e., >1 m deep for at least 50% of the reach) and inappropriate waterbody types (e.g., tidally influenced, impounded, etc.). Sites with temporary accessibility or permission issues (e.g., road closures, late responses from landowners) were re-evaluated for sampling in subsequent years.

Defining and Determining Perennial Streams

Perennial streams were defined as those with continuous flow that lasts until the end of the hydrologic year (i.e., September 30) in most years. Determining if a site met these criteria required that field crews find the best available data, including stream gauges, field indicators, historical imagery, consultation with local experts, and best professional judgment. Although all reasonable efforts were made to confirm the perenniality of the sampled sites, it is likely that some of them do not meet the survey's criteria for perennial streams during the years of the study. Therefore, the survey reflects the condition of a mixture in unknown proportions of perennial and long-lasting nonperennial streams. Development of an objective tool to characterize hydrologic regimes remains a priority research area for the SMC.

Sampling Methods

Biological Indicators

Benthic Macroinvertebrates

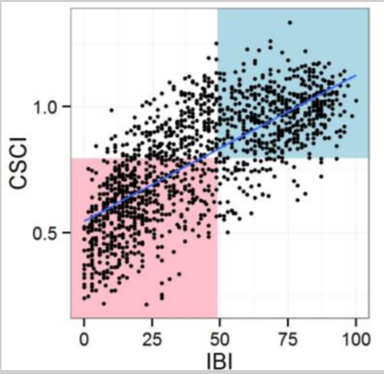
Benthic macroinvertebrates were collected using protocols described by Ode (2007). At each transect established for physical habitat sampling, a sample was collected using a D-frame kicknet at 25, 50, or 75% of the stream width. A total of 11 ft^2 (~1.0 m^2) of streambed was sampled. This method was identical to the Reach-Wide Benthos method used by EMAP (Peck *et al.* 2006). However, in low-gradient streams (i.e., gradient <1%), sampling locations were adjusted to 0, 50, and 100% of the stream width, because traditional sampling methods fail to capture sufficient organisms for bioassessment indices in these types of streams (Mazor *et al.* 2010). Benthic macroinvertebrates were collected and preserved in 95% ethanol (final concentration 70%), and sent to one of five labs for identification. At all labs, a target number of at least 600 organisms were removed from each sample and identified to the highest taxonomic resolution that can be consistently achieved (i.e., SAFIT Level 2 in Richards and Rogers 2011); in general, most taxa were identified to species and Chironomidae (i.e., midges) were identified to genus. Benthic macroinvertebrate data was used to calculate the California Stream Condition Index (CSCI; Mazor et al. In Press). Samples from streams in reference condition are expected to have a mean CSCI score of 1.

CSCI vs. IBI

Like the Southern and Central California Index of Biotic Integrity (IBI), the CSCI was designed to measure the biological condition of streams, as indicated by benthic macroinvertebrate assemblage structure. The CSCI characterizes benthic macroinvertebrate assemblage structure in two ways: 1) As the ratio of observed-to-expected taxa (an O/E index), and 2) as a multi-metric index (MMI), where biological metrics related to important ecological attributes (e.g., number of sensitive taxa) are compared with expected values. Both components are compared to expectations that vary from site to site, and these expectations are derived from reference sites in similar environmental settings.

The CSCI was developed specifically to address some of the shortcomings of traditional indices like the IBI and provides a better measure of stream health than its predecessor because of two key features. First, the CSCI was developed with a much larger, more representative data set. For example, 473 reference sites were used to calibrate the CSCI (including 27 from lower elevation South Coast xeric sites), versus 88 for the IBI (of which only 9 were from South Coast xeric regions). More importantly, the CSCI sets biological benchmarks for a site based on its environmental setting (determined by environmental factors, like climate, geology, watershed area, and elevation) whereas the IBI makes minimal adjustments for natural environmental influences on stream communities.

Overall, the CSCI and IBI have similar performance, and samples that score high for one index usually score high for the other (Pearson's $r^2 = 0.54$). In general, the CSCI is more accurate, and is less likely than the IBI to give false indications of nonreference condition. However, it is also less sensitive, and is less likely to indicate nonreference conditions at severely stressed sites. If a threshold based on the 10th percentile of reference sites is applied to both indices (i.e., 0.79 for the CSCI and 49 for the IBI), approximately one-third of streams below the IBI threshold would be above the CSCI threshold; in contrast, only 2% of streams below the CSCI threshold would be above the IBI threshold.



Correlation between IBI and CSCI scores for sites in southern California. The pink area indicates sites where both indices suggest likely altered biological condition (i.e., Class 3 and 4), and the blue area indicates sites where both indices suggest intact or possibly altered biological condition (i.e., Class 1 and 2). The blue line represents a linear regression between the two indices.

Benthic Algae

Benthic algae samples were collected using the protocols of Fetscher *et al.* (2009), approximately 1 foot upstream of each location where benthic macroinvertebrates were collected. Diatom samples were preserved in formalin, and soft algae samples were preserved in glutaraldehyde. Unpreserved, qualitative soft algae samples were also collected to produce fruiting bodies that facilitate identification of soft algae species. Benthic algae samples were identified to the best taxonomic resolution possible, which was typically species. Benthic algae was assessed using two indices from Fetscher *et al.* (2014): a soft algae index (S2), and a diatom index (D18). Calculations were completed using custom scripts in the statistical software R. Samples from streams in reference condition are expected to have a mean D18 score of 79 and a mean S2 score of 69. Although these indices are not "predictive" like the CSCI score, little bias from natural gradients was evident at reference sites (Fetscher *et al.*2014).

Riparian Wetlands

Riparian wetland condition was assessed using the California Rapid Assessment Method (CRAM; Collins *et al.* 2008). Briefly, the CRAM method assesses four attributes of wetland condition: buffer and landscape, hydrologic connectivity, physical structure, and biotic structure. Each of these attributes is comprised of a number of metrics and submetrics that are evaluated in the field for a prescribed assessment area. Streams in reference condition are expected to have a mean CRAM score of 84.

Water Chemistry

Field crews measured pH, specific conductance, dissolved oxygen, salinity, and alkalinity at each site visit using digital field sensors (or by collecting samples for lab analyses, where appropriate). In addition, samples of stream water were collected for measurements of 36 different analytes, including: total suspended solids, total hardness (as $CaCO_3$), silica, sulfate and other major ions, nutrients, dissolved and total metals, and pyrethroid pesticides. Analytical methods and quality assurance protocols are described in SWAMP QAT (2008).

Toxicity

At each site, ~4 L of water were collected for toxicity assays, primarily using the water flea *Ceriodaphnia dubia*. Six to eight day exposures to undiluted field-collected stream water were conducted, and both survival (acute toxicity as percent mortality) and reproduction (chronic toxicity as young per female) endpoints were recorded. In samples with specific conductivity ≥2500 µS/cm, a 10-day survival assay using the amphipod *Hyalella azteca* was used instead, with no reproductive endpoint (USEPA 2002, SWAMP QAT 2008).

Physical Habitat

At each site, physical habitat was evaluated using a physical habitat assessment as specified in Ode (2007) and Fetscher *et al.* (2009), which were adapted from EMAP (Peck *et al.* 2006). Briefly, a 150-m reach (250-m for streams over 10 m wide) was divided into 11 equidistant transects, with 10 inter-transects located halfway between them. At each transect, the following parameters were measured: bank dimensions, wetted width, water depth in five locations, substrate size, cobble embeddedness, bank stability, microalgae thickness, presence of coarse particulate organic matter, presence of attached or unattached macroalgae, presence of macrophytes, riparian vegetation, instream habitat complexity, canopy cover using a densiometer, human influence, and flow habitats. A subset of these variables were measured at each inter-transect as well. The slope of the water surface was measured across the entire reach at each site. Metrics based on physical habitat data were calculated using custom scripts in R, based on those presented in Kaufmann *et al.* (1999).

Challenges in Assessing Physical Habitat

Although many studies point to a crucial role for physical habitat in supporting healthy streams, assessing the condition of physical habitat remains a challenge for bioassessments. There are four parts to this challenge: 1) measuring the right variables, 2) calculating meaningful metrics from these variables, 3) comparing these metrics to benchmarks that are appropriate for the environmental setting of a site, and 4) ensuring that the metrics are comprehensive enough to characterize important aspects of habitat degradation. To some extent, the first two problems have been addressed. The protocol developed by SWAMP, based on methods developed by the EPA (Peck *et al.* 2006), encompasses over 1000 individual measurements per site, and these measurements are converted into more than 150 metrics that characterize the physical habitat, again based on earlier efforts of the EPA (Kaufmann *et al.* 1999). However, most of these metrics vary widely among reference sites, based on environmental factors like climate and watershed size. Predictive models to set reference-based expectations for physical habitat metrics are in development, but are not yet available. Once such models are developed, a remaining challenge will be to select which metrics (and in which combinations) are most useful in characterizing the overall condition of the physical habitat of a site.

Landscape Variables

Landscape variables were calculated for three purposes: CSCI calculation (see Mazor *et al.* In review), reference site screening (see Ode *et al.* In review), and biological relationships. Using a GIS, watersheds were delineated for each site from 30-m digital elevation models (USGS 1999), and visually corrected to reflect local conditions. For sites draining ambiguous watersheds with minimal topography, delineations were modified using CALWATER boundaries (California Department of Forestry and Fire Protection 2004) or by consulting local experts. Watersheds were clipped at 5 km and 1 km to evaluate local conditions, creating a total of three scales (abbreviated as WS, 5k, and 1k). A fourth scale (i.e., point), based only on the site location, was used to calculate distance-based metrics. These delineations were then used to calculate metrics from source layers relating to landcover (NOAA 2001), transportation (CDFG custom roads layer, P. Ode, unpublished data), geology (J. Olson and C. Hawkins, unpublished data), and hydrology (National Inventory of Dams and NHD Plus). For sites sampled in 2013, only variables related to the CSCI were calculated.

Summary of Data from Other Surveys

Data from other surveys were included in this report, where possible. In order to be included, these surveys had to meet the several criteria: 1) benthic macroinvertebrates were collected using similar protocols (e.g., EMAP), 2) benthic macroinvertebrates were identified to equivalent taxonomic resolution, 3) survey design documentation (including stratifications) and site evaluation data were available, and 4) compatible sample frames were used for survey design (specifically, the NHD Plus or its predecessor RF3). These surveys are summarized in Table S-2. Note that some sites, although selected for sampling for a probabilistic survey, were revisited under other programs (such as reference sampling, fire studies, or other targeted designs), and these data were included in the current assessment as well. With few exceptions, limited data types (generally, benthic macroinvertebrates and physical habitat) were collected for these surveys.

Climate Data

Monthly rainfalls for stations throughout the region were downloaded from The National Oceanic and Atmospheric Administration's California and Nevada River Forecast Center (www.cnrfc.noaa.gov/rainfall_data.php). Annual totals were then calculated and plotted to evaluate the conditions during the study period relative to longer term trends. Three representative stations were selected for plotting (i.e., downtown Los Angeles, Big Bear Lake, and Lindbergh Field).

Data Analysis

Weighted Magnitudes and Extent Estimates

Adjusted sample weights were calculated for each site. Because multiple surveys with different designs were included in analysis, weights needed to be recalculated for each site. Stratification approaches from all surveys were combined to create "cross-strata" in which all evaluated sites have an equal probability of being sampled. Adjusted weights were recalculated as the total stream length within each strata, divided by the number of sites evaluated in that stratum. Strata with no evaluations were excluded from analysis. Because these strata comprised less than 2% of the total stream length, these exclusions are unlikely to affect condition estimates. These weights were used to estimate distribution points for selected variables and extents (e.g., % of stream-length in classes of interest) using the Horvitz-Thompson estimator (Horvitz-Thompson 1952). These estimates were calculated for reporting units of interest, including watersheds, land use classes, and (for trend estimates) years. Confidence intervals (CIs) were based on local neighborhood variance estimators (Stevens and Olsen 2004). All calculations were conducted using the spsurvey package (Kincaid and Olsen 2013) in R version 3.0.3 (R Core Team 2012).

Extent Estimates

When surveys use a probabilistic design, the data they produce can be used to make inferences about the region as a whole, and not just about sampled sites. Therefore, statements about the extent of perennial wadeable streams, or about the average CSCI score in a watershed can be made. Probabilistic surveys provide context about ambient condition, which can be used to compare against sites of interest.

The key benefit of a probabilistic survey is its ability to estimate the true extent of a resource of interest, such as perennial, wadeable streams. Sites sampled under a targeted design provide valuable information about local conditions, but cannot be used to estimate the condition of the region as a whole. Because targeted studies are typically designed to assess known impacts (e.g., downstream of discharges), the sites may be in worse condition than the average site in the region; therefore, estimates of regional condition from targeted sites may be biased.

When sites are sampled according to a probabilistic design, measurements represent not just local conditions, but also reflect conditions of a much larger population. The condition of each probabilistic site therefore contributes to condition estimates of the region as a whole. The weight (i.e., the contribution to regional estimates) of each site varies; sites in large, sparsely sampled regions (e.g., open streams) make a larger contribution to regional estimates than sites in small or densely sampled regions (e.g., agricultural streams).

Results

A total of 760 probabilistic sites were sampled in the South Coast region, of which 515 were sampled by the SMC or affiliated programs (Table S-2). To attain this sample size, 4330 unique sites were evaluated, yielding a rejection rate of 82%. The most common cause for rejecting a site was nonperenniality (75% of rejected sites), followed by physical barriers (9% of rejected sites). Determinations of nonperenniality were made during both office and field reconnaissance. Other causes for rejection (e.g., map errors, inappropriate waterbody types, nonwadeability) were infrequently encountered (≤5% of rejected sites; Table S-3; Figure S-2).

Analysis of rejected sites indicated large differences in the extent of perennial streams by watershed and land use. For example, perennial streams made up 53% of stream-miles in the Los Angeles watershed, but only 6% of the San Jacinto watershed (median watershed extent: 26%). Land-use was strongly associated with perenniality, as 35% of urban stream-length, but 12% of agricultural stream-length and 16% of open stream-length were perennial (Figures S-2, S-3, S-4).

Overall, the survey occurred in a drier than normal period. Rainfall during 2011 was slightly above average, although most other years were well below normal. Notably, the survey occurred shortly after one of the driest years on record (i.e., 2007), when even the rainier weather stations (e.g., Big Bear Lake) reported extremely low precipitation (Figure S-5).

Discussion

Perennial wadeable streams are a small component of the region, and protecting this limited resource may be a high priority for watershed managers, particularly because of their importance to a variety of beneficial uses (such as fisheries, wildlife, and swimming). At the same time, the need to expand attention to nonperennial streams is apparent: A comprehensive assessment of the coastal watersheds of southern California should not exclude the large extent of nonperennial streams. Ongoing research in the region addresses the question of whether the condition indices used in this survey are valid in nonperennial streams. However, it is likely that assessment tools currently available to watershed managers are adequate to include at least some portion of nonperennial streams in future surveys.

The observed extents of perennial streams in urban and agricultural areas are probably elevated by imported water sources (either as wastewater effluent or as runoff). Because nonperennial streams are so extensive in undeveloped areas, it is likely that this survey excludes many of the healthiest, least disturbed streams in the region. Therefore, although this survey provides an unbiased assessment of the perennial portion of southern California streams, extrapolation to the nonperennial portion may lead to incorrect conclusions about the health of the region as a whole.

Climatic trends may have also influenced the extent and location of perennial streams. Frequently, field crews were unable to sample reaches that were historically perennial, suggesting that long-term drought or changes in water management may have converted some perennial streams to nonperennial. The variability of flow regimes in southern California streams has been documented in special studies commissioned by the SMC (e.g., Mazor *et al.* 2014), and this variability underscores the need for a flexible approach towards characterizing stream hydrology.

The widespread conversion of streams from nonperennial to perennial (and vice versa) presents a question about setting appropriate ecological objectives. Should a converted stream be compared to perennial reference streams? Or is it more appropriate to compare them to their historical conditions? This survey used the former approach, although in certain applications, such as setting restoration objectives, different goals may be appropriate.

However objectives are set for streams with altered hydrology, managing flows may be an important tool in supporting their ecological health. The causes of elevated water flows were not investigated in this survey. In major tributaries and mainstems of large rivers, elevated flows may be driven by effluent from treatment plants managed by sanitation districts. In smaller streams, runoff may be an important driver, where flood control agencies manage stream flows. Diversions and groundwater extraction are particularly important in streams in agricultural areas. Therefore, if flow regime management needs to change to support ecological health, coordination among several agencies working under different permits may be required.

Table S-1. Characteristics of each watershed.

Watersheds	Stream Order	Area (km^2)	Total Stream Length (km)	Land Use (%)		
				Open	Agricultural	Urban
Ventura	6	642	236	68	15	17
Santa Clara	7	4327	1429	81	14	6
Calleguas	5	891	315	28	35	36
Santa Monica Bay	4	1171	200	73	2	25
Los Angeles	5	2160	519	41	1	59
San Gabriel	5	1758	487	50	0	50
Santa Ana River	6	7092	1708	49	15	36
–Lower Santa Ana	6	1253	298	36	10	53
–Middle Santa Ana	6	2135	519	38	14	48
–Upper Santa Ana	5	1721	523	64	12	24
–San Jacinto	4	1984	367	55	24	21
San Juan	4	1019	337	66	5	29
Northern San Diego	6	3640	1055	58	28	14
Central San Diego	5	1725	430	38	12	51
Mission Bay/San Diego River	5	1270	322	64	4	32
Southern San Diego	5	2355	535	80	6	14
Entire Region	7	28051	7574	59	13	28

Table S-2. Probabilistic surveys included in the study. Note that the SMC program includes sites sampled under nested programs that used the same master sample draw, such as the San Gabriel River Regional Monitoring Program, the Los Angeles Watershed Monitoring Program, and Region 4 Probabilistic Sampling; sites from these surveys were included only if they were part of the SMC's target population of second-order or higher perennial, wadeable streams.

Survey	Years	Sites
Environmental Monitoring and Assessment Program (EMAP)	2000 to 2003	42
California Monitoring and Assessment Program (CMAP)	2004 to 2007	12
National Rivers and Streams Assessment (NRSA)	2009 and 2013	1
Perennial Streams Assessment (PSA)	2008	11
Stormwater Monitoring Coalition (SMC)	2008 through 2013	515
Region 8 Trend Monitoring (R8T)	2006 through 2013	102

Table S-3. Extent (in percent stream-miles) of perennial and non-perennial streams by subpopulation.

Subpopulation	Perennial, sampled (n sampled)	Perennial, not sampled	Rejected		
			Nonperennial	Physical Barrier	Other
South Coast	20.7 (682)	2.3	58.5	10.0	8.4
Land Use					
Agricultural	11.9 (92)	4.0	70.7	1.2	12.3
Open	15.9 (306)	1.4	61.1	16.3	5.3
Urban	35.3 (284)	3.4	47.2	0.8	13.4
Watershed					
Region 4					
Ventura	25.3 (37)	0.8	62.6	7.1	4.3
Santa Clara	16.2 (94)	2.1	55.2	24.0	2.6
Calleguas	30.2 (38)	6.0	48.2	3.0	12.6
Santa Monica Bay	23.6 (72)	2.1	52.7	9.6	11.9
Los Angeles	47.1 (44)	5.6	25.3	13.2	8.8
San Gabriel	43.7 (39)	1.1	23.0	16.6	15.5
Region 8					
Lower Santa Ana	16.3 (45)	3.1	46.6	8.2	25.8
Middle Santa Ana	13.1 (57)	4.0	61.3	4.7	16.9
Upper Santa Ana	25.1 (67)	2.8	44.6	22.2	5.3
San Jacinto	5.3 (28)	0.7	77.5	8.6	7.9
Region 9					
San Juan	27.5 (30)	1.0	68.0	1.1	2.5
Northern San Diego	7.1 (36)	0.7	81.0	1.5	9.6
Central San Diego	37.1 (35)	3.1	54.3	0.5	5.2
Mission Bay and San Diego River	14.5 (29)	2.8	74.6	1.3	6.8
Southern San Diego	8.3 (31)	0.8	83.7	0.8	6.3

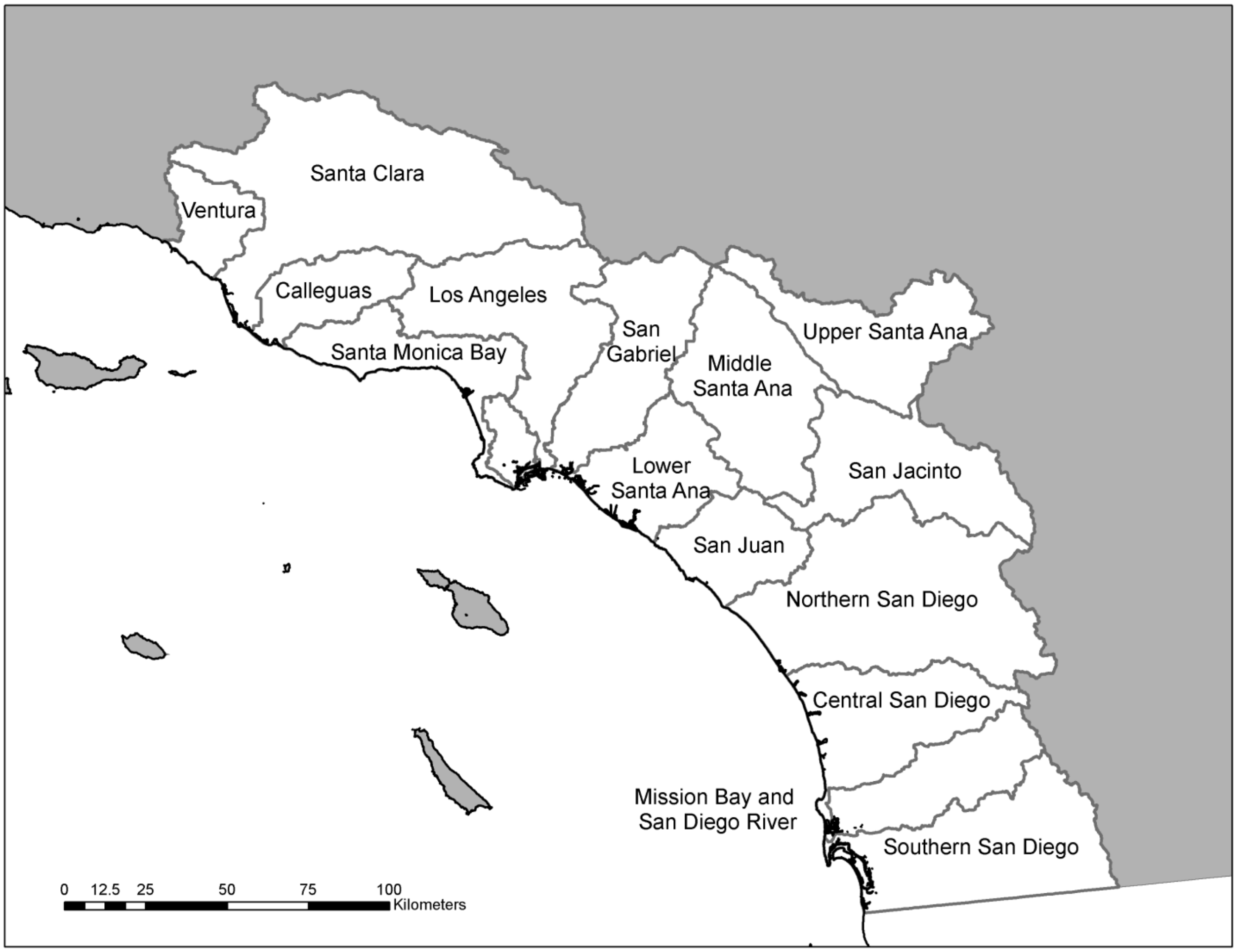


Figure S-1. Major watersheds in the South Coast survey area.

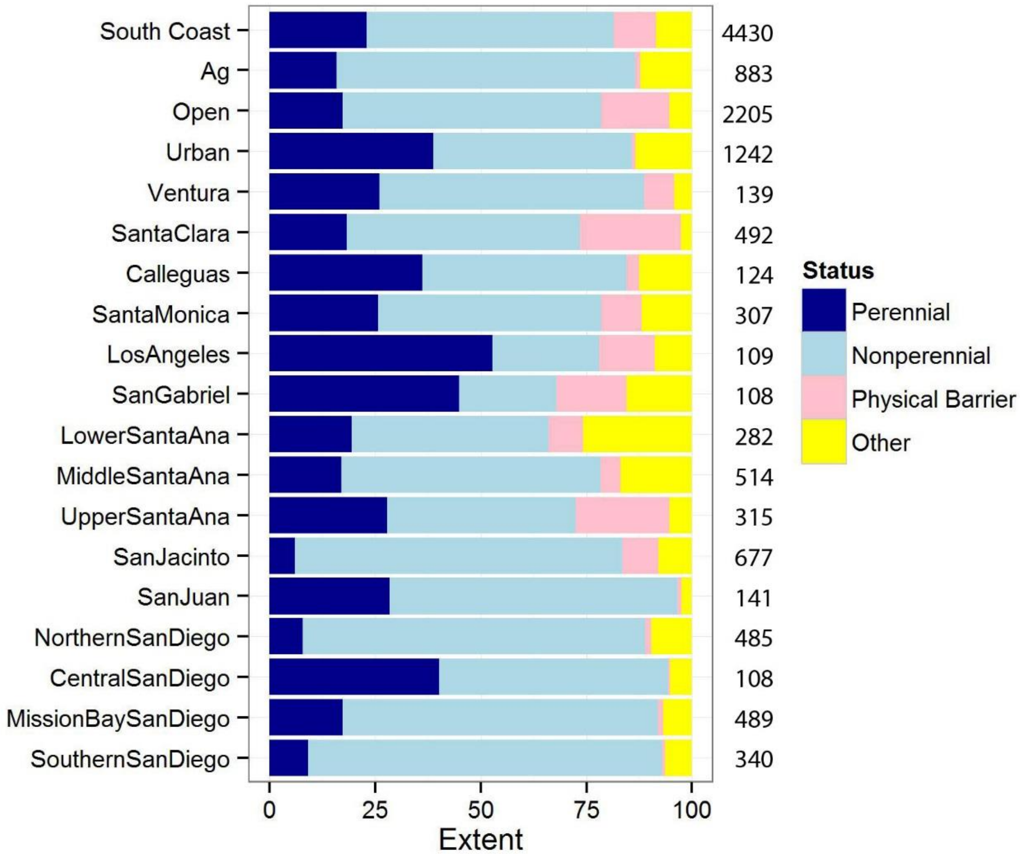


Figure S-2. Site evaluation results by watershed or land use. Numbers to the right of each bar represent the total number of sites evaluated for inclusion in the SMC and other survey.

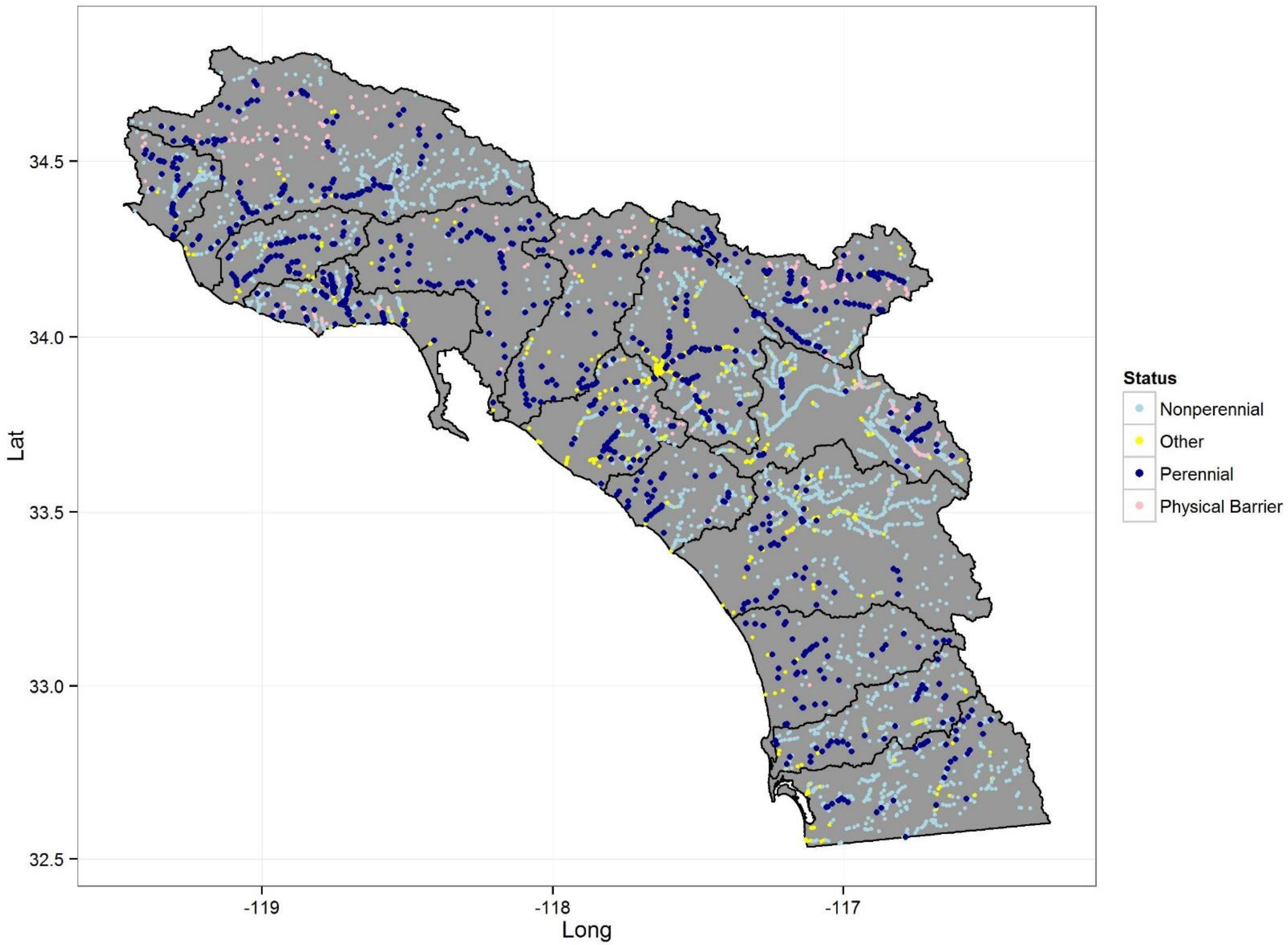


Figure S-3. Map of site evaluation results.

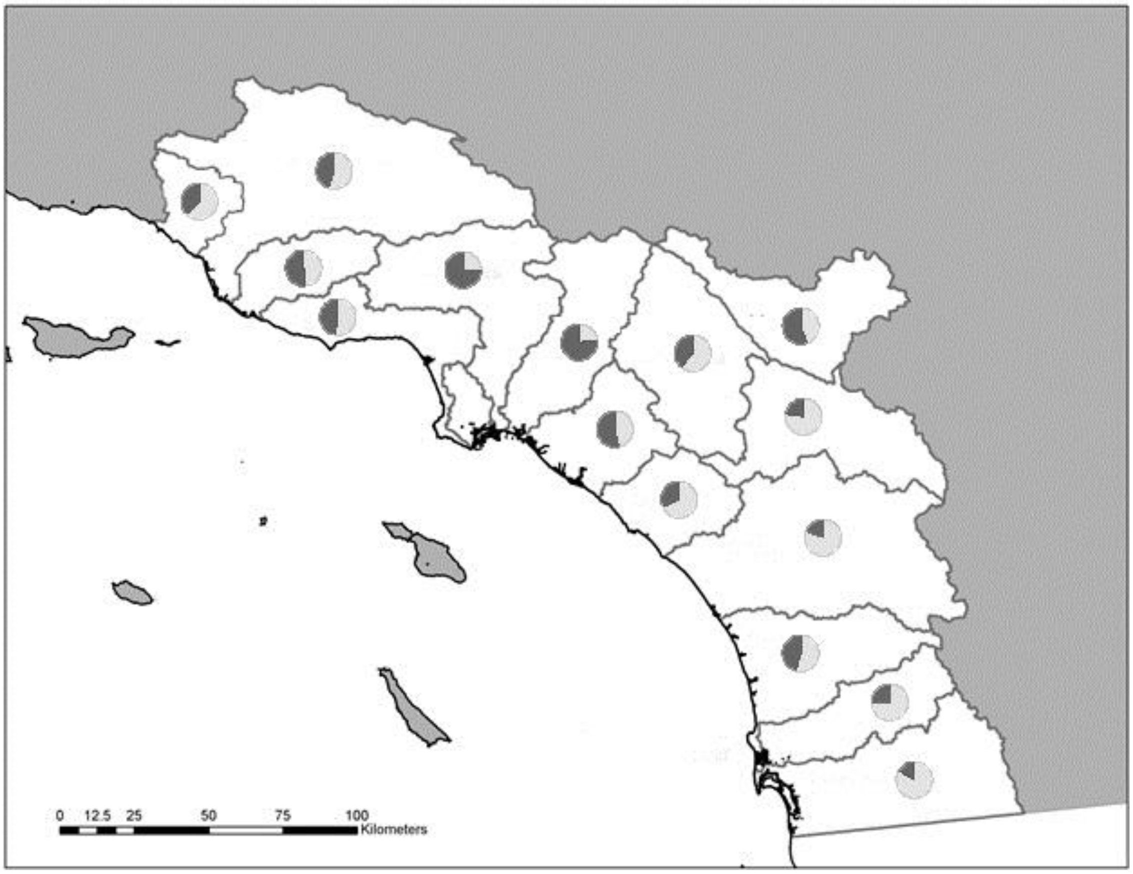


Figure S-4. Percent of nonperennial stream-miles (shown in light gray) for each watershed.

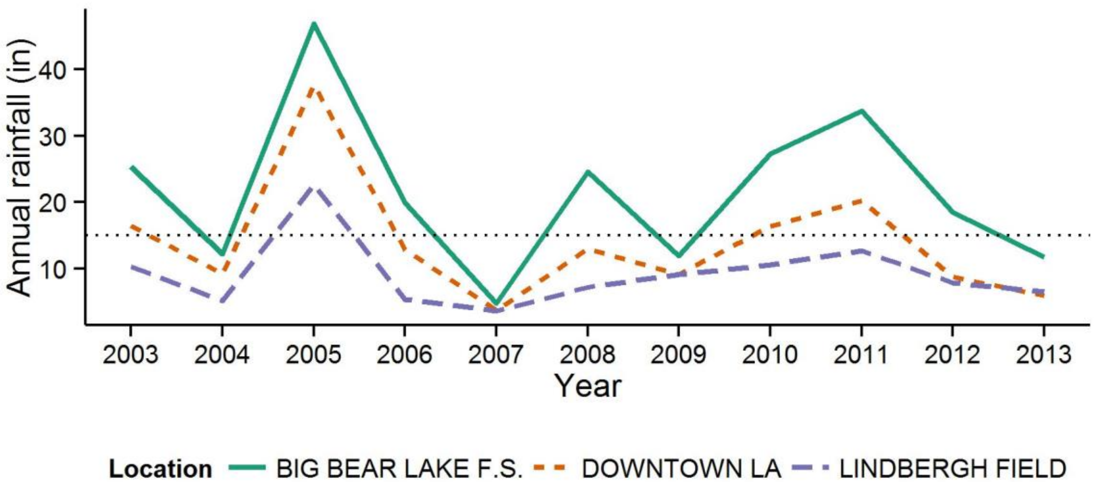
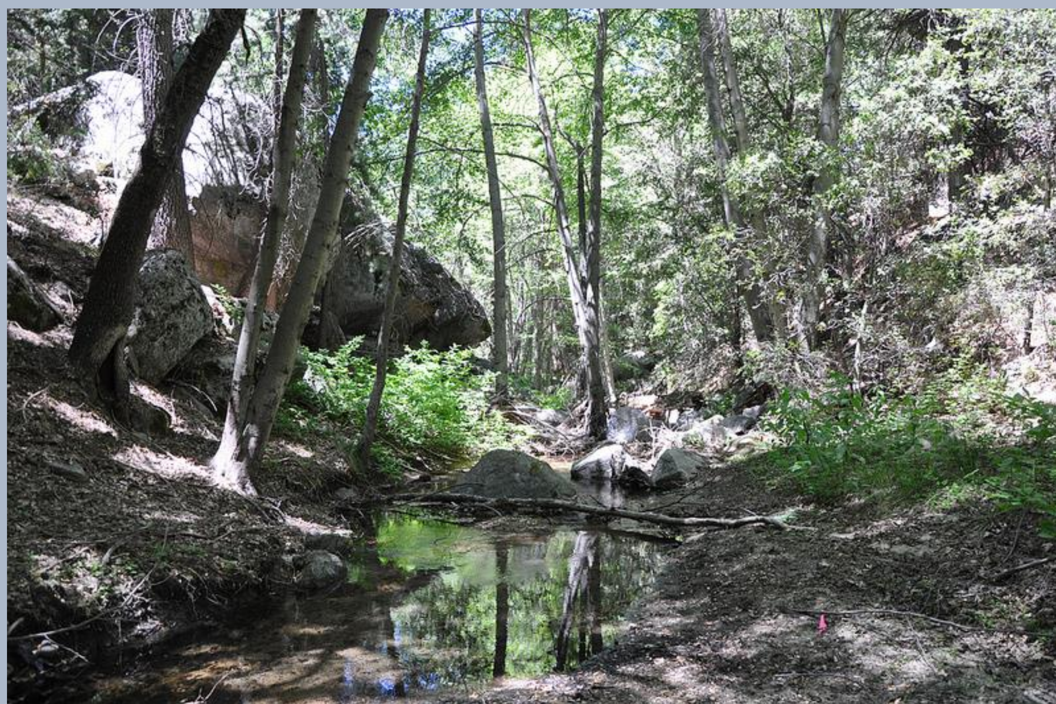


Figure S-5. Annual precipitation at three weather stations in the South Coast. The horizontal line reflects the average for downtown Los Angeles between 1877 and 2012.

QUESTION 1: WHAT IS THE BIOLOGICAL CONDITION OF PERENNIAL STREAMS IN THE SOUTH COAST REGION?



Healthy perennial streams, like this site on the North Fork of the San Jacinto River, are a scarce resource in the South Coast region.

Introduction

Surveys of ambient biological condition provide essential context for watershed management. At larger geographic scales, ambient surveys allow watershed managers to identify regional priorities. At local scales, ambient surveys allow managers to compare sites of interest to typical ranges in the region. This context informs decisions about which sites need protection or rehabilitation.

The biological condition of perennial streams was assessed by sampling four key biological indicators (i.e., benthic macroinvertebrates, diatoms, soft algae, and CRAM) at sites throughout the region, and comparing them to thresholds benchmarked to the distribution of scores at reference sites. These biological indicators provide a direct measurement of ecological health, and are an effective tool to determine if streams are supporting aquatic life or other beneficial uses. Additionally, their ability to integrate multiple stressors across both time and space make them a superior measure of biological condition to direct measures of stressors.

Methods

Data Collection

Data were collected as described in the Survey Overview.

Data Aggregation

Where multiple biological samples were collected at a single site within a year, data were aggregated as the maximum value within a site (with the assumption that index scores may be spuriously low, but not spuriously high). Multi-year mean values for each site were then calculated from these aggregated values if sites were revisited in multiple years. Missing values were ignored for all relevant analyses, where appropriate.

Thresholds

Biological indicators were compared to the 30th, 10th, and 1st percentile of reference sites (Table 1-1); these percentiles correspond to different probabilities that a score is from a site in reference condition. This approach creates four biological condition-classes that may be interpreted as indicating a stream's biology is likely intact (Class 1), possibly altered (Class 2), likely altered (Class 3), and very likely altered (Class 4). These percentiles were selected to reflect a range of conditions. Because this approach is consistent across indicators, it is possible to compare results from one index to another. Means and standard deviations were from published sources (CSCI: Mazor et al. In review; algae IBIs: Fetscher *et al.* 2014) or unpublished data (CRAM). Each threshold has an associated error rate; for example, 10% of reference sites are in Class 3 or 4, despite the fact that they are, by definition, intact.

Integrating Multiple Indicators

In order to determine a stream's overall condition, the four biological indicators were evaluated together to provide a comprehensive assessment of ecological health. To be considered intact for multiple indicators, all four indicators need to suggest that a stream is in reference condition. A single indicator below this threshold suggests that a stream is not in reference condition. To maintain an overall error rate of 10%, a site had to have scores above the 2.5^{th} percentile of reference sites for each indicator (Table 1-1).

Weighted Magnitudes and Extent Estimates

Adjusted sample weights were calculated for each site. Because multiple surveys with different designs were included in analysis, weights needed to be recalculated for each site. Stratification approaches from all surveys were combined to create "cross-strata" in which all evaluated sites have an equal probability of being sampled. Adjusted weights were recalculated as the total stream length within each strata, divided by the number of sites evaluated in that stratum. Strata with no evaluations were excluded from analysis. Because these strata comprised less than 2% of the total stream length, these exclusions are unlikely to affect condition estimates. These weights were used to estimate distribution points for selected variables and extents for selected categories using the Horvitz-Thompson estimator (Horvitz-Thompson 1952). These estimates were calculated for reporting units of interest, including watersheds, land use classes, and (for trend estimates) years. Confidence intervals (CIs) were based on local neighborhood variance estimators (Stevens and Olsen 2004). All calculations were conducted using the spsurvey package (Kincaid and Olsen 2013) in R version 3.0.3 (R Core Team 2012).

Results

All data used in this report can be downloaded from ftp.sccwrp.org/pub/download/SMCReport/SMCDataFor5yearReport.zip.

Benthic Macroinvertebrates

Biological indicators suggested that most stream-kilometers in the survey's target population (i.e., perennial wadeable streams in southern coastal California) do not support healthy biology (Table 1-2a to c; Figures 1-1 and 1-2). For example, the mean CSCI score for the region was 0.77 and only 29% of stream-miles were in the top biological condition class for this indicator. Of the two components of the CSCI, the pMMI (which measures ecological structure) was more sensitive; the pMMI indicated that only 22% of South Coast stream-miles were in Class 1, whereas the O/E (which measures taxonomic completeness) indicated 46% were in Class 1.

The CSCI indicated that open streams were in better condition than agricultural streams, which were in turn better than urban streams. In fact, at open sites, mean CSCI scores were close to reference (i.e., 0.93), and only 5% of open stream-miles was in Class 4 (i.e., the worst condition class). In contrast, 31% of agricultural streams and 58% of urban streams were in Class 4.

Although this ranking of land use classes was evident with both components of the CSCI, the O/E generally categorized agricultural streams as intermediate between open and urban classes, whereas the difference was small when examined with the pMMI.

The watersheds with the greatest proportion of streams in Class 1 were located, roughly, in the northern and southern ends of the region, while the middle portions of the region had streams in poorer health. For example, the greatest extent of Class 1 stream-miles was located in the Ventura watershed (68%), followed by Southern San Diego (65%). These watersheds, along with the Santa Clara, all had mean CSCI scores greater than 0.9. The smallest extents of Class 1 stream-miles were observed in the Calleguas (9%), Central San Diego (10%), Lower Santa Ana (11%) and Middle Santa Ana (11%) watersheds.

Benthic Algae

In general, the algae indices showed similar patterns of regional stream condition as the CSCI (Table 1-2d and e; Figures 1-1 and 1-2). For example, the diatom index (D18) showed that 27% of stream-miles were in Class 1, while the soft algae index (S2) showed that 25% were in this class; these numbers are only slightly less than the estimate for the CSCI (i.e., 29%).

In contrast with the CSCI, algae-based indices only weakly differentiated between urban and agricultural streams, and estimated both to be in far worse condition than open streams. For example, D18 rarely identified developed streams as Class 1 (Agricultural: 11%; Urban: 2%). Uniquely, S2 scores were generally lower at agricultural streams (mean: 26) than urban streams (mean: 32). In contrast, mean D18 scores were similar in both urban (43) and agricultural (45) streams.

Although there were some differences among the two algae indices, they both showed that the watersheds in the northern portions of the region had the greatest extent of streams in Class 1. For example, D18 indicated the greatest extent of streams in Class 1 in the Ventura (84%) and Upper Santa Ana (63%,) watersheds, whereas S2 indicated the greatest extent of stream-miles in Class 1 in the Upper Santa Ana (47%) and Santa Clara (46%) watersheds. Depending on the index used, Class 1 streams were rarely or never observed in the Calleguas, Santa Monica Bay, Lower Santa Ana, San Juan, and Central San Diego watersheds.

Riparian Condition

Most streams in southern California did not support healthy riparian communities, as only 30% of stream-miles in the region had CRAM scores in the top condition class (i.e., a CRAM score ≥ 79), and the mean CRAM score (64) was much lower than the reference mean (i.e., 84). However, the extent of stream-miles in Class 1 was greater for individual attributes (e.g., 40% for the landscape and buffer attribute), indicating that different attributes limit overall riparian condition at different sites (Table 1-2f; Figures 1-1 and 1-2).

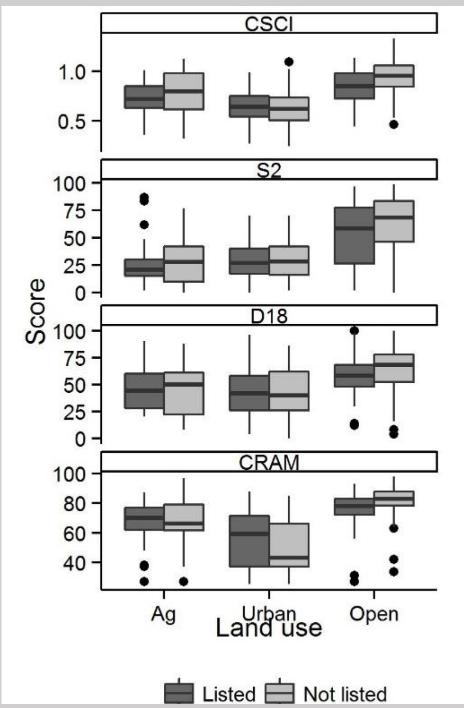
Land use was strongly associated with CRAM scores, even more so than with other indicators. For example, Class 1 CRAM scores were observed at 65% of open stream-miles (mean: 81), but only 20% of agricultural streams (mean: 68) and 7% of urban stream-miles (mean: 51). This contrast was particularly strong at the attribute level (especially the buffer and landscape attribute). For example, hydrologic conditions were in the top class at 57% of open stream-miles, but only 17% of agricultural stream-miles and 17% of urban stream-miles.

Class 1 riparian conditions were observed at the majority of stream-miles within five watersheds that were geographically dispersed across the region, with the greatest extents in the San Jacinto (63%) and Northern San Diego (57%) watersheds, followed by Ventura (54%) and Southern San Diego (52%). Streams with Class 1 riparian condition were scarce in the Calleguas (3%) and Los Angeles (14%) watersheds. Across the four attributes, four watersheds ranked among the worst in terms of the extent of streams in Class 4: Los Angeles, San Gabriel, Lower Santa Ana and Middle Santa Ana. All attributes were in the worst condition class for at least 50% of these watersheds (Table 1-2g to j) with the exception of the biotic structure attribute in the Lower Santa Ana (36% in Class 4).

303(d)-Listed Streams

The State Water Resources Control Board has designated approximately 2000 stream-kilometers in southern California as impaired for water quality pursuant to Section 303(d) of the Clean Water Act. Streams are usually listed as "impaired" due to exceedances of a chemical water quality standard. The potential relationship between designated impairments and instream biological condition was evaluated by comparing biological index scores from streams listed as impaired to streams from comparable land use categories that are not listed. Listed streams were obtained from the State Water Board 303(d) list; in Ventura and Riverside counties, agency staff modified this list by reclassifying listings believed to be unrelated to aquatic life uses (e.g., bacteria) as "not listed" for this analysis.

Land use was more strongly associated with scores than with status on the 303(d) list. For example, scores at urban and agricultural sites were lower than scores at open sites, whether or not the sites were included on the 303(d) list. There was no significant difference in scores between listed and unlisted streams at urban or agricultural sites. Scores at open listed sites were slightly lower than at open unlisted sites; however, this difference was small, and the proportion of Class 3 or 4 sites was no greater at open listed sites than open unlisted sites.



Index scores based on benthic macroinvertebrates (CSCI), soft algae (S2), diatoms (D18) and riparian condition (CRAM) for 303(d)-listed and unlisted streams, by land use.

Condition of Engineered Channels: Exploring options for alternative thresholds

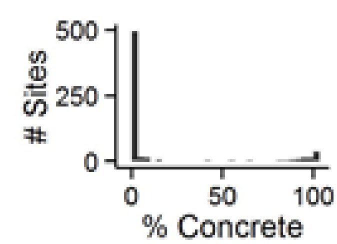
Many of the streams in this survey have been engineered to some degree for flood management purposes, and these engineered features may constrain biological condition. Therefore, we estimated the biological condition of streams with engineered channels relative to those with natural channels. The best condition observed in engineered channels may be a more realistic threshold than a reference-based threshold, assuming that the effects of channel engineering cannot be mitigated. If the best observed condition in engineered channels is substantially below a reference-based threshold, an alternative threshold may be appropriate.

Because consistently derived region-wide maps identifying the location of engineered channels are not available, habitat data was used to classify streams as likely concrete-lined (i.e., at least 5% concrete in the streambed), or likely non-concrete lined (i.e., less than 5% concrete in the streambed). This approach overlooks forms of engineered channels that do not use concrete, such as ungrouted rock, while also misclassifying streams affected by other types of concrete structures, such as road crossings. It also ignores the substantial variation of channel forms in engineered systems, which may affect biological condition. But despite these shortcomings, this approach represents a useful starting point until better data are available about engineered channels.

Overall, approximately 26% of perennial stream-miles were estimated to be concrete-lined. About half of urban streams were concrete lined and 13% of agricultural streams, but only 2% of open streams. Concrete-lined streams comprised a majority of stream-miles in the Los Angeles and San Gabriel watersheds, but none were sampled in the Northern and Southern San Diego watersheds.

Extent of concrete channels in southern California

Subpopulation	Concrete-Lined Channels	
	# sites	% stream-miles
South Coast	130	26
Land use		
Urban	107	53
Open	10	2
Agricultural	13	13
Watershed		
Los Angeles Region		
Ventura	2	4
Santa Clara	3	3
Calleguas	12	29
Santa Monica Bay	13	19
Los Angeles	22	51
San Gabriel	23	69
Santa Ana Region		
Lower Santa Ana	11	26
Middle Santa Ana	22	41
Upper Santa Ana	1	2
San Jacinto	5	19
Northern San Diego		
San Juan	6	24
Northern San Diego	0	0
Mission Bay and San Diego River	6	24
Central San Diego	4	14
Southern San Diego	0	0



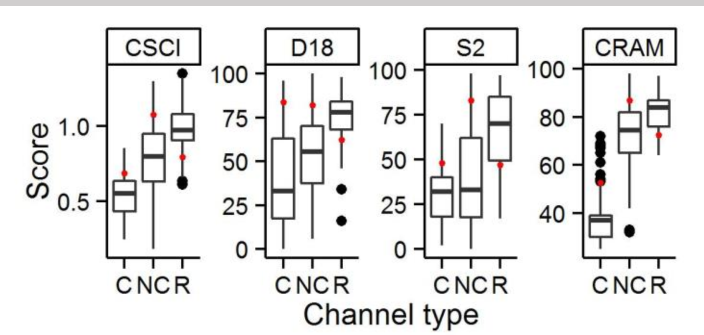
% concrete substrate at each sampled site. Concrete was absent from most sites, but comprised nearly 100% for a small handful of sites. Intermediate values were rarely observed.

Condition of Engineered Channels (Continued)

To investigate the constraints concrete lining imposes on biological condition, sites were divided into three classes: concrete-lined, no concrete, and reference. The range of index scores within each class was examined by creating boxplots. For indices where the 90th percentile of concrete-lined channels is less than the 10th percentile of reference streams, lower thresholds may be appropriate.

In general, scores of all indices were lower in concrete-lined channels than in reference streams, suggesting that these streams were typically in poor condition. For most indices the highest scores in concrete-lined channels were lower than lowest scores observed at reference sites (estimated at the 90th and 10th percentiles, respectively). For example, the 90th percentile of CSCI scores was 0.69 (i.e., "Class 3"), suggesting that an alternative threshold may reflect a more attainable management objective than the 10th percentile of reference sites. Additional data and analyses (particularly on channel type) are needed if alternative thresholds for concrete-lined channels are used for regulatory purposes.

In contrast, this analysis did not support alternative thresholds for algae indices. High scores were frequently observed in concrete-lined channels. In fact, the 90th percentile of D18 scores in concrete-lined channels was 84, which is substantially higher than the threshold based on the 10th percentile of reference sites (i.e., 62). Therefore, it is probable that low D18 and S2 scores in concrete-lined channels are attributable to impacts not directly related to channelization, and may instead be related to water quality impacts.



Distribution of scores at concrete-lined channels (C), nonconcrete-lined channels (NC), and reference streams (R). The red dot represents the 90th percentile of scores of concrete- and nonconcrete-lined channels and the 10th percentile of reference streams.

Options for setting thresholds in concrete-lined channels. A traditional approach is based on the distribution of scores at reference sites, whereas an alternative approach is based on the distribution of scores at concrete-lined channels. These numbers reflect preliminary analyses.

Index	Option 1: Threshold based on reference	Option 2: Threshold based on concrete-lined channels
CSCI	0.79	0.68
D18	62	84
S2	47	48
CRAM	72	53

Multiple indicators

Only 25% of streams-miles in the region were intact for all four indices, and these conditions were almost exclusively observed at streams with undeveloped watersheds (Table 1-3, Figures 1-3 and 1-4). Overall, 60% of open stream-miles were in this category. Streams with index scores above the multi thresholds were absent from the Calleguas watershed and scarce in Santa Monica Bay, Los Angeles, Middle Santa Ana, and Central San Diego watersheds. In contrast, a majority of stream-miles were intact for multiple indicators in the Upper Santa Ana (62%), Southern San Diego (61%), San Jacinto (53%) and Ventura (50%) watersheds.

Most commonly, streams were limited (i.e., below the "multi" threshold) for multiple indicators, and all four indicators were identified as limiting for 15% of stream-miles region-wide (Table 1-3; Figures 1-3 and 1-4). More than a quarter of stream-miles were limited for all indicators in certain watersheds (specifically, Calleguas, Los Angeles, Lower Santa Ana, and San Jacinto watersheds) and in urban streams, but this situation was rare in other watersheds (specifically, Ventura, Upper Santa Ana, Northern San Diego, and Mission Bay and San Diego watersheds), and in open streams. Streams limited for single indicators were more extensive in these open streams, and algae indices (D18, S2, or both) were most commonly the only limiting indicator. For example, 41% of stream-miles in the Northern San Diego and 37% in the Ventura watersheds were limited for D18 or S2, but not CRAM or CSCI.

Discussion

The scarcity of streams with intact biology may prompt managers to evaluate ways to protect these streams, or improve the condition of streams where indicators suggest altered biological condition. The emphasis may vary from protection in one part of the region to rehabilitation in another, depending on local needs and interests. However, many watershed managers in southern California would benefit from a coordinated approach towards prioritizing local objectives, given the extent of streams with altered biology. Uncoordinated efforts to address pervasive challenges have historically met with little success (Bernstein and Schiff 2002).

Multiple indicators proved valuable for several reasons. 1) Redundancy improves precision and guards against incorrect conclusions from sampling error or natural variability. 2) The different life histories of each indicator provided a broader assessment of ecosystem function. 3) The unique properties of the indices increase overall sensitivity to different stressors. 4) The different responsiveness of the indices allows better discrimination among condition-classes along the biological condition gradient.

The identification of "limiting indicators" may provide initial steps towards diagnosing stressors or prioritizing sites for rehabilitation. The fact that so many streams were limited for multiple indicators (frequently all four indicators used in the survey) suggests that pressures on many streams are diverse, severe, or both, and fixing these streams may be major challenge. But 19% of the region was limited for a single indicator, and this may indicate that pressures are less severe or more similar in action; rehabilitating these streams may be a more surmountable challenge than streams with fewer indicators in intact condition.

Table 1-1. Thresholds for identifying non-reference condition for biological indicators. Ref mean: Mean of reference sites. Ref SD: Standard deviation of reference sites. Numbers in parentheses refer to the percentiles used to set boundaries between classes. "Multi" refers to the threshold used in multiple-indicator analyses (i.e., the 2.5th percentile); samples with scores above all "multi" thresholds are considered to be in reference condition, with a 10% error rate.

Index	Ref N	Ref mean	Ref SD	Class 1 (≥30th Intact)	Class 2 (10th to 30th)	Class 3 (1st to 10th)	Class 4 (<1st Altered)	Multi
Benthic Macroinvertebrates								
CSCI	479	1.00	0.16	≥0.92	0.79 to 0.92	0.63 to 0.79	<0.63	0.69
-pMMI	479	1.00	0.18	≥0.91	0.77 to 0.91	0.58 to 0.77	<0.58	--
-OE	479	1.00	0.19	≥0.90	0.76 to 0.90	0.56 to 0.76	<0.56	--
Benthic Algae								
D18	122	79	13	≥72	62 to 72	49 to 62	<49	54
S2	122	69	17	≥60	47 to 60	29 to 47	<29	69
CRAM								
Overall Score	86	84	9	≥79	72 to 79	63 to 72	<63	66
Buffer and Landscape	86	95	10	≥90	82 to 90	72 to 82	<72	--
Hydrologic Connectivity	86	81	13	≥74	64 to 74	51 to 64	<51	--
Physical Structure	86	81	16	≥73	60 to 73	44 to 60	<44	--
Biotic Structure	86	75	16	≥67	54 to 67	38 to 54	<38	--

Table 1-2a: Mean CSCI scores and extent estimates for each condition class. n: number of sites used in the analysis. SD: Standard deviation. Class 1: % of streams with scores above the 30% percentile of reference sites. Class 2: % of streams with scores between the 10th and 30th percentiles of reference sites. Class 3: % of streams with scores between the 1st and 10th percentiles of reference sites. Class 4: % of streams with scores below the 1st percentile of reference sites.

Subpopulation	n	Mean	SD	Class 1	Class 2	Class 3	Class 4
South Coast	682	0.76	0.24	29	16	23	31
Land Use							
Agricultural	92	0.74	0.19	20	17	31	31
Open	306	0.93	0.17	59	21	15	5
Urban	284	0.59	0.16	2	11	30	58
Watershed							
Region 4							
Ventura	37	0.95	0.15	68	17	15	0
Santa Clara	94	0.91	0.21	54	20	15	11
Calleguas	38	0.65	0.15	9	3	38	49
Santa Monica Bay	72	0.70	0.20	18	9	31	43
Los Angeles	44	0.70	0.23	15	23	29	33
San Gabriel	39	0.62	0.25	17	11	15	57
Region 8							
Lower Santa Ana	45	0.59	0.21	11	14	10	65
Middle Santa Ana	57	0.64	0.23	11	16	30	43
Upper Santa Ana	67	0.88	0.20	49	16	26	10
San Jacinto	28	0.72	0.19	14	24	31	31
Region 9							
San Juan	30	0.72	0.18	15	20	27	38
Northern San Diego	36	0.83	0.19	55	11	13	21
Central San Diego	35	0.72	0.17	10	17	37	35
Mission Bay and San Diego	29	0.78	0.27	33	9	25	33
Southern San Diego	31	0.91	0.16	65	19	5	11

Table 1-2b. Mean pMMI scores and extent estimates for each condition class. n: number of sites used in the analysis. SD: Standard deviation. Class 1: % of streams with scores above the 30% percentile of reference sites. Class 2: % of streams with scores between the 10th and 30th percentiles of reference sites. Class 3: % of streams with scores between the 1st and 10th percentiles of reference sites. Class 4: % of streams with scores below the 1st percentile of reference sites.

Subpopulation	n	Mean	SD	Class 1	Class 2	Class 3	Class 4
South Coast	682	0.68	0.25	22	10	24	44
Land Use							
Agricultural	92	0.62	0.17	4	16	36	45
Open	306	0.87	0.20	47	19	27	7
Urban	284	0.49	0.12	0	1	18	81
Watershed							
Region 4							
Ventura	37	0.83	0.22	32	26	27	15
Santa Clara	94	0.86	0.22	49	16	25	11
Calleguas	38	0.54	0.09	0	0	32	68
Santa Monica Bay	72	0.64	0.19	13	13	24	50
Los Angeles	44	0.61	0.23	10	1	35	53
San Gabriel	39	0.57	0.25	15	9	6	70
Region 8							
Lower Santa Ana	45	0.50	0.18	0	12	19	68
Middle Santa Ana	57	0.59	0.21	9	9	24	58
Upper Santa Ana	67	0.86	0.23	39	19	34	8
San Jacinto	28	0.62	0.19	12	10	27	51
Region 9							
San Juan	30	0.56	0.22	13	4	6	76
Northern San Diego	36	0.72	0.21	32	14	21	33
Central San Diego	35	0.60	0.18	10	2	34	54
Mission Bay and San Diego	29	0.72	0.27	27	10	11	52
Southern San Diego	31	0.81	0.19	41	33	9	18

Table 1-2c. Mean O/E scores and extent estimates for each condition class. n: number of sites used in the analysis. SD: Standard deviation. Class 1: % of streams with scores above the 30% percentile of reference sites. Class 2: % of streams with scores between the 10th and 30th percentiles of reference sites. Class 3: % of streams with scores between the 1st and 10th percentiles of reference sites. Class 4: % of streams with scores below the 1st percentile of reference sites.

Subpopulation	n	Mean	SD	Class 1	Class 2	Class 3	Class 4
South Coast	682	0.85	0.27	46	20	17	18
Land Use							
Agricultural	92	0.86	0.24	47	14	29	10
Open	306	1.00	0.21	71	18	7	4
Urban	284	0.69	0.23	20	23	24	33
Watershed							
Region 4							
Ventura	37	1.09	0.15	94	3	3	0
Santa Clara	94	0.96	0.23	67	15	11	6
Calleguas	38	0.76	0.23	21	20	45	15
Santa Monica Bay	72	0.77	0.24	28	20	35	17
Los Angeles	44	0.80	0.27	31	36	5	28
San Gabriel	39	0.68	0.28	19	25	17	39
Region 8							
Lower Santa Ana	45	0.68	0.27	22	15	32	31
Middle Santa Ana	57	0.70	0.29	28	17	21	34
Upper Santa Ana	67	0.91	0.26	60	15	8	17
San Jacinto	28	0.82	0.27	46	11	24	19
Region 9							
San Juan	30	0.87	0.18	42	33	18	7
Northern San Diego	36	0.96	0.24	70	7	17	6
Central San Diego	35	0.83	0.23	51	10	21	17
Mission Bay and San Diego	29	0.85	0.28	38	29	19	15
Southern San Diego	31	1.01	0.18	75	14	11	0

Table 1-2d. Mean D18 and extent estimates for each condition class. n: number of sites used in the analysis. SD: Standard deviation. Class 1: % of streams with scores above the 30% percentile of reference sites. Class 2: % of streams with scores between the 10th and 30th percentiles of reference sites. Class 3: % of streams with scores between the 1st and 10th percentiles of reference sites. Class 4: % of streams with scores below the 1st percentile of reference sites.

Subpopulation	n	Mean	SD	Class 1	Class 2	Class 3	Class 4
South Coast	525	53	25	27	13	18	42
Land Use							
Agricultural	70	45	23	11	15	27	47
Open	221	67	21	47	19	16	18
Urban	234	43	24	12	9	18	62
Watershed							
Region 4							
Ventura	35	79	11	84	11	4	2
Santa Clara	63	59	18	28	16	31	25
Calleguas	38	34	16	0	1	19	80
Santa Monica Bay	54	45	18	3	12	36	48
Los Angeles	40	41	26	15	13	12	60
San Gabriel	32	69	23	52	9	19	21
Region 8							
Lower Santa Ana	33	39	23	3	19	12	66
Middle Santa Ana	30	63	25	41	17	14	28
Upper Santa Ana	27	72	23	63	14	7	16
San Jacinto	21	58	25	24	37	10	29
Region 9							
San Juan	30	41	25	10	16	17	57
Northern San Diego	33	58	19	30	23	17	30
Central San Diego	29	46	23	16	8	14	62
Mission Bay and San Diego	30	56	27	28	18	17	37
Southern San Diego	30	58	22	21	32	19	28

Table 1-2e. Mean S2 scores and extent estimates for each condition class. n: number of sites used in the analysis. SD: Standard deviation. Class 1: % of streams with scores above the 30% percentile of reference sites. Class 2: % of streams with scores between the 10th and 30th percentiles of reference sites. Class 3: % of streams with scores between the 1st and 10th percentiles of reference sites. Class 4: % of streams with scores below the 1st percentile of reference sites.

Subpopulation	n	Mean	SD	Class 1	Class 2	Class 3	Class 4
South Coast	524	44	25	25	16	27	32
Land Use							
Agricultural	71	26	18	5	6	27	61
Open	217	62	24	59	13	15	12
Urban	236	32	16	2	19	35	43
Watershed							
Region 4							
Ventura	36	49	25	39	4	33	24
Santa Clara	60	58	27	46	16	23	15
Calleguas	38	26	15	0	13	28	59
Santa Monica Bay	54	37	24	20	19	15	46
Los Angeles	41	41	20	21	11	35	33
San Gabriel	32	49	21	26	23	27	24
Region 8							
Lower Santa Ana	33	32	22	11	10	26	53
Middle Santa Ana	30	36	16	8	13	46	33
Upper Santa Ana	26	53	28	47	10	19	23
San Jacinto	21	54	24	51	10	21	19
Region 9							
San Juan	30	45	29	27	6	35	32
Northern San Diego	33	45	26	36	15	12	37
Central San Diego	30	33	19	4	31	22	43
Mission Bay and San Diego	30	49	31	39	11	22	29
Southern San Diego	30	57	27	41	21	21	17

Table 1-2f. Mean CRAM and extent estimates for each condition class. n: number of sites used in the analysis. SD: Standard deviation. Class 1: % of streams with scores above the 30% percentile of reference sites. Class 2: % of streams with scores between the 10th and 30th percentiles of reference sites. Class 3: % of streams with scores between the 1st and 10th percentiles of reference sites. Class 4: % of streams with scores below the 1st percentile of reference sites.

Subpopulation	n	Mean	SD	Class 1	Class 2	Class 3	Class 4
South Coast	529	64	21	30	13	16	41
Land Use							
Agricultural	77	68	15	20	19	29	32
Open	203	81	10	65	20	12	2
Urban	249	51	18	7	7	16	70
Watershed							
Region 4							
Ventura	32	79	9	54	19	25	2
Santa Clara	69	76	11	48	24	16	12
Calleguas	31	57	18	3	22	17	59
Santa Monica Bay	67	64	19	25	15	22	38
Los Angeles	41	50	19	14	4	16	66
San Gabriel	37	52	22	24	6	2	68
Region 8							
Lower Santa Ana	33	56	18	11	12	20	57
Middle Santa Ana	29	52	23	24	6	4	67
Upper Santa Ana	23	74	10	34	19	30	17
San Jacinto	18	79	13	63	10	10	16
Region 9							
San Juan	31	66	21	38	6	11	45
Northern San Diego	31	81	10	57	19	21	4
Central San Diego	29	63	17	17	14	28	41
Mission Bay and San Diego	30	70	21	50	13	13	25
Southern San Diego	28	76	15	52	19	13	16

Table 1-2g. Mean CRAM Buffer and Landscape attribute scores and extent estimates for each condition class. n: number of sites used in the analysis. SD: Standard deviation. Class 1: % of streams with scores above the 30% percentile of reference sites. Class 2: % of streams with scores between the 10th and 30th percentiles of reference sites. Class 3: % of streams with scores between the 1st and 10th percentiles of reference sites. Class 4: % of streams with scores below the 1st percentile of reference sites.

Subpopulation	n	Mean	SD	Class 1	Class 2	Class 3	Class 4
South Coast	529	75	24	40	10	11	39
Land Use							
Agricultural	77	81	18	44	13	21	21
Open	203	92	13	81	12	4	4
Urban	249	62	22	10	8	14	67
Watershed							
Region 4							
Ventura	32	91	12	71	16	11	2
Santa Clara	69	91	12	70	13	10	7
Calleguas	31	65	21	7	15	27	52
Santa Monica Bay	67	72	26	38	8	21	34
Los Angeles	41	67	23	26	9	5	61
San Gabriel	37	68	21	27	5	0	68
Region 8							
Lower Santa Ana	33	59	26	11	12	14	62
Middle Santa Ana	29	53	28	16	0	14	69
Upper Santa Ana	23	86	23	69	8	0	23
San Jacinto	18	79	23	43	13	16	27
Region 9							
San Juan	31	71	24	33	6	10	52
Northern San Diego	31	93	8	74	12	12	2
Central San Diego	29	71	24	29	13	26	31
Mission Bay and San Diego	30	77	24	50	8	7	35
Southern San Diego	28	87	21	67	11	10	12

Table 1-2h. Mean CRAM Hydrologic structure attribute scores and extent estimates for each condition class. n: number of sites used in the analysis. SD: Standard deviation. Class 1: % of streams with scores above the 30% percentile of reference sites. Class 2: % of streams with scores between the 10^{th} and 30^{th} percentiles of reference sites. Class 3: % of streams with scores between the 1^{st} and 10^{th} percentiles of reference sites. Class 4: % of streams with scores below the 1^{st} percentile of reference sites.

Subpopulation	n	Mean	SD	Class 1	Class 2	Class 3	Class 4
South Coast	529	63	21	25	18	24	33
Land Use							
Agricultural	77	66	15	17	28	34	22
Open	203	81	15	57	22	18	3
Urban	249	51	17	4	15	26	55
Watershed							
Region 4							
Ventura	32	80	15	52	26	19	4
Santa Clara	69	74	13	35	30	28	7
Calleguas	31	54	16	8	9	32	51
Santa Monica Bay	67	63	17	25	16	30	30
Los Angeles	41	52	22	20	6	22	52
San Gabriel	37	53	24	22	8	9	61
Region 8							
Lower Santa Ana	33	53	20	12	6	28	53
Middle Santa Ana	29	50	20	11	6	26	57
Upper Santa Ana	23	75	19	48	12	31	10
San Jacinto	18	76	22	58	19	0	23
Region 9							
San Juan	31	65	21	18	30	17	35
Northern San Diego	31	79	15	44	28	25	2
Central San Diego	29	65	15	12	28	41	19
Mission Bay and San Diego	30	69	19	30	28	20	22
Southern San Diego	28	78	16	46	25	22	7

Table 1-2i. Mean CRAM Physical structure attribute scores and extent estimates for each condition class. n: number of sites used in the analysis. SD: Standard deviation. Class 1: % of streams with scores above the 30% percentile of reference sites. Class 2: % of streams with scores between the 10th and 30th percentiles of reference sites. Class 3: % of streams with scores between the 1st and 10th percentiles of reference sites. Class 4: % of streams with scores below the 1st percentile of reference sites.

Subpopulation	n	Mean	SD	Class 1	Class 2	Class 3	Class 4
South Coast	529	56	25	38	12	15	35
Land Use							
Agricultural	77	59	20	32	23	20	25
Open	203	75	17	71	14	10	4
Urban	249	43	22	16	9	17	58
Watershed							
Region 4							
Ventura	32	76	21	65	15	16	4
Santa Clara	69	73	17	60	22	13	5
Calleguas	31	52	25	31	7	21	41
Santa Monica Bay	67	63	22	46	23	13	19
Los Angeles	41	39	20	17	1	18	64
San Gabriel	37	44	26	21	13	2	64
Region 8							
Lower Santa Ana	33	49	26	29	10	5	56
Middle Santa Ana	29	40	22	18	2	17	63
Upper Santa Ana	23	55	18	22	26	32	20
San Jacinto	18	59	22	50	0	24	26
Region 9							
San Juan	31	66	25	58	5	15	22
Northern San Diego	31	71	16	63	21	8	9
Central San Diego	29	55	20	28	11	29	32
Mission Bay and San Diego	30	64	24	50	23	2	25
Southern San Diego	28	67	17	63	10	17	10

Table 1-2j. Mean CRAM Biotic structure attribute scores and extent estimates for each condition class. n: number of sites used in the analysis. SD: Standard deviation. Class 1: % of streams with scores above the 30% percentile of reference sites. Class 2: % of streams with scores between the 10th and 30th percentiles of reference sites. Class 3: % of streams with scores between the 1st and 10th percentiles of reference sites. Class 4: % of streams with scores below the 1st percentile of reference sites.

Subpopulation	n	Mean	SD	Class 1	Class 2	Class 3	Class 4
South Coast	529	57	24	42	17	11	30
Land Use							
Agricultural	77	63	19	46	27	13	13
Open	203	72	17	69	19	8	4
Urban	249	45	22	22	15	13	50
Watershed							
Region 4							
Ventura	32	66	12	50	29	18	2
Santa Clara	69	66	16	53	24	17	6
Calleguas	31	55	20	35	30	7	28
Santa Monica Bay	67	59	19	42	28	14	16
Los Angeles	41	41	22	19	14	6	61
San Gabriel	37	42	24	24	6	9	62
Region 8							
Lower Santa Ana	33	51	23	33	8	23	36
Middle Santa Ana	29	43	26	21	13	10	56
Upper Santa Ana	23	58	24	38	25	16	22
San Jacinto	18	75	21	73	12	4	11
Region 9							
San Juan	31	63	23	52	7	16	26
Northern San Diego	31	81	13	84	14	2	0
Central San Diego	29	62	19	41	32	15	13
Mission Bay and San Diego	30	69	23	74	4	0	22
Southern San Diego	28	70	16	70	16	6	8

Table 1-3. Percent of stream-miles intact for multiple indicators, or limiting for specific indicators, for each subpopulation. Note that, in contrast to Table 1-2, these results are based on an adjusted "multi" threshold in Table 1-1, which reduces the error associated with multiple comparisons. CI: Confidence interval.

Subpopulation	n	% Intact			Indicators of Poor Condition						
		Estimate	95% CI		CSCI Alone	D18 Alone	S2 Alone	D18 or S2	All Benthic Indicators	CRAM Alone	All Four Indicators
South Coast	453	25	21	28	2	6	7	18	4	3	15
Land Use											
Agricultural	66	9	4	15	1	6	15	29	6	3	22
Open	172	60	51	68	4	11	10	25	1	6	0
Urban	215	2	0	4	1	3	4	10	6	0	25
Watershed											
Region 4											
Ventura	31	50	31	69	9	5	32	37	0	0	0
Santa Clara	51	43	30	55	5	17	6	25	1	3	7
Calleguas	30	0	0	0	0	0	12	29	11	0	32
Santa Monica Bay	47	10	3	16	5	10	6	25	10	0	12
Los Angeles	33	13	5	21	0	0	4	4	0	10	34
San Gabriel	31	28	19	37	0	0	3	3	0	3	7
Region 8											
Lower Santa Ana	32	15	7	23	0	3	6	15	0	0	46
Middle Santa Ana	25	5	0	13	4	0	7	12	3	1	13
Upper Santa Ana	19	62	42	82	0	0	0	5	9	8	0
San Jacinto	14	53	35	70	13	0	0	0	7	0	27
Region 9											
San Juan	29	18	9	27	10	7	6	13	7	0	16
Northern San Diego	31	33	4	62	2	8	23	41	9	2	0
Central San Diego	25	6	0	15	0	15	9	28	4	0	19
Mission Bay and San Diego	29	32	22	41	0	10	0	14	13	0	0
Southern San Diego	26	61	53	70	0	10	0	20	0	2	2

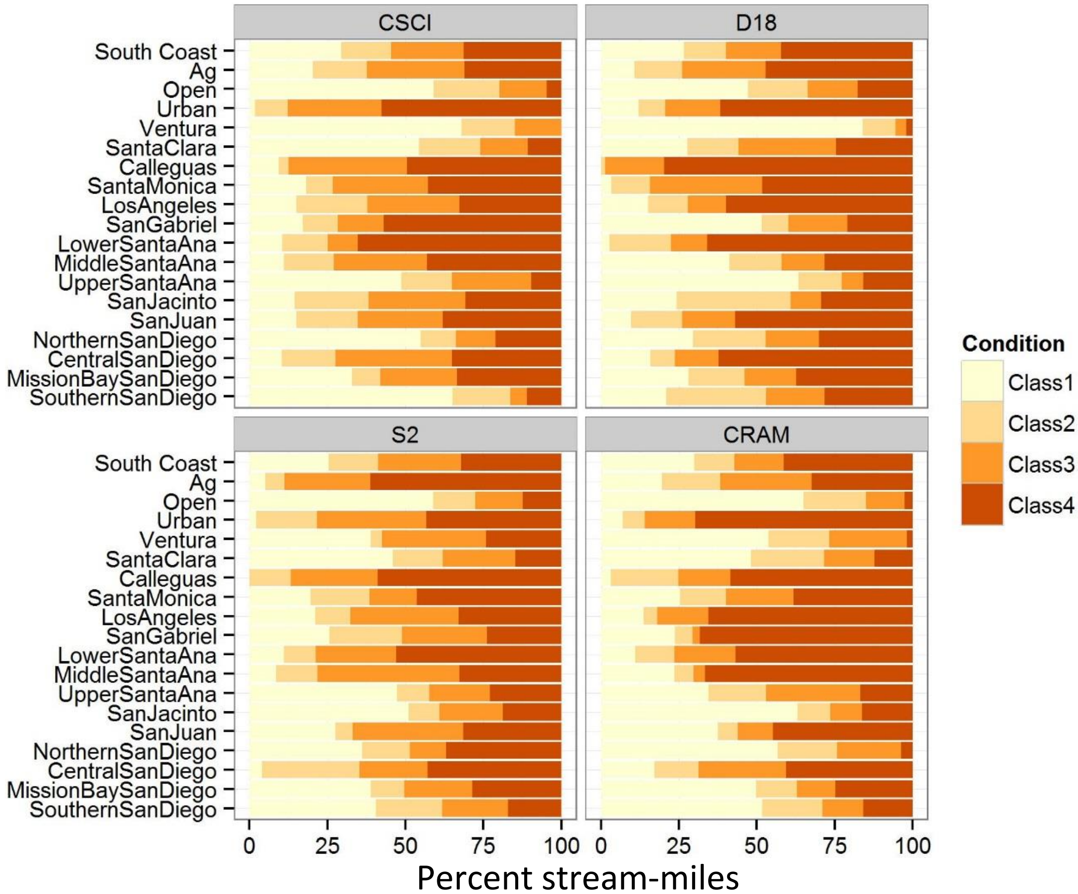


Figure 1-1. Percent of stream-miles in each condition class for each indicator by subpopulation.

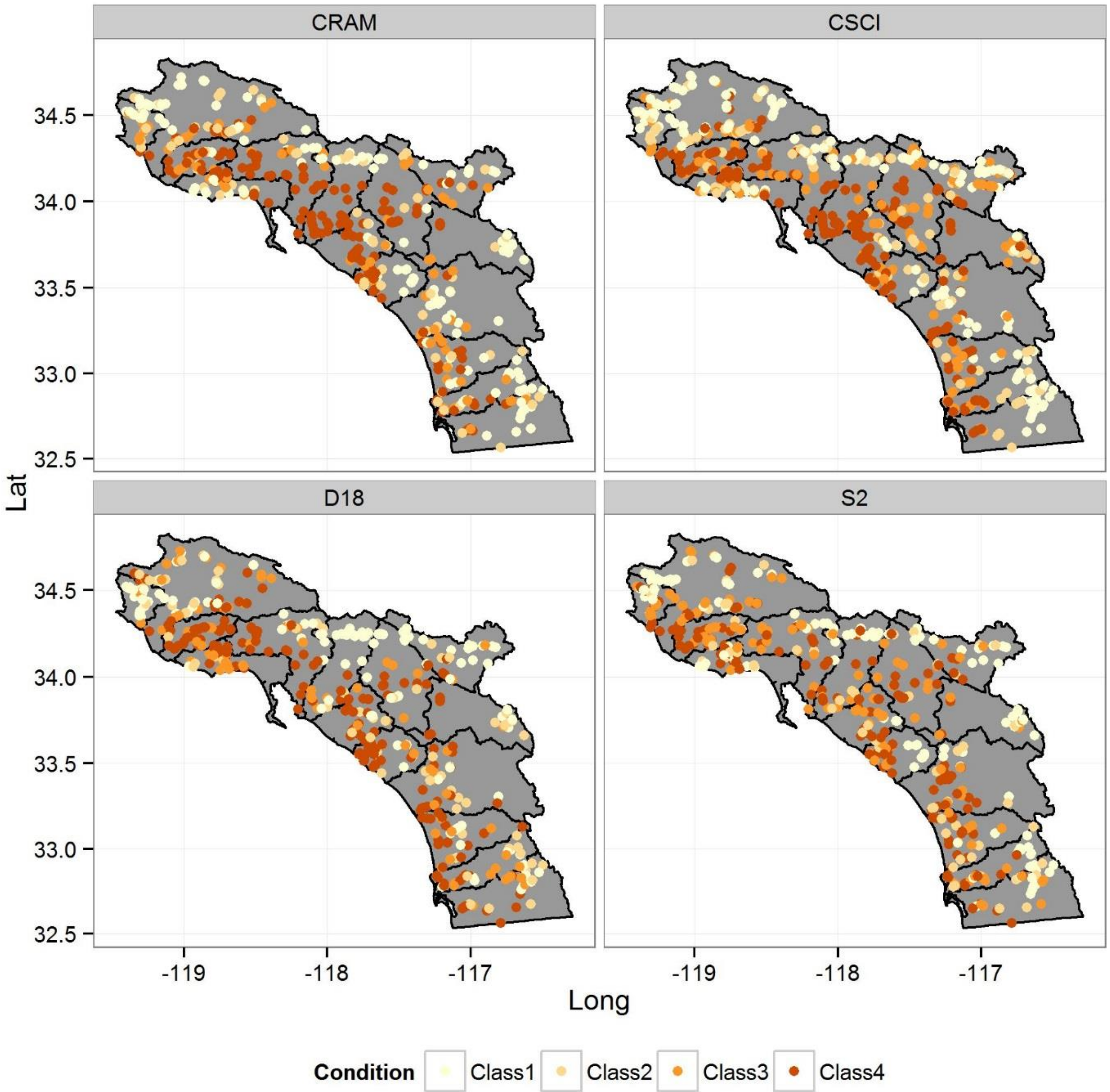


Figure 1-2. Map of scores for key indicators.

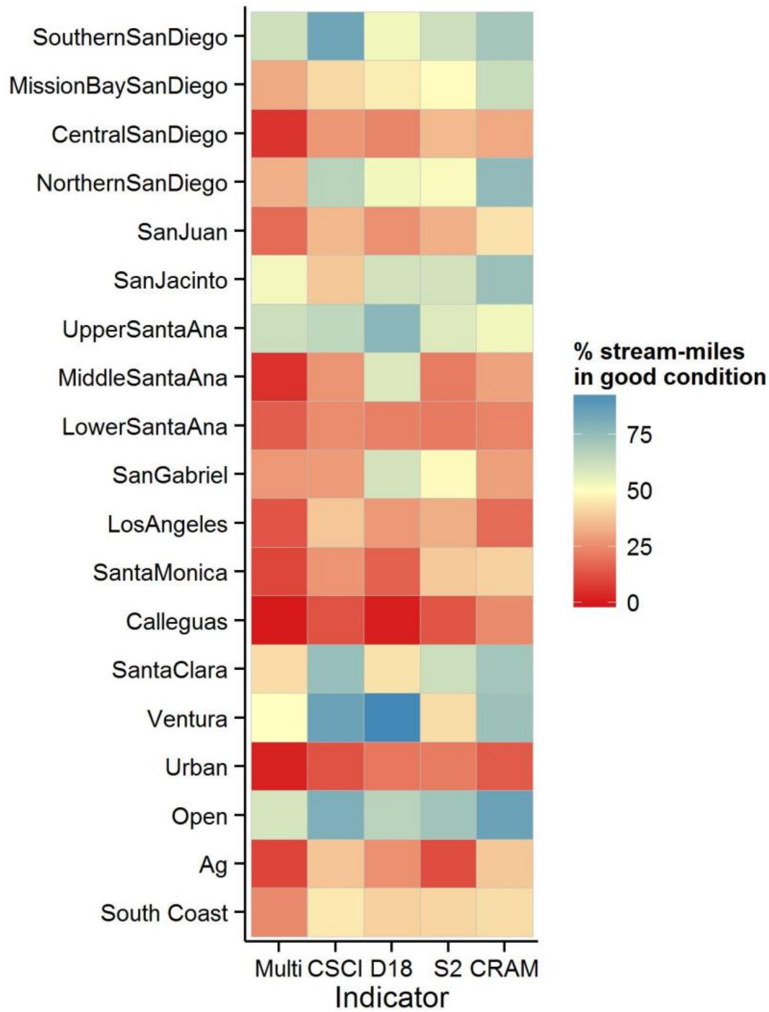


Figure 1-3. Percent of stream-miles in good condition by subpopulation. For the "multi" column, the number reflects the percent of stream-miles with scores for all indicators above the 2.5th percentile of reference sites; all other columns reflect the percent of stream-miles with scores above the 10th percentile of reference sites.

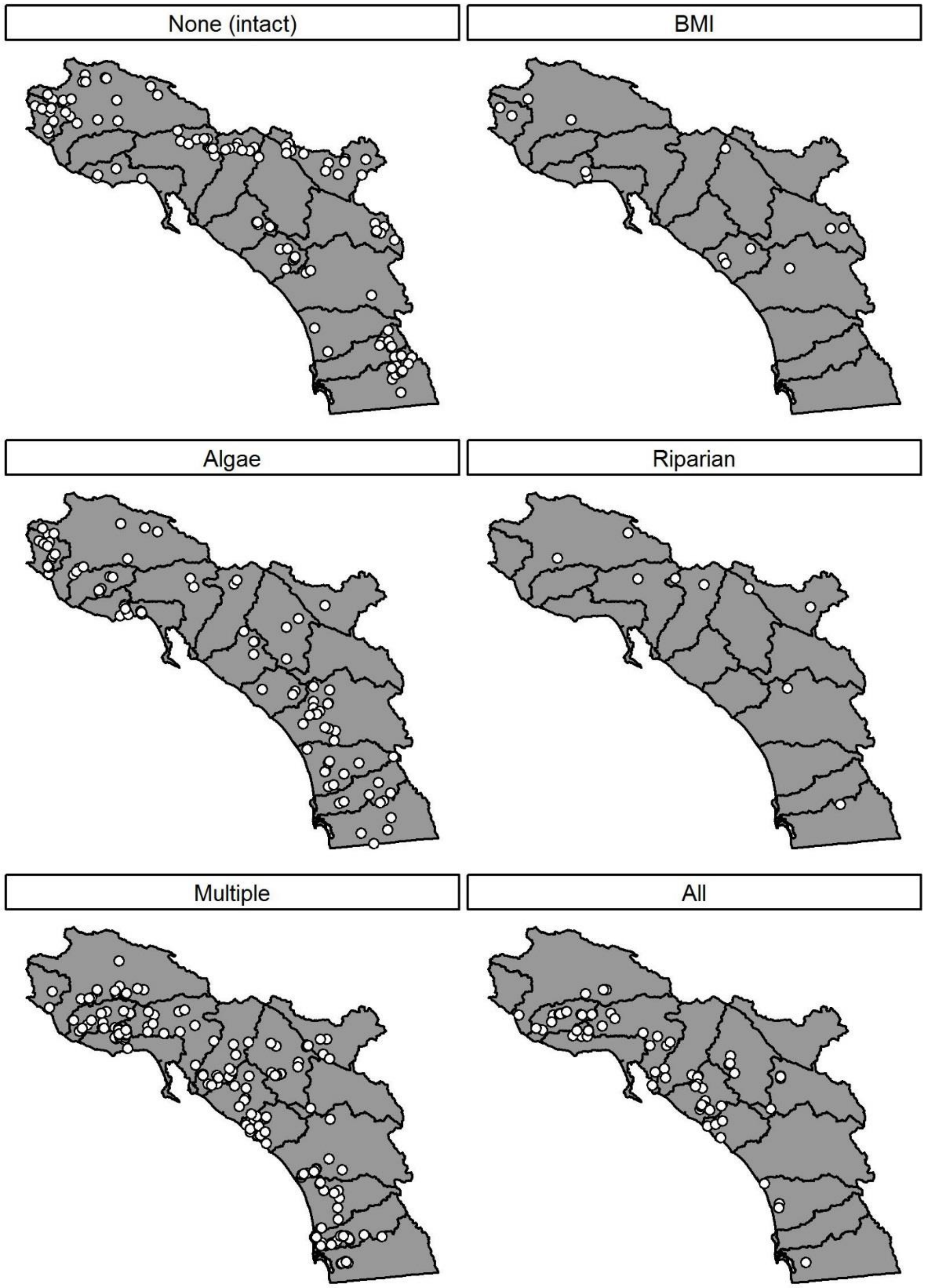


Figure 1-4. Map of limiting indicators. In the top left panel, points represent sites where scores for all four indicators above the 2.5th percentile of reference sites. For all other panels, points represent sites where scores for the specified indicator or indicators were below the 2.5th percentile of reference sites.

QUESTION 2: WHICH STRESSORS ARE ASSOCIATED WITH POOR BIOLOGICAL CONDITION?

Caballero Creek, in the Los Angeles watershed, exemplifies both the severe habitat alteration and nutrient enrichment that affects many streams in southern California.

Introduction

Although the direct measurement of stressors cannot determine the ecological health of a stream, it is essential in determining which factors may limit its health, and provides essential data to inform causal assessment at degraded sites. The SMC stream survey took a notably broad approach towards assessing stressors, measuring nutrients, total and dissolved metals, major ions, water column toxicity, and physical habitat. For some constituents, this survey represents the first unbiased estimate of the extent and magnitude of stressors in aquatic systems. By assessing the extent of these stressors and assessing their associations with biological condition, this survey allows the prioritization of stressors of regional interest, which can then inform local management decisions.

Methods

Data Collection

Data were collected as described in the Survey Overview.

Data Aggregation

Where multiple samples were collected at a single site within a year, data were aggregated as the maximum value within a site. Multi-year mean values for each site were then calculated from these aggregated values if sites were revisited in multiple years. Missing values were ignored for all relevant analyses, where appropriate.

Thresholds

Our goal in setting stressor thresholds was to prioritize stressors in terms of their associated risks to biological condition, as opposed to validating the adequacy of existing regulatory thresholds or assessing compliance with permit requirements. Therefore, the best threshold for this goal is one that is associated with the biggest change in biological condition. Stressor thresholds do not necessarily reflect the most appropriate water quality standards for a given site, which may vary based on site-specific conditions. Therefore, exceeding one of the stressor thresholds used in this analysis may not necessarily indicate impairment or noncompliance with permit requirements.

Stressor thresholds were derived from values published in relevant literature or regulations, where possible (Tables 2-1, 2-2). For chemical nutrients and for most habitat metrics (which are occur naturally and do not have regionally applicable regulatory thresholds), thresholds were established at the 90th or 10th percentile of the distribution among reference sites (as per Ode *et al.* In review). For pyrethroids without published thresholds, a threshold of zero was used.

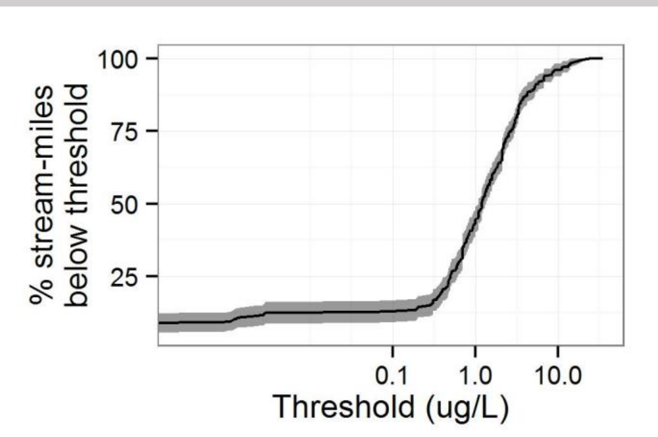
Toxicity tests were compared against controls. If endpoints were significantly different from controls and had values that were 80% of control values or lower, the samples were considered toxic. Toxic survival endpoints were given precedence over nonlethal endpoints (e.g., depressed reproduction).

Reference-Based Thresholds

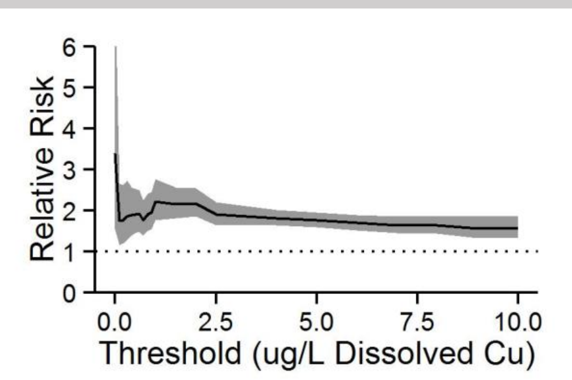
Reference-based thresholds, while appropriate for assessing whether biological indices reflect reference condition, may not be appropriate for water chemistry or physical habitat variables, as they may be excessively stringent. Because of uncertainty about the applicability of certain water chemistry thresholds, a number of alternative thresholds recommended by participating agencies were evaluated.

Copper

To evaluate the impacts of metals on stream condition, this survey used hardness-adjusted thresholds from the California Toxics Rule (EPA 2000). These thresholds are intended to prevent toxic effects on a variety of aquatic species based on the concentration of bio-available toxicants. However, because many of these metals have natural geological sources in the region (e.g., Yoon and Stein 2008), a reference-based threshold, such as those used for nutrients, would better identify sites that exceed natural concentrations. Therefore, a reference-based threshold for copper was calculated as the 90^{th} percentile of concentrations at reference sites within the South Coast region (i.e., 3.4 ug/L), and the extent of stream-miles below this threshold was estimated. Whereas 96% of stream-miles across the region were below the hardness-adjusted threshold for total copper, only 67% were below the reference-based threshold. The difference was even greater for dissolved Copper: 99% of stream-miles were below the hardness-adjusted CTR threshold, whereas only 39% were below the reference threshold of 0.8. Relative risk estimates were only marginally affected (e.g., risk to CSCI scores went up from 1.7 to 1.9 for dissolved copper). However, attributable risks increased considerably (e.g., from 0.004 to 0.360), reflecting the larger number of stream-miles exceeding the reference-based threshold, which would have increased the priority given to this stressor.



Effects of varying thresholds on the percent of perennial stream-miles below threshold for dissolved copper. The gray band indicates the 95% confidence interval.

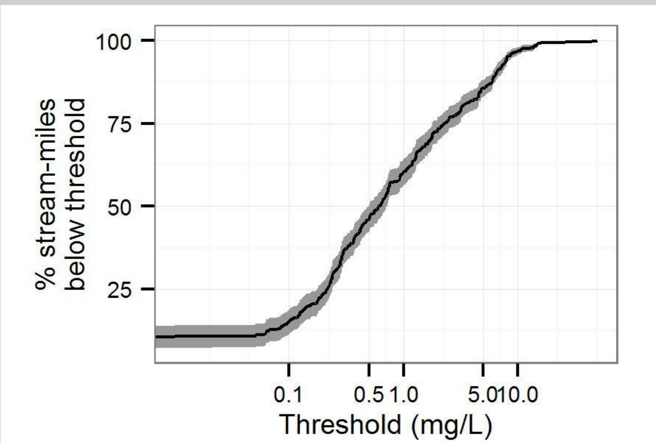


Risk to CSCI scores remain high at all levels of dissolved copper analyzed. The gray band represents the 95% confidence interval. Relative risks greater than 1 (represented by the dotted line) indicate that the stressor is associated with poor biological condition.

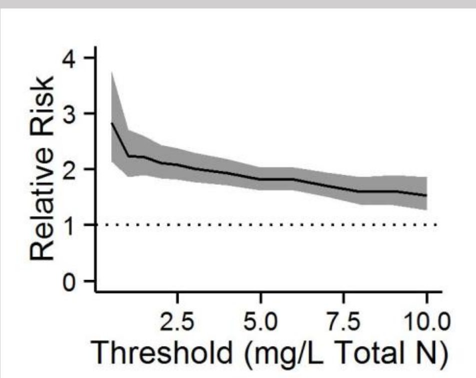
Reference-Based Thresholds (Continued)

Total Nitrogen

This study and others (see Herlihy and Sifneos 2008) have shown a strong association between nutrient concentrations and poor biological condition. However, the reference based thresholds used here are much lower than those used in basin plans or TMDLs throughout the region. For example, the reference-based threshold for total nitrogen (TN) was 0.37 mg/L, whereas the San Diego Basin Plan specifies a threshold of 1 mg/L. The Los Angeles Basin Plan sets a much higher threshold of 10 mg/L (although this threshold is explicitly linked to risks to human health and municipal water uses, not aquatic life). Although 39% of stream-miles across the region were below the reference threshold, this number increased to 60% if a threshold of 1 mg/L was used, and to 98% if a threshold of 10 mg/L was used.



Effect of varying thresholds on the percent of perennial stream-miles below threshold for total nitrogen. The gray band indicates the 95% confidence interval.



Risk to CSCI scores remain high at all levels of total N analyzed. The gray band represents the 95% confidence interval. Relative risks greater than 1 (represented by the dotted line) indicate that the stressor is associated with poor biological condition.

Stressor Extent Estimates

Extent estimates and related distribution points were calculated as described in the Survey Overview. These estimates were calculated for land use classes and for the region as a whole, but not for individual watersheds.

Stressor Associations and Prioritization

Relative risk analysis was used to estimate the likelihood of poor biological condition given the presence of a stressor, relative to the likelihood in the absence of a stressor (Van Sickle *et al.* 2006). Attributable risk analysis was then used to estimate the proportion of streams in the region where biological condition may improve if a stressor were removed. Biological condition was determined as described in the section on Question 1, except that Class 1 and 2 streams (Table 1-1) were both treated as “good”, and Class 3 and 4 streams were both treated as “poor”.

Stressors were then designated as very high priority (attributable risk > 25% of the region for any indicator), high priority (attributable risk between 10% and 25% for any indicator), moderate (attributable risk <10%, but relative risk > 1 for any indicator), and low (relative risk <1 for all indicators).

Relative and Attributable Risk

Relative risk assessment is statistical method of associating the increased risk associated with a stressor (Van Sickle *et al.* 2006). Originally developed for public health studies, relative risk analysis has become popular in environmental assessment because it facilitates prioritization of stressors by identifying which ones are most strongly associated with poor condition. Relative risk compares the odds of observing poor biological condition when a stressor is present to the odds of observing it when the stressor is absent:

$$\text{Relative risk} = \frac{Proportion\ of\ stressed\ stream{-}miles\ in\ poor\ condition}{Proportion\ of\ unstressed\ stream{-}miles\ in\ poor\ condition}$$

Stressors with relative risks greater than 1 are considered to be associated with poor condition; larger relative risks indicate stronger associations, although any stressor with a risk greater than 1 is a good candidate for further study (e.g., causal analysis).

Relative risk analysis can be extended through attributable risk analysis, which accounts for the fact that low-risk but extensive stressors may be higher regional priorities than high-risk stressors that affect few stream miles (Van Sickle and Paulsen 2008). Attributable risk is calculated as follows:

$$\text{Attributable risk} = \frac{(Proportion\ of\ stressed\ stream{-}miles)\times(Relative\ risk-1)}{1+(Proportion\ of\ stressed\ stream{-}miles)\times(Relative\ risk-1)}$$

Thus, the attributable risk of a stressor is large if a stressor is extensive and has a relative risk greater than 1. If one assumes a perfect causal relationship between the stressor and poor condition, the attributable risk represents the proportion of the region that would be improved if the stressor were eliminated (Van Sickle and Paulsen 2008). But even when this assumption is violated, attributable risk is a useful metric for ranking stressors by regional importance because it accounts for both stressor extent and strength of association with biological condition.

Both relative risk and attributable risk require stressor thresholds for calculation, and modifying the threshold may alter estimates of risk. If stressor thresholds are set too high, relative risk estimates will go down as the proportion of unstressed stream-miles in poor condition increases. Similarly, if stressor thresholds are set too low, relative risk estimates will also go down as the proportion of stressed stream-miles in poor condition decreases. Ideally, stressor thresholds are set at the level where streams are most likely to switch from poor to good condition (or vice-versa), thereby allowing more direct comparisons of risk across stressors.

Results

All data used in this report can be downloaded from ftp.sccwrp.org/pub/download/SMCReport/SMCDataFor5yearReport.zip.

Stressor Extents

Regional results for all analytes are presented, but only subpopulations where at least 5% of the stream-miles exceeded the threshold are included.

Water Chemistry

In general, nutrients and sulfate exceeded the threshold in extensive portions of the region, while exceedances of pyrethroids and metals were rare (Table 2-3a, Figures 2-1 and 2-2). For example, total Nitrogen exceeded the reference benchmark of 0.37 mg/L in 61% of stream-miles across the region, and sulfates exceeded the benchmark of 250 mg/L in 45% of stream-miles. In contrast, Bifenthrin, the most commonly detected pyrethroid, exceeded the benchmark of 0.0006 ug/L in only 16% of stream-miles, and Selenium exceeded the threshold of 5 ug/L in only 13% of stream-miles. Even within urban areas, pyrethroid and metal exceedances were observed in fewer than 24% of stream-miles (Table 2-3b). Several analytes (e.g., Alkalinity, Arsenic, Nickel, and Zinc) were within thresholds at all sites in the survey. Nonetheless, exceedances of certain constituents were extensive in individual watersheds (Table 2-3c). For example, Bifenthrin exceeded the benchmark in 35% of stream-miles in the Santa Monica Bay watershed, and 30% of the Lower Santa Ana, whereas Selenium exceeded its threshold in 40% of the Calleguas and 55% of the Santa Monica Bay watersheds. Geographic clustering of exceedances was evident for both Selenium and Chloride (Figure 2-2), suggesting a localized (perhaps geological) source for these constituents. Exceedances of the reference-based threshold for total dissolved solids (TDS; i.e., 498 mg/L) were also widespread, affecting 76% of stream-miles region-wide, and nearly all agricultural (97%) and urban (99%) stream-miles. However, a large extent (50%) of open stream-miles also exceeded this threshold, as did 100% of certain watersheds (i.e., Calleguas, Santa Monica, and Lower Santa Ana).

With the exception of Ammonia (whose threshold is based on its toxicity to aquatic invertebrates), nutrients frequently exceeded their benchmarks, based on concentrations observed at reference sites, and these extents were closely related to land use. For example, 71% of open streams were below the threshold for total nitrogen (TN), yet only 12% of urban and 13% of agricultural streams had similarly low concentrations of nitrogen. Exceedances for TN were relatively limited in the Ventura (26%) and Santa Clara (30%) watersheds, but pervasive within the Calleguas (94%). and Lower Santa Ana (90%) watersheds. Total phosphorous (TP) exceedances exhibited similar patterns. For example, 57% of stream-miles exceeded the reference-based benchmark of 0.03 mg/L. As with nitrogen, phosphorous exceedances were pervasive in urban (83% of stream-miles) and agricultural (72%) land uses, and were relatively common in open streams (29%).

Toxicity

Toxicity was detected in surprising geographic patterns. Sublethal toxicity (i.e., depressed reproduction) was somewhat common (evident in 25% of stream-length), and was more extensive in open (33%) than agricultural (30%) or urban (19%) streams (Table 2-4, Figure 2-3). Sublethal toxicity was particularly extensive in the Los Angeles (57%) and Santa Clara (49%) watersheds, but rare within neighboring watersheds, like the San Gabriel (6%) and Calleguas (8%) watersheds. In contrast, toxicity to survival endpoints was evident in only 6% of streams region-wide, and was less extensive in open streams (2%) than urban (8%) or agricultural (15%). Lethal toxicity was most extensive in the Central San Diego watershed (26%), but was fairly limited (extent <10%) in most other watersheds.

Physical habitat

Region-wide, the majority of stream-miles were within the reference distribution for all habitat variables examined, although the more aggregated measures of habitat condition tended to show the most extensive alteration (Table 2-5). For example, the three diversity metrics (i.e., Shannon_Flow, Shannon_Habitat, and Shannon_Substrate), as well as the fish cover metric (i.e., XFC_NAT_SWAMP) were depressed for more than 25% of stream-miles in the region (Figures 2-4 and 2-5).

With the exception of algal biomass variables, the extent of open streams exceeding a benchmark was typically close to the expected distribution at reference sites (i.e., 10%). For example, the Shannon flow metric was outside threshold in 32% of urban stream-miles, 20% of agricultural stream-miles, and only 7% of open stream-miles. This pattern, with the greatest extent of streams exceeding thresholds in urban, followed by agricultural streams, was typical of most habitat variables. A notable exception includes variables directly related to fine sediment (e.g., % sands and fines (PCT_SAFN) and % cobble embeddedness (XEMBED)) were more extensively above threshold in agricultural streams than in urban streams; these metrics may reflect channelization or other flood-control activities that reduce particulate substrates (such as cobbles and sand grains) in urban streams.

Biomass variables frequently exceeded reference-based thresholds across different land-use types, including undeveloped streams. For example, macroalgae cover (i.e., PCT_MAP) exceeded the threshold in 42% of urban streams, 31% of agricultural streams, and 17% of open streams. In contrast, variables related to habitat complexity or riparian vegetation showed a more familiar pattern across land use types.

The extent of altered habitat varied widely by watershed. For example, the extent of exceedances of biomass thresholds was about a third or less for most watersheds, with the notable exception of benthic Chlorophyll a and ash-free dry mass, where exceedances affected nearly two-thirds of the Santa Monica Bay watershed. The exceedances of the Shannon habitat metric affected 3% or less of the Ventura and Northern San Diego watersheds, but more than half of the Los Angeles, San Gabriel, and Middle Santa Ana watersheds. In fact, exceedances affected more than 50% of these three watersheds for many habitat variables.

Stressor prioritization

Nutrients, variables related to ionic concentration (e.g., TDS, sulfates), and several habitat variables were classified as very high priority stressors, having both high relative and attributable risks for several indicators (Tables 2-6 and 2-7, Figure 2-6). For example, TN had an attributable risk of 0.51 for the CSCI. Total dissolved solids and sulfate were also high priority because of their high attributable risk for the CSCI and S2. In contrast, metals and pyrethroids were typically classified as moderate priority. Some, like Bifenthrin or copper, had comparatively high relative risks (>1.5), but because of their limited extents, were estimated to affect less than 10% of the region. Variables related to biomass were also classified as moderate, but for the opposite reason: low risk, but extensive exceedances of threshold contributed to elevated attributable risks.

While there was general agreement among indices, risks were overall greater for the CSCI, followed by S2, with D18 showing the lowest risks. The same five stressors (TDS, PCT_BIGR, W1_HALL, TP, and TN) had the highest attributable risk for all indices. Copper and XEMBED had relatively high attributable risk for the algae indices, compared to the CSCI, which in turn had higher risk for several habitat complexity measures (e.g., Shannon_Substrate, XPCMG).

Discussion

Nutrients, altered physical habitat, and major ions were both widespread and strongly associated with altered biology. Although metals and pyrethroids may be important stressors at specific sites, they should be considered a lower priority for regional programs (generally because they affected only a limited extent of streams).

Although physical habitat was repeatedly identified as a high-risk stressor, it was not possible to characterize these impacts in a precise, unbiased manner. Many physical habitat variables show large site-to-site variability within undisturbed areas, reflecting the influence of environmental gradients, like watershed size, climate, and geology. Establishing site-specific benchmarks based on environmental setting would probably yield a more accurate assessment of physical habitat. Data collected at reference sites could be used to develop models that can set these benchmarks for different stream types. Additionally, integrating multiple physical habitat variables into one or more indices would probably provide a more comprehensive characterization of habitat condition than the metric-by-metric approach used here.

Why were nutrients so strongly associated with poor biology if elevated biomass, the presumed mechanism of impact, had only a moderately high risk? This apparent conflict could result from several possible reasons: 1) timing of sampling, which may miss peak algae biomass; 2) co-occurrence with other stressors (such as habitat alteration; Bernal *et al.* 2013), or 3) other mechanisms of impact, such as cyanotoxins or microsystins (e.g., Aboal *et al.* 2002). Because nutrients are such a high priority for the region, further investigation of these explanations may be warranted.

Table 2-1. Analyte threshold by category. Asterisks indicate thresholds that were used when hardness data were unavailable.

Category	Analyte	Threshold	Unit	Source
Ions	Alkalinity as CaCO3	20000	mg/L	EPA (1986)
Ions	Chloride	260	mg/L	EPA (1986)
Ions	Sulfate	250	mg/L	EPA (1986)
Field	pH	6.5 and 8.5		EPA (1986)
Field	Turbidity	3.8	NTU	Ref (n=47)
Field	Specific conductance	878	uS/cm	Ref (n=77)
Solids	Suspended solids	9.5	mg/L	Ref (n=65)
Solids	Dissolved solids	498	mg/L	Ref (n=19)
Metals	Arsenic	150	ug/L	EPA (2000)
Metals	Cadmium	2.2	ug/L	EPA (2000)
Metals	Copper	9*	ug/L	EPA (2000)
Metals	Nickel	2.5*	ug/L	EPA (2000)
Metals	Lead	52*	ug/L	EPA (2000)
Metals	Selenium	5	ug/L	EPA (2000)
Metals	Zinc	120*	ug/L	EPA (2000)
Nutrients	TN	0.42	mg/L	Ref (n=65)
Nutrients	Ammonia-N	1.71	mg/L	EPA 2000
Nutrients	TP	0.03	mg/L	Ref (n=64)
Pyrethroids	Allethrin	0	ug/L	Detection
Pyrethroids	Bifenthrin	0.0006	ug/L	Central Valley draft TMDL (2014)
Pyrethroids	Cyfluthrin	0.00005	ug/L	Central Valley draft TMDL (2014)
Pyrethroids	Cyhalothrin Lambda	0.0005	ug/L	Central Valley draft TMDL (2014)
Pyrethroids	Cypermethrin	0.0002	ug/L	Central Valley draft TMDL (2014)
Pyrethroids	Deltamethrin/Tralomethrin	0	ug/L	Detection
Pyrethroids	Esfenvalerate/Fenvalerate	0.003	ug/L	Central Valley draft TMDL (2014)
Pyrethroids	Permethrin	0.002	ug/L	Central Valley draft TMDL (2014)

Table 2-2. Thresholds for physical habitat variables. n: number of reference sites used to estimate reference distribution. Ref: estimated from reference distribution. RCMP: Reference Condition Monitoring Program, from Ode *et al.* (In review).

Variable	Description	Direction	Threshold	Units	n	Source
Biomass						
Chlorophyll_a	Benthic chlorophyll a	Increase	56	ug/cm^2	66	Ref
AFDM	Benthic ash-free dry mass	Increase	37	mg/cm^2	64	Ref
PCT_MAP	% macro-algae cover	Increase	41	%	49	Ref
XMIATP	Mean microalgae thickness (where present)	Increase	1.0	mm	53	Ref
PCT_MIAT1	% thick (>1 mm) microalgae cover	Increase	18	%	53	Ref
PCT_MCP	% macrophyte cover	Increase	37	%	49	Ref
PCT_CPOM	% coarse particulate organic matter cover	Increase	71	%	60	Ref
Instream habitat						
XFC_NAT_SWAMP	Natural fish cover	Decrease	18	%	73	Ref
Shannon_Habitat	Fish cover diversity	Decrease	1.1		73	Ref
Shannon_Flow	Flow habitat diversity	Decrease	2.4		61	Ref
PCT_FAST	% fast-water habitat	Decrease	7	%	61	Ref
Riparian						
XCDENMID	% shading	Decrease	17	%	72	Ref
XCMG	Mean riparian vegetation cover	Decrease	32	%	62	Ref
XPCMG	Proportion of reach with all three layers present	Decrease	0.09	Proportion	62	Ref
XPMGVEG	Mean vegetative cover	Decrease	0.23	Proportion	73	Ref
W1_HALL_SWAMP	Human activity metric	Decrease	1.5		60	RCMP
Substrate						
PCT_BIGR	% large substrate (>128 mm)	Decrease	27	%	73	Ref
PCT_SAFN	% sands and fines (<2 mm)	Increase	57	%	73	Ref
Shannon_Substrate	Substrate diversity	Decrease	0.53		73	Ref
XEMBED	% cobble embeddedness	Increase	55	%	73	Ref

Table 2-3a. Regional extent and distributions for chemical stressors.

Stressor	n	% Below Threshold			Concentration		
		Estimate	95% CI		Median	Mean	SD
Ions							
Alkalinity as CaCO3	558	100	100	100	200	217	100
Chloride	513	81	77	84	108	182	316
Sulfate	507	55	51	59	228	294	327
Metals (dissolved)							
Arsenic (d)	443	100	100	100	1.9	2.3	2.7
Copper (d)	443	99	99	100	1.2	2.3	3.3
Nickel (d)	443	100	100	100	2.2	4.3	15.4
Lead (d)	443	100	100	100	0.00	0.05	0.17
Selenium (d)	469	89	86	91	0.99	2.59	6.51
Zinc (d)	486	100	100	100	2.0	4.1	7.2
Metals (total)							
Arsenic (t)	458	100	100	100	2.3	2.9	7.5
Copper (t)	458	96	94	98	2.0	5.2	9.6
Nickel (t)	458	100	100	100	2.6	5.9	18.1
Lead (t)	458	95	93	97	0.08	1.57	3.85
Selenium (t)	458	87	84	89	1.20	3.33	13.24
Zinc (t)	458	100	100	100	3.9	15.8	31.1
Nutrients							
TN	503	39	35	43	0.6	2.2	4.1
Ammonia-N	516	99	97	100	0.01	1.58	19.52
TP	513	43	39	47	0.05	3.91	65.11
Pyrethroids							
Bifenthrin	430	84	81	88	0	0.8	4.2
Cyfluthrin	430	93	90	96	0	0.2	1.6
Cyhalothrin lambda	430	95	92	97	0	0.022	0.228
Cypermethrin	430	92	88	95	0	0.20	1.32
Deltamethrin	169	89	84	94	0	0.0001	0.0022
Esfenvalerate/Fenvalerate	406	98	97	100	0	0.0282	0.3271
Permethrin	430	97	95	99	0	0.146	1.769
Solids							
Suspended solids	528	75	71	79	4	16	57
Dissolved solids	226	24	19	28	856	1034	774
Field							
pH	645	85	82	88	8.05	8.07	0.62
Turbidity	418	76	72	81	1.7	7.9	48.7
Specific conductance	656	75	72	78	1034	1259	1210

Table 2-3b. Extent and distributions for chemical stressors in each land use class. Only analytes with extents greater than 5% exceeding a threshold are shown.

Stressor	n	% Below Threshold			Concentration		
		Estimate	95% CI		Median	Mean	SD
Agricultural							
Ions							
Chloride	73	84	77	90	133	209	280
Sulfate	74	31	22	39	324	424	344
Metals (dissolved)							
Selenium	68	74	64	85	3.06	6.23	12.00
Metals (total)							
Selenium	67	77	66	88	3.31	6.34	11.83
Nutrients							
TN	72	13	7	20	2.5	6.5	9.9
TP	73	28	21	35	0.08	0.50	0.78
Pyrethroids							
Bifenthrin	62	90	82	97	0	0.2	1.1
Cyfluthrin	62	95	86	100	0	0.2	0.7
Cypermethrin	62	90	80	100	0	0.08	0.45
Esfenvalerate/Fenvalerate	58	89	78	99	0	0.31	1.07
Solids							
Suspended solids	73	79	69	89	5	43	144
Dissolved solids	25	3	0	9	983	1037	383
Field							
pH	87	94	91	97	7.98	8.03	0.45
Turbidity	56	70	58	81	2.4	45.0	159.0
Specific conductance	87	69	61	78	1322	1542	888
Open							
Ions							
Sulfate	220	73	68	77	71	170	214
Metals (total)							
Lead	178	93	89	97	0.03	1.40	3.37
Selenium	178	92	88	96	0.78	1.52	2.22
Nutrients							
TN	219	71	65	77	0.2	0.5	1.2
TP	225	71	66	76	0.02	0.09	0.43
Pyrethroids							
Bifenthrin	163	95	92	98	0	0.0	0.1
Deltamethrin	74	92	86	97	0	0	0
Solids							
Suspended solids	227	89	85	93	2	4	7
Dissolved solids	108	50	42	58	493	678	490

Stressor	n	% Below Threshold			Concentration		
		Estimate	95% CI		Median	Mean	SD
Field							
Turbidity	187	87	83	92	0.9	2.3	6.8
Specific conductance	291	91	88	94	478	672	570
Urban							
Ions							
Chloride	223	66	60	72	190	303	397
Sulfate	213	42	35	48	289	391	369
Metals (dissolved)							
Selenium	207	84	80	89	1.20	3.27	7.36
Metals (total)							
Selenium	213	84	80	88	1.30	4.17	17.41
Nutrients							
TN	212	12	6	19	1.5	3.0	3.4
TP	215	17	11	22	0.11	8.35	96.04
Pyrethroids							
Bifenthrin	205	76	69	83	0	1.4	5.7
Cyfluthrin	205	90	85	95	0	0.4	2.2
Cyhalothrin lambda	205	93	88	97	0	0.041	0.313
Cypermethrin	205	88	82	93	0	0.36	1.79
Deltamethrin	74	85	75	95	0	0	0
Solids							
Suspended solids	228	61	54	69	8	22	56
Dissolved solids	93	1	0	3	1093	1388	885
Field							
pH	272	72	66	79	8.17	8.24	0.69
Turbidity	175	65	57	74	2.3	7.2	19.8
Specific conductance	278	62	56	67	1397	1800	1439

Table 2-3c. Extent and distributions for chemical stressors in each watershed. Only analytes with extents greater 5% exceeding a threshold are shown. Physical habitat variable abbreviations are provided in Table 2-2.

Stressor		n	% Below Threshold			Concentration		
			Estimate	95% CI		Median	Mean	SD
Region 4								
Ventura								
Ions	Sulfate	38	36	23	50	270	262	66
Nutrients	TN	38	74	64	84	0.1	0.5	1.0
Nutrients	TP	36	92	87	97	0	0.02	0.06
Pyrethroids	Bifenthrin	35	93	86	100	0	0.0	0.0
Solids	Dissolved solids	5	50	4	97	477	560	96
Field	Turbidity	8	76	39	100	0.5	1.9	1.7
Santa Clara								
Ions	Sulfate	75	59	50	68	221	305	333
Metals (dissolved)	Selenium	70	92	86	97	0.81	1.69	3.25
Metals (total)	Copper	59	91	85	98	0.8	6.3	16.1
Metals (total)	Lead	59	91	86	97	0.01	2.17	4.21
Metals (total)	Selenium	59	90	83	97	0.89	3.15	12.17
Nutrients	TN	70	70	61	78	0.2	0.9	2.4
Nutrients	TP	73	82	75	89	0.02	0.10	0.41
Pyrethroids	Bifenthrin	53	93	86	99	0	0.0	0.0
Pyrethroids	Cyfluthrin	53	92	85	100	0	0.1	0.6
Pyrethroids	Cypermethrin	53	94	87	100	0	0.00	0.02
Pyrethroids	Deltamethrin	33	84	73	95	0	0	0
Pyrethroids	Esfenvalerate/Fenvalerate	50	94	87	100	0	0.1178	0.6286
Solids	Suspended solids	73	91	84	98	2	16	83
Solids	Dissolved solids	45	28	15	42	667	751	467
Field	Turbidity	72	89	84	94	1.5	16.9	98.9
Calleguas								
Ions	Chloride	34	86	70	100	182	193	54
Ions	Sulfate	40	25	13	38	419	484	347
Metals (dissolved)	Selenium	38	60	46	74	4.16	7.14	11.46
Metals (total)	Selenium	37	60	47	74	4.18	7.12	11.01
Nutrients	TN	38	6	0	14	4.4	6.7	9.9
Nutrients	Ammonia-N	35	95	87	100	0.06	0.23	0.70
Nutrients	TP	37	23	6	39	0.13	0.83	1.02
Pyrethroids	Bifenthrin	37	86	76	97	0	0.2	1.0
Pyrethroids	Cypermethrin	37	92	82	100	0	0.15	0.53
Pyrethroids	Esfenvalerate/Fenvalerate	31	94	87	100	0	0.1290	0.7575
Solids	Suspended solids	33	72	56	88	6	27	89
Field	pH	34	86	75	98	7.94	8.04	0.47

Stressor		n	% Below Threshold			Concentration		
			Estimate	95% CI		Median	Mean	SD
Field	Turbidity	9	73	43	100	1.4	2.9	3.0
Field	Specific conductance	34	60	43	77	1691	1785	597
Santa Monica Bay								
Ions	Chloride	47	86	80	93	190	199	72
Ions	Sulfate	54	8	4	12	884	954	570
Metals (dissolved)	Selenium	53	41	34	49	6.61	13.76	20.47
Metals (total)	Selenium	54	45	38	53	5.33	21.80	58.27
Nutrients	TN	50	30	22	39	0.6	1.3	2.0
Nutrients	TP	49	18	11	24	0.10	0.15	0.18
Pyrethroids	Bifenthrin	42	65	52	78	0	3.5	15.6
Pyrethroids	Cyfluthrin	42	89	81	97	0	1.0	4.7
Pyrethroids	Cyhalothrin lambda	42	74	62	86	0	0.237	1.083
Pyrethroids	Cypermethrin	42	83	73	93	0	0.42	1.73
Pyrethroids	Deltamethrin	24	71	56	87	0	0	0
Pyrethroids	Esfenvalerate/Fenvalerate	42	93	86	100	0	0.0291	0.1146
Pyrethroids	Permethrin	42	86	76	95	0	1.119	4.593
Solids	Suspended solids	47	88	81	96	2	10	44
Field	Turbidity	65	70	61	80	1.8	10.9	46.0
Field	Specific conductance	69	59	52	67	1640	1899	1265
Los Angeles								
Ions	Sulfate	32	86	76	96	84	137	152
Metals (total)	Copper	26	82	67	98	7.0	10.4	10.1
Metals (total)	Lead	26	92	82	100	0.65	1.60	2.26
Nutrients	TN	31	34	19	49	1.1	2.5	2.6
Nutrients	TP	22	18	0	36	0.17	0.20	0.16
Pyrethroids	Bifenthrin	26	73	57	89	0	0.5	1.1
Pyrethroids	Cypermethrin	26	92	80	100	0	0.55	1.90
Solids	Suspended solids	19	63	43	84	5	22	35
Solids	Dissolved solids	9	28	4	52	653	1061	837
Field	pH	42	66	53	78	8.25	8.45	0.79
Field	Turbidity	8	67	33	100	0.4	7.6	11.7
Field	Specific conductance	44	91	83	100	570	838	561
San Gabriel								
Ions	Chloride	29	89	76	100	146	127	97
Ions	Sulfate	28	79	59	99	168	151	115
Metals (total)	Copper	27	94	86	100	2.7	7.0	11.4
Metals (total)	Lead	27	91	81	100	0.16	2.04	5.39
Metals (total)	Selenium	27	88	80	97	1.29	2.16	2.00
Nutrients	TN	29	36	20	52	0.6	1.6	2.1
Nutrients	TP	30	44	26	62	0.06	0.12	0.24

Stressor		n	% Below Threshold			Concentration		
			Estimate	95% CI		Median	Mean	SD
Pyrethroids	Bifenthrin	24	87	72	100	0	1.7	6.3
Pyrethroids	Cyfluthrin	24	87	72	100	0	0.8	2.9
Pyrethroids	Cyhalothrin lambda	24	87	72	100	0	0.105	0.371
Pyrethroids	Cypermethrin	24	87	72	100	0	0.82	3.10
Solids	Suspended solids	30	69	51	86	8	37	96
Solids	Dissolved solids	14	13	5	22	859	823	262
Field	pH	33	59	42	76	8.25	8.39	0.65
Field	Turbidity	17	67	44	90	2.1	4.3	4.3
<u>Region 8</u>								
Lower Santa Ana								
Ions	Chloride	29	81	68	94	179	186	91
Ions	Sulfate	24	40	22	58	300	372	248
Metals (dissolved)	Selenium	28	86	76	97	1.30	5.38	10.38
Metals (total)	Selenium	28	86	76	97	1.40	5.37	10.17
Nutrients	TN	24	10	0	20	2.2	3.4	3.5
Nutrients	TP	27	20	8	31	0.12	157.2	398.9
Pyrethroids	Bifenthrin	27	70	55	85	0	0.9	2.0
Pyrethroids	Cyhalothrin lambda	27	93	86	100	0	0.000	0.000
Pyrethroids	Permethrin	27	87	75	99	0	0.121	0.727
Solids	Suspended solids	36	63	52	75	6	11	15
Field	pH	41	87	80	94	7.98	7.97	0.64
Field	Turbidity	36	87	79	95	1.9	2.7	3.6
Field	Specific conductance	41	68	57	80	1408	1587	580
Middle Santa Ana								
Metals (dissolved)	Copper	10	89	70	100	3.1	3.9	3.5
Metals (total)	Copper	15	93	80	100	3.7	5.1	4.4
Nutrients	TN	23	16	2	30	2.0	4.1	4.4
Nutrients	TP	33	14	7	21	0.19	0.52	0.59
Solids	Suspended solids	35	72	62	83	5	8	8
Field	pH	55	65	54	75	8.20	8.29	0.90
Field	Turbidity	23	63	45	81	3.1	5.4	6.2
Field	Specific conductance	55	78	68	88	935	866	416
Upper Santa Ana								
Metals (dissolved)	Copper	12	93	81	100	0.9	1.8	2.8
Nutrients	TN	31	50	37	64	0.3	0.6	0.9
Nutrients	Ammonia-N	43	91	77	100	0.01	23.61	75.91
Nutrients	TP	42	54	42	67	0.02	0.29	0.66
Pyrethroids	Bifenthrin	15	90	77	100	0	0.0	0.0
Solids	Suspended solids	44	75	62	88	3	9	20

Stressor		n	% Below Threshold			Concentration		
			Estimate	95% CI		Median	Mean	SD
Field	pH	67	83	75	91	7.98	7.66	0.96
Field	Turbidity	32	88	77	99	0.4	1.5	2.6
San Jacinto								
Ions	Chloride	16	83	73	94	16	90	142
Nutrients	TN	14	53	41	65	0.3	0.8	1.1
Nutrients	TP	17	18	2	36	0.08	0.17	0.23
Solids	Suspended solids	17	82	70	95	2	6	9
Field	pH	27	81	73	89	7.48	7.67	0.84
Field	Turbidity	6	66	32	99	2.3	38.1	57.4
Field	Specific conductance	27	84	75	94	192	451	568
Region 9								
San Juan								
Ions	Chloride	31	65	51	79	151	205	149
Ions	Sulfate	31	43	31	56	289	450	432
Metals (dissolved)	Selenium	30	76	62	90	1.96	5.00	6.85
Metals (total)	Lead	30	94	88	100	0.00	1.83	2.68
Metals (total)	Selenium	30	75	61	89	1.99	5.10	6.75
Nutrients	TN	30	56	40	71	0.3	0.7	1.1
Nutrients	TP	27	29	18	41	0.06	1.26	4.27
Pyrethroids	Bifenthrin	30	77	64	90	0	0.7	2.0
Pyrethroids	Cyfluthrin	30	86	75	97	0	0.2	0.6
Pyrethroids	Cyhalothrin lambda	30	92	84	100	0	0.017	0.097
Pyrethroids	Cypermethrin	30	86	75	97	0	0.08	0.24
Pyrethroids	Deltamethrin	13	92	84	100	0	0	0
Solids	Suspended solids	30	87	76	97	3	7	12
Solids	Dissolved solids	30	27	18	37	1193	1331	1061
Field	Turbidity	29	83	70	96	0.9	1.8	2.6
Field	Specific conductance	31	59	47	71	1394	1690	1191
Northern San Diego								
Ions	Chloride	31	74	61	87	120	161	141
Ions	Sulfate	31	58	41	75	220	203	190
Nutrients	TN	31	16	1	31	1.2	2.3	3.3
Nutrients	TP	29	51	36	67	0.03	0.07	0.10
Solids	Suspended solids	33	86	76	97	4	6	11
Solids	Dissolved solids	7	22	0	51	780	767	268
Field	Turbidity	28	83	70	96	0.7	6.0	17.5
Field	Specific conductance	33	63	49	77	834	1046	772
Central San Diego								
Ions	Chloride	36	42	29	55	289	507	631
Ions	Sulfate	36	23	13	32	330	359	273

Stressor		n	% Below Threshold			Concentration		
			Estimate	95% CI		Median	Mean	SD
Metals (dissolved)	Selenium	31	89	78	100	1.09	1.65	1.85
Metals (total)	Selenium	31	89	78	100	1.14	1.74	2.03
Nutrients	TN	33	16	6	25	1.3	3.5	4.3
Nutrients	TP	29	12	3	21	0.09	0.10	0.06
Pyrethroids	Bifenthrin	31	77	62	92	0	2.2	5.7
Pyrethroids	Cyfluthrin	31	88	75	100	0	0.2	0.5
Pyrethroids	Cyhalothrin lambda	31	93	83	100	0	0.007	0.029
Pyrethroids	Cypermethrin	31	87	75	99	0	0.01	0.03
Pyrethroids	Deltamethrin	21	83	68	99	0	0	0
Pyrethroids	Permethrin	31	94	85	100	0	0.114	0.462
Solids	Suspended solids	35	52	36	67	9	15	23
Solids	Dissolved solids	9	16	0	38	1306	1112	517
Field	pH	36	95	86	100	7.89	7.90	0.32
Field	Turbidity	30	63	45	80	2.6	8.6	17.1
Field	Specific conductance	37	25	14	35	2112	2469	2151
Mission Bay and San Diego								
Ions	Chloride	30	37	32	42	447	398	332
Ions	Sulfate	30	41	35	46	314	345	334
Metals (dissolved)	Selenium	30	93	84	100	0.77	1.25	1.71
Metals (total)	Selenium	30	93	84	100	0.82	1.34	1.74
Nutrients	TN	28	28	19	37	1.1	2.2	3.4
Nutrients	TP	28	35	21	49	0.05	0.11	0.13
Pyrethroids	Bifenthrin	30	86	75	97	0	0.0	0.2
Pyrethroids	Cyfluthrin	30	93	86	100	0	0.0	0.1
Pyrethroids	Cyhalothrin lambda	30	91	83	99	0	0.004	0.020
Pyrethroids	Cypermethrin	30	89	79	99	0	0.00	0.02
Pyrethroids	Deltamethrin	19	94	85	100	0	0	0
Solids	Suspended solids	31	66	52	80	4	11	14
Solids	Dissolved solids	9	88	72	100	333	450	368
Field	pH	30	93	86	100	7.95	7.94	0.40
Field	Turbidity	26	64	50	77	2.5	4.8	5.1
Field	Specific conductance	30	39	32	47	2385	1933	1532
Southern San Diego								
Ions	Chloride	33	78	72	84	60	308	538
Ions	Sulfate	33	81	75	87	68	128	145
Metals (total)	Lead	30	93	84	100	0.09	1.21	2.36
Nutrients	TN	33	60	49	70	0.3	0.9	1.7
Nutrients	TP	30	38	22	54	0.04	0.23	0.83
Pyrethroids	Bifenthrin	30	98	95	100	0	0.0	0.1
Pyrethroids	Cypermethrin	30	98	95	100	0	0.00	0.03

Stressor		n	% Below Threshold			Concentration		
			Estimate	95% CI		Median	Mean	SD
Solids	Suspended solids	33	83	71	94	4	6	10
Solids	Dissolved solids	10	63	40	86	479	510	219
Field	Turbidity	29	71	55	86	1.6	3.5	4.1
Field	Specific conductance	33	54	42	65	671	1500	1911

Table 2-4. Extent of toxicity by subpopulation.

Subpopulation	n	% stream-miles with toxicity to survival	% stream-miles with toxicity to reproduction	% stream-miles with no toxicity
South Coast	431	6	25	67
Land Use				
Agricultural	67	15	30	55
Open	171	2	33	61
Urban	193	8	19	73
Watershed				
Region 4				
Ventura	34	1	15	77
Santa Clara	56	8	42	45
Calleguas	36	1	8	91
Santa Monica	38	7	33	60
Los Angeles	34	2	57	42
San Gabriel	26	1	6	90
Region 8				
Lower Santa Ana	28	0	26	67
Middle Santa Ana	22	0	4	96
Upper Santa Ana	14	11	12	77
San Jacinto	14	0	12	88
Region 9				
San Juan	25	8	23	69
Northern San Diego	30	3	23	74
Central San Diego	24	26	12	61
Mission Bay and San Diego River	26	4	31	65
Southern San Diego	24	13	11	76

Table 2-5a. Extent and mean values of selected physical habitat variables within the region. Abbreviations are provided in Table 2-2.

Variable	n	% Within Threshold			Median	Mean	SD
		Estimate	95% CI				
Biomass							
AFDM	526	82	78	85	7	652	2877
Chlorophyll a	531	83	79	87	10	165	880
PCT_CPOM	599	90	88	92	28	33	26
PCT_MAP	481	69	65	74	26	30	25
PCT_MCP	481	89	86	92	5	13	18
PCT_MIAT1	519	92	90	94	0	4	11
XMIATP	519	91	89	94	0.10	0.32	0.63
Instream habitat							
PCT_FAST	601	75	72	79	28	37	33
Shannon_Flow	601	80	76	83	2.7	2.7	0.3
Shannon_Habitat	634	68	65	72	1.4	1.2	0.5
XFC_NAT_SWAMP	634	73	69	76	51	54	41
Riparian							
W1_HALL_SWAMP	597	55	52	59	1.2	1.8	1.9
XCDENMID	617	69	66	73	43	45	35
XCMG	602	68	65	72	80	80	60
XPCMG	602	71	68	74	0.65	0.53	0.42
XPMGVEG	634	70	67	73	0.75	0.59	0.41
Substrate							
PCT_BIGR	634	49	45	52	25	30	28
PCT_SAFN	634	78	75	81	25	33	27
Shannon_Substrate	634	73	69	77	1.0	0.9	0.5
XEMBED	485	89	86	92	35	36	18

Table 2-5b. Extent and mean values of selected physical habitat variables by land use. Only variables with exceedances greater than 5% of a subpopulation are shown.

Variable		n	% Within Threshold			Median	Mean	SD
			Estimate	95% CI				
Agricultural								
Biomass	AFDM	75	72	62	81	13	703	2427
Biomass	Chlorophyll a	75	74	64	84	20	486	1837
Biomass	PCT_CPOM	76	86	79	94	36	38	27
Biomass	PCT_MAP	69	69	60	79	28	30	22
Biomass	PCT_MCP	69	88	81	95	12	18	18
InstreamHab	PCT_FAST	76	71	61	81	24	37	33
InstreamHab	Shannon_Flow	76	80	72	89	2.6	2.6	0.3
InstreamHab	Shannon_Habitat	81	80	73	87	1.4	1.3	0.4
InstreamHab	XFC_NAT_SWAMP	81	79	72	87	49	61	47
Riparian	W1_HALL_SWAMP	76	70	63	78	0.6	1.0	1.2
Riparian	XCDENMID	76	58	49	67	23	35	35
Riparian	XCMG	76	80	72	88	104	94	59
Riparian	XPCMG	76	76	68	84	0.79	0.61	0.41
Riparian	XPMGVEG	81	85	78	91	0.81	0.70	0.35
Substrate	PCT_BIGR	81	24	16	32	9	18	21
Substrate	PCT_SAFN	81	40	30	49	63	60	27
Substrate	Shannon_Substrate	81	78	69	88	0.8	0.9	0.4
Substrate	XEMBED	54	81	71	92	40	41	22
Open								
Biomass	AFDM	224	82	77	87	11	173	672
Biomass	Chlorophyll a	227	85	80	90	12	62	201
Biomass	PCT_CPOM	261	88	85	92	34	38	25
Biomass	PCT_MAP	203	83	78	88	14	21	21
Biomass	PCT_MCP	203	87	83	91	7	14	16
Biomass	PCT_MIAT1	217	94	90	97	0	4	9
Biomass	XMIATP	217	94	90	97	0.10	0.26	0.49
InstreamHab	PCT_FAST	263	92	89	95	40	46	29
InstreamHab	Shannon_Flow	263	93	90	95	2.8	2.8	0.3
InstreamHab	Shannon_Habitat	290	90	87	93	1.5	1.4	0.3
InstreamHab	XFC_NAT_SWAMP	290	93	89	97	71	72	35
Riparian	W1_HALL_SWAMP	261	91	87	94	0.2	0.5	0.8
Riparian	XCDENMID	289	85	82	89	61	58	31
Riparian	XCMG	264	93	89	98	108	106	45
Riparian	XPCMG	264	93	90	95	0.86	0.70	0.33
Riparian	XPMGVEG	290	93	90	96	0.91	0.78	0.29
Substrate	PCT_BIGR	290	82	78	86	54	49	24

Variable		n	% Within Threshold			Median	Mean	SD
			Estimate	95% CI				
Substrate	PCT_SAFN	290	88	84	91	24	29	21
Substrate	Shannon_Substrate	290	92	87	96	1.2	1.2	0.4
Substrate	XEMBED	276	91	88	94	35	36	16
Urban								
Biomass	AFDM	227	83	77	89	5	1089	3944
Biomass	Chlorophyll a	229	83	77	89	7	206	991
Biomass	PCT_CPOM	262	92	89	96	17	27	27
Biomass	PCT_MAP	209	58	50	65	37	38	27
Biomass	PCT_MCP	209	91	87	95	2	12	20
Biomass	PCT_MIAT1	232	90	86	94	0	5	12
Biomass	XMIATP	232	89	84	93	0.11	0.37	0.68
InstreamHab	PCT_FAST	262	62	55	69	14	30	34
InstreamHab	Shannon_Flow	262	68	62	74	2.6	2.6	0.2
InstreamHab	Shannon_Habitat	263	44	38	50	0.9	0.9	0.6
InstreamHab	XFC_NAT_SWAMP	263	50	45	56	19	34	36
Riparian	W1_HALL_SWAMP	260	23	87	98	2.9	3.0	1.8
Riparian	XCDENMID	252	54	48	60	20	32	35
Riparian	XCMG	262	44	39	49	22	54	62
Riparian	XPCMG	262	51	46	57	0.10	0.37	0.42
Riparian	XPMGVEG	263	44	39	49	0.09	0.37	0.42
Substrate	PCT_BIGR	263	20	15	24	1	13	21
Substrate	PCT_SAFN	263	74	69	79	25	33	30
Substrate	Shannon_Substrate	263	53	47	59	0.6	0.6	0.5
Substrate	XEMBED	155	86	80	92	35	35	20

Table 2-5c. Extent and mean values of selected physical habitat variables by watershed. Only variables with exceedances greater than 5% of a subpopulation are shown.

Variable		n	% within Threshold			Median	Mean	SD
			Estimate	95% CI				
Region 4								
Ventura								
Biomass	AFDM	37	89	79	100	4	786	3883
Biomass	Chlorophyll a	37	89	79	100	5	88	384
Biomass	PCT_MAP	24	78	60	96	19	25	22
Biomass	PCT_MCP	24	93	85	100	1	7	14
InstreamHab	PCT_FAST	36	95	90	99	36	45	26
Riparian	W1_HALL_SWAMP	36	93	87	98	0.5	0.6	0.6
Riparian	XCDENMID	37	87	75	98	58	59	32
Riparian	XPMGVEG	38	90	78	100	0.69	0.66	0.23
Substrate	PCT_BIGR	38	86	79	94	62	62	22
Santa Clara								
Biomass	AFDM	73	78	70	86	23	153	917
Biomass	Chlorophyll a	75	83	75	92	18	64	200
Biomass	PCT_CPOM	72	73	63	83	54	54	26
Biomass	PCT_MAP	66	75	66	84	28	29	21
Biomass	PCT_MCP	66	84	76	92	18	19	18
Biomass	PCT_MIAT1	70	93	87	99	0	3	8
Biomass	XMIATP	70	91	84	98	0.02	0.24	0.43
InstreamHab	PCT_FAST	72	87	80	94	28	37	27
InstreamHab	Shannon_Flow	72	92	86	98	2.8	2.8	0.3
InstreamHab	Shannon_Habitat	83	86	78	93	1.5	1.4	0.3
InstreamHab	XFC_NAT_SWAMP	83	94	89	99	61	69	34
Riparian	W1_HALL_SWAMP	72	92	87	97	0.0	0.4	0.8
Riparian	XCDENMID	83	72	63	80	37	44	32
Riparian	XCMG	72	93	90	97	112	108	44
Riparian	XPCMG	72	89	84	94	0.86	0.69	0.35
Riparian	XPMGVEG	83	94	91	98	0.90	0.81	0.25
Substrate	PCT_BIGR	83	74	67	81	47	44	24
Substrate	PCT_SAFN	83	83	77	90	30	35	23
Substrate	Shannon_Substrate	83	92	86	98	1.3	1.2	0.4
Substrate	XEMBED	75	87	81	93	34	36	17
Calleguas								
Biomass	AFDM	40	73	59	88	9	1435	3373
Biomass	Chlorophyll a	40	68	53	83	23	1035	2807
Biomass	PCT_MAP	27	61	43	80	37	36	22
InstreamHab	PCT_FAST	37	84	73	94	30	37	25
InstreamHab	Shannon_Flow	37	89	80	98	2.7	2.7	0.2

Variable		n	% within Threshold			Median	Mean	SD
			Estimate	95% CI				
InstreamHab	Shannon_Habitat	39	73	60	86	1.4	1.2	0.5
InstreamHab	XFC_NAT_SWAMP	39	74	62	86	41	38	27
Riparian	W1_HALL_SWAMP	37	28	14	43	2.7	2.6	1.3
Riparian	XCDENMID	39	60	47	72	25	33	30
Riparian	XCMG	37	67	54	81	58	56	40
Riparian	XPCMG	37	71	58	83	0.25	0.42	0.38
Riparian	XPMGVEG	39	67	55	79	0.40	0.44	0.36
Substrate	PCT_BIGR	39	27	14	41	8	18	23
Substrate	PCT_SAFN	39	62	49	76	43	42	29
Substrate	Shannon_Substrate	39	69	57	80	0.8	0.8	0.5
Substrate	XEMBED	26	89	80	99	32	38	19
Santa Monica Bay								
Biomass	AFDM	53	36	25	47	55	59	40
Biomass	Chlorophyll a	54	39	28	49	67	107	109
Biomass	PCT_CPOM	66	43	33	53	77	71	24
Biomass	PCT_MAP	60	53	42	63	40	40	26
Biomass	PCT_MCP	60	91	85	97	6	13	17
Biomass	PCT_MIAT1	60	91	85	98	0	5	13
Biomass	XMIATP	60	94	89	100	0.08	0.40	1.19
InstreamHab	PCT_FAST	66	77	70	85	17	21	17
InstreamHab	Shannon_Flow	66	86	79	93	2.7	2.8	0.3
InstreamHab	Shannon_Habitat	66	86	80	92	1.6	1.5	0.4
InstreamHab	XFC_NAT_SWAMP	66	90	85	95	84	82	44
Riparian	W1_HALL_SWAMP	66	69	61	78	0.6	1.1	1.3
Riparian	XCDENMID	66	88	82	94	83	71	31
Riparian	XCMG	66	86	81	92	138	124	54
Riparian	XPCMG	66	91	87	96	0.98	0.85	0.31
Riparian	XPMGVEG	66	85	79	91	0.95	0.81	0.34
Substrate	PCT_BIGR	66	70	63	76	43	44	28
Substrate	PCT_SAFN	66	92	87	96	17	24	20
Substrate	Shannon_Substrate	66	88	83	93	1.3	1.2	0.5
Los Angeles								
Biomass	AFDM	31	80	67	92	4	907	2294
Biomass	Chlorophyll a	31	74	61	87	7	133	364
Biomass	PCT_MAP	33	67	52	82	28	33	23
InstreamHab	PCT_FAST	44	77	65	89	53	51	37
InstreamHab	Shannon_Flow	44	72	61	83	2.6	2.6	0.2
InstreamHab	Shannon_Habitat	47	49	39	60	0.9	0.9	0.6
InstreamHab	XFC_NAT_SWAMP	47	45	33	57	14	32	36
Riparian	W1_HALL_SWAMP	44	45	33	56	2.8	2.7	2.4
Riparian	XCDENMID	47	58	45	70	21	31	34

Variable		n	% within Threshold			Median	Mean	SD
			Estimate	95% CI				
Riparian	XCMG	44	32	20	43	16	32	36
Riparian	XPCMG	44	53	40	65	0.09	0.26	0.35
Riparian	XPMGVEG	47	37	26	48	0.00	0.27	0.38
Substrate	PCT_BIGR	47	40	30	50	1	21	26
Substrate	Shannon_Substrate	47	52	38	65	0.5	0.6	0.5
San Gabriel								
Biomass	AFDM	28	72	53	92	5	1758	3644
Biomass	Chlorophyll a	28	75	57	94	6	279	550
Biomass	PCT_MAP	28	52	35	68	36	40	33
InstreamHab	PCT_FAST	40	62	46	77	27	42	39
InstreamHab	Shannon_Flow	40	69	54	83	2.5	2.6	0.3
InstreamHab	Shannon_Habitat	40	39	28	50	0.7	0.8	0.6
InstreamHab	XFC_NAT_SWAMP	40	42	29	55	14	33	40
Riparian	W1_HALL_SWAMP	38	26	19	34	3.2	3.0	1.9
Riparian	XCDENMID	40	50	38	61	11	28	33
Riparian	XCMG	40	35	25	44	9	36	45
Riparian	XPCMG	40	39	28	49	0.00	0.27	0.39
Riparian	XPMGVEG	40	29	19	40	0.00	0.24	0.35
Substrate	PCT_BIGR	40	28	18	39	0	21	30
Substrate	PCT_SAFN	40	91	82	100	6	15	20
Substrate	Shannon_Substrate	40	47	34	60	0.5	0.6	0.6
Substrate	XEMBED	24	91	77	100	34	33	18
Region 8								
Lower Santa Ana								
Biomass	AFDM	29	91	82	99	4	193	754
Biomass	Chlorophyll a	29	91	82	99	9	89	354
Biomass	PCT_MAP	27	57	43	71	39	36	18
InstreamHab	PCT_FAST	38	57	43	71	16	23	28
InstreamHab	Shannon_Flow	38	59	45	74	2.5	2.5	0.3
InstreamHab	Shannon_Habitat	38	66	55	77	1.3	1.2	0.4
InstreamHab	XFC_NAT_SWAMP	38	71	60	82	53	53	45
Riparian	W1_HALL_SWAMP	38	17	7	26	2.3	2.7	1.5
Riparian	XCDENMID	38	50	36	65	18	36	38
Riparian	XCMG	38	46	31	60	27	47	41
Riparian	XPCMG	38	52	38	66	0.10	0.34	0.40
Riparian	XPMGVEG	38	53	38	68	0.28	0.45	0.42
Substrate	PCT_BIGR	38	35	22	47	7	21	25
Substrate	PCT_SAFN	38	69	55	82	48	45	27
Substrate	Shannon_Substrate	38	78	67	88	0.8	0.8	0.4
Substrate	XEMBED	28	87	73	100	37	37	20
Middle Santa Ana								

Variable		n	% within Threshold			Median	Mean	SD
			Estimate	95% CI				
Biomass	AFDM	28	91	79	100	3	11	17
Biomass	PCT_CPOM	52	95	90	100	21	23	21
Biomass	PCT_MAP	32	87	79	95	15	21	20
Biomass	PCT_MCP	32	89	80	98	0	9	14
Biomass	PCT_MIAT1	32	77	63	91	1	13	21
Biomass	XMIATP	32	77	63	91	0.37	0.98	1.66
InstreamHab	PCT_FAST	53	42	31	53	2	22	32
InstreamHab	Shannon_Flow	53	39	29	50	2.3	2.4	0.4
InstreamHab	Shannon_Habitat	54	29	19	40	0.9	0.8	0.6
InstreamHab	XFC_NAT_SWAMP	54	41	32	49	11	28	35
Riparian	W1_HALL_SWAMP	52	49	40	58	1.6	2.0	1.7
Riparian	XCDENMID	54	39	29	48	2	27	36
Riparian	XCMG	53	54	46	62	42	51	49
Riparian	XPCMG	53	47	37	57	0.00	0.36	0.42
Riparian	XPMGVEG	54	58	51	66	0.41	0.46	0.43
Substrate	PCT_BIGR	54	23	17	29	0	17	29
Substrate	PCT_SAFN	54	63	56	69	31	41	40
Substrate	Shannon_Substrate	54	43	33	53	0.4	0.6	0.5
Substrate	XEMBED	28	94	86	100	33	33	20
Upper Santa Ana								
Biomass	PCT_MAP	27	90	82	98	3	13	19
Biomass	PCT_MCP	27	93	85	100	1	8	16
Biomass	XMIATP	27	94	87	100	0.14	0.28	0.52
InstreamHab	PCT_FAST	47	93	87	99	81	66	33
InstreamHab	Shannon_Flow	47	69	57	81	2.6	2.6	0.2
InstreamHab	Shannon_Habitat	52	58	47	68	1.2	1.1	0.5
InstreamHab	XFC_NAT_SWAMP	52	88	81	95	58	63	39
Riparian	W1_HALL_SWAMP	47	96	91	100	0.2	0.4	0.5
Riparian	XCDENMID	52	68	58	78	66	55	38
Riparian	XCMG	47	75	65	86	73	79	54
Riparian	XPCMG	47	63	51	74	0.68	0.51	0.42
Riparian	XPMGVEG	52	79	70	89	0.72	0.64	0.37
Substrate	PCT_BIGR	52	82	74	90	60	55	24
Substrate	PCT_SAFN	52	92	87	98	25	29	17
Substrate	Shannon_Substrate	52	92	86	99	1.1	1.1	0.4
Substrate	XEMBED	49	88	80	96	38	41	11
San Jacinto								
Biomass	AFDM	17	91	79	100	12	19	24
Biomass	PCT_MAP	22	88	76	99	5	13	15
Biomass	PCT_MCP	22	77	62	92	16	20	20
InstreamHab	PCT_FAST	26	44	31	58	5	20	28

Variable		n	% within Threshold			Median	Mean	SD
			Estimate	95% CI				
InstreamHab	Shannon_Flow	26	53	38	69	2.4	2.5	0.2
InstreamHab	Shannon_Habitat	27	72	58	85	1.3	1.2	0.4
Riparian	W1_HALL_SWAMP	26	65	52	77	1.0	1.4	1.4
Riparian	XCDENMID	27	81	74	89	85	69	33
Riparian	XCMG	26	95	87	100	80	93	49
Riparian	XPCMG	26	79	67	91	0.77	0.67	0.39
Riparian	XPMGVEG	27	90	81	99	0.86	0.75	0.30
Substrate	PCT_BIGR	27	65	55	74	39	34	26
Substrate	PCT_SAFN	27	70	56	84	44	46	26
Substrate	Shannon_Substrate	27	83	71	95	1.1	1.0	0.4
Substrate	XEMBED	23	90	79	100	41	41	9
Region 9								
San Juan								
Biomass	AFDM	31	76	62	90	6	1916	7004
Biomass	Chlorophyll a	31	75	60	90	18	123	333
Biomass	PCT_MAP	28	48	31	65	42	41	25
Biomass	PCT_MCP	28	92	85	99	3	10	14
Biomass	PCT_MIAT1	30	82	70	93	0	7	12
Biomass	XMIATP	30	85	75	95	0.04	0.45	0.95
InstreamHab	PCT_FAST	31	83	72	94	31	36	26
InstreamHab	Shannon_Habitat	31	76	63	90	1.4	1.2	0.5
InstreamHab	XFC_NAT_SWAMP	31	74	59	88	46	43	29
Riparian	W1_HALL_SWAMP	31	46	33	58	2.1	2.5	2.1
Riparian	XCDENMID	31	77	62	91	53	50	29
Riparian	XCMG	31	71	56	87	77	74	53
Riparian	XPCMG	31	79	67	92	0.57	0.54	0.36
Riparian	XPMGVEG	31	69	54	83	0.72	0.57	0.42
Substrate	PCT_BIGR	31	54	39	69	29	29	23
Substrate	PCT_SAFN	31	88	80	97	39	36	21
Substrate	Shannon_Substrate	31	69	54	83	0.7	0.8	0.4
Substrate	XEMBED	25	90	80	99	34	34	14
Northern San Diego								
Biomass	AFDM	36	91	84	99	4	12	18
Biomass	Chlorophyll a	36	94	88	100	4	13	26
Biomass	PCT_CPOM	31	90	79	100	41	45	16
Biomass	PCT_MAP	29	76	63	89	13	21	23
Biomass	PCT_MCP	29	79	66	92	15	21	19
InstreamHab	PCT_FAST	31	73	61	85	26	25	24
InstreamHab	Shannon_Flow	31	82	68	96	2.7	2.6	0.3
Riparian	W1_HALL_SWAMP	31	96	91	100	0.1	0.4	0.5
Riparian	XCDENMID	29	93	87	100	70	71	25

Variable		n	% within Threshold			Median	Mean	SD
			Estimate	95% CI				
Substrate	PCT_BIGR	33	55	38	72	28	31	26
Substrate	PCT_SAFN	33	45	20	70	58	57	24
Substrate	Shannon_Substrate	33	84	72	96	1.1	1.0	0.4
Substrate	XEMBED	21	75	54	97	35	40	21
Central San Diego								
Biomass	PCT_CPOM	27	78	62	94	55	55	22
Biomass	PCT_MAP	26	87	76	98	21	22	22
Biomass	PCT_MCP	26	86	74	99	12	20	26
Biomass	PCT_MIAT1	26	78	62	93	9	13	14
Biomass	XMIATP	26	69	51	88	0.66	0.76	0.64
InstreamHab	PCT_FAST	27	70	53	88	12	21	25
InstreamHab	Shannon_Flow	27	85	74	97	2.7	2.7	0.2
InstreamHab	Shannon_Habitat	31	74	58	91	1.5	1.4	0.5
InstreamHab	XFC_NAT_SWAMP	31	80	68	93	70	62	38
Riparian	W1_HALL_SWAMP	27	28	12	44	2.1	2.1	1.1
Riparian	XCMG	28	94	87	100	137	132	55
Riparian	XPCMG	28	90	78	100	0.90	0.77	0.34
Riparian	XPMGVEG	31	94	89	100	0.95	0.88	0.24
Substrate	PCT_BIGR	31	27	13	41	13	18	20
Substrate	PCT_SAFN	31	43	27	59	62	56	29
Substrate	Shannon_Substrate	31	80	65	95	1.1	1.0	0.5
Substrate	XEMBED	23	77	61	93	42	42	23
Mission Bay and San Diego								
Biomass	AFDM	30	95	87	100	4	10	13
Biomass	PCT_CPOM	27	90	82	97	47	48	18
Biomass	PCT_MAP	27	81	68	94	12	21	21
Biomass	PCT_MCP	27	72	58	86	15	22	18
Biomass	PCT_MIAT1	27	77	63	91	2	12	18
Biomass	XMIATP	27	77	62	91	0.44	0.71	0.68
InstreamHab	PCT_FAST	27	66	54	77	17	29	30
InstreamHab	Shannon_Flow	27	78	66	90	2.8	2.8	0.3
InstreamHab	Shannon_Habitat	27	84	75	94	1.5	1.4	0.4
InstreamHab	XFC_NAT_SWAMP	27	88	81	95	82	75	39
Riparian	W1_HALL_SWAMP	27	52	42	62	0.4	1.6	1.8
Riparian	XCDENMID	23	85	76	94	66	53	29
Riparian	XCMG	27	84	75	94	131	110	54
Riparian	XPCMG	27	84	75	94	0.86	0.69	0.35
Riparian	XPMGVEG	27	92	84	100	0.99	0.78	0.31
Substrate	PCT_BIGR	27	51	37	65	28	29	26
Substrate	PCT_SAFN	27	66	51	82	40	44	26
Substrate	Shannon_Substrate	27	88	81	95	1.1	1.1	0.5

Variable		n	% within Threshold			Median	Mean	SD
			Estimate	95% CI				
Substrate	XEMBED	21	91	82	100	39	38	18
Biomass	AFDM	32	76	62	90	5	23	35
Southern San Diego								
Biomass	PCT_CPOM	25	76	62	90	49	50	23
Biomass	PCT_MAP	25	66	50	82	10	24	28
Biomass	PCT_MCP	25	56	36	76	35	34	23
Biomass	PCT_MIAT1	25	89	80	99	4	8	9
Biomass	XMIATP	25	92	82	100	0.51	0.55	0.37
InstreamHab	PCT_FAST	26	85	77	92	29	32	21
InstreamHab	Shannon_Flow	26	94	87	100	2.9	2.8	0.2
InstreamHab	Shannon_Habitat	28	85	74	96	1.4	1.4	0.3
InstreamHab	XFC_NAT_SWAMP	28	94	85	100	60	67	36
Riparian	W1_HALL_SWAMP	25	93	87	99	0.3	0.5	0.6
Riparian	XCDENMID	24	90	77	100	53	58	28
Riparian	XPCMG	26	91	80	100	0.76	0.64	0.33
Substrate	PCT_BIGR	28	48	30	66	25	28	22
Substrate	PCT_SAFN	28	51	33	68	51	52	23
Substrate	Shannon_Substrate	28	95	88	100	1.1	1.0	0.3
Substrate	XEMBED	20	86	72	100	37	39	16

Table 2-6. Relative (RR) and attributable (AR) risks for selected indicators. n: number of sites included in the analysis. 95% CI: 95% confidence interval around estimate. (t) indicates that the total fraction of metals were used in the analysis. (d) indicates that the dissolved fraction of metals were used in the analysis. VH: Very high priority (i.e., attributable risk ≥ 0.25 for at least 1 indicator). H: High priority (i.e., attributable risk ≥ 0.1 for at least 1 indicator). M: Moderate priority (i.e., relative risk > 1). L: Low priority (relative risk ≤ 1). Physical habitat variable abbreviations are provided in Table 2-2. *Some chemistry variables are excluded because they had too few exceedances of thresholds to permit relative risk analysis.

Stressor	Priority	CSCI							D18							S2						
		RR	95% CI		AR	95% CI		n	RR	95% CI		AR	95% CI		n	RR	95% CI		AR	95% CI		n
Chemistry																						
Nutrients																						
TP	VH	2.8	2.1	3.7	0.51	0.39	0.61	469	2.4	1.8	3.1	0.46	0.34	0.56	411	2.1	1.7	2.6	0.08	0.06	0.11	411
TN	VH	2.7	2.0	3.8	0.51	0.36	0.63	473	1.7	1.4	2.2	0.32	0.18	0.43	439	2.7	1.9	3.8	0.53	0.37	0.65	439
NH4	M	1.1	0.5	2.5	0.00	0.00	0.01	473	1.0	0.5	2.4	0.00	0.00	0.01	412	0.6	0.1	2.9	0.00	0.00	0.00	412
Metals																						
Se (d)	M	1.8	1.6	2.0	0.08	0.05	0.11	454	1.5	1.4	1.7	0.06	0.04	0.09	437	1.5	1.3	1.8	0.06	0.03	0.09	438
Cu (d)	M	1.7	1.6	1.8	0.00	0.00	0.01	428	1.6	1.5	1.7	0.00	0.00	0.00	435	1.7	1.5	1.8	0.00	0.00	0.00	437
Se (t)	M	1.5	1.3	1.7	0.06	0.03	0.09	441	1.4	1.2	1.6	0.05	0.02	0.08	450	1.4	1.2	1.6	0.05	0.02	0.08	452
Cu (t)	M	1.4	1.1	1.8	0.02	0.00	0.04	441	1.2	0.9	1.7	0.01	0.00	0.03	450	1.6	1.4	1.9	0.02	0.01	0.04	452
Pb (t)	L	0.8	0.5	1.3	0.00	0.00	0.01	441	0.6	0.4	1.1	0.00	0.00	0.00	450	1.0	0.7	1.4	0.00	0.00	0.02	452
Pyrethroids																						
Bifenthrin	M	1.6	1.4	1.9	0.09	0.05	0.13	415	1.4	1.2	1.7	0.06	0.03	0.10	423	1.5	1.2	1.7	0.07	0.03	0.10	425
Delta/ Tralomethrin	M	1.6	1.1	2.3	0.05	0.00	0.11	162	1.1	0.7	1.5	0.01	0.00	0.04	168	0.4	0.2	0.9	0.00	0.00	0.00	168
Cypermethrin	M	1.5	1.3	1.8	0.04	0.01	0.07	415	1.2	0.9	1.6	0.01	0.00	0.04	423	1.4	1.1	1.8	0.03	0.00	0.06	425
Cyfluthrin	M	1.4	1.2	1.8	0.03	0.00	0.06	415	1.3	1.0	1.7	0.02	0.00	0.04	423	1.3	0.9	1.7	0.02	0.00	0.04	425
Cyhalothrin	M	1.3	1.0	1.6	0.01	0.00	0.03	415	1.1	0.8	1.6	0.01	0.00	0.03	423	1.0	0.7	1.5	0.00	0.00	0.02	425
Esfenvalerate/ Fenvalerate	M	1.3	0.8	2.1	0.01	0.00	0.02	391	1.2	0.8	2.0	0.00	0.00	0.01	399	1.2	0.7	2.0	0.00	0.00	0.01	401
Permethrin	M	1.1	0.7	1.6	0.00	0.00	0.02	415	1.6	1.5	1.7	0.02	0.01	0.03	423	0.8	0.5	1.4	0.00	0.00	0.01	425
Other chemistry																						
TDS	VH	5.2	2.1	12.6	0.76	0.44	0.90	221	1.8	1.3	2.6	0.38	0.16	0.55	222	3.1	1.9	5.3	0.62	0.39	0.76	222
pH	H	1.9	1.7	2.1	0.12	0.08	0.16	593	1.2	1.0	1.5	0.03	0.00	0.07	492	1.6	1.4	1.8	0.08	0.05	0.12	491
Cl	H	1.9	1.6	2.1	0.14	0.09	0.19	489	1.3	1.1	1.5	0.05	0.01	0.09	436	1.1	0.9	1.3	0.02	0.00	0.06	437
SO4	VH	1.8	1.5	2.1	0.26	0.17	0.34	489	1.5	1.3	1.7	0.19	0.11	0.26	459	1.4	1.2	1.7	0.17	0.08	0.24	459
SpCond	H	1.7	1.5	1.9	0.14	0.10	0.18	603	1.5	1.3	1.7	0.13	0.08	0.18	494	1.5	1.3	1.8	0.13	0.08	0.18	493
TSS	H	1.7	1.4	2.0	0.14	0.08	0.19	485	1.3	1.1	1.6	0.07	0.03	0.12	422	1.2	1.0	1.4	0.04	0.00	0.10	423

Stressor	Priority	CSCI							D18							S2						
		RR	95% CI		AR	95% CI		n	RR	95% CI		AR	95% CI		n	RR	95% CI		AR	95% CI		n
Turbidity	H	1.5	1.2	1.8	0.10	0.04	0.16	379	1.2	1.0	1.5	0.06	0.00	0.12	292	0.9	0.7	1.2	0.00	0.00	0.05	289
PHAB																						
Biomass																						
PCT_MAP	H	1.5	1.3	1.8	0.15	0.08	0.21	433	1.3	1.1	1.5	0.08	0.02	0.14	432	1.5	1.3	1.7	0.14	0.08	0.19	431
PCT_CPOM	M	1.2	1.0	1.5	0.02	0.00	0.04	534	1.1	0.9	1.4	0.01	0.00	0.04	494	1.0	0.8	1.2	0.00	0.00	0.02	493
Chl a	M	1.2	0.9	1.4	0.03	0.00	0.07	495	1.2	1.0	1.4	0.03	0.00	0.06	480	1.3	1.1	1.5	0.05	0.02	0.09	479
PCT_MIAT1	M	1.1	0.9	1.5	0.01	0.00	0.04	470	0.9	0.7	1.2	0.00	0.00	0.01	469	0.8	0.6	1.2	0.00	0.00	0.01	468
XMIATP	M	1.1	0.9	1.5	0.01	0.00	0.04	470	0.9	0.7	1.2	0.00	0.00	0.01	469	1.0	0.7	1.3	0.00	0.00	0.02	468
AFDM	M	1.0	0.8	1.3	0.01	0.00	0.05	490	1.1	0.9	1.3	0.02	0.00	0.06	477	1.2	1.0	1.4	0.04	0.00	0.08	476
PCT_MCP	L	0.9	0.7	1.2	0.00	0.00	0.02	433	0.9	0.7	1.2	0.00	0.00	0.02	432	0.8	0.6	1.1	0.00	0.00	0.00	431
Substrate																						
PCT_BIGR	VH	3.1	2.5	3.9	0.51	0.42	0.59	568	2.0	1.7	2.4	0.34	0.26	0.42	494	2.0	1.7	2.4	0.35	0.26	0.42	493
Shannon_Substrate	VH	2.4	2.1	2.7	0.27	0.21	0.32	568	1.4	1.2	1.7	0.11	0.05	0.16	494	1.6	1.4	1.8	0.14	0.09	0.19	493
XEMBED	M	1.3	0.9	1.9	0.04	0.00	0.08	432	1.5	1.3	1.9	0.04	0.01	0.07	374	1.7	1.3	2.3	0.04	0.02	0.07	372
PCT_SAFN	H	1.3	1.1	1.5	0.06	0.02	0.10	568	1.5	1.3	1.7	0.11	0.07	0.14	494	1.3	1.1	1.5	0.06	0.02	0.10	493
Instream habitat																						
XFC_NAT	VH	2.5	2.2	2.9	0.30	0.24	0.35	568	1.3	1.1	1.5	0.07	0.02	0.12	494	1.6	1.4	1.9	0.15	0.10	0.20	493
Shannon_Habitat	VH	2.3	2.0	2.6	0.28	0.22	0.34	568	1.3	1.1	1.5	0.09	0.04	0.15	494	1.6	1.4	1.9	0.17	0.11	0.22	493
PCT_FAST	H	1.7	1.4	1.9	0.14	0.09	0.19	536	1.3	1.1	1.5	0.07	0.02	0.11	494	1.3	1.1	1.5	0.07	0.02	0.11	493
Shannon_Flow	H	1.6	1.4	1.9	0.11	0.07	0.16	536	1.3	1.1	1.5	0.05	0.01	0.09	494	1.4	1.2	1.7	0.07	0.03	0.11	493
Riparian																						
W1_HALL	VH	3.0	2.5	3.6	0.47	0.40	0.54	534	1.8	1.5	2.1	0.25	0.18	0.32	494	1.8	1.6	2.1	0.26	0.19	0.33	493
XCMG	VH	2.4	2.1	2.7	0.30	0.25	0.36	537	1.4	1.2	1.6	0.11	0.06	0.16	494	1.5	1.3	1.8	0.14	0.09	0.20	493
XPMGVEG	VH	2.1	1.9	2.5	0.25	0.19	0.30	568	1.4	1.3	1.7	0.12	0.07	0.17	494	1.5	1.3	1.7	0.14	0.08	0.19	493
XPCMG	H	2.0	1.8	2.3	0.23	0.17	0.28	537	1.3	1.1	1.5	0.07	0.02	0.12	494	1.4	1.2	1.6	0.11	0.06	0.15	493
XCDENMID	H	1.9	1.7	2.3	0.22	0.16	0.28	551	1.2	1.0	1.4	0.05	0.00	0.10	478	1.3	1.1	1.5	0.08	0.03	0.14	477
Toxicity																						
Toxicity (lethal)	M	1.3	1.0	1.7	0.02	0.00	0.04	420	1.2	1.0	1.6	0.02	0.00	0.03	437	1.3	1.1	1.7	0.02	0.00	0.04	438
Toxicity (all endpoints)	M	1.0	0.8	1.2	0.00	0.00	0.05	420	1.2	1.0	1.4	0.05	0.00	0.11	437	1.0	0.8	1.2	0.01	0.00	0.06	438

Table 2-7. Summary of stressor prioritization.

Very high (AR > 0.25)	High (AR 0.1 to 0.25)	Moderate (RR >1)	Low (RR <1)
Water Chemistry	Water Chemistry	Water Chemistry	Water Chemistry
Nutrients	*Other chemistry*	*Nutrients*	*Metals*
TP	Cl	NH4	Pb (t)
TN	pH	*Metals*	Habitat
Habitat	TSS	As (t)	*Biomass*
Instream habitat	SpCond	Se (t, d)	PCT_MCP
XFC_NAT	Habitat	Cu (t, d)	
Shannon_Habitat	*Biomass*	*Pyrethroids*	
Substrate	PCT_MAP	Delta/Tralomethrin	
Shannon_Substrate	*Instream habitat*	Esfenvalerate/Fenvalerate	
PCT_BIGR	Shannon_Flow	Permethrin	
Riparian	PCT_FAST	Cyhalothrin	
XPMGVEG	*Substrate*	Cyfluthrin	
XCMG	PCT_SAFN	Cypermethrin	
W1_HALL	*Riparian*	Bifenthrin	
	XCDENMID	Habitat	
	XPCMG	*Biomass*	
		PCT_MIAT1	
		XMIATP	
		PCT_CPOM	
		AFDM	
		Chl a	
		Substrate	
		XEMBED	
		Toxicity	
		Reproduction	
		Survival	

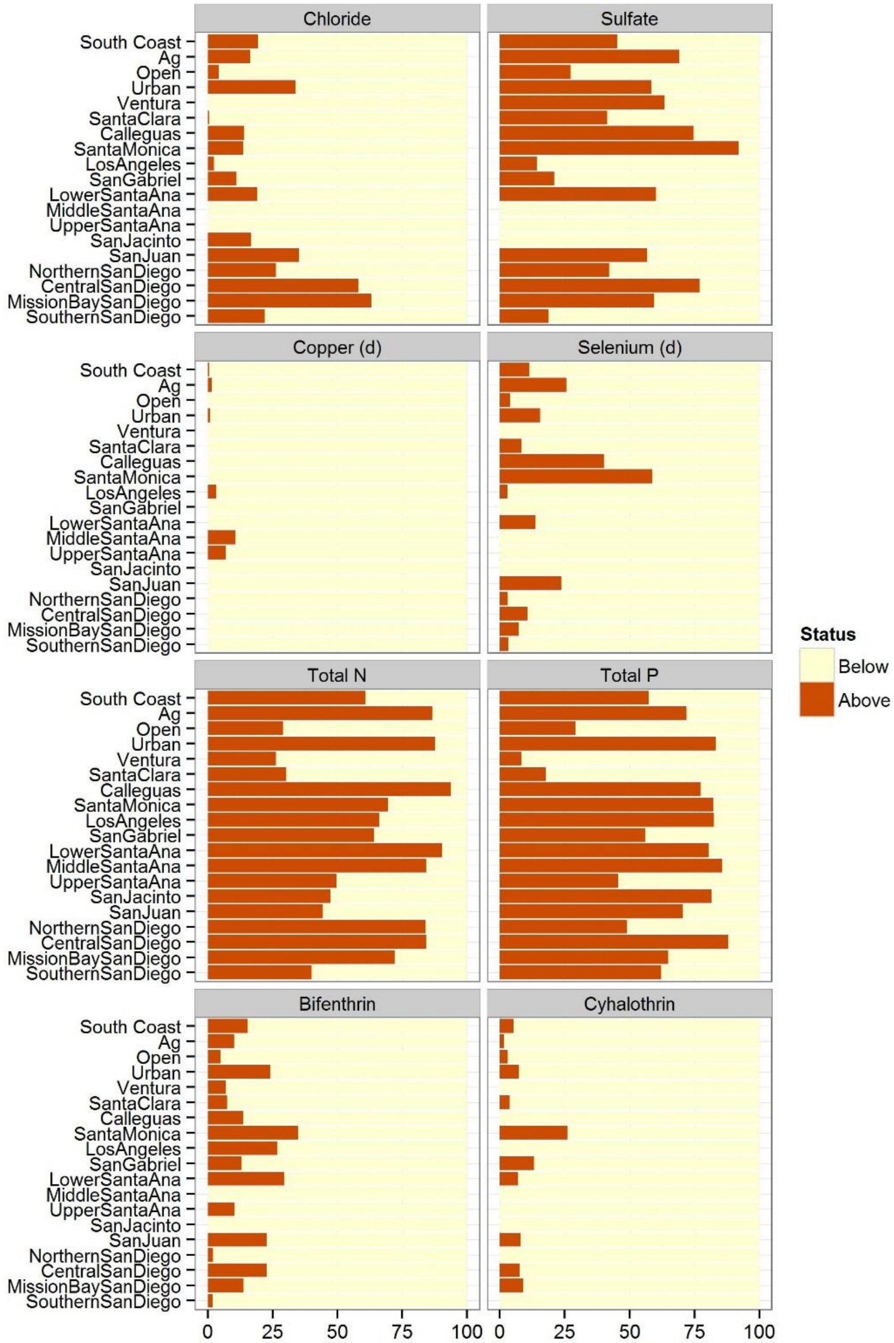


Figure 2-1. Extents of selected water-chemistry variables exceeding thresholds.

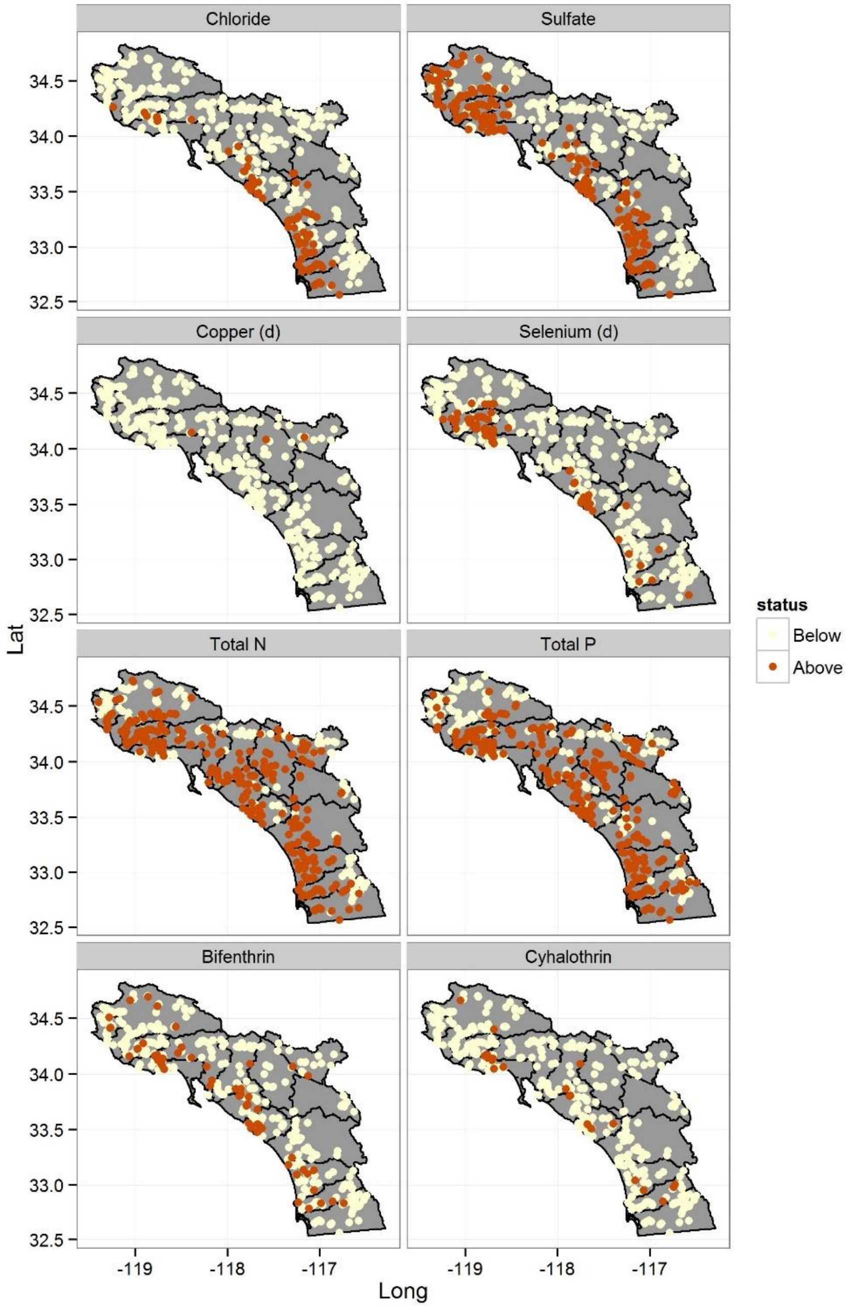


Figure 2-2. Maps of selected water-chemistry variables

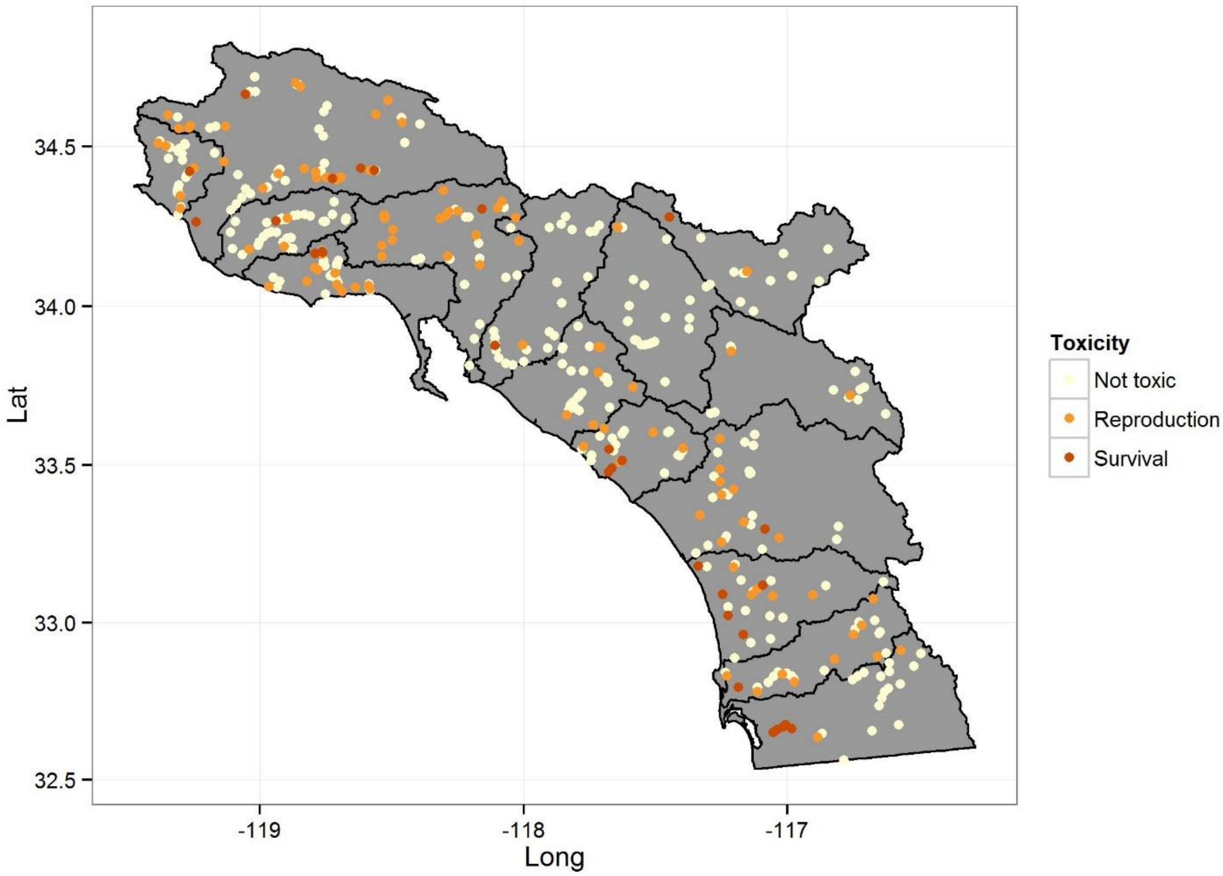


Figure 2-3. Map of toxicity.

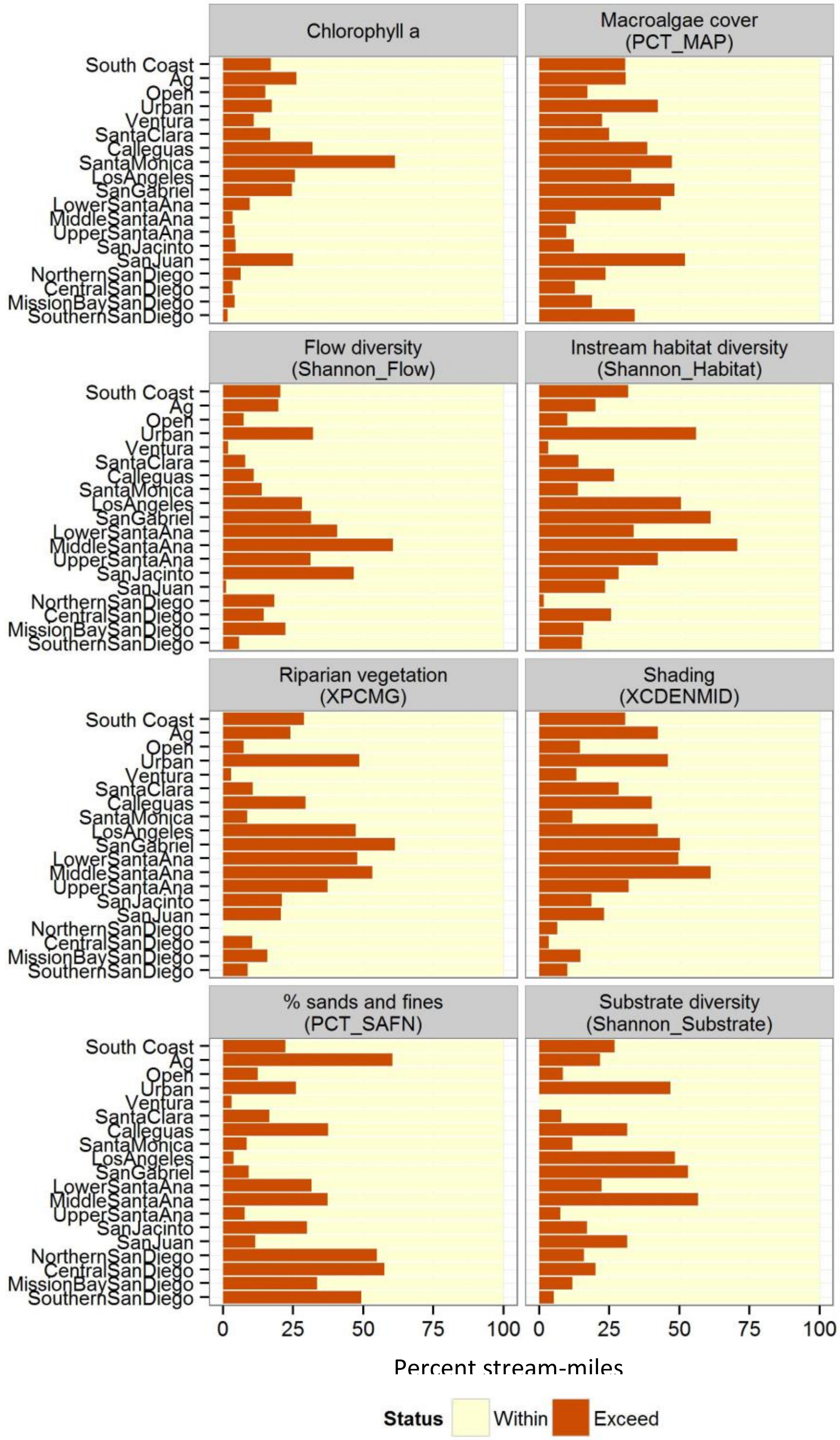


Figure 2-4. Extents of selected physical habitat variables.

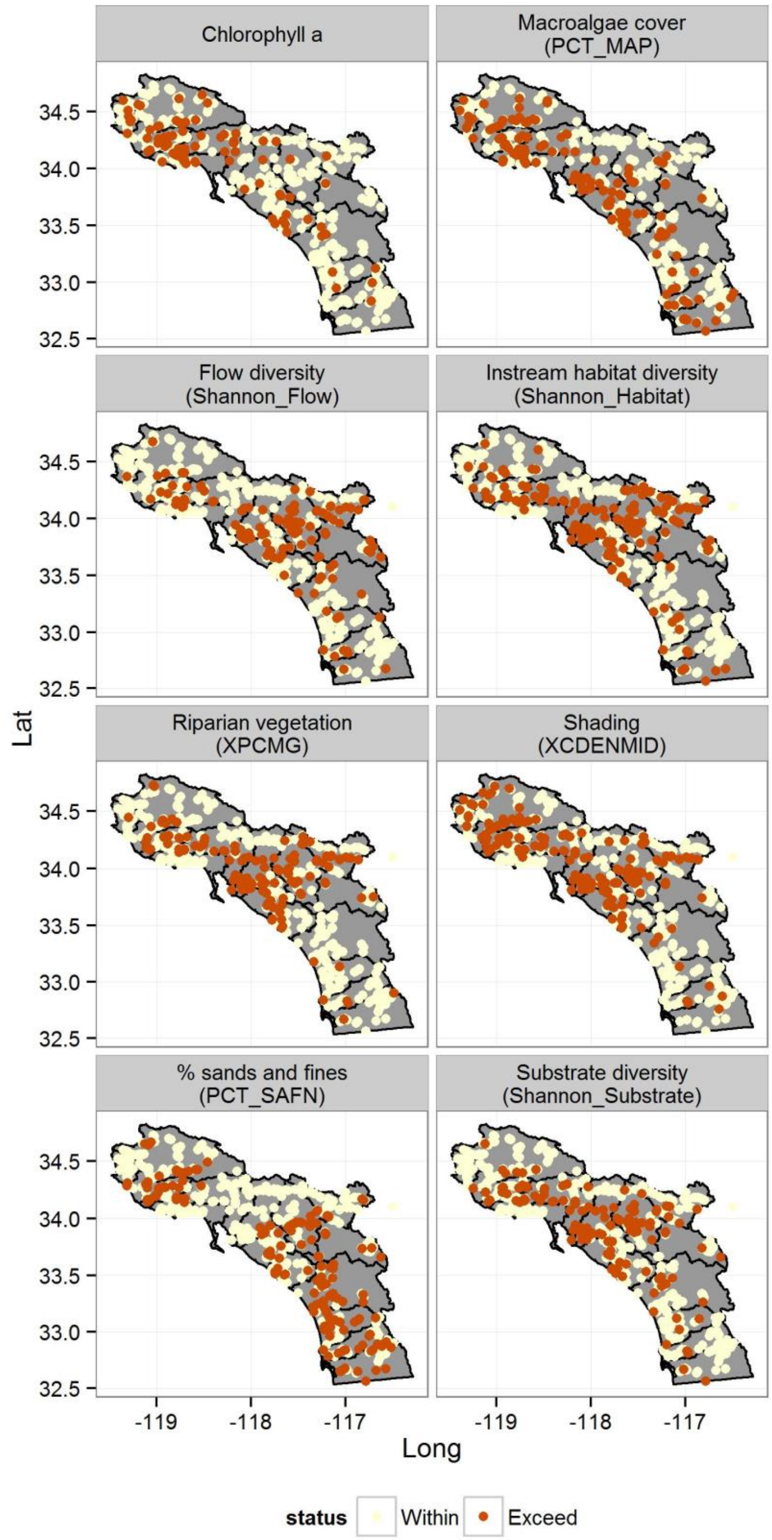


Figure 2-5. Map of selected physical habitat variables.

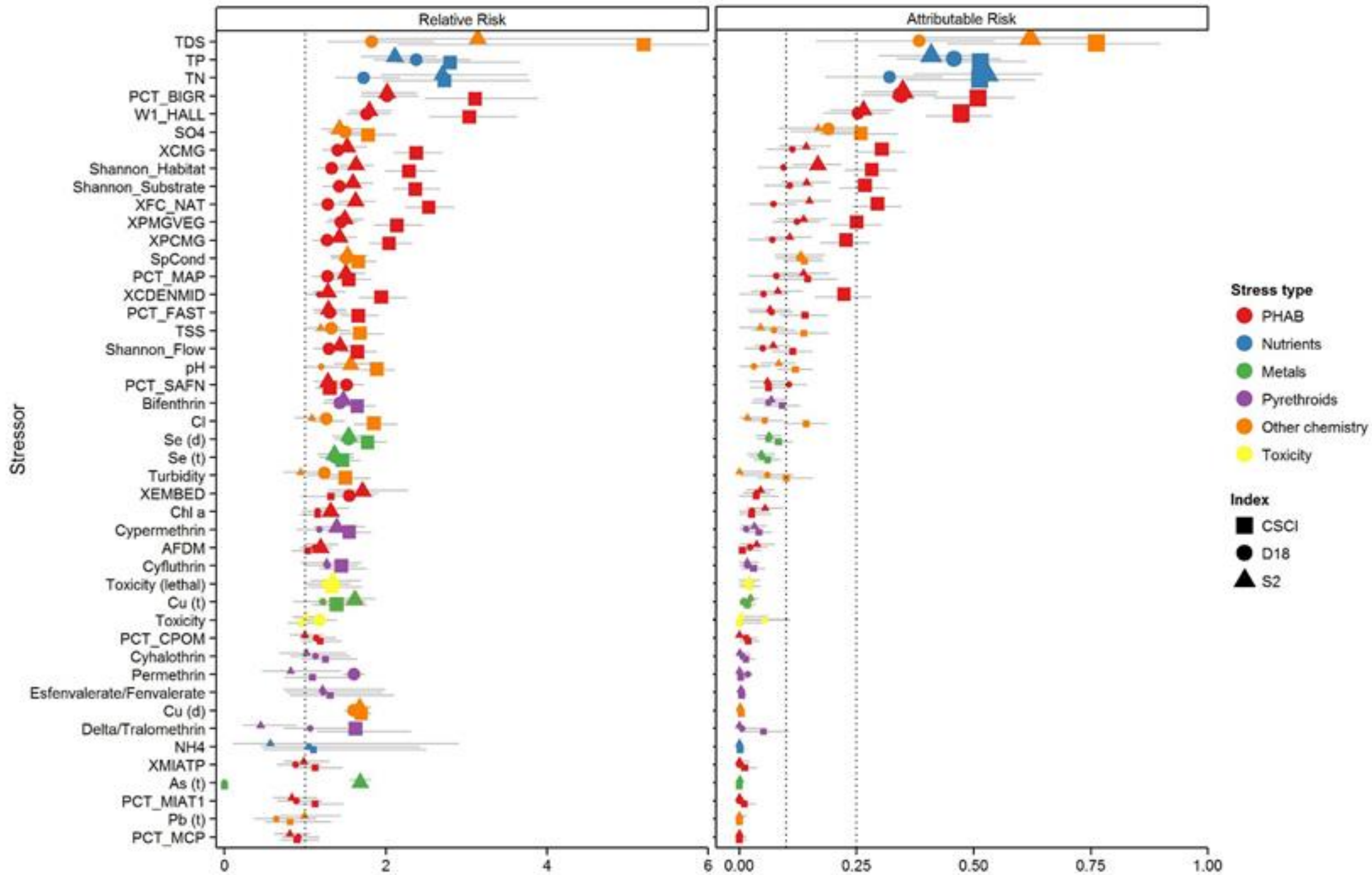


Figure 2.6. Relative and attributable risks. The horizontal lines represent the 95% confidence interval around each estimate. The dotted vertical lines represent the thresholds used to prioritize stressors.

QUESTION 3: HOW ARE BIOLOGICAL CONDITIONS CHANGING OVER TIME?

Murrieta Creek, Fall 2003

Murrieta Creek, Spring 2004

Changes in land use, such as the installation of a sand mining operation, can profoundly alter the habitat and degrade biological condition.
Photos by Scott Johnson.

Introduction

Analysis of trends allows managers to assess the effects of policies that have been implemented during the study period, the influence of disturbances like wildfire, or other activities that might change the biological condition of streams in the region. Changes observed in the region provide context to understanding site specific changes. For example, if conditions deteriorate in less disturbed areas (such as open streams), then degradation observed at an urban site might be attributable to regional stressors, such as climate change or atmospheric deposition of nutrients, rather than to management activities.

Methods

Data Collection

Data were collected as described in the Survey Overview.

Data Aggregation

Where multiple samples were collected at a single site within a year, data were aggregated as the maximum value within a site. Missing values were ignored for all relevant analyses, where appropriate.

Thresholds

Thresholds were applied as described in the section on Question 1.

Weighted Magnitudes and Extent Estimates

Weighted estimates were calculated as described in the section on Question 1, using each year (or year within land use class) as a stratum. Extents of streams in each condition class were estimated for the CSCI, S2, D18, and CRAM. In addition, the extent of streams intact for all indicators was estimated as well.

Results

All data used in this report can be downloaded from
ftp.sccwrp.org/pub/download/SMCReport/SMCDataFor5yearReport.zip.

Since 2009, no obvious trends were evident for any indicator, although all indicators showed a slight depression in scores in the year 2010 (Tables 3-1 and 3-2; Figure 3-1). The median score for the CSCI, S2, and CRAM fluctuated between Class 2 and 3, while D18 fluctuated between Class 3 and 4. The percent of streams that were intact for all four indicators was highest (at 36%) in 2012, but was only 14% in 2010 (Figure 3-2). Most of the fluctuations in score affected the open streams, while the extent of healthy agricultural and urban streams remained low throughout the survey (Table 3-1, 3-2). Extent estimates were particularly imprecise for agricultural streams, as in some years very few of these sites were sampled (e.g., 5 agricultural sites were sampled for all indicators in 2011 and 2012), leading to erratic confidence intervals

(Figure 3-1). Although CSCI scores were generally high in the earlier years of the survey, these estimates were based on very small sample sizes (<25 sites in any year), and should be interpreted with caution.

Discussion

We were unable to detect trends in condition. Our inability to detect trends stems from the relatively short time frame of the survey (i.e., 5 years), as well as a study design that did not include site revisits over multiple years. These two characteristics of the survey make it difficult to distinguish trends from natural variation driven by climate or other factors. Given that a different set of sites was examined each year, the regional focus of the program, and that only five years of data are presented, it is not surprising that no distinct trends were observed. For a trend at this regional scale to be evident, a longer time period would be required and/or site revisits. It is possible that site-specific management activities affecting stream health were within the sample frame, but may have been obscured by the overall regional focus. Revisiting sites sampled in early years of this survey would provide site-specific trend estimates, which could then provide a better estimate of trends across the region. Additionally, we would be able to explore potential drivers of any observed trends.

Table 3-1. Medians for key indicators by year.

Subpopulation	2009	2010	2011	2012	2013
South Coast					
CSCI	0.71	0.70	0.81	0.80	0.65
D18	55	50	54	59	57
S2	37	34	39	43	50
CRAM	71	62	72	69	67
Agricultural					
CSCI	0.70	0.74	0.79	0.79	0.71
D18	49	49	67	61	37
S2	25	17	17	41	38
CRAM	64	66	66	74	72
Open					
CSCI	0.95	0.77	0.93	0.95	0.96
D18	75	67	68	71	75
S2	83	75	52	68	61
CRAM	82	78	83	82	84
Urban					
CSCI	0.65	0.52	0.61	0.67	0.53
D18	52	41	41	39	35
S2	33	26	27	33	48
CRAM	56	45	40	37	52

Table 3-2. Percent of stream-miles within the 10th percentile of scores at reference sites for each year

Subpopulation	2009	2010	2011	2012	2013
South Coast					
CSCI	41	28	56	52	36
D18	41	35	38	45	43
S2	34	41	36	44	59
CRAM	46	34	50	48	39
Multiple indicators	23	14	24	36	31
Agricultural					
CSCI	42	39	47	35	39
D18	28	19	61	33	42
S2	15	4	19	28	17
CRAM	25	36	35	77	51
Multiple indicators	2	8	0	40	22
Open					
CSCI	84	46	88	87	82
D18	70	62	60	71	79
S2	70	86	54	84	72
CRAM	87	70	91	85	89
Multiple indicators	57	34	51	83	79
Urban					
CSCI	8	12	19	17	7
D18	20	24	17	26	20
S2	11	23	19	12	58
CRAM	23	13	12	15	11
Multiple indicators	1	4	0	1	3

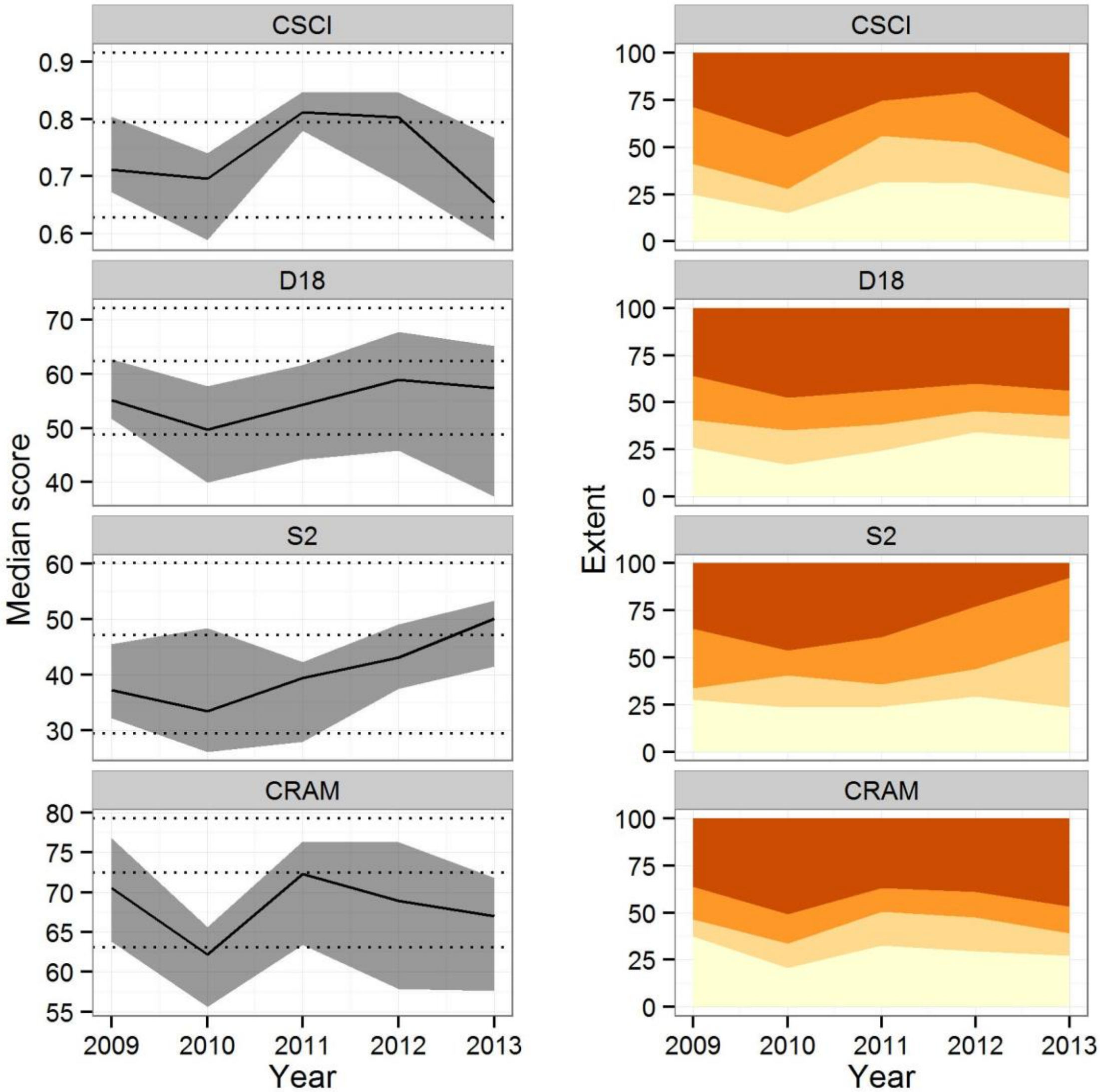


Figure 3-1. Median score and extent of condition classes by year for each indicator. The gray band in the left panel indicates the 95% confidence interval. Color in the right panel indicates condition class; lighter colors indicate better condition.

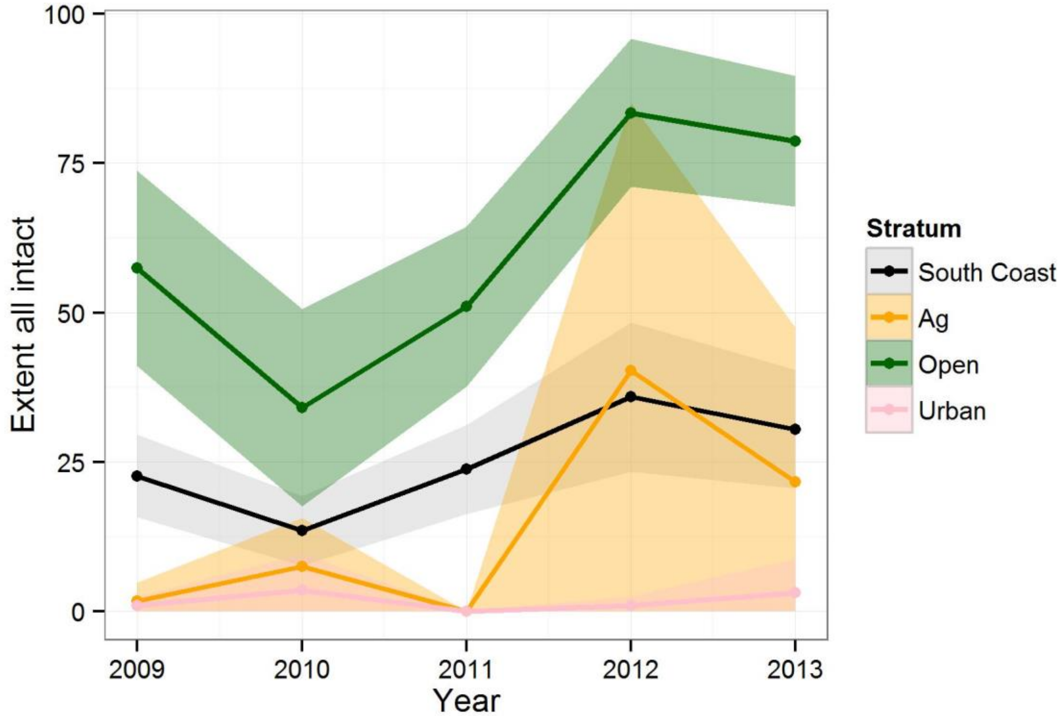


Figure 3-2. Percent of stream-miles that were intact for all four indicators

RECOMMENDATIONS

- Continue the survey for another five years, focusing on key biological indicators of stream condition, as well as high-priority stressors.
- Expand the survey to include nonperennial streams.
- Improve trend estimates by revisiting previously sampled probabilistic sites.
- Continue to investigate high priority stressors, such as habitat degradation and nutrient enrichment.
- Support studies that identify constraints on biological condition imposed by natural factors, channel engineering, water chemistry, and habitat degradation.

LITERATURE CITED

Aboal, M., M.A. Puig, P. Mateo and E. Perona. 2002. Implications of cyanophyte toxicity on biological monitoring of calcareous streams in north-east Spain. *Journal of Applied Phycology* 14:49-56

Barbour, M.T., J. Gerritsen, G.E. Griffith, R. Frydenborg, E. McCarron, J.S. White and M.L. Bastian. 1996. A framework for biological criteria for Florida streams using benthic macroinvertebrates. *Journal of the North American Benthological Society* 15:185-211.

Bernal, S., D. Von Schiller, F. Sabater and E. Marti. 2013. Hydrological extremes modulate nutrient dynamics in Mediterranean climate streams across different spatial scales. *Hydrobiologia* 719:31-42.

Bernstein, B., and K. Schiff. 2002. Stormwater Research Needs in Southern California. SCCWRP Technical Report 358. Costa Mesa, CA. Available from http://www.socalsmc.org/Docs/StormwaterResearchNeedsinSouthernCalifornia.pdf

California Department of Forestry and Fire Protection. 2004. The California Interagency Watershed Map of 1999, version 2.2.1.

Central Valley Regional Water Quality Control Board. 2014. Central Valley Pyrethroid TMDL and Basin Plan Ammendment [Draft]. Available from http://www.waterboards.ca.gov/centralvalley/water_issues/tmdl/central_valley_projects/central_valley_pesticides/pyrethroid_tmdl_bpa/index.shtml.

Collins, J.N., E.D. Stein, M. Sutula, R. Clark, A.E. Fetscher, L. Grenier, C. Grosso, and A. Wiskind. 2008. California Rapid Assessment (CRAM) for Wetlands, v5.0.2. 157 pp. San Francisco Estuary Institute. Oakland, CA.

Environmental Protection Agency (EPA). 1986. Quality Criteria for Water. EPA 440/5-86-001. US Environmental Protection Agency, Office of Water. Washington, DC.

EPA. 2000. Establishment of numeric criteria for priority toxic pollutants for the state of California. *Federal Register* 65:31682-31719.

Fetscher, A.E., L.B. Busse and P.R. Ode. 2009. Standard Operating Procedures for Collecting Stream Algae Samples and Associated Physical Habitat and Chemical Data for Ambient Bioassessments in California. California State Water Resources Control Board Surface Water Ambient Monitoring Program (SWAMP) Bioassessment SOP 002. (updated May 2010). SWAMP. Sacramento, CA.

Fetscher, A.E., R. Stancheva, J.P. Kociolek, R.G. Sheath, E.D. Stein, R.D. Mazor, P.R. Ode and L.B. Busse. 2014. Development and comparison of stream indices of biotic integrity using diatoms vs. non-diatom algae vs. a combination. *Journal of Applied Phycology* 26:433-450.

Gibson, J.R., M.T. Barbour, J.B. Stribling, J. Gerritsen, and J.R. Karr. 1996. Biological Criteria: Technical Guidance for Streams and Rivers (revised edition). EPA 822-B-96-001. US Environmental Protection Agency, Office of Water. Washington, DC.

Herlihy, A.T. and J.C. Sifneos. 2008. Developing nutrient criteria and classification schemes for wadeable streams in the conterminous US. *Journal of the North American Benthological Society* 27:932-948.

Horvitz, D.G. and D.J. Thompson. 1952. A generalization of sampling without replacement from a finite universe. *Journal of the American Statistical Association* 47:663-685.

Kaufmann, P.R., P. Levine, E.G. Robinson, C. Seeliger and D.V. Peck. 1999. Quantifying Physical Habitat in wadeable streams. EPA/620/R-99/003. US Environmental Protection Agency, Research Ecology Branch. Corvallis, OR.

Kincaid, T.M., and A.R. Olsen. 2013. Spsurvey: Spatial survey design and analysysis. R package version 2.6. R Foundation for Statistical Computing. Vienna, Austria.

Larsen, D.P., A.R. Olsen and D.L. Stevens. 2008. Using a master sample to integrate stream monitoring programs. *Journal of Agricultural, Biological, and Environmental Statistics* 13:243-254.

Mazor, R.D., K. Schiff, K. Ritter, A. Rehn and P. Ode. 2010. Bioassessment tools in novel habitats: An evaluation of indices and sampling methods in low-gradient streams in California. *Environmental Monitoring and Assessment* 167:91-104.

Mazor, R.D., A. Rehn, P.R. Ode, M. Engeln, K. Schiff, E.D. Stein, D. Gillett, D.B. Herbst and C.P. Hawkins. In Press. Bioassessment in complex environments: Designing an index for consistent meaning in different settings. Freshwater Science.

Mazor, R.D., E.D. Stein, P.R. Ode and K. Schiff. 2014. Integrating intermittent streams into watershed assessments: Applicability of an index of biotic integrity. *Freshwater Science* 33:459-474.

National Oceanic and Atmospheric Administration (NOAA). 2001. Coastal Change Analysis Program (C-CAP): Guidance for Regional Implementation. Technical Report NMFS 123. Department of Commerce. Available from http://www.csc.noaa.gov/crs/lca/pdf/protocol.pdf.

Ode, P.R. 2007. Standard operating procedures for collecting benthic macroinvertebrate samples and associated physical and chemical data for ambient bioassessment in California. Surface Water Ambient Monitoring Program. Sacramento, CA.

Ode, P.R., A.C. Rehn, R.D. Mazor, K.C. Schiff, E.D. Stein, J.T. May, L.R. Brown, D.B. Herbst, D. Gillett, K. Lunde and C.P. Hawkins. In review. Evaluating the adequacy of a reference site pool for the ecological assessment of streams in environmentally complex regions.

Peck, D.V., A.T. Herlihy, B.H. Hill, R.M. Hughes, P.R. Kaufmann, D.J. Klemm, J.M. Lazorchek, F.H. McCormick, S.A. Peterson, S.A. Ringold, T. Magee and M. Cappaert. 2006. Environmental Monitoring and Assessment Program - Surface Waters Western Pilot Study: field operations manual for wadeable streams. EPA/620/R-06/003. US Environmental Protection Agency, Office of Research and Development. Corvallis, OR.

R Core Team. 2012. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing. Vienna, Austria.

Reynoldson, T.B., R.H. Norris, V.H. Resh, K.E. Day and D.M. Rosenberg. 1997. The reference condition: A comparison of multimetric and multivariate approaches to assess water quality impairment using benthic macroinvertebrates. *Journal of the North American Benthological Society* 16:833-852.

Richards, A.B. and D.C. Rogers. 2011. List of Freshwater Macroinvertebrate Taxa from California and Adjacent States Including Standard Taxonomic Effort Levels. Southwest Association of Freshwater Invertebrate Taxonomists. Chico, CA.

Stevens, D.L. and A.R. Olsen. 2004. Spatially balanced sampling of natural resources. *Journal of the American Statistical Association* 99:262-278.

SWAMP QAT. 2008. Quality Assurance Program Plan. Surface Water Ambient Monitoring Program Quality Assurance Team. Sacramento, CA.

United State Environmental Protection Agency (USEPA). 2002. Short-term Methods for Estimating the Chronic Toxicity of Effluents and Receiving Waters to Freshwater Organisms. Fourth Edition. EPA-821-R-02-013. USEPA, Office of Water. Washington, DC.

United States Geological Survey (USGS). 1999. National Elevation Database. Sioux Falls, SD. Accessed from: http://ned.usgs.gov.

United States Geological Survey and United States Environmental Protection Agency. 2005. National Hydrography Dataset Plus. Reston, VA.

Van Sickle, J., J.L. Stoddard, S.G. Paulsen and A.R. Olsen. 2006. Using relative risk to compare the effects of aquatic stressors at a regional scale. *Environmental Management* 38:1020-1030.

Van Sickle, J. and S.G. Paulsen. 2008. Assessing the attributable risks, relative risks, and regional extents of aquatic stressors. *Journal of the North American Benthological Society* 27:920-931.

Yoon, V.K. and E.D. Stein. 2008. Natural catchments as sources of background levels of stormwater metals, nutrients, and solids. *Journal of Environmental Engineering* 134:961-973