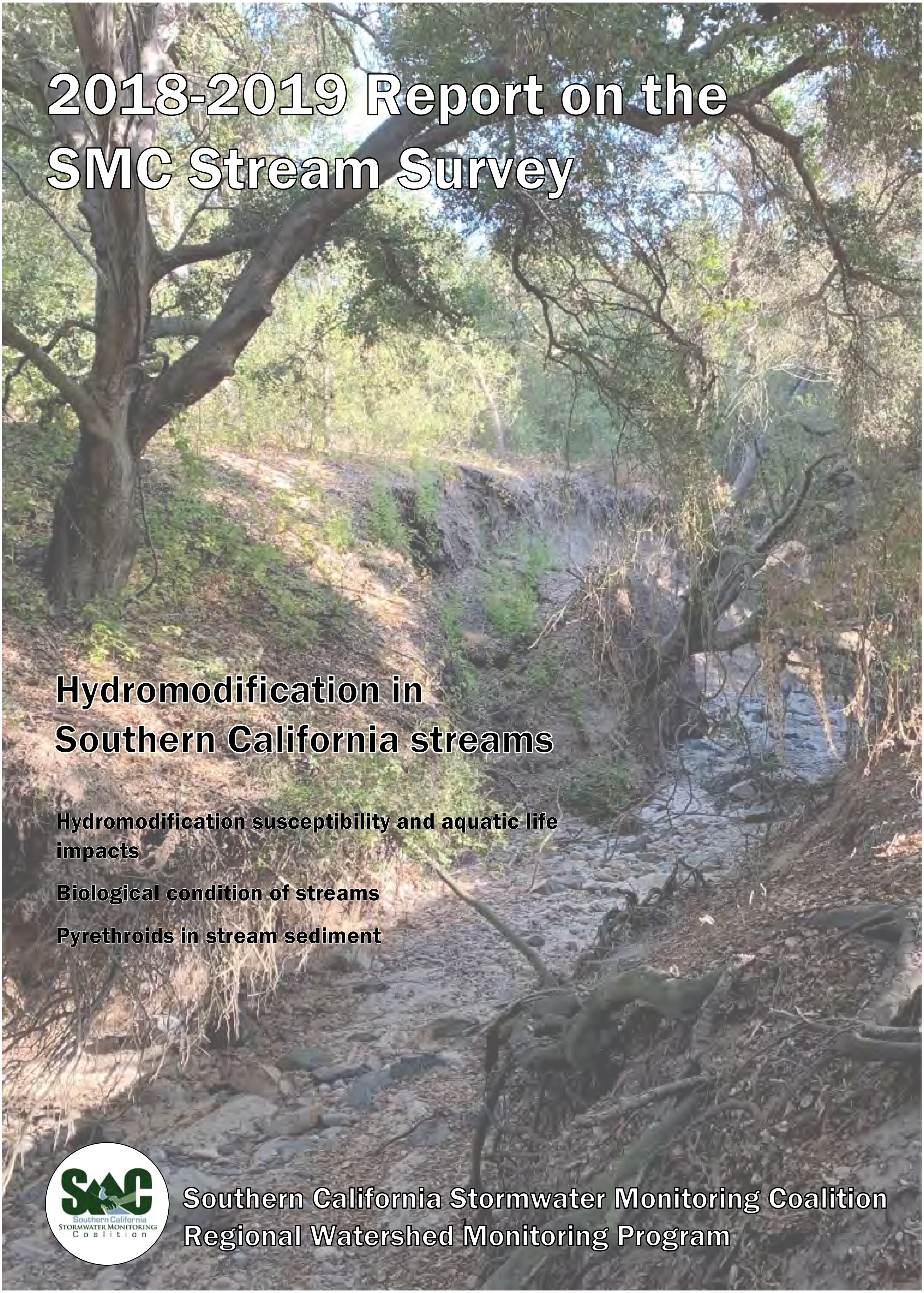


2018-2019 Report on the SMC Stream Survey

Hydromodification in Southern California streams

Hydromodification susceptibility and aquatic life impacts

Biological condition of streams

Pyrethroids in stream sediment

Southern California Stormwater Monitoring Coalition
Regional Watershed Monitoring Program

Contents

Cover Photo: Wagon Wheel creek in Orange County exhibits signs of hydromodification. Bank erosion threatens oaks and other riparian vegetation.

This report should be cited as:

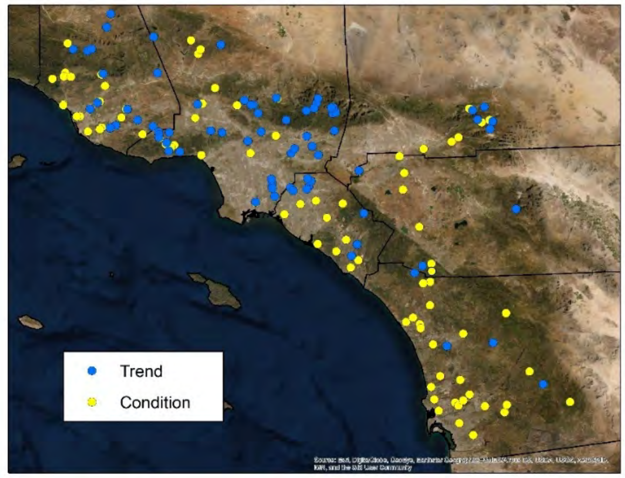
Taniguchi-Quan, K., R.D. Mazor, J. Brown, R. Guill, M. Yeager, A. Suter, J. Rudolph, B. Isham, and S. Johnson. 2020. 2018-2019 Report on the SMC Stream Survey. Technical Report #1127. Southern California Coastal Water Research Project. Costa Mesa, CA.

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.

Sampling Inventory

In 2018 and 2019, the SMC collected data from 187 samples at 164 unique sites, including 77 trend sites and 87 condition sites. Urban areas were well represented (48 condition sites and 33 trend sites), although open/undeveloped (23 and 34) and agricultural (15 and 8) areas were also covered.



Sampling effort in 2018 and 2019. Condition sites are selected probabilistically to characterize conditions in the region. Trend sites are former condition sites that have been selected for revisits to improve trend estimates.

At each site, benthic macroinvertebrate and algae assemblages were sampled for scoring in bioassessment indices (the California Stream Condition Index and Algal Stream Condition Index, respectively).

In addition, physical habitat was characterized using the standard SWAMP Standard Operating Procedures (Ode et al. 2016). The California Rapid Assessment Method was used to assess riparian wetland condition. Hydromodification susceptibility was assessed using a modified field tool developed by Bledsoe et al. (2010). Water chemistry analytes included specific conductivity, dissolved oxygen, water temperature, pH, nutrients, suspended solids, and major ions. Where fine-grained sediment was found, sediment samples were collected and analyzed for pyrethroid concentration and toxicity to the amphipod *Hyalella azteca.*

Number of unique sites sampled by participating agencies in 2018 and 2019. Note that multiple samples were collected at some sites.

County	Participating agency	Condition (# sites)	Trend (# sites)	Total (# sites)
Non-regulatory agencies				
Ventura	Ventura County Watershed Protection District	21	9	30
Los Angeles	Los Angeles County Flood Control District	10	2	12
	Los Angeles Watershed Regional Monitoring Program	7	12	19
	San Gabriel River Regional Monitoring Program	0	19	19
Orange	Orange County Public Works	10	9	19
Riverside	Riverside County Flood Control and Water Conservation District	6	3	9
San Diego	San Diego Watershed Management Areas	27	5	32
Regulatory agencies				
Los Angeles Region		0	16	16
Santa Ana Region		6	2	8
San Diego Region (contributions focused on reference sampling in non-perennial streams)		0	0	0
Total		87	77	164

Hydromodification susceptibility is widespread, but impacts to aquatic life may vary

The SMC sought to answer two questions about streams in southern California: what's the extent of hydromodification susceptibility and what's the relationship to biological condition?

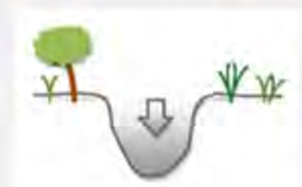
Land-use changes associated with urbanization and agriculture can drastically alter watershed hydrology, which can lead to physical changes in a stream channel, also referred to as "hydromodification." Stormwater managers are charged with preventing hydromodification and its impacts to stream beneficial uses. Traditional management efforts have historically focused on armoring channels to improve resistance, but more recently, stormwater agencies have turned to new methods, such as retrofitting existing development with structural hydrological source control or low-impact development (LID) in their Hydromodification Management Plans (HMPs), which focus on limiting or mitigating hydrologic alteration. The SMC's stream survey suggests that these new approaches might avoid past tradeoffs between managing hydromodification and protecting aquatic life.

Beginning in 2015, the SMC included hydromodification susceptibility assessment as part of its annual stream survey (see sidebar on methods, page 4) and through the 2019 sampling season have assessed 296 unique sites. Highly susceptible streams for lateral adjustments were observed in many natural streams across the entire SMC region. All channels that exhibited very high lateral susceptibility (i.e., susceptibility to bank erosion) were also highly susceptible to vertical incision (i.e., susceptibility to downcutting).

Key findings

- The SMC survey found widespread evidence of hydromodification susceptibility in streams in southern CA, including natural and unhardened streams in urban and agricultural areas.
- Although hydromodification susceptibility may have a negative relationship with bioassessment index scores in natural and fully soft engineered channels, channel hardening has a stronger association.
- New approaches to prevent hydromodification that focus on sources (e.g., retrofitting existing development with hydrologic source control or low-impact development) may be better for aquatic life than management actions that focus solely on in-stream solutions (e.g., channel hardening).

Hydromodification Impacts



Incision, or channel deepening, leads to disturbed bed material and limits the ability of a stream to access its natural floodplain

Bank erosion, or channel widening, can degrade streamside riparian habitat

Excess eroded sediment can lead to sedimentation of aquatic habitats (e.g. in-stream or downstream wetlands or estuaries)

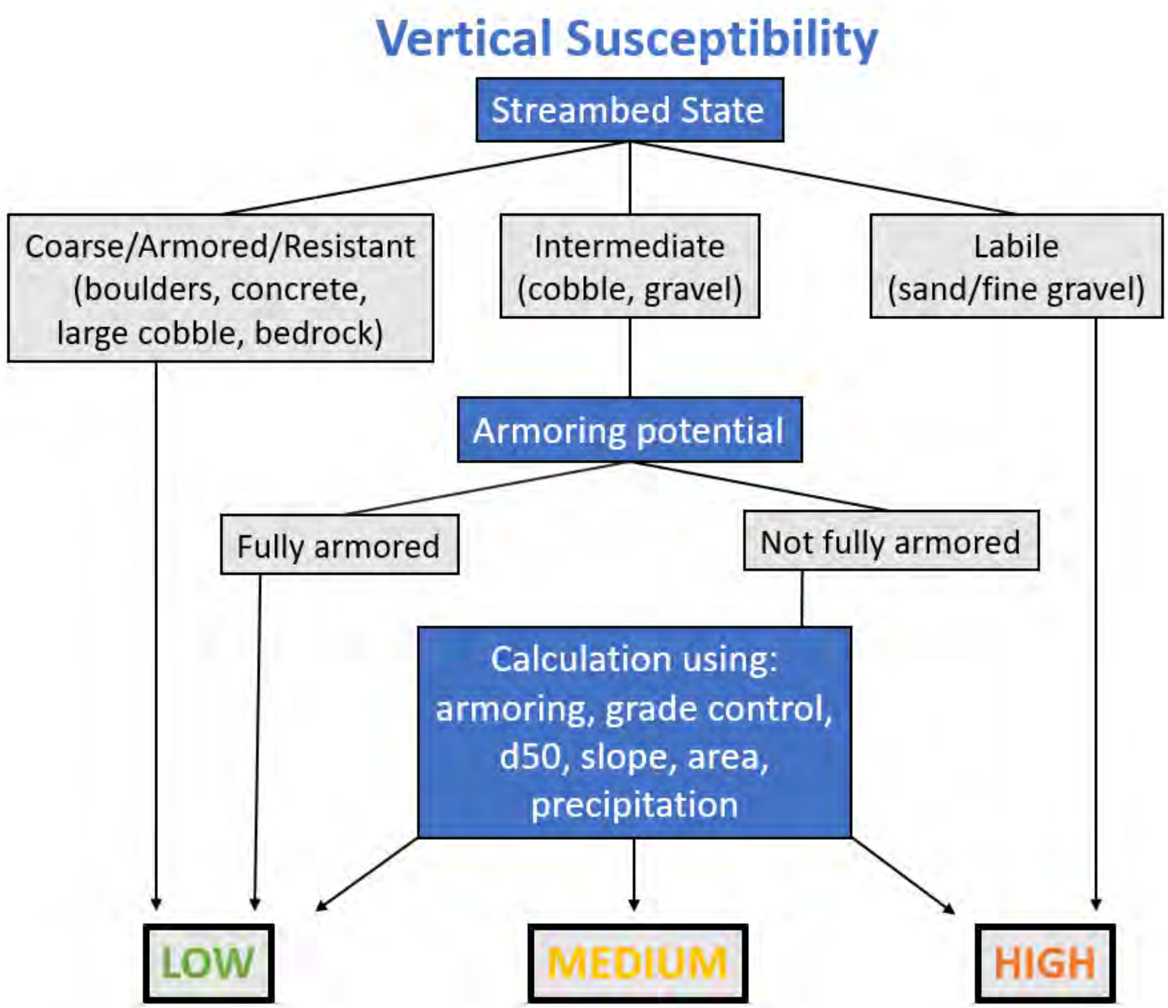
Illustrations adapted from Hawley et al., 2012

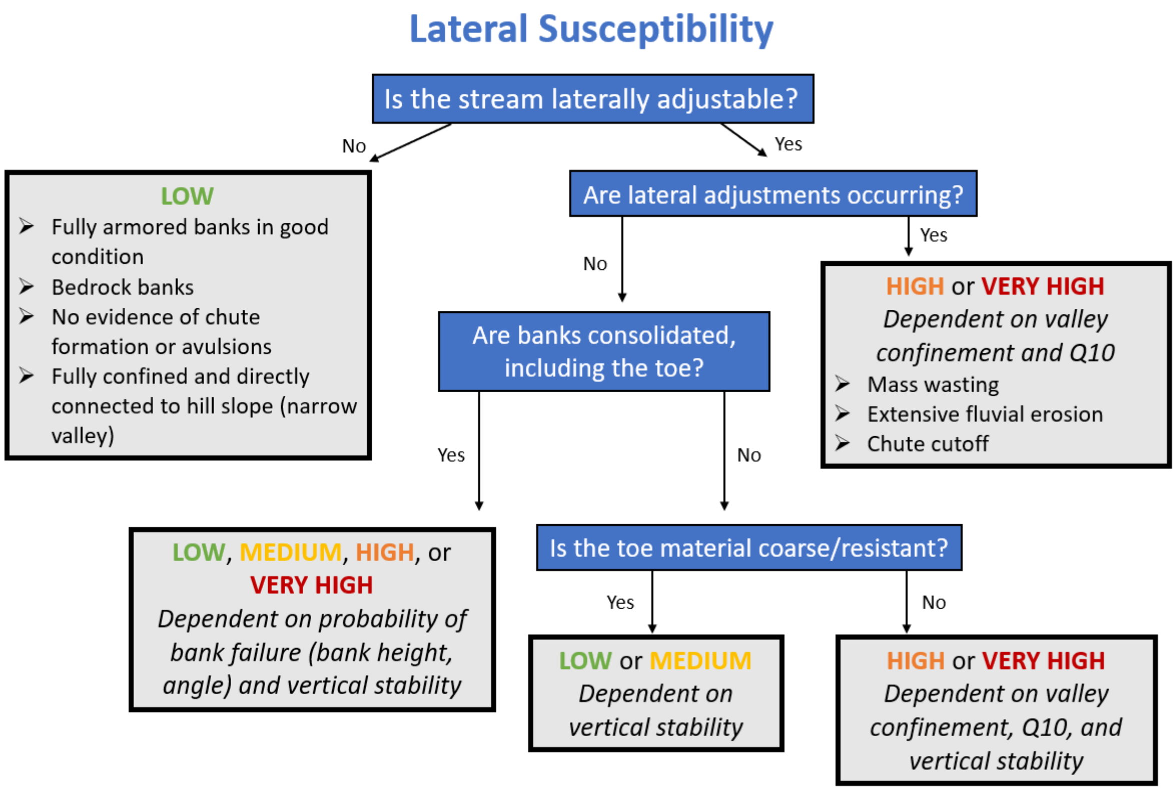
What is hydromodification susceptibility, and how is it measured?

Hydromodification susceptibility is the sensitivity of a channel system to morphological change caused by altered flow regimes. It is determined by the ratio of disturbing forces (e.g., shear stress from high flow velocities) to resisting forces (e.g., particle consolidation or armoring in the streambed). The field assessment tool used in the SMC stream survey is based on a combination of field measurements which are used as inputs to a set of decision trees that assign susceptibility ratings for vertical (Low to High) and lateral (Low to Very High) directions (see simplified decision trees below).

For vertical susceptibility, the survey measured indicators of resisting forces, like bed armoring, bed particle size (specifically, the median particle size, d50), presence of grade control, and longitudinal slope in addition to indicators of disturbing forces such as precipitation and watershed area (which are proxies for discharge).

For lateral susceptibility, the survey measured indicators of resisting forces, including bank material consolidation, toe material resistance, and valley width confinement; indicators of disturbing forces include discharge associated with a 10-year flood (Q10, estimated from precipitation and watershed area) and indicators of bank failure (i.e., bank angle and height). For more details on the field assessment tool, please refer to SCCWRP's technical report.





Hydromodification can produce geomorphological changes in streambed topography and habitat characteristics through aggradation (excess sediment build-up) or degradation (loss of channel banks or bed). These and other hydromodification symptoms cause a divergence from the natural ecological condition to a more disturbed state. However, channel response can vary based on factors such as channel material, slope, in-stream or streamside vegetation, or catchment properties. All of these factors impact hydromodification susceptibility or the likelihood of a channel to erode.

Historically, hydromodification susceptibility has been managed by armoring channels with concrete lining or riprap. These engineered channels reduce the risk of erosion and provide flood control and safety measures for communities; however, they have been associated with biological degradation (see previous SMC report).

Although many streams in urban areas of southern California are engineered to resist morphological changes via channel hardening, natural and unhardened engineered streams are sensitive environments that are susceptible to hydromodification. Sandy sediments are common in natural and earthen streams, and a high proportion of sand in a stream increases susceptibility to channel incision.

Similarly, stream bank erosion is related to the material, angle, and height of the stream banks, where taller, steeper, and sandier banks are more susceptible to erosion. Together, channel incision and bank erosion describe the vertical and lateral susceptibility of a stream to hydromodification. Understanding stream susceptibility to changes in flow can help to identify streams that are likely to be affected by hydromodification and can help guide land use planning and mitigation measures during land development in the watersheds (e.g., by directing development towards more resistant watersheds, or increasing stormflow retention in susceptible watersheds). Agencies that conduct restoration can also use this information.

Naturally resistant channels have cobbles, boulders, and other coarse materials that protect the banks and streambed from the shearing force of peak flows from most storms. This stream in Santa Barbara County would be rated as having low vertical and lateral susceptibility, meaning that only exceptionally large storms are likely to result in changes in channel morphology

Streams with naturally high levels of fine-grained substrate are more susceptible to erosion when peak flows are elevated due to hydrologic alteration. This stream in Orange County would be rated as highly susceptible, meaning that smaller, more frequent storms may alter the channel morphology. Details on these susceptibility categories can be found in Bledsoe et al. (2010).

Hydromodification management plans (HMPs) and specific provisions to municipal stormwater permits have been developed to address the effects of hydromodification in natural and earthen streams including adverse impacts to beneficial uses such as recreation and aquatic life (typically, HMPs do not apply to fully hardened streams). These management plans recommend new approaches to prevent hydromodification that focus on sources (e.g., hydrologic source control and low-impact development [LID]). However, many HMPs do not require long-term monitoring of biological response following the construction of upstream developments, LID strategies or hydrologic source control, stream restoration, or in-channel modifications, such as channel armoring or softer in-channel measures. Consequently, the linkage between hydromodification, management actions, and biological response remains unclear.

Channel Type Definitions

Natural

A channel whose physical structure has been minimally impacted by humans

Engineered

Earthen

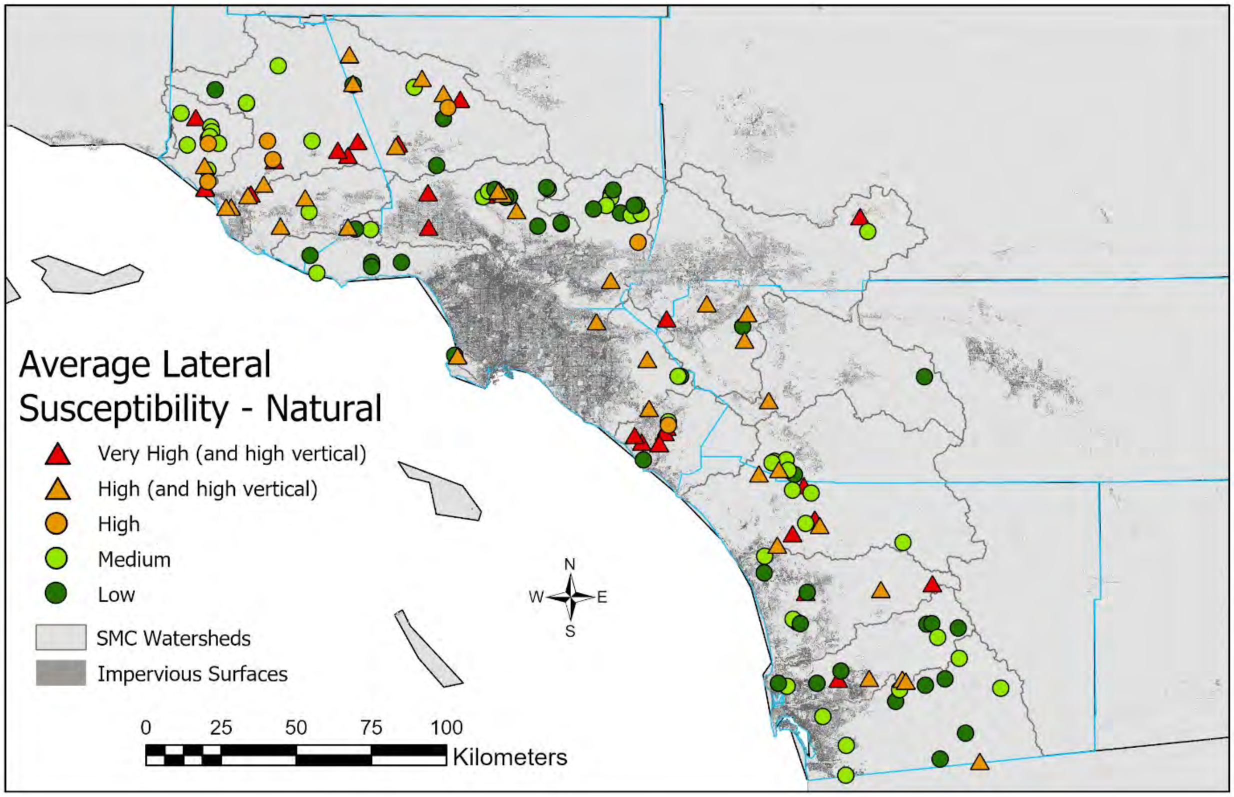
An engineered channel that is fully earthen or soft on all sides

Hardened Side(s)

An engineered channel that has a soft bottom with one or more hardened sides

Hardened Entire

An engineered channel that has been entirely hardened with concrete or riprap



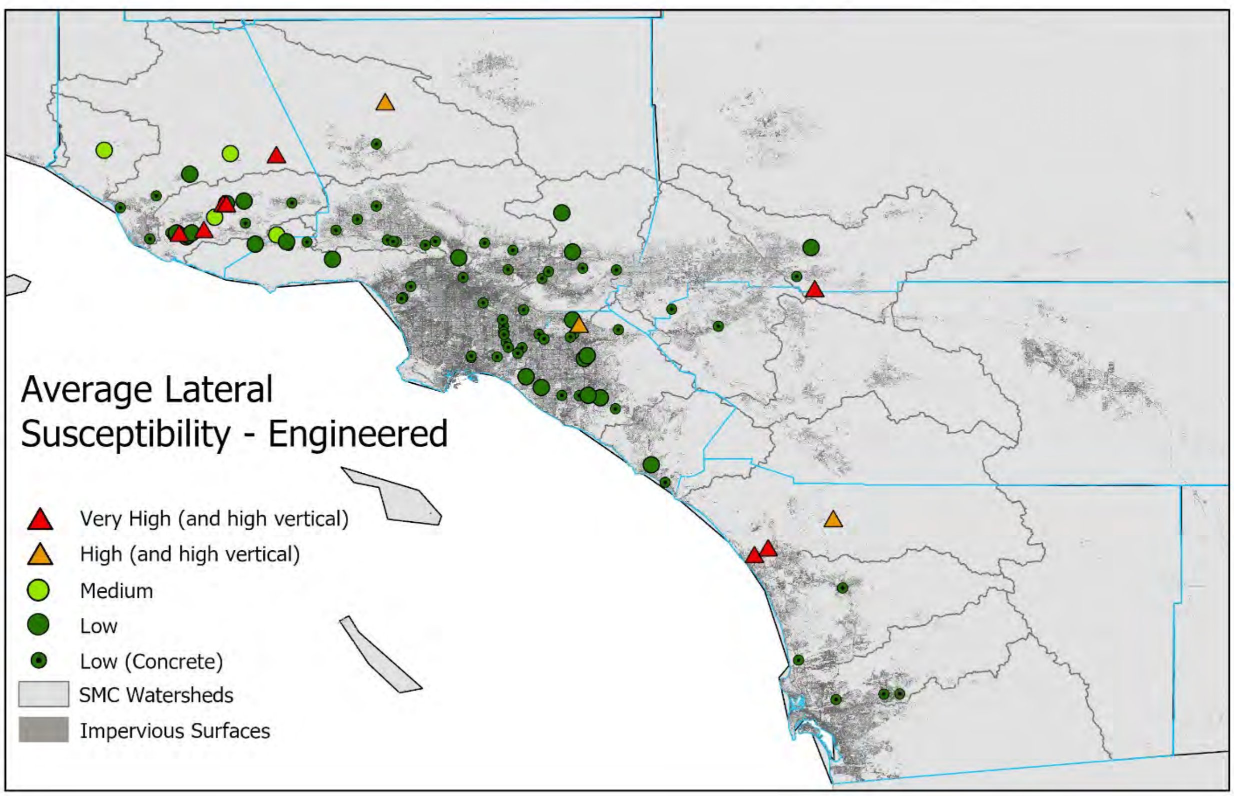
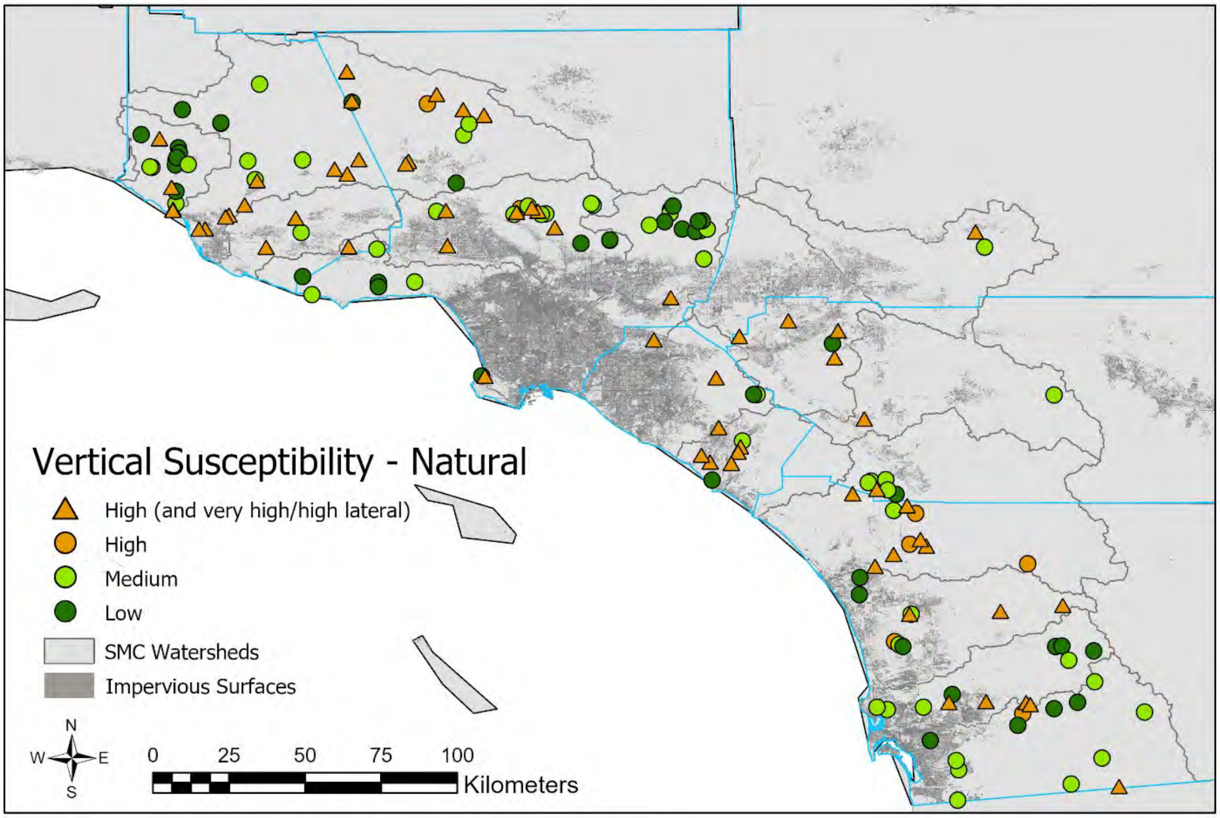


Figure 1a. Lateral susceptibility to channel change from hydromodification in South Coast streams. Concrete channels are included, although hydromodification management plans do not apply to them.



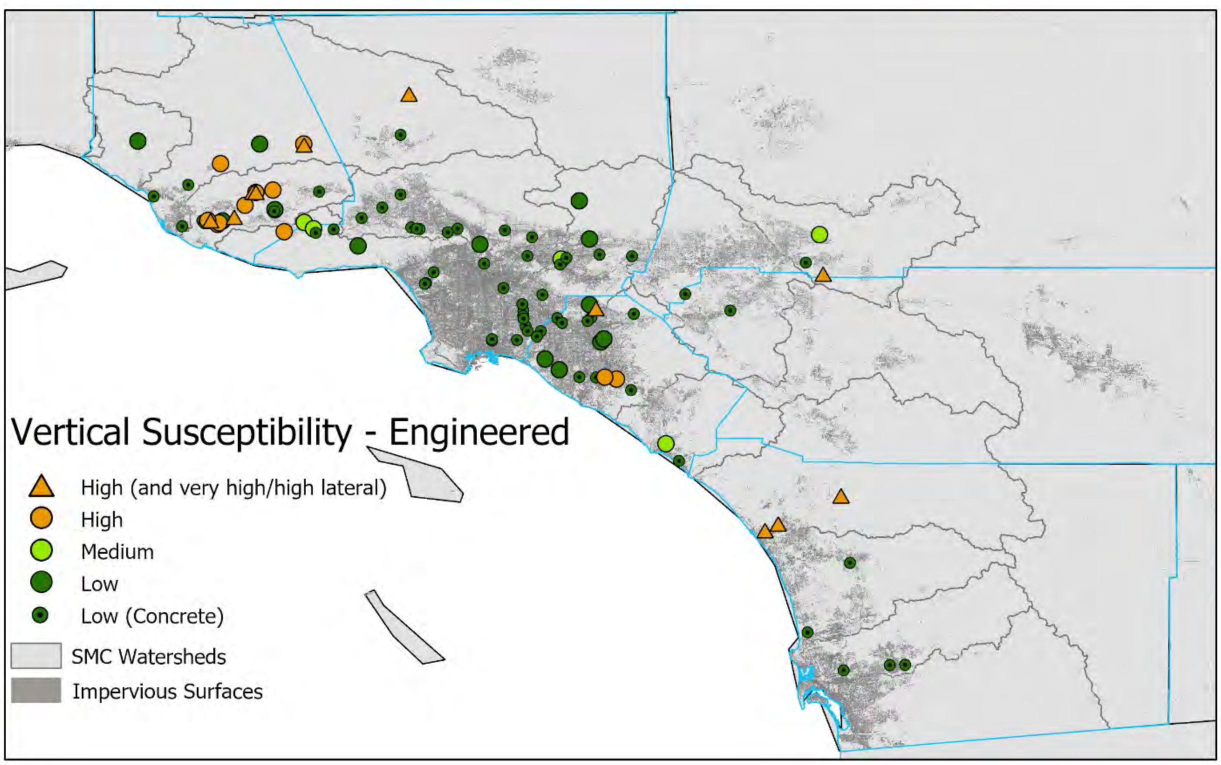


Figure 1b. Vertical susceptibility to channel change from hydromodification in South Coast streams. Unlike lateral susceptibility, the modified SMC hydromodification screening tool did not include a “very high” category for vertical susceptibility. Concrete channels are included, although hydromodification management plans do not apply to them.

Unhardened streams are vulnerable to hydromodification

The spatial extent of hydromodification susceptibility within the SMC Stream Survey region was assessed by evaluating differences across land use (i.e., open, agriculture, and urban) and channel type (i.e., natural versus a gradient of engineered channels) (Figures 2 and 3).

- Of the natural streams surveyed, nearly half were highly susceptible to hydromodification, with 42% ranking very high or high in lateral susceptibility and 43% of streams ranking high in vertical susceptibility. In general, high lateral and vertical susceptibility tended to co-occur.
- Natural streams in both agricultural and urban settings were the most susceptible to hydromodification. A previous SMC analysis (p. 15-16) concluded that agricultural streams were highly susceptible and urban streams had the highest proportion of low-susceptibility streams but it did not consider channel type (i.e., natural versus engineered).

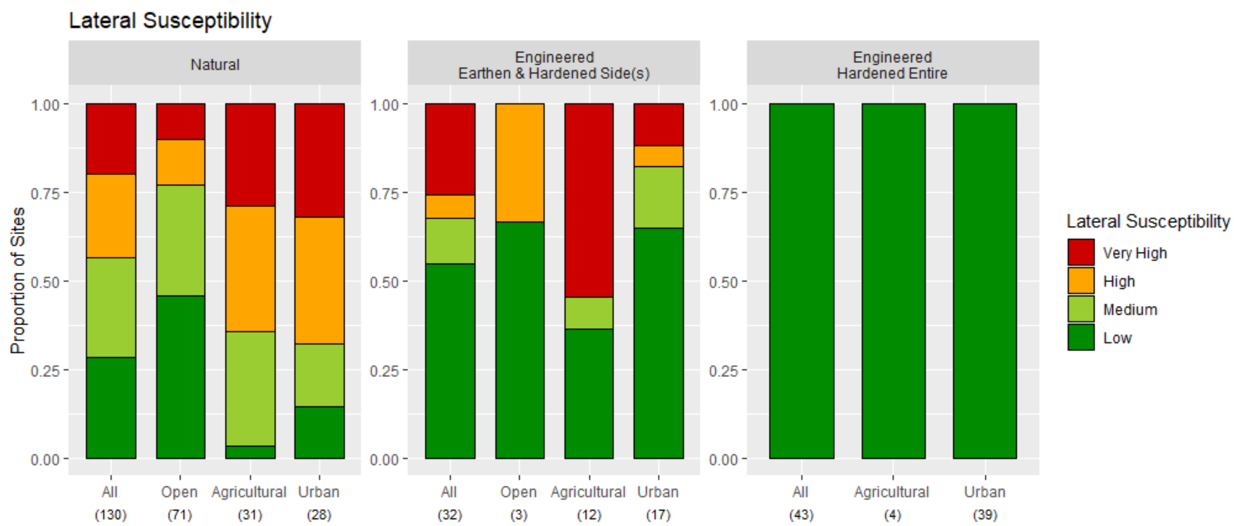


Figure 2. Of the natural channels, over 64% of both agricultural and urban streams exhibited high or very high lateral susceptibility versus 23% for open. For earthen and partially hardened channels, 83% of the very highly susceptible channels in agricultural areas were earthen and 81% of the low susceptible channels in urban areas had hardened side(s) with a soft bottom. The number in parentheses is the total number of sites in each bin. The engineered category includes earthen, partially hardened, and fully hardened streams. Fully hardened channels, regardless of land use, were dominated by low lateral susceptibility ratings (as expected).

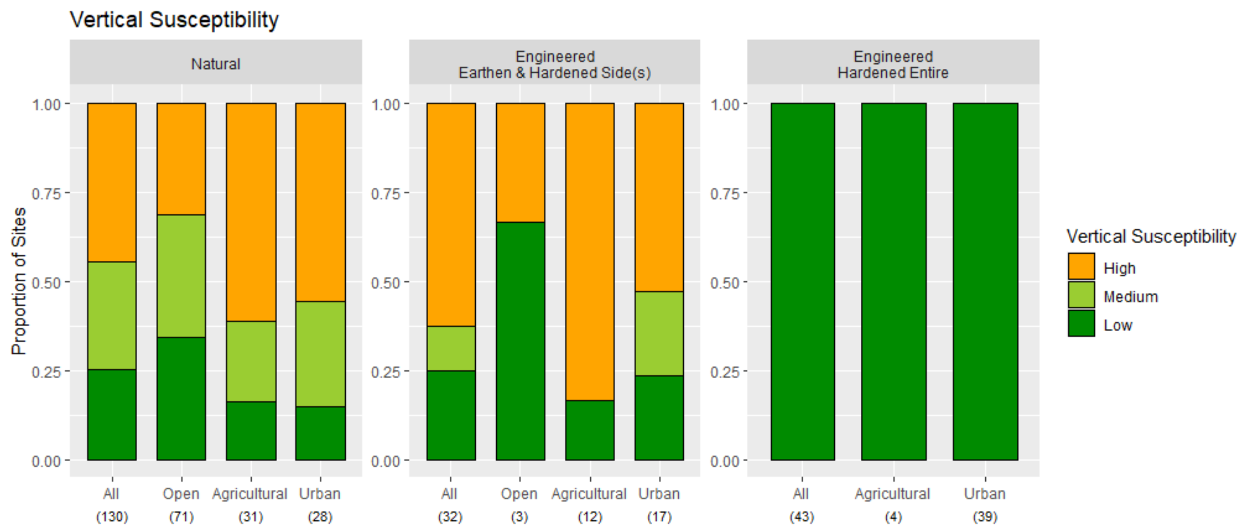


Figure 3. Both urban and agricultural natural streams were more susceptible to vertical adjustments than open streams, with 56% and 61% of streams exhibiting high vertical susceptibility, respectively, versus 31% for open streams. For earthen and soft bottom channels, 83% of agricultural streams and 53% of urban streams were highly susceptible to vertical erosion. The number in parentheses is the total number of sites in each bin. The engineered category includes earthen, partially hardened, and fully hardened streams. Fully hardened channels, regardless of land use, were dominated by low vertical susceptibility ratings (as expected).

Overall, engineered channels that were earthen or soft bottom with hardened bank(s) were less susceptible to lateral erosion compared to vertical erosion. The exception to this was earthen engineered streams in agricultural settings which were highly susceptible to both lateral and vertical erosion. The majority (71%) of soft bottom agricultural streams with at least one hardened side exhibited high vertical susceptibility (Figure 3). The hardened sides tend to increase flow velocities which then scour the unhardened stream bottoms.

Hydromodification susceptibility may influence biological communities

The influence of hydromodification susceptibility on stream biological communities was evaluated using two established stream biological indices, the California Stream Condition Index (CSCI) and the Algal Stream Condition Index (ASCI), for benthic macroinvertebrates (i.e., aquatic insects, snails, and other organisms that live on the streambed) and periphyton (i.e., diatoms and other algae that grow attached to the stream bottom), respectively. These two indicators are broadly reflective of how well a stream supports aquatic life. Other indicators that focus on wildlife or riparian condition, may provide additional insights.

Hydromodification susceptibility was negatively but weakly associated with CSCI scores, in contrast to the large decline in scores associated with channel hardening

- In natural channels, hydromodification susceptibility is associated with a small decline in CSCI scores. Channels with very high susceptibility had a high (>50%) frequency of CSCI scores below 0.79 (a threshold for identifying scores indicative of natural conditions, see Mazor et al. 2016; Figure 4). However, in almost all cases, these scores are only slightly below the reference threshold.
    - Causal relationships between CSCI and hydromodification susceptibility are not clear, particularly because the CSCI has been calibrated to work in a range of natural stream types. However, low-gradient, sandy streams with naturally high susceptibility may be more

frequently associated with disturbances that degrade biological condition than naturally resistant streams.

- In contrast, CSCI scores in engineered channels were nearly always below the 0.79 threshold, regardless of hydromodification susceptibility (consistent with the SMC's previous study). Many of the engineered streams (both hardened and earthen) fell well below the 0.79 threshold. The few high-scoring sites were typically mountain streams with natural bottoms and armored banks that protect streamside roads or other infrastructure.
    - Lower index scores are expected in engineered channels due to their limited habitat complexity and the potentially higher likelihood of additional stressors present in these highly modified channels.

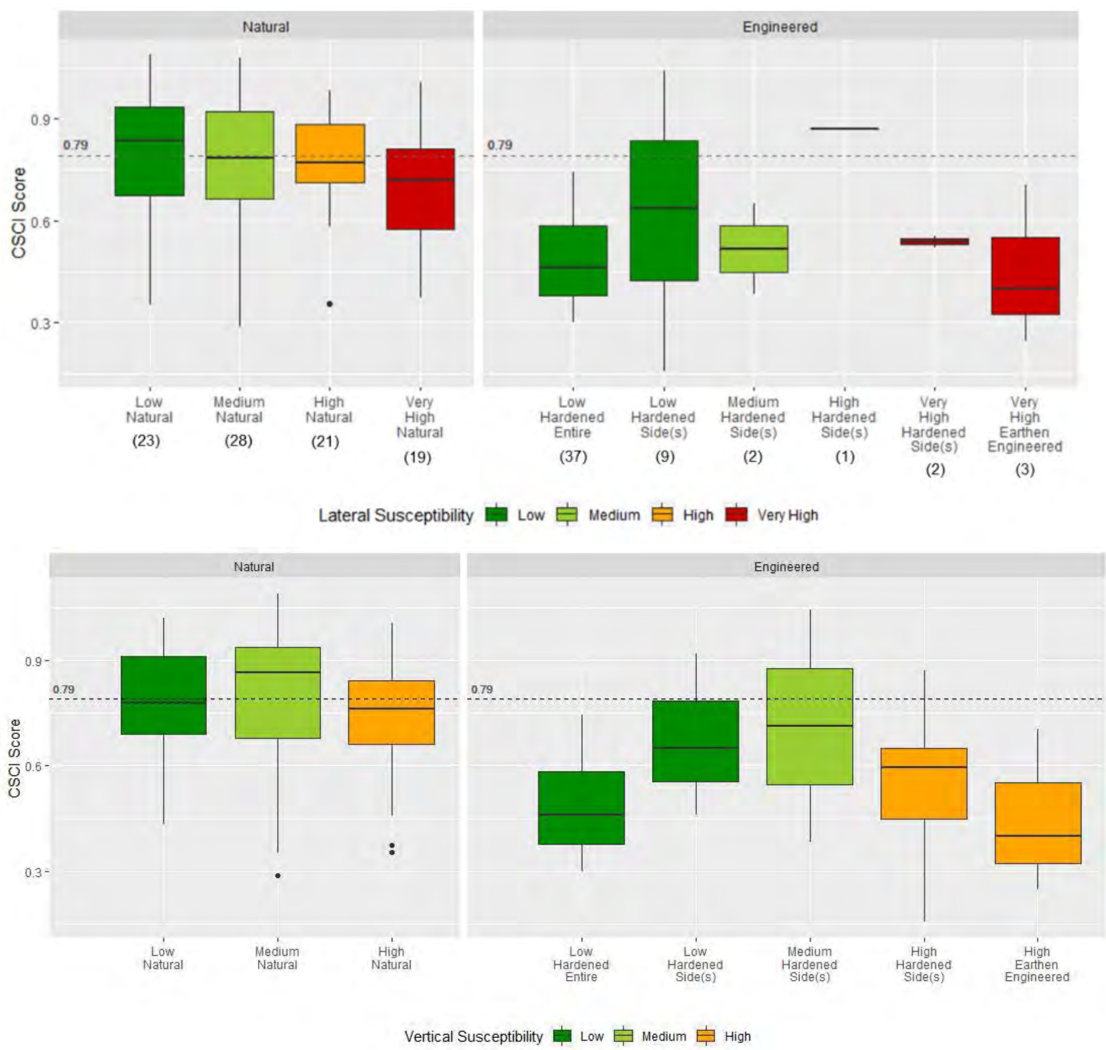


Figure 4. Comparison of CSCI scores across all channel types indicated that engineered channels tended to have lower CSCI scores compared to unhardened natural channels. Of the natural channels, median CSCI scores incrementally declined with increasing lateral susceptibility, from low susceptibility (0.84) to the very high susceptibility (0.72); this relationship was not evident for vertical susceptibility. Number in parentheses is number of sites in each bin. Categories not shown were not present in the CSCI database (e.g. entirely hardened channels with medium or high susceptibility). Dashed line represents the 10th percentile of reference scores (0.79).

CSCI scores across the categories of vertical susceptibility showed a similar pattern to lateral susceptibility. Streams that are highly susceptible to hydromodification are composed of finer, sandier sediment that are more easily scoured or disturbed compared to less susceptible, coarser and more resistant streams. In susceptible streams, even small hydrologic alteration could result in severe habitat degradation leading to lower CSCI scores.

Hydromodification susceptibility was more strongly associated with ASCI scores than CSCI scores

- The highest quality periphyton communities (highest median ASCI score, 0.96) were observed in natural channels of the low vertical susceptibility category (Figure 5). Natural channels with high vertical susceptibility had significantly ($p < 0.01$) lower scores compared to natural channels of the low and medium susceptibility categories.
- Natural channels, regardless of hydromodification susceptibility rating, supported notably higher quality algal communities than entirely and partially hardened channels. The exception to this were primarily natural streams with a hardened bank that were classified as low hardened side(s) (e.g., mountain streams near a road). A previous study found that hardening the sides but retaining a soft bottom may have small to negligible impacts on index scores, at least in otherwise natural watersheds.
- Within natural and partially hardened channel types, median ASCI scores incrementally declined with increasing susceptibility.
- The susceptibility/channel type combinations with the lowest median ASCI scores were entirely hardened low susceptibility (0.63) and partially hardened soft-bottom high-susceptibility (0.52) streams. A previous SMC study also found that ASCI scores were low in entirely hardened channels.

ASCI scores across the categories of lateral susceptibility showed a similar pattern as vertical susceptibility.

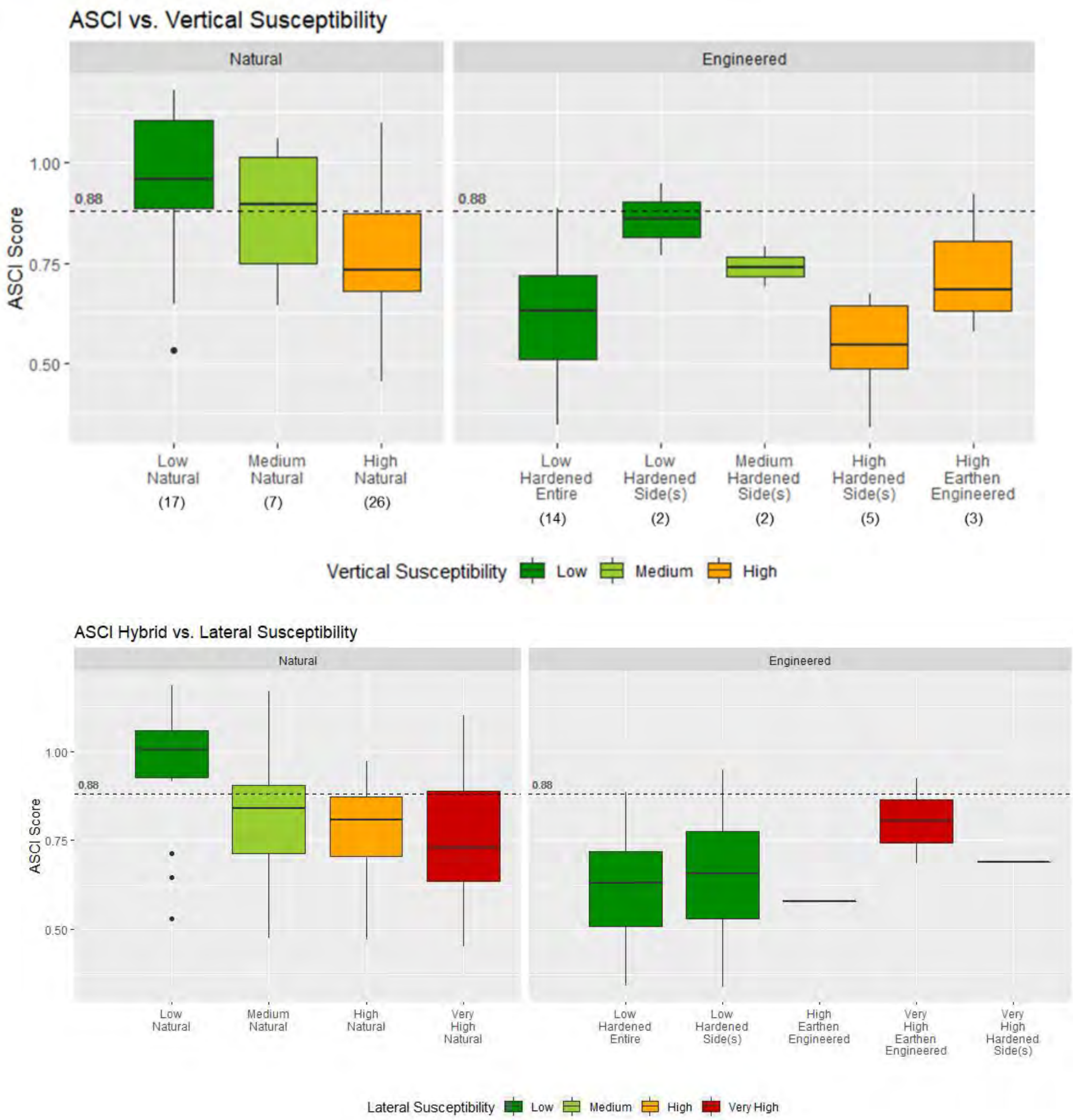


Figure 5. Comparison of ASCI scores across natural and partially hardened channel types indicated that ASCI scores tended to decline with increased vertical (and to a lesser extent, lateral) susceptibility. Number in parentheses is number of sites in each bin. Categories not shown were not present in the ASCI database (e.g., entirely hardened channels with medium or high susceptibility). Dashed line represents the 10th percentile of reference scores (0.88).

Conclusions

- Many natural and partially hardened streams throughout southern California are susceptible to impacts of hydromodification, including streams in urban and agricultural settings where flow alteration tends to occur. This highlights the importance of hydromodification management across the region.
    - However, traditional methods successfully used to prevent channel erosion, such as channel armoring, may impact aquatic life. Newer management strategies that focus on limiting hydrologic alteration (e.g., retrofitting existing development with hydrologic source control, low-impact development, and other elements of hydromodification plans) may avoid this tradeoff, achieving both hydromodification reduction while also protecting aquatic life in natural streams.
- Although there was a negative but weak relationship between hydromodification susceptibility and biological condition, the survey did not quantify changes in channel form due to hydromodification nor similar measures that would be required to assess the severity of hydromodification impacts.
    - Long term studies of changes in stream morphology associated with hydromodification and implementation of best management practices are needed to fully answer this question.

Hydromodification management implications and recommendations for future directions

Continue to include rapid hydromodification susceptibility assessment as part of its annual stream survey

The SMC hydromodification susceptibility assessment is a cost-effective and integral component for understanding the relationship between hydromodification and biological condition. This evaluation is the first regional study to incorporate channel condition, hydromodification susceptibility, and biological condition. As more sites are assessed through time and space, regional stream stability can be evaluated over time and the spatial extent of potential geomorphic and biological impacts related to this stability will be more clearly understood. In order to better evaluate trends over time, the survey checklist should be modified to aid in identifying conditions that warrant repeat site visits and more intensive field screening in more susceptible streams (e.g., natural rather than concrete channels). Additionally, future hydromodification studies should evaluate potential risks in susceptible natural streams (e.g., grazing, culverted road crossings, effective impervious cover). Because these factors go beyond stormwater management, the SMC should partner with other groups, such as those that focus on managing irrigated lands.

Consider new methods of measuring hydromodification

The hydromodification screening tool used in the SMC survey is a useful, rapid, and low-cost method to determine how susceptible a channel is to erosion, but it can only be applied over a limited spatial extent, nor does it provide enough resolution to determine where within a reach hydromodification is likely to occur. Furthermore, it only assesses susceptibility, and cannot indicate when hydromodification has already occurred. To supplement hydromodification screening tools, rapid and cost-effective technologies such as unmanned aerial vehicles (UAVs) could be used to quantify hydromodification impacts (e.g., changes in channel form) and characterize the physical habitat conditions of multiple stream reaches across broader geographies with better accuracy and in less time compared to traditional survey methods. Additionally, current hydromodification measurement tools may have limited ability to detect trends over time. UAVs can be flown in a repeatable programmed flight path, reducing human error and removing any artifact caused by survey landmarks shifting. Although vegetation can hamper accurate UAV results and may restrict the number of sites where this tool can be used, adding this assessment method could greatly improve long-term understanding of hydromodification impacts on stream morphology. To better understand mechanisms driving stream stability and hydromodification impacts, a focus should be given to areas designated for future development (to track changes over time following development) and to streams draining different land uses and gradients of disturbances. Additionally, the use of freely available remote sensing products, such as synthetic aperture radar, could have the potential to detect changes in channel morphology in natural streams with high susceptibility after large storm events.

Develop an evaluation framework for assessing Hydromodification Management Plan (HMP) effectiveness in protecting aquatic life and other beneficial uses

The SMC stream survey provided valuable information regarding the spatial extent of stream susceptibility to hydromodification impacts. However, special studies are needed to develop a framework for more precisely assessing impacts of hydromodification and HMP effectiveness in reducing or mitigating those impacts. For example, a paired study with sites managed with and without hydrologic source control and an evaluation pre- and post-HMP implementation would be instrumental in answering key questions including "how effective have HMPs been in preventing physical habitat degradation," "has there been improvement in the biological conditions of streams in response to HMPs," "how can we tease out impacts associated with other stressors (e.g., pollutants)," and "will it be possible for streams to recover from legacy hydromodification impacts, and if so, how long will it take?"

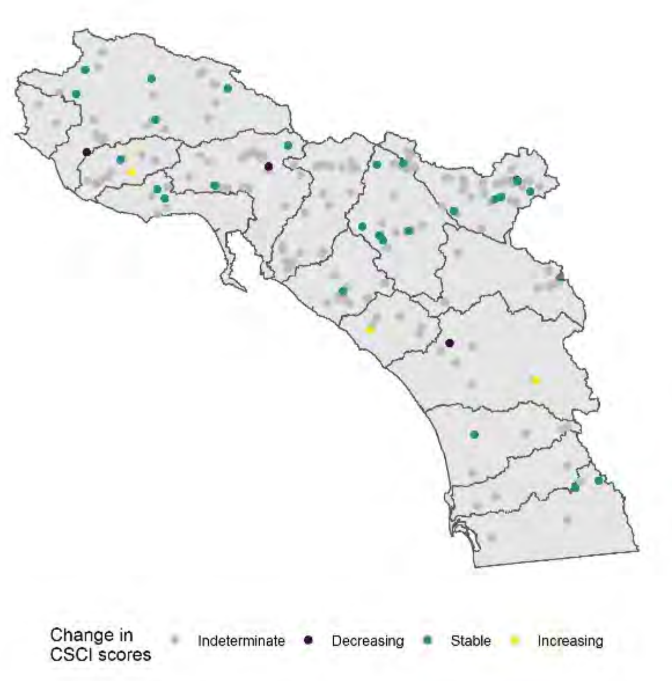
Develop models for assessing the impacts of hydromodification resulting from changing water management landscape (i.e. changing water use, land use, and climate)

The current hydromodification screening tools allow stormwater managers to map where channels are likely susceptible to hydromodification at discrete points, but it does not indicate where hydromodification impacts are likely occurring and which streams are likely to experience the greatest impact in the future. Models are needed to predict channel changes over time in relation to future changes in water use, land use, and climate, and then relate these changes to biological condition. Such models will be essential to identify the most vulnerable streams and to inform hydromodification management, stream rehabilitation, and protection into the future.

SMC survey reveals stable biological conditions in many streams in Southern California

Are conditions in Southern California streams changing over time? Recent redesigns to the survey provide answers to this question with greater clarity than previously possible.

Beginning in 2014, the SMC survey began to revisit sites to improve trend detection, ultimately revisiting a total of 199 sites. Of these sites, 70% were visited on two occasions, and the rest (60 sites) between 3 and 9 times. These numbers exceeded the design set forth in the SMC's workplan because many probabilistic sites were serendipitously located near sites targeted for regular monitoring, such as mass emission stations, and thus could be treated as trend sites. At the typical site, data collection spanned 6 years, although a handful had data spanning 18 years, with samples dating back to 2000.

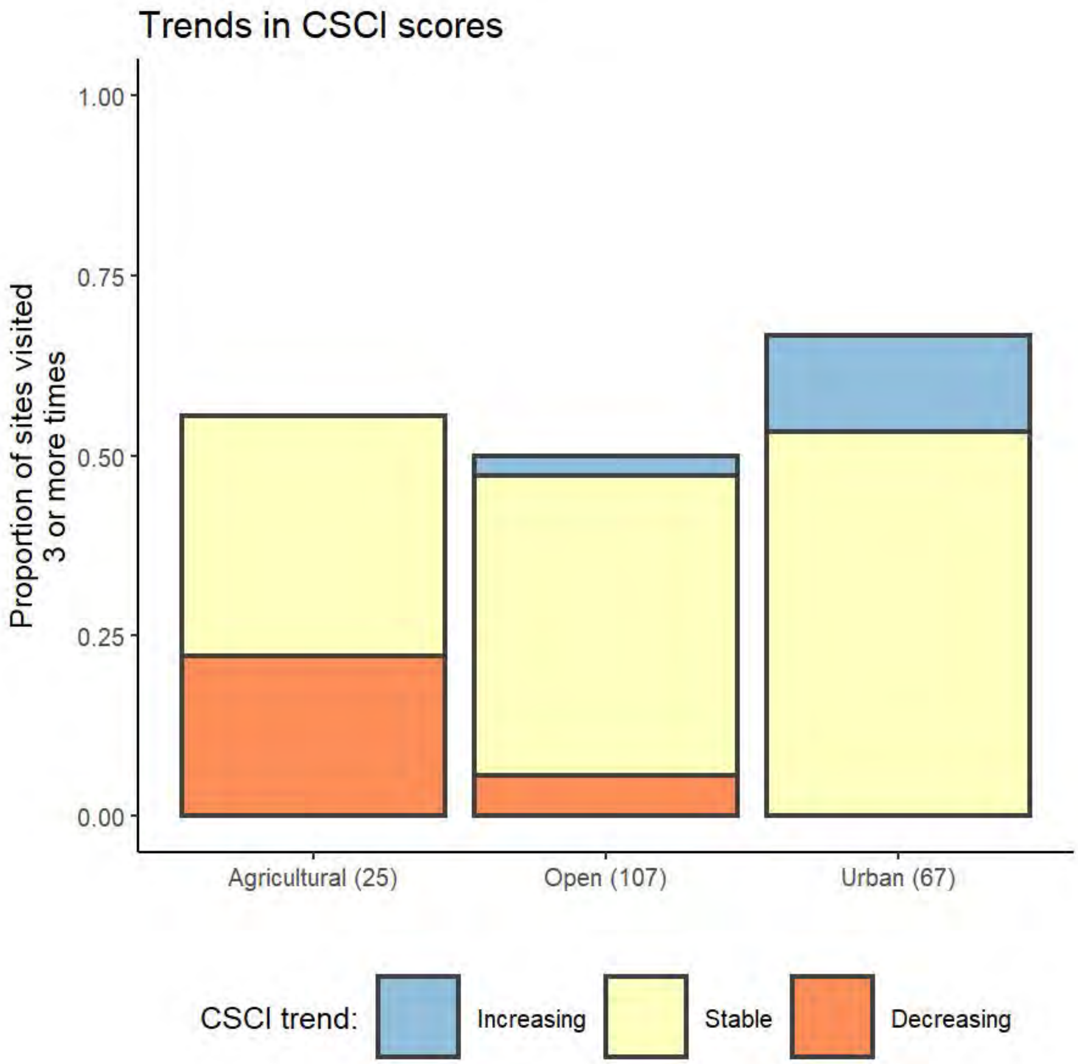


Changes in CSCI scores at sites with revisits. Gray dots indicate revisited sites where trends could not be classified (i.e., sites visited twice, or sites where the range exceeded 0.22 and lacked statistical significance).

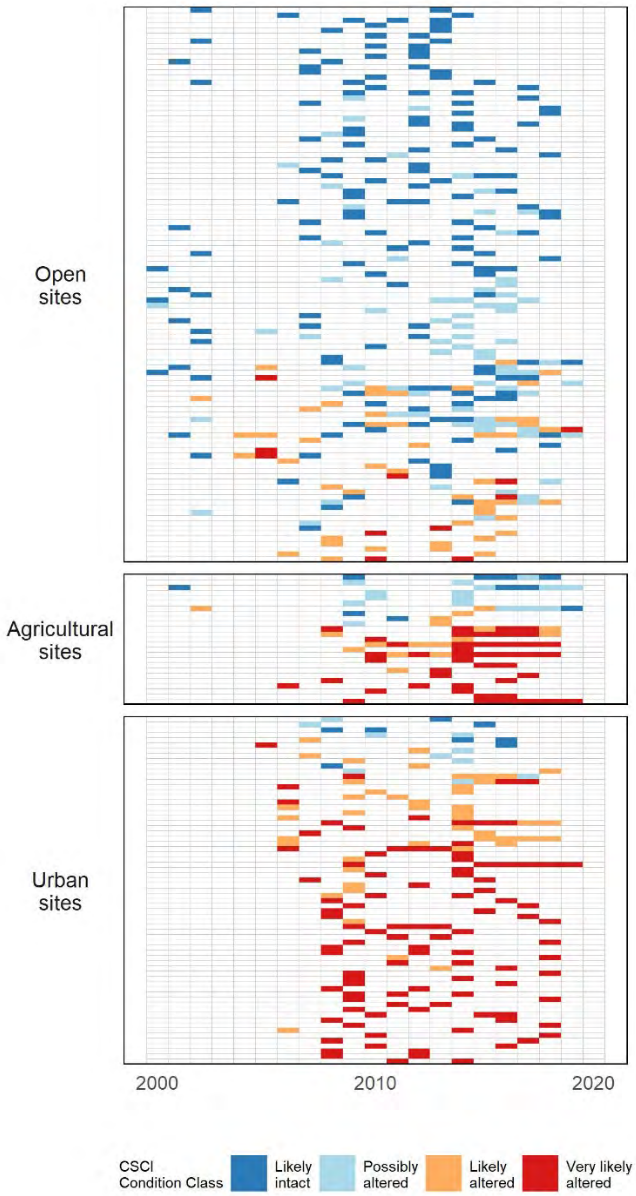
Although California Stream Condition Index (CSCI) scores varied at these sites, scores significantly changed over time ($p < 0.1$) at 7 sites (3 increasing and 4 decreasing); another 26 were classified as stable (i.e., total change was less than 0.22 CSCI points, within the natural range of variability estimated during CSCI development). The number of sites with significant changes was too low to associate with environmental factors, although no decreases were detected at urban sites, and no increases were detected at agricultural sites. Trends were indeterminate (i.e., no significant change, and no indication of stability) at 45% of sites with 3 or more sampling events.

Key findings

- Many streams exhibited stable biological conditions, and significant changes in assessment scores were detected at only a small handful of sites.
- Revisiting sites increases confidence in estimating trends at most sites, but at some high-variability sites, additional monitoring is necessary to estimate trends.



Trends could be classified at 55% of sites with 3 or more revisits. Most of these sites were stable, with few significant increases (n=3) or decreases (n=4) detected.



Although scores at many sites varied from year to year, there was little evidence of a consistent pattern across the region or in any land use class. Each row represents a site, and each column represents a year. The color of each tile indicates the condition, as inferred from CSCI score; white tiles indicate that the site wasn't sampled in that year.

These results underscore the effectiveness of the SMC survey's redesign in 2015, when sampling efforts switched from sampling a new set of sites each year to revisiting a set of probabilistically identified sites that had been sampled in the past. The SMC saw no changes in regional condition over the course of its initial 5-year survey, but questions remained about whether its analysis of different sites each year might obscure trends. By redesigning the survey to revisit sites, the SMC builds on those results, suggesting that condition in most of the region is stable, and further finding that significant changes are limited to a small number of locations.

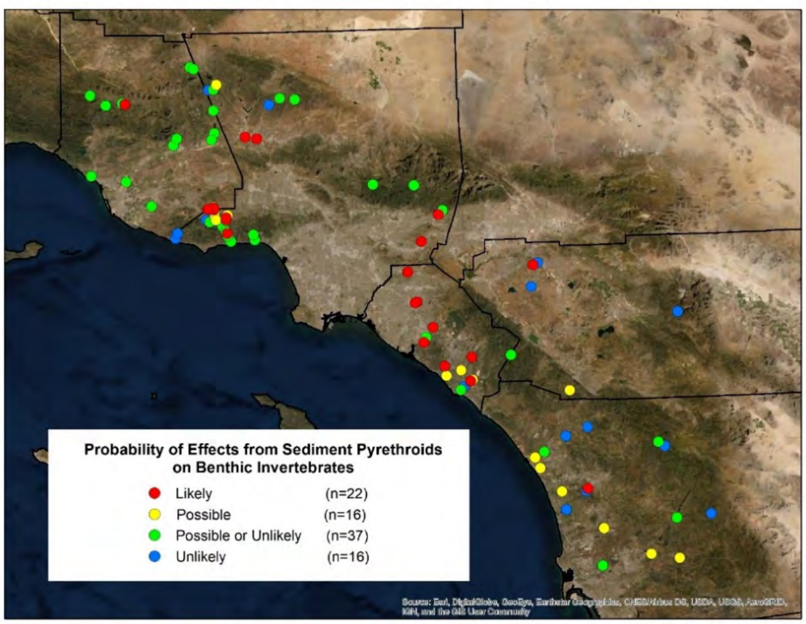
Recommendations

- Continue or expand revisits at trend sites, particularly at sites where trends could not be classified (e.g., sites that have been sampled twice, or sites with high variability in CSCI scores).
- Explore classification methods based on ecologically meaningful change. The statistical approach used in this study should be viewed as a starting point for further refinement.
- Improve the use of data collected at trend sites to support causal assessments and other management decisions. Trend sites with multiple years of data are better suited for analysis than sites with data from a single visit.

Pyrethroids are widespread in Southern California stream sediments, but evidence of direct impacts to aquatic life is unclear

Earlier analysis showed that pyrethroid pesticides were rarely detected in water samples collected in southern California streams, but new analysis of sediment samples provides a better picture of potential risk from these contaminants.

In past surveys, sediment sampling was conducted sporadically; in 2015, the SMC began to collect sediment samples consistently as part of its survey, yielding a data set of 124 sites with concurrent sediment and bioassessment samples. Samples were collected from reaches with sufficient fine-grained sediment, which accounted for about one-third of sites in the survey. Where sediment was collected, pyrethroid pesticides were detected in 60% of samples. Comparing organic content-normalized concentrations to adverse effects benchmarks from Nowell et al.

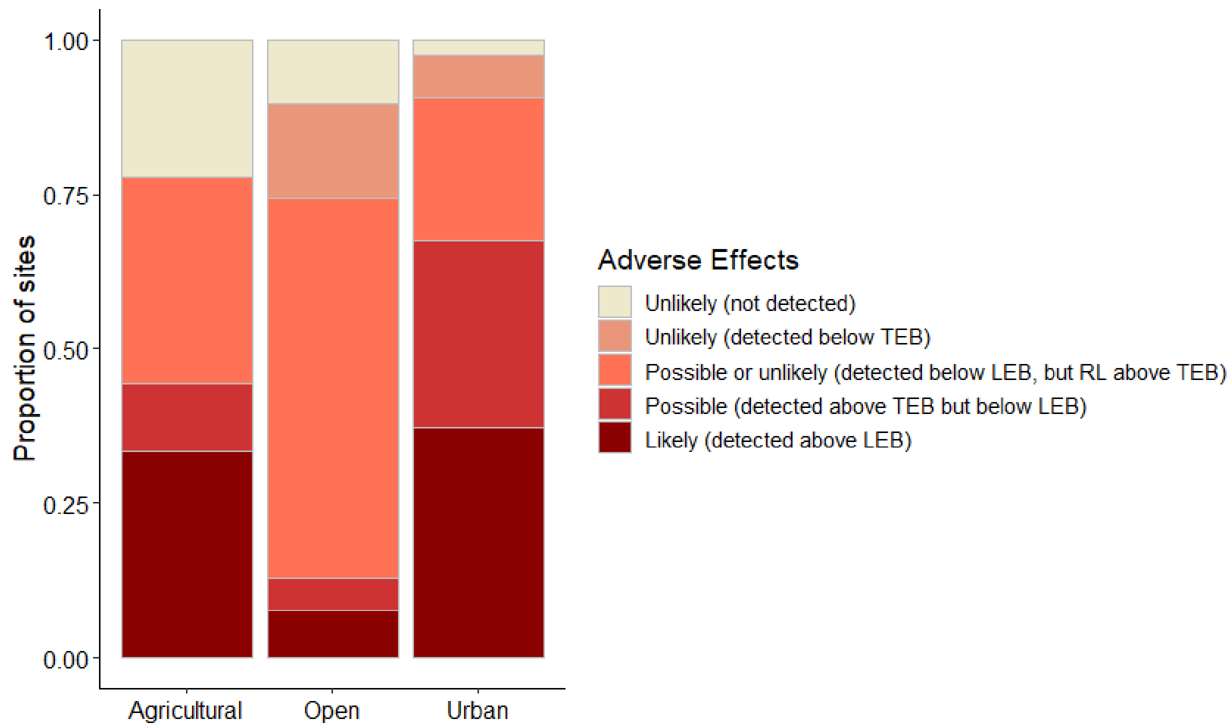


Comparison of pyrethroid concentrations to adverse effect thresholds (Nowell et al. 2016) at sites where sediment was collected by the SMC stream survey. Twenty-one sites where reporting limits exceeded likely effects benchmarks are not shown. Likely: Concentration exceeded the likely effect benchmark (LEB). Possible: Concentration exceeded the threshold effect benchmark (TEB). Possible or unlikely: Concentration did not exceed LEB, but reporting limit (RL) exceeded TEB. Unlikely: Neither concentration nor RL exceeded TEB. The benchmarks vary from site to site, depending on total organic carbon concentration in the sediment.

Key findings

- Pyrethroid pesticides were detected in 60% of stream sediment samples, and their concentrations exceeded likely adverse effects benchmarks from the scientific literature for at least one constituent at 20% of these samples. Bifenthrin was the most widespread pesticide detected. These results contrast with previous analyses of water column samples, in which pyrethroid detections were relatively rare.
- Sediment samples were collected in about 35% of streams where bioassessment was conducted; the lack of abundant fine-grained sediment prevented sampling at the other streams. It is unclear if pyrethroids present a risk in streams where fine-grained sediment is lacking.
- Acute toxicity was rarely detected. However, CSCI scores were low where total pyrethroid concentrations in the sediment were high, suggesting that the organisms used to calculate the CSCI may be more sensitive to pyrethroid pesticides than the organisms used in standard toxicity assays. However, other stressors that co-occur with sediment pyrethroids (e.g., degraded physical habitat) might account for this relationship.

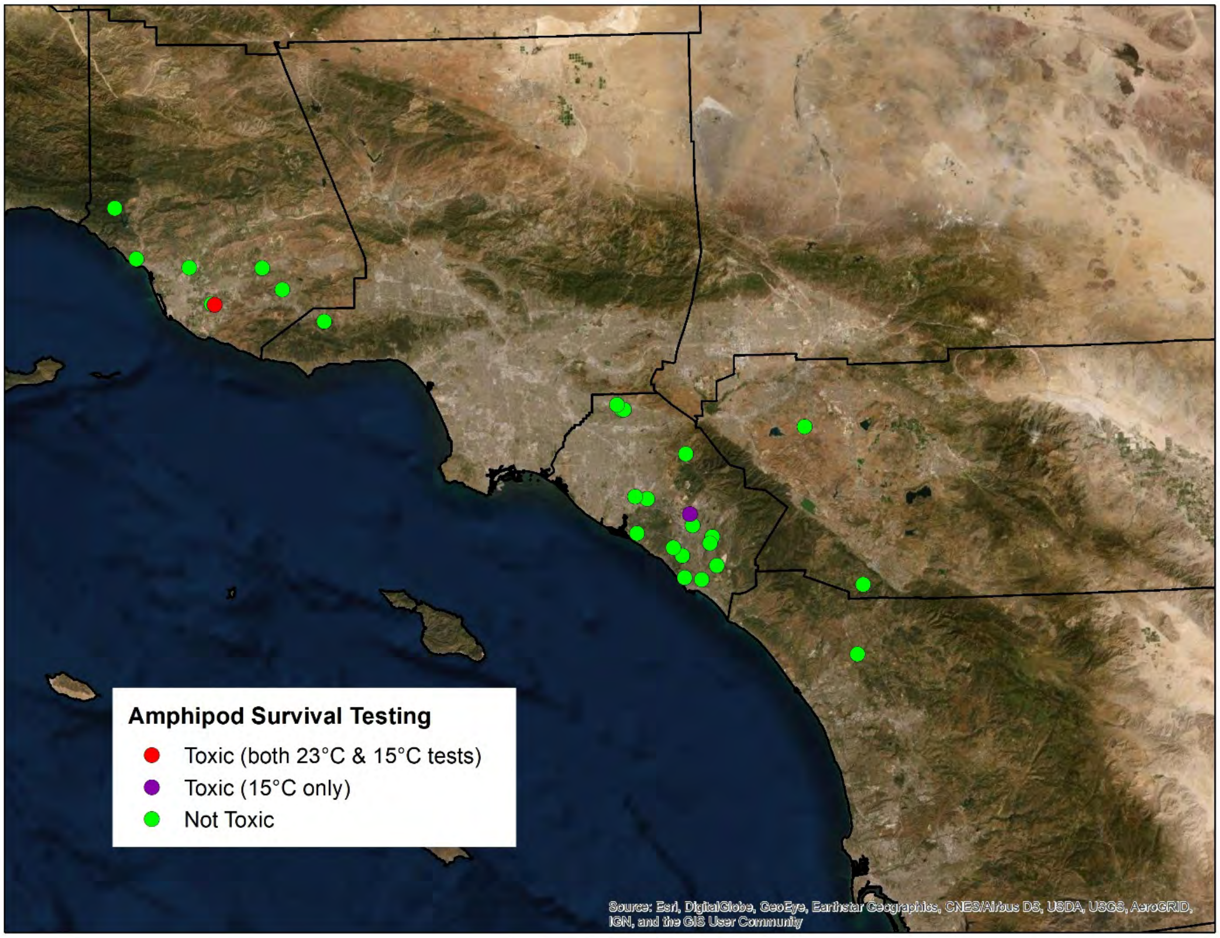
(2016) showed that impacts from at least one pyrethroid analyte were likely at 20% of sites, and possible at another 14%; the combined effects of multiple constituents was not analyzed and may present additional unknown risk of adverse effects. Bifenthrin was the most widespread of all pyrethroid analytes, detected at 54% of sites.



Proportion of sites exceeding adverse effect benchmarks. TEB: threshold effect benchmark. LEB: likely effects benchmark. RL: Reporting limit.

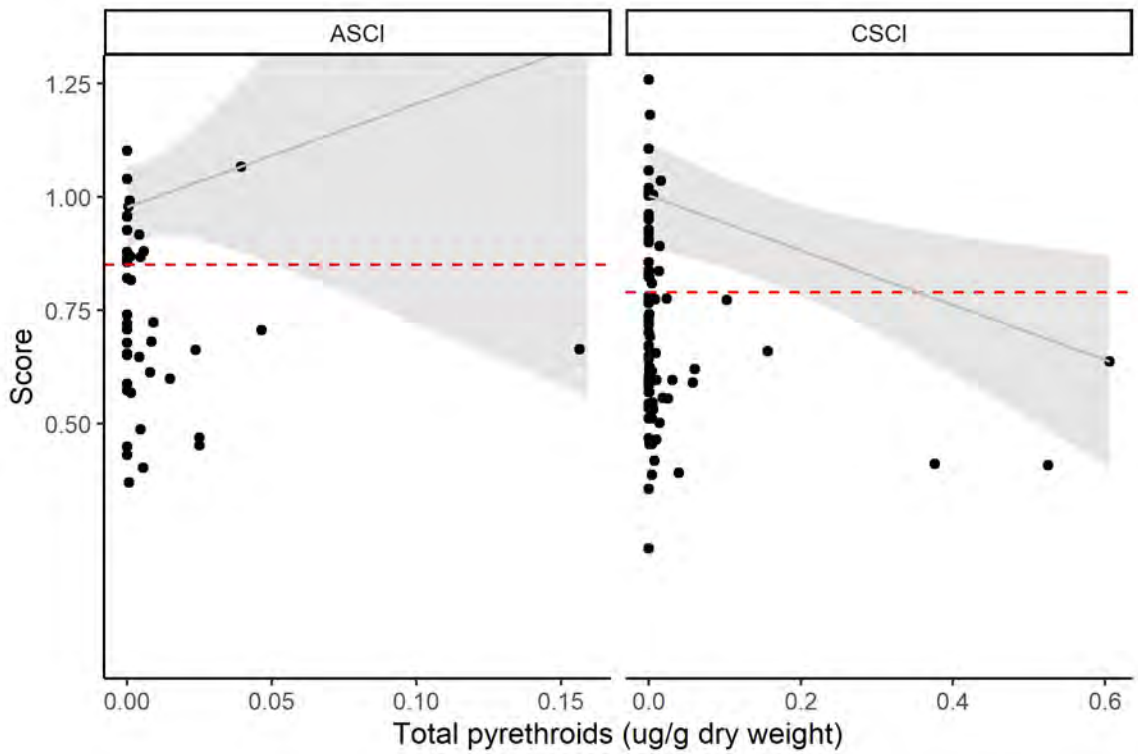
An agricultural stream in the lower Santa Clara River had the highest values of total pyrethroid concentrations (0.605 µg/g dry weight, at a site in the lower Santa Clara River); however, exceedances of possible and likely effects benchmarks were more frequent in urban streams (i.e., 67% of urban sites vs. 44% of agricultural and 13% of open sites).

The ability to draw conclusions about pyrethroids in sediment was limited by data quality. High reporting limits that exceeded benchmarks meant that analyses were inconclusive at many sites for certain analytes. In fact, reporting limits were too high to draw conclusions about any analyte at 19% of sites; at another 33%, reporting limits were low enough to rule out likely effects, but too high to rule out possible effects. Furthermore, the lack of organic content data (which is necessary to calculate benchmarks that are appropriate for each sample) prevented analysis at 9 sites, adding yet another constraint to this analysis.



Acute sediment toxicity was evident at two of the sites where it was evaluated.

Evidence of these potential impacts on aquatic life was mixed. Despite the potential for widespread impacts of contaminated sediments, acute toxicity under standard testing conditions (i.e., 23°C) was observed at only one of the 27 sites (this site lacked chemistry data); testing under more sensitive conditions (i.e., 15°C) revealed toxicity at one additional site in Orange County. However, toxicity was only assessed at 27 sites, limiting conclusions about the extent of toxicity in the region.



Relationship between the Algal Stream Condition Index (ASCI) and the California Stream Condition Index (CSCI) scores versus total pyrethroids. Gray lines indicate quantile regressions at the 90th quantile; the gray ribbon indicates the 95% confidence interval. Red dashed lines indicate thresholds derived from the 10th percentile of scores at reference sites.

Quantile regression indicated that pyrethroids might limit California Stream Condition Index scores where concentrations are high. Results were inconclusive for diatom and soft-bodied hybrid Algal Stream Condition Index (ASCI) scores, because ASCI scores were unavailable at sites with high concentrations (note the wide confidence interval for the ASCI panel in the figure above, in contrast to the narrow confidence interval in the CSCI panel); however, there is little evidence in the scientific literature that pyrethroid pesticides affect algae.

Recommendations

- Continue assessing sediment pyrethroid concentrations, and consider assessing other priority contaminants
- Support efforts to improve method detection limits at SMC labs. Because high volumes of sampleable sediment are sometimes unavailable at certain sites, the SMC should explore methods suited for measuring concentrations from small sample volumes.

Cited works

Bledsoe, B.P., R.J. Hawley, E.D. Stein, and D.B. Booth. 2010. Hydromodification Screening Tools: Field Manual for Assessing Channel Susceptibility. Technical Report 606. Southern California Coastal Water Research Project. Costa Mesa, CA.

Hawley, R.J., B.P. Bledsoe, E.D. Stein, and B.E. Haines. 2012. Channel Evolution Model of Semiarid Stream Response to Urban-Induced Hydromodification. Journal of the American Water Resources Association, 48(4), 722–744. https://doi.org/10.1111/j.1752-1688.2012.00645.x

Mazor, R.D., A.D. Rehn, P.R. Ode, M. Engeln, K.C. Schiff, E.D. Stein, D.J. Gillett, D.B. Herbst, D. B., and C.P. Hawkins. 2016. Bioassessment in complex environments: Designing an index for consistent meaning in different settings. Freshwater Science 35(1): 249-271. DOI: 10.1086/684130.

Nowell, L.H., J.E. Norman, C.G. Ingersoll, and P.W. Moran. 2016. Development and application of freshwater sediment-toxicity benchmarks for currently used pesticides. Science of the Total Environment 550:835-850.

Ode, P.R., A.E. Fetscher, and L. Busse. 2016. Standard Operating Procedures (SOP) for the Collection of Field Data for Bioassessment of California Wadeable Streams. SWAMP Bioassessment SOP 004.