SWAMP
Surface Water Ambient Monitoring Program

SWAMP-MM-2015-0001

Management Memo | **Perennial Streams Assessment 2015**

THE PERENNIAL STREAMS ASSESSMENT (PSA):

An Assessment of Biological Condition using the new California Stream Condition Index (CSCI)

OBJECTIVE

The objective of this memo is to describe the biological condition of streams in California based on a next-generation indicator of stream health applied to a robust 13-year data set.

Overview

PSA stream surveys found that the majority of stream length in the Sierra Nevada and North Coast is in good biological condition, while the majority of stream length in the South Coast, Chaparral and Central Valley is in poor or very poor condition. Similarly, most of the stream length draining forested watersheds is in good condition, while most of the stream length draining watersheds dominated by agricultural and urban land use is in poor or very poor condition. On average, stream condition showed no directional change over time, either for better or for worse. Streams where phosphorous concentration or riparian disturbance exceeded thresholds had the greatest relative risk of biological impairment.

Wadeable streams and rivers provide vital resources for all Californians, including fresh drinking water, water for irrigation, healthy places to fish and swim, and critical habitat for freshwater organisms and other wildlife. Land use practices such as urbanization,

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agriculture, logging and mining can have negative impacts on water and habitat quality and continue to expand in support of California's economy and growing population even as the state faces unprecedented drought. The Perennial Streams Assessment (PSA) has been California's primary means of monitoring the health of its wadeable streams and rivers since 2000. Over 1,300 unique perennial stream sites throughout the state have been sampled by PSA and its partner programs[1] using a statistical survey design where each sampled site represents a portion of the total wadeable stream length in California. Probability survey designs allow extrapolation of results from relatively few sampled sites to all wadeable stream length in the state, providing an objective means of assessing the health of the entire stream population. Benthic macroinvertebrates (BMIs) and algae were collected from each survey site as indicators of biological condition, together with associated data on the chemical and physical environment in each stream. Now in its 15th year, the PSA program provides a long-term, statistically robust data set to answer 4 key questions at the heart of SWAMP's statewide water quality program:

1. ***What is the biological condition of California streams?***
2. ***Is stream condition changing over time?***
3. ***What is the relative condition of streams draining agricultural, urban and forested landscapes?***
4. ***Which chemical and physical stressors have the strongest association with biological condition?***

Because of the rigor and scope of this program, PSA data also have been used as the foundation for a wide range of environmental management and assessment efforts including the State's Healthy Watersheds Partnership, The Nature Conservancy's Atlas of Freshwater Biodiversity and Freshwater Conservation Blueprint, Nutrient Numeric Endpoints, and the US Forest Service's Management Indicator Species program.

The California Stream Condition Index (CSCI): A New Biological Scoring Tool

The California Stream Condition Index (CSCI) is a new statewide biological scoring tool that translates complex data about individual BMIs found living in a stream into an overall measure of stream health (Mazor et al. in review). Finalized in 2013, the CSCI represents the next generation of biological indicator for assessing stream health in California. The CSCI combines two separate types of index that each provides unique information about the biological condition at a stream: a multi-metric index (MMI) that measures ecological structure and function, and an observed-to-expected (O/E) index that measures taxonomic completeness. Unlike previous MMI or O/E indices that were applicable only on a regional basis or poorly represented large portions of the state, the CSCI was built with a statewide dataset of nearly 600 reference sites[2] that represents the broad range of environmental conditions across California (Figure 1). The CSCI provides consistency and accuracy in the interpretation of biological data collected by both statewide and regional monitoring programs and will be the basis of the new statewide Biological Integrity Policy.

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[1] Probability surveys began in California in 2000 with the USEPA's Environmental Monitoring and Assessment Program (EMAP) and were continued by PSA. Since 2009, the Southern Monitoring Coalition (SMC) has collected most of the probability data from southern coastal California and the US Forest Service has collected PSA-comparable data from National Forests in the Sierra Nevada.

[2] Reference sites are the core of any bioassessment program and set the benchmark for biological conditions expected when human activity in the landscape is absent or minimal (see Ode et al. (in review) for description of SWAMP's reference program).

<u>CSCI scoring thresholds</u>:

The CSCI was calibrated during its development so that the mean score of reference sites is 1. Scores that approach 0 indicate great departure from reference condition and degradation of biological condition. Scores > 1 can be interpreted to indicate greater taxonomic richness and more complex ecological function than predicted for a site given its natural environmental setting. In practice, CSCI scores observed from nearly 2000 study reaches sampled across California range from about 0.1 to 1.4. For the purposes of making a statewide assessment, three thresholds were established based on the 30th; 10th; and 1st percentiles of CSCI scores at reference sites. These three thresholds divide the CSCI scoring range into 4 categories of biological condition as follows: ≥0.92 = good condition; 0.91 to 0.80 = fair condition; 0.79 to 0.63 = poor condition; ≤0.62 = very poor condition.

This report, the first on statewide stream condition since 2011[3] and the first to use the CSCI in an assessment, summarizes and updates the major survey findings from the first 13 years of PSA (2000-2012) with regard to the 4 questions listed above. Objective answers to these questions provide a comprehensive interpretive context for all water quality programs in the state, and thus serve as a vital foundation for consistent statewide assessment of biological integrity, development of nutrient criteria directly tied to aquatic life uses, support of long-term climate change monitoring, evaluation of the success of stream restorations, and prioritization of the healthiest streams and rivers to protect for future generations, just to name a few applications. The results in this report are based on 1,318 sampling sites (more than three times the number in Ode et al. 2011) that together represent an estimated 38,426 km of perennial, wadeable stream length in California. The results do not apply to an estimated 10,500km of large, non-wadeable rivers, nor do they apply to an estimated 226,668 km of non-perennial streams (nearly 5 times the length of perennial streams and large rivers combined) that were excluded from these surveys.

Figure 1. The California Stream Condition Index (CSCI) was calibrated with nearly 600 reference sites that represent the diversity of stream types throughout the state and is applicable statewide.

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[3] The most recent PSA report (Ode et al. 2011) covered the first 8 years of survey data (2000-2007).

Question 1: What is the biological condition of California streams?

Answer: Approximately 44% (± 4%) of the statewide stream length is in good biological condition (Figure 2, see inset). Of the other 56%, approximately 34% is degraded (i.e., either in poor or very poor condition) and 22% is in fair condition. Results vary by PSA region however, with the North Coast and Sierra Nevada having the highest percentage of sites in good condition and the Central Valley having the lowest percentage of sites in good condition (Figure 2).

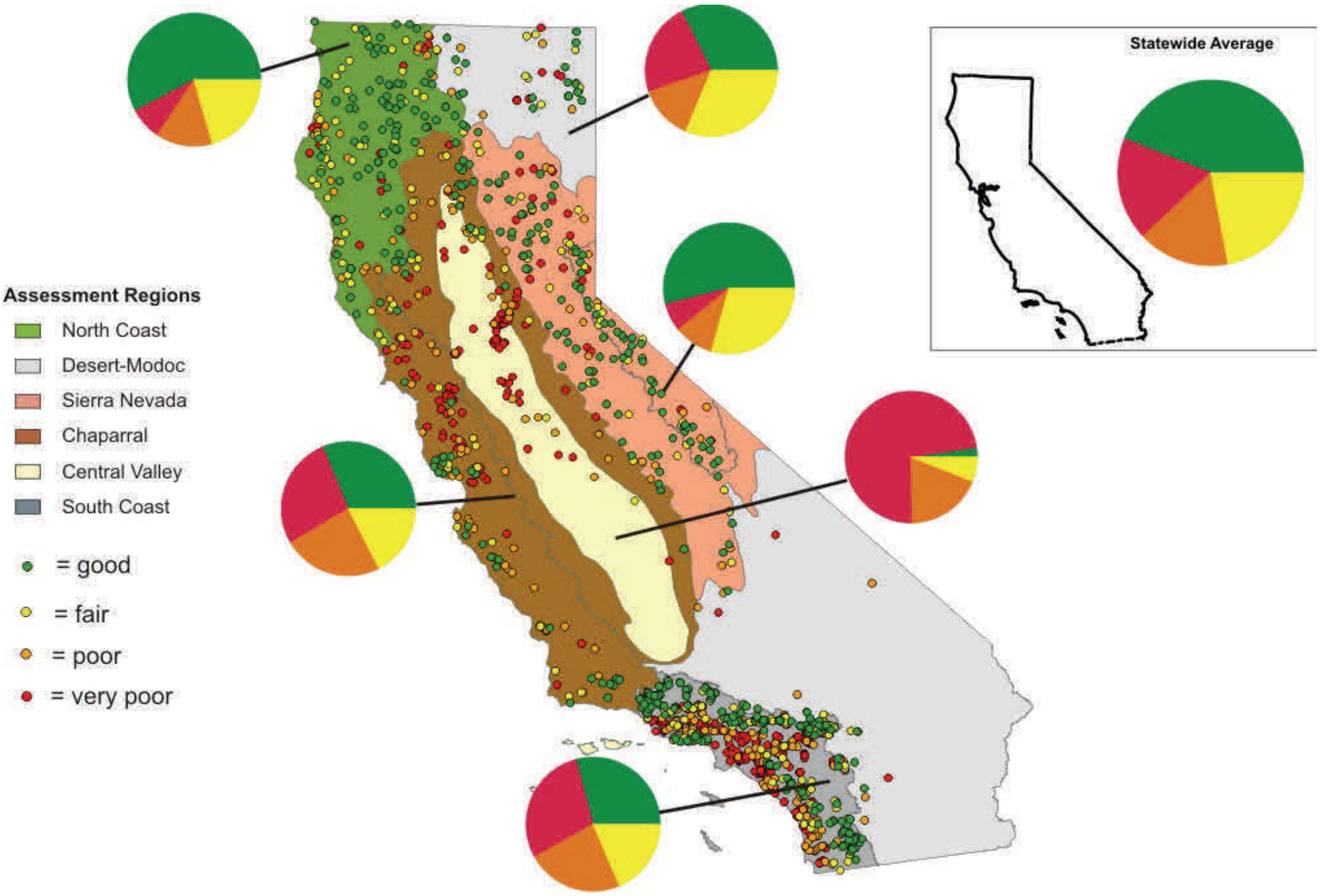

Figure 2. Map of 1,318 probability sites sampled by the PSA program in 2000-2012. Sampling sites are color-coded by biological condition according to CSCI score. Pie charts show percent of stream length in each of 4 condition categories by PSA region.

Question 2: Is stream condition changing over time?

Answer: Stream condition fluctuated somewhat during the first 13 years of PSA, but no trend (i.e., no consistent directional change over time) was observed (Figure 3). A moving average (a series of averages based on different subsets of the full dataset) was used to analyze inter-annual data for trends. Moving averages are often used with time-series data to smooth out short-term fluctuations and highlight longer-term trends or cycles. Annual results from PSA surveys were averaged for 4-year time blocks, with each block "shifting forward" one year by excluding the first year in the series and including the next year in the series (Figure 3). Over 50% of the stream length in California was estimated to be in good condition during the first 4 years of the study (2000- 2003; Figure 3). After that, good condition stream length decreased to approximately 42% of the total for the next 4 time blocks, then increased again starting with the 2005-2008 time block, and equaled or exceeded 50% of the total for the last 4 time blocks. It is important to note that most of the data for this analysis were collected before the current severe drought began in 2012.

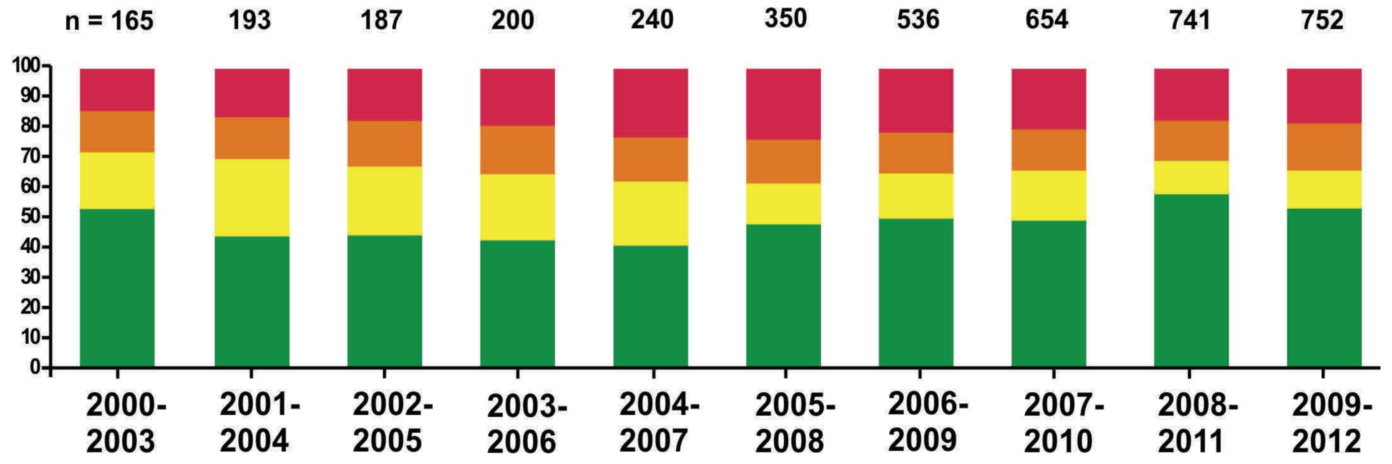

Figure 3. Moving average of stream condition from 2000-2012 in 4-year time blocks. Green boxes = percent of stream length in good condition for a 4-year time block; yellow boxes = fair condition; orange boxes = poor condition; red boxes = very poor condition. Margins of error range between 3% and 9% across the data series (not shown in box plots). Numbers of sites sampled per 4-year time block are shown above bars.

Question 3: What is the relative condition of streams draining agricultural, urban and forested landscapes?

Answer: Most of the stream length draining watersheds dominated by agricultural and urban land use practices[4] is in poor or very poor condition (Figures 4 and 5). By contrast, most of the stream length draining forested watersheds, and much of the stream length draining "other" watersheds, is in good condition.

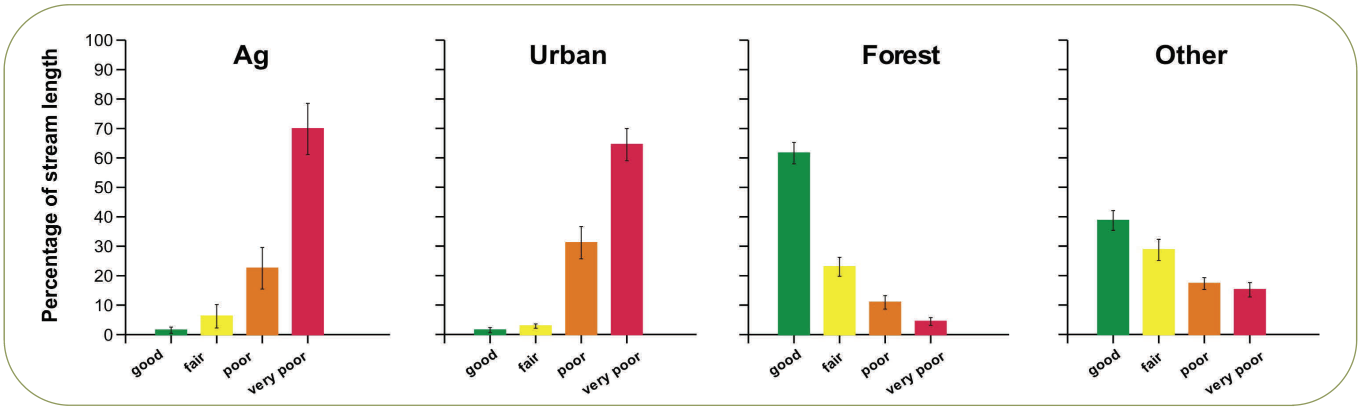

Figure 4. The percentage of wadeable, perennial stream length in each of 4 biological condition categories by predominant upstream land use. **NOTE**: Only 4% of sites were classified as "ag dominated" using the ≥25% criterion, calculated either by simple tally or by statistical weight.

Figure 5. Streams with agriculture and urbanization as the predominant land use at the local or watershed scale are rarely in good biological condition. Channelization, removal of riparian corridors, access to stream channels by livestock, and increased pesticide and nutrient loads all contribute to ecological degradation in these systems.

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[4] Sites were classified into 4 categories based on land use/land cover in the local and full upstream watershed: ag sites had ≥25% agricultural land use at either local or watershed scale; urban sites had ≥50% urban land use at either local or watershed scale; forest sites had ≥75% forest land cover at either local or watershed scale; "other" sites did not meet any of these criteria.

Question 4: Which chemical and physical stressors have the strongest association with biological condition?

Answer: This question must be answered in two parts: First, thresholds were defined to identify "most-disturbed" conditions for a subset of 11 chemical and physical stressors shown by previous studies (e.g., Stoddard et al. 2005; Ode et al. 2011) to be associated with biological impairment (Table 1). The percent of stream length where stressor values exceeded the most-disturbed criteria varied among land use classes (Figure 6). Second, relative risk estimates were calculated for each of the 11 stressors (Figure 7). Relative risk is the increased risk of biological impairment when stressor values exceed criteria in Table 1. For example, the risk of biological impairment at stream sites where the phosphorous concentration exceeded most-disturbed thresholds was nearly 3 times greater than at sites where thresholds were not exceeded (Figure 7). By contrast, there was relatively little increased risk of biological impairment when conductivity thresholds were exceeded (Figure 7). Weighted distributions for the primary chemical and physical analytes assessed in statewide surveys are summarized by PSA region and by land use category in Appendix 1.

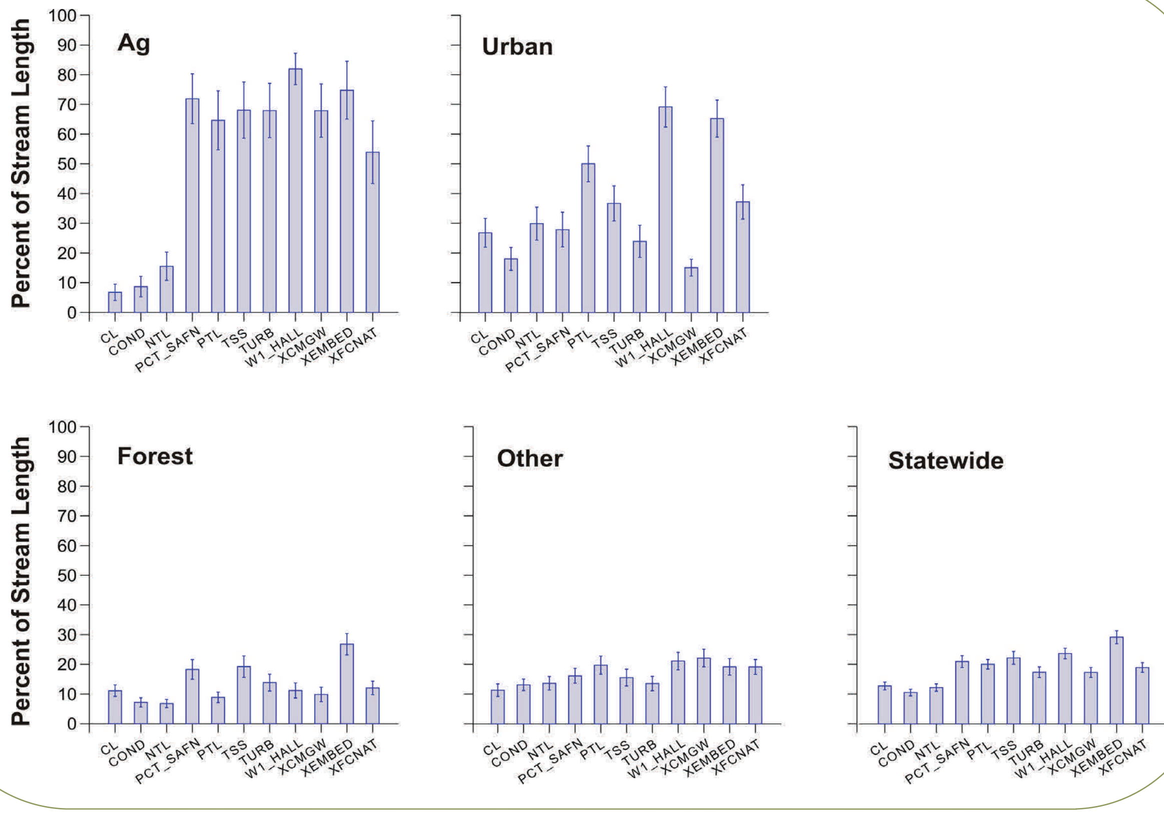


Figure 6. Percent of stream length exceeding most-disturbed stressor thresholds (see Table 1) by land use categories and statewide. Definitions of stressor acronyms are given in Table 1. Note that the variables XFC_NAT and XCMGW decline with degradation, so "exceedence" in these cases means a site has values *lower* than the thresholds in Table 1.

Figure 7. Examples of the relative risk of biological impairment when most-disturbed stressor thresholds are exceeded (left panel). Streams with excess sand and fine sediment (center panel) have more than 2 times the risk of degraded biological condition compared to streams without excess fine sediment. Streams with excess riparian disturbance (right panel) are nearly 3 times more likely to have degraded biological condition compared to streams with intact riparian zones. Definitions of stressor acronyms are given in Table 1. Note that the variables XFC_NAT and XCMGW decline with degradation, so "exceedence" in these cases means a site has values *lower* than the thresholds in Table 1.

Conclusions

California is a large and diverse landscape with wide geographic variation in the ecological condition of its streams. The CSCI is the first biological scoring tool that covers the entire state and allows streams in all regions to be evaluated with equivalent thresholds. The Sierra Nevada and North Coast have the majority of their stream length in good biological condition. By contrast, roughly 75% of stream length in the Central Valley is in very poor ecological condition. However, the Central Valley also has less stream length than all other PSA regions except Desert-Modoc. Ironically, even though the Valley has the highest proportion of stream length in poor biological condition, both the Sierra and the North Coast have more kilometers of stream in poor condition, because the stream resource is so much more extensive in those regions (Figure 8). The Chaparral and South Coast regions are intermediate between the North Coast and Sierra and the Central Valley, both in terms of the biological condition of those streams and the total stream length they contain.

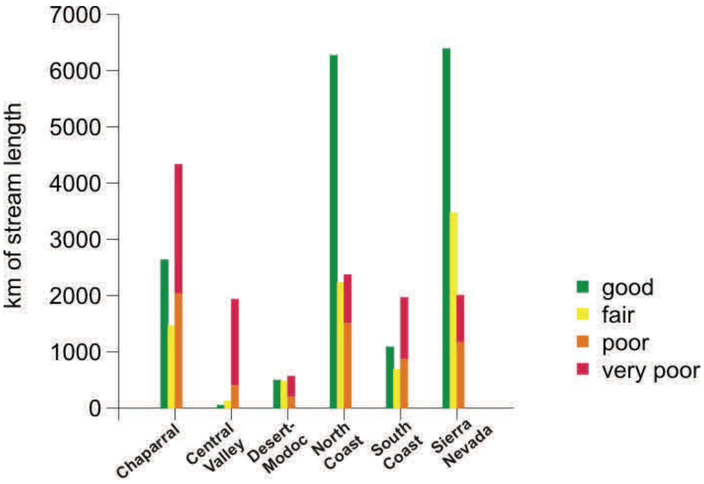


Figure 8. Number of kilometers of stream length in good, fair, poor and very poor condition per PSA region. Note that the Sierra Nevada and the North Coast have more kilometers of stream in poor or very poor condition than the Central Valley, even though a much larger *proportion* of Valley streams is in poor or very poor condition.

Watersheds where agriculture and urban are the dominant land uses have a much greater percentage of stream length in exceedence of most-disturbed stressor thresholds compared to forested watersheds or the statewide average. More than 50% of stream length in agricultural settings exceeded most-disturbed thresholds for all physical habitat variables evaluated. Phosphorous was the most prevalent chemical stressor in urban settings and was among the most prevalent chemical stressors in agricultural settings. Phosphorous also has the highest relative risk of all stressors evaluated for biological impairment when most-disturbed thresholds are exceeded, most likely through excessive growth of primary producers and a shift in algal community composition, both of which directly impact food webs and BMI community composition. Of the chemical stressors, phosphorous, total suspended solids and turbidity were more prevalent than nitrogen, chloride and conductivity. Despite the fact that none of the stressors evaluated was "by far" the most widespread on a statewide scale, they all contribute to degraded biological condition, given that 34% of statewide stream length is in poor or very poor biological condition and nearly all stressors have relative risk > 2.

Recommendations:

1. Monitoring programs using a probabilistic design should remain a core element of SWAMP's statewide monitoring. Probabilistic monitoring provides the only objective way to assess the condition of the entire stream population in California over time. In addition, PSA data provide a unique, unbiased perspective on the distribution of natural and stressor variables in different regions. For example, the evaluation of how well SWAMP's statewide reference site pool represents the natural environmental diversity of streams throughout California would not have been possible without PSA data (see Ode et al. *in press*). Continuing to track statewide stream condition over time in an objective way will provide the context in which data from targeted monitoring programs can be evaluated.

2. Maintaining an annual sampling schedule is essential for evaluating the effects of climate change. As interest in measuring the effects of short and long term changes in climate grows, PSA should retain the ability to provide inter-annual variation data that will guide management decisions.

3. SWAMP should consider adjusting the PSA design to shift resources toward more site revisits. The trends analysis presented here indicates that stream condition showed no directional change during the first 13 years of PSA, either for better or for worse, although data from the drought years 2013-14 have not yet been included. This suggests that site-specific revisits may provide a more sensitive way to detect trends over time, rather than requiring an average directional change in the entire stream population (assessed by a different set of sites each year) before a trend can be detected. Annual revisits have been an infrequent component of PSA surveys (in recent years, only 5 sites have been revisited annually and only between 2008 and 2010). More annual site visits should be added to the program. SWAMP should consider the continued funding of 30 probabilistic sites annually, with half of those sites being revisited annually, and with revisits continuing for 3 to 5 years per site. In fact, one of SWAMP's key partners, the Southern Monitoring Coalition (SMC), has recently implemented a more intensive site revisit component in regional probabilistic surveys to improve site-specific trend detection.

4. SWAMP should build on previous success in fostering partnerships to extend the scope and scale of its probabilistic monitoring program. There is great opportunity for SWAMP to continue its partnerships with the many collaborators in California who have implemented regional probabilistic surveys so that survey designs are compatible with statewide questions, data sharing is maximized, and the costs of statewide monitoring can be shared by all interested partners. Examples of ongoing collaborations include the U.S. Forest Service (with surveys in the Sierra Nevada since 2009), the SMC (with surveys in southern coastal California since 2009), and the Regional Monitoring Coalition (with surveys in the Bay Area since 2012). In addition, private timber industry scientists have recently expressed interest in surveys of private timber lands. This partnership could fill key gaps in coverage and could lead to opportunities to build support for ecological monitoring of forested lands.

References

Mazor, R.D., A.C. Rehn, P.R. Ode, M. Engeln, K.C. Schiff, E.D. Stein, D. Gillett and C.P. Hawkins. *In review*. Improving consistency of a bioassessment index across environmentally diverse settings.

Ode, P.R., T.M. Kincaid, T. Fleming and A.C. Rehn. 2011. Ecological Condition Assessments of California's Perennial Wadeable Streams: Highlights from the Surface Water Ambient Monitoring Program's Perennial Streams Assessment (PSA) (2000-2007). A collaboration between the State Water Resources Control Board's Non-Point Source Pollution Control Program (NPS Program), Surface Water Ambient Monitoring Program (SWAMP), California Department of Fish and Game Aquatic Bioassessment Laboratory, and the U.S. Environmental Protection Agency.

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 press*. Evaluating the adequacy of a reference site pool for the ecological assessment of streams in environmentally complex regions.

Stoddard, J. L., D. V. Peck, S. G. Paulsen, J. Van Sickle, C. P. Hawkins, A. T. Herlihy, R. M. Hughes, P.R. Kaufmann, D. P. Larsen, G. Lomnicky, A. R. Olsen, S. A. Peterson, P. L. Ringold, and T. R. Whittier. 2005. *An Ecological Assessment of Western Streams and Rivers*. EPA 620/R-05/005, U.S. Environmental Protection Agency, Washington, DC.

Table 1. Criteria for identifying most-disturbed sites in 4 aggregate Level III ecoregions (see Stoddard et al. 2005 for aggregate ecoregion definitions). Criteria were developed using the biology-based approach suggested (but not actually used) by Ode et al. (2011). The 90th percentile of stressor values at sites in good biological condition defined the most-disturbed threshold for variables where higher values indicate more disturbance (i.e., chloride, conductivity, total nitrogen, % sand and fines, total phosphorous, total suspended solids, turbidity, riparian disturbance index, mean embeddedness). The 10th percentile of stressor values at sites in good biological condition defined the most-disturbed threshold for variables where lower values indicate more disturbance (i.e., woody riparian cover index, stream habitat diversity index). Aggregate ecoregions were used to define thresholds rather than PSA regions because the Central Valley has too few sites in good biological condition to establish robust thresholds, and because xeric and mountainous regions in the South Coast had very different distributions for the stressors evaluated. An illustrated example of the biology-based approach to setting stressor thresholds is shown below in Figure 9.

	Chloride mg/L (CL)	Conductivity µS/cm (COND)	Total Nitrogen mg/L (NTL)	Percent sand & fines (PCT_SAFN)	Total Phosphorous mg/L (PTL)	Total Suspended Solids mg/L (TSS)	Turbidity NTU (TURB)	Riparian disturbance index (W1_HALL)	Woody riparian cover index (XCMGW)	Mean percent embeddedness (XEMBED)	Stream habitat diversity index (XFC_NAT)
Sierra and North Coast	10.1	282	0.27	35	0.056	5.5	2.4	1.27	0.55	46	0.18
Southern California Mtns	25	930	0.586	54	0.19	10.1	3.2	0.73	0.37	59	0.27
Xeric California (= xeric SoCal, Central Valley and Chaparral)	122	1460	2.3	69	0.122	7.2	5.1	1.3	0.54	54	0.14
Xeric Southwest (= Desert-Modoc)	3.2	205	0.173	47	0.048	9.2	4.2	1.9	0.45	57	0.19

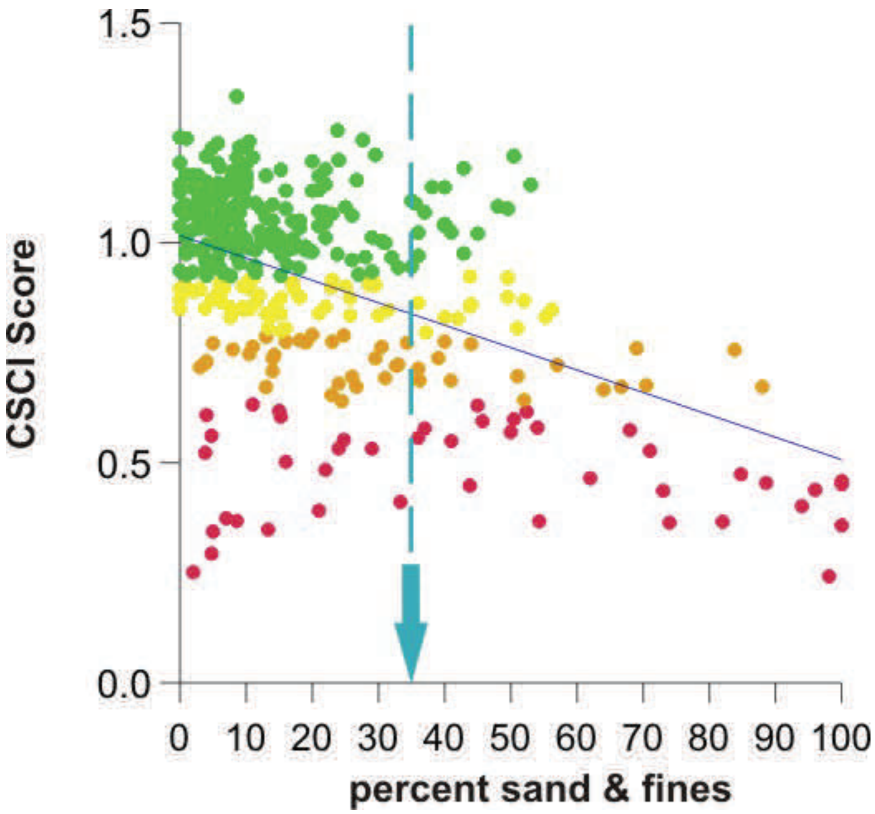
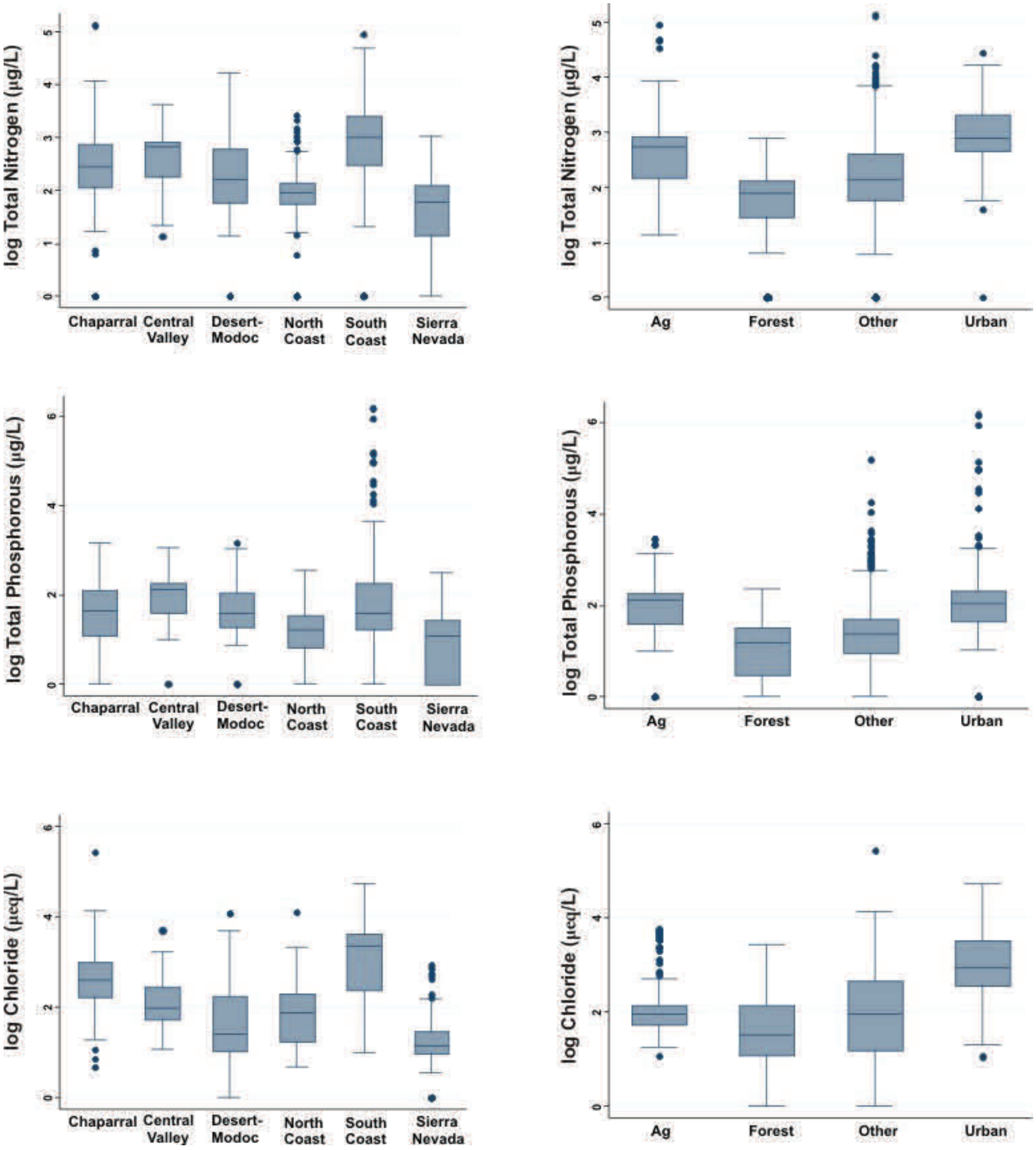


Figure 9. Example of how a biology-based stressor threshold was established for percent sand and fine sediment in the North Coast and Sierra Nevada (= the Pacific Northwest aggregate ecoregion of Stoddard et al. 2005). Green dots are sites in good biological condition, yellow dots are sites in fair biological condition, orange dots are sites in poor biological condition, and red dots are sites in very poor biological condition. The dashed blue arrow shows that the 90th percentile of percent sand and fine sediment observed at sites in good biological condition was 35%. Because biological condition tends to become degraded (i.e., is no longer in good condition) at sites with more than 35% sand and fine sediment, this value was used to define the most-disturbed threshold for this particular stressor in this aggregate ecoregion (Table 1).

Appendix 1. Box plots showing weighted distributions of the primary chemical and physical stressors assessed in statewide surveys summarized by PSA region and land use category.



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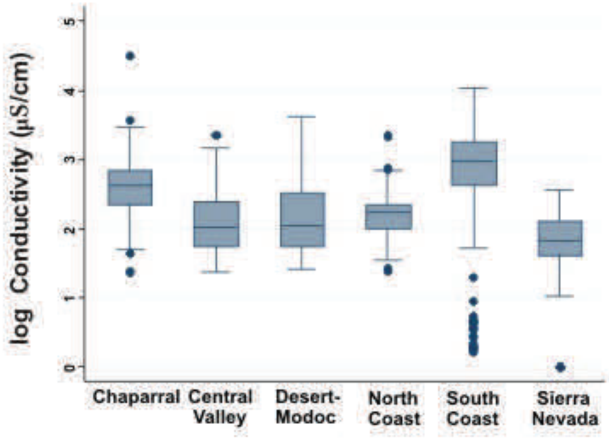

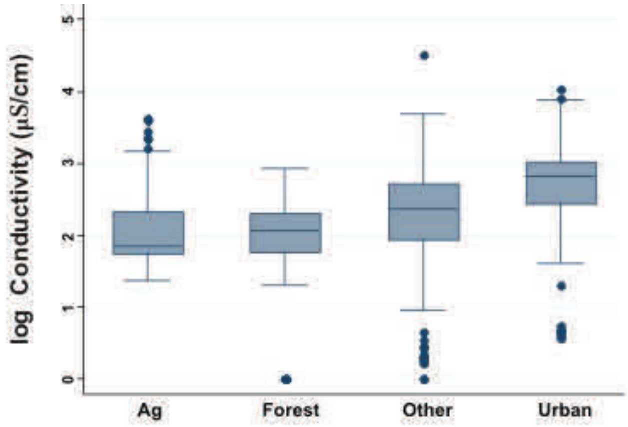

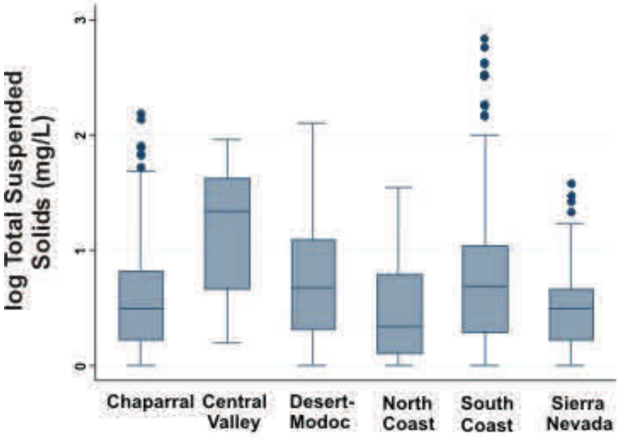

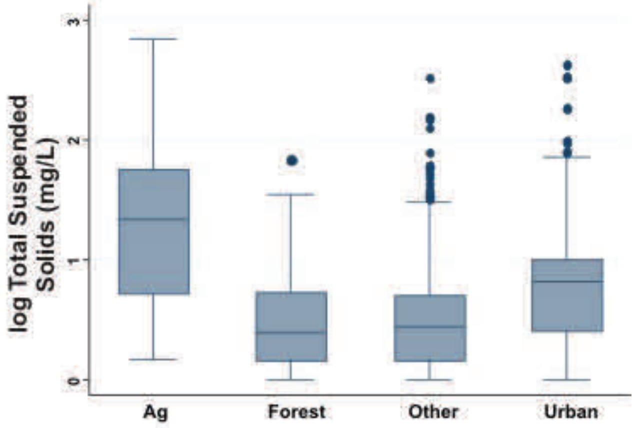

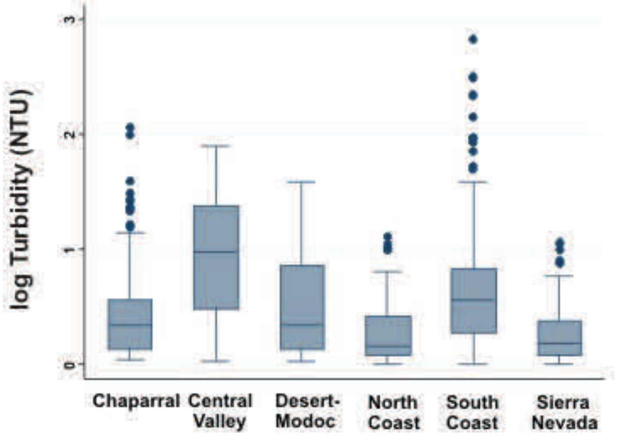

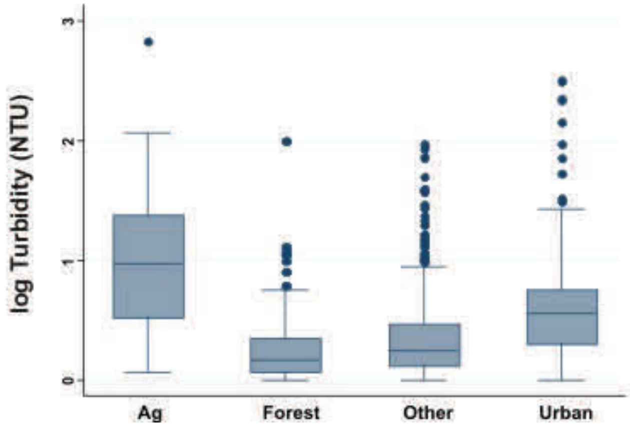

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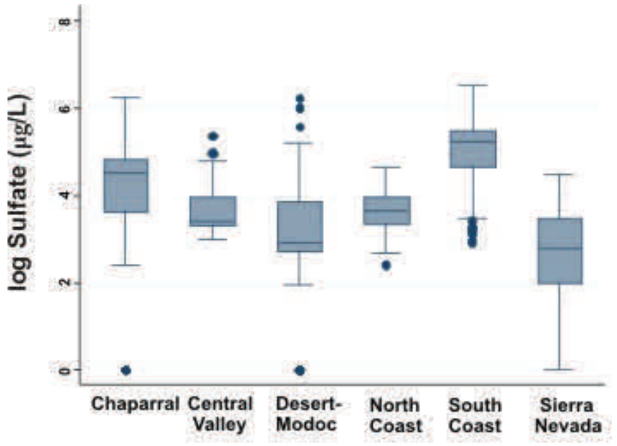

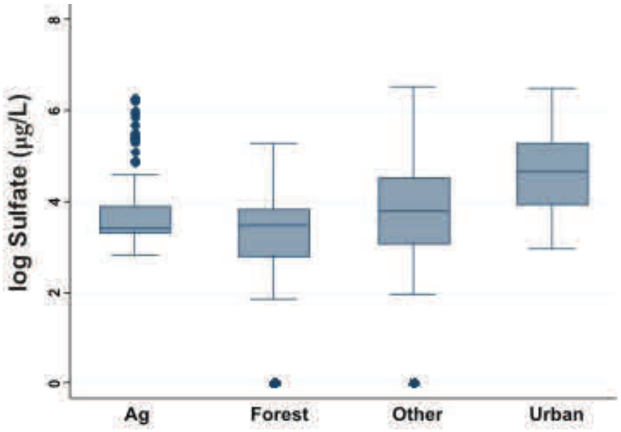

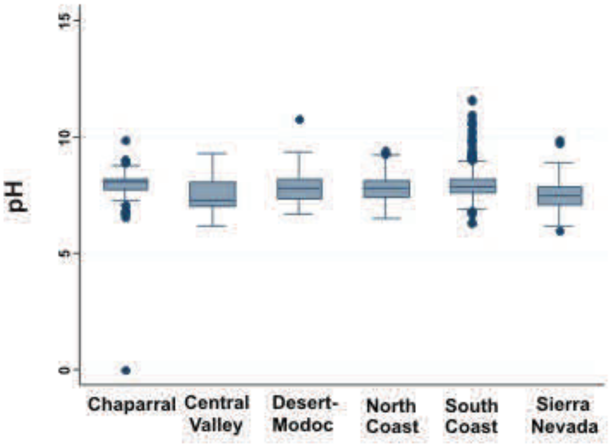

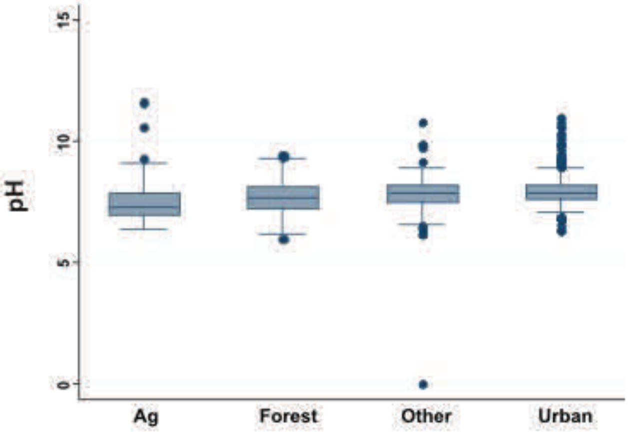

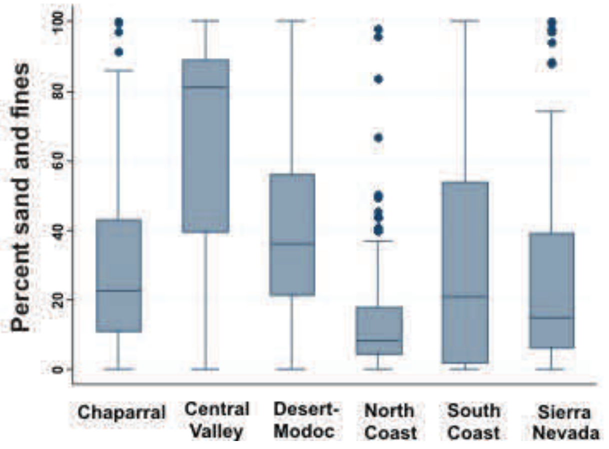

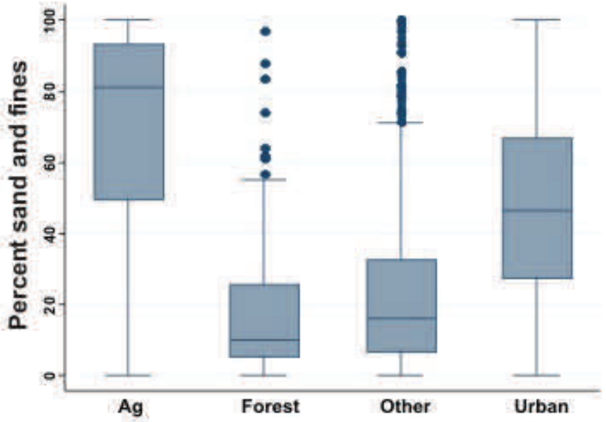

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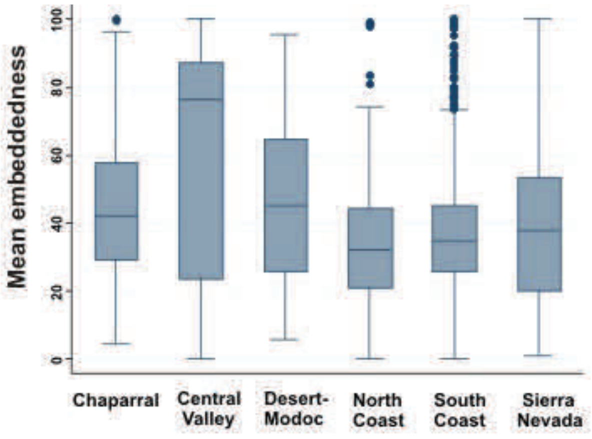

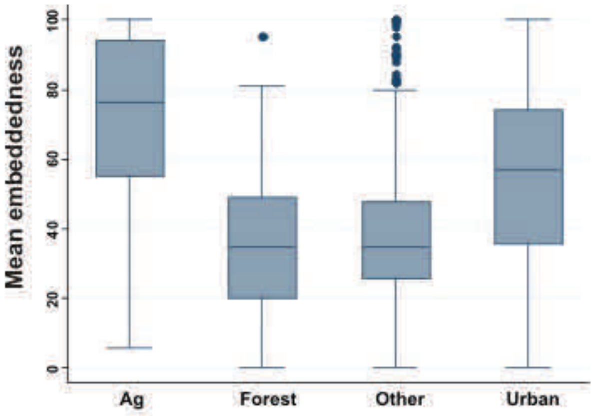

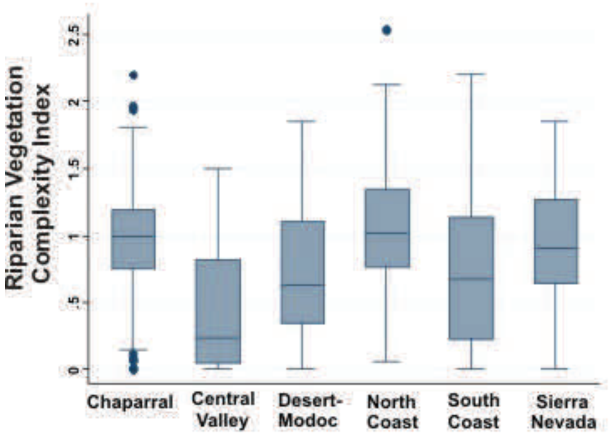

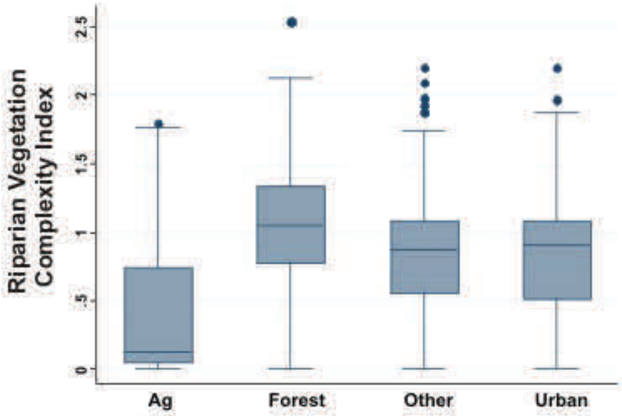

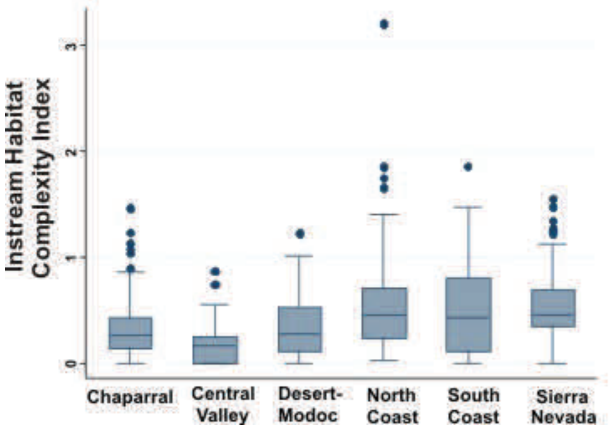

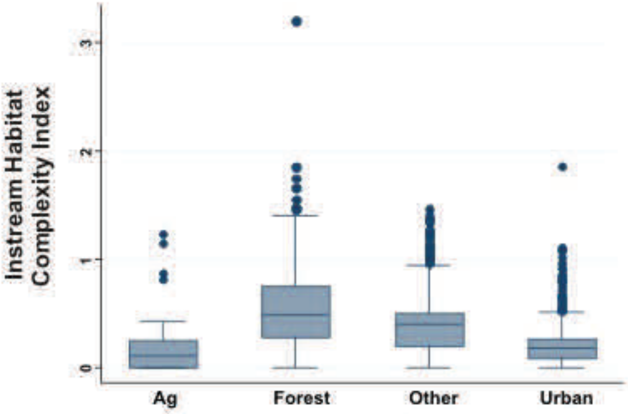

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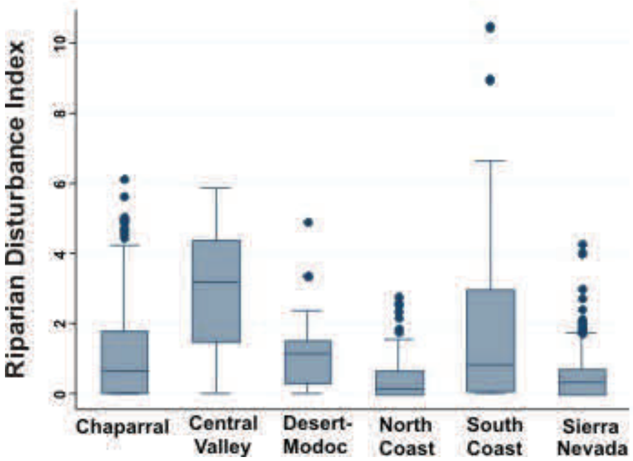

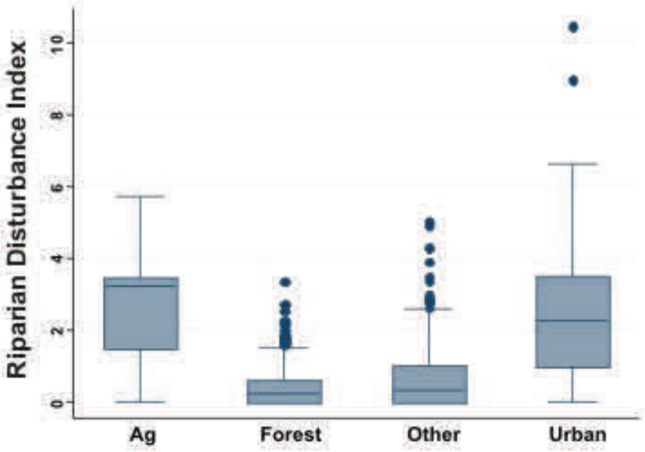

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