An Ecological Assessment of California's Perennial Wadeable Streams and Rivers (2008-2018)

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Overview

The State Water Board's Perennial Streams Assessment (PSA) program, in collaboration with several other regional and national partners, conducted bioassessment sampling at nearly 2,000 probabilistic stream locations in California from 2008-2018. This included enhanced access to private industrial timber lands to augment surveys in previously under-sampled regions of the state. Two biological indices, the California Stream Condition Index (CSCI) based on benthic macroinvertebrates and the Algal Stream Condition Index (ASCI) based on benthic algae, and two independent indices of physical habitat condition were used to assess the overall ecological condition, or health, of streams statewide. Both CSCI and ASCI indicated that nearly half of the stream length in California was in 'Likely Intact' (i.e., the healthiest) condition; one physical habitat index indicated slightly more than half to be in healthiest condition, the other indicated only about a third to be in healthiest condition. In general, all indices agreed that the North Coast and Sierra Nevada had the greatest percentage of stream length in healthiest condition, the South Coast and Central Valley had the lowest percentage of stream length in healthy condition, and the Desert-Modoc and Chaparral regions had intermediate percentages of stream length in healthy condition. The CSCI and both physical habitat indices indicated that statewide stream condition showed no directional change over the 11-year time frame assessed, but subtle trends were sometimes observed within regions. By contrast, ASCI indicated that stream condition improved over time both statewide and in all regions except the South Coast and Desert-Modoc. Probabilistic monitoring provides an important long-term perspective on stream health across California, and together with monitoring at high-quality (relatively undisturbed) reference sites, provides a robust context for interpreting conditions at targeted sites, which are usually sampled because they have known problems and are often the subject of restoration or other management actions.

Introduction

Probabilistic surveys have been used to assess the ecological condition of wadeable streams and rivers throughout California since 2000. In these surveys, sites are selected randomly from a digitized stream network (sample frame). Each sampled site represents a portion of the total stream length in the state, allowing extrapolation of results from relatively few sampled sites to all wadeable stream length. The earliest surveys (namely, the Environmental Monitoring and Assessment Program [EMAP] from 2000-2003 and the California Monitoring and Assessment Program [CMAP] from 2004-2007) were foundational in establishing probabilistic survey designs as the most objective way to address the State's 305(b) reporting requirements (e.g., see Ode et al. 2011). In 2008, the Perennial Streams Assessment (PSA) program continued the statewide probabilistic approach, but several modifications were made to field and lab protocols used by EMAP and CMAP: the physical habitat (PHAB) portion of field protocols was reduced and streamlined to allow addition and enhancement of other protocol elements, the California Rapid Assessment Method (CRAM) was added as a standard component at all survey sites, the algae field-sampling protocol was made more rigorous, a soft-bodied algae sample was added to complement the diatom sample, and laboratory standards were improved to enhance taxonomic consistency among algae samples. In addition, several regional surveys have been implemented since 2009 and have (mostly) followed statewide protocols, allowing for their integration into a statewide assessment. Given that data sets from the original surveys are now as many as 20 years old, that combining multiple surveys into a single integrated assessment becomes unfeasible as more surveys are added, and that the original EMAP and CMAP surveys lack both CRAM data and algae data compatible with current standards, the decision was made to omit them from the current assessment. This assessment is therefore based on data sets collected between 2008 and 2018.

Previous statewide stream condition assessments in California were based only on benthic macroinvertebrates (BMIs) since interpretive indices based on other aquatic assemblages (e.g., algae) or other data types either were lacking or were applicable only on regional scales (the last statewide assessment [Rehn 2015] used the BMI-based California Stream Condition Index [CSCI] which was new at the time). Recently, interpretative indices with statewide applicability have been developed for PHAB data (i.e., the Index of Physical Integrity [IPI] of Rehn et al. 2018) and for diatoms and soft-bodied algae (i.e., the Algal Stream Condition Index [ASCI] of Theroux et al. 2020). The 2008-2018 assessment is therefore the first statewide analysis to incorporate four indices of stream health: CSCI, ASCI[1], IPI and CRAM. Each index provides an independent line of evidence of ecological condition at sampling sites, and while often complementary (e.g., see Rehn 2016), they do not always agree with respect to the percent of statewide stream length in different condition categories.

The main purpose of the PSA program and related regional surveys is to provide long-term, statistically robust data sets to answer four key questions at the heart of the statewide Surface Water Ambient Monitoring Program (SWAMP):

[1] Three ASCI indices were developed by Theroux et al. (2020): a diatom index, a soft-bodied algae index and a hybrid index combining both algae assemblages. The diatom ASCI was used for the 2008-2018 assessment.

1. What is the biological, physical and chemical 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?

Data Sets

Data were aggregated from six different statewide and regional probabilistic surveys (Table 1), four of which have been ongoing for long enough that they also contributed to the last statewide assessment (Rehn 2015). Two additional, more recent surveys conducted since the last statewide assessment include a regionally-intensified stream survey in the San Francisco Bay Area funded by the Regional Monitoring Coalition (RMC), and a survey focused on privately-owned timber lands in northern California funded by the California Natural Resources Agency (CNRA). The goal of the CNRA-funded survey was to help address a data gap in forested portions of the state due to the high frequency of private timber owners denying permission to sample their streams in previous surveys. Finally, not only do probabilistic surveys revisit a certain number of sites over time, but two "Other" programs have also revisited sites that were originally sampled by probabilistic surveys (Table 1). In all, 2,419 sampling events from nearly 2,000 unique sites were included in the 2008-2018 assessment (Figure 1).

Table 1. Statewide and regional probabilistic surveys from which data were aggregated for inclusion in the 2008-2018 statewide assessment.

Program	Geographic Scope	Years Included	Number of Sites
National Rivers and Streams Assessment (NRSA)†	Statewide	2008-09; 2013-14; 2018	72
Perennial Streams Assessment (PSA)	Statewide except s. coast	2008-2018	483
Stormwater Monitoring Coalition (SMC)	South coast	2009-2018	924
USFS Management Indicator Species Program (MIS)	Sierra National Forests	2009-2018 (no 2011)	114
Regional Monitoring Coalition (RMC)	SF Bay Area	2012-2016	276
California Natural Resources Agency (CNRA)	NorCal private timber	2016-2018	60
Other (Regional Board 9 and RCMP*)	Statewide	2009-2018	51
TOTAL			**1,980**

† The U.S. EPA's NRSA program is national in scope, but sites in California are distributed statewide.
*RCMP = Reference Condition Monitoring Program

Assessment Thresholds

Thresholds based on the 30th, 10th and 1st percentiles of index scores at statewide reference sites were used to define four stream condition categories for each of the indices (Table 2). Criteria for identifying reference sites in California were defined by Ode et al. (2016). Thresholds for CSCI were defined by Mazor et al. (2016), for ASCI by Theroux et al. (2020), and for IPI by Rehn et al. (2018). For CRAM, thresholds were newly defined for this assessment based on reference site data aggregated by Rehn (2016) as part of a multi-indicator analysis of stream condition in California.

Table 2. Thresholds used to define stream condition categories for each index used in the 2008-2018 stream condition assessment.

	Condition Category			
Index	**Likely Intact**	**Possibly Altered**	**Likely Altered**	**Very Likely Altered**
CSCI	≥ 0.92	0.91-0.80	0.79-0.63	≤0.62
ASCI	≥ 0.94	0.93-0.87	0.86-0.76	≤0.75
IPI	≥ 0.94	0.93-0.84	0.83-0.71	≤0.70
CRAM	≥ 82	81-76	75-66	≤ 65

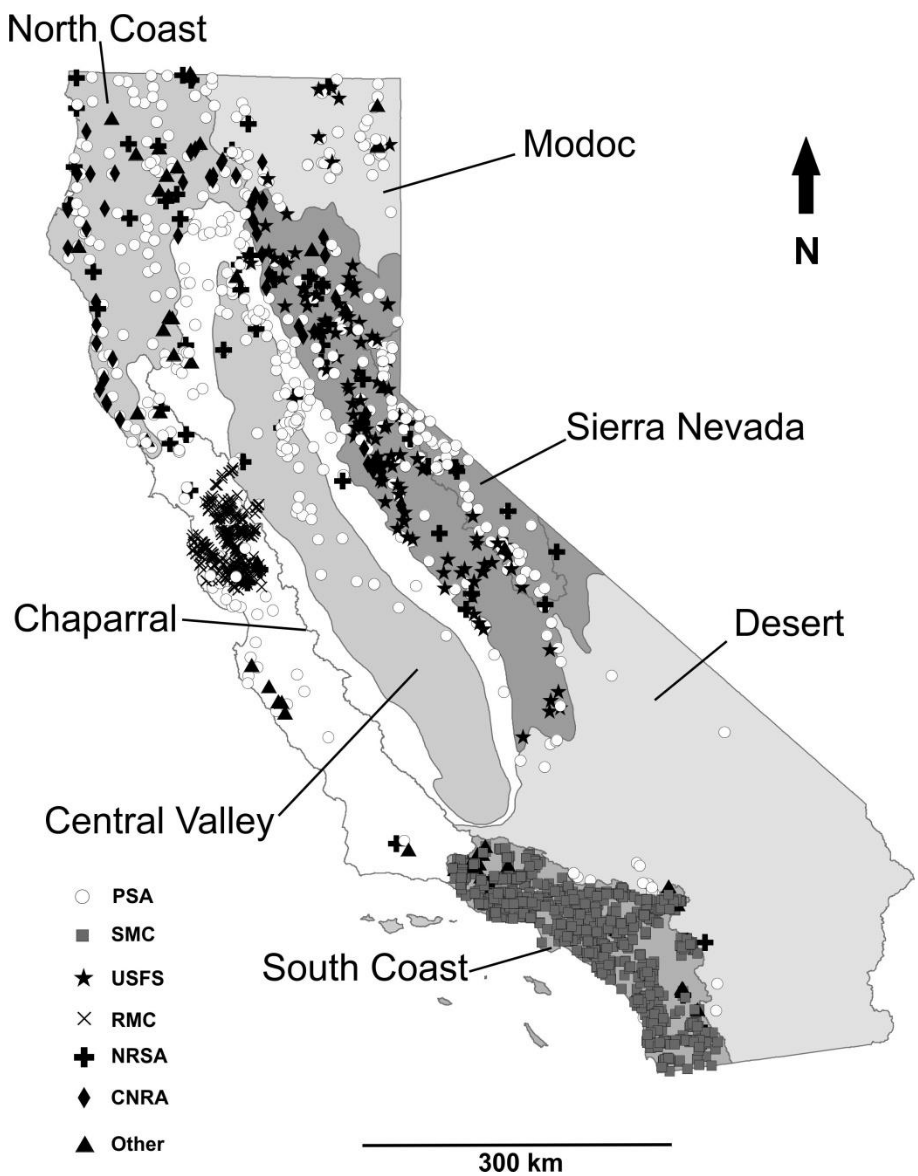

Figure 1. Map of 1,980 unique sites sampled by the PSA and its partner programs in 2008-2018 and their distribution among PSA reporting regions.

Question 1: What is the biological and physical[2] condition of streams in California?

Benthic Macroinvertebrates

According to the CSCI, 47% of perennial, wadeable stream length in California was in 'Likely Intact' condition for the 11-year time period 2008-2018 (Figure 2a). However, the percentage of stream length in best biological condition during that time frame varied greatly by region (Figure 2b), with the North Coast and Sierra Nevada having the highest percentage (70% and 65%, respectively), and the South Coast, Chaparral and Central Valley having the lowest percentage (31%, 27% and <1% respectively). Most of the stream length in the Central Valley (78%) was in 'Very Likely Altered' condition for CSCI.

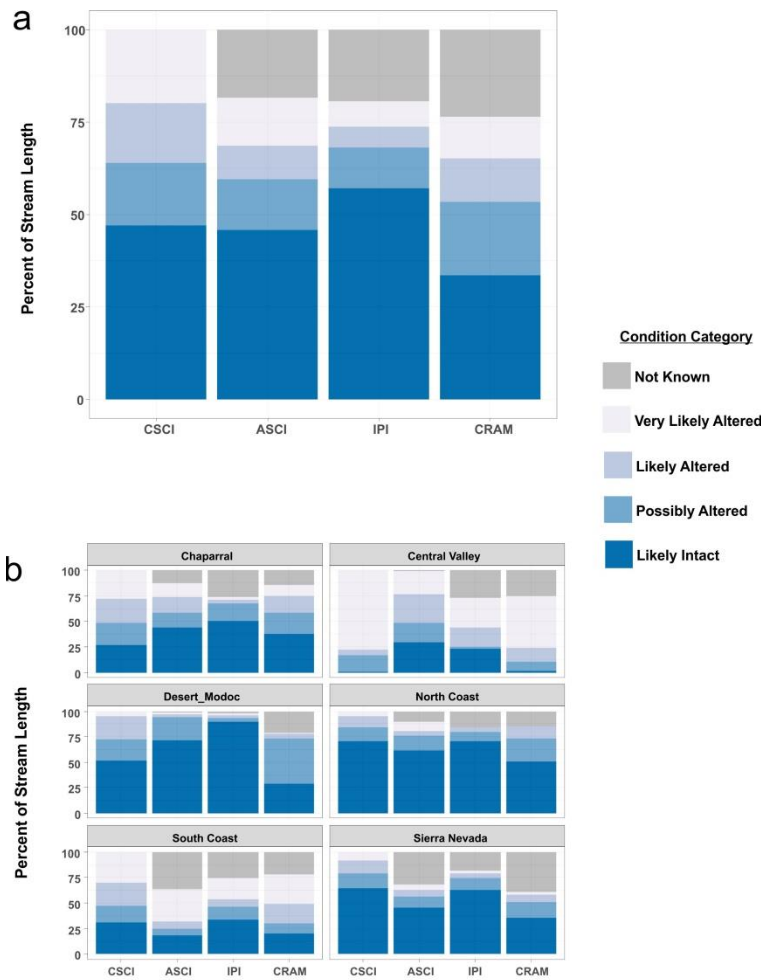

Figure 2. Bar charts of percent stream length in each of four stream condition categories (and percent Not Known where data were missing) for each of four bioassessment indices: a) statewide, and b) by PSA region.

[2] Interpretive indices are not developed for water chemistry data, so chemical conditions are summarized by PSA region and land use category in Appendix 1.

Benthic algae

At the statewide scale, the percent of stream length that scored as 'Likely Intact' for ASCI (46%) was almost identical to CSCI (Figure 2a). As with CSCI, the percentage of 'Likely Intact' stream length varied greatly by region (Figure 2b), with the Desert-Modoc and North Coast having the highest percentage (71% and 61%, respectively), and the South Coast only 18%. There were also some noteworthy contrasts with CSCI results, e.g., ASCI scored 29% of stream length in the Central Valley and 44% of stream length in the Chaparral as 'Likely Intact' (i.e., much higher than observed for CSCI), but only 46% in the Sierra Nevada (i.e., much lower than observed for CSCI).

Physical Habitat and CRAM

IPI and CRAM results are discussed together since both are physical habitat/ landscape condition indices and neither is a biological index. The IPI is perhaps the least sensitive index with >50% of stream length scored as 'Likely Intact", not only for the statewide average, but in all but 2 regions (Figures 2a,b). CRAM results tell a considerably different story, with only 34% of statewide stream length scored as 'Likely Intact' (lower than any other index), and all but one region (the North Coast) had well under 50% of stream length scored as 'Likely Intact'. One of the few respects in which IPI and CRAM agreed was that the Central Valley had the least amount of stream length in 'Likely Intact' condition, but even then results were quite different (23% and 2%, respectively). It is worth noting, however, that CRAM includes measures of disturbance as components of the final index score (i.e., it is not strictly an index based on responses to disturbance as are the other three), which may explain why it frequently assesses less stream length as being in 'Likely Intact' condition than any other index.

Question 2: Is stream condition changing over time?

To address this question, the full 11-year data set was divided into 8 overlapping 4-year time blocks, with each block shifting forward by one year. For example, the first time block included sites sampled in 2008-2011, the second included sites sampled in 2009-2012, and the last included sites sampled in 2015-2018. Each time block was labeled by its End-year in graphics that follow. Statistical weights (i.e., the amount of statewide stream length represented by each site) were calculated separately for each 4-year time block. This approach is similar to a rolling average which is often used in trend analyses to smooth out short-term fluctuations and highlight longer-term trends or cycles.

Benthic Macroinvertebrates

Statewide stream condition fluctuated somewhat during the 2008-2018 time period, but no trend (i.e., no consistent directional change over time) was observed (Figure 3a). Slightly over 50% of stream length in California was estimated to be in 'Likely Intact' condition during the first 4 years of the study (2008-2011). In End-years 2013 through 2016, 'Likely Intact' stream length decreased to approximately 44% of the total, then increased again starting in End-years 2017 and 2018. The decline during End-years 2013-2016 was most likely driven by two sites in the Desert-Modoc region that had very high statistical weights, one of which scored as 'Possibly Altered' and the other as 'Likely Altered' (see End-years 2013-2016 in the Desert-Modoc panel of Figure 3b).

Different PSA regions showed somewhat different trends, with CSCI condition getting slightly better over time in the North Coast, slightly worse over time in the Chaparral and South Coast, staying about the same in the Sierra Nevada, spuriously "tanking" in End-years 2013-2016 in Desert-Modoc (mentioned above), and while never showing 'Likely Intact' conditions in the Central Valley, the percent of stream length in 'Possibly Altered' condition changed erratically, again most likely due to relatively few sites with high statistical weights (Figure 3b).

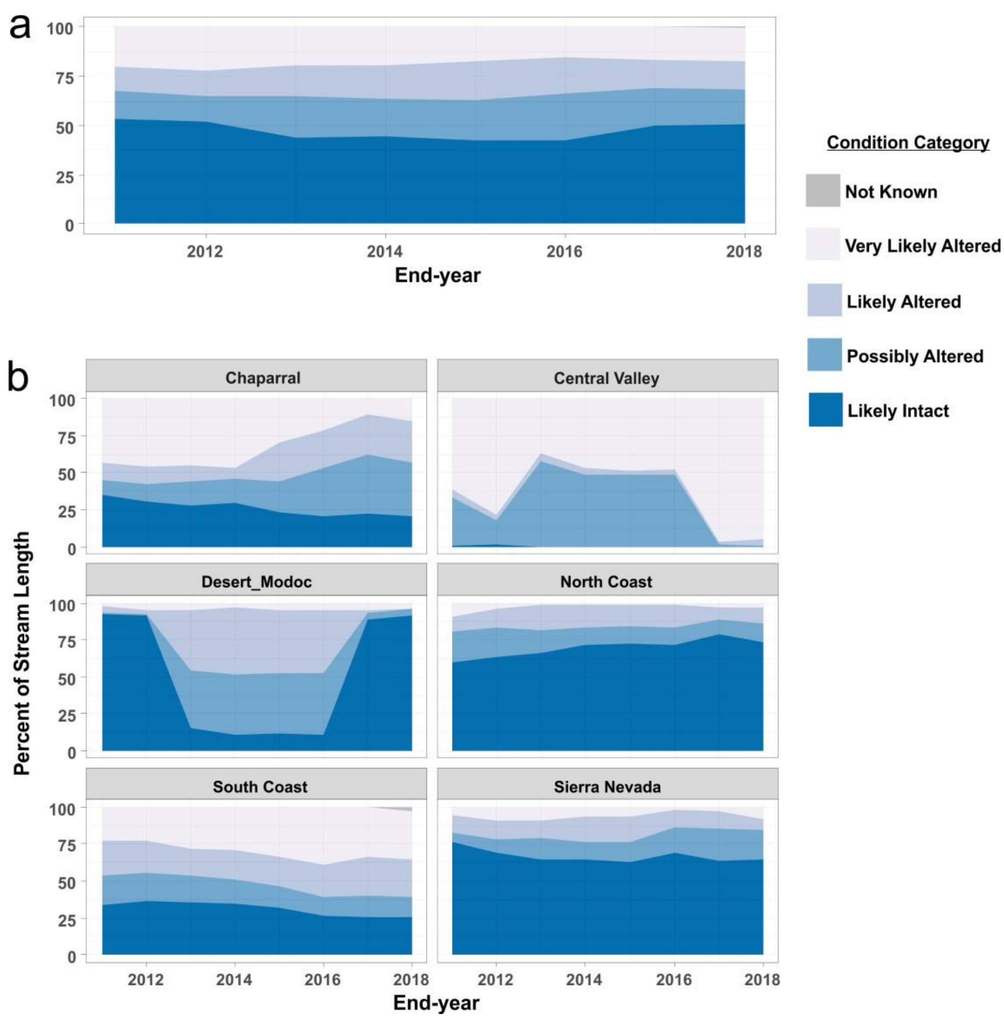

Figure 3. Stream condition over time based on CSCI scores a) statewide and b) by PSA region.

Benthic Algae

Trends for ASCI were different from those observed for CSCI at the statewide scale and in several regions. Whereas the CSCI showed little change in statewide or regional conditions over time, ASCI showed that the percentage of stream length scored as 'Likely Intact' increased somewhat markedly over time (Figures 4a,b). The abrupt improvement in the Central Valley in End-years 2017-2018 (after having relatively little stream length in 'Likely Intact' condition in End-years 2011-2016) was again most likely due to few sites with high statistical weights and high scores. In the Chaparral, North Coast and Sierra Nevada regions, and at the statewide scale, the percent of stream length in 'Likely Intact' condition was, in part, inversely proportional to the percent of 'Not Known' stream length where ASCI data was missing. The net increase in percent 'Likely Intact' stream length over time (i.e., percent 'Likely Intact' in End-year 2018 minus percent 'Likely Intact' in End-year 2011) was reduced when 'Not Known' stream length was omitted from calculations: from 16% to 10% in the Chaparral, from 29% to 14% in the North Coast, from 12% to 7% in the Sierra Nevada and from 15% to 11% statewide (data not shown; available on request). The remaining net increase in 'Likely Intact' stream length in these regions and statewide may be due to a related statistical artifact wherein weights calculated from the full set of survey sites may be inappropriate if applied to a subset of sites that happens to have a certain data type, or may represent real improvement over time from an algae perspective. ASCI trends in the South Coast and Desert-Modoc were more consistent with those observed for CSCI, i.e., the percentage of stream length scored as 'Likely Intact' declined over time in the South Coast, and the Desert-Modoc showed a (probably spurious) decline in End-years 2013-2016.

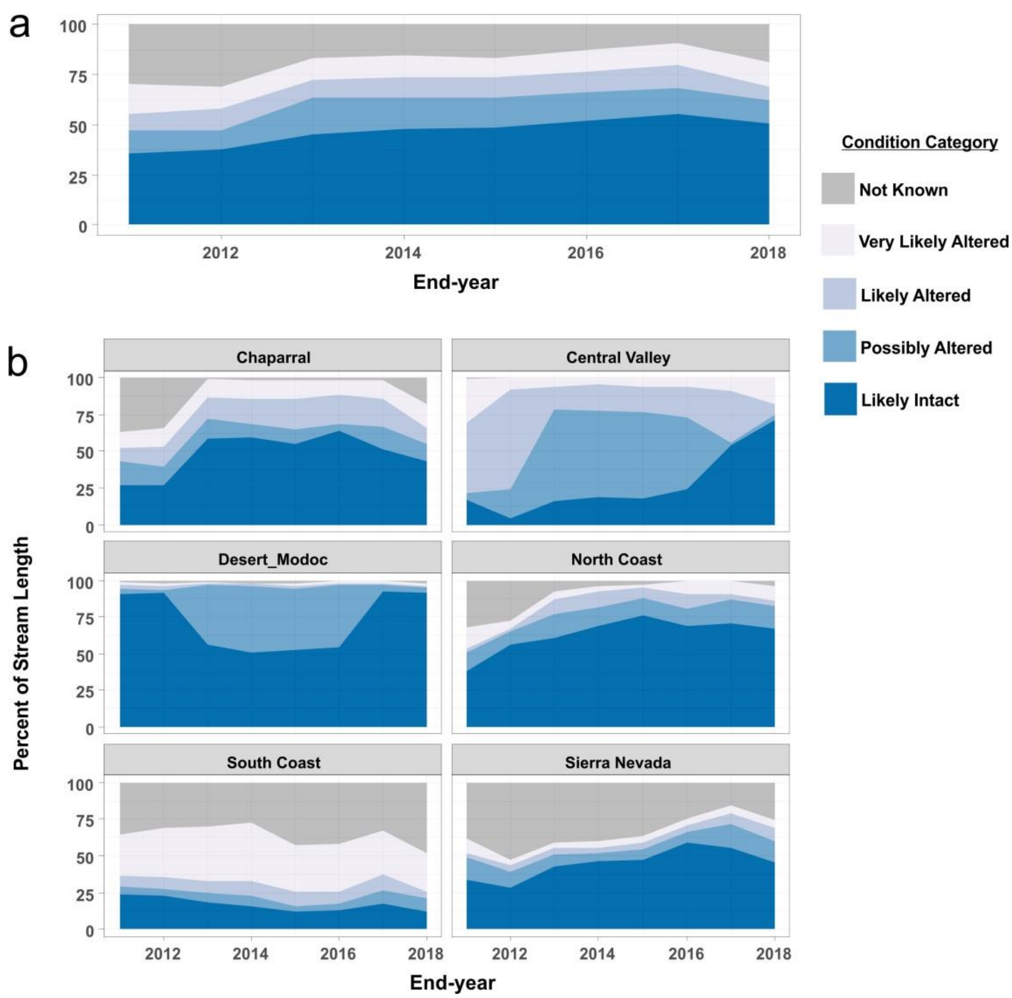

Figure 4. Stream condition over time based on ASCI scores a) statewide and b) by PSA region.

Physical Habitat and CRAM

Neither the IPI nor CRAM showed statewide trends over time during the 2008-2018 assessment period (Figures 5a and 6a, respectively). Based on percent stream length in 'Likely Intact' condition at regional scales, the IPI showed slightly improving conditions in the Chaparral, North Coast and Sierra Nevada, but slightly worsening conditions in the South Coast (Figure 5b). The Desert-Modoc region was almost always 'Likely Intact', and conditions in the Central Valley fluctuate erratically. Again, Desert-Modoc and Central Valley results most likely are due to relatively few sites that represent large amounts of stream length (note that in the Central Valley, the percent of stream length in 'Likely Intact' condition over time for IPI strongly mirrors the percent of stream length in 'Possibly Altered' condition for CSCI, reinforcing that results are being driven by relatively few sites with high statistical weights that are in relatively good condition for those two indices).

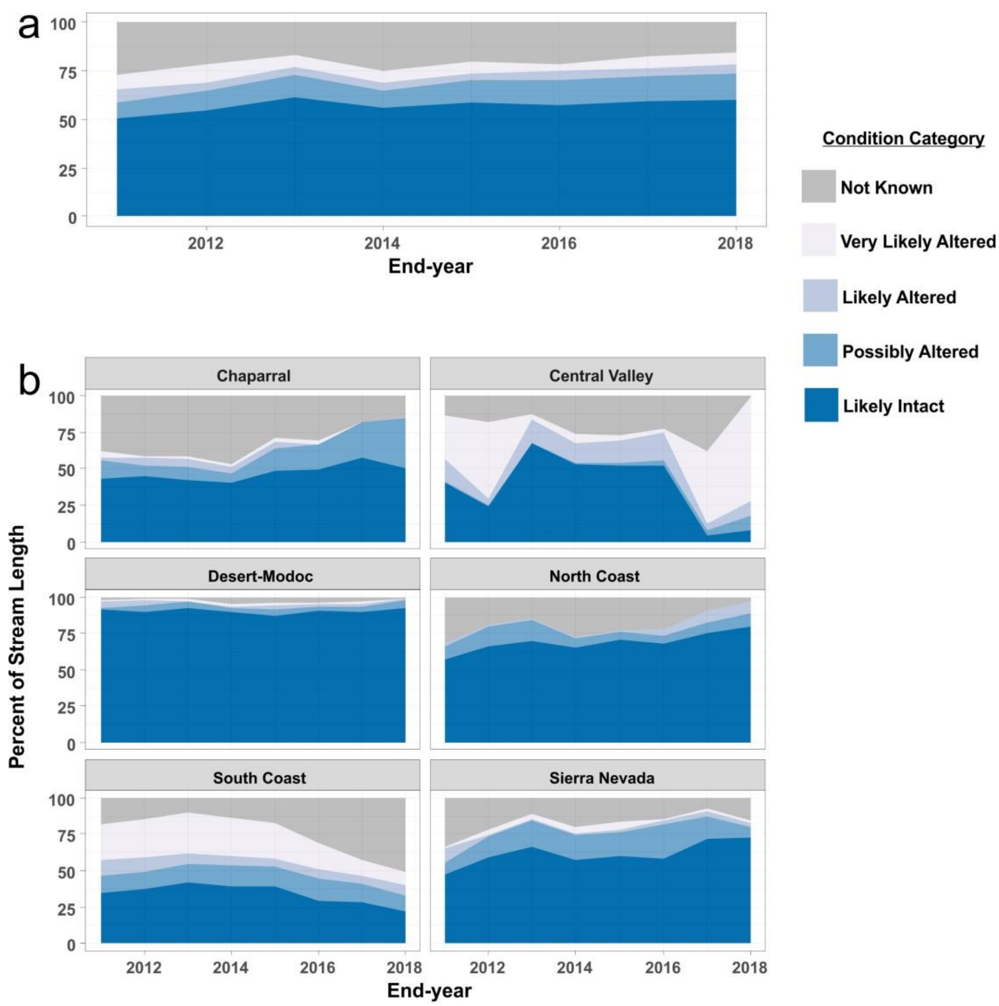

Figure 5. Stream condition over time based on IPI scores a) statewide and b) by PSA region.

The only region that showed an increasing percent of stream length in "Likely Intact' condition for CRAM was the Chaparral, with no clear trends evident in the North Coast, Sierra Nevada and Central Valley (the latter always having very little stream length in the best condition, see Figure 6b). CRAM conditions may have worsened in the South Coast over time as 'Likely Intact' stream length slightly declined with a concurrent increase in the percent of stream length in 'Likely Altered' and 'Very Likely Altered' condition. Interestingly, no sites in the North Coast scored as 'Very Likely Altered' for either IPI or CRAM. Finally, IPI consistently assesses more stream length as being in 'Likely Intact' condition compared to CRAM at both statewide and regional scales, again indicating that it is the least sensitive index of the four.

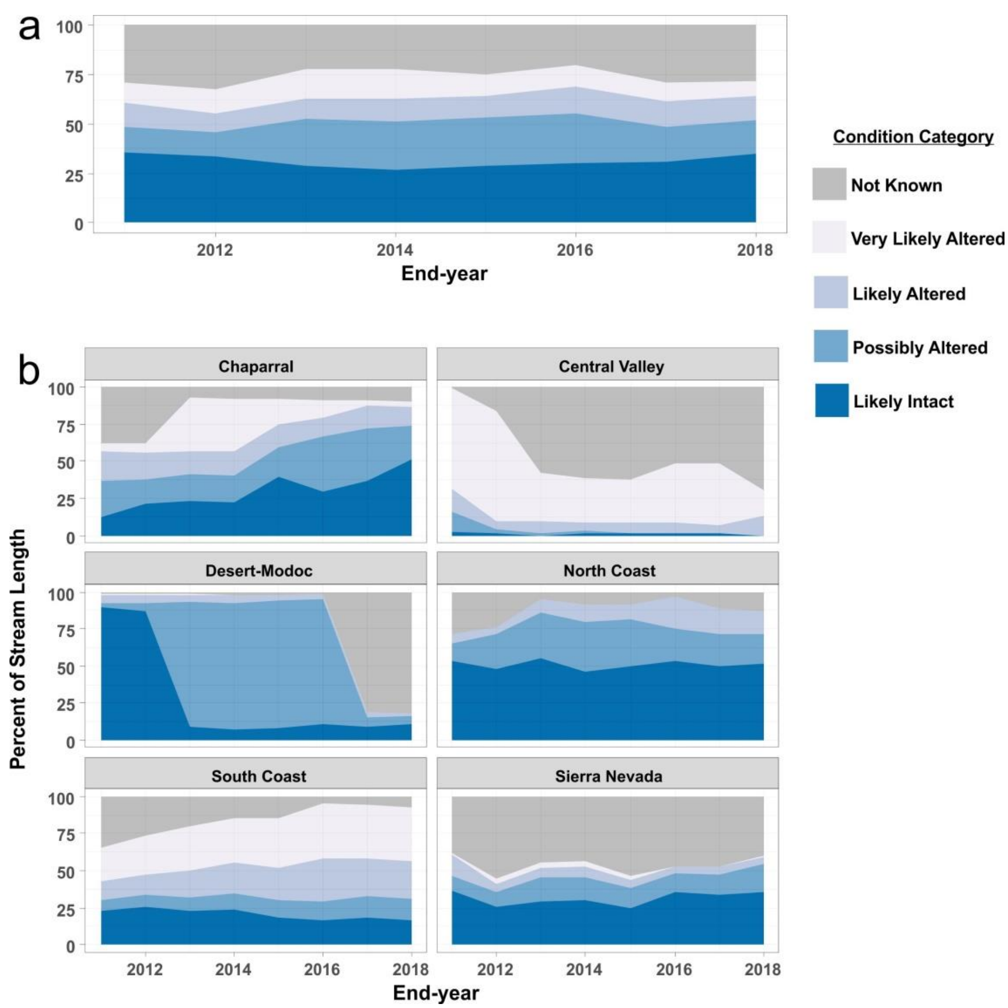

Figure 6. Stream condition over time based on CRAM scores a) statewide and b) by PSA region.

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

Sites were classified into four land use categories based on land use/land cover in the local and entire upstream watershed: urban sites had ≥ 25% urban land use at either local or watershed scale; ag sites had ≥ 50% agricultural 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[3]. Most of the stream length draining watersheds dominated by agricultural and urban land use practices was in either 'Likely Altered' or 'Very Likely Altered' condition for all four stream condition indices (Figure 7), including IPI in ag-dominated streams even though that index was missing for a large portion of sites. By contrast, most of the stream length draining forested watersheds was in 'Likely Intact' condition for CSCI, ASCI and IPI, but somewhat less so for CRAM. As was discussed above under Question 1, CRAM includes measures of disturbance as components of the final index score (i.e., it is not strictly an index based on response to disturbance as are the other three), which may explain why it frequently assesses less stream length as 'Likely Intact' than any other index. Most of the stream length draining watersheds with "other" land use was in 'Likely Intact' condition for ASCI and IPI, less so for CSCI, least so for CRAM.

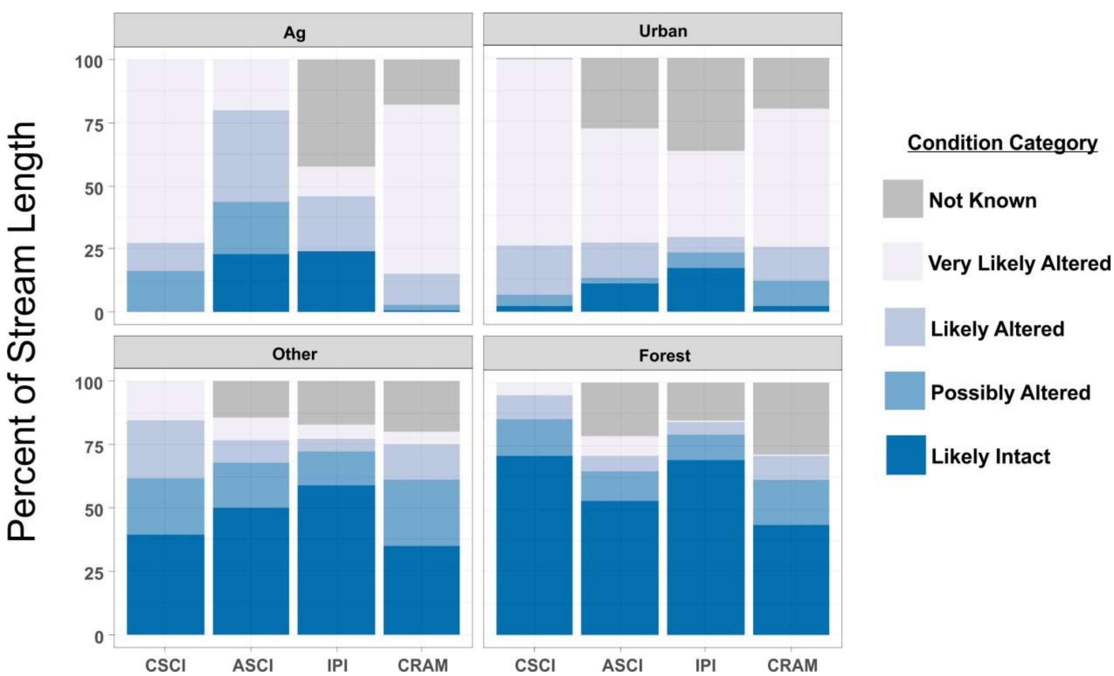

Figure 7. Bar charts of percent stream length in each of four stream condition categories (and percent Not Known where data were absent) for each of four bioassessment indices at survey sites dominated by different types of land use.

[3] The percent of target-sampled stream length in each land use category was as follows: urban = 11%; ag = 4%; forested = 43%; other = 42%.

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

Relative risk analysis (Van Sickle et al. 2006) was used to address this question. Relative risk is the increased chance of observing degraded biological condition when the value of some stressor variable also exceeds a threshold that represents degraded or 'most-disturbed' conditions for that stressor. Biological response variables in relative risk analyses were CSCI and ASCI; sites in either 'Likely Altered' or 'Very Likely Altered' condition (Table 2) were considered to be in degraded biological condition. Stressor variables included IPI and CRAM; sites in either 'Likely Altered' or 'Very Likely Altered' condition (Table 2) were considered to be in most-disturbed physical condition. Most-disturbed thresholds were also defined for 11 other chemical and physical stressors shown by previous studies (e.g., Stoddard et al. 2005; Ode et al. 2011) to be associated with biological impairment (Tables 3 and 4).

For CSCI, the IPI and other measures of riparian and in-stream habitat had the highest relative risk of degraded biological condition when most-disturbed thresholds were exceeded, with somewhat lower relative risk for water chemistry analytes, including nutrients (Figure 8). For ASCI, chloride had the highest relative risk of associated degradation in biological condition, but relative risk was also high for percent sand and fine substrate and CRAM (Figure 8). ASCI showed higher relative risk of degradation than CSCI when total nitrogen thresholds were exceeded, but the two indices showed similar relative risk when total phosphorus thresholds were exceeded. Weighted distributions for the primary chemical and physical analytes assessed in statewide and regional surveys are summarized by PSA region and by land use category in Appendix 1.

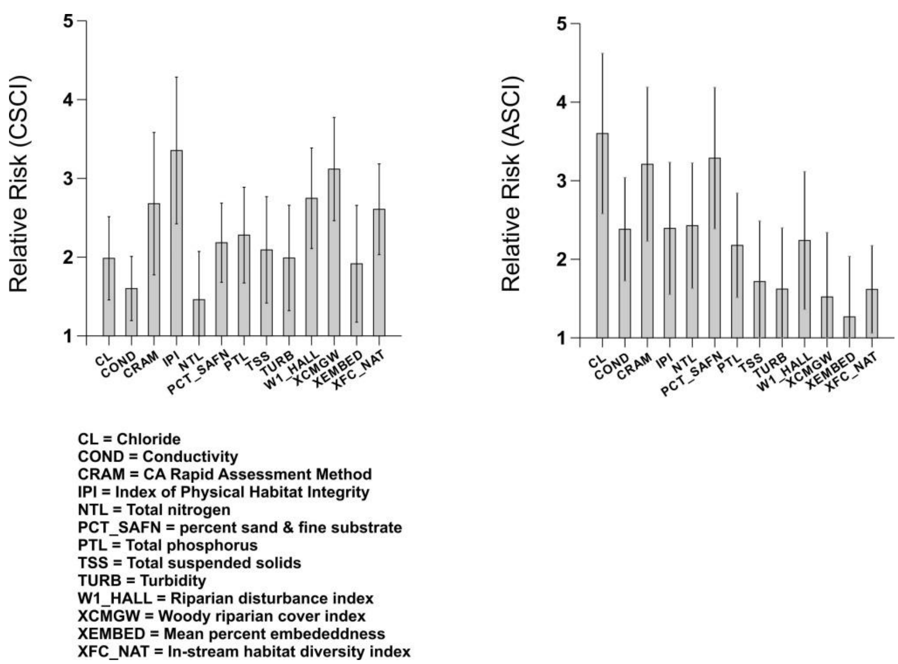

Figure 8. Relative risk of observing biological degradation for CSCI (left panel) and ASCI (right panel) when most-disturbed thresholds are exceeded for the primary chemical and physical stressor variables measured by PSA and other probabilistic surveys.

Table 3. Criteria for identifying most-disturbed sites in 4 aggregate Level III ecoregions (see Stoddard et al. 2005 for aggregate ecoregion definitions) according to **CSCI**. The 90th percentile of stressor values at sites in 'Likely Intact' 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 'Likely Intact' 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 had 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 stressors evaluated.

	Chloride mg/L (CL)	Conductivity µS/cm (COND)	Total Nitrogen mg/L (NTL)	Percent sand & fine substrate (PCT_SAFN)	Total Phosphorus 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)	In-stream habitat diversity index (XFC_NAT)
Sierra and North Coast	**10.1**	**282**	**0.27**	**35**	**0.056**	**5.5**	**2.4**	**1.27**	**55**	**46**	**18**
Southern California Mtns	**25**	**930**	**0.586**	**54**	**0.19**	**10.1**	**3.2**	**0.73**	**37**	**59**	**27**
Xeric California (= xeric SoCal, Central Valley and Chaparral)	**122**	**1460**	**2.3**	**69**	**0.122**	**7.2**	**5.1**	**1.3**	**54**	**54**	**14**
Xeric Southwest (= Desert-Modoc)	**3.2**	**205**	**0.173**	**47**	**0.048**	**9.2**	**4.2**	**1.9**	**45**	**57**	**19**

Table 4. Criteria for identifying most-disturbed sites in 4 aggregate Level III ecoregions (see Stoddard et al. 2005 for aggregate ecoregion definitions) according to **ASCI**. The 90th percentile of stressor values at sites in 'Likely Intact' 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 'Likely Intact' 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 had 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 stressors evaluated.

	Chloride mg/L (CL)	Conductivity µS/cm (COND)	Total Nitrogen mg/L (NTL)	Percent sand & fine substrate (PCT_SAFN)	Total Phosphorus 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)	In-stream habitat diversity index (XFC_NAT)
Sierra and North Coast	**5.5**	**209**	**0.2**	**35**	**0.06**	**3.2**	**2.24**	**0.94**	**54**	**39**	**19**
Southern California Mtns	**28**	**891**	**0.62**	**56**	**0.08**	**16.4**	**4.24**	**1.4**	**25**	**49**	**20**
Xeric California (= xeric SoCal, Central Valley and Chaparral)	**85**	**1361**	**1.02**	**51**	**0.18**	**7.6**	**5.1**	**2.7**	**11**	**48**	**6**
Xeric Southwest (= Desert-Modoc)	**6.9**	**333**	**0.6**	**56**	**0.11**	**7.8**	**4.3**	**1.7**	**22**	**45**	**9**

Recommendations

1. SWAMP should continue to annually fund sampling of at least 30 PSA sites in northern and central California (the South Coast being covered by the SMC program). The fact that the current assessment and previous statewide assessments by Ode et al. (2011) and Rehn (2015) have indicated that stream condition is relatively stable over time provides an important long-term management perspective, i.e., stream condition may not be getting markedly worse, but it is also not getting markedly better. In addition, probabilistic surveys provide objective estimates of the distribution of stressor variables and biological condition in the entire stream population. These average distributions in the overall population together with distributions at high-quality reference sites provide the most robust context for interpreting conditions at targeted sites, which are usually sampled because they have known problems and are often the subject of restoration or other management actions.
2. Managers interested in trends in stream condition related to climate change should consider supporting analyses using interpretive tools for biological data other than CSCI or ASCI, such as raw metrics and/or taxa lists. Indices like CSCI and ASCI have been modeled so as to factor out responsiveness to natural gradients such as precipitation and temperature so that remaining responsiveness is primarily to upstream development, not climate. Furthermore, probabilistic surveys are less well-suited for detecting climate-related trends than are surveys that target high-quality reference sites (preferably with annual revisits at a certain number of sites) where changes over time are most likely due to climate or other natural factors. SWAMP’s Reference Condition Monitoring Program (RCMP) has begun collecting data annually at approximately 30 sites per year over the past 5 years that could serve as a good foundation for these analyses.
3. Poor conditions affected a large proportion of streams in the state (especially in certain regions). Management actions directed at stream restoration and protection should therefore be prioritized in regulatory and non-regulatory Water Board programs, including the non-point source program, municipal stormwater program, 401 water quality certification/wetland program, ag permits and other policy development efforts (e.g., Biostimulatory/Biointegrity Policy) to reduce the risk of biological impairment and related chemical and physical impairment. Riparian and in-stream habitat stressors had the highest relative risk of associated biological impairment for CSCI and were among the highest-risk stressors for ASCI. Water Board programs directed at riparian and habitat protection/restoration are no less necessary to protect and improve biological integrity than programs directed at reducing nutrient or other chemical loads.

Acknowledgments

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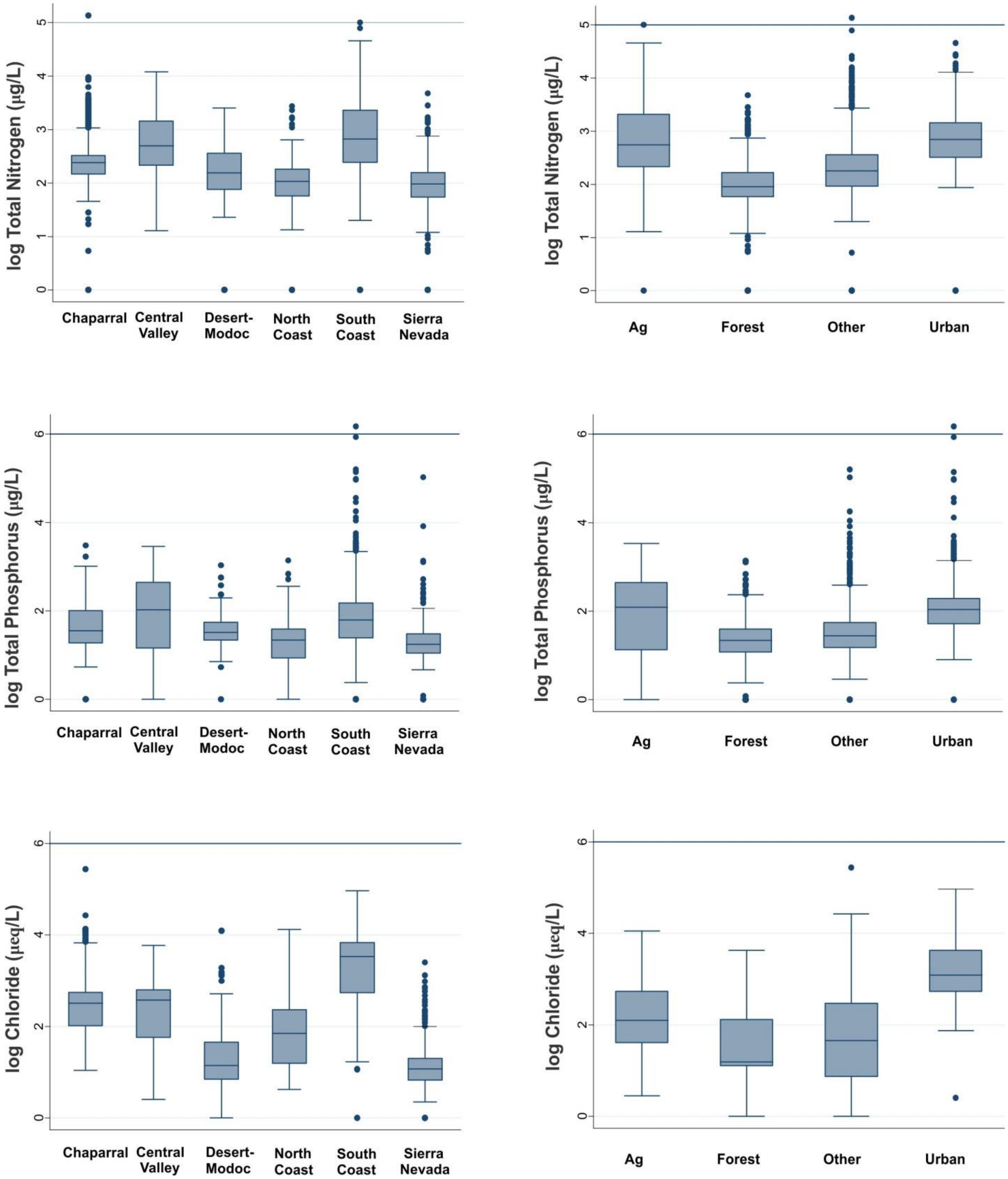
Appendix 1. Box plots showing weighted distributions of the primary chemical and physical stressors assessed in statewide surveys summarized by PSA region and land use category.



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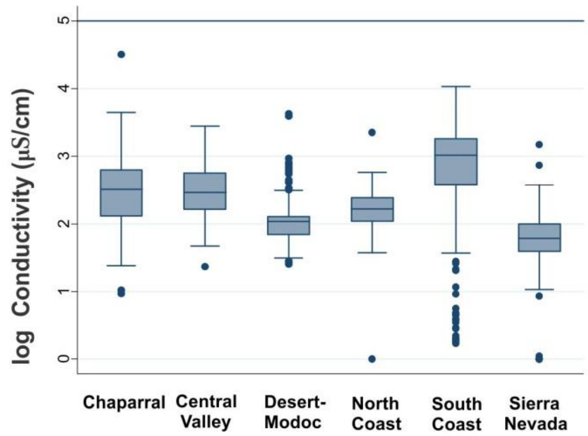

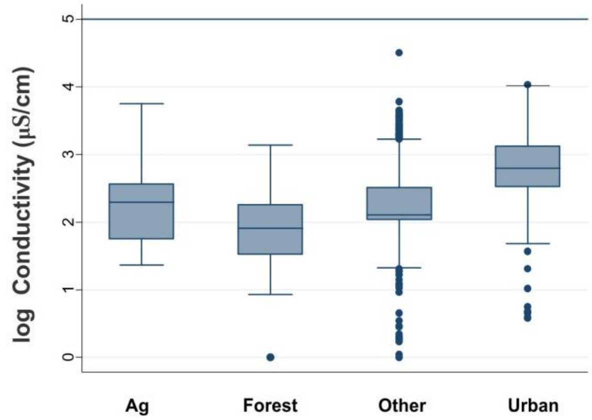

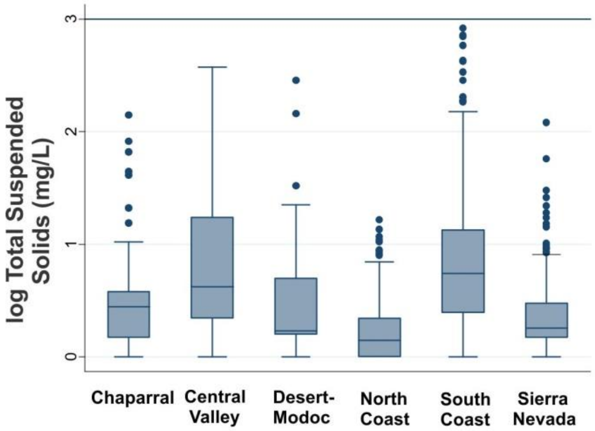

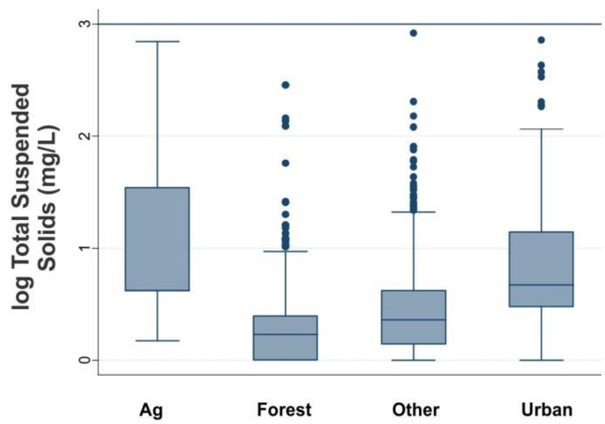

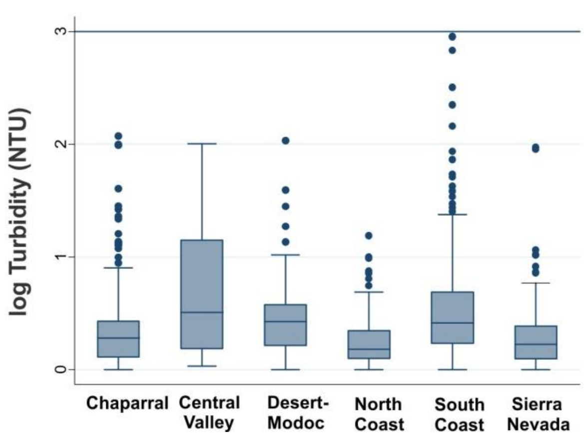

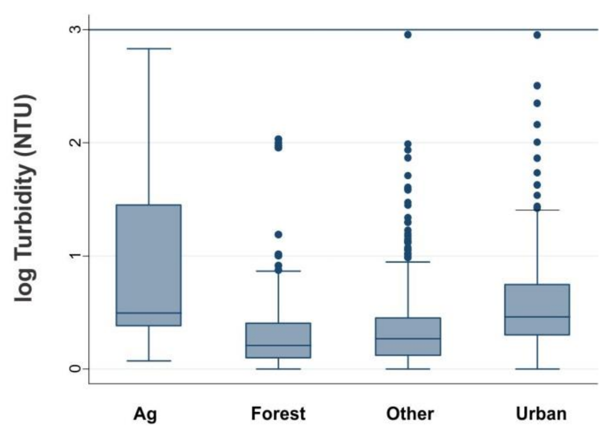

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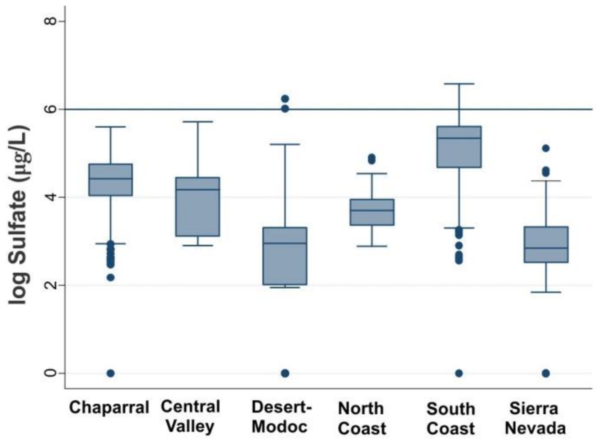

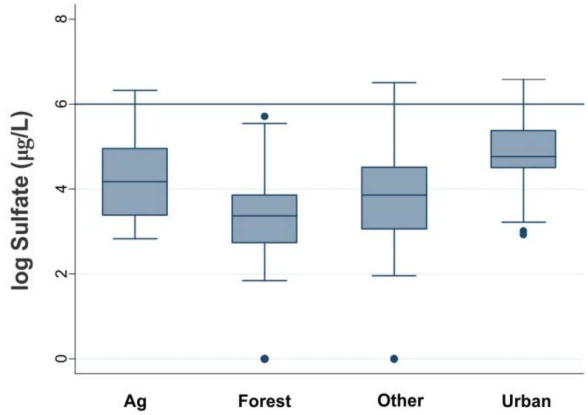

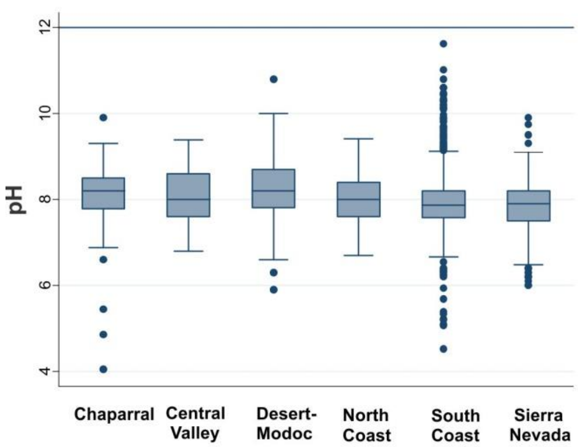

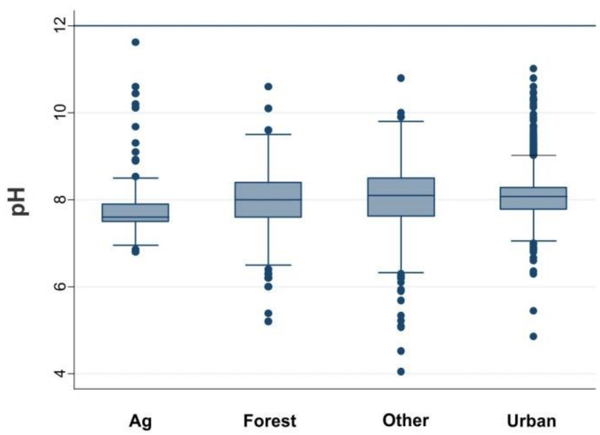

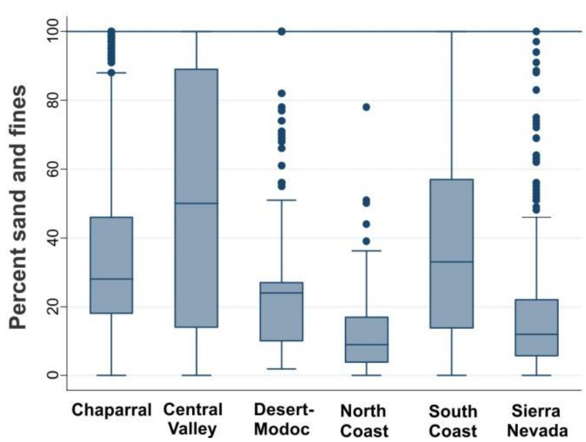

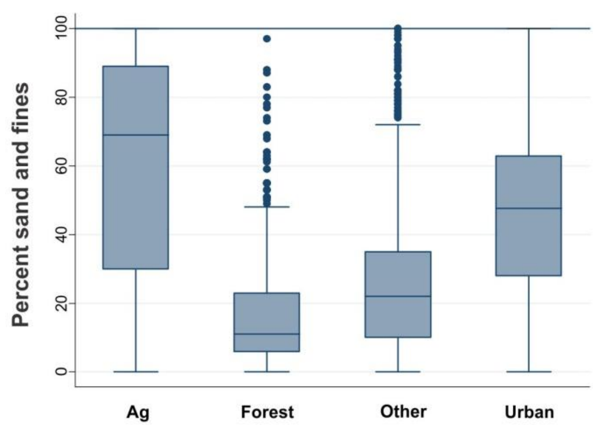

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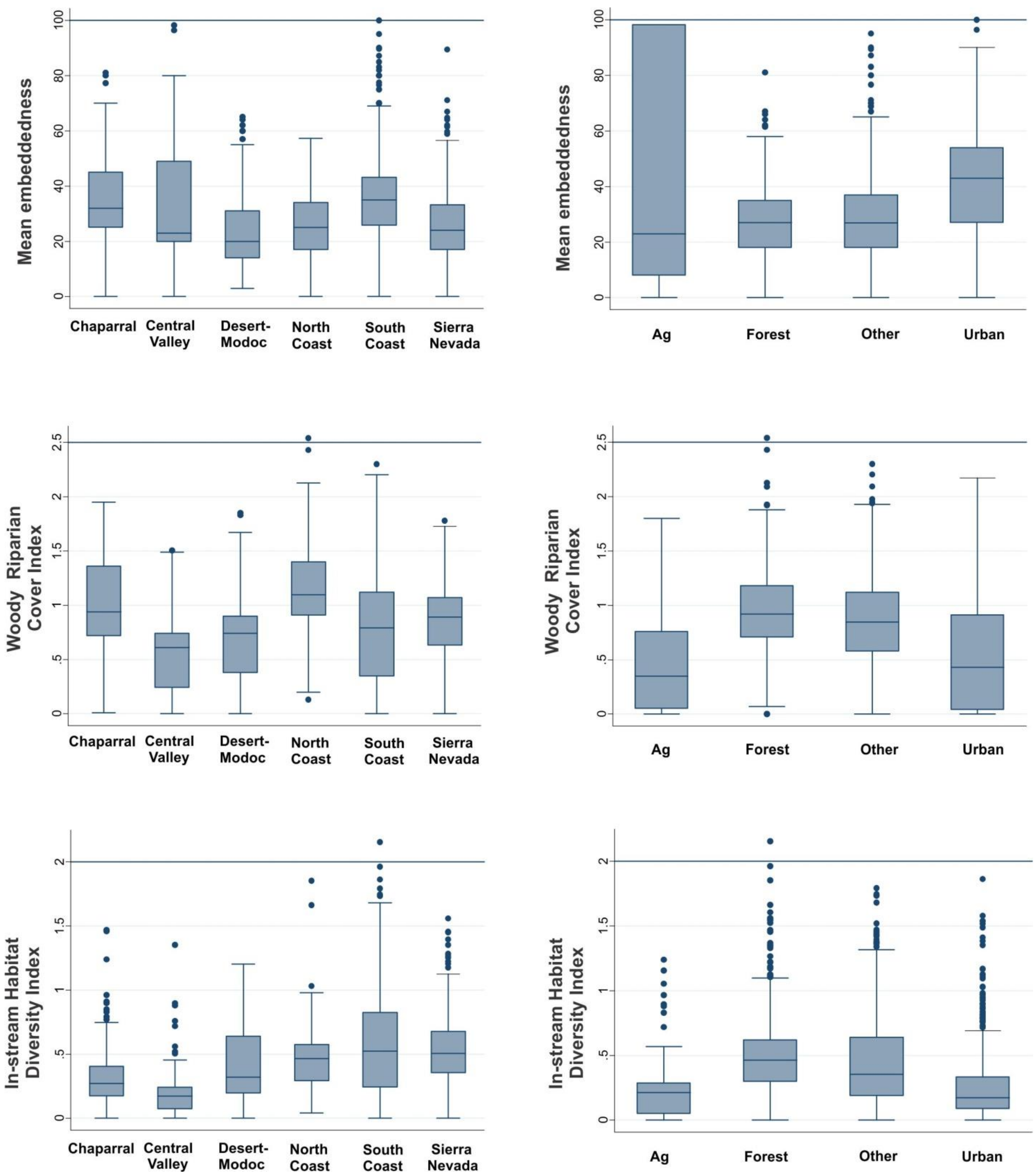

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