2015 Report on the SMC Regional Stream Survey

Special study on engineered channels

Program update

Preliminary results from new indicators

Applications of SMC data

Southern California Stormwater Monitoring Coalition
Regional Watershed Monitoring Program

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Cover photo: Los Angeles River at the confluence of Calabasas and Bell Creek.

This report should be cited as:
Southern California Stormwater Monitoring Coalition. 2017. 2015 Report on the Stormwater Monitoring Coalition Regional Stream Survey. SCCWRP Technical Report 963. Southern California Coastal Water Research Project. Costa Mesa, CA.

Program update

Overview of a redesigned survey

In 2015, the SMC initiated the first year of its redesigned stream bioassessment survey, sampling 102 sites and implementing several major changes to address information gaps identified in the initial five-year survey, including:

- Inclusion of nonperennial streams in the survey. Whereas nonperennial streams were previously excluded from sampling, we now attempt to include them among the 55 “condition” sites (i.e., sites selected in a probabilistic way to represent the typical condition of streams in the region) where bioassessment occurs. By shifting the sampling period earlier in the season (starting as early as March), intermittent streams that dry up before May are more likely to be represented in the survey.
- Improved trend detection through site revisits. A total of 47 “trend” sites that were sampled in the first cycle of the survey were revisited in 2015. With a sufficient number of revisits, the survey will be able to determine the extent of stream-miles that are improving or degrading over time, and identify factors that are associated with these trends.
- A change in analytes and indicators measured at each site. In order to focus on new priorities and concerns, SMC participants sampled a number of new indicators (highlighted elsewhere in this report), such as hydromodification impact potential, aquatic invasive vertebrate occurrences, hydrologic state, cellular bioassays, and non-target analysis of chemicals of emerging concern. Assessment of sediment contamination, although part of the updated survey workplan, was deferred so that a pilot study in limited areas could be completed in 2016.

What is the Stormwater Monitoring Coalition (SMC)?

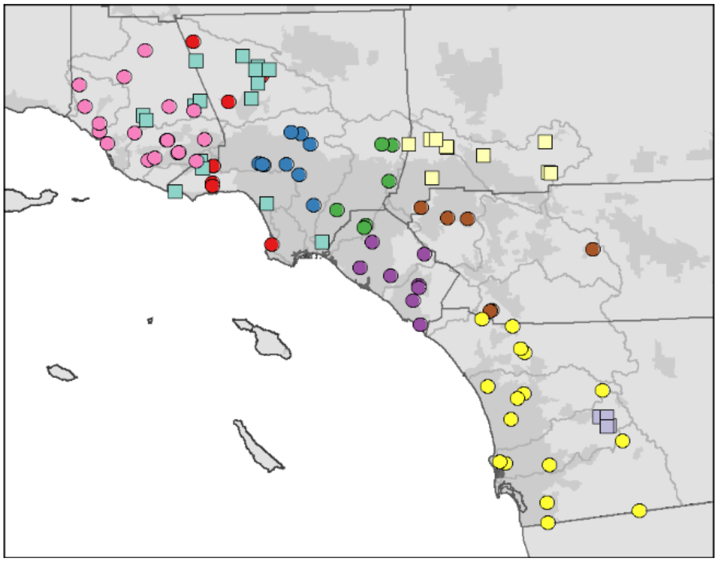
The SMC is a coalition of multiple state, federal, and local agencies that works collaboratively to improve the management of stormwater in Southern California. SMC members include regulatory agencies, flood control districts, and research agencies: County of Los Angeles Department of Public Works, County of Orange Public Works, County of San Diego Department of Public Works, Riverside County Flood Control and Water Conservation District, San Bernardino County Flood Control District, Ventura County Watershed Protection District, City of Long Beach Public Works Department, City of Los Angeles Department of Public Works, California Regional Water Quality Control Board—Santa Ana Region, Los Angeles Region, and San Diego Region, State Water Resources Control Boards, California Department of Transportation, Southern California Coastal Water Research Project (SCCWRP). In addition, the SMC collaborates with the U.S. Environmental Protection Agency Office of Research and Development. For more information, visit the SMC webpage at www.socalsmc.org.

The SMC has conducted a probabilistic survey of streams in the South Coast region since 2009. The goals of this survey are to provide the technical foundation for scientifically sound management of stormwater by answering three questions:

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

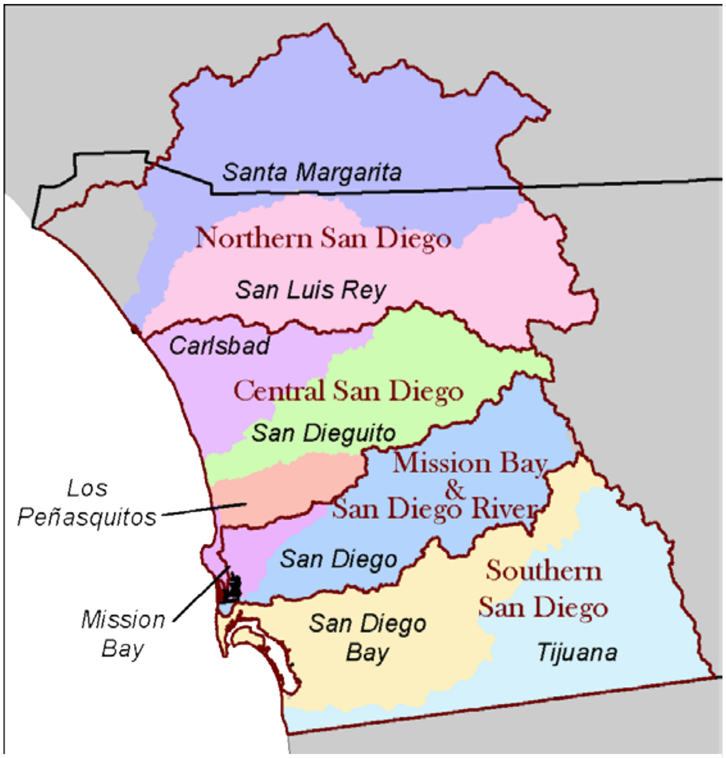
The first five-year cycle of survey took place between 2009 and 2013. The results of the first cycle are summarized in a report available on SCCWRP’s website. The survey continues with a new cycle that spans from 2015 to 2019, evolving to address new questions. This report summarizes the current status of the survey and describes major developments and accomplishments that occurred in 2015. A comprehensive report will be released after completion of the fifth year of the current cycle.

Changes in cost from the first cycle were minimized, as certain indicators (i.e., toxicity, metals, and pyrethroids in the water column) were dropped based on recommendations by the SMC workgroup. Priority indicators that were retained, such as benthic macroinvertebrates, algae, riparian wetlands (i.e., CRAM), physical habitat, nutrients, and major ions, were sampled at every site.



Sampling effort in 2015 by agency.

Stormwater agencies	Condition (# sites)	Trend (# sites)	Total (# sites)
● Ventura County	10	8	18
● Los Angeles County	5	2	7
● Los Angeles WMP	3	6	9
● San Gabriel RMP	2	4	6
● Orange County	5	3	8
● Riverside County	3	3	6
● San Diego WMAs	12	4	16
Water boards			
■ RB4	9	7	16
■ RB8	4	6	10
■ RB9	2	4	6
Total	55	47	102



San Diego Watershed Management Areas (black text) nested within SMC watersheds (brown text). Local jurisdictions take the lead in monitoring each WMA and setting management priorities, contributing to and making use of the SMC's regional survey.

New watershed-based permits enhance interactions with multiple agencies in San Diego County

Marking a major transition in the implementation of the SMC survey in San Diego County, smaller municipalities (including the cities of Oceanside, Encinitas, San Diego, and Imperial Beach) are now working directly alongside SMC member agencies to collect data for the survey, as opposed to working indirectly through San Diego County Public Works as a lead agency. This transition is intended to increase interaction between stormwater co-permittees and the San Diego Regional Water Quality Control Board, while also making the survey more useful to local managers. These municipalities contribute to the survey through coalitions focused within Watershed Management Areas (WMAs). The WMAs have the effect of spreading responsibility among the individual municipalities to fulfill the permit obligations. As a result, more municipalities are engaged with the regional monitoring program in supporting their management and regulatory needs.

The formation of WMAs began when the San Diego Regional Water Board consolidated municipal stormwater permits into a single regional stormwater permit. Whereas previously, all monitoring in San Diego County was coordinated through a single agency (i.e., the County of San Diego), each WMA coalition is now tasked with collecting data and identifying management priorities for its own WMAs. Survey data are used to develop a Water Quality Improvement Plan, or WQIP (see article on the San Juan WQIP below) for each WMA, with stakeholders responsible for identifying priority issues and associated stressors that each coalition should address. For watersheds that cross county borders (e.g., Santa Margarita), the WMAs facilitate cooperation among municipalities in the different jurisdictions.

Not only do the WMAs help the partners outside the SMC with the survey, but they also carry forward the SMC's vision of collaborative monitoring to the local level. Through minor adjustments to the SMC's sampling plan (e.g., allocating trend sites by watershed rather than by land use), combined with enhanced dialogue between permittees and the Regional Board, the new partners were able to acquire data for their own needs, as well as contribute to the regional assessment goals of the SMC survey.

What are the biological conditions in engineered channels?

The SMC survey helps managers evaluate biological conditions in engineered channels and understand the potential policy implications.

Engineered channels are common features in urban stormwater systems, protecting surrounding neighborhoods from floods that could damage property or endanger lives. However, this service often comes at a cost, as engineered channels do not provide the same quality habitat that natural stream channels provide. Additionally, engineered channels may reduce groundwater recharge, or degrade water quality through alterations of biochemical processes. Consequently, engineered channels often fail to support designated beneficial uses related to ecosystem health, such as those related to aquatic life or wildlife. Faced with these tradeoffs between competing uses, stormwater agencies and regulators encounter questions from stakeholders, such as what range of ecological conditions are possible in engineered channels? And what factors can be managed to support better conditions? The SMC stream survey provides a rich source of data to answer these questions. By developing methods to characterize engineered channels, analyzing bioassessment scores in different channel types, and exploring responses to water chemistry gradients, the SMC stream survey offers preliminary answers to these questions.

Key Points

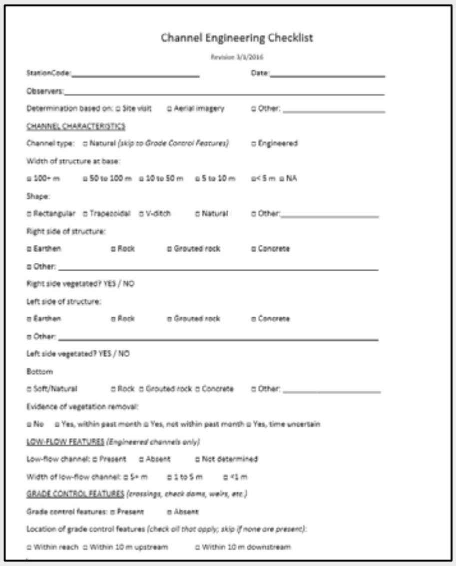
- Engineered channels surveyed to date are, generally speaking, in worse ecological health than natural channels based on biological indicators based on benthic macroinvertebrate and algae assemblages. These preliminary results suggest that tradeoffs between ecological health and flood protection may be unavoidable.
- While engineered channels invariably have poor scores for the California Stream Condition Index (CSCI) based on benthic macroinvertebrates, algal indices occasionally indicated better biological conditions—sometimes similar to reference condition. This wide range in index scores suggest that some engineered channels support more ecosystem functions than others.
- Within engineered channels, design and construction characteristics (e.g., armoring material or presence of low-flow features) did not influence index scores or other measures of ecological condition
- Within engineered channels, algal indices may reflect water quality conditions better than the macroinvertebrate index. For example, lower specific conductivity was associated with higher diatom index scores, but not CSCI scores. However, both types of indices have some capacity to respond to stressor gradients in these systems.
- Targeted sampling (particularly from hardened channels with good water quality, or engineered channels with high bioassessment index scores) and experimental studies may clarify the factors that support better ecological conditions.
- Survey data can provide a context for evaluating the biological condition of streams in engineered channels, thereby helping managers recognize factors, such as water quality or stream temperature, that may lead to better conditions.

Bioassessment indices, such as the California Stream Condition Index (CSCI, based on benthic macroinvertebrate communities) and the Southern California algal Indices of Biotic Integrity (IBIs), are the key indicators used by the State and Regional Water Boards to assess attainment of aquatic life beneficial uses in streams. These indices will have a central role in the implementation of the State's bio-integrity policies; it is therefore necessary that stormwater managers understand how these indices work in engineered channels. Aquatic organisms have diverse life history traits with sensitivities to a wide range of stressors. As a result, bioassessment indices provide a holistic measure of the combined impacts of poor water quality, habitat alteration, hydrologic modification, and other disturbances. This integration allows assessment of cumulative and diverse impacts on ecosystem health. Three indices are sampled in the SMC program: the CSCI, a diatom index, and a soft algal index; each of these three indices provide an independent measure of a stream's ability to support aquatic life.

To assess the range of biological conditions in engineered channels, the SMC took advantage of the extensive bioassessment data collected by the survey since its inception in 2009. In prior years, the SMC collected benthic macroinvertebrates and algae samples at hundreds of sampling reaches across Southern California, many of which were in engineered channels. In order to make the use of these data, the SMC bioassessment workgroup developed a simple procedure for characterizing and classifying the different types of channels found in the region (Sidebar 1). The protocol was designed for rapid application in the field or in the office (if aerial imagery or other data are available). This ease of use meant that the SMC could generate a large data set from recent and older data that would support robust analyses on the features of engineered channels associated with variability in bioassessment scores. Elements of this protocol have been adopted by the Surface Water Ambient Monitoring Program (SWAMP), and resource managers throughout the state are looking to the SMC to provide guidance on how to evaluate engineered channels in their regions. These data will also be used in mapping and modeling efforts to determine locations of engineered channels in the landscape.

Characterizing engineered channels

Modification of stream channels takes many forms, exhibiting a variety of designs and constructions. To characterize the diversity of engineered channels, the SMC developed simple forms to record key features, like shape, material, size, and presence of low-flow channels. These forms were filled out during site visits for the 2015 sampling season, as well as for sites visited in earlier years (relying on aerial imagery, photographs, data from earlier field visits, and other sources of information). Elements of the SMC's approach for characterizing engineered channels have been incorporated into SWAMP's standard bioassessment protocols.



Channel Engineering Checklist

Revision 3/1/2016

StationCode: ____________ Date: ____________

Observers: ____________

Determination based on: ☐ Site visit ☐ Aerial imagery ☐ Other: ____________

CHANNEL CHARACTERISTICS

Channel type: ☐ Natural *(skip to Grade Control Features)* ☐ Engineered

Width of structure at base:

☐ 100+ m ☐ 50 to 100 m ☐ 10 to 50 m ☐ 5 to 10 m ☐< 5 m ☐ NA

Shape:

☐ Rectangular ☐ Trapezoidal ☐ V-ditch ☐ Natural ☐ Other: ____________

Right side of structure:

☐ Earthen ☐ Rock ☐ Grouted rock ☐ Concrete

☐ Other: ____________

Right side vegetated? YES / NO

Left side of structure:

☐ Earthen ☐ Rock ☐ Grouted rock ☐ Concrete

☐ Other: ____________

Left side vegetated? YES / NO

Bottom

☐ Soft/Natural ☐ Rock ☐ Grouted rock ☐ Concrete ☐ Other: ____________

Evidence of vegetation removal:

☐ No ☐ Yes, within past month ☐ Yes, not within past month ☐ Yes, time uncertain

LOW-FLOW FEATURES *(Engineered channels only)*

Low-flow channel: ☐ Present ☐ Absent ☐ Not determined

Width of low-flow channel: ☐ 5+ m ☐ 1 to 5 m ☐ <1 m

GRADE CONTROL FEATURES *(crossings, check dams, weirs, etc.)*

Grade control features: ☐ Present ☐ Absent

Location of grade control features *(check all that apply; skip if none are present)*:

☐ Within reach ☐ Within 10 m upstream ☐ Within 10 m downstream

Forms developed by the SMC to characterize engineered channels are simple enough to complete within minutes during field visits, or from the office if aerial imagery and other data are available.

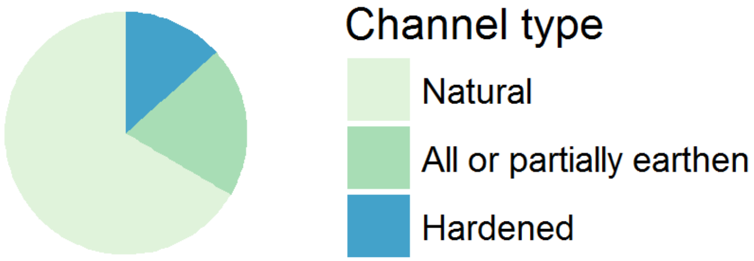


Figure 1. Proportion of stream types observed in the study

Armed with this protocol, the SMC bioassessment workgroup evaluated 724 unique bioassessment sites, with about 20% of these evaluations being made in the field. About two-thirds of the sites were natural, lacking any evident armoring, artificial structures (apart from road or bridge crossings), or straightening (Figure 1). Ninety-seven sites were entirely hardened, with concrete or grouted rock banks and a hardened bottom. The remaining 145 sites retained some earthen elements—typically a natural bottom, with earthen or partially armored banks. Because CSCI and algae IBI scores had already been calculated for these sites from the previous survey cycle, and because water chemistry and habitat quality measurements were also available, the data set was a good starting point for analyzing biological conditions in engineered channels.

Engineered channels are largely in poor condition, but some are in better condition than others

Nearly all engineered channels were in poor health, as measured by both the CSCI and the algal IBIs (Figure 2). Although a wide range of invertebrate CSCI scores was evident in engineered channels (inter-quartile range: 0.44 to 0.66), they rarely exceeded 0.79 (the threshold used in previous SMC reports to identify healthy streams similar to reference conditions). None of the entirely hardened channels met this benchmark, and only 14% of the earthen or partially hardened engineered channels did so. In contrast, 63% of the natural channels in the analysis met the healthy stream benchmark. Aquatic insect communities appear to be strongly affected by partial or complete channel hardening (see Sidebar 2).

Algal indices, however, provided different insights into stream condition. While the diatom and soft algae IBIs, like the CSCI, showed that engineered channels were generally in worse condition than natural channels, high algal IBI scores indicative of healthy (i.e., similar to reference) conditions were not uncommon. In fact, 43% of hardened channels had diatom IBI scores above the reference threshold, and 20% had high soft algae IBI scores. Whereas the CSCI indicated almost exclusively poor conditions in engineered channels, algal indicators suggest that engineered channels can support healthy streams under conducive conditions (such as good water quality).

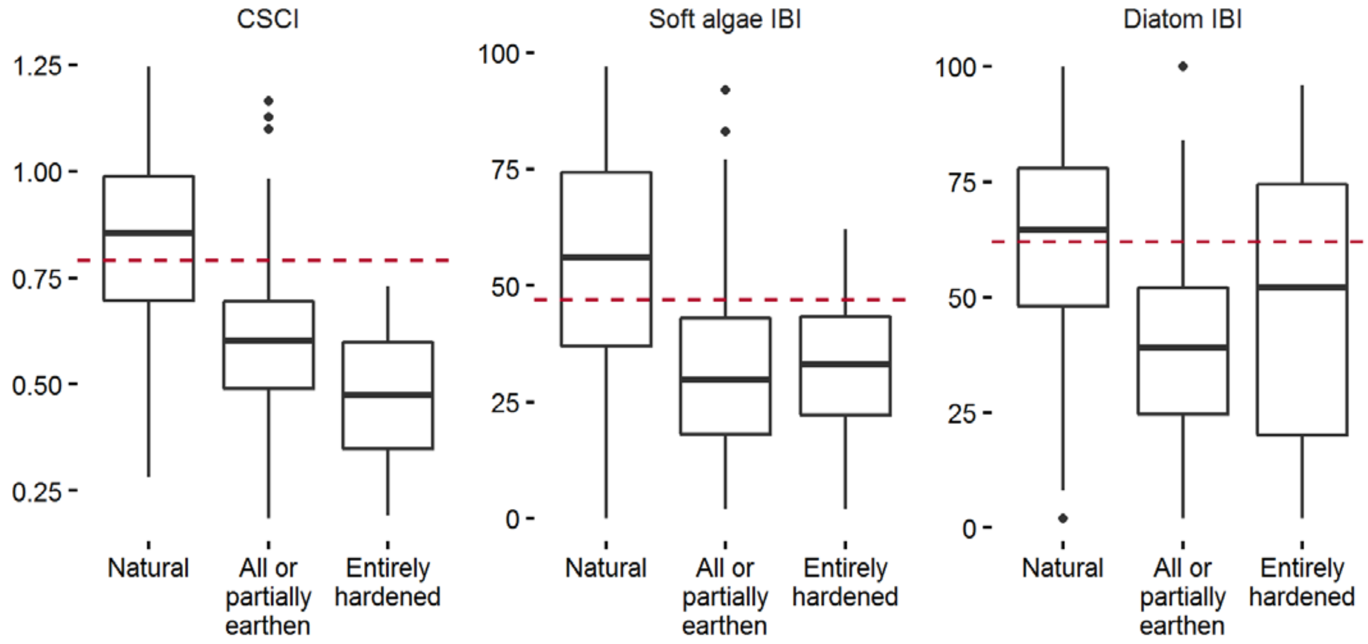


Figure 2. Bioassessment scores were typically higher in natural channels than in engineered channels. However, high scores for the algal indices were sometimes observed in engineered channels, occasionally exceeding the threshold for identifying sites in reference condition (red dashed line).

What kind of organisms are found in engineered channels?

Despite the poor in-stream ecological condition noted in this study, engineered channels do, in fact, support aquatic life, as well as terrestrial wildlife that depend on streams and rivers. Because of their accessibility and proximity to populated areas, engineered channels are frequently enjoyed for their wildlife-viewing opportunities, particularly for waterfowl and wading birds that forage in shallow areas. Although fish and amphibians are sometimes observed as well, these are almost exclusively non-native species, such as carp (*Cyprinus carpio*), tilapia (Cichlidae), bullhead (*Ameiurus*), and mosquito fish (*Gambusia affinis*).

Great blue herons and black-necked stilts forage on the concrete banks of the San Gabriel River.

Photo courtesy of Kerry Matz

***Dasyhelea*, a fly in the family of biting midges (*Ceratopogonidae*), are particularly common in hardened channels.**

The benthic macroinvertebrates found in engineered channels are only a small subset of the diversity of species found in the natural channels, typically with life history adaptations that provide resilience to disturbance (for example, rapid life-cycles with multiple generations per year, or tolerance to temperature extremes). A few invertebrate species show a particular affinity for engineered channels: Biting midges (*Dasyhelea*), soldier flies (*Euparyphus*), minnow mayflies (*Fallceon*), snails (*Physa*), worms (Oligochaeta), flatworms (Turbellaria), and seed shrimp (Ostracoda) were all more common than expected within hardened channels. Species that require complex substrates, such as those that burrow in the substrate (e.g., midges in the subfamily Tanypodinae) were less common than might be expected in a natural channel. Most sensitive and moderately tolerant species (e.g., net-spinning caddisflies, like *Hydropsyche*) were entirely eliminated. The abundance of tolerant species, and rarity of sensitive species, is reflected in the lower CSCI scores observed in engineered channels.

As with macroinvertebrates, algal assemblages within engineered channels contained subsets of species found in natural channels. Many planktonic diatoms, such as species in the *Scenedesmus* genus, were common, as well as the green filamentous algae *Cladophera glomerata*, found at nearly all concrete channels. These species are sometimes a concern. For example, *C. glomerata* form large, unsightly mats that trap debris, smother streambeds, and create odor problems.

The green alga *Cladophora glomerata* often proliferates in engineered channels, particularly if nutrient inputs are high and shading has been reduced.

What factors support higher bioassessment scores in engineered channels?

Why do some engineered channels score better than others? And why are high scores more common for algal IBIs than for the invertebrate CSCI? Design features (such as construction material or presence of a low-flow channel) had no discernible impact on either CSCI or algal IBI scores, so perhaps water quality or other habitat features were more important. That is, relatively high scores in engineered channels may indicate better water or habitat quality than lower scores.

Analyses of the data provide some support for this hypothesis. The diatom index responded to a range of water quality conditions, even within concrete channels (Figure 3, Table 1). For example, the diatom IBI declined with increasing specific conductivity in all channel types, whereas scores for the soft algae index and the CSCI exhibited responses within natural or partially earthen channels. The hypothesis that the constraints within engineered channels overwhelm the ability of bioassessment indicators to respond to stress is not well supported for diatoms.

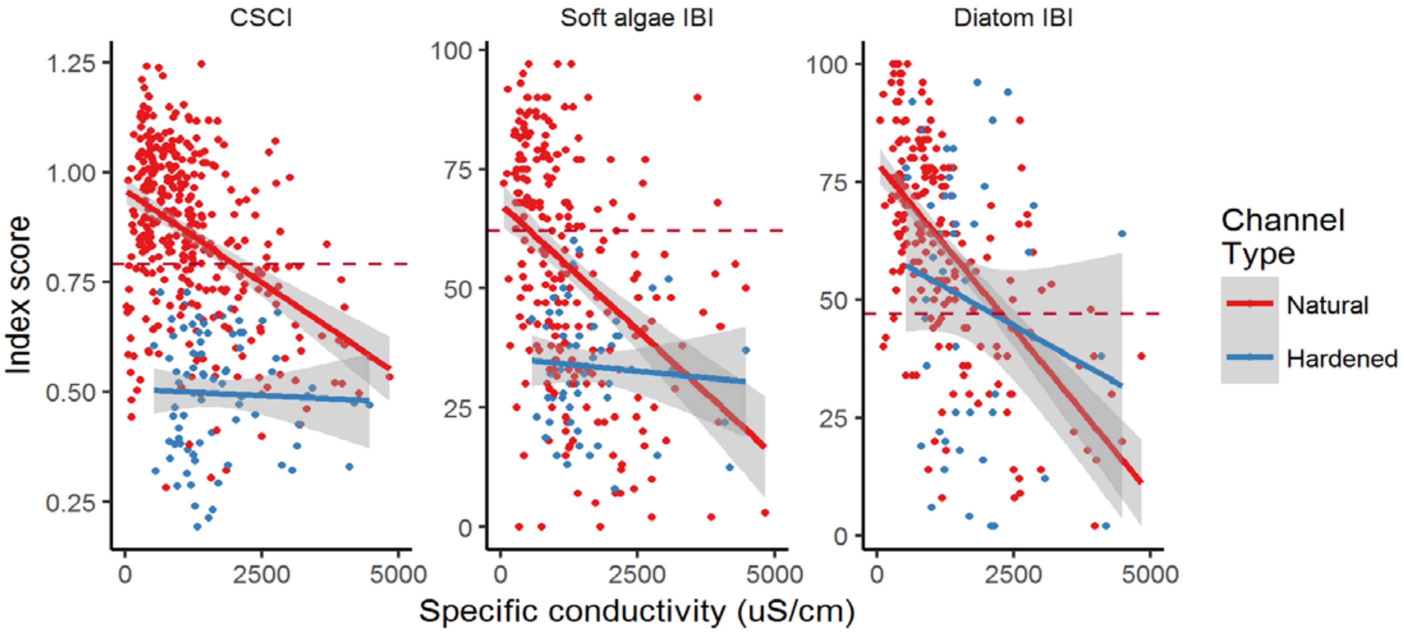


Figure 3. Specific conductivity versus bioassessment index scores in hardened and natural channels. The red dashed line is the threshold for sites in reference condition. For clarity, earthen and partially hardened channels are excluded from this plot.

Factors related to habitat showed a similar pattern of responses. For example, high levels of sands and fines in the streambed were associated with lower scores for all indices, but the relationships within hardened channels were strongest for the diatom index (Figure 4). Although the CSCI did not respond to many water chemistry and physical habitat gradients within hardened channels, shading and temperature appears to be important for this index, with higher scores observed in hardened channels where shading was high (Figure 5). Stream-side vegetation, which is often removed for flood control purposes, may provide the conditions that improve CSCI scores. However, shading had the opposite relationship with diatom IBI scores, and no relationship with soft algae IBI scores.

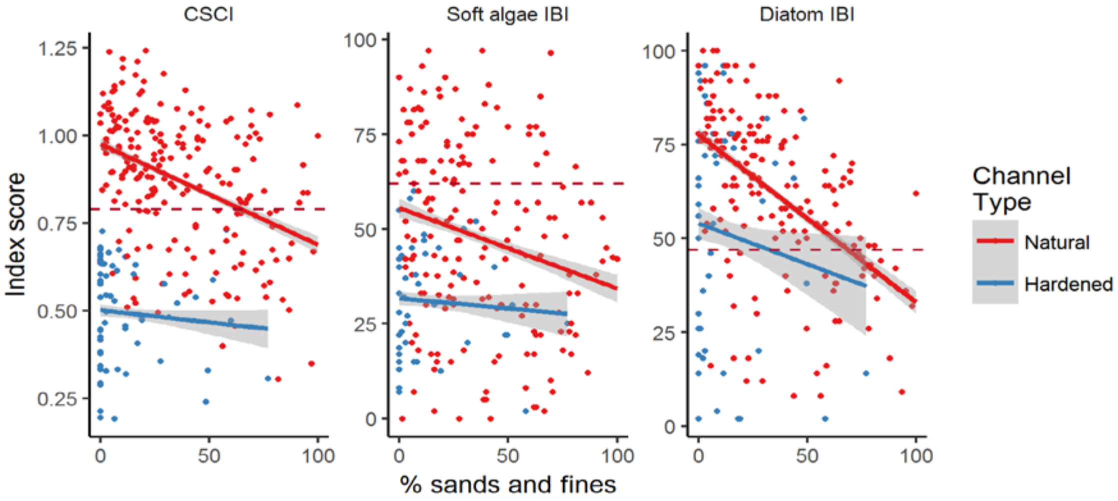


Figure 4. Percent sands and fines in the streambed versus bioassessment index scores in hardened and natural channels. The red dashed line is the threshold for sites in reference condition. For clarity, earthen and partially hardened channels are excluded from this plot.

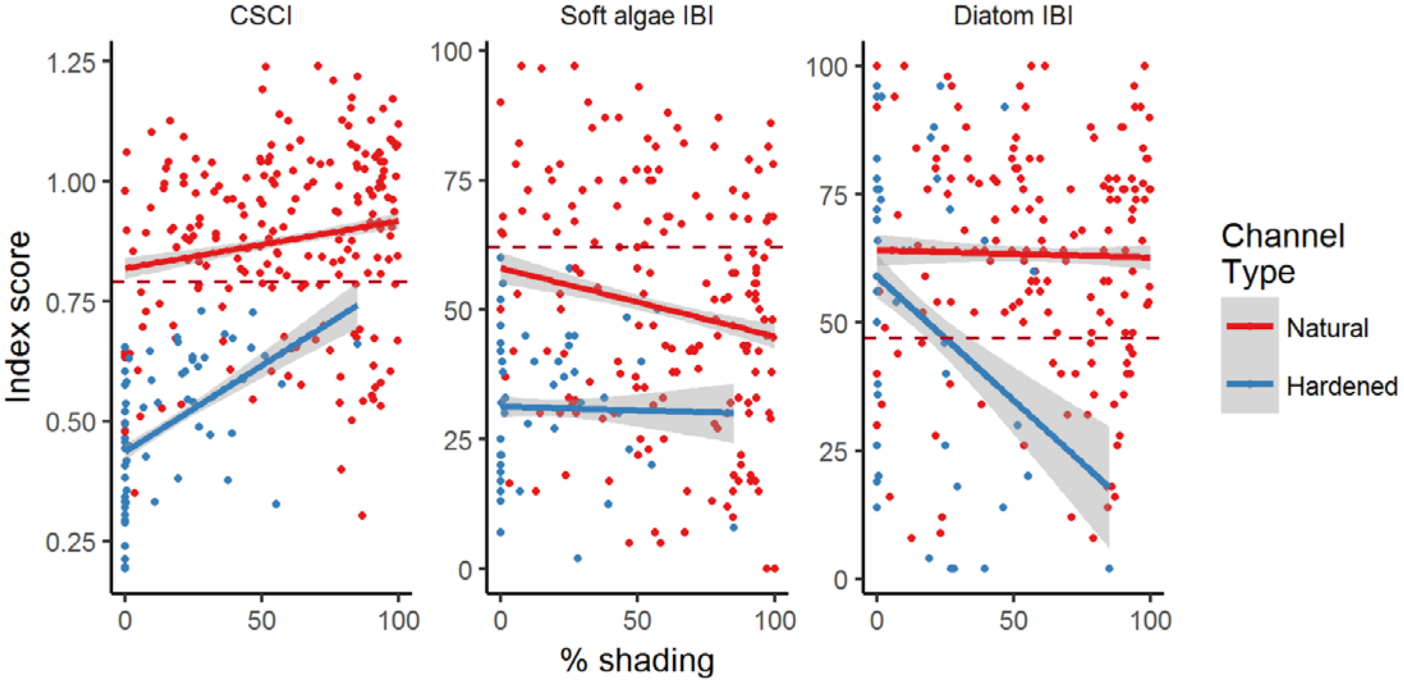


Figure 5. Shading versus index scores in natural and hardened channels. The red dashed line is the threshold for sites in reference condition. For clarity, earthen and partially hardened channels are excluded from this plot.

Table 1. Correlations between water quality and habitat variables and index scores in different channel types. ρ: Spearman rank correlation coefficient. Coefficients indicating stronger relationships (ρ > 0.3) are highlighted in blue. *: p-value < 0.05.

	CSCI			Diatom IBI			Soft Algae IBI		
	Natural	Partial	Hardened	Natural	Partial	Hardened	Natural	Partial	Hardened
	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ	ρ
Water quality									
Alkalinity	-0.30 *	0.02	0.21	-0.49 *	0.18	-0.39	-0.31 *	-0.16	-0.16
Chloride	-0.66 *	-0.52 *	-0.05	-0.73 *	-0.19	-0.30	-0.44 *	-0.34	-0.10
Total Nitrogen	-0.44 *	-0.38 *	-0.42	-0.52 *	-0.42 *	0.23	-0.51 *	-0.43 *	-0.38
pH	0.25 *	-0.16	0.08	0.15	-0.36 *	0.04	-0.05	-0.20	0.22
Temperature	-0.36 *	-0.21	-0.30	-0.42 *	-0.23	-0.13	-0.11	-0.38 *	0.11
Specific conductivity	-0.58 *	-0.51 *	-0.05	-0.66 *	-0.16	-0.25	-0.46 *	-0.29	-0.11
Physical habitat									
% fast-water	0.45 *	0.31	0.24	0.53 *	-0.11	-0.44 *	0.09	-0.18	-0.37
% thick algae cover	-0.31 *	-0.35	-0.16	-0.45 *	0.01	0.55 *	-0.03	-0.60 *	0.09
% sands and fines	-0.51 *	-0.64 *	-0.23	-0.64 *	-0.36 *	0.15	-0.19	-0.56 *	0.17
Flow diversity	0.29 *	0.36 *	0.43 *	0.31 *	-0.06	-0.27	0.15	0.23	0.01
Habitat diversity	-0.01	0.14	0.18	-0.28 *	0.14	0.40 *	-0.07	0.24	0.34
Substrate diversity	0.09	0.30	-0.18	0.09	0.25	0.20	0.23 *	0.45 *	0.20
Riparian disturbance	-0.36 *	-0.23	-0.25	-0.22 *	-0.31	0.22	-0.33 *	-0.38 *	0.24
Shading	0.13	0.43 *	0.63 *	-0.03	0.23	-0.10	-0.13	0.41 *	0.40 *
Riparian vegetation	-0.17	0.21	0.47 *	-0.20	0.20	-0.06	0.03	0.14	0.28

Little Dalton Wash: An example of a high-scoring engineered channel

Figure 6. Little Dalton Wash.

Index	Score	Percentile of reference	Percentile of hardened channels
CSCI	0.73	3	92
Diatom IBI	92	84	92
Soft algae IBI	23	0	15

Table 2. Index scores at Little Dalton Wash compared to reference sites and to other hardened channels. Percentiles calculated through a normal approximation.

Perhaps the most valuable insight provided by the SMC's study of engineered channels is that it helps managers identify examples of high-scoring sites, providing a target for managing streams in poorer condition. One such site is Little Dalton Wash, part of the San Gabriel River watershed in Azusa (Figure 6). Although the CSCI score of 0.73 was somewhat lower than the threshold of 0.79 for identifying sites in reference condition, it was higher than nearly all other hardened channels in the data set. Moreover, the diatom IBI score of 92 was well above the threshold of 62, although the soft algae IBI score was low (23). When compared to other hardened channels in the SMC survey, the unusually high scores at Little Dalton Wash are evident (Table 2).

The field conditions at Little Dalton Wash are not different from other hardened channels in any obvious way. The sampled reach is in a rectangular concrete box that lacks low-flow features. Located in the midst of a heavily developed area, it receives drainage from a 27-km^2 watershed that is more than one-third urbanized. However, comparison with survey data from other hardened channels suggest a few possibilities. Several water quality analytes, as well as physical habitat metrics, were better at Little Dalton Wash than at lower-scoring hardened channels, including chloride, total nitrogen, temperature, and specific conductivity (Figure 7). The diversity of flow microhabitats (e.g., riffles and glides) was high as well. These factors may explain the higher scores observed at this site.

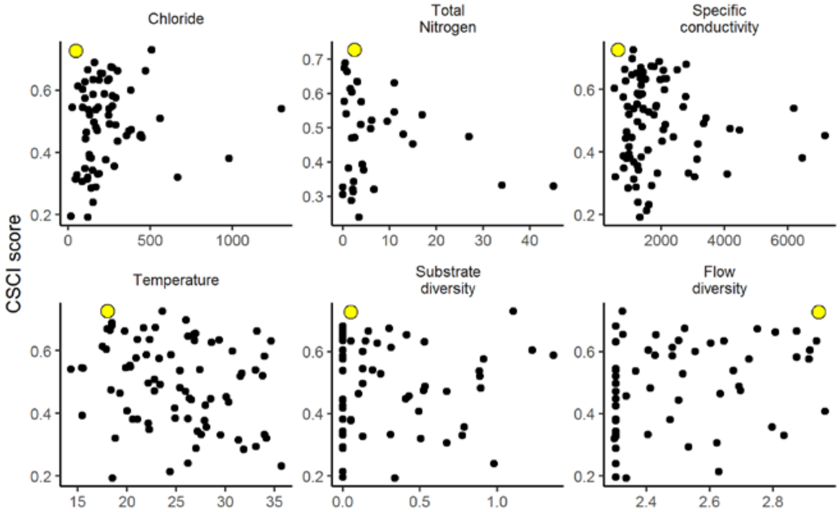


Figure 7. CSCI scores versus water quality and habitat metrics in hardened channels. The large yellow symbol represents Little Dalton Wash.

Conclusions

These preliminary results suggest that, although ecological health is clearly degraded in hardened channels, higher bioassessment index scores could be supported in certain reaches if water quality and in-stream habitat conditions are good. The ranges of observed index scores provide a starting point for managers, regulators, and stakeholders to discuss which types of actions are needed to achieve the desired level of health in modified channels, or in downstream receiving waters.

The SMC survey has cleared up a few major questions about engineered channels. It demonstrated that, although conditions in engineered channels are generally poor, some channels support better conditions than others. Additionally, this analysis underscores the value of a multi-indicator approach to ecological health assessment, as each assemblage adds to a more well-rounded view of the condition of engineered channels. Additional data may help further identify the factors that lead to better ecosystem health in engineered channels, including targeted sampling of concrete channels with good water quality, monitoring after the removal of concrete features from a channel (see Sidebar 3), and tracking water quality improvements following the implementation of best management practices that remove pollutants. Although this opportunistic analysis of available SMC survey data suggests that an engineered channel may not be able to support aquatic life as well as natural streams can, and tradeoffs between flood protection and ecological condition may be unavoidable, it shows that a range of conditions is possible, and that better conditions may be possible through management of water quality and habitat.

Restoration of engineered channels

Restoring natural features in engineered channels is sometimes proposed as a way to improve ecological conditions, as well as create amenities like improved flood control and enhanced recreational opportunities. In the County of San Diego, concrete walls and bank armoring were removed from a 1.2-mile segment of Forester Creek in 2006 at a cost of $36 million, returning the channel to a more naturalistic, vegetated form. Some water quality impairments improved following restoration (e.g., pH), while others did not (e.g., total dissolved solids). Bioassessment scores (measured with the Southern California IBI, which preceded the CSCI) increased from 25 to 40 points, although too few samples have been collected to see if this difference is statistically significant.

Left: Forester Creek upstream of the restoration site. Right: The restored portion of Forester Creek.

The Los Angeles River provides a much larger-scale example. The revitalization master plan for the Los Angeles River calls for the removal of concrete walls from up to 32 miles of the river, wherever it is safe and feasible to do so. This project may be one of the largest urban river restoration efforts undertaken in the country. With a cost that will exceed $1 billion, the impact on the river’s ability to support aquatic life are not clear. Fortunately, the SMC stream survey provides abundant data, both from the Los Angeles River itself, as well as from comparable hardened and restored rivers, to provide benchmarks that enable the success of this effort to be evaluated.

Updates on new indicators

Cell bioassays evaluate the potential for harm from chemicals of emerging concern

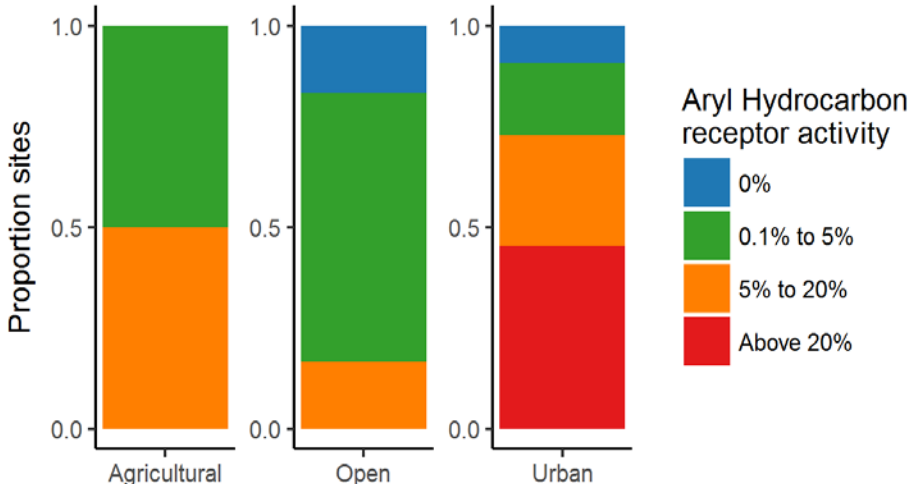


Figure 1. Aryl hydrocarbon receptor (AhR) responses were measured at sites representing different land uses within the SMC stream survey area.

Chemicals of emerging concern (CECs) have the potential to degrade ecological condition and harm human health through endocrine disruption and other physiological pathways. Comprising over 10,000 distinct chemical compounds, CECs come from pharmaceuticals, personal care products, and other sources. Many of them are biologically active, with the potential to disrupt hormonal pathways of organisms. With hundreds of new compounds being added to commercial markets every year, most without disclosure of their composition, measuring the extent and impact of CECs in the environment through traditional (i.e., single-compound) approaches is unrealistic.

The SMC survey tested an alternative approach that promises to be more effective and less expensive than traditional methods. First, samples are used in bioassays to detect cellular-level responses, followed by a non-target (i.e., multiple-compound) analysis to identify the compounds that could cause the observed response. This screening approach provides new information about potential risks of contaminant exposure to humans, aquatic life, and wildlife. For example, estrogen receptor (ER) assays can help detect the presence of hormone-mimicking chemicals that affect growth, development, and reproduction. The SMC screened 31 samples collected in 2015—one of the first applications of this new technology to a stream biomonitoring program.

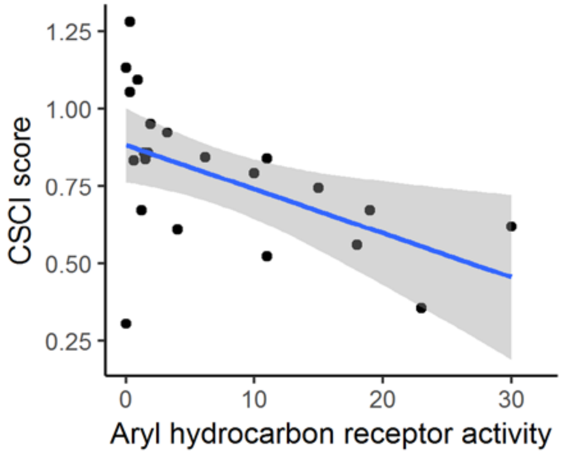


Figure 2. Aryl hydrocarbon receptor response versus CSCI scores

Responses for receptors of steroid hormones, such as glucocorticoid and estrogen, were rare, affecting only 2 and 8 sites respectively. In contrast, aryl hydrocarbon receptor (AhR) responses were widespread, affecting 28 of the 31 sites; furthermore, AhR responses were stronger at urban sites than at undeveloped sites (Figure 1). The AhR receptor is thought to play a role in mediating environmental toxicity and immune response, as well as supporting normal vascular development. Dioxins and other pollutants are known to provoke AhR responses.

Bioassay responses may explain why some sites are in poor biological condition. For example, AhR activity was negatively correlated with CSCI scores (r = -0.84, Figure 2), suggesting that contaminants known to cause AhR responses (e.g., polycyclic aromatic hydrocarbons, commonly associated with runoff from asphalt or combustion) may alter benthic macroinvertebrate assemblages (Figure 2). Follow-up targeted chemical analyses found sunscreen ingredients at sites with ER activity and flame retardants at sites with AhR activity, although concentrations were generally too low to explain the observed responses, meaning that other, unmeasured compounds are responsible. Field blanks were clean, meaning that contamination of the samples was not a likely cause of the response. Non-targeted analyses to identify these unknown chemicals are underway.

Assessing the ability of streams in southern California to support aquatic vertebrates

Figure 1. California tree frog (*Pseudacris cadaverina*), one of the more common native species of vertebrate found in Southern California streams.

Although the initial SMC stream survey provided a great quantity of data about stream condition based on benthic macroinvertebrates and algae, a lingering question remained about what our findings meant for higher trophic levels, such as fish, amphibians, and other vertebrates (Figure 1). Although a thorough investigation of this question is beyond the scope of the current regional monitoring program, the SMC found a way to get some answers, and at remarkably low costs.

In 2015, SMC field crews received training in identifying common aquatic vertebrates in the region, and began reporting observations of species they encountered during normal bioassessment sampling (that is, no additional time was spent trying to observe vertebrates). This effort began as a collaborative venture initiated by the SMC, the US Geological Survey (USGS), the US Fish and Wildlife Service (USFWS), and SWAMP, all of whom were hoping to improve their understanding of the spatial distributions of both native and non-native vertebrates in the region. The survey provided a concrete example of how the core regional monitoring program can be used to opportunistically collect data to answer important management questions. The resources necessary to successfully complete the survey were relatively trivial for several reasons: the SMC field teams were already visiting the sites; the teams already included biologists easily trained to identify stream vertebrates; and the sampling design was based on a time-saving casual observation approach, instead of a more traditional rigorous search at each site.

Despite the low costs, this survey provided a great deal of new and valuable data on vertebrates in the region's streams, with observations attempted at a total of 95 sites (Figure 2). Vertebrates were seen at 46% of the sites, and surprisingly, the distributions of native frogs were fairly widespread across urban, agricultural and open land use types. These native amphibians were unexpectedly tolerant to the presence of non-native fish, frogs or crayfish. In contrast, native fish species were only observed at five mountainous sites. Mosquito fish (*Gambusia affinis*) were observed at 21 sites and were the most common non-native fish species, likely as a result of deliberate introduction as a vector-control measure.

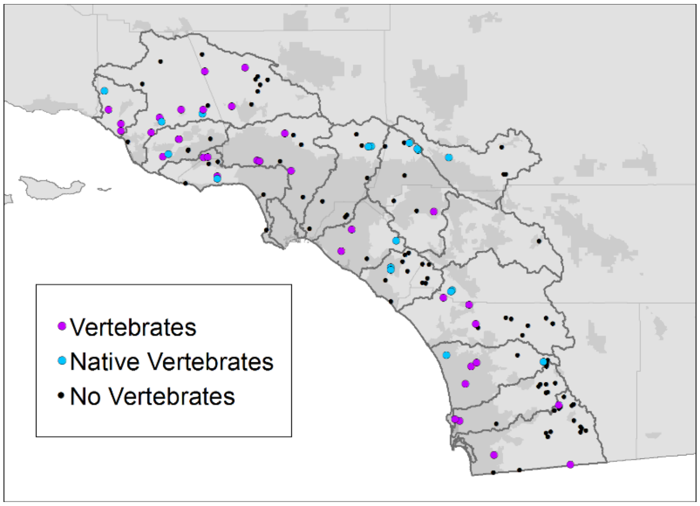


Figure 2. Location of vertebrate observations conducted in 2015.

Of the sites located on agricultural land, 68% supported vertebrates, although the many of these were non-natives (47%). In contrast, 49% of open land sites supported vertebrates, but only 17% of these were non-natives. It is important to note that these numbers likely underestimate the actual distribution of vertebrates because the field crews did not conduct exhaustive surveys of each site.

The addition of vertebrate observations to the survey yielded detailed information regarding the distributions of vertebrates throughout the southern California region, despite the limited amount of resources and training required to successfully implement it. Although more intensive efforts may have detected more species (especially nocturnal or cryptic species), opportunistic sampling was sufficient to improve our understanding of the ability of Southern California streams to support wildlife. Future work for this program might focus on the environmental and habitat factors that contribute to the presence or absence of vertebrates on agricultural, urban and open land use types; investigation of the relationships among vertebrates and other biological condition indicators including the CSCI, CRAM and Southern California algal IBIs; and improving our understanding of the spatial distribution of these important taxa by combining the SMC vertebrate dataset with those from iNaturalist, regional fish surveys, the USFWS, the USGS, and the California Department of Fish and Wildlife.

Applications of survey data

A water-quality improvement plan supported by survey data

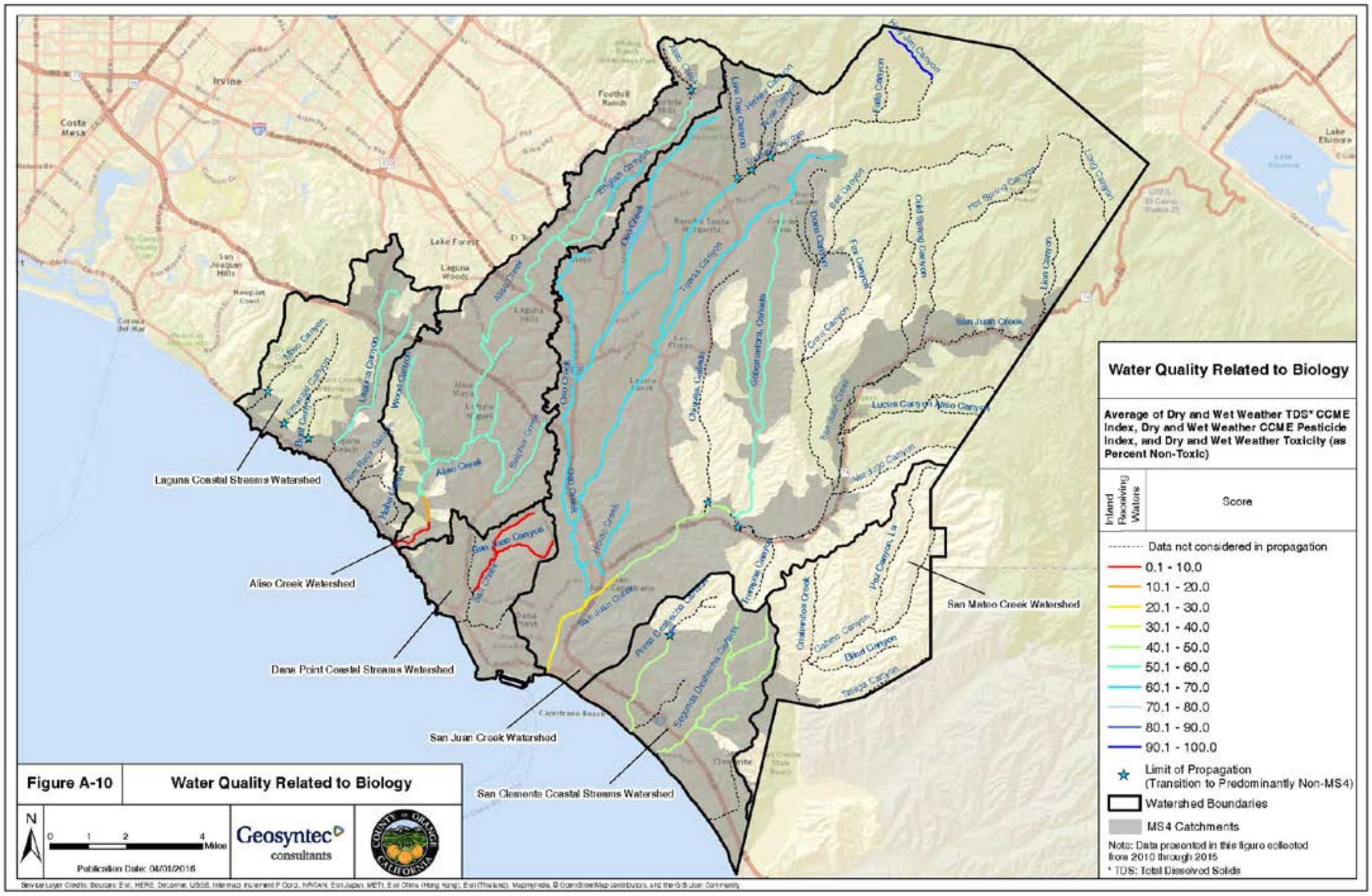


Figure 1. Excerpt from the San Juan Water Quality Improvement Plan shows how the County of Orange used SMC bioassessment and water quality data to prioritize problem areas in the watershed. Red, orange, and yellow stream segments have low-scoring bioassessment sites, in conjunction with measures of poor water quality. A separate analysis identifies stream reaches where low-scoring bioassessment occur in conjunction with geomorphic alteration.

A key objective of the SMC stream survey is to provide participants with data that helps them manage watersheds. One recent notable example is Orange County’s Water Quality Improvement Plan (WQIP) for the San Juan Hydrologic Unit, which prioritizes problems in the watershed based on SMC data, emphasizing biological indicators like benthic macroinvertebrates and algae. The goal of the WQIP is to 1) determine high-priority water-quality problems; 2) identify goals, strategies, and schedules to address them; and 3) propose an approach to monitor and assess progress. In all three elements, the SMC survey provides the foundation and the framework for implementing these goals.

The WQIP identified three priority problems, and two of them were determined through bioassessment data: geomorphic alteration, and unnatural flow regimes. These problems were identified by the association of stressors related to these problems (e.g., hydromodification and habitat degradation), and their relationships with poor bioassessment index scores (Figure 1). Best management practices to mitigate these stressors will be identified, and their success will be partly determined in terms of improvements in biological condition. The monitoring and assessment component of the WQIP is currently under preparation, and it is expected that biological monitoring through the SMC stream survey will play a crucial role in this component.

Regional flow targets to support biological integrity

The SMC stream survey data provides a strong foundation to explore the problems affecting streams in the region, such as hydrologic alteration, which previous surveys suggested is a major factor affecting biological condition. Hydrologic alteration results from water diversions, inter-basin transfers, and increased imperviousness that alter the natural flow regime in a stream. Taking advantage of a new ensemble-modeling approach to estimate current and historic flows at ungauged streams, hydrologic alteration was estimated at 572 bioassessment sites, most of which are part of the SMC stream survey. The ensemble was built by calibrating simple rainfall-runoff models at 26 stream gauges in Southern California, then assigning one model to ungauged sites with similar catchment properties. Biological responses (e.g., California Stream Condition Index [CSCI] scores) were modeled against metrics reflecting hydrologic alteration, thresholds of biological response were established for multiple flow metrics, and metrics were combined into an overall index of hydrologic alteration with scores ranging from 0 (no alteration) to 14 (all metrics severely altered).

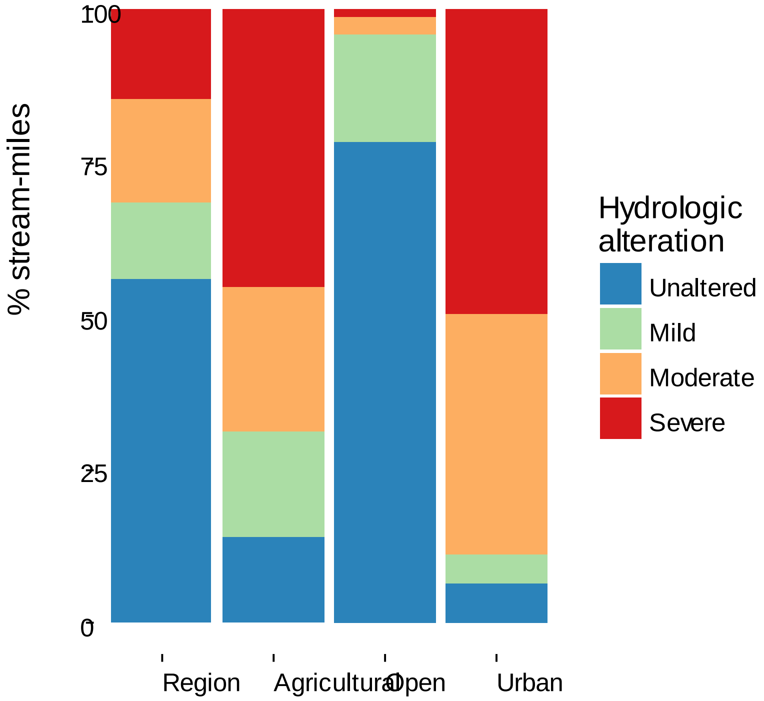


Figure 1. Extent of hydrologically altered streams in the region, as well as within three land-use classes.

Because this index was applied to survey data, it allowed the first-ever estimate of the extent of hydrologic alteration in the region. Approximately 34% of stream-miles in Southern California were estimated to be moderately or severely hydrologically altered, and alteration was more pervasive in urban (91% stream-miles altered) and agricultural (80%) than undeveloped (11%) streams (Figure 1).

The index also allowed rapid setting of management priorities and causal assessment screenings (Table 1, Figure 2). Among the biologically healthy sites (i.e., CSCI scores > 0.79), hydrologically unaltered sites (52% of total stream-miles) were prioritized for protection, and hydrologically altered sites (4%) were prioritized for monitoring. Among the biologically degraded sites, 30% were hydrologically altered, and prioritized for evaluation of flow management (such as increased stormwater detention or groundwater infiltration). Evaluation of other stressors was prioritized at the remaining 14% of stream-miles.

Table 1: Management action priorities based on measures of biological condition and hydrologic alteration.

	Unhealthy biology	Healthy biology
Altered hydrology	Evaluate flow management: 30%	Monitor: 4%
Unaltered hydrology	Evaluate other stressors: 14%	Protect: 52%

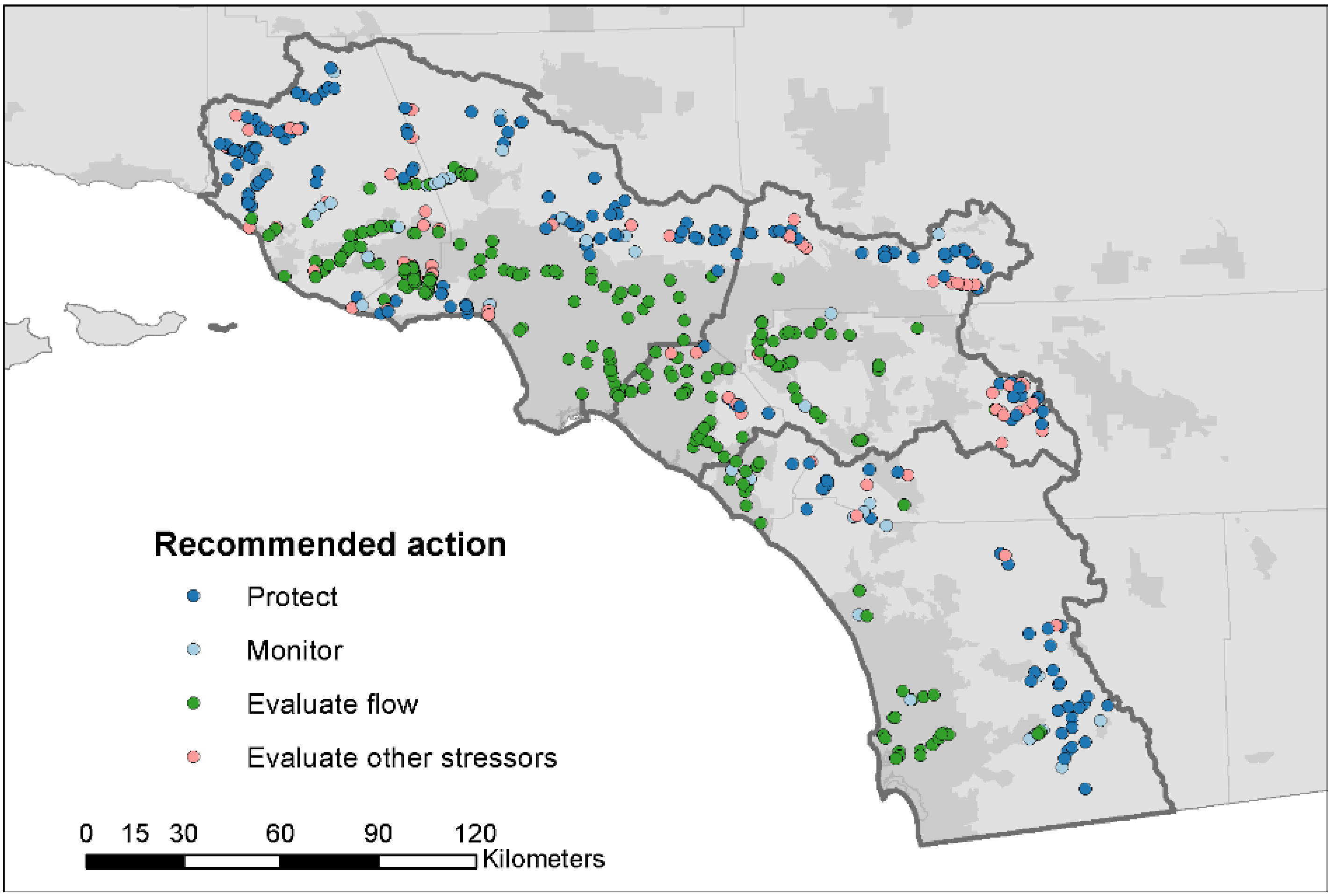


Figure 2. Management priorities for streams in the SMC region, based on estimates of hydrologic alteration and biological condition.

Regionally derived, biologically based targets for flow allow watershed managers to rapidly prioritize activities and conduct screenings for causal assessments at many sites across large spatial scales. Furthermore, regional tools pave the way for incorporation of hydrologic management in policies and watershed planning designed to support or enhance biological integrity in streams. Development of regional tools should be a priority in regions where hydrologic alteration is pervasive or expected to increase in response to climate change.