An assessment of the biological condition of streams in the San Francisco Bay

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SOUTHERN CALIFORNIA COASTAL WATER RESEARCH PROJECT

Technical Report 1340

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Southern California Coastal Water Research Project, Costa Mesa, CA

December 2023

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Acknowledgments

This work was funded by the Regional Water Quality Control Board – San Francisco Region under State Water Resources Control Board Agreement 19-078-270.

EXECUTIVE SUMMARY

An assessment of more than 1,500 sites sampled over 20 years of bioassessment data in the San Francisco Bay Area shows that the majority of sampled reaches are in poor biological condition, whether measured with biointegrity indices for benthic macroinvertebrates (i.e., the California Stream Condition Index; CSCI), algae (i.e., the algal Stream Condition Indices for diatoms [ASCI-D] or a hybrid of diatoms and soft-bodied algal taxa; ASCI-H), or riparian condition (i.e., the California Rapid Assessment Method; CRAM). Condition scores were correlated with stressor gradients, such as pollutant concentrations or extent of non-natural land use in the watershed.

Intermittency could negatively influence assessments made with the CSCI, as reference non-perennial sites scored lower than expected. That is, the CSCI may be biased in naturally intermittent streams and incorrectly indicate degraded conditions. Thus, alternative thresholds to distinguish between reference and non-reference conditions are appropriate for using this index in intermittent streams, such as those presented in Mazor et al. (in prep) and reproduced in Table 12. Although the geographic extent of where alternative thresholds could be used is under investigation, we have high confidence that they are appropriate for intermittent streams in the Bay Area. Streamflow duration did not influence other condition indices. Standard reference-based thresholds for the CSCI are appropriate for historically perennial streams that have become intermittent due to human activity (e.g., water diversion).

Channel type (e.g., modified vs. natural) was strongly associated with bioassessment index scores. Scores for modified channel types (both hard bottom and soft bottom) were generally low, with high scores only rarely being attained. Although standard reference-based thresholds are appropriate for assessing the conditions of these channels, additional thresholds may be useful for prioritization or setting interim management goals as long as channel modifications remain in place. Potential thresholds based on “best observed” scores for each channel type are presented in (Mazor et al. in prep) and reproduced in Table 10.

This study is not intended to endorse the use of specific thresholds or waterbody classifications in policy or regulatory programs. Rather, the intention is to illuminate how streamflow duration and channel modification can influence decisions regarding the boundaries between reference and non-reference conditions.

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INTRODUCTION

Streams and wetlands are essential elements of the Bay Area's natural heritage. They also work in many ways to protect and enhance water quality throughout the region. Streams and wetlands, and the water that flows through them, shape the landscape as they support the ecological processes all human, plant, and animal watershed residents depend on. Aquatic and terrestrial habitats associated with streams and wetlands provide critical habitat for diverse plant and animal communities. Vegetated riparian and wetland corridors protect and enhance water quality. Healthy stream and wetland systems store flood waters, provide flood control during large storm events, and recharge groundwater.

The San Francisco Bay Area Regional Water Quality Control Board has collected bioassessment data from the region over several years. Bioassessment index scores have been calculated using appropriate data (the California Stream Condition Index [CSCI], the Algal Stream Condition Index [ASCI], the Index of Physical-habitat Integrity [IPI], and the California Rapid Assessment Method [CRAM]). This report analyzes these data to answer key questions about the condition of wadeable streams in the Bay Area, such as:

- What proportion of stream sites have scores indicating "good" conditions (i.e., scores above the 10^{th} percentile of scores at reference sites) in the region and in subpopulations of interest?
- How do scores from different indices correspond to each other?
- What stressors are associated with variability in index scores?

METHODS

Samples

Samples were collected from 1,507 wadeable stream sites within the jurisdiction of the San Francisco Bay Regional Water Quality Control Board (Water Board Region 2) between 4/30/1998 and 6/17/2021, under a number of bioassessment programs lead by the State and Regional Waterboards (such as the Surface Water Ambient Monitoring Program, the Perennial Streams Assessment, and the Reference Condition Monitoring Program), as well as the Regional Monitoring Program led by the Bay Area Stormwater Agencies Association (Table 1). Under these programs, benthic macroinvertebrates, diatom and soft-bodied algae, and chemistry samples were collected according to the methods of Ode et al. 2011 and habitat measurements were made according to CWMW 2013.

Table 1. Source of bioassessment data. Parent Projects found in CEDEN (California Environmental Data Exchange Network) that are associated with the bioassessment monitoring data in this report.

Parent Project	Number of Sampling Events
Alameda Creek Aquatic Resource Monitoring	67
BASMAA RMC Monitoring in WY2012	58
BASMAA RMC Monitoring in WY2013	66
BASMAA RMC Monitoring in WY2014	59
BASMAA RMC Monitoring in WY2015	59
BASMAA RMC Monitoring in WY2016	66
BASMAA RMC Monitoring in WY2017	74
BASMAA RMC Monitoring in WY2018	50
BASMAA RMC Monitoring in WY2019	58
BASMAA RMC Monitoring in WY2020	60
DFW_ABL_Monitoring	31
EPA EMAP - 2001	1

Parent Project	Number of Sampling Events
EPA EMAP - 2002	1
EPA EMAP - 2003	1
EPA National Rivers and Streams Assessment	1
Historic (pre 2012) BASMAA monitoring	972
ICARE BMI Surveys	26
RWB2 Zone 7 Bioassessment Monitoring	27
San Mateo Creek Aquatic Resource Monitoring	56
SWAMP California Monitoring and Assessment Program	27
SWAMP Low Gradient Methods Comparison	2
SWAMP Monitoring	1
SWAMP Perennial Stream Surveys	40
SWAMP Reference Condition Management Plan	29
SWAMP Repeat Sampling Field Methods Comparison	3
SWAMP RWB2 Monitoring	415
Sampling events without a CEDEN Parent Project	221

Measurements

Benthic macroinvertebrate samples were scored with the California Stream Condition Index (CSCI; Mazor et al. 2016), and benthic algal samples were scored with the Algal Stream Condition Index for Diatoms (ASCI-D; Theroux et al. 2020) and the hybrid index for diatoms and soft-bodied algae (ASCI-H). Habitat data were scored with the California Rapid Assessment Method (CRAM; CWMW 2013) and the Index of Physical-habitat Integrity (IPI; Rehn et al. 2018). All indices assess condition relative to reference conditions.

The possible range of scores for the CSCI, ASCI-D, ASCI-H and IPI is 0 to 1.0, with lower scores indicative of a greater deviation from expectations at minimally impacted reference sites. Scores > 1 are interpreted to indicate greater physical complexity than predicted for a site given its natural environmental setting. Possible CRAM scores range from 25 to 100 (most to least impacted). For sites with multiple field replicates, the maximum index score was used. Scores were averaged across multiple sampling events.

Chemistry measurements included total nitrogen (TN), total phosphorus (TP), specific conductivity, stream algae ash free dry mass (AFDM), temperature, dissolved oxygen, and benthic chlorophyll a. Total nitrogen was measured directly as TN or was calculated as the sum of nitrate, nitrite and total Kjeldahl nitrogen. Total phosphorus was calculated as the sum of phosphorus as P and orthophosphate as P. For data analysis, non-detects for each analyte were treated as equal to half the reporting level (Table 2). The average chemistry value was calculated for each site across replicates and revisits.

Table 2. Methods and reporting levels used for chemistry measurements.

Analyte	Method	Range in Reporting Levels
TN	EPA 300.0, EPA 300.1, EPA 351.1, EPA 351.2, EPA 351.3, EPA 353.2, EPA 353.3, FR 8507, Hach Method 10071, QC 10107041B, QC 10107044B, QC 10107062E, SM 4500-N C v22, SM 4500-N CM v21, SM 4500-N org C, SM 4500-NH3 C v20, SM 4500-NO2 B, SM 4500-NO2 B v20, SM 4500-NO3 D v20, SM 4500-NO3 E, SM 4500-NO3 F, SM 4500-NO3 I v21, WRS 34A.2, WRS 40A.2	0.001 – 1 mg/L

Analyte	Method	Range in Reporting Levels
TP	EPA 300.0, EPA 300.1, EPA 365.1M, EPA 365.3, QC 10115011D, QC 10115011M, QC 10115012B, SM 4500-P BE, SM 4500-P E, SM 4500-P H, WRS 34A.2	0.001 – 2.1 mg/L
AFDM	CALTEST B-AFDW, EcoAnalysts SOP Algae Biomass, EPA 160.4, WRS 73A.1, WRS 73A.3	0.004 – 78.1 g/m²
Specific conductivity	Field measurement, with no method indicated	Not indicated
Temperature	Field measurement, with no method indicated	Not indicated
Dissolved oxygen	Field measurement, with no method indicated	Not indicated
Chlorophyll a	EPA 446.0, SM 10200 H, SM 10200 H-2ab, SM 10200 H-2b, WRS 71A.1	0.004 – 3242 mg/m²

Analyses

Index results were examined by several aggregation strategies, including by county, by Perennial Streams Assessment (PSA) region (using PSA9 boundaries), by SWAMP Hydrologic Unit Code (HUC, using HUC8 boundaries), and by landscape stressors [% urban, agriculture, open, Code 21 (developed open space), and road and railroad density (km/km²) at three scales (1km, 5km, watershed)]. Code 21 is defined by NLCD 2001 as: “Areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.”

Indices were also examined by comparing results from reference vs non-reference sites (as defined in Ode et al. 2016) and by flow regime (perennial vs non-perennial streams). To investigate the contribution and potential interactions between reference status and flow regime, two-way analysis of variance (ANOVA) tests were conducted using unbalanced designs.

The influence of channel type was investigated by comparing index scores from stream bed material using two classification methods. First, sites were classified using the San Francisco Bay Region Flood Control Channel Classification (Dusterhoff et al. 2021, referred to in this document as the SFEI approach) as "natural unmodified" (soft bed and bank, original channel planform geometry), "natural non-FCC" (natural channels not within the jurisdiction of a flood control district), "hard" (hardened bed with hardened or soft banks), "soft" (soft bank and bed, recontoured and modified channel), or "mixed" (soft earthen bed and hard rock- or concrete-lined banks). Assessments with the SFEI approach were conducted using aerial imagery. The second classification method used direct observation of channel bed and bank materials (referred to in this document as the Direct Observation approach) and classified channels as "natural", "hard", or "soft". Among the sites with index scores, channel type information was only available for sites in Santa Clara County.

The relationship between index scores and chemistry values was assessed using Spearman rank correlations and logistic regression. All calculations were conducted using R Statistical Software (version 4.1.2).

Box plots were used to show the distribution of data. For each box plot, the dark horizontal line in the middle of the box represents the median value, while the upper and lower edges of the box represent the upper and lower quartile (respectively). The whiskers represent the range of values, with circles representing possible outliers.

Each sampling location was assessed for the corresponding predicted Stream Classification and Priority Explorer (SCAPE, Beck et al. 2019) category. This approach predicts CSCI scores from land use gradient information and produces quotients relative to the CSCI 10^{th} percentile reference threshold. Sites predicted to be in poorer condition are categorized as "constrained", while sites predicted to have less impact are categorized as "unconstrained". The full range of SCAPE categories are:

- "Very likely unconstrained" when q10 > 0.79;
- "Likely unconstrained" when q25 > 0.79 but q10 < 0.79;
- "Possibly unconstrained" when q50 > 0.79 but q25 < 0.79;
- "Possibly constrained" when q75 > 0.79 but q50 < 0.79;
- "Likely constrained" when q90 > 0.79 but q75 < 0.79;
- "Very likely constrained" when q90 < 0.79

We also examined how the measured CSCI scores compared with the predicted SCAPE values. Scores were classified either as:

- "Substantially better than expected" when CSCI scores were >q90;
- "Better than expected" when CSCI scores were between q75 and q90;
- "As expected" when CSCI scores were between q25 and q75;
- "Worse than expected" when CSCI scores were between q10 and q25;
- "Substantially worse than expected" when CSCI scores were <q10.

Indicator Thresholds

All index scores were classified into condition classes based on ranges derived from statewide reference distributions (Table 3). Condition was further divided into an "intact" rating (combination of "likely intact" and "possibly altered" categories, i.e., ≥10th percentile reference threshold) and a "degraded" rating (combination of "likely altered" and "very likely altered" categories, i.e., < 10th percentile reference threshold). For CSCI, the threshold came from Mazor et al. 2016 (CSCI = 0.79), while the ASCI threshold came from Theroux et al. 2020 (ASCI = 0.86), the IPI threshold came from Rehn et al. 2018, and the CRAM threshold came from Stein et al. 2022 (CRAM = 76).

Table 3. Ranges of index scores for each condition class.

Index	Likely intact (≥30th percentile of reference)	Possibly altered (30th to 10th percentile)	Likely altered (10th to 1st percentile)	Very likely altered (<1st percentile)
CSCI	≥0.92	0.79 to 0.92	0.63 to 0.79	<0.63
ASCI-D	≥0.94	0.86 to 0.94	0.75 to 0.86	<0.75
ASCI-H	≥0.94	0.86 to 0.94	0.75 to 0.86	<0.75
IPI	≥0.94	0.84 to 0.94	0.71 to 0.84	<0.71
CRAM	≥81	76 to 81	68 to 76	<68

RESULTS

Index Scores in Water Board Region 2 and by County

Most locations in Water Board Region 2 had CSCI, ASCI-D and ASCI-H scores below the 10th percentile reference threshold, indicating degraded conditions (Figures 1 to 15 and Table 4). Poor conditions were identified at 72% of sites for CSCI, 76% of sites for ASCI-D and 85% of sites for ASCI-H. Alameda, Contra Costa, Santa Clara and Solana Counties had the highest proportion of degraded sites for these three indicators. ASCI-D and -H scores were also low in Sonoma County, while CSCI scores were marginal in this county. ASCI scores (-D and -H) tended to be relatively high in Napa County, and CSCI scores tended to be high in Marin County. CSCI, ASCI-D and ASCI-H scores indicated intact conditions in Santa Cruz County, although the results represent only two sampling locations. In contrast to the CSCI and ASCI scores, IPI scores were above the 10th percentile reference threshold at the majority of sites in Water Board Region 2 (74%), indicating intact physical habitat (Figures 4, 9 and 14). The highest overall IPI scores were in Marin, Napa, San Mateo, Santa Clara and Santa Cruz Counties, each with >80% intact sites. Overall CRAM scores indicated degraded habitat conditions in Water Board Region 2 (63% of sites), although the number of sites evaluated using CRAM was relatively low (41 sites total). The highest CRAM scores were identified in Napa County (75% intact sites), while the lowest CRAM scores were in Alameda and Contra Costa Counties (0% intact sites, with three and four sites sampled, respectively).

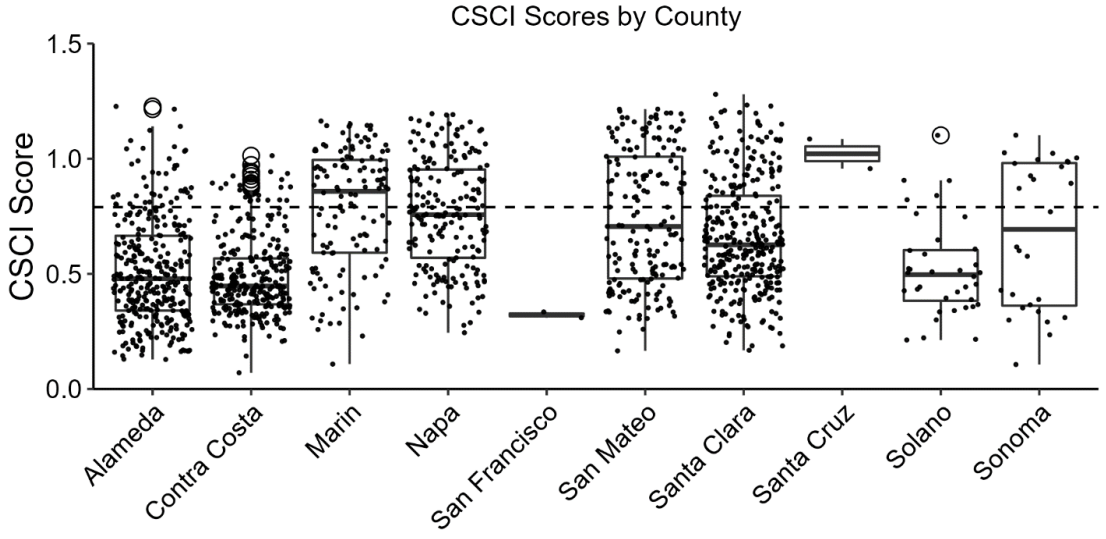


Figure 1. CSCI scores by county. Each point represents the score at a sampling location, with circles representing possible outliers. The dashed horizontal line is the 10th percentile reference threshold.

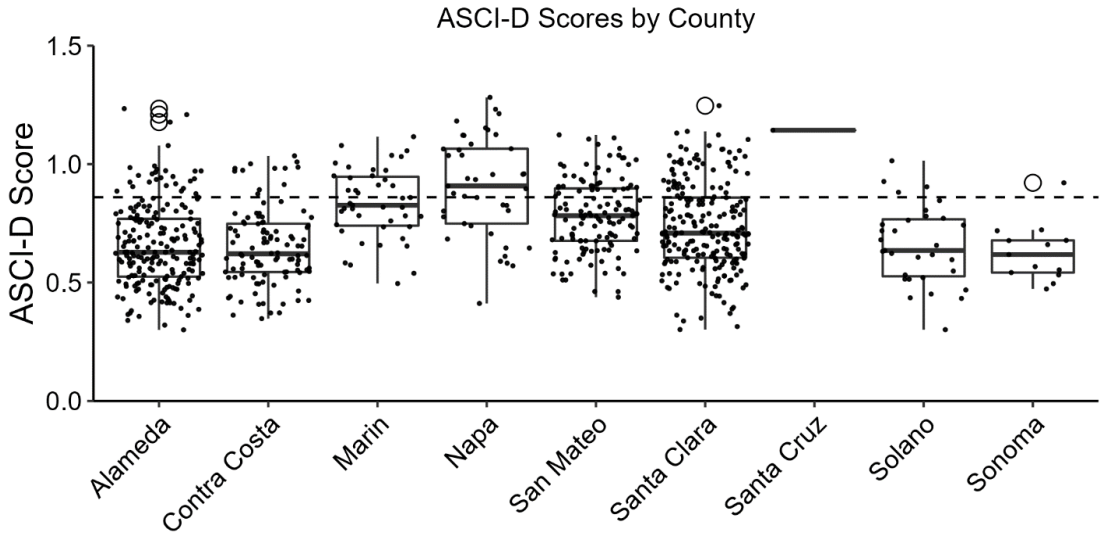


Figure 2. ASCI-D scores by county. Each point represents the score at a sampling location, with circles representing possible outliers. The dashed horizontal line is the 10th percentile reference threshold.

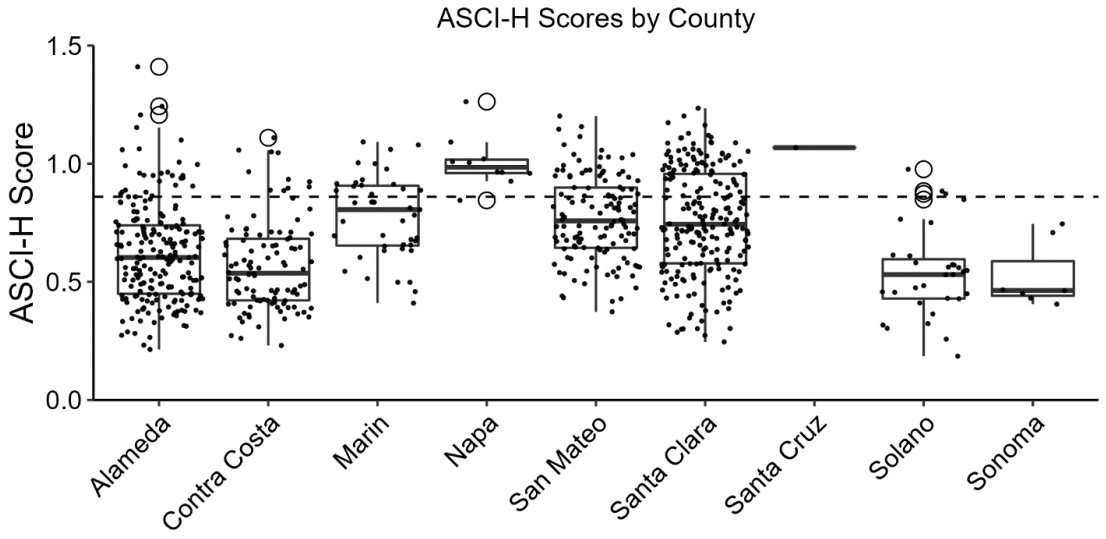


Figure 3. ASCI-H scores by county. Each point represents the score at a sampling location, with circles representing possible outliers. The dashed horizontal line is the 10th percentile reference threshold.

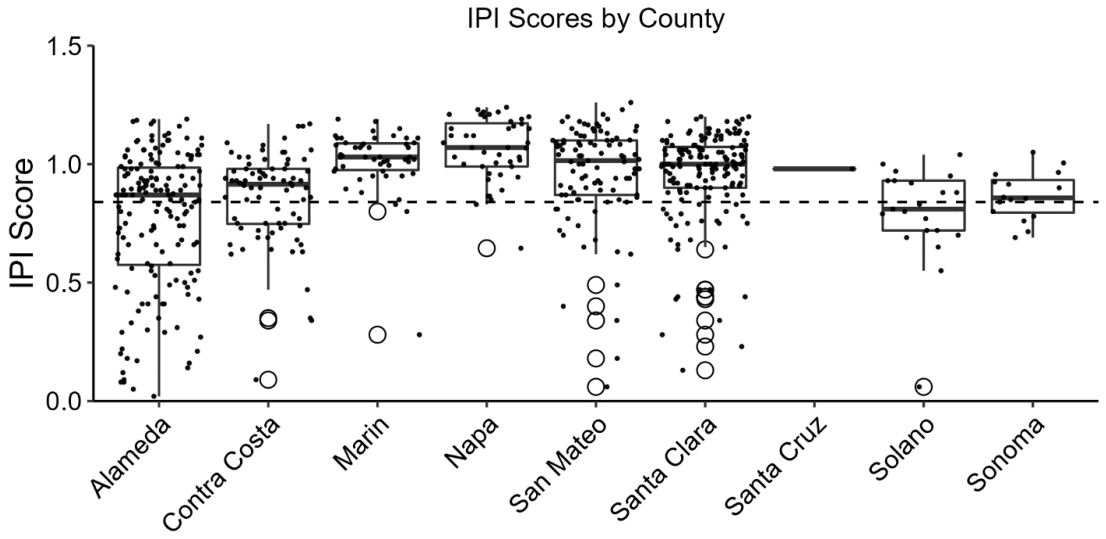


Figure 4. IPI scores by county. Each point represents the score at a sampling location, with circles representing possible outliers. The dashed horizontal line is the 10th percentile reference threshold.

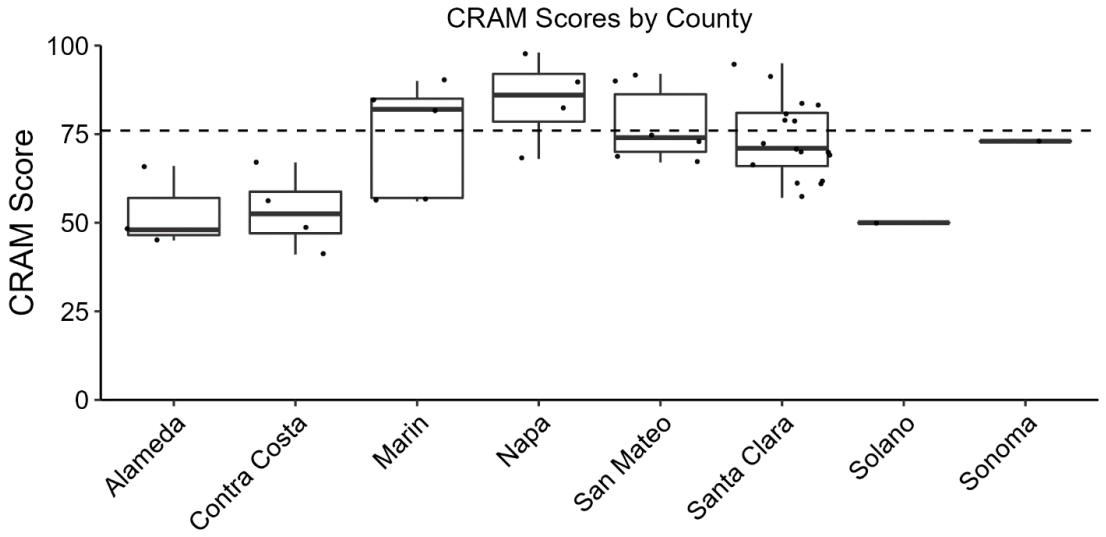


Figure 5. CRAM scores by county. Each point represents the score at a sampling location. The dashed horizontal line is the 10th percentile reference threshold.

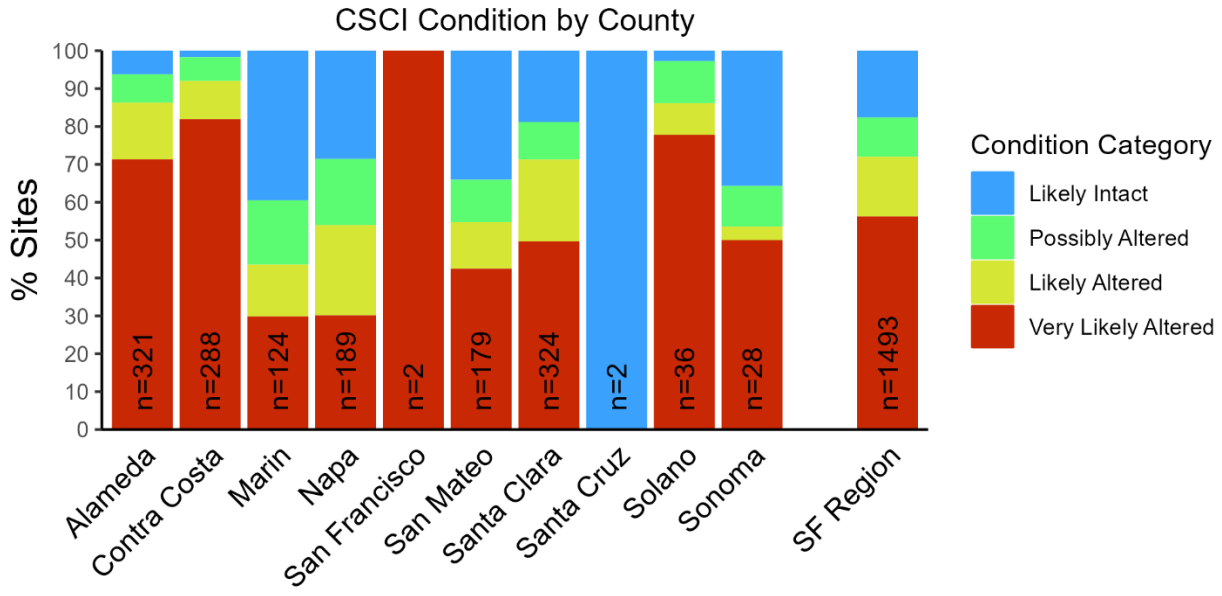


Figure 6. CSCI condition by county and total Water Board Region 2. The numbers in the plot indicate the total number of sites per county.

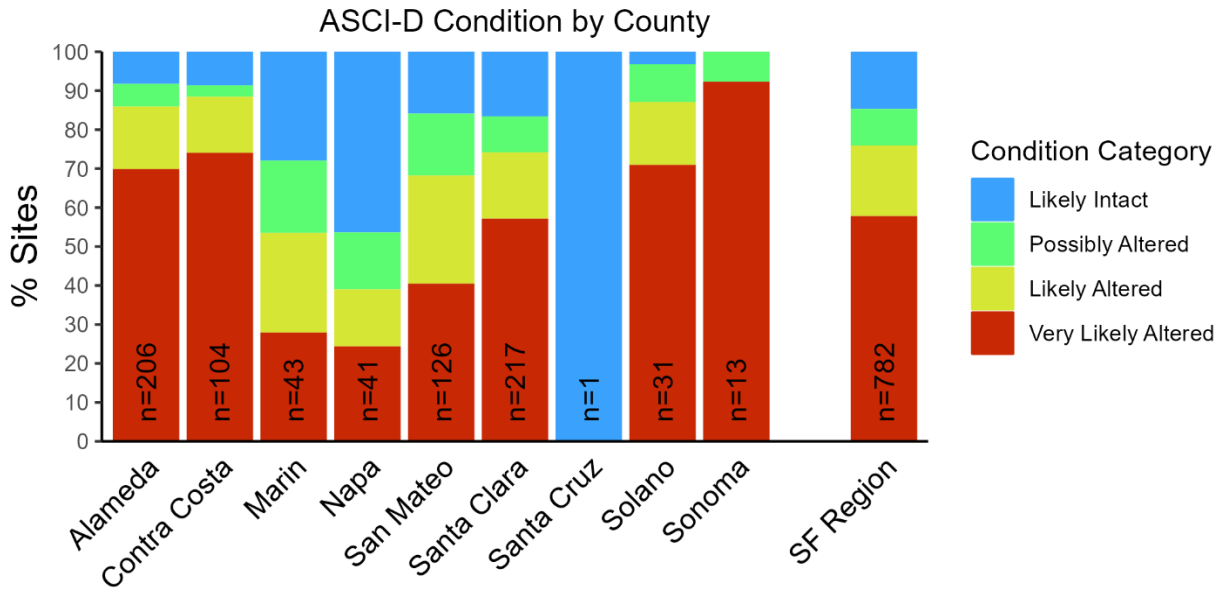


Figure 7. ASCI-D condition by county and total Water Board Region 2. The numbers in the plot indicate the total number of sites per county.

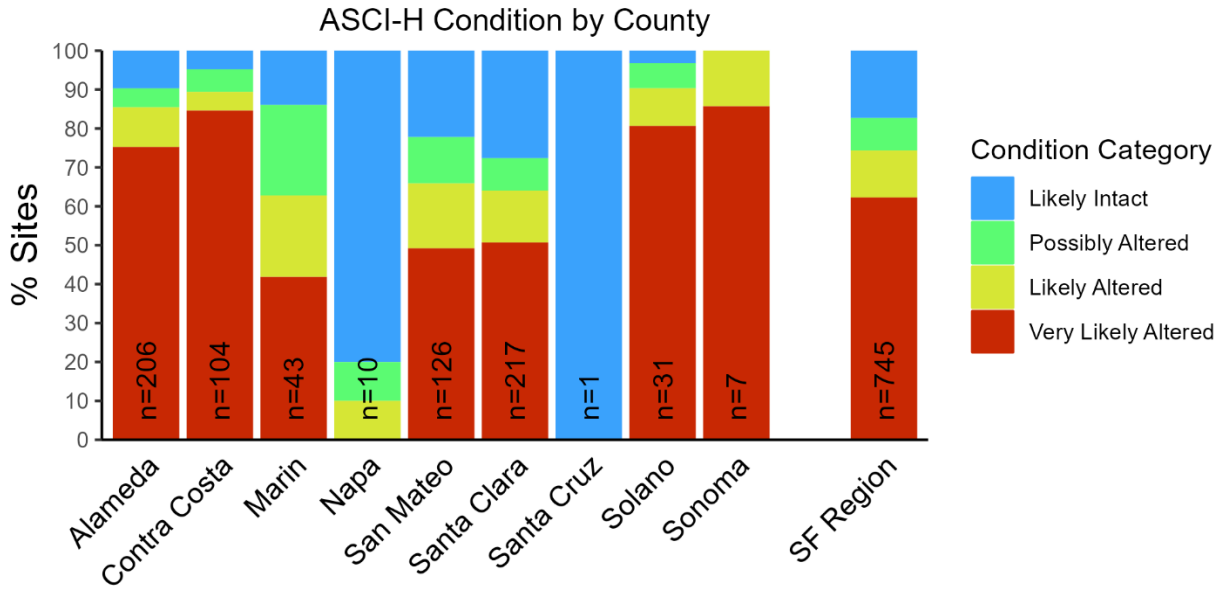


Figure 8. ASCI-H condition by county and total Water Board Region 2. The numbers in the plot indicate the total number of sites per county.

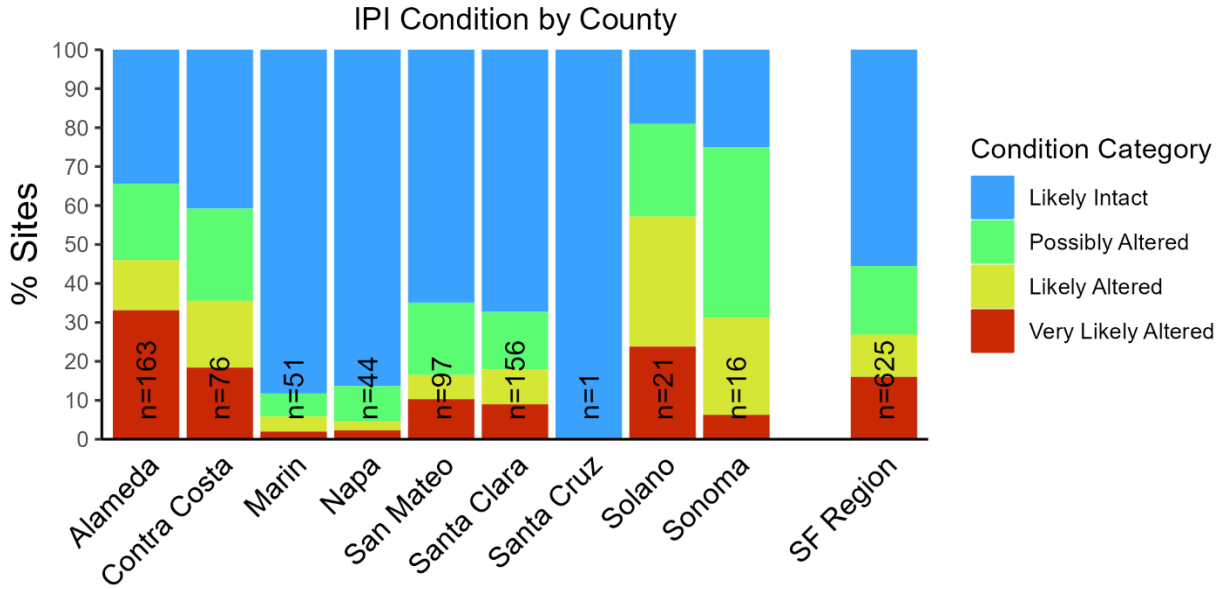


Figure 9. IPI condition by county and total Water Board Region 2. The numbers in the plot indicate the total number of sites per county.

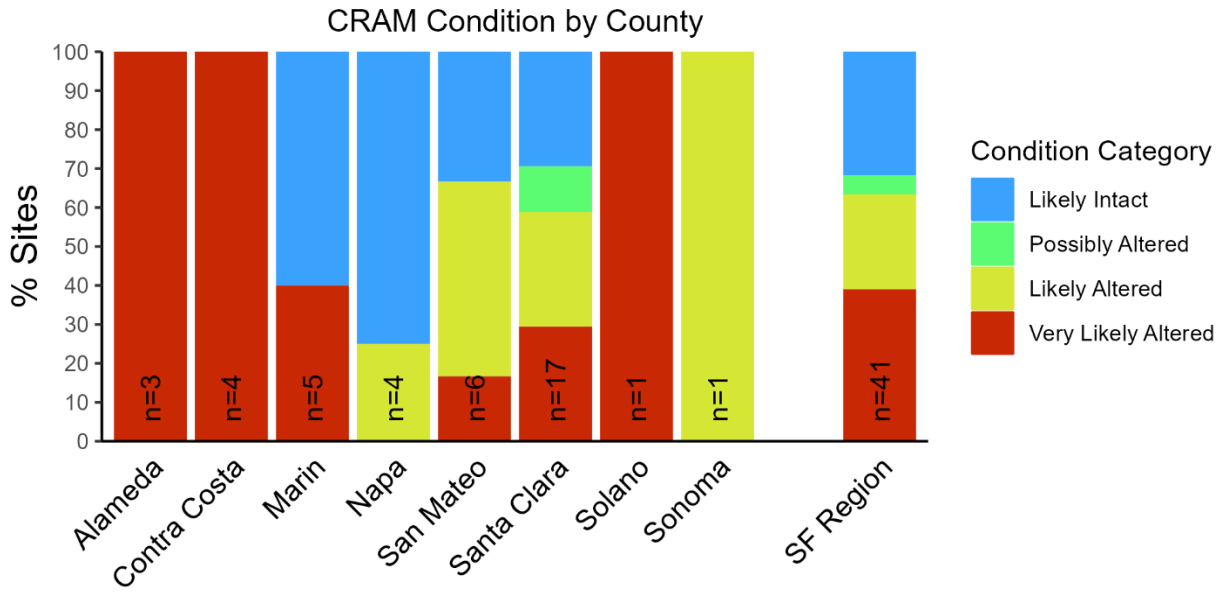


Figure 10. CRAM condition by county and total Water Board Region 2. The numbers in the plot indicate the total number of sites per county.

Table 4. Summary of index scores by county and all of Water Board Region 2.

Index	Subpopulation	N	Likely intact	Possibly altered	Likely altered	Very likely altered	Mean	SD
CSCI	Water Board Region 2	1,493	18%	10%	16%	56%	0.63	0.26
CSCI	Alameda	321	6%	7%	15%	71%	0.51	0.23
CSCI	Contra Costa	288	2%	6%	10%	82%	0.49	0.17
CSCI	Marin	124	40%	17%	14%	30%	0.78	0.26
CSCI	Napa	189	29%	17%	24%	30%	0.76	0.23
CSCI	San Francisco	2	0%	0%	0%	100%	0.32	0.02
CSCI	San Mateo	179	34%	11%	12%	42%	0.74	0.29
CSCI	Santa Clara County	324	19%	10%	22%	50%	0.66	0.24

Index	Subpopulation	N	Likely intact	Possibly altered	Likely altered	Very likely altered	Mean	SD
CSCI	Santa Cruz	2	100%	0%	0%	0%	1.02	0.09
CSCI	Solano	36	3%	11%	8%	78%	0.52	0.21
CSCI	Sonoma	28	36%	11%	4%	50%	0.67	0.32
ASCI-D	Water Board Region 2	782	15%	9%	18%	58%	0.72	0.19
ASCI-D	Alameda	206	8%	6%	16%	70%	0.66	0.18
ASCI-D	Contra Costa	104	9%	3%	14%	74%	0.65	0.16
ASCI-D	Marin	43	28%	19%	26%	28%	0.83	0.15
ASCI-D	Napa	41	46%	15%	15%	24%	0.90	0.21
ASCI-D	San Mateo	126	16%	16%	28%	40%	0.78	0.15
ASCI-D	Santa Clara	217	17%	9%	17%	57%	0.74	0.19
ASCI-D	Santa Cruz	1	100%	0%	0%	0%	1.14	0.00
ASCI-D	Solano	31	3%	10%	16%	71%	0.66	0.17
ASCI-D	Sonoma	13	0%	8%	0%	92%	0.63	0.12
ASCI-H	Water Board Region 2	745	17%	8%	12%	62%	0.69	0.22
ASCI-H	Alameda	206	10%	5%	10%	75%	0.62	0.21
ASCI-H	Contra Costa	104	5%	6%	5%	85%	0.57	0.19
ASCI-H	Marin	43	14%	23%	21%	42%	0.78	0.17
ASCI-H	Napa	10	80%	10%	10%	0%	1.00	0.11
ASCI-H	San Mateo	126	22%	12%	17%	49%	0.77	0.18
ASCI-H	Santa Clara	217	28%	8%	13%	51%	0.76	0.22
ASCI-H	Santa Cruz	1	100%	0%	0%	0%	1.07	0.00

Index	Subpopulation	N	Likely intact	Possibly altered	Likely altered	Very likely altered	Mean	SD
ASCI-H	Solano	31	3%	6%	10%	81%	0.54	0.19
ASCI-H	Sonoma	7	0%	0%	14%	86%	0.52	0.14
IPI	Water Board Region 2	625	56%	18%	11%	16%	0.90	0.24
IPI	Alameda	163	34%	20%	13%	33%	0.77	0.29
IPI	Contra Costa	76	41%	24%	17%	18%	0.86	0.19
IPI	Marin	51	88%	6%	4%	2%	1.01	0.14
IPI	Napa	44	86%	9%	2%	2%	1.06	0.13
IPI	San Mateo	97	65%	19%	6%	10%	0.96	0.21
IPI	Santa Clara	156	67%	15%	9%	9%	0.95	0.19
IPI	Santa Cruz	1	100%	0%	0%	0%	0.98	0.00
IPI	Solano	21	19%	24%	33%	24%	0.79	0.21
IPI	Sonoma	16	25%	44%	25%	6%	0.87	0.10
CRAM	Water Board Region 2	41	32%	5%	24%	39%	71	14.6
CRAM	Alameda	3	0%	0%	0%	100%	53	11.4
CRAM	Contra Costa	4	0%	0%	0%	100%	53	11.0
CRAM	Marin	5	60%	0%	0%	40%	74	16.2
CRAM	Napa	4	75%	0%	25%	0%	84	12.8
CRAM	San Mateo	6	33%	0%	50%	17%	77	10.7
CRAM	Santa Clara	17	29%	12%	29%	29%	73	10.9
CRAM	Solano	1	0%	0%	0%	100%	50	0.0
CRAM	Sonoma	1	0%	0%	100%	0%	73	0.0

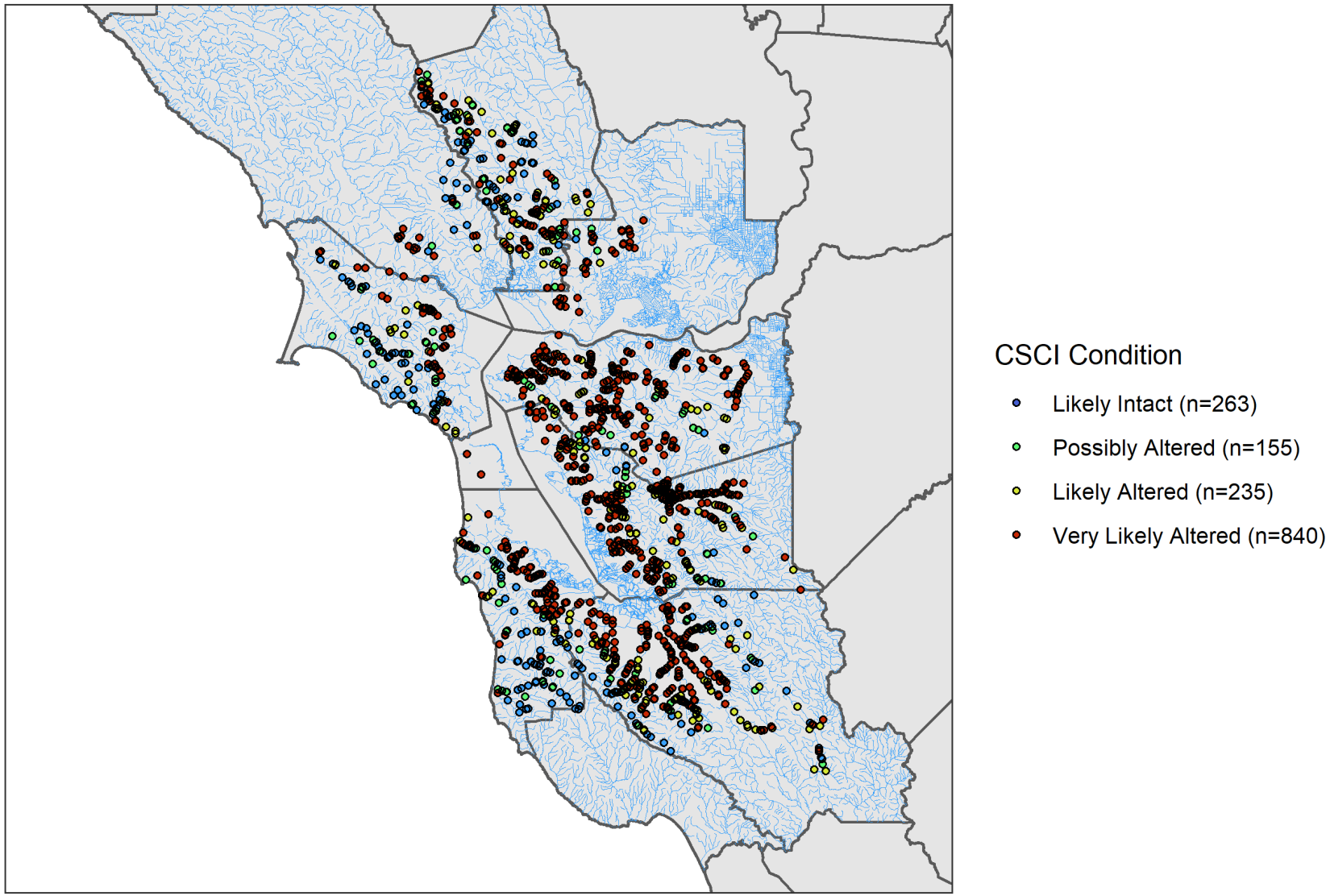


Figure 11. Map of CSCI condition by county in Water Board Region 2. National Hydrography Dataset Plus (NHD Plus) flowlines are also shown.

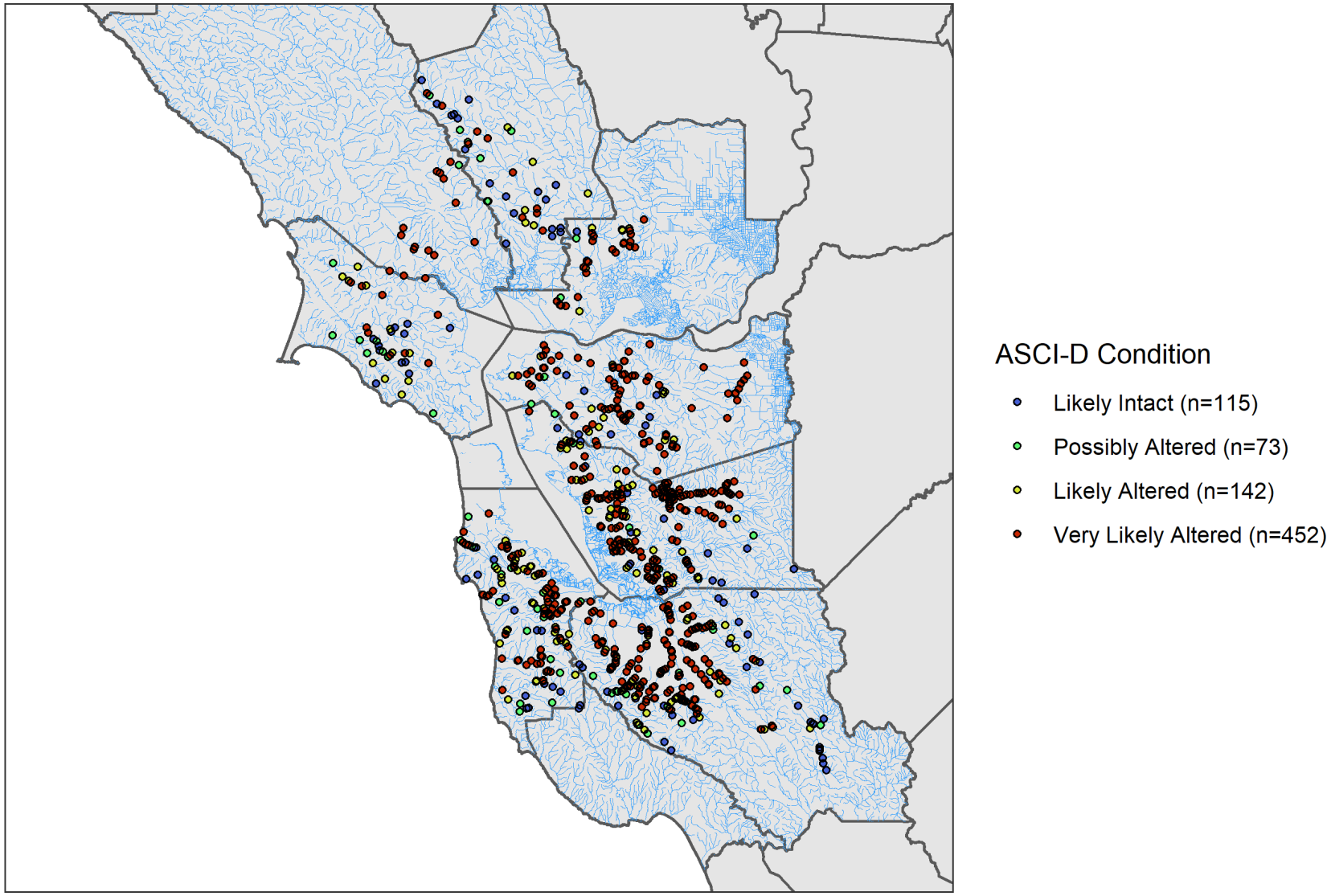


Figure 12. Map of ASCI-D condition by county in Water Board Region 2. National Hydrography Dataset Plus (NHD Plus) flowlines are also shown.

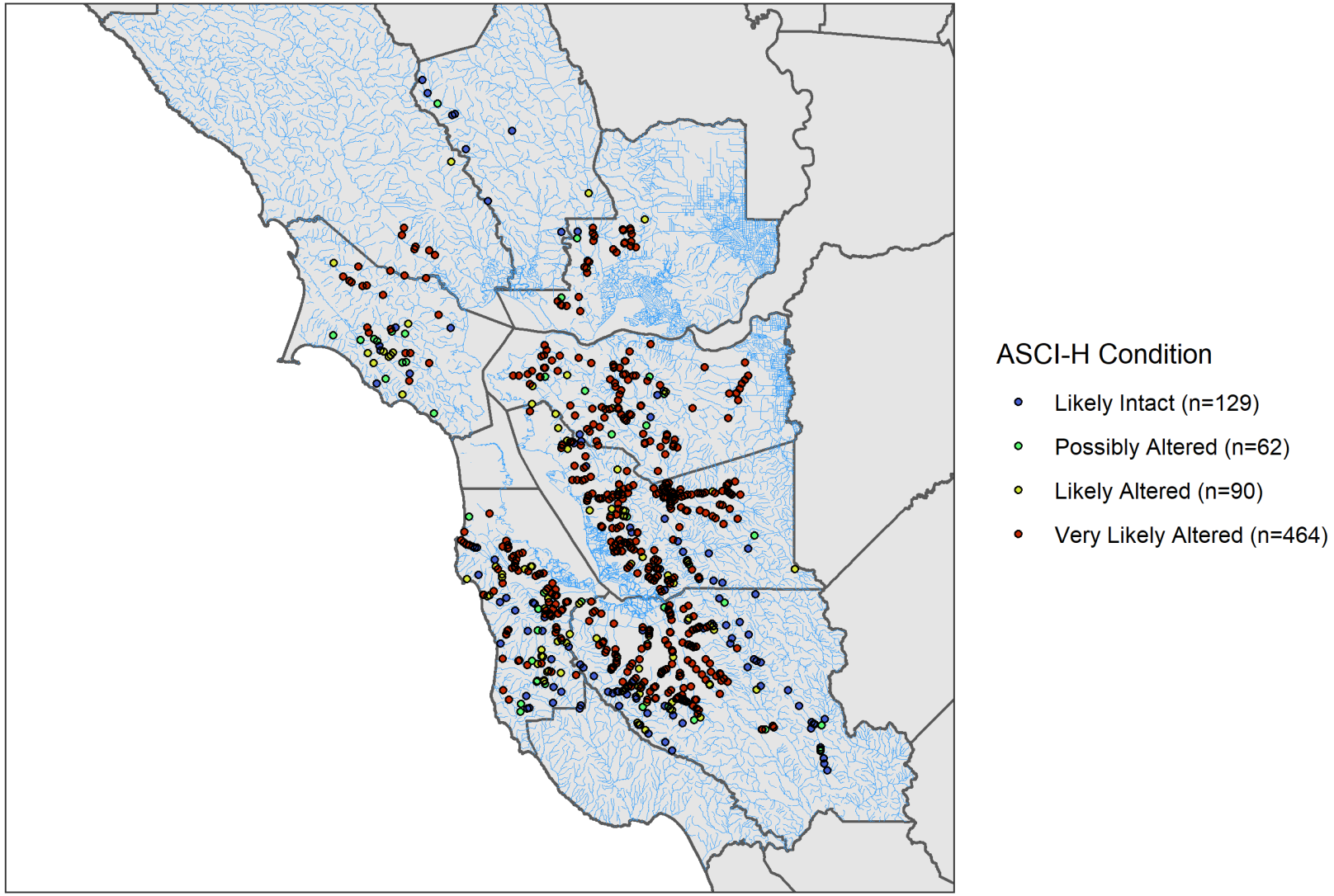


Figure 13. Map of ASCI-H condition by county in Water Board Region 2. National Hydrography Dataset Plus (NHD Plus) flowlines are also shown.

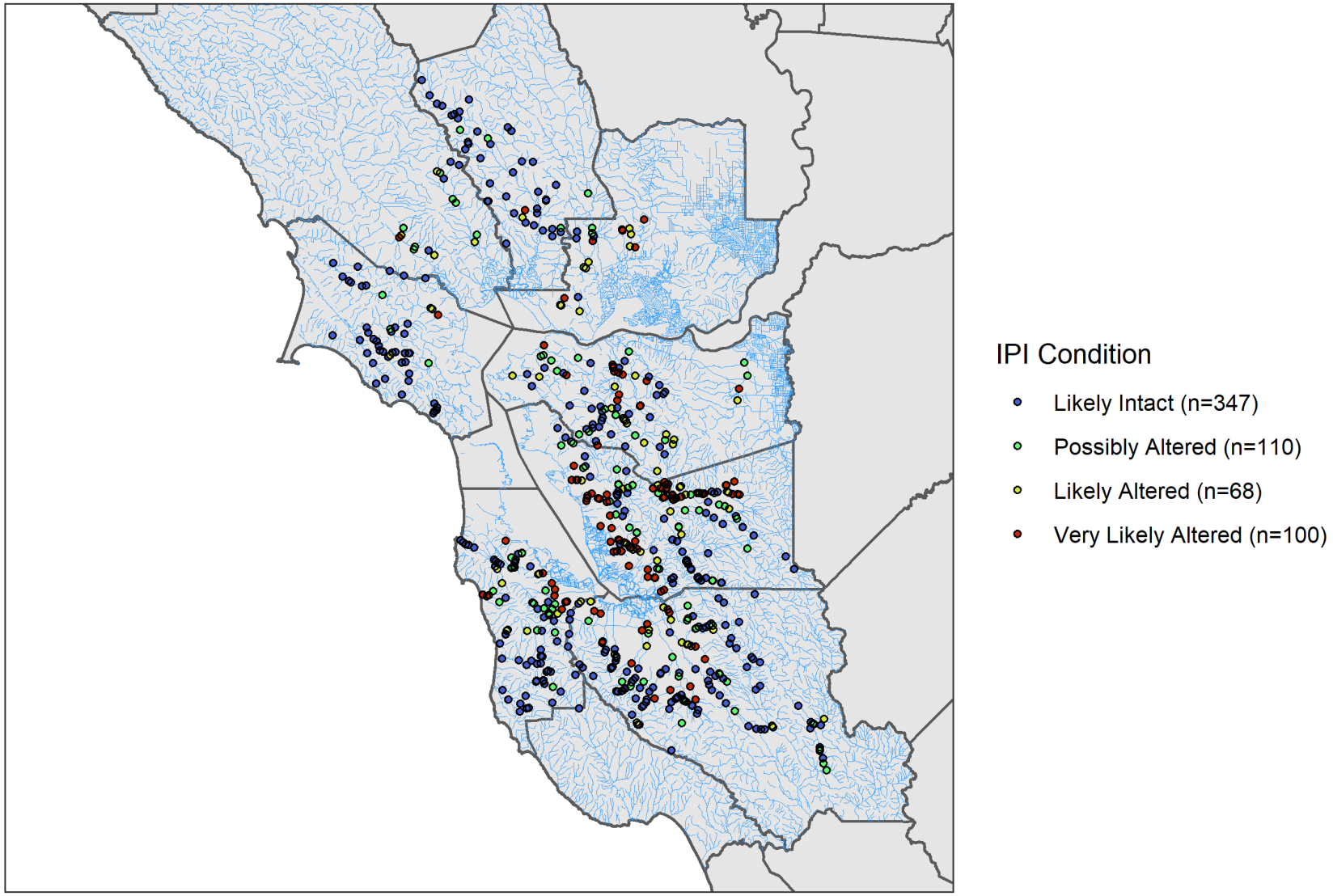


Figure 14. Map of IPI condition by county in Water Board Region 2. National Hydrography Dataset Plus (NHD Plus) flowlines are also shown.

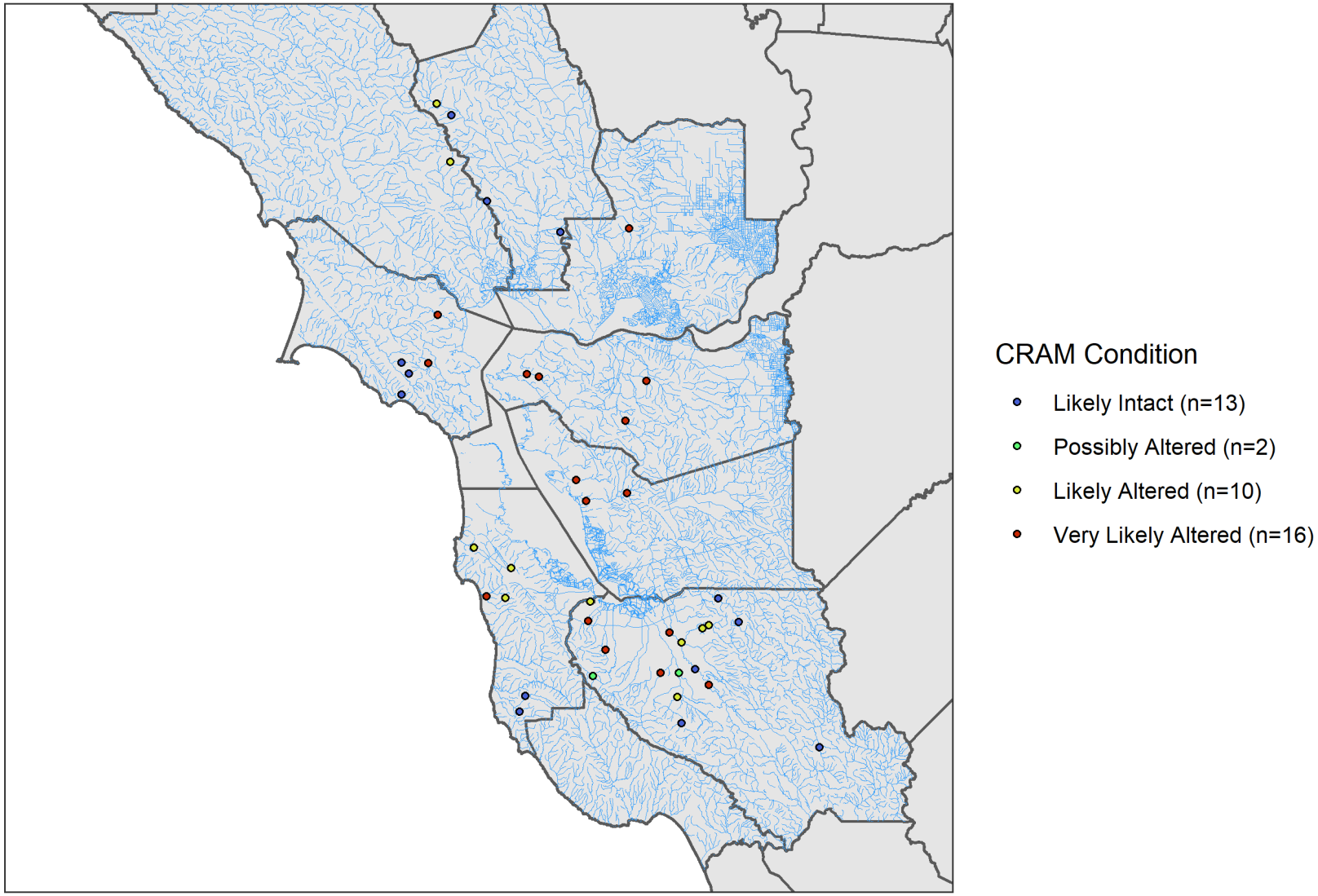


Figure 15. Map of CRAM condition by county in Water Board Region 2. National Hydrography Dataset Plus (NHD Plus) flowlines are also shown.

Indices by Perennial Streams Assessment Region

Most sites were located in the Coastal Chaparral Perennial Streams Assessment region (97-99% of sites, by indicator), while the Central Valley and Interior Chaparral regions made up the remainder of sites for CSCI and ASCI; IPI and CRAM were not represented in the Interior Chaparral region. The median CSCI, ASCI-D, ASCI-H and CRAM scores were below their respective 10th percentile reference threshold across all PSA9 regions (Figures 16 to 30, Table 5). Most IPI scores were intact in the Coastal Chaparral region and degraded in the Central Valley region.

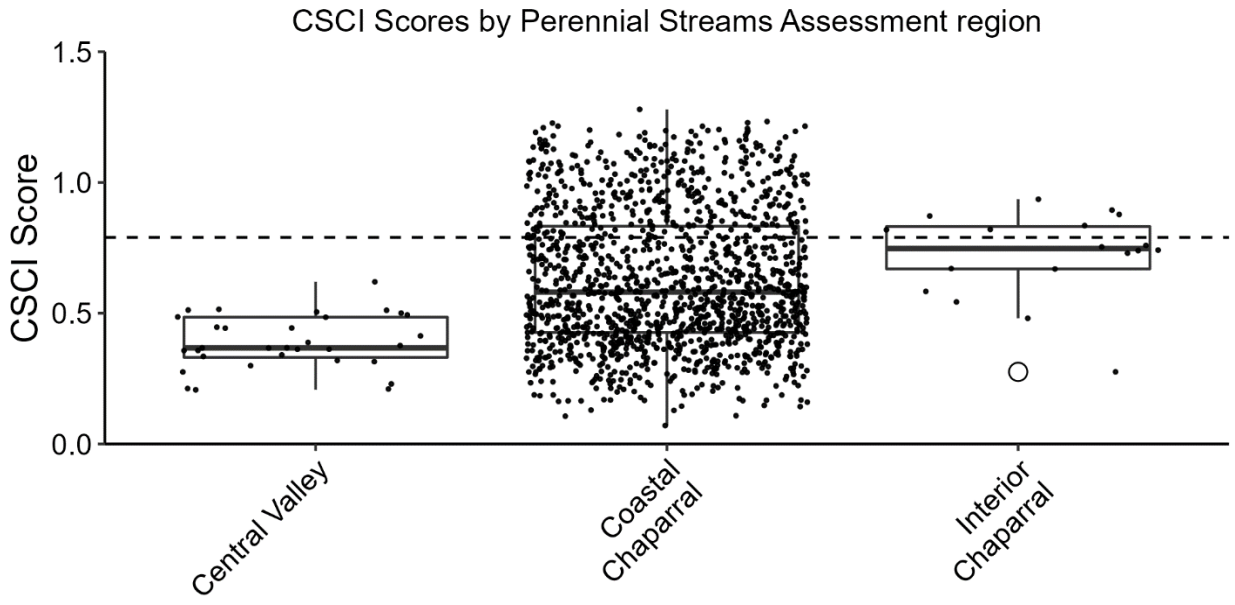


Figure 16. CSCI scores by Perennial Streams Assessment region. Each point represents the score at a sampling location, with circles representing possible outliers. The dashed horizontal line is the 10th percentile reference threshold.

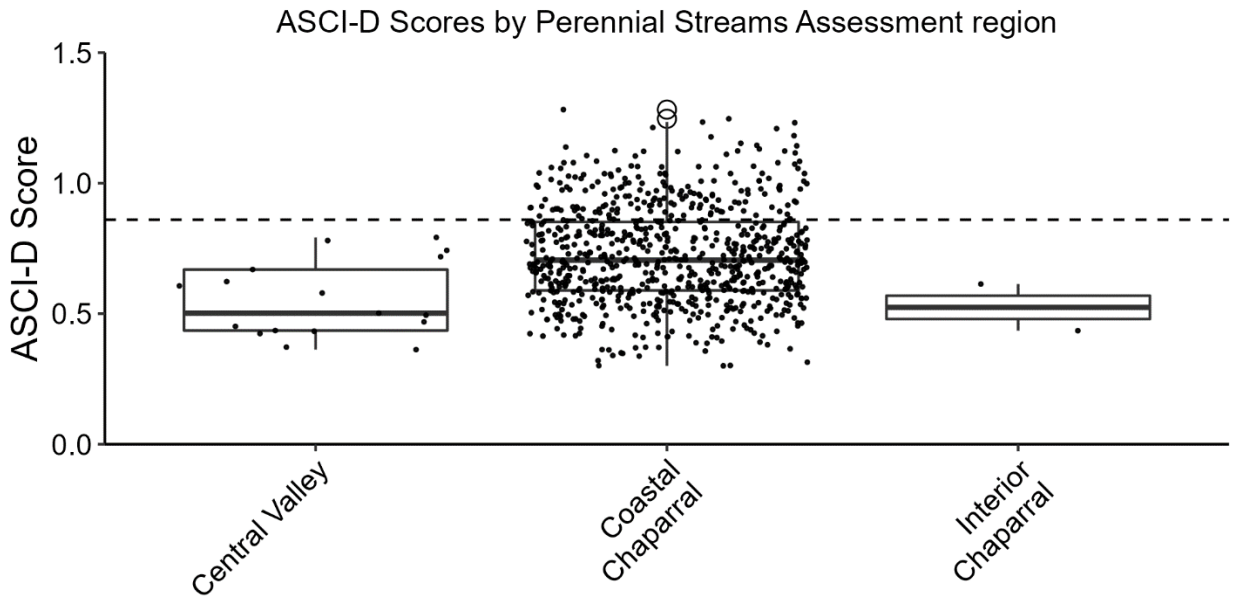


Figure 17. ASCI-D scores by Perennial Streams Assessment region. Each point represents the score at a sampling location, with circles representing possible outliers. The dashed horizontal line is the 10th percentile reference threshold.

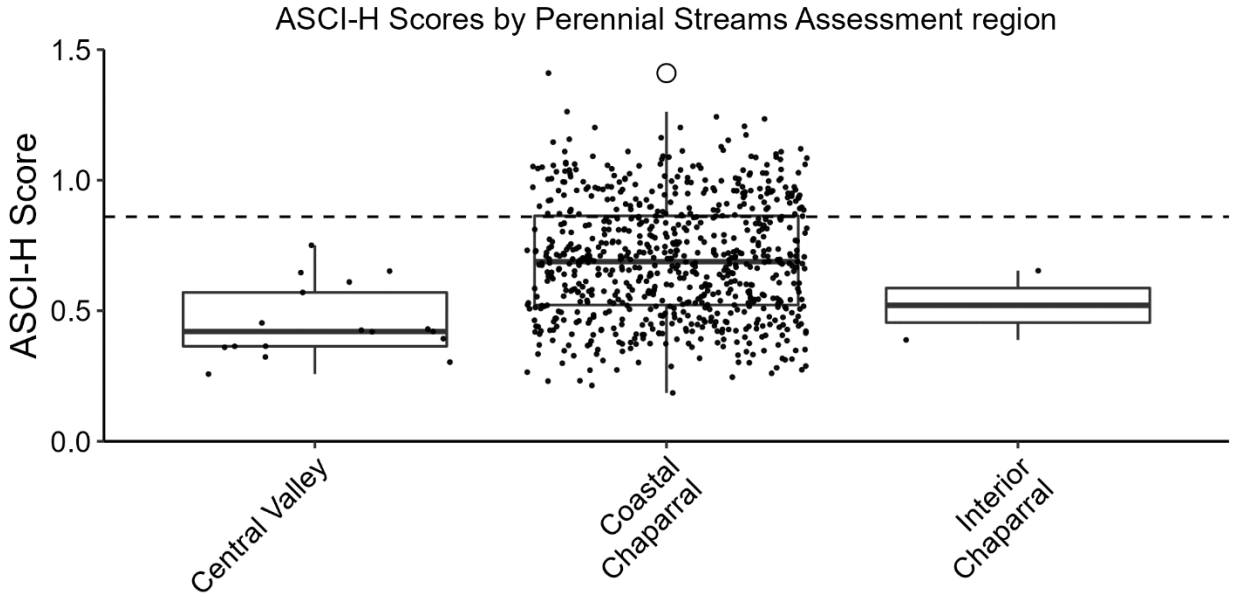


Figure 18. ASCI-H scores by Perennial Streams Assessment region. Each point represents the score at a sampling location, with circles representing possible outliers. The dashed horizontal line is the 10th percentile reference threshold.

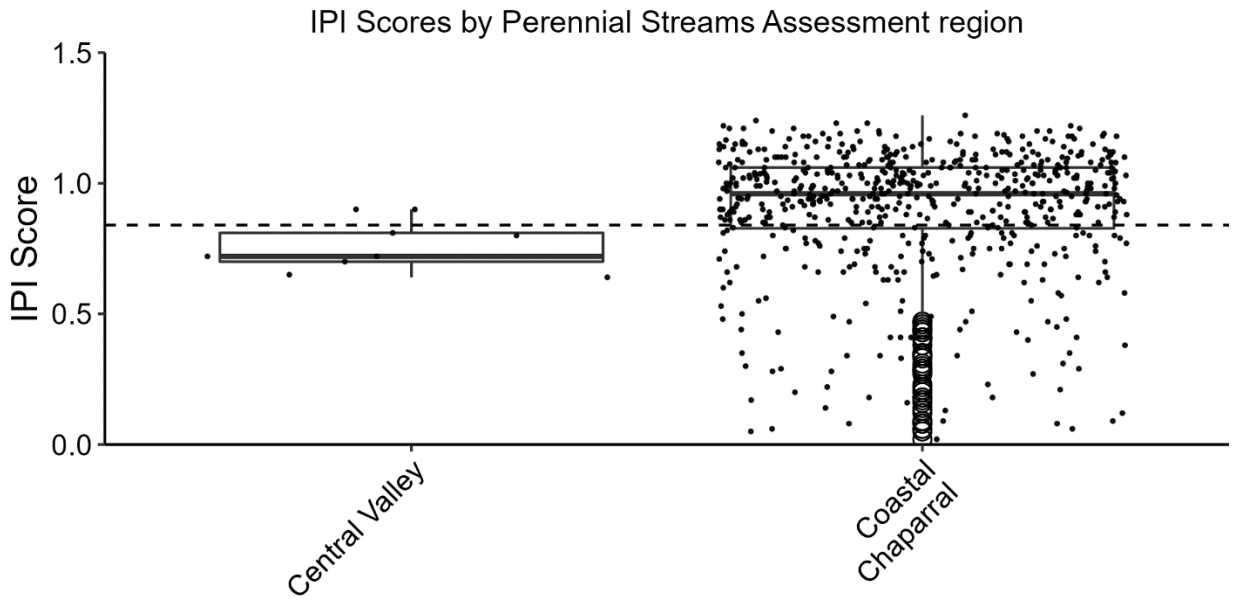


Figure 19. IPI scores by Perennial Streams Assessment region. Each point represents the score at a sampling location, with circles representing possible outliers. The dashed horizontal line is the 10th percentile reference threshold.

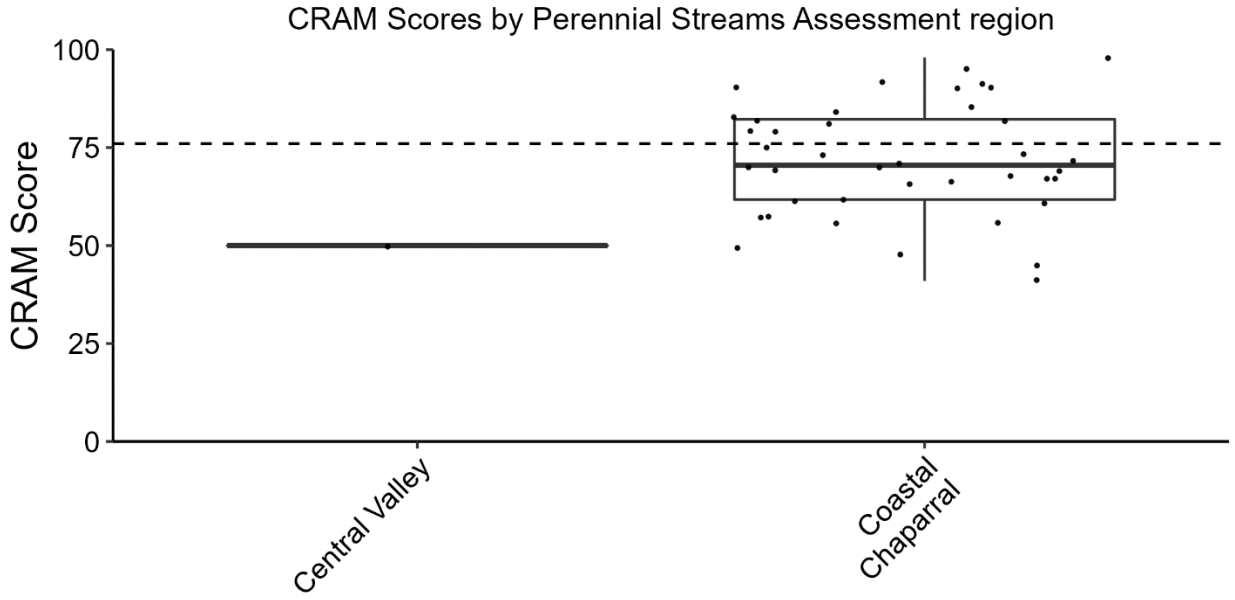


Figure 20. CRAM scores by Perennial Streams Assessment region. Each point represents the score at a sampling location. The dashed horizontal line is the 10th percentile reference threshold.

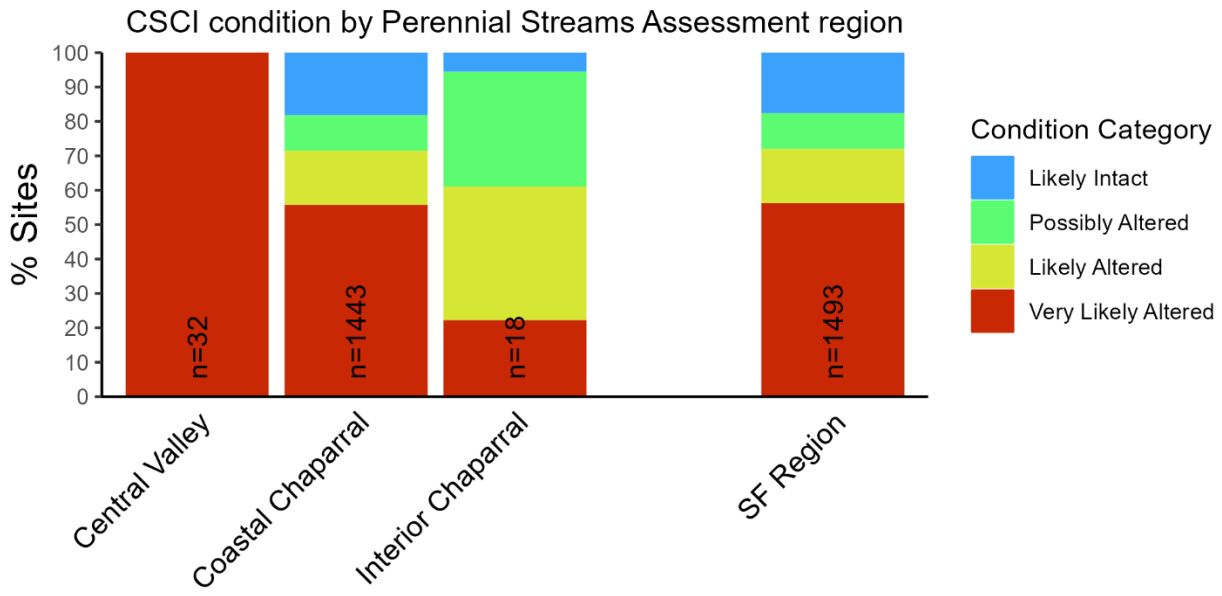


Figure 21. CSCI condition by Perennial Streams Assessment region and total Water Board Region 2. The numbers in the plot indicate the total number of sites per PSA region.

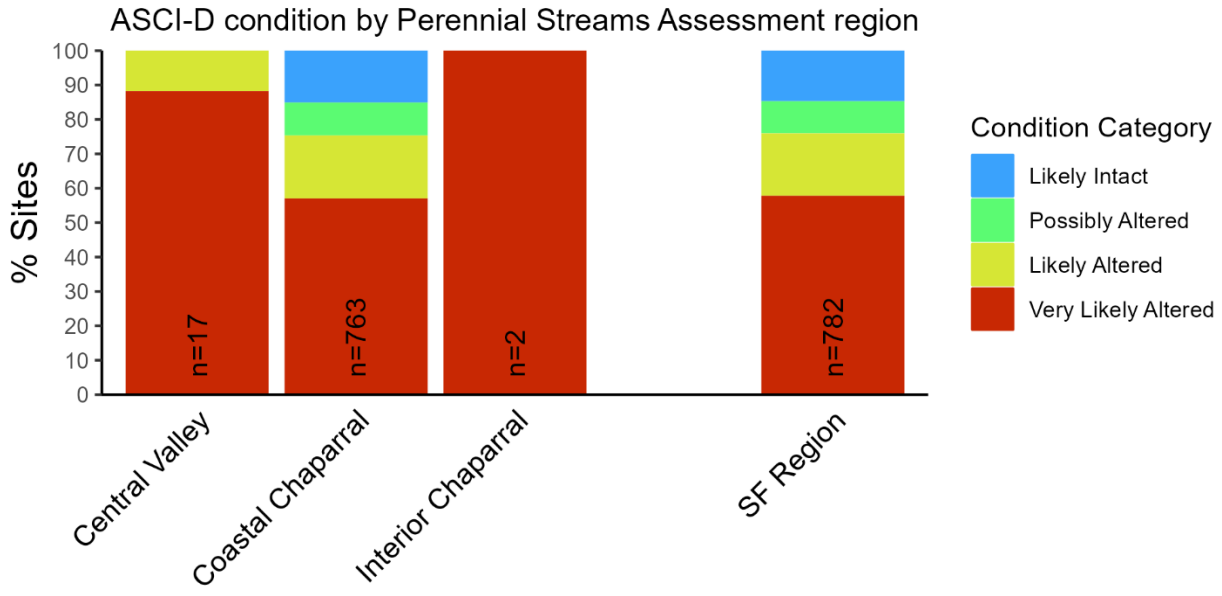


Figure 22. ASCI-D condition by Perennial Streams Assessment region and total Water Board Region 2. The numbers in the plot indicate the total number of sites per PSA region.

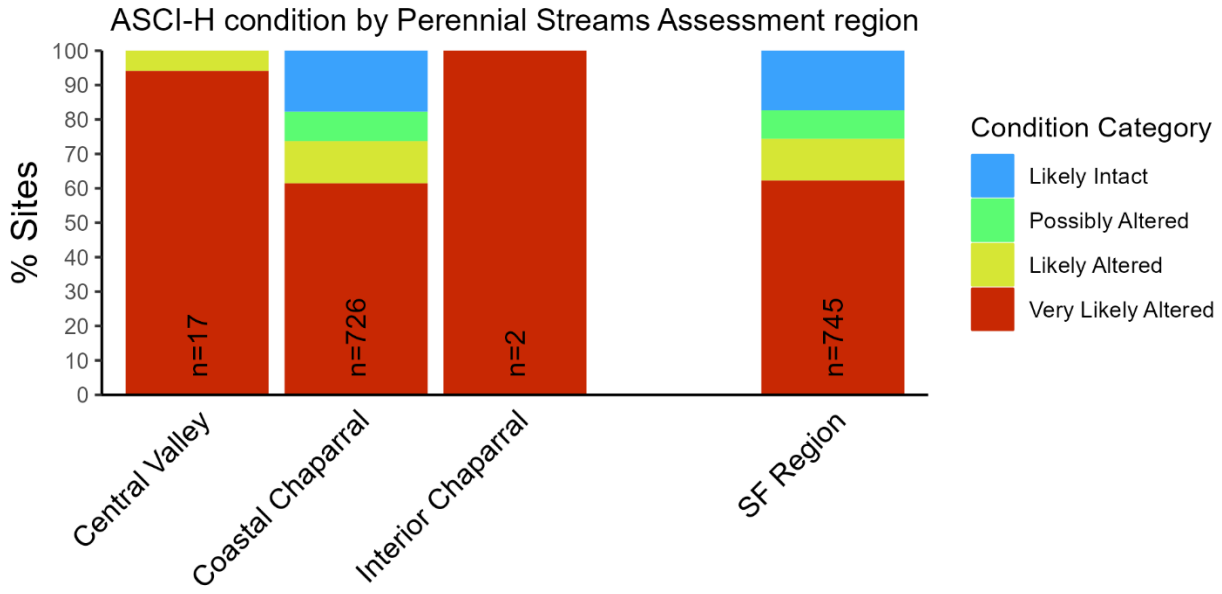


Figure 23. ASCI-H condition by Perennial Streams Assessment region and total Water Board Region 2. The numbers in the plot indicate the total number of sites per PSA region.

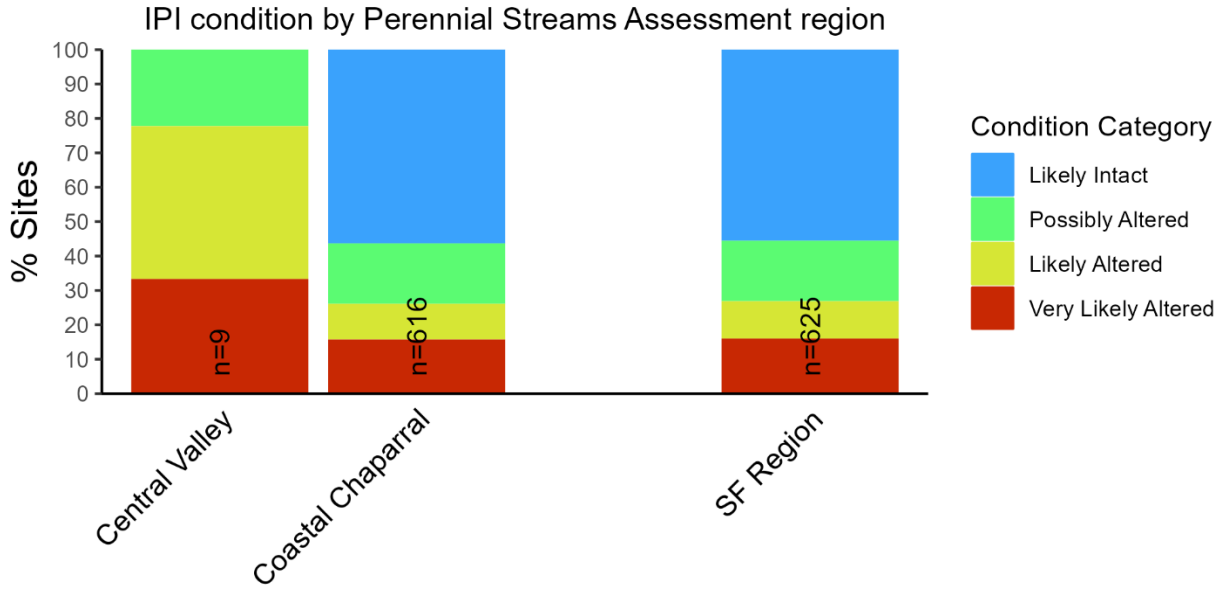


Figure 24. IPI condition by Perennial Streams Assessment region and total Water Board Region 2. The numbers in the plot indicate the total number of sites per PSA region.

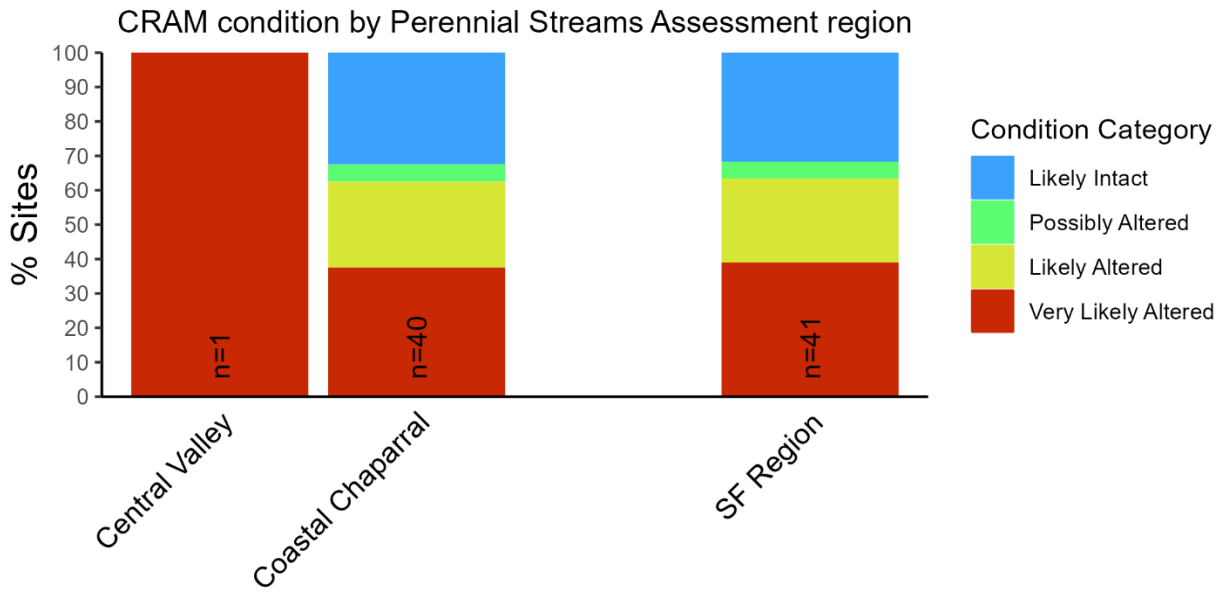


Figure 25. CRAM condition by Perennial Streams Assessment region and total Water Board Region 2. The numbers in the plot indicate the total number of sites per PSA region.

Table 5. Index scores by Perennial Streams Assessment region and all of Water Board Region 2.

Index	Subpopulation	N	Likely intact	Possibly intact	Possibly altered	Likely altered	Mean	SD
CSCI	Water Board Region 2	1,493	18%	10%	16%	56%	0.63	0.26
CSCI	Central Valley	32	0%	0%	0%	100%	0.39	0.10
CSCI	Coastal Chaparral	1,443	18%	10%	16%	56%	0.63	0.26
CSCI	Interior Chaparral	18	6%	33%	39%	22%	0.72	0.17
ASCI-D	Water Board Region 2	782	15%	9%	18%	58%	0.72	0.19
ASCI-D	Central Valley	17	0%	0%	12%	88%	0.56	0.14

Index	Subpopulation	N	Likely intact	Possibly intact	Possibly altered	Likely altered	Mean	SD
ASCI-D	Coastal Chaparral	763	15%	10%	18%	57%	0.72	0.19
ASCI-D	Interior Chaparral	2	0%	0%	0%	100%	0.52	0.13
ASCI-H	Water Board Region 2	745	17%	8%	12%	62%	0.69	0.22
ASCI-H	Central Valley	17	0%	0%	6%	94%	0.46	0.14
ASCI-H	Coastal Chaparral	726	18%	9%	12%	61%	0.69	0.22
ASCI-H	Interior Chaparral	2	0%	0%	0%	100%	0.52	0.19
IPI	Water Board Region 2	625	56%	18%	11%	16%	0.90	0.24
IPI	Central Valley	9	0%	22%	44%	33%	0.76	0.10
IPI	Coastal Chaparral	616	56%	18%	10%	16%	0.90	0.24
CRAM	Water Board Region 2	41	32%	5%	24%	39%	71	14.6
CRAM	Central Valley	1	0%	0%	0%	100%	50	0.0
CRAM	Coastal Chaparral	40	33%	5%	25%	38%	72	14.3

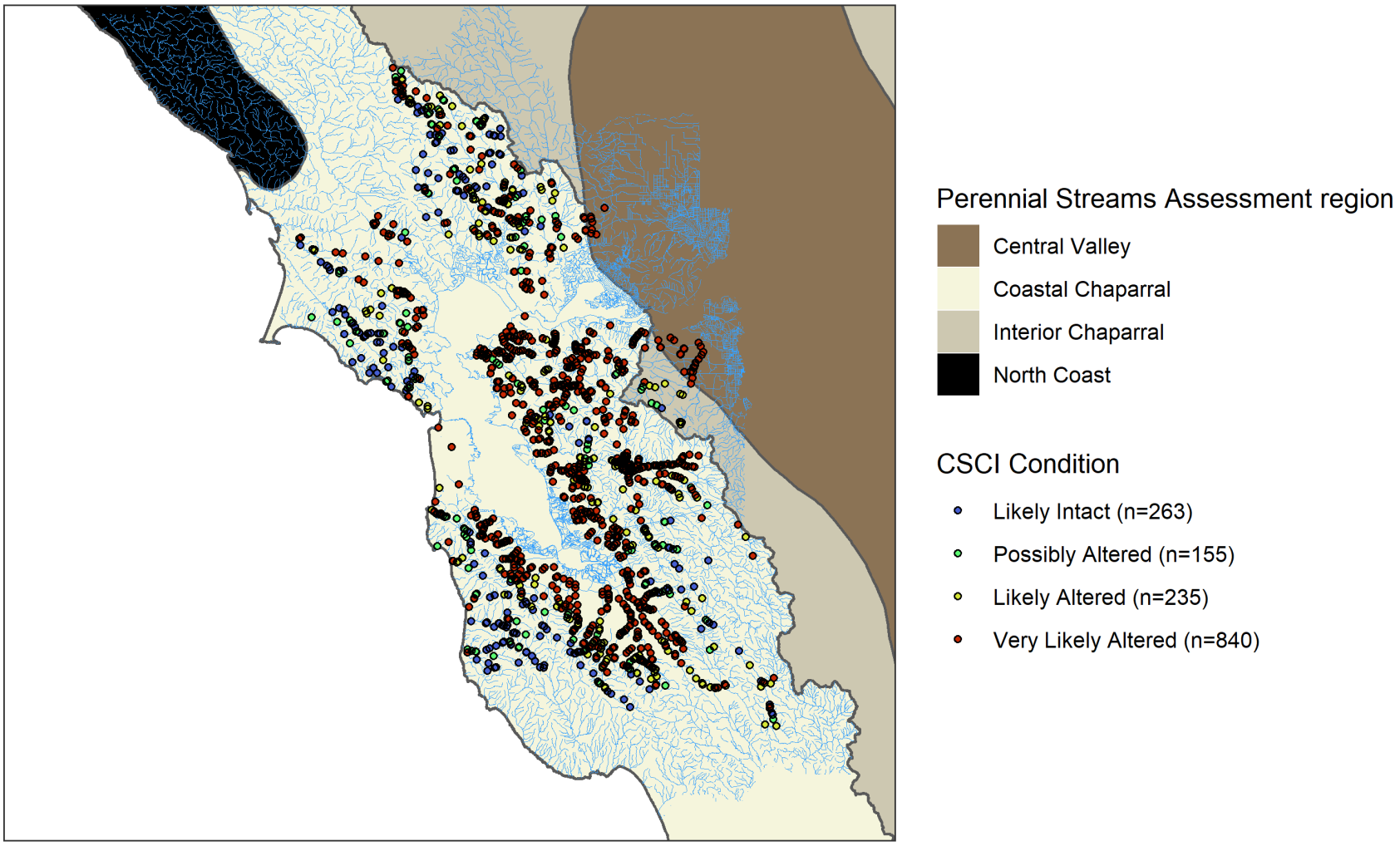


Figure 26. Map of CSCI condition by Perennial Streams Assessment region.

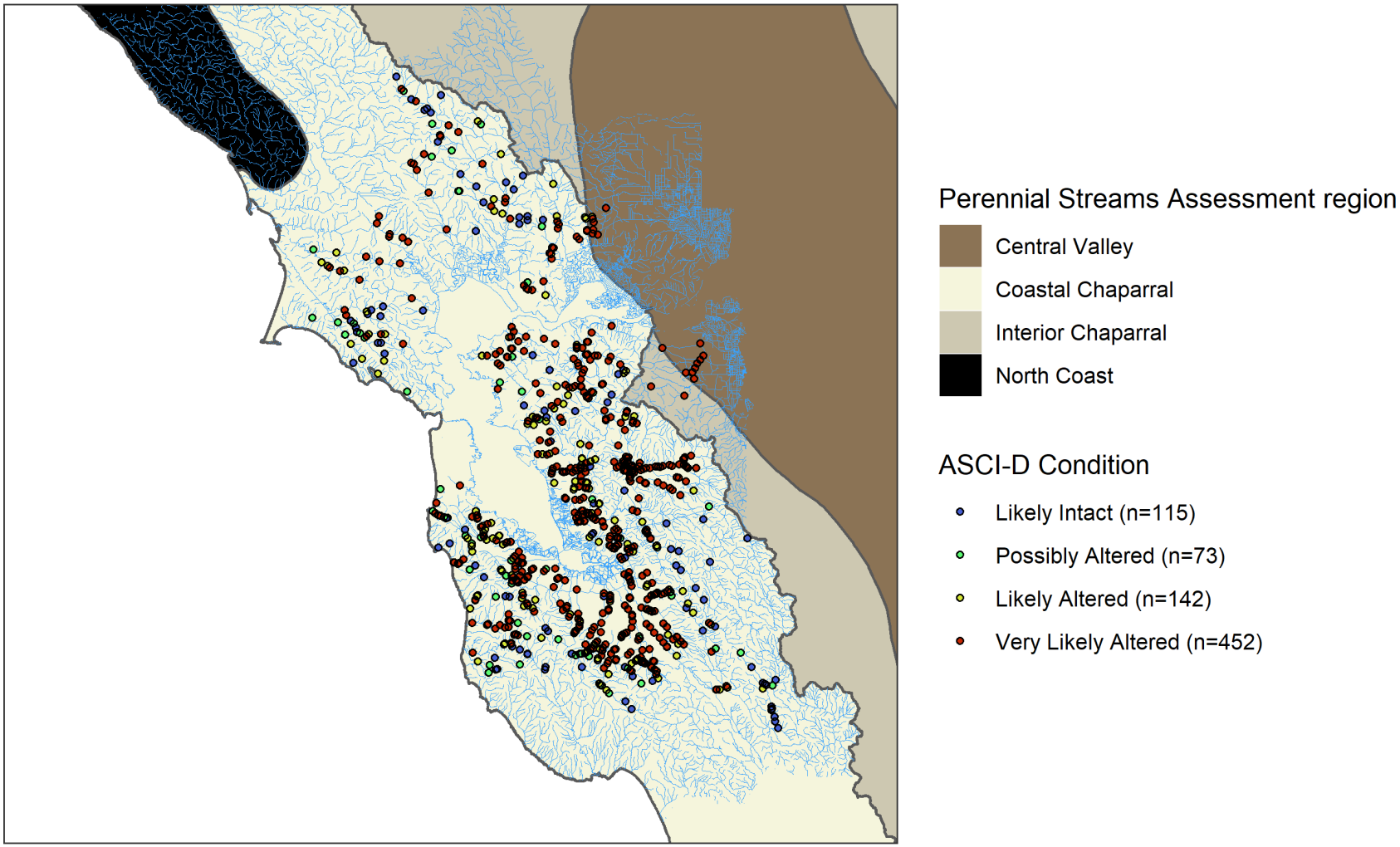


Figure 27. Map of ASCI-D condition by Perennial Streams Assessment region.

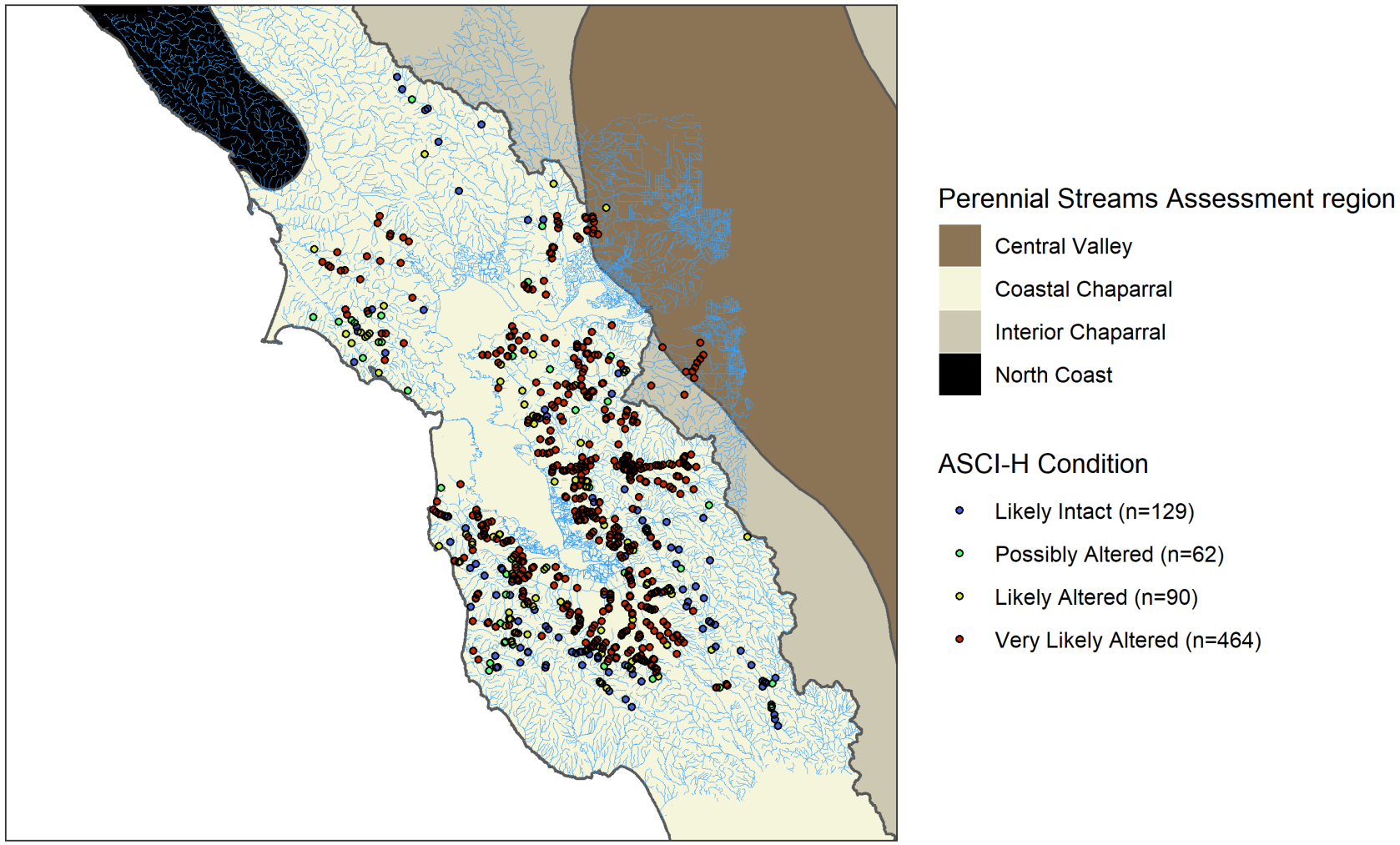


Figure 28. Map of ASCI-H condition by Perennial Streams Assessment region.

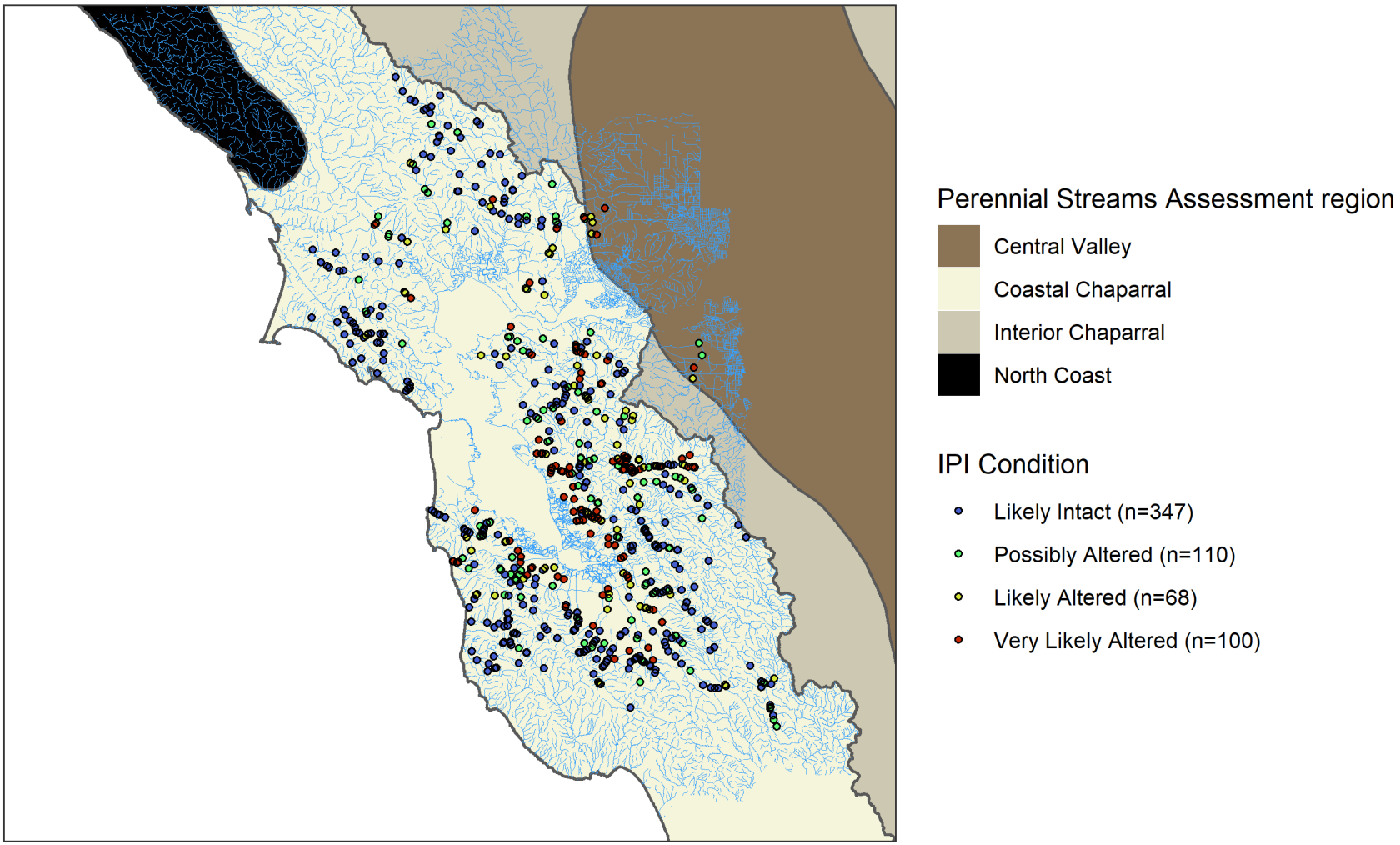


Figure 29. Map of IPI condition by Perennial Streams Assessment region.

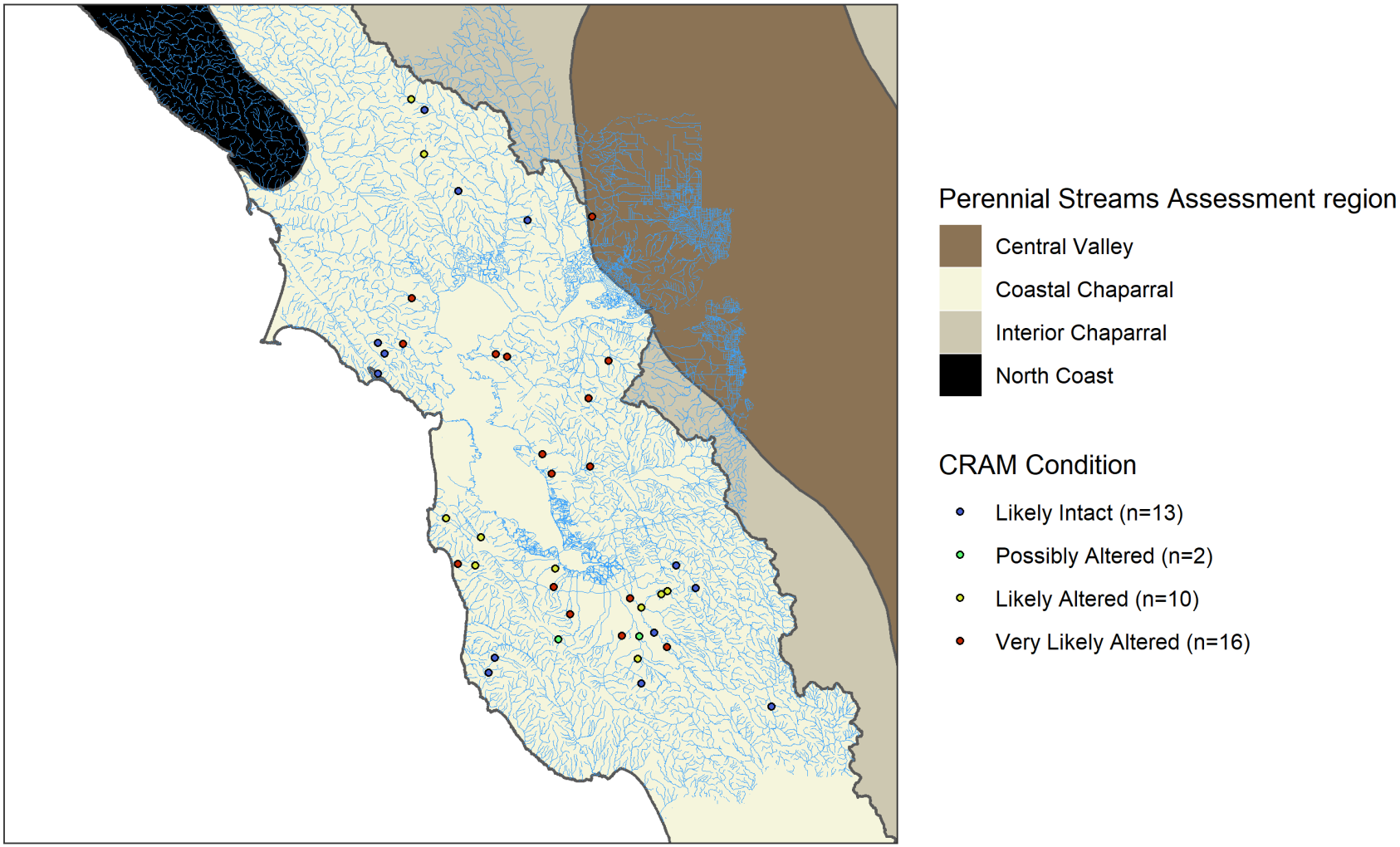


Figure 30. Map of CRAM condition by Perennial Streams Assessment region.

Indices by Hydrologic Unit Code (HUC8)

Samples were collected from nine HUC8 basins in Water Board Region 2, with the majority of sites from three of the basins (71-74% of sites by indicator were located among HUCs 204, 205 and 206). There was little consistency in which HUCs had the majority of intact sites among indicators (Figures 31 to 45, Table 6). For example, HUC 201 had a high proportion of intact sites among CSCI (78% of sites intact), IPI (98% intact) and CRAM (100% intact), but marginal scores among ASCI-D (52% intact) and ASCI-H (41% intact). There appeared to be greater consistency in identifying basins with a high proportion of degraded sites. HUC 204, 205, 206 and 207 each had high proportions of degraded sites for CSCI (66-93% of sites degraded), ASCI-D (64-88% degraded), ASCI-H (69-88% degraded), and CRAM (63-100% degraded). IPI scores were generally intact for these four basins (58-82% of sites intact).

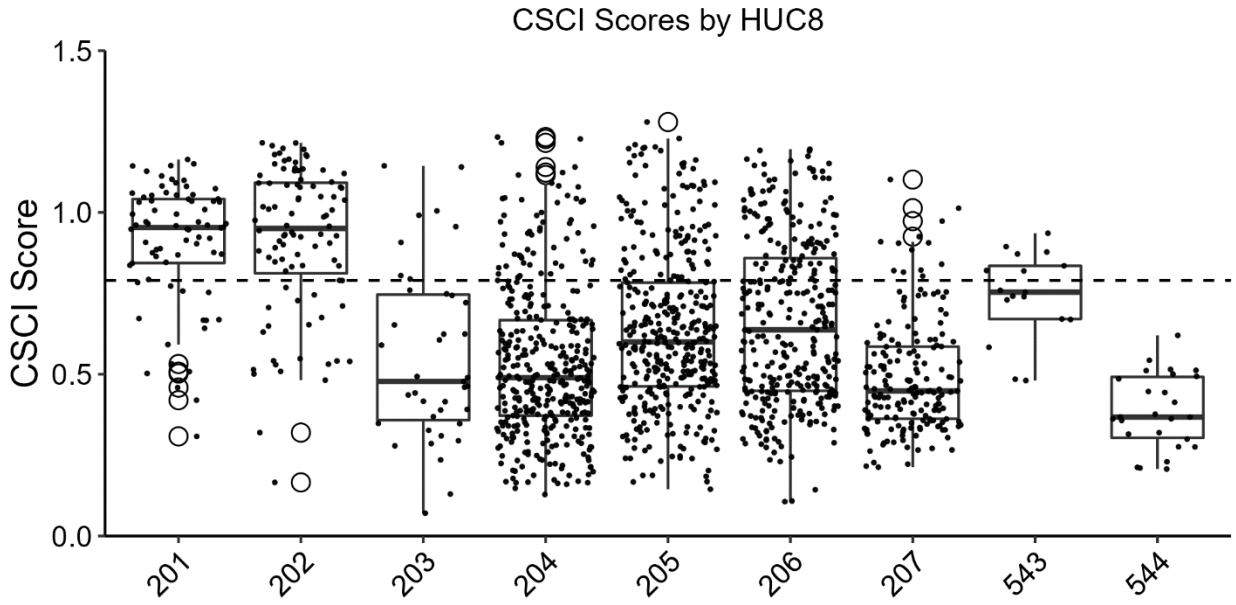


Figure 31. CSCI scores by HUC8. Each point represents the score at a sampling location, with circles representing possible outliers. The dashed horizontal line is the 10th percentile reference threshold.

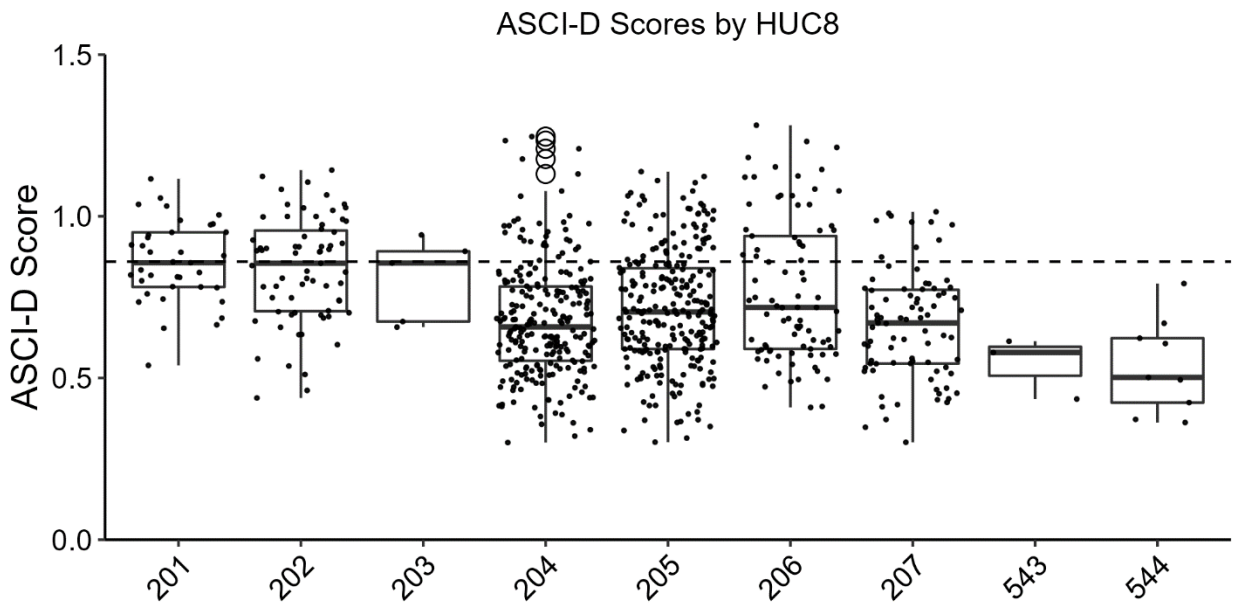


Figure 32. ASCI-D scores by HUC8. Each point represents the score at a sampling location, with circles representing possible outliers. The dashed horizontal line is the 10th percentile reference threshold.

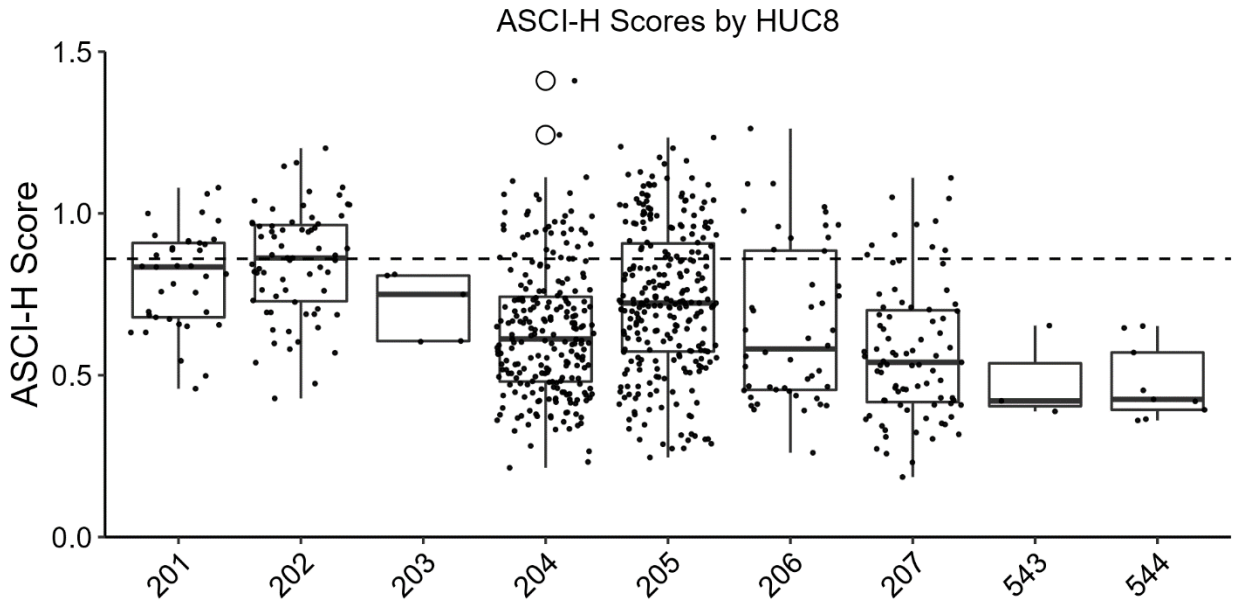


Figure 33. ASCI-H scores by HUC8. Each point represents the score at a sampling location, with circles representing possible outliers. The dashed horizontal line is the 10th percentile reference threshold.

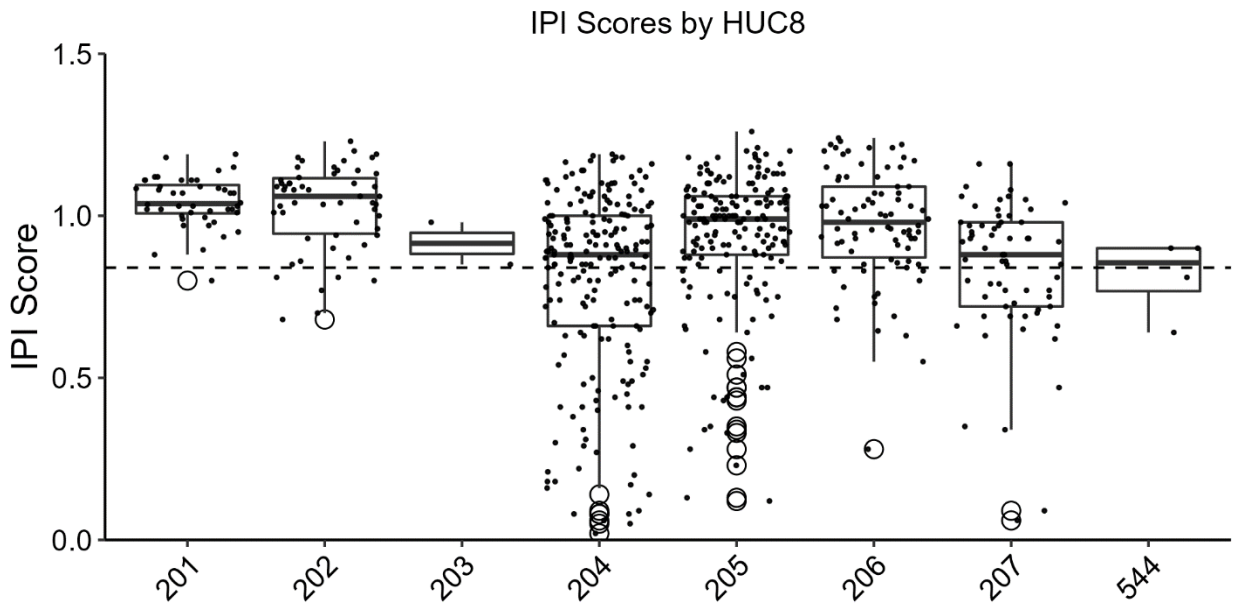


Figure 34. IPI scores by HUC8. Each point represents the score at a sampling location, with circles representing possible outliers. The dashed horizontal line is the 10th percentile reference threshold.

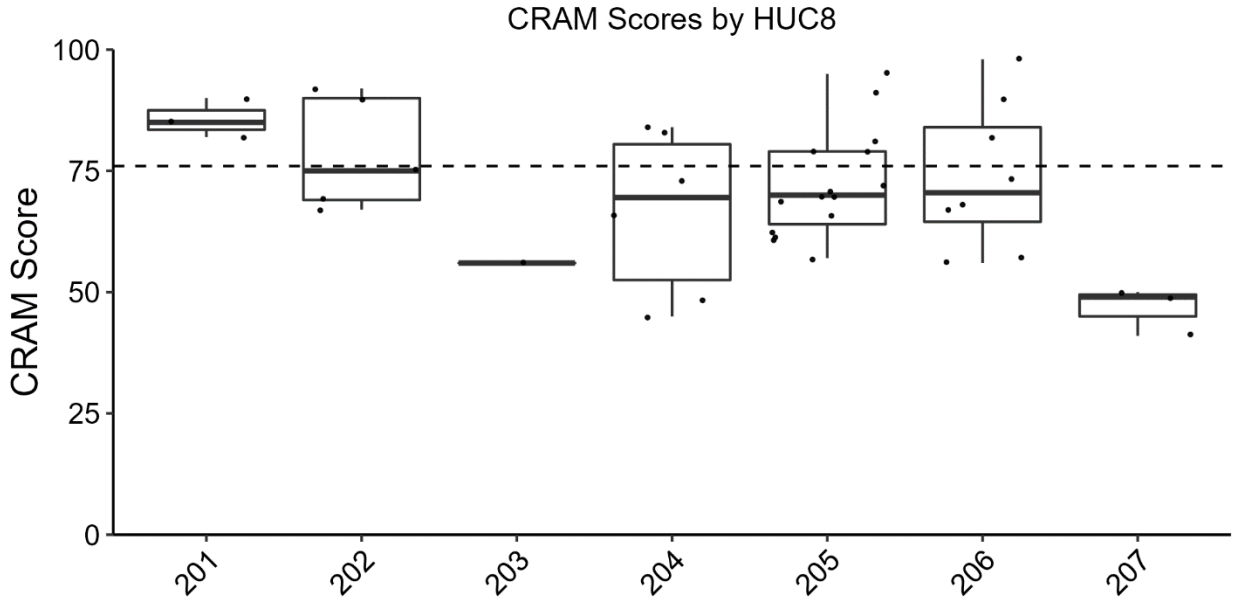


Figure 35. CRAM scores by HUC8. Each point represents the score at a sampling location. The dashed horizontal line is the 10th percentile reference threshold.

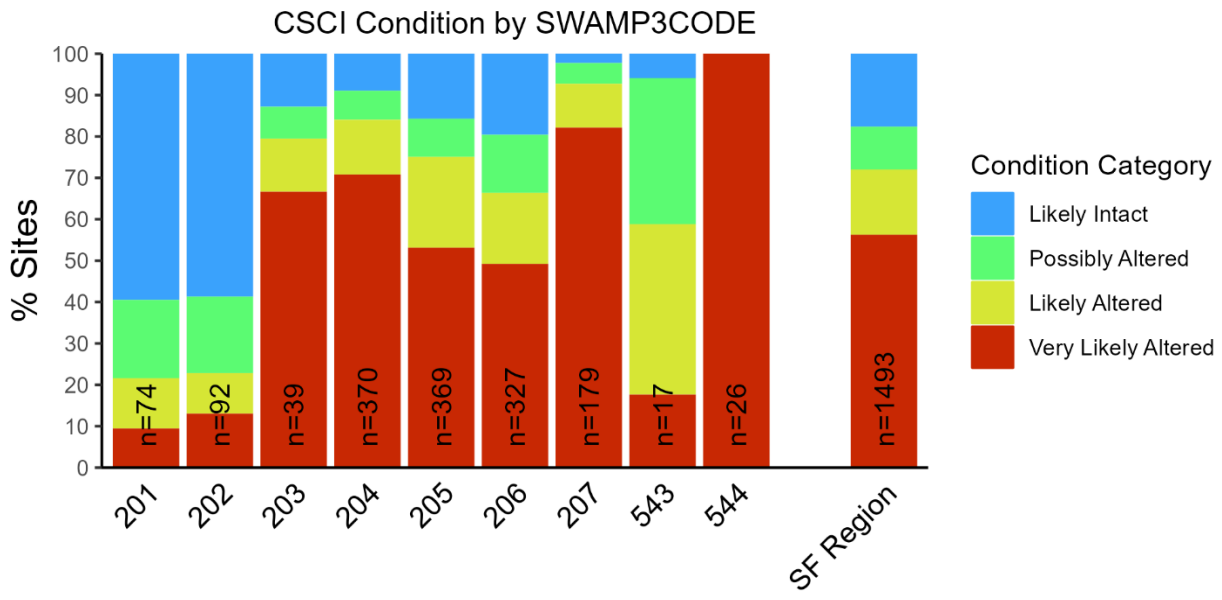


Figure 36. CSCI condition by HUC 8 and total Water Board Region 2. The numbers in the plot indicate the total number of sites per HUC 8.

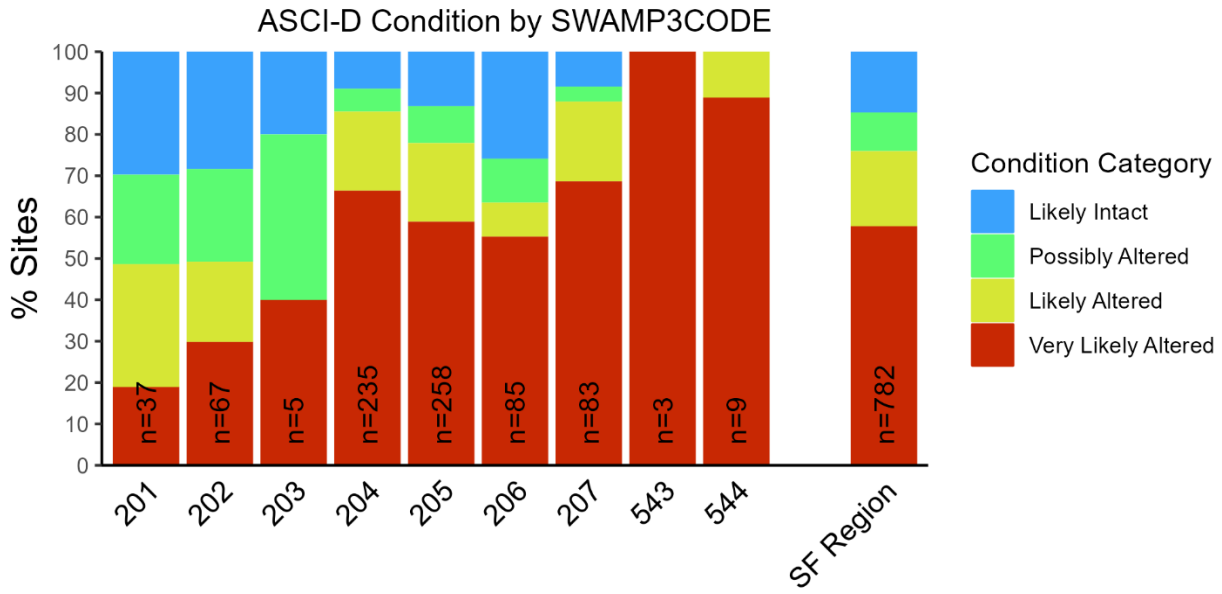


Figure 37. ASCI-D condition by HUC 8 and total Water Board Region 2. The numbers in the plot indicate the total number of sites per HUC 8.

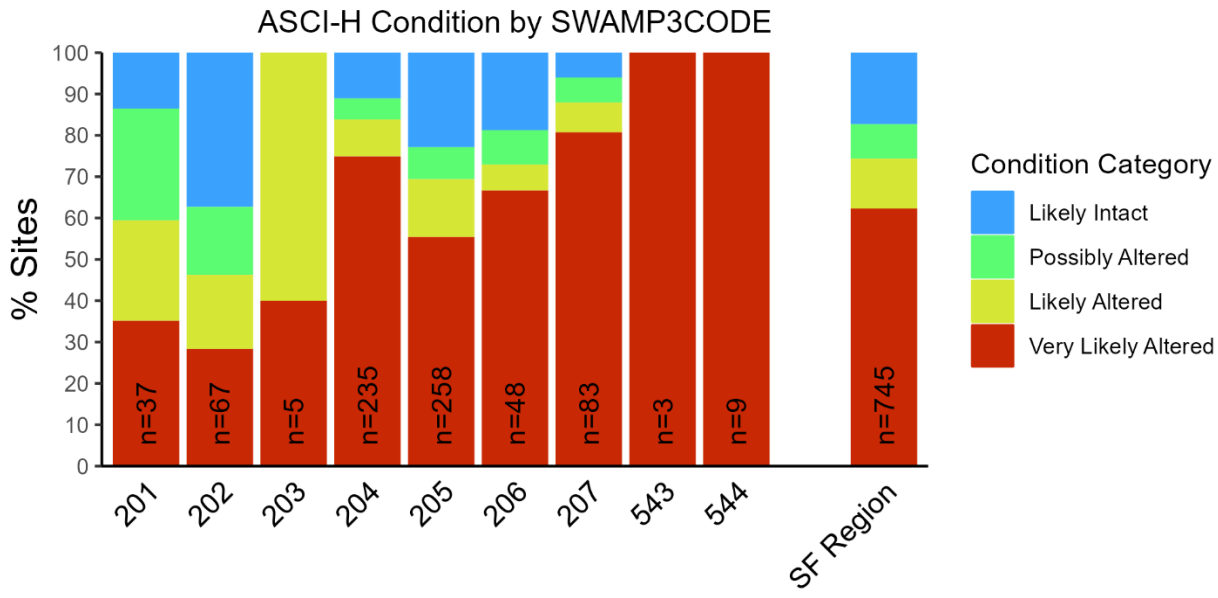


Figure 38. ASCI-H condition by HUC 8 and total Water Board Region 2. The numbers in the plot indicate the total number of sites per HUC 8.

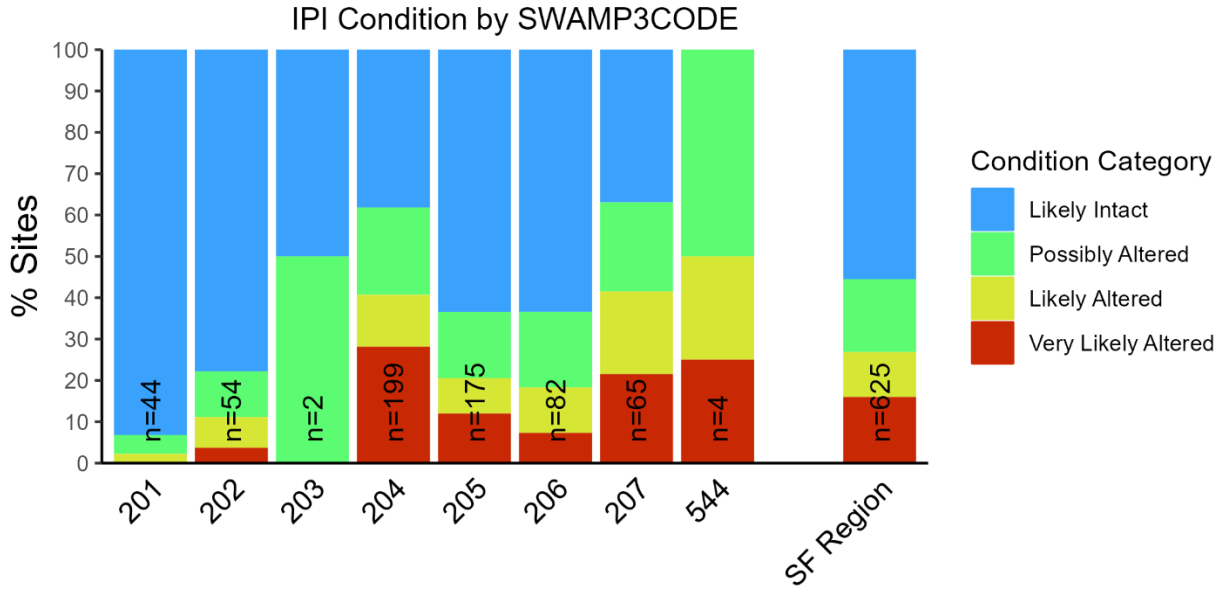


Figure 39. IPI condition by HUC 8 and total Water Board Region 2. The numbers in the plot indicate the total number of sites per HUC 8.

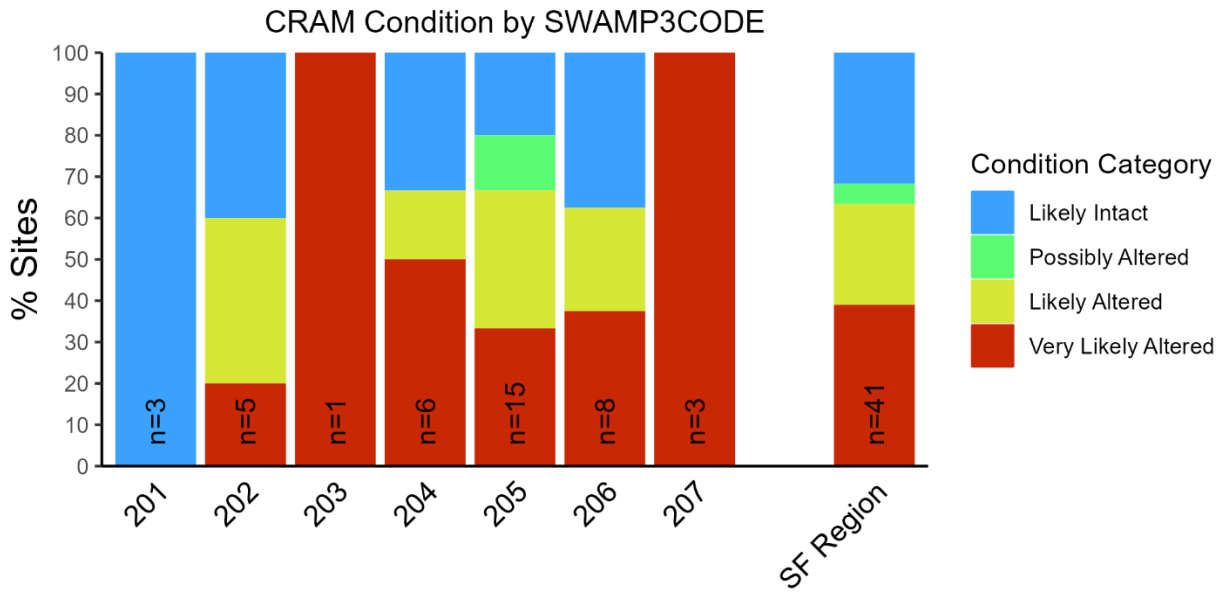


Figure 40. CRAM condition by HUC 8 and total Water Board Region 2. The numbers in the plot indicate the total number of sites per HUC 8.

Table 6. Index scores by hydrologic unit code (HUC8) and all of Water Board Region 2.

Index	HUC8	N	Likely intact	Possibly intact	Possibly altered	Likely altered	Mean	SD
CSCI	Water Board Region 2	1,493	18%	10%	16%	56%	0.63	0.26
CSCI	201	74	59%	19%	12%	9%	0.91	0.19
CSCI	202	92	59%	18%	10%	13%	0.92	0.23
CSCI	203	39	13%	8%	13%	67%	0.56	0.27
CSCI	204	370	9%	7%	13%	71%	0.53	0.23
CSCI	205	369	16%	9%	22%	53%	0.64	0.24
CSCI	206	327	20%	14%	17%	49%	0.66	0.25
CSCI	207	179	2%	5%	11%	82%	0.49	0.17
CSCI	543	17	6%	35%	41%	18%	0.75	0.13

Index	HUC8	N	Likely intact	Possibly intact	Possibly altered	Likely altered	Mean	SD
CSCI	544	26	0%	0%	0%	100%	0.39	0.12
ASCI-D	Water Board Region 2	782	15%	9%	18%	58%	0.72	0.19
ASCI-D	201	37	30%	22%	30%	19%	0.86	0.13
ASCI-D	202	67	28%	22%	19%	30%	0.84	0.16
ASCI-D	203	5	20%	40%	0%	40%	0.80	0.13
ASCI-D	204	235	9%	6%	19%	66%	0.68	0.18
ASCI-D	205	258	13%	9%	19%	59%	0.72	0.18
ASCI-D	206	85	26%	11%	8%	55%	0.77	0.22
ASCI-D	207	83	8%	4%	19%	69%	0.66	0.17
ASCI-D	543	3	0%	0%	0%	100%	0.54	0.09
ASCI-D	544	9	0%	0%	11%	89%	0.54	0.15
ASCI-H	Water Board Region 2	745	17%	8%	12%	62%	0.69	0.22
ASCI-H	201	37	14%	27%	24%	35%	0.80	0.15
ASCI-H	202	67	37%	16%	18%	28%	0.85	0.17
ASCI-H	203	5	0%	0%	60%	40%	0.72	0.10
ASCI-H	204	235	11%	5%	9%	75%	0.64	0.20
ASCI-H	205	258	23%	8%	14%	55%	0.73	0.22
ASCI-H	206	48	19%	8%	6%	67%	0.66	0.24
ASCI-H	207	83	6%	6%	7%	81%	0.57	0.21
ASCI-H	543	3	0%	0%	0%	100%	0.49	0.14
ASCI-H	544	9	0%	0%	0%	100%	0.48	0.12

Index	HUC8	N	Likely intact	Possibly intact	Possibly altered	Likely altered	Mean	SD
IPI	Water Board Region 2	625	56%	18%	11%	16%	0.90	0.24
IPI	201	44	93%	5%	2%	0%	1.04	0.08
IPI	202	54	78%	11%	7%	4%	1.03	0.13
IPI	203	2	50%	50%	0%	0%	0.92	0.09
IPI	204	199	38%	21%	13%	28%	0.80	0.28
IPI	205	175	63%	16%	9%	12%	0.93	0.21
IPI	206	82	63%	18%	11%	7%	0.97	0.18
IPI	207	65	37%	22%	20%	22%	0.83	0.22
IPI	544	4	0%	50%	25%	25%	0.81	0.12
CRAM	Water Board Region 2	41	32%	5%	24%	39%	71	14.6
CRAM	201	3	100%	0%	0%	0%	86	4.0
CRAM	202	5	40%	0%	40%	20%	79	11.7
CRAM	203	1	0%	0%	0%	100%	56	0.0
CRAM	204	6	33%	0%	17%	50%	67	16.9
CRAM	205	15	20%	13%	33%	33%	72	11.0
CRAM	206	8	38%	0%	25%	38%	74	15.1
CRAM	207	3	0%	0%	0%	100%	47	4.9

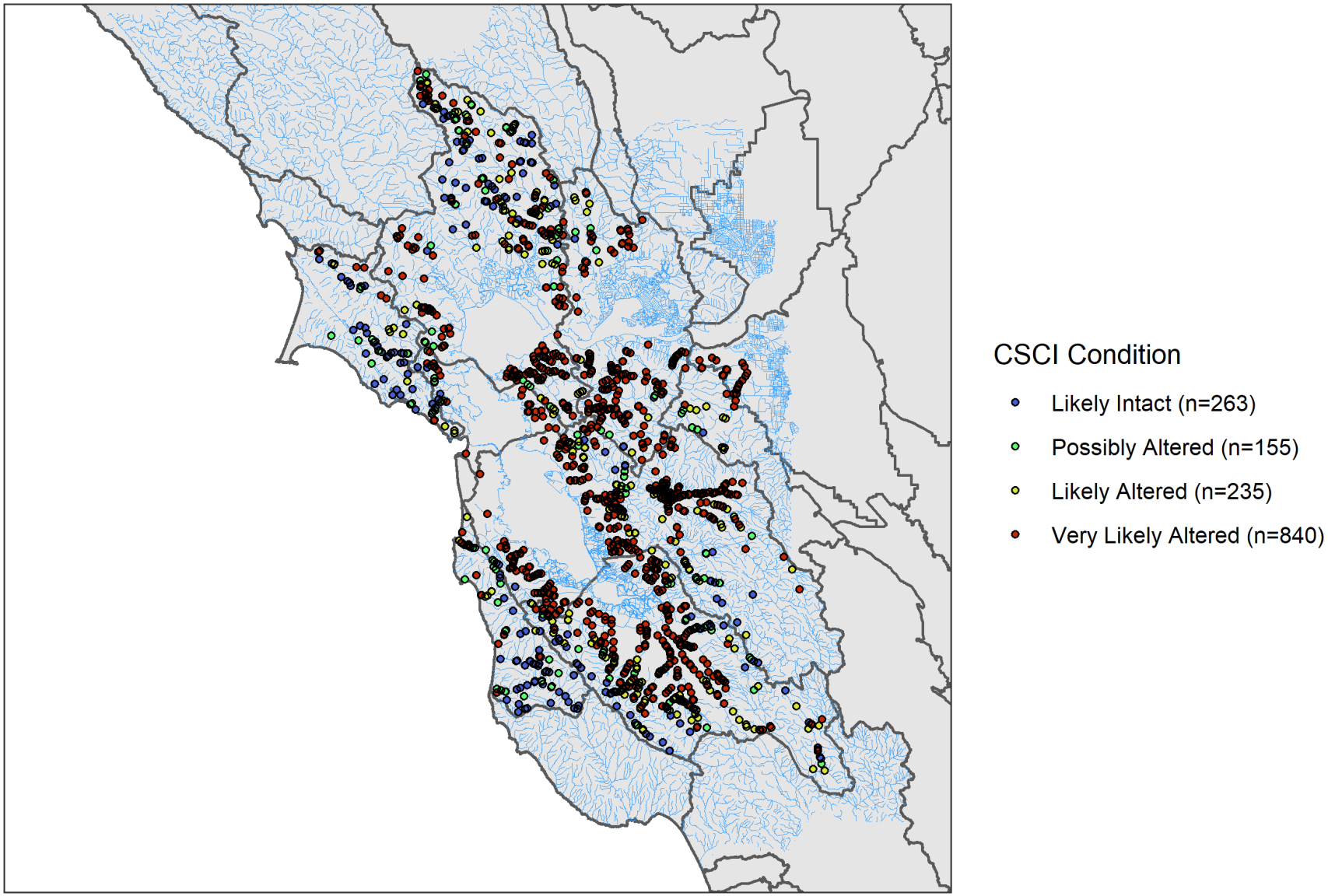


Figure 41. Map of CSCI condition by SWAMP Hydrologic Unit Code (HUC8).

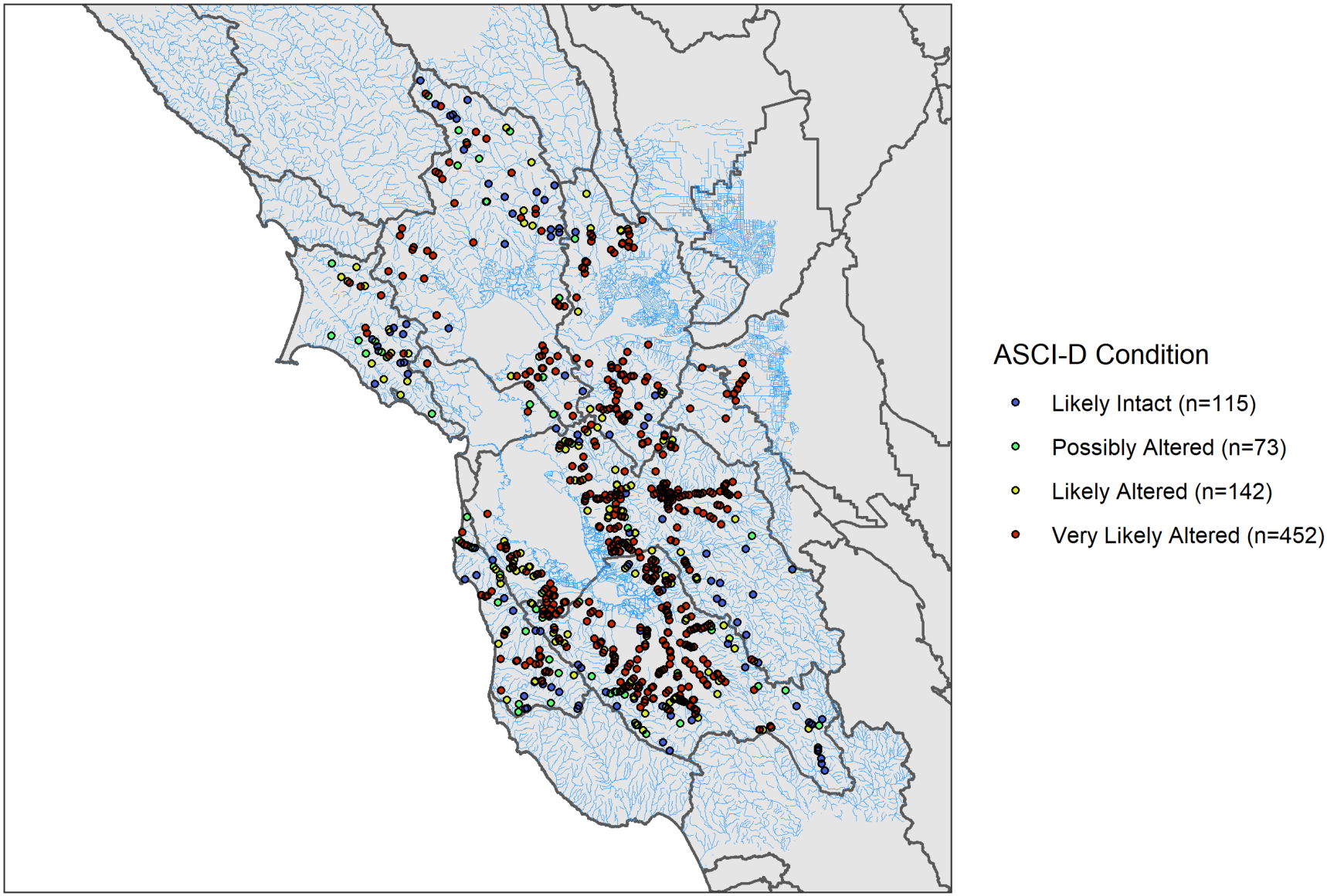


Figure 42. Map of ASCI-D condition by SWAMP Hydrologic Unit Code (HUC8).

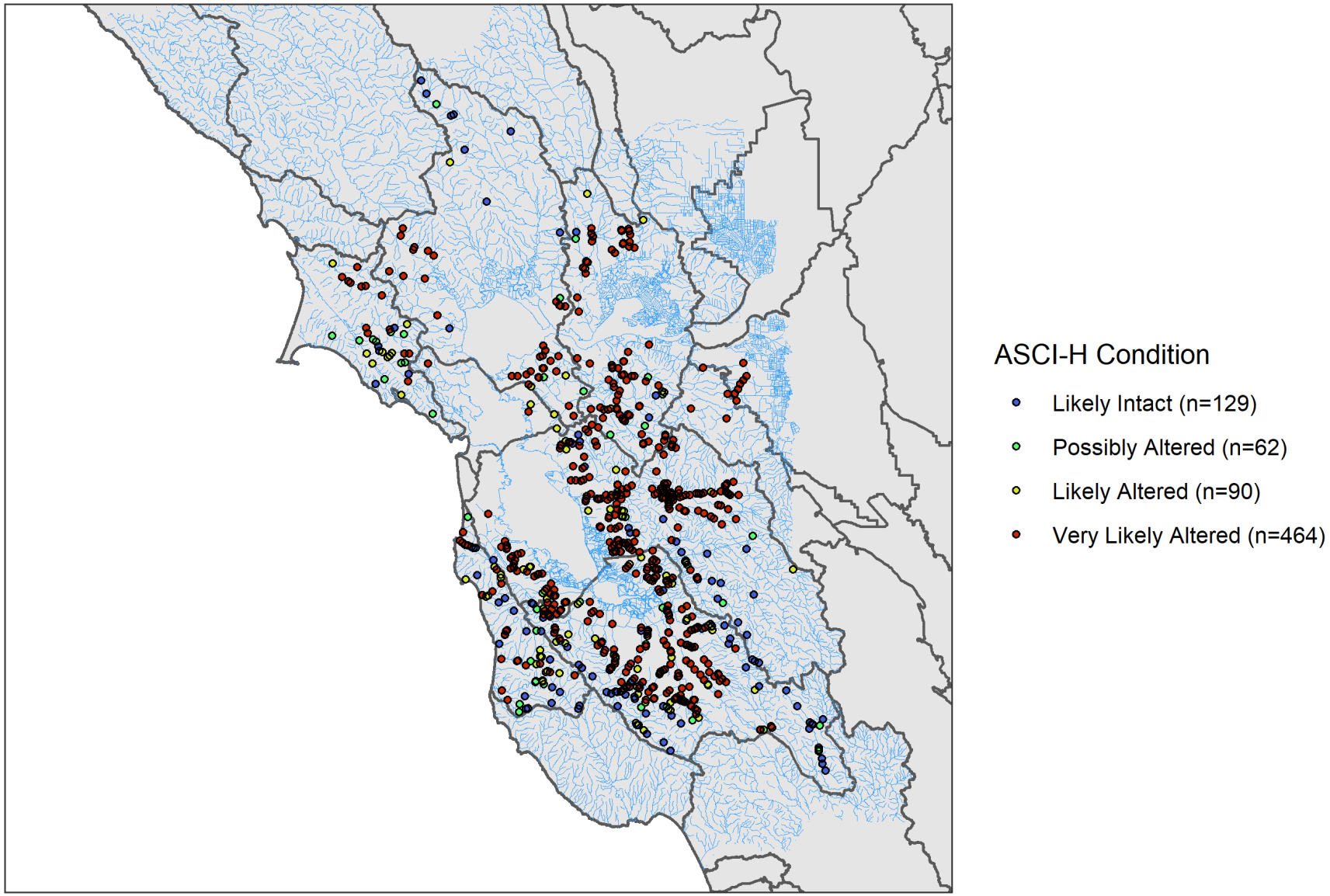


Figure 43. Map of ASCI-H condition by SWAMP Hydrologic Unit Code (HUC8).

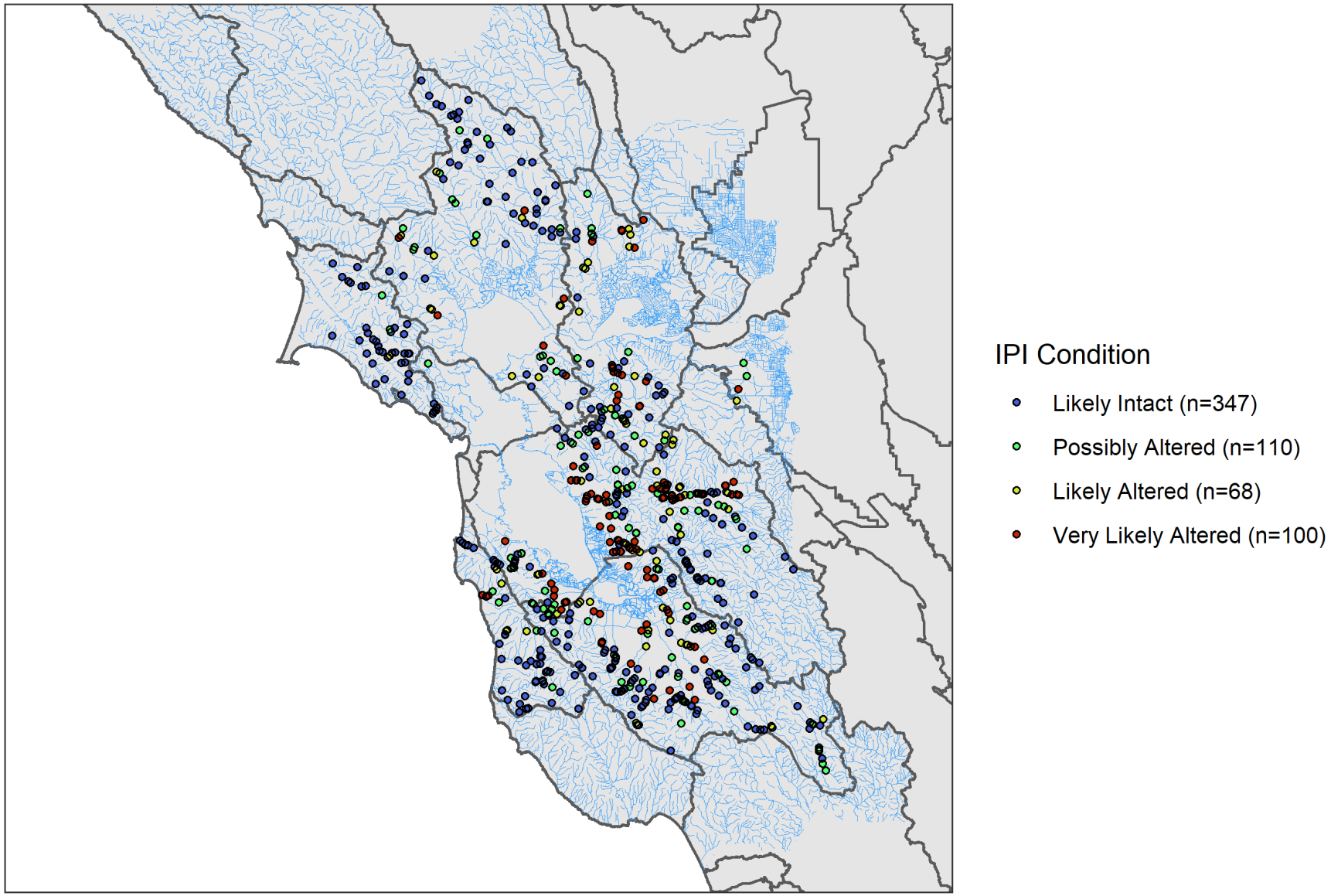


Figure 44. Map of IPI condition by SWAMP Hydrologic Unit Code (HUC8).

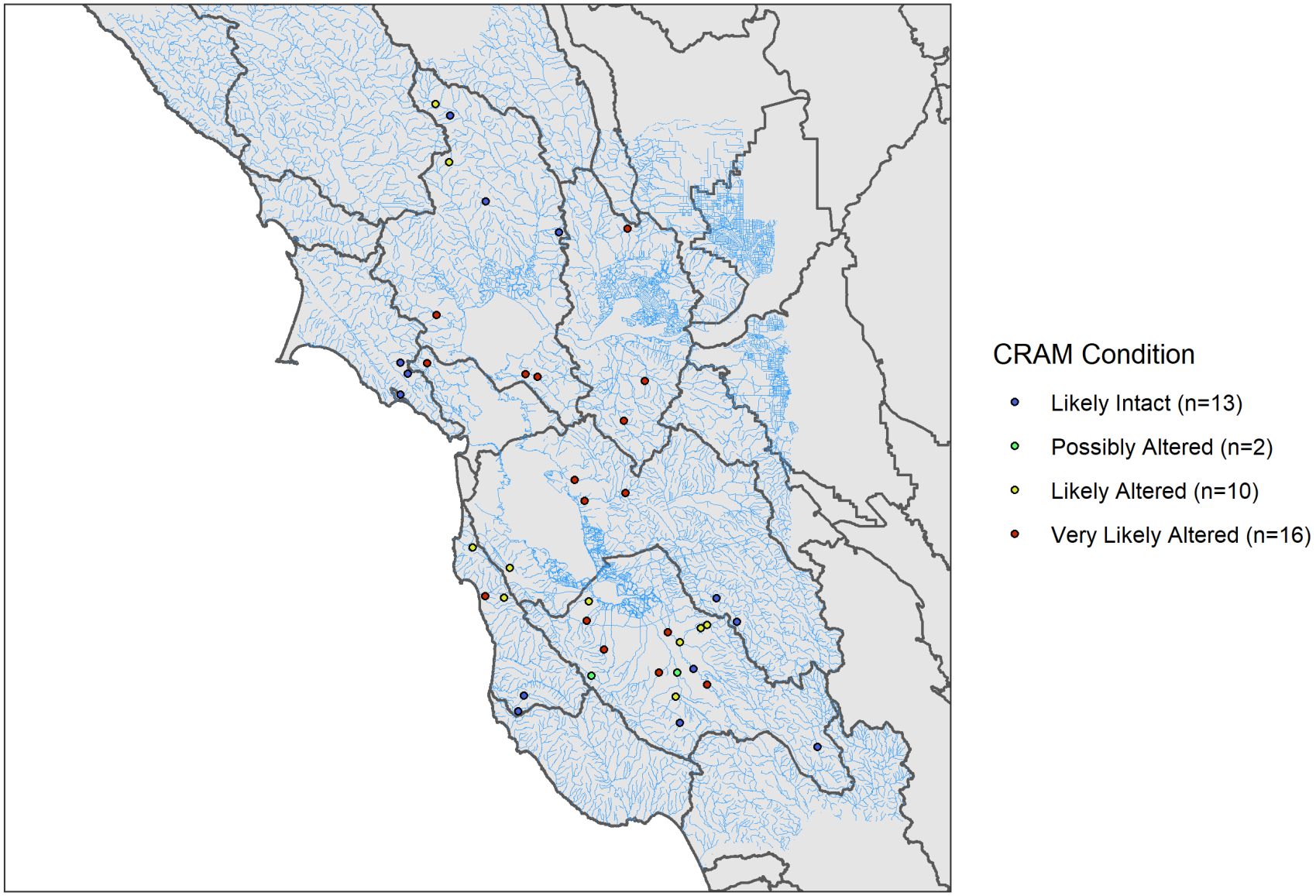


Figure 45. Map of CRAM condition by SWAMP Hydrologic Unit Code (HUC8).

Indices by Channel Type

Channel types defined by SFEI study

Most sites with channel type information available were from "natural unmodified" channels (e.g., 49% of sites with CSCI data). The channel category with the fewest number of sites was "mixed" (e.g., 4% of sites with CSCI data); no CRAM assessments were conducted in this channel type.

Median CSCI, ASCI-D, ASCI-H and CRAM scores were above the 10th percentile reference threshold at "natural non-FCC" channels, but below the threshold at channel types classified as "hard", "mixed", "natural unmodified" and "soft" (Figure 46 to 60, Table 7). For IPI, median scores were above the 10th percentile reference threshold for all channel type classes.

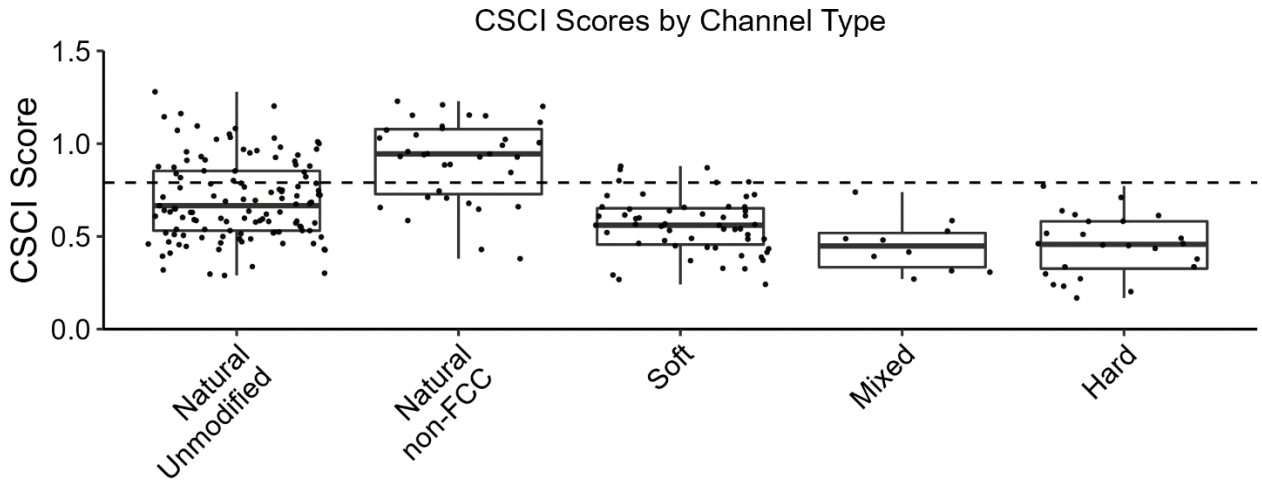


Figure 46. CSCI scores by channel type (SFEI categories) in Santa Clara County. Each point represents the score at a sampling location. The dashed horizontal line is the 10th percentile reference threshold.

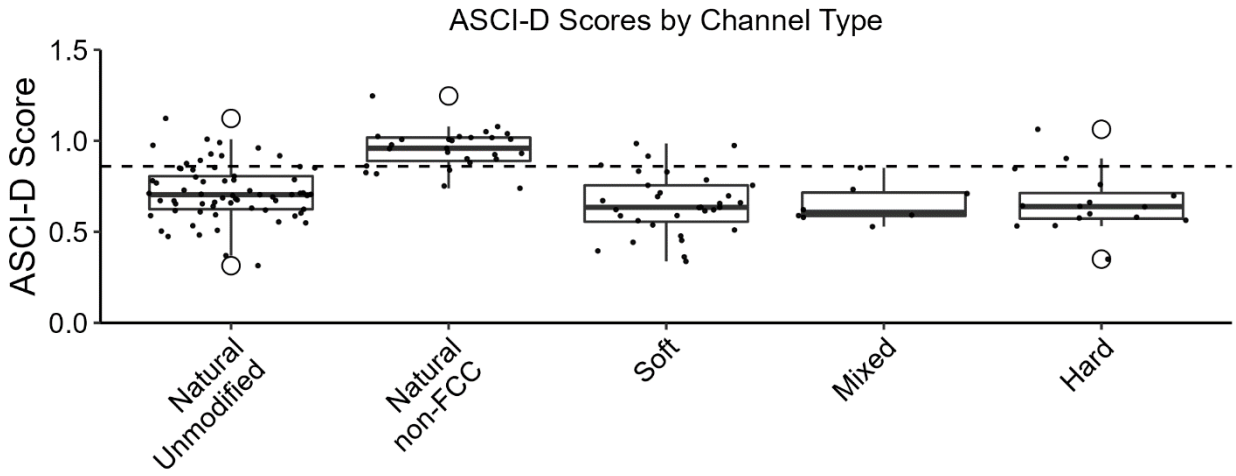


Figure 47. ASCI-D scores by channel type (SFEI categories) in Santa Clara County. Each point represents the score at a sampling location. The dashed horizontal line is the 10th percentile reference threshold.

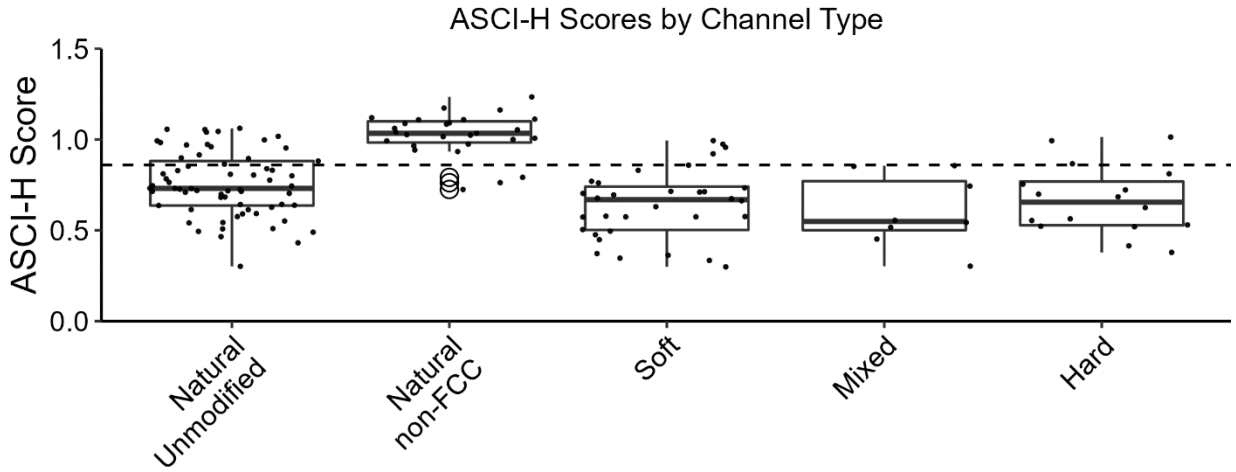


Figure 48. ASCI-H scores by channel type (SFEI categories) in Santa Clara County. Each point represents the score at a sampling location. The dashed horizontal line is the 10th percentile reference threshold.

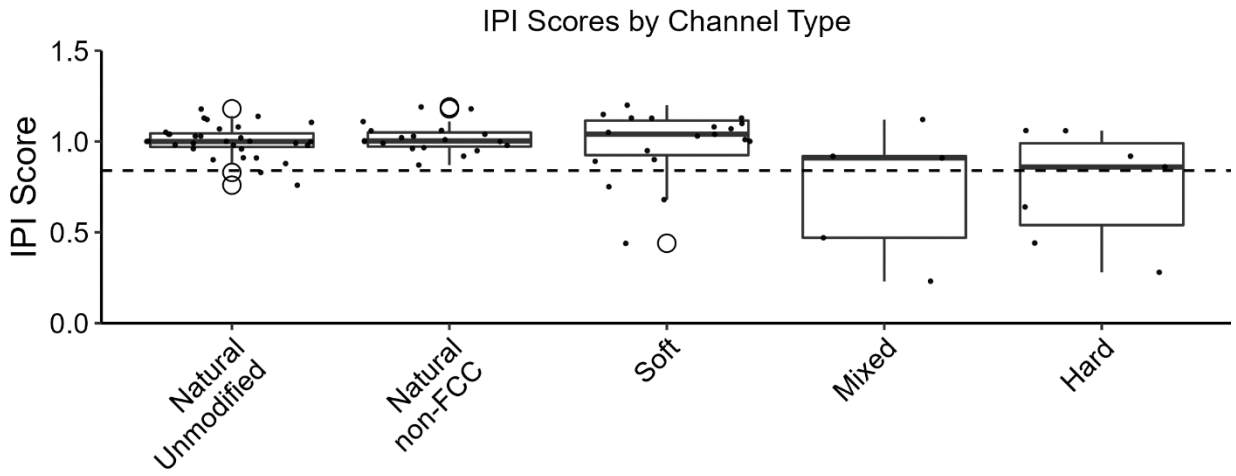


Figure 49. IPI scores by channel type (SFEI categories) in Santa Clara County. Each point represents the score at a sampling location. The dashed horizontal line is the 10th percentile reference threshold.

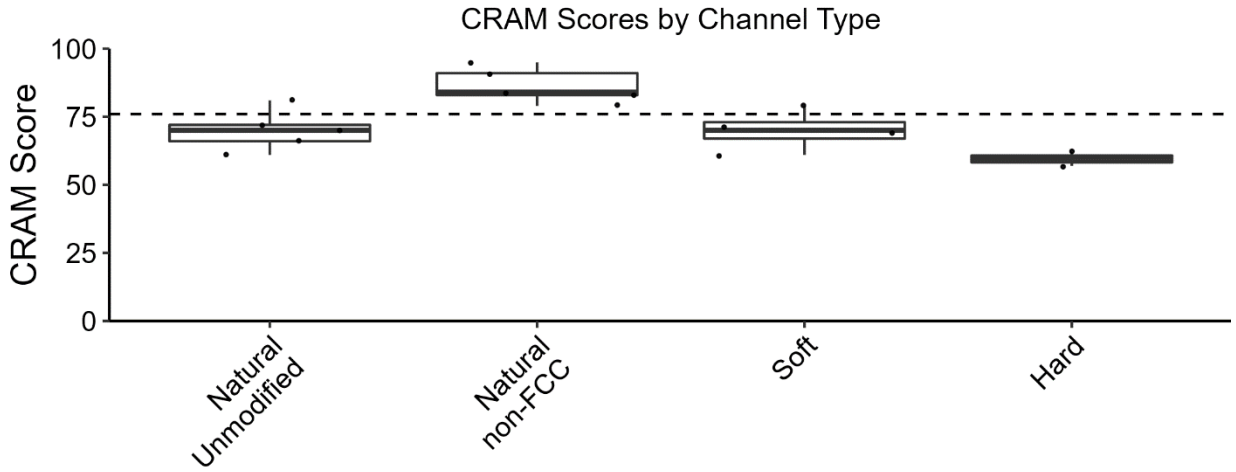


Figure 50. CRAM scores by channel type (SFEI categories) in Santa Clara County. Each point represents the score at a sampling location. The dashed horizontal line is the 10th percentile reference threshold.

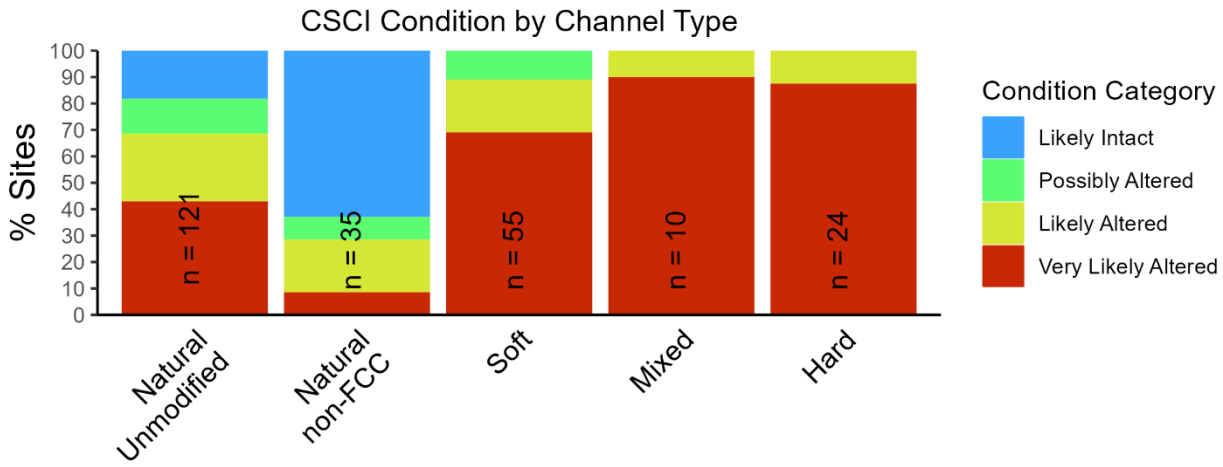


Figure 51. CSCI condition by channel type (SFEI categories) in Santa Clara County. The numbers in the plot indicate the total number of sites per channel type.

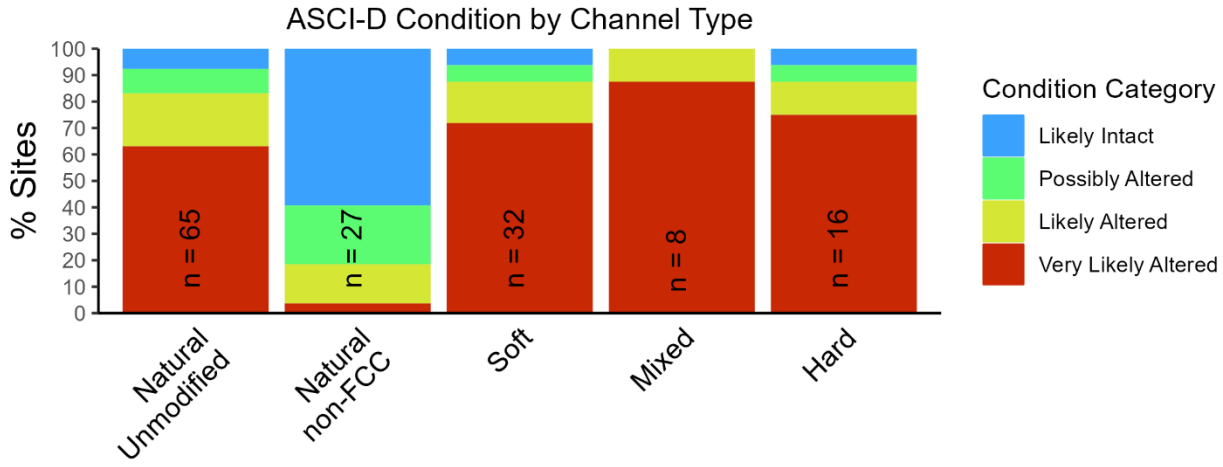


Figure 52. ASCI-D condition by channel type (SFEI categories) in Santa Clara County. The numbers in the plot indicate the total number of sites per channel type.

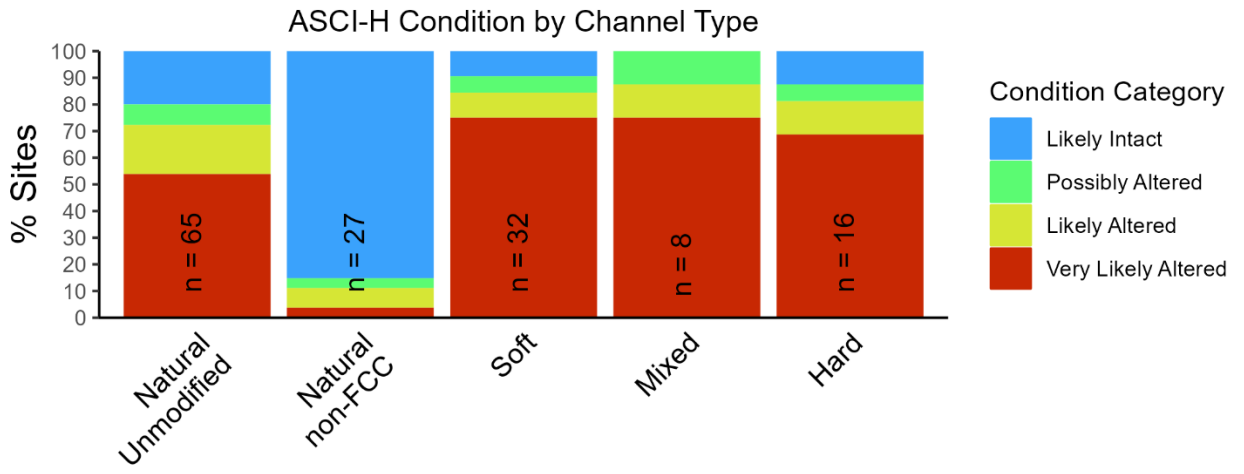


Figure 53. ASCI-H condition by channel type (SFEI categories) in Santa Clara County. The numbers in the plot indicate the total number of sites per channel type.

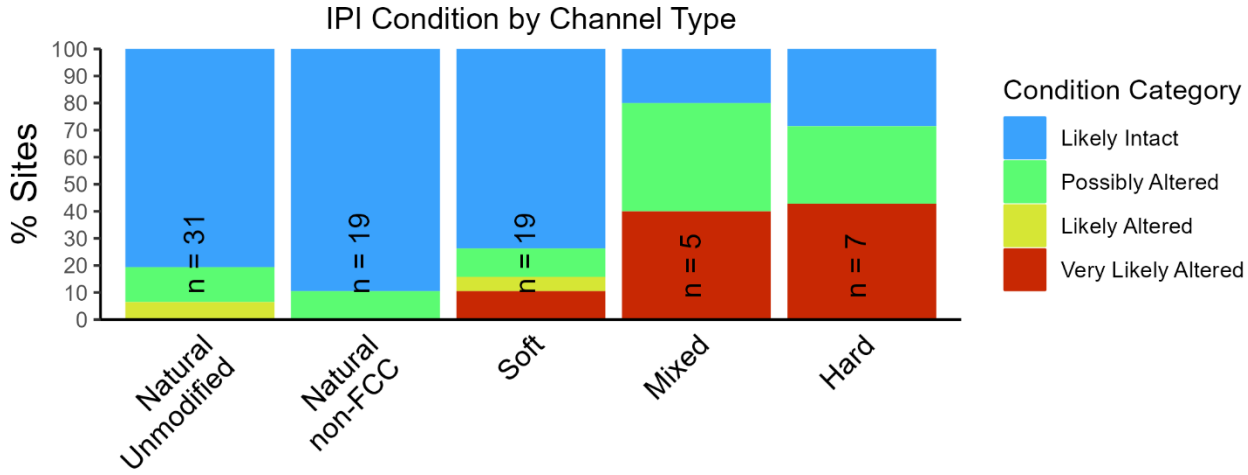


Figure 54. IPI condition by channel type (SFEI categories) in Santa Clara County. The numbers in the plot indicate the total number of sites per channel type.

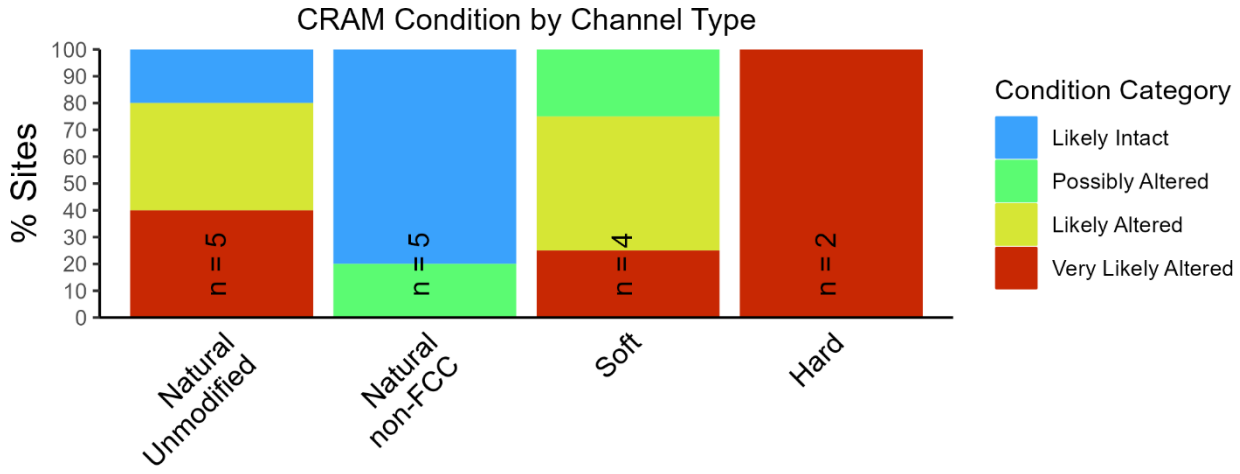


Figure 55. CRAM condition by channel type (SFEI categories) in Santa Clara County. The numbers in the plot indicate the total number of sites per channel type.

Table 7. Summary of index condition by channel type (SFEI categories) in Santa Clara County. NA = no data available.

Index	Channel type	N	Likely intact	Possibly intact	Possibly altered	Likely altered	Mean	SD
CSCI	Hard	24	0%	0%	13%	88%	0.45	0.16
CSCI	Mixed	10	0%	0%	10%	90%	0.45	0.14
CSCI	Natural non-FCC	35	63%	9%	20%	9%	0.91	0.22
CSCI	Natural Unmodified	121	18%	13%	26%	43%	0.70	0.22
CSCI	Soft	55	0%	11%	20%	69%	0.56	0.15
ASCI-D	Hard	16	6%	6%	13%	75%	0.66	0.17
ASCI-D	Mixed	8	0%	0%	13%	88%	0.65	0.11
ASCI-D	Natural non-FCC	27	59%	22%	15%	4%	0.95	0.11

Index	Channel type	N	Likely intact	Possibly intact	Possibly altered	Likely altered	Mean	SD
ASCI-D	Natural Unmodified	65	8%	9%	20%	63%	0.72	0.15
ASCI-D	Soft	32	6%	6%	16%	72%	0.65	0.17
ASCI-H	Hard	16	13%	6%	13%	69%	0.67	0.19
ASCI-H	Mixed	8	0%	13%	13%	75%	0.60	0.20
ASCI-H	Natural non-FCC	27	85%	4%	7%	4%	1.02	0.12
ASCI-H	Natural Unmodified	65	20%	8%	18%	54%	0.75	0.18
ASCI-H	Soft	32	9%	6%	9%	75%	0.64	0.19
IPI	Hard	7	29%	29%	0%	43%	0.75	0.31
IPI	Mixed	5	20%	40%	0%	40%	0.73	0.37
IPI	Natural non-FCC	19	89%	11%	0%	0%	1.02	0.08
IPI	Natural Unmodified	31	81%	13%	6%	0%	1.00	0.09
IPI	Soft	19	74%	11%	5%	11%	0.99	0.19
CRAM	Hard	2	0%	0%	0%	100%	60	3.5
CRAM	Mixed	NA	NA	NA	NA	NA	NA	NA
CRAM	Natural non-FCC	5	80%	20%	0%	0%	86	6.5
CRAM	Natural Unmodified	5	20%	0%	40%	40%	70	7.4
CRAM	Soft	4	0%	25%	50%	25%	70	7.4

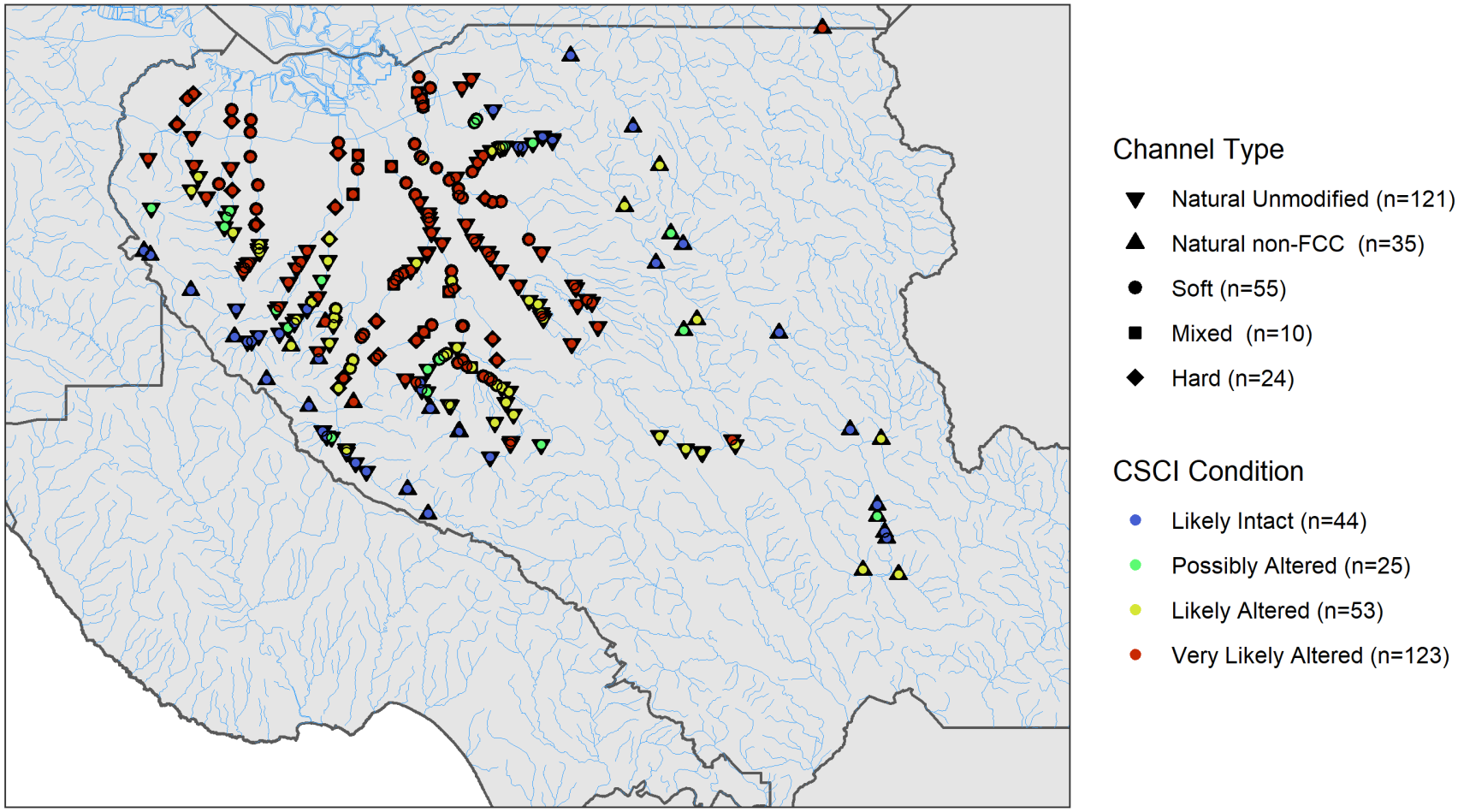


Figure 56. Map of CSCI condition by channel type (SFEI categories) in Santa Clara County.

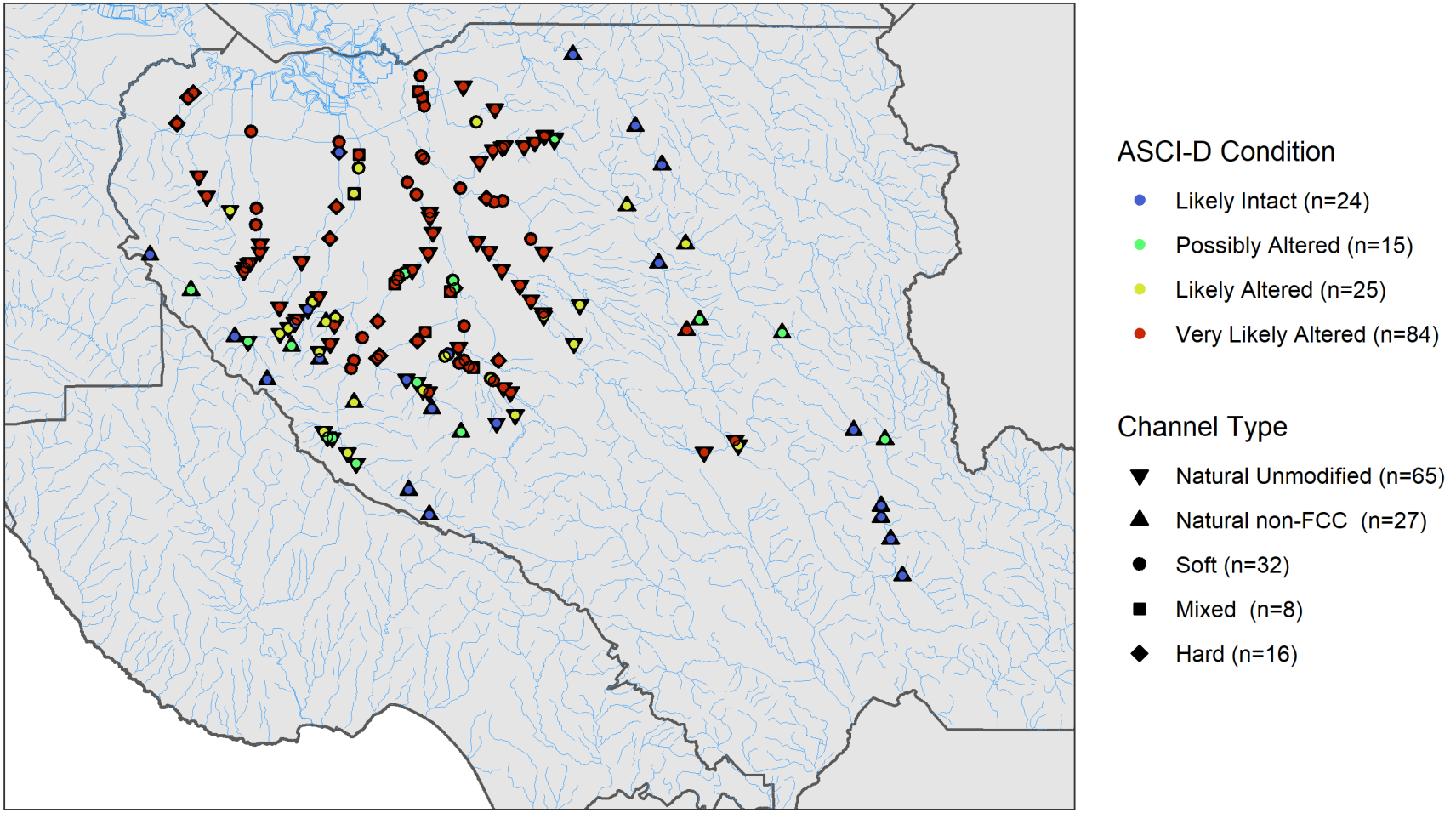


Figure 57. Map of ASCI-D condition by channel type (SFEI categories) in Santa Clara County.

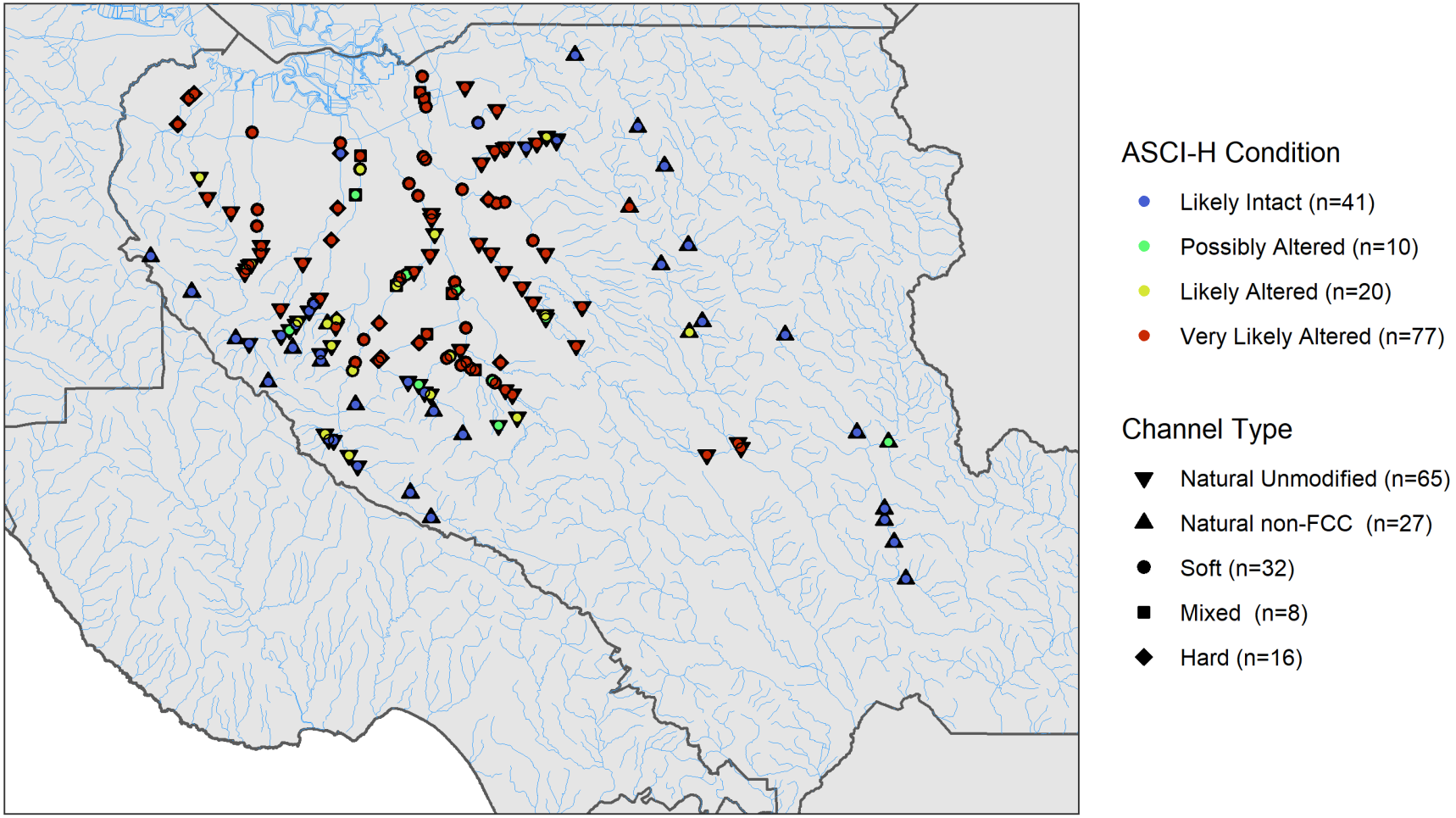


Figure 58. Map of ASCI-H condition by channel type (SFEI categories) in Santa Clara County.

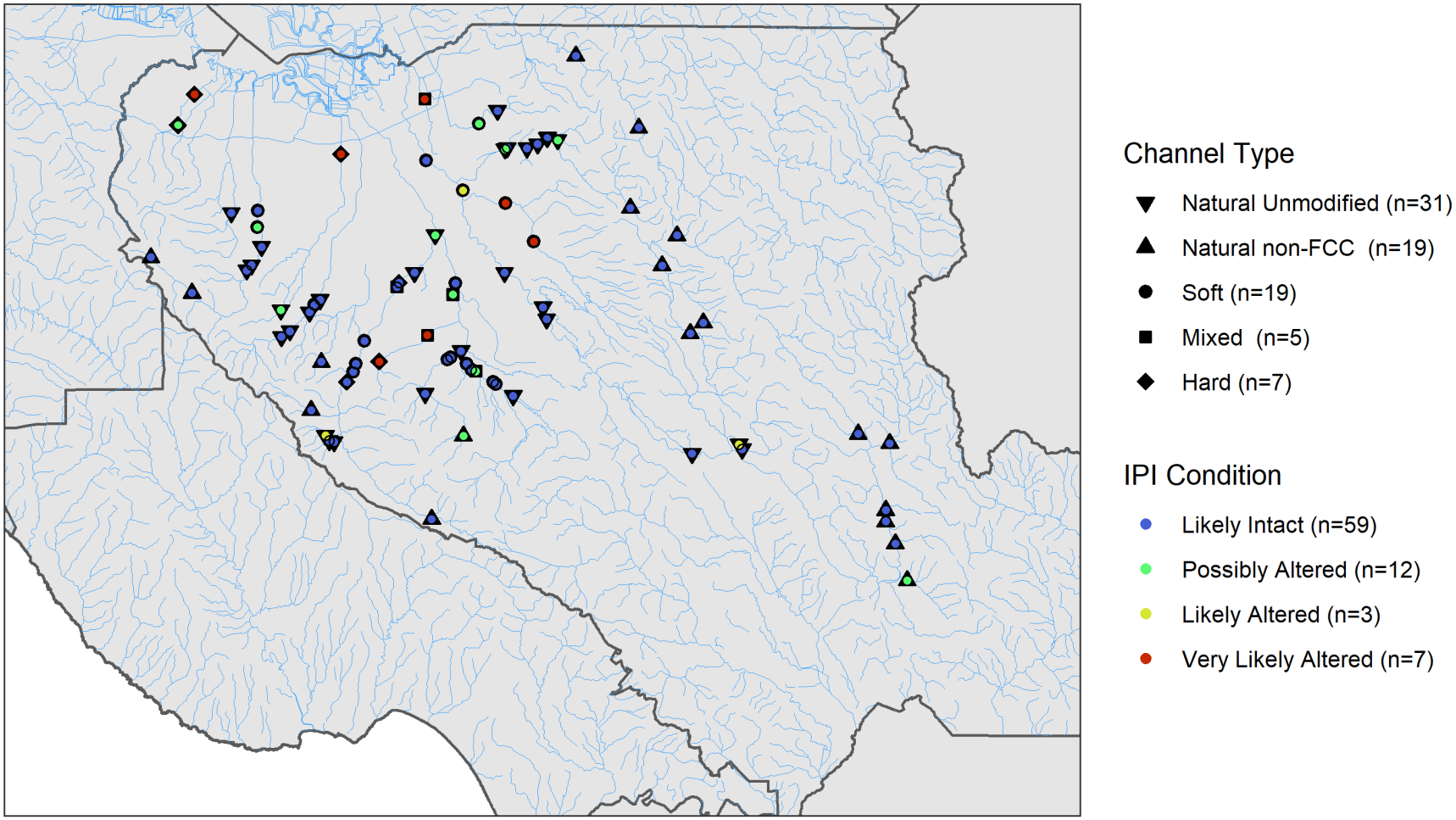


Figure 59. Map of IPI condition by channel type (SFEI categories) in Santa Clara County.

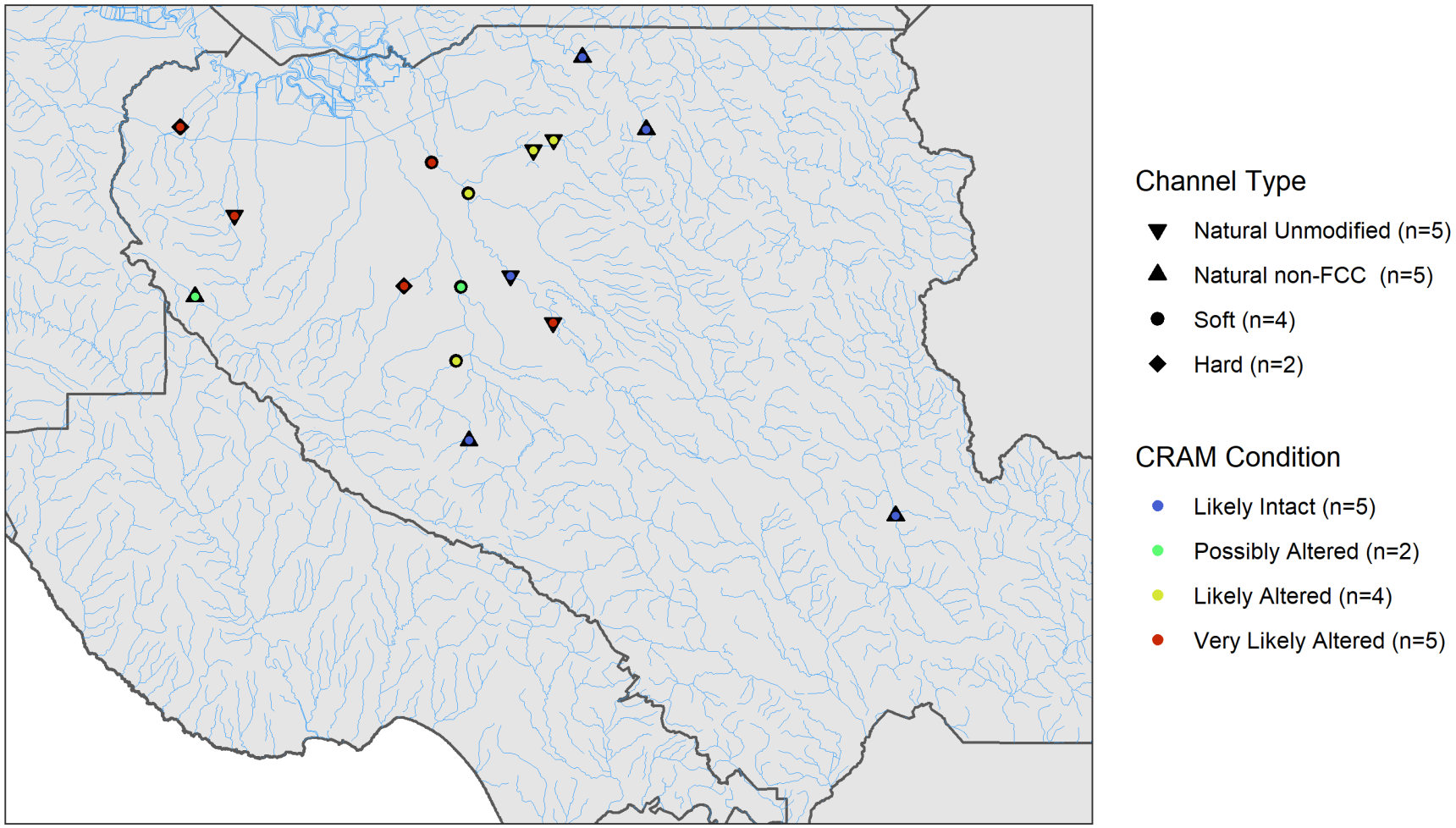


Figure 60. Map of CRAM condition by channel type (SFEI categories) in Santa Clara County.

Channel types defined by field observations of bed and bank material

Using Direct Observation of the streams, most sites with available channel type information were in the "natural" category (64%), followed by "soft" (27%) and "hard" (9%) (Table 8). Median CSCI, ASCI-D and ASCI-H scores were below the 10th percentile reference threshold for all channel type categories (Figures 61 to 75). In contrast, median IPI scores were above the threshold for all channel types. Median CRAM scores were above the threshold only at natural channels.

There were differences in channel type classifications for some sites using the SFEI approach vs the Direct Observation method (Table 9). For example, many of the sites classified as hard bottom under the SFEI approach were classified as soft bottom in the Direct Observation approach (11 out of 24 hard bottom sites). The greatest agreement in channel type between the approaches was for the natural non-FCC (SFEI) and natural (Direct Observation) categories (121 of the 245 sites). None of the natural non-FCC or natural unmodified sites were reclassified as hard or soft in the Direct Observation approach, and none of the natural sites were reclassified as hard or soft using the SFEI approach.

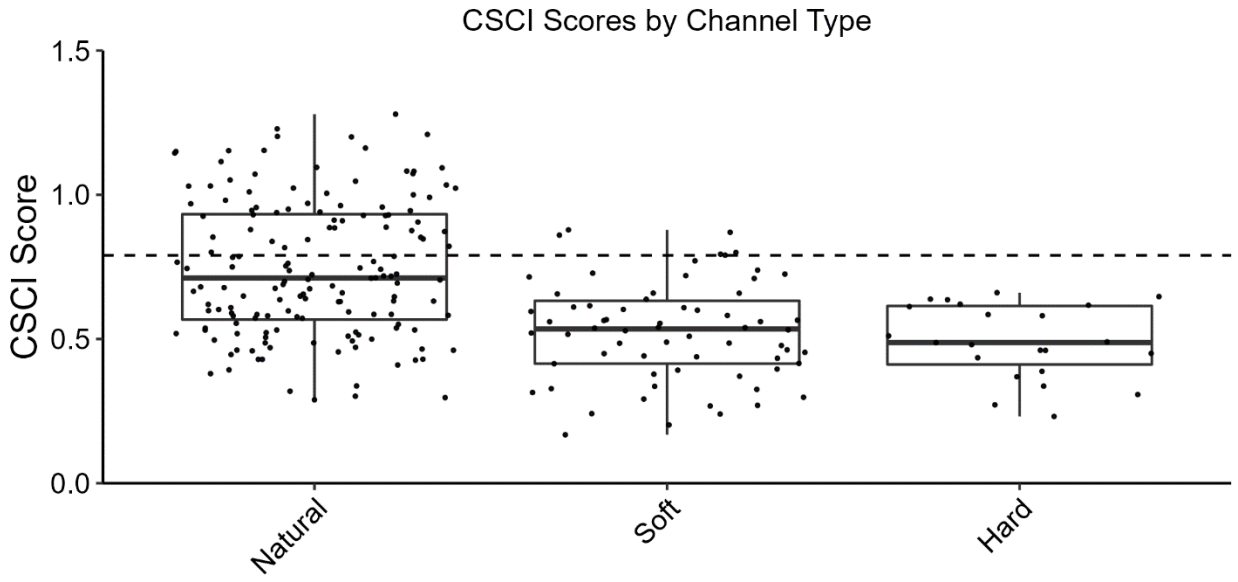


Figure 61. CSCI scores by channel type (Direct Observation categories) in Santa Clara County. Each point represents the score at a sampling location. The dashed horizontal line is the 10th percentile reference threshold.

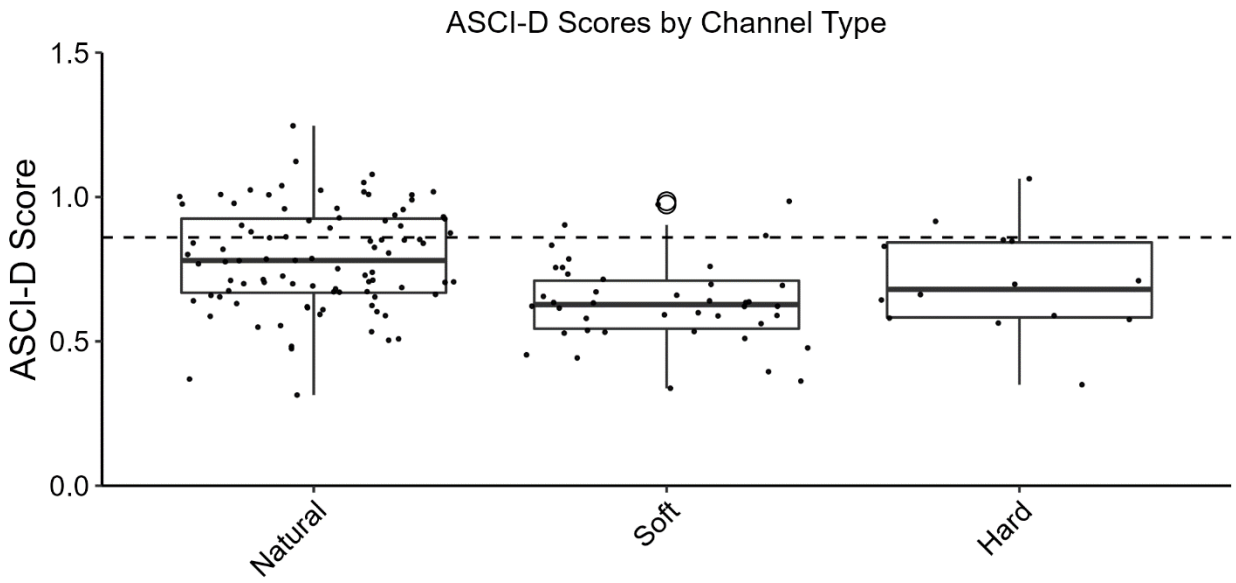


Figure 62. ASCI-D scores by channel type (Direct Observation categories) in Santa Clara County. Each point represents the score at a sampling location. The dashed horizontal line is the 10th percentile reference threshold.

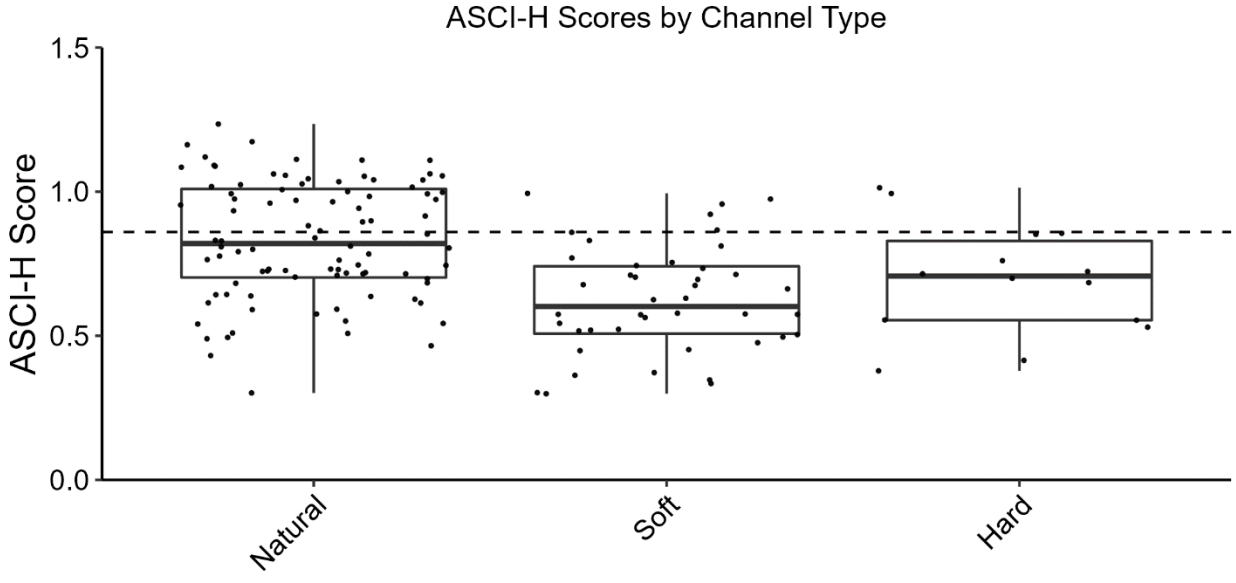


Figure 63. ASCI-D scores by channel type (Direct Observation categories) in Santa Clara County. Each point represents the score at a sampling location. The dashed horizontal line is the 10th percentile reference threshold.

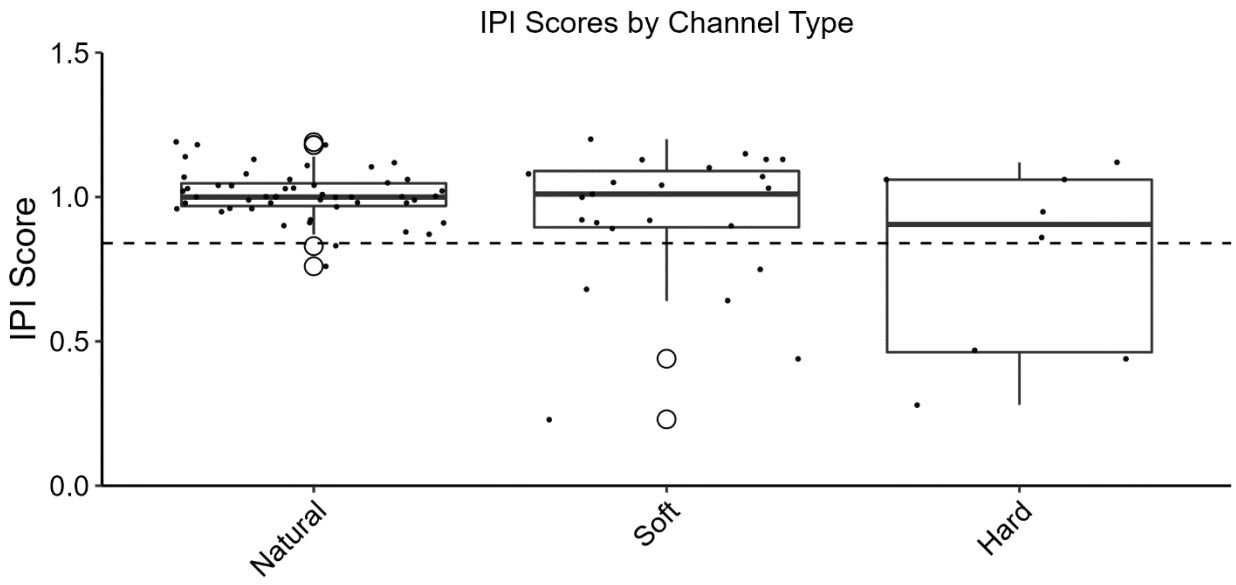


Figure 64. IPI scores by channel type (Direct Observation categories) in Santa Clara County. Each point represents the score at a sampling location. The dashed horizontal line is the 10th percentile reference threshold.

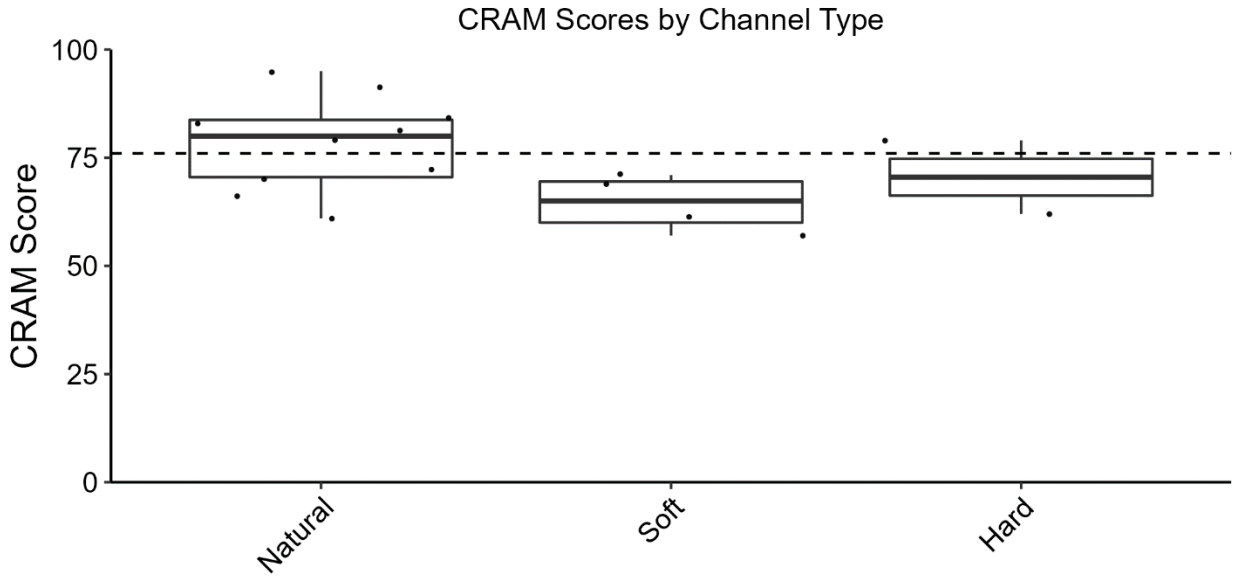


Figure 65. CRAM scores by channel type (Direct Observation categories) in Santa Clara County. Each point represents the score at a sampling location. The dashed horizontal line is the 10th percentile reference threshold.

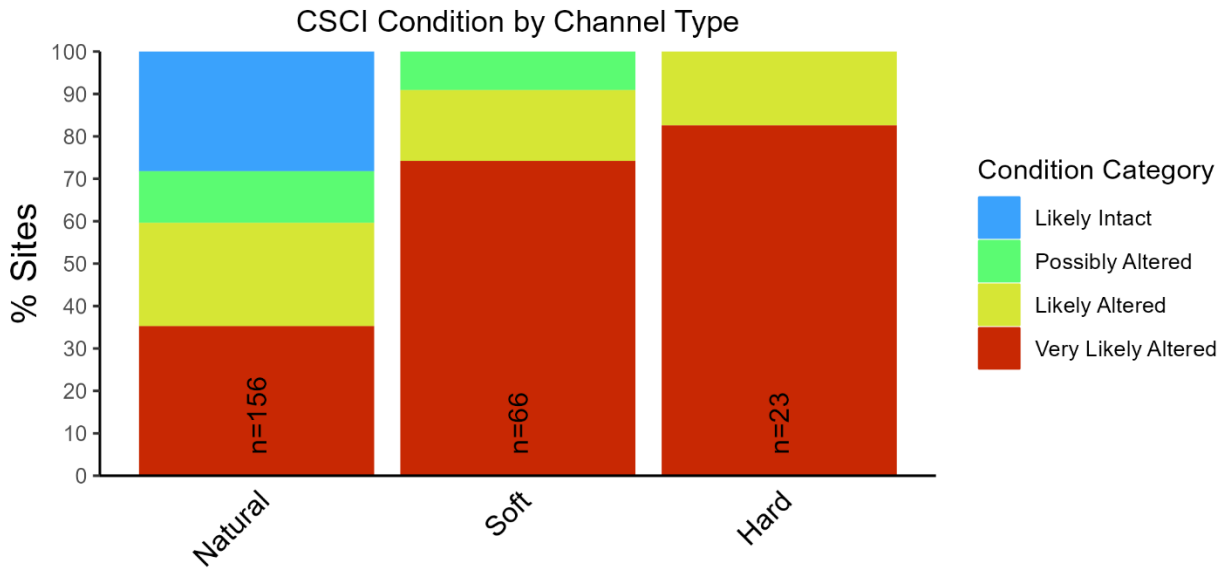


Figure 66. CSCI condition by channel type (Direct Observation categories) in Santa Clara County. The numbers in the plot indicate the total number of sites per channel type.

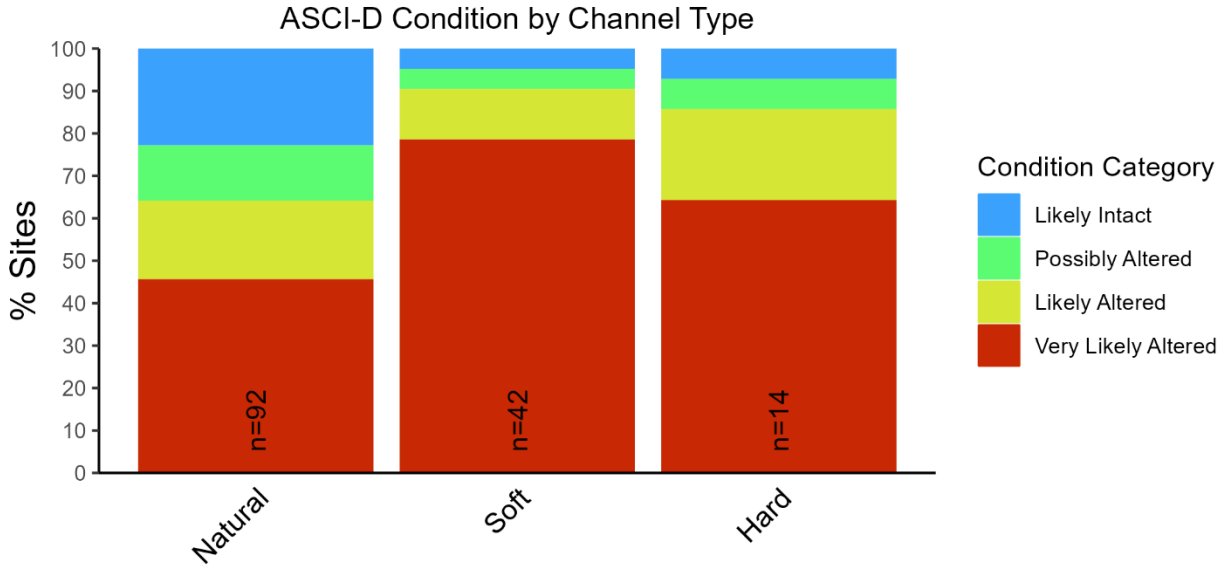


Figure 67. ASCI-D condition by channel type (Direct Observation categories) in Santa Clara County. The numbers in the plot indicate the total number of sites per channel type.

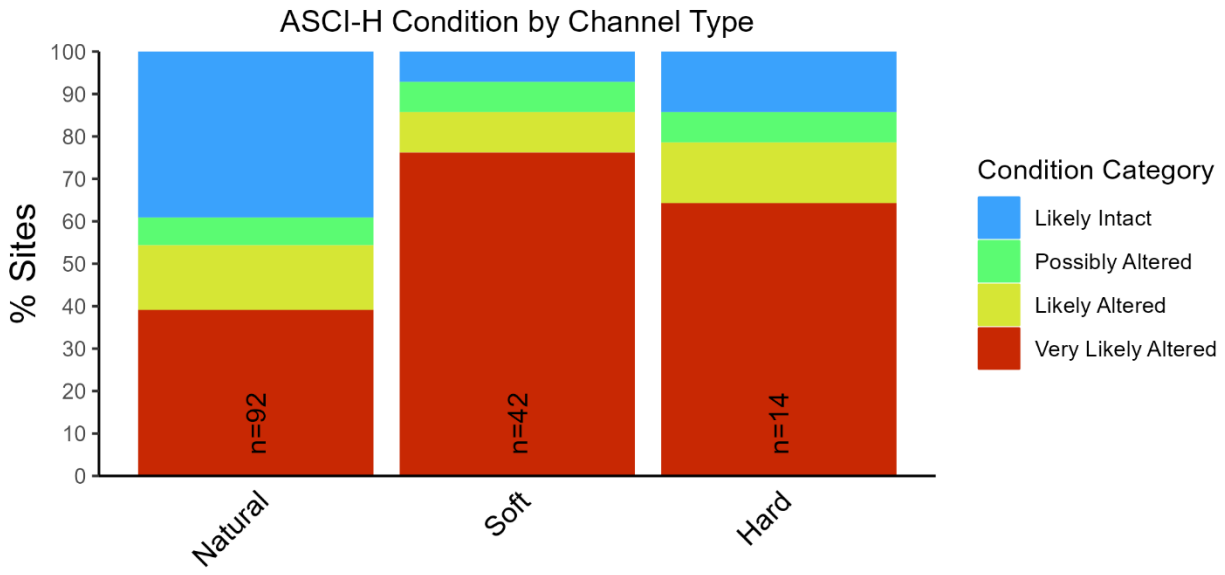


Figure 68. ASCI-H condition by channel type (Direct Observation categories) in Santa Clara County. The numbers in the plot indicate the total number of sites per channel type.

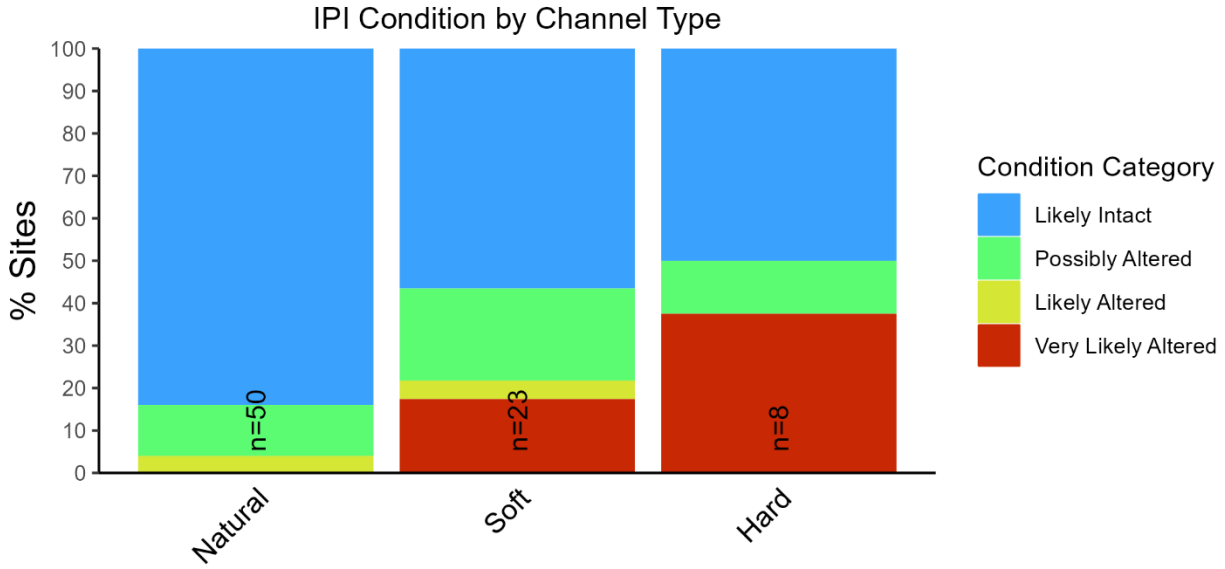


Figure 69. IPI condition by channel type (Direct Observation categories) in Santa Clara County. The numbers in the plot indicate the total number of sites per channel type.

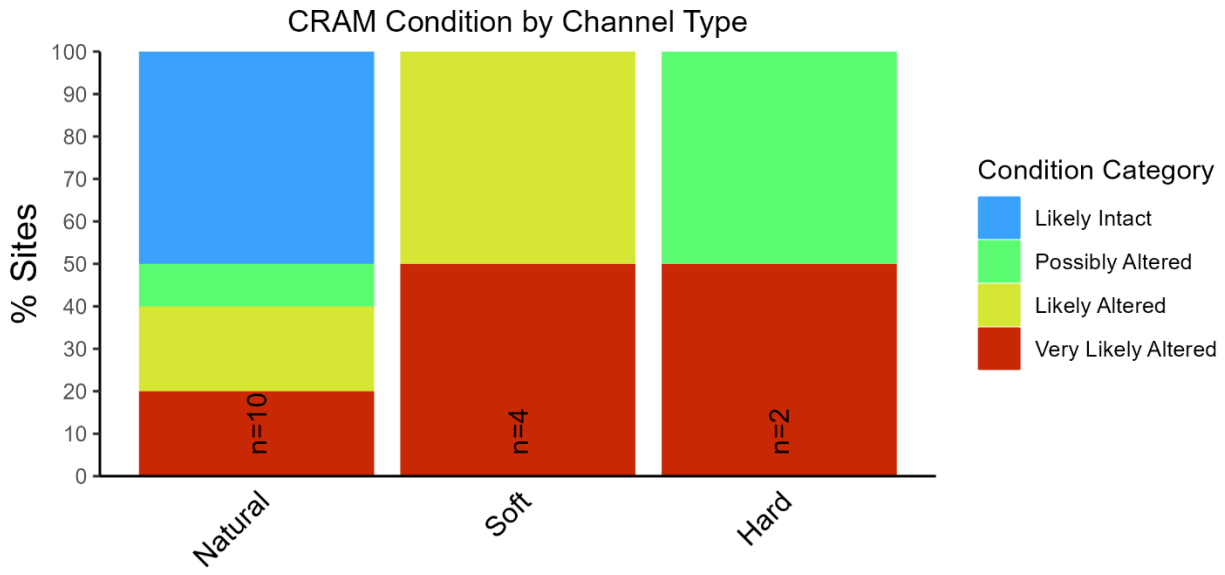


Figure 70. CRAM condition by channel type (Direct Observation categories) in Santa Clara County. The numbers in the plot indicate the total number of sites per channel type.

Table 8. Summary of index condition by channel type (Direct Observation approach) in Santa Clara County.

Index	Channel type	N	Likely intact	Possibly intact	Possibly altered	Likely altered	Mean	SD
CSCI	Hard	23	0%	0%	17%	83%	0.49	0.13
CSCI	Natural	156	28%	12%	24%	35%	0.74	0.23
CSCI	Soft	66	0%	9%	17%	74%	0.53	0.17
ASCI-D	Hard	14	7%	7%	21%	64%	0.71	0.18
ASCI-D	Natural	92	23%	13%	18%	46%	0.79	0.18
ASCI-D	Soft	42	5%	5%	12%	79%	0.64	0.15
ASCI-H	Hard	14	14%	7%	14%	64%	0.69	0.19
ASCI-H	Natural	92	39%	7%	15%	39%	0.83	0.20
ASCI-H	Soft	42	7%	7%	10%	76%	0.62	0.19

Index	Channel type	N	Likely intact	Possibly intact	Possibly altered	Likely altered	Mean	SD
IPI	Hard	8	50%	13%	0%	38%	0.78	0.33
IPI	Natural	50	84%	12%	4%	0%	1.01	0.09
IPI	Soft	23	57%	22%	4%	17%	0.93	0.24
CRAM	Hard	2	0%	50%	0%	50%	71	12.0
CRAM	Natural	10	50%	10%	20%	20%	78	10.9
CRAM	Soft	4	0%	0%	50%	50%	65	6.6

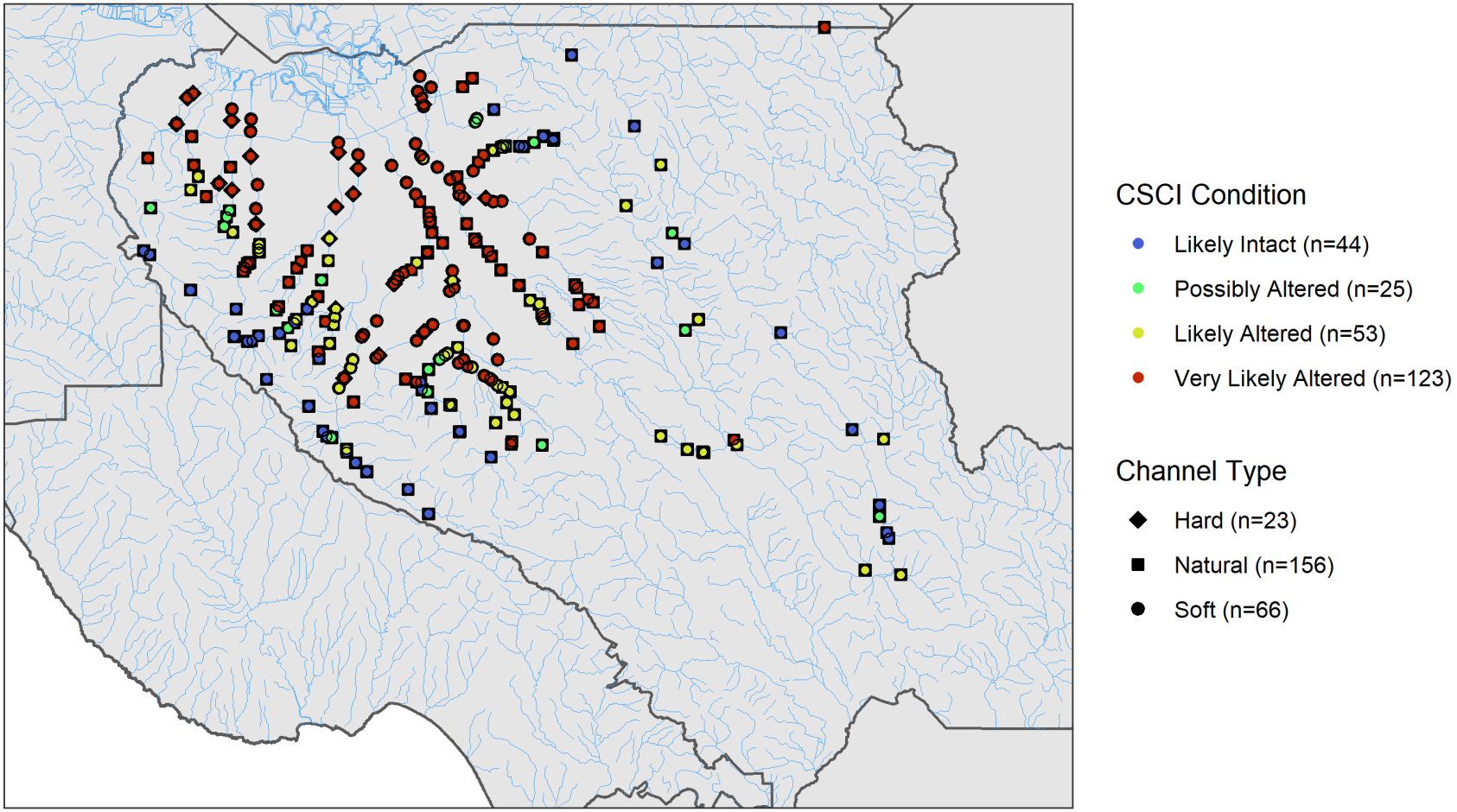


Figure 71. Map of CSCI condition by channel type (Direct Observation categories) in Santa Clara County.

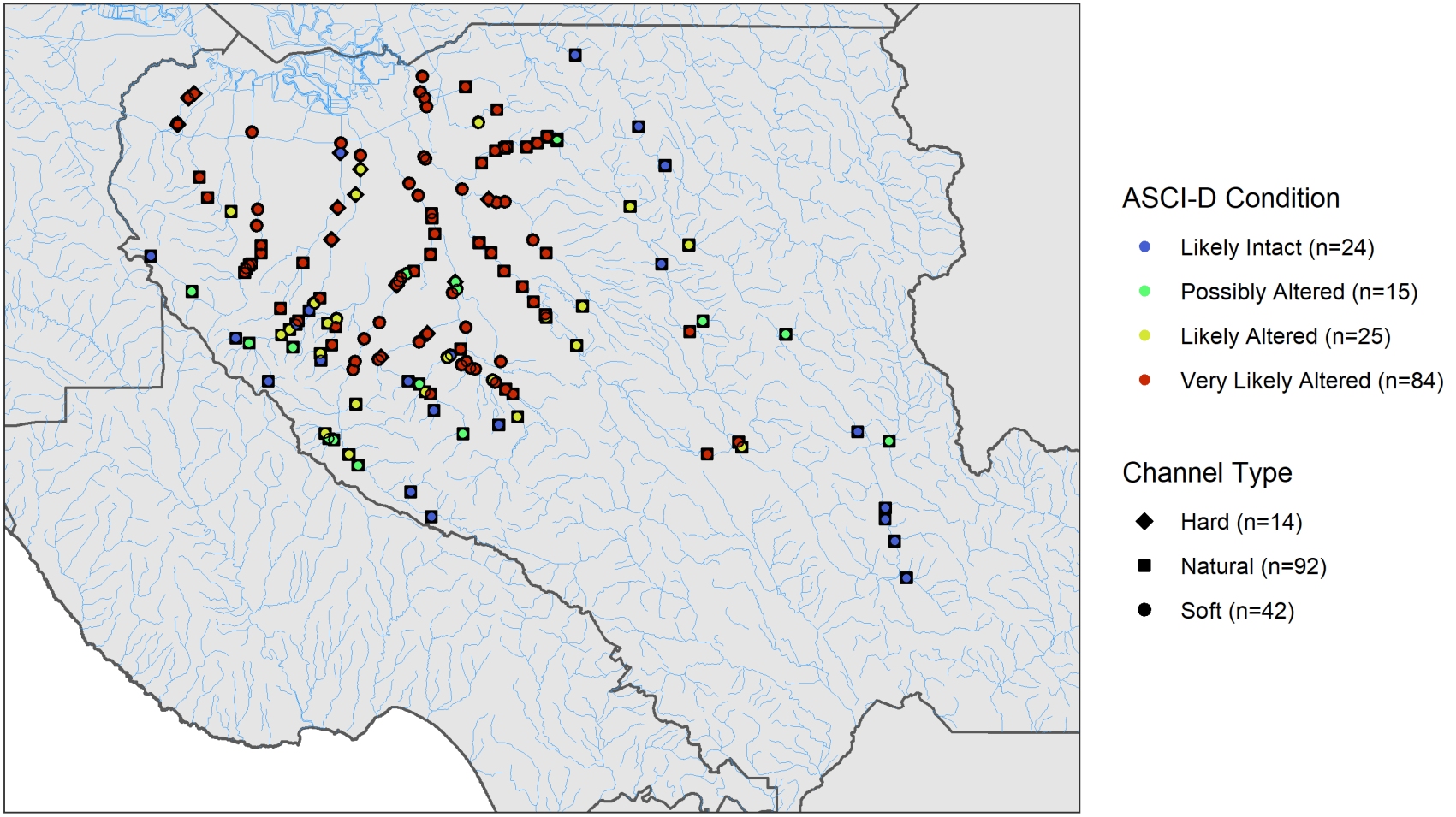


Figure 72. Map of ASCI-D condition by channel type (Direct Observation categories) in Santa Clara County.

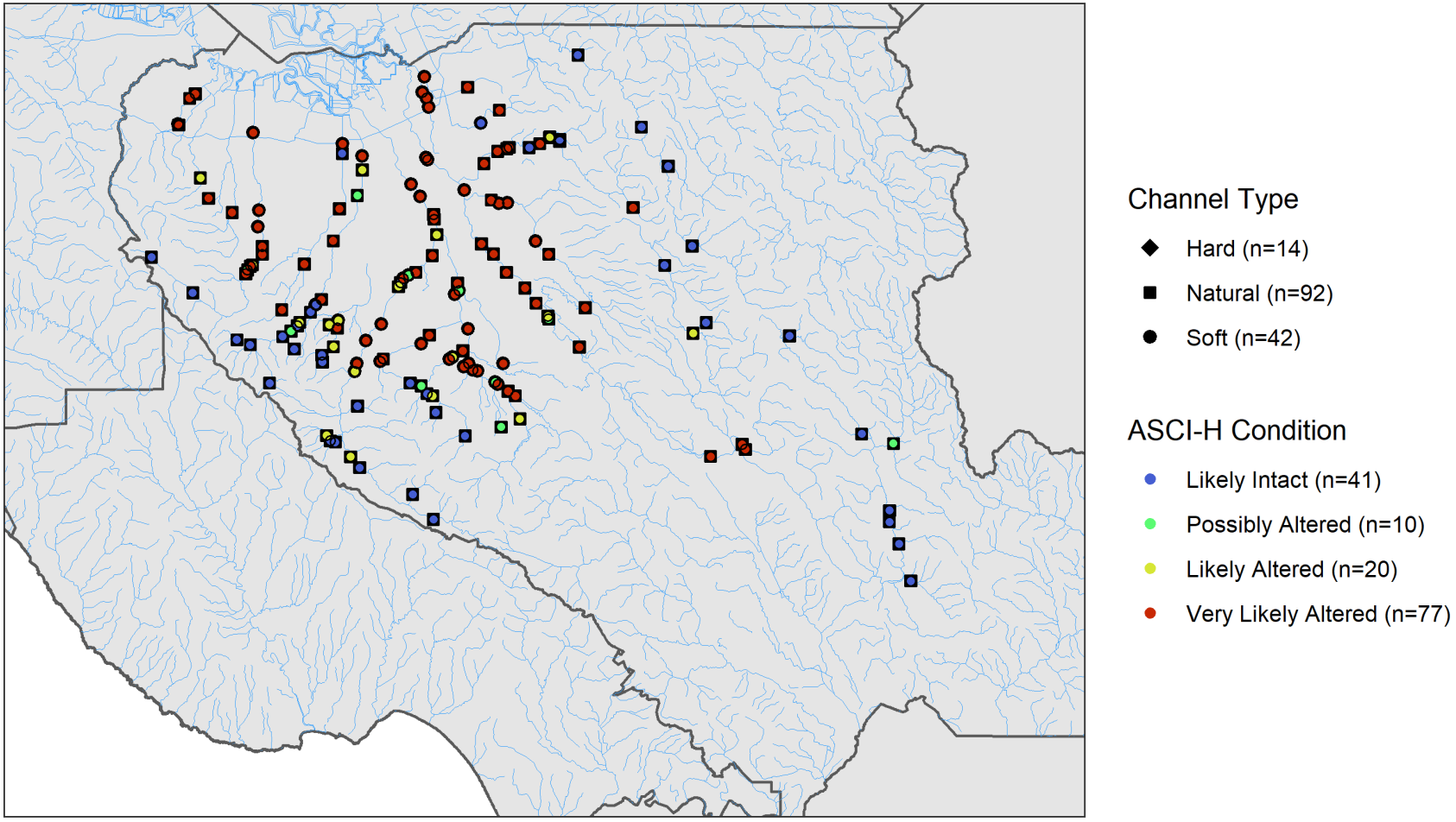


Figure 73. Map of ASCI-H condition by channel type (Direct Observation categories) in Santa Clara County.

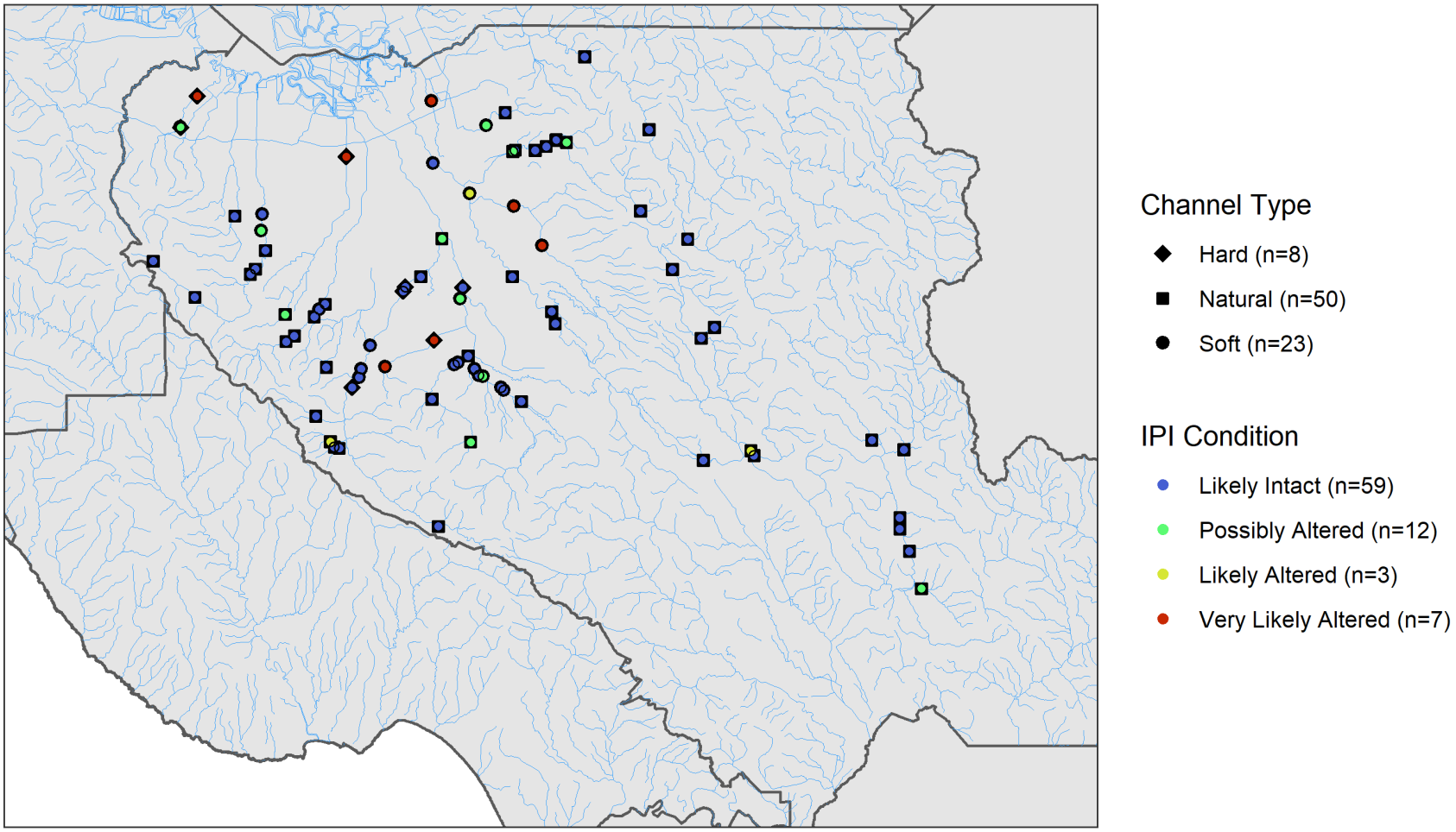


Figure 74. Map of IPI condition by channel type (Direct Observation categories) in Santa Clara County.

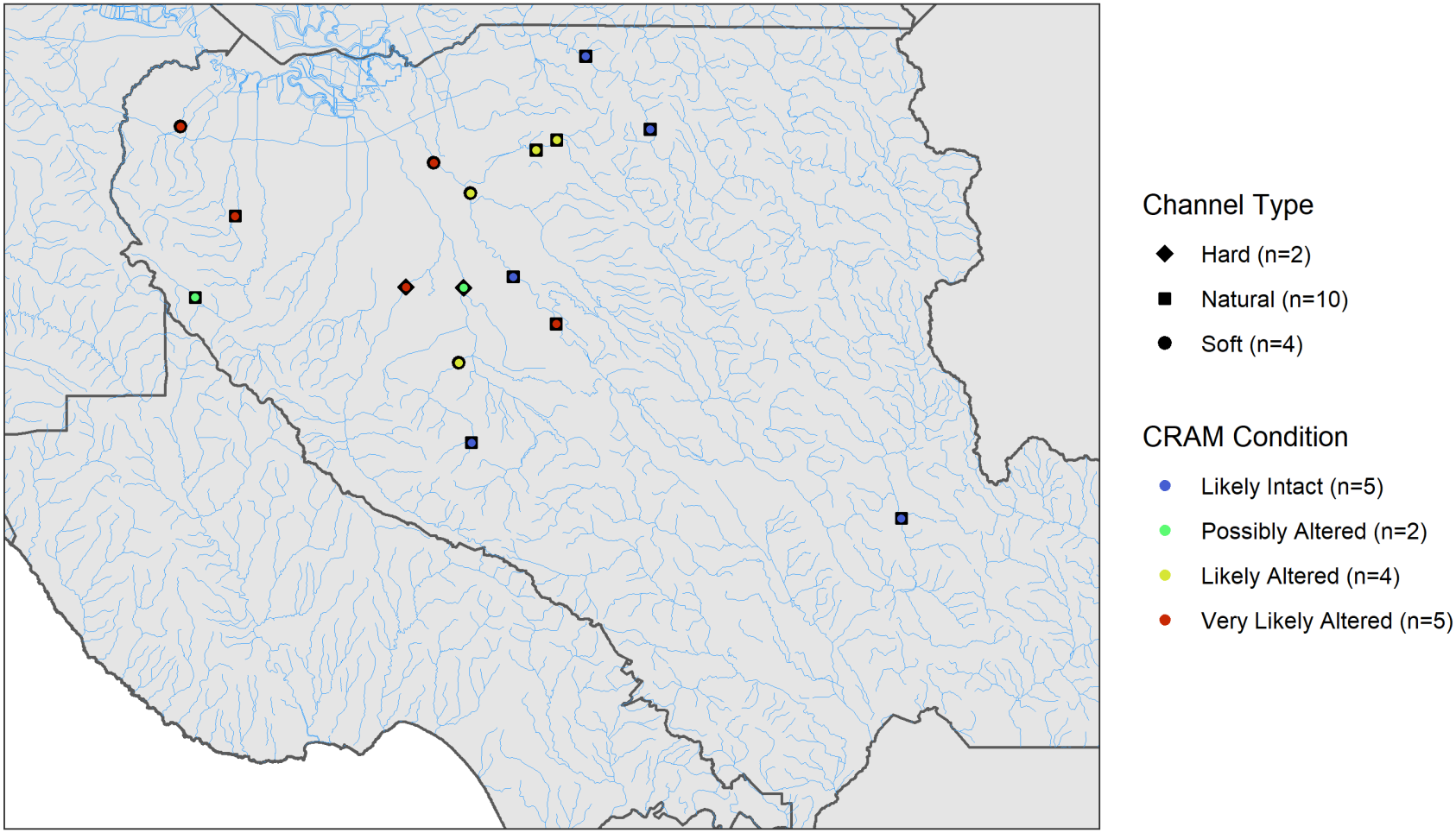


Figure 75. Map of CRAM condition by channel type (Direct Observation categories) in Santa Clara County.

Table 9. Contingency table of agreement between field observations (direct observations) and SFEI classes. Values represent the number of stations in each category cross-over. Non-FCC = not within the jurisdiction of a flood control district.

	Direct Observation Category		
SFEI Category	Hard	Natural	Soft
Hard	13	0	11
Mixed	4	0	6
Natural non-FCC	0	35	0
Natural Unmodified	0	121	0
Soft	6	0	49

Concurrent with the present study, Mazor et al. (2023a) conducted a statewide analysis of the effects of channel modification on CSCI and ASCI scores. They found that the CSCI rarely attained high scores in hard-bottom modified channels, whereas the ASCIs rarely attained high scores in soft-bottom modified channels with 0 or 2 hard sides. Both indices frequently attained high scores in soft-bottom modified channels with 1 hard side (perhaps due to the preponderance of this type of modification in less developed watersheds). Statistical distributions of scores at different channel types calculated in that study, which may be used to identify alternative “best observed” thresholds for modified channels, are shown in Table 10.

Table 10. Potential biointegrity index thresholds for different classes of streams. N: number of sites used to calculate percentiles. SB0: Soft-bottom channels with no hardened sides. SB1: Soft-bottom channels with one hardened side. SB2: Soft-bottom channels with two hardened sides. HB: Hard-bottom channels. CC: Constructed channels, or channels with ambiguous watersheds. ND: Insufficient data to make a determination. Data are reproduced from Mazor et al. (2023b).

Threshold type	Population	Index	N	99th percentile	90th percentile	70th percentile
Best observed	SB0	ASCI_D	51	1.01	0.77	0.68
Best observed	SB0	ASCI_H	51	0.94	0.79	0.64
Best observed	SB0	CSCI	78	0.99	0.78	0.66
Best observed	SB1	ASCI_D	36	1.01	0.85	0.68
Best observed	SB1	ASCI_H	36	0.97	0.86	0.67
Best observed	SB1	CSCI	52	1.10	1.00	0.81
Best observed	SB2	ASCI_D	57	0.93	0.77	0.64
Best observed	SB2	ASCI_H	57	0.88	0.76	0.60
Best observed	SB2	CSCI	67	0.96	0.75	0.64
Best observed	HB	ASCI_D	152	1.05	0.88	0.74
Best observed	HB	ASCI_H	152	1.02	0.87	0.74
Best observed	HB	CSCI	203	0.74	0.67	0.55
Best observed	CC	ASCI_D	ND	ND	ND	ND
Best observed	CC	ASCI_H	ND	ND	ND	ND
Best observed	CC	CSCI	65	0.53	0.45	0.37

Indices by Reference and Flow Status

Median scores were significantly higher at reference sites compared with scores at non-reference sites for all five indicators (Figures 76 to 80, Table 11). For example, among perennial streams the median CSCI score was 0.99 at reference sites compared to 0.54 at non-reference sites. Among non-perennial streams, the median CSCI score was 0.85 at reference sites and 0.54 at non-reference sites.

Flow regime (perennial vs non-perennial) did not appear to be related to index scores for most indicators (Figures 76 to 80, Table 11). CSCI was the exception, with a significant difference between perennial and non-perennial sites ($p = 0.001$). A two-way ANOVA also indicated there was an interaction between reference status and flow regime for CSCI ($p = 0.02$). There was no interaction between reference status and flow regime for the other indices.

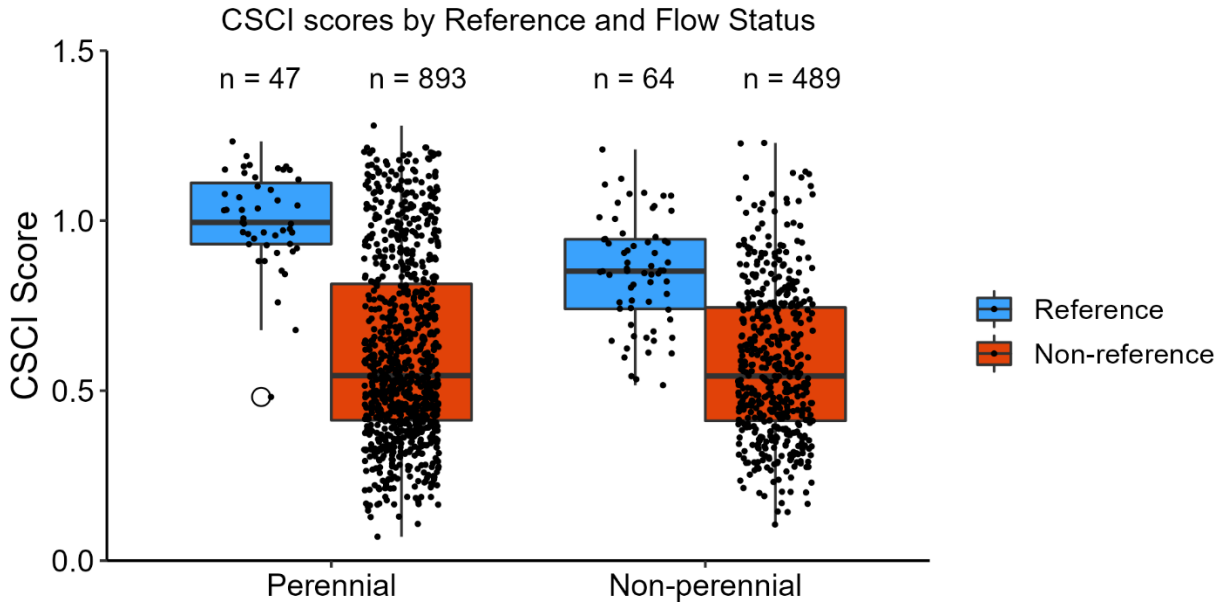


Figure 76. CSCI scores by reference and surface water flow regime. Each point represents the score at a sampling location, with circles representing possible outliers.

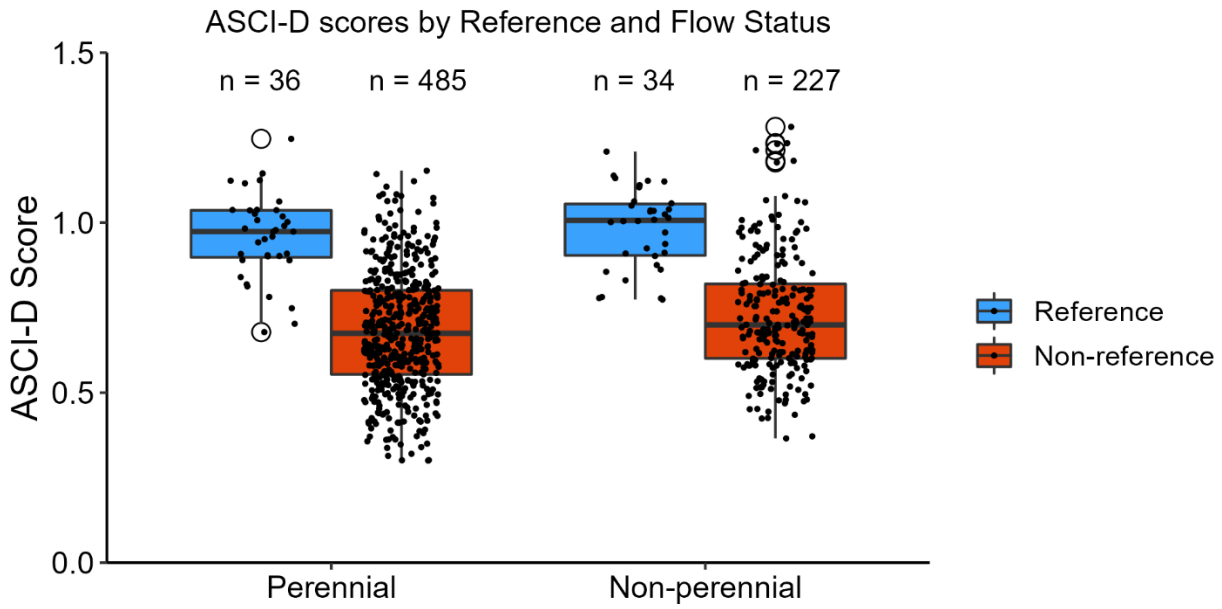


Figure 77. ASCI-D scores by reference and surface water flow regime. Each point represents the score at a sampling location, with circles representing possible outliers.

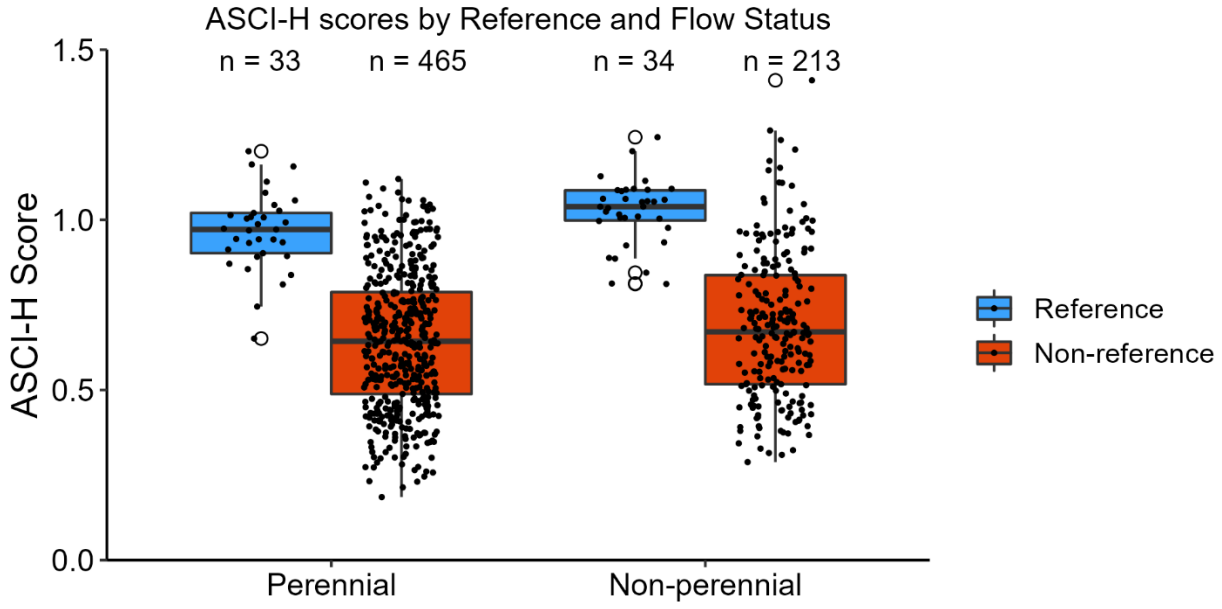


Figure 78. ASCI-H scores by reference and surface water flow regime. Each point represents the score at a sampling location, with circles representing possible outliers.

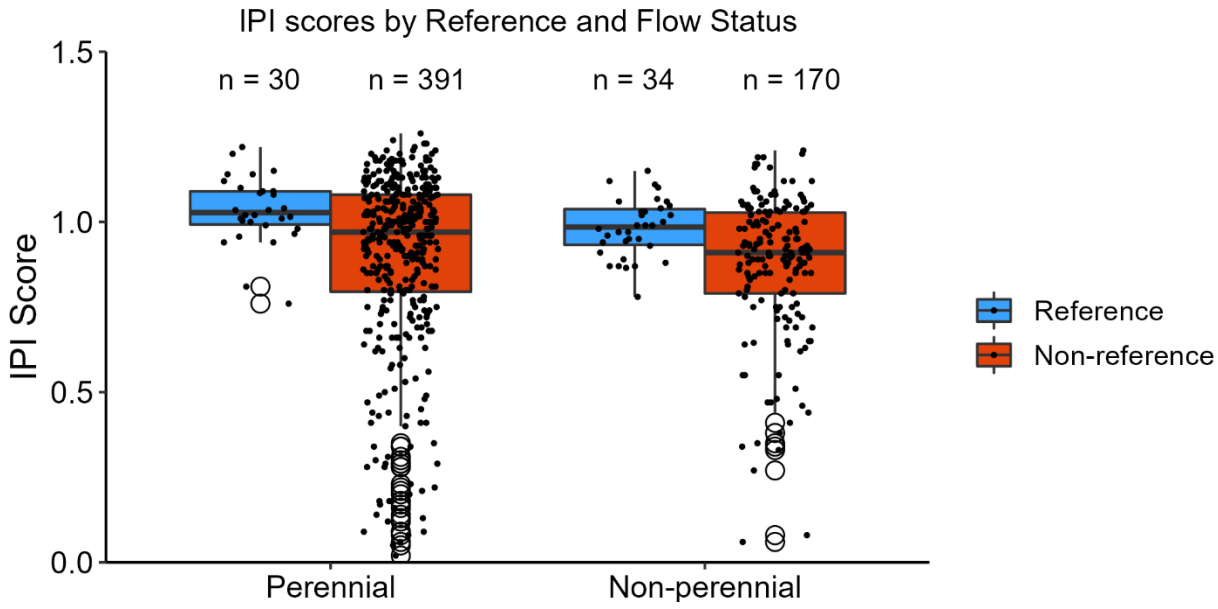


Figure 79. IPI scores by reference and surface water flow regime. Each point represents the score at a sampling location, with circles representing possible outliers.

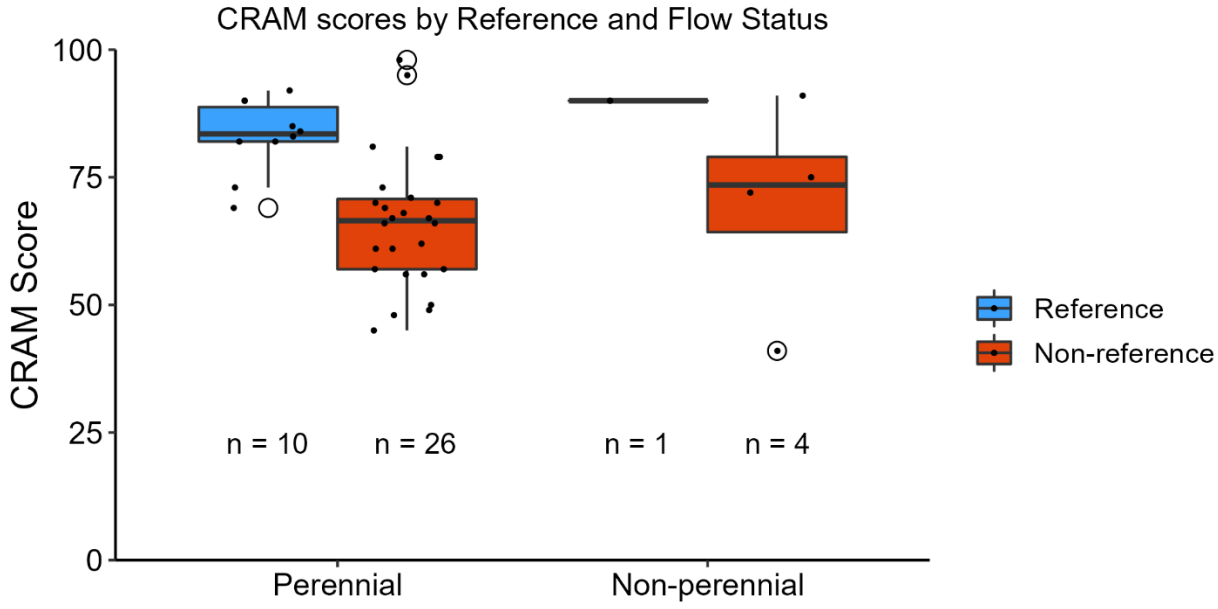


Figure 80. CRAM scores by reference and surface water flow regime. Each point represents the score at a sampling location, with circles representing possible outliers.

Table 11. Results of two-way analysis of variance (ANOVA) testing using reference status and flow regime.

Indicator	Indicator by reference status (p-value)	Indicator by flow regime (p-value)	Interaction between reference status and flow regime (p-value)
CSCI	$<2 \times 10^{-16}$	0.001	0.02
ASCI-D	$<2 \times 10^{-16}$	0.54	0.64
ASCI-H	$<2 \times 10^{-16}$	0.23	0.76
IPI	0.002	0.37	0.61
CRAM	0.001	0.61	0.82

Concurrent with the present study, Mazor et al. (2023a) conducted a statewide analysis of the effects of streamflow duration on CSCI and ASCI scores. They also found that CSCI scores were lower in intermittent streams compared to perennial streams in Northern California, but not in Southern California. They too found that algal index scores at reference were similar at perennial and intermittent reaches. Statistical distributions of scores at intermittent reference sites calculated in that study, which may be used to identify alternative assessment thresholds for intermittent streams, are shown in Table 12.

Table 12. Summary statistics of index scores at regularly flowing intermittent reference streams. N: Number of unique sites. SD: Standard deviation of index scores. Q30, q10 and q01: 30th, 10th, and 1st percentiles of scores at reference sites. Data are reproduced from Mazor et al. (2023a).

Region	Index	N	Mean	SD	q30	q10	q01
Regional Board 2	ASCI_D	21	1.00	0.09	0.97	0.90	0.79
Regional Board 2	ASCI_H	21	0.98	0.10	0.95	0.88	0.74
Regional Board 2	CSCI	67	0.82	0.17	0.73	0.56	0.49
Regional Board 3	ASCI_D	2	0.95	0.01	0.94	0.94	0.94
Regional Board 3	ASCI_H	2	0.93	0.02	0.92	0.92	0.92
Regional Board 3	CSCI	2	0.75	0.02	0.74	0.74	0.73
Regional Board 5	ASCI_D	9	1.11	0.10	1.07	0.99	0.95
Regional Board 5	ASCI_H	9	1.04	0.08	1.02	0.93	0.92
Regional Board 5	CSCI	10	0.63	0.13	0.55	0.48	0.43
Northern regions	ASCI_D	32	1.03	0.11	0.97	0.91	0.80
Northern regions	ASCI_H	32	0.99	0.10	0.95	0.89	0.75
Northern regions	CSCI	79	0.79	0.18	0.69	0.54	0.46
Regional Board 7	ASCI_D	10	1.04	0.07	1.00	0.95	0.93
Regional Board 7	ASCI_H	10	1.02	0.06	0.99	0.97	0.91
Regional Board 7	CSCI	10	0.88	0.09	0.87	0.74	0.72
Regional Board 9	ASCI_D	35	0.97	0.15	0.92	0.78	0.60
Regional Board 9	ASCI_H	35	0.98	0.16	0.91	0.78	0.59
Regional Board 9	CSCI	43	0.96	0.10	0.91	0.86	0.75
Southern regions	ASCI_D	45	0.99	0.14	0.94	0.81	0.61
Southern regions	ASCI_H	45	0.99	0.15	0.92	0.85	0.59
Southern regions	CSCI	53	0.94	0.10	0.89	0.85	0.71
All regions	ASCI_D	77	1.00	0.13	0.95	0.84	0.64
All regions	ASCI_H	77	0.99	0.13	0.94	0.88	0.61
All regions	CSCI	132	0.85	0.17	0.76	0.61	0.47

Chemistry Data

Mean TN concentrations varied by a factor of four among counties, from 0.43 – 1.75 mg/L (Santa Cruz – Alameda), while mean TP varied by a factor of 209 (1 – 209 mg/L, San Francisco – Santa Clara), mean AFDM ranged by a factor of 26 (18 – 472 g/m², Santa Cruz – Contra Costa), and specific conductivity varied by a factor of three (321 – 1037 µS/cm, Marin – Contra Costa) (Figures 81 to 87, Table 13). Because these analyses are based on mean concentrations, it may underestimate the variability in constituent values among sample dates within a site.

Alameda and Contra Costa Counties tended to have the highest mean concentrations of water quality parameters. Mean concentrations of TN were higher at non-reference sites, compared with reference sites (Table 14). Across Water Board Region 2, the mean concentration of TN at non-reference sites was 3.6 times greater than at reference sites. Differences ranged from a factor of 1.6 at San Mateo County to a factor of 6.2 at Sonoma County. There were much fewer reference sites in each county than non-reference sites, which may have influenced the differences observed.

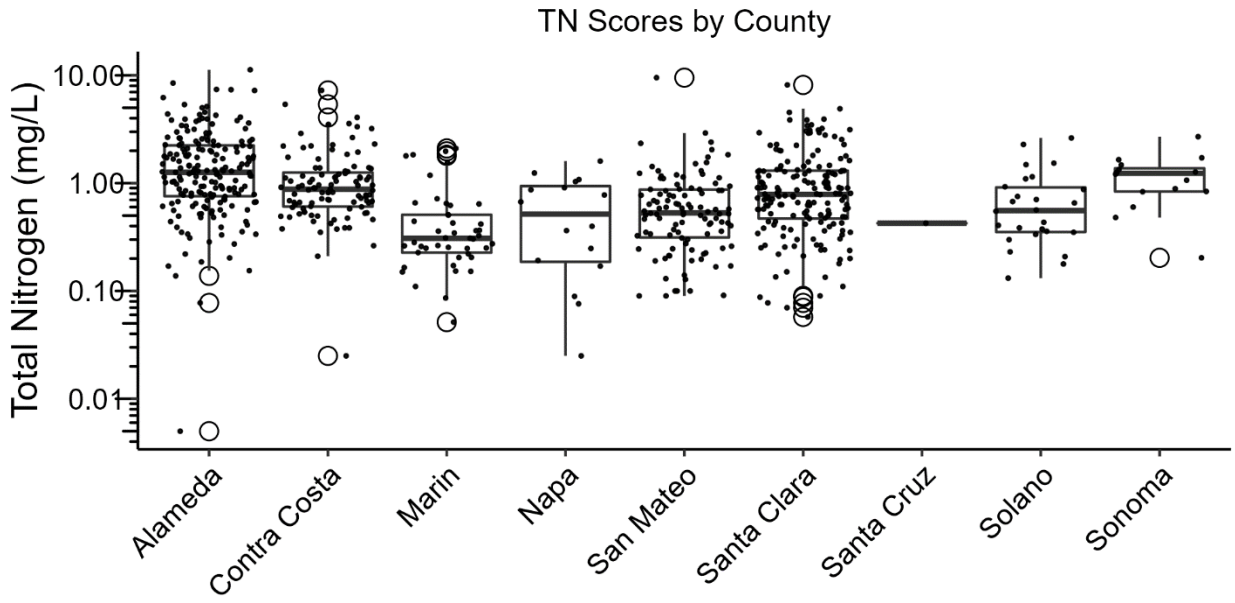


Figure 81. Total nitrogen concentrations by county. Each point represents the value at a sampling location, with circles representing possible outliers.

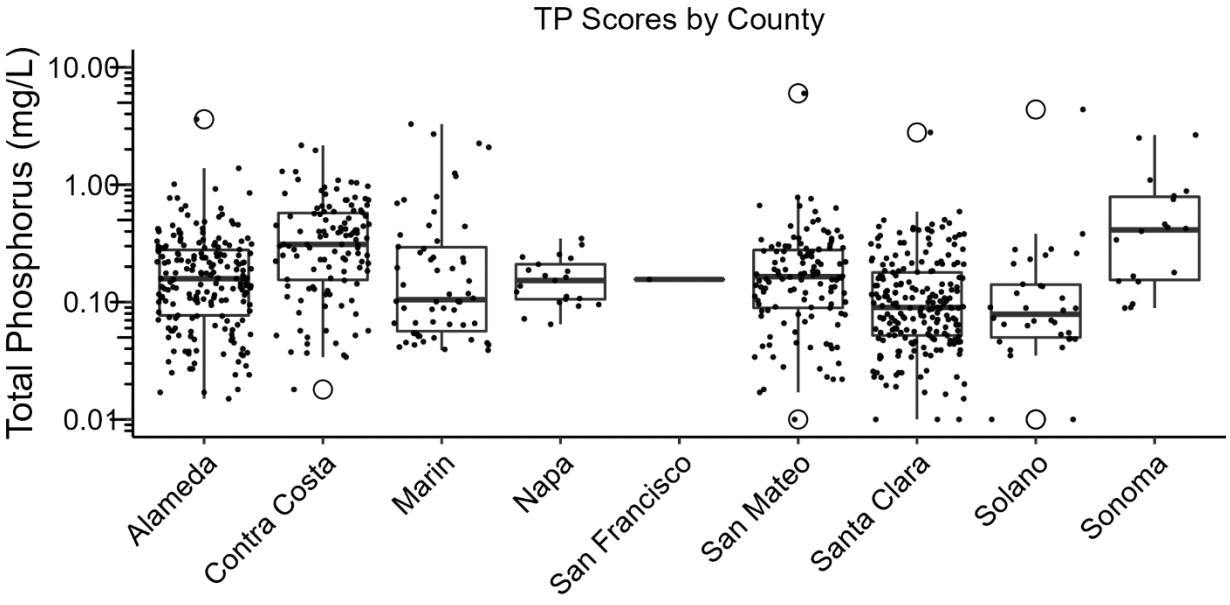


Figure 82. Total phosphorus concentrations by county. Each point represents the value at a sampling location, with circles representing possible outliers.

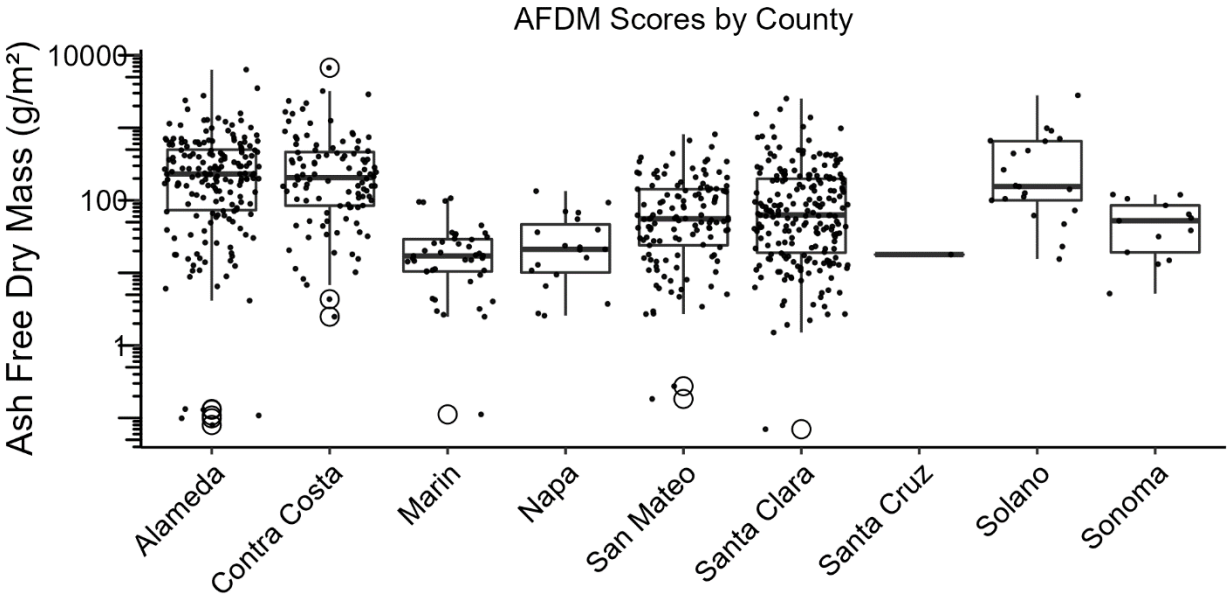


Figure 83. Ash free dry mass concentrations by county. Each point represents the value at a sampling location, with circles representing possible outliers.

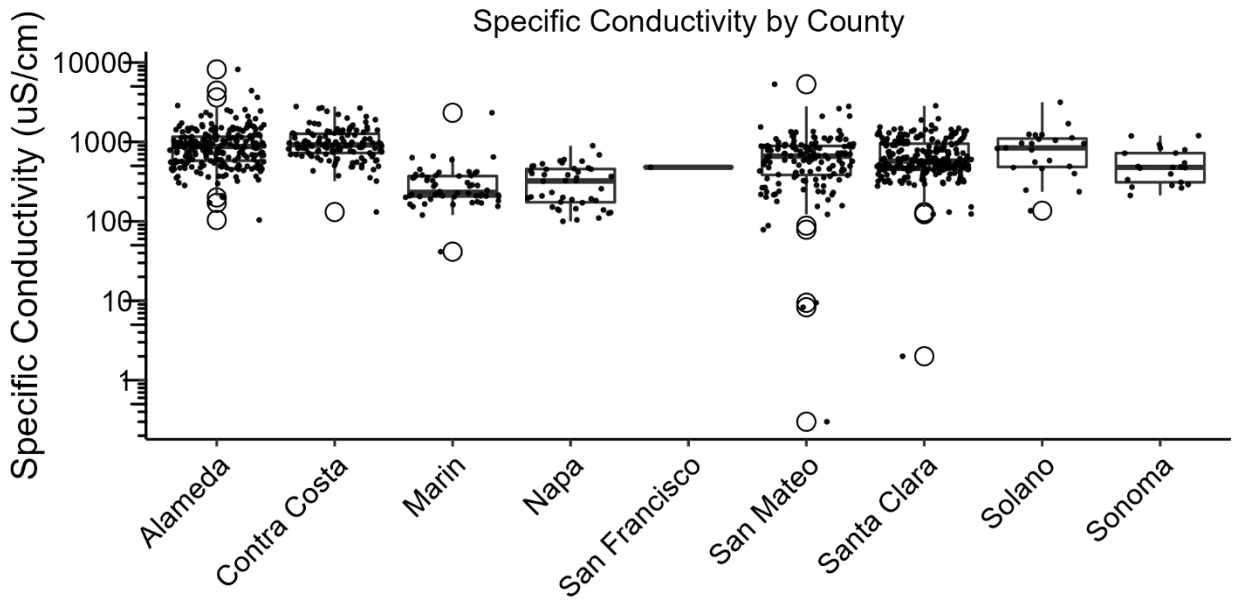


Figure 84. Specific conductivity levels by county. Each point represents the value at a sampling location, with circles representing possible outliers.

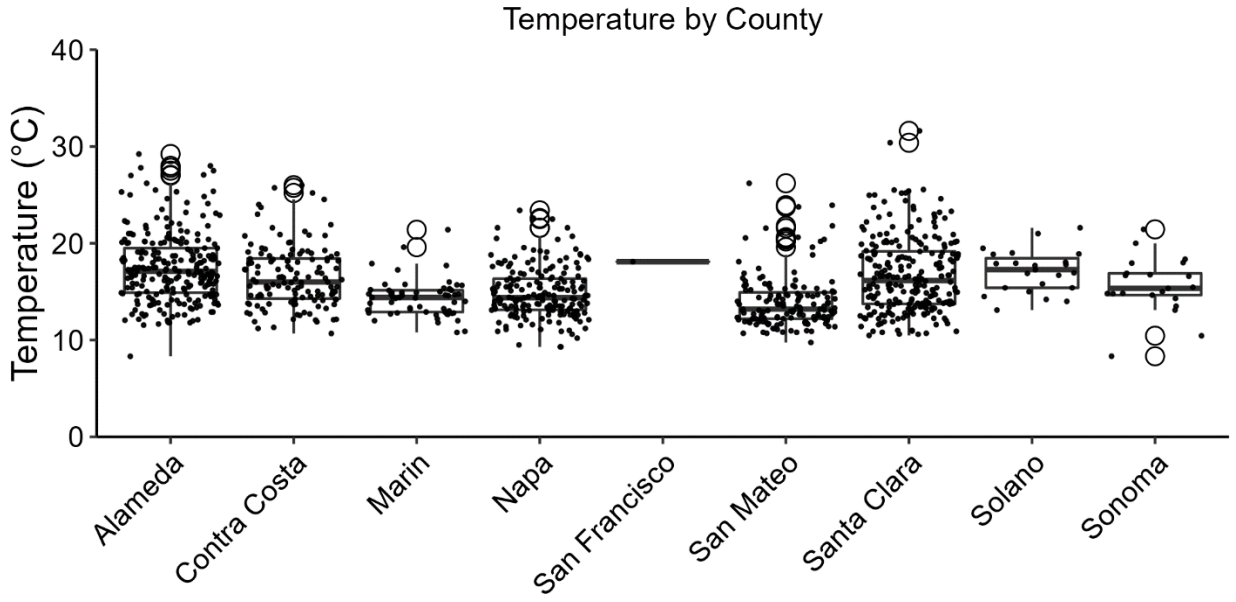


Figure 85. Temperature values by county. Each point represents the value at a sampling location, with circles representing possible outliers.

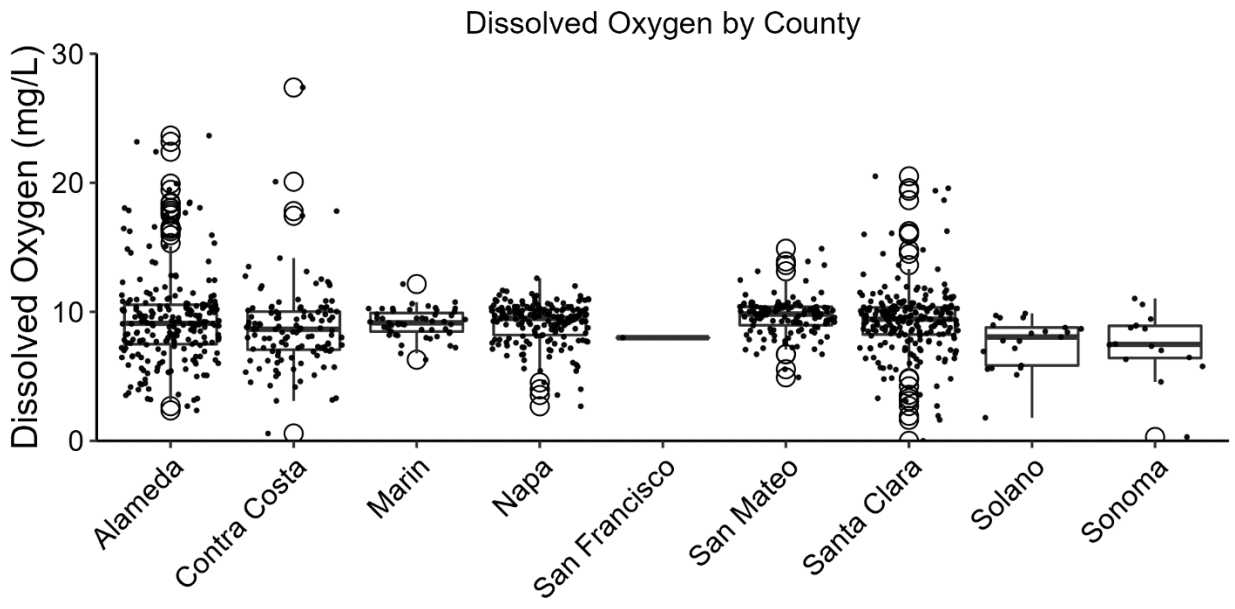


Figure 86. Dissolved oxygen values by county. Each point represents the value at a sampling location, with circles representing possible outliers.

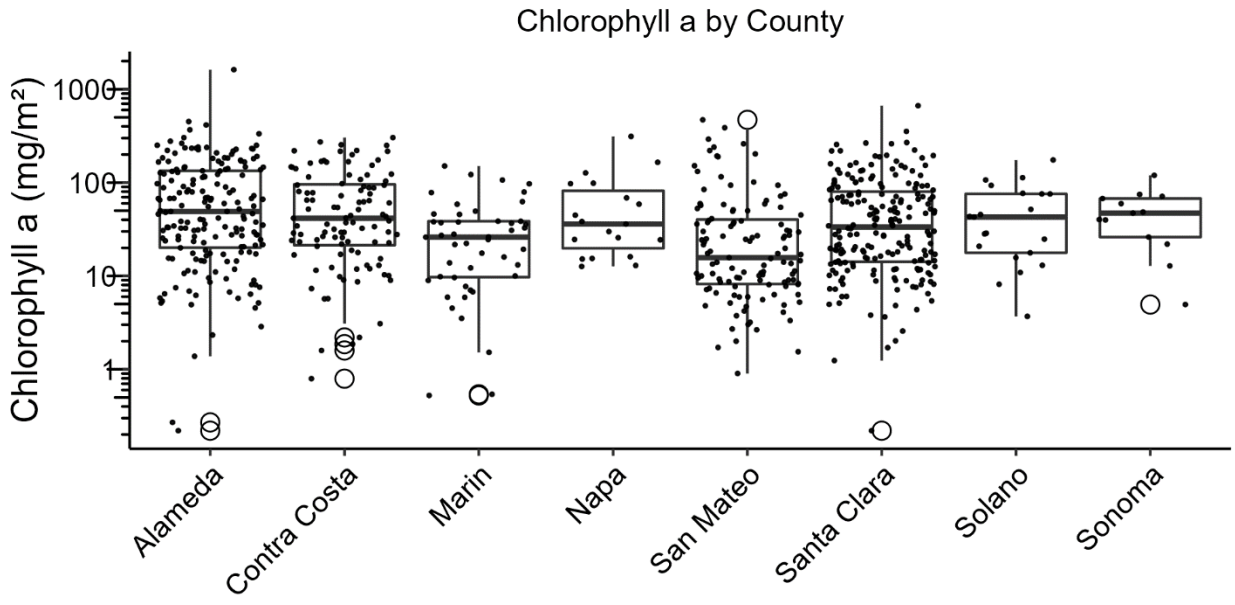


Figure 87. Chlorophyll-a values by county. Each point represents the value at a sampling location, with circles representing possible outliers.

Table 13. Summary of water quality sampling effort and measured values by county and all of Water Board Region 2. NA = no data available.

	Total Nitrogen			Total Phosphorus			Ash Free Dry Mass			Specific Conductivity		
County	N	Mean (mg/L)	SD	N	Mean (mg/L)	SD	N	Mean (g/m^2)	SD	N	Mean (µS/cm)	SD
Alameda	191	1.75	1.62	197	0.23	0.31	180	409	649	235	994	729
Contra Costa	103	1.19	1.07	115	0.42	0.37	104	472	849	131	1037	497
Marin	45	0.51	0.52	58	0.38	0.67	43	25	26	58	321	298
Napa	16	0.61	0.48	21	0.16	0.08	19	34	35	44	328	185
San Francisco	NA	NA	NA	1	0.16	NA	NA	NA	NA	1	479	NA
San Mateo	106	0.75	1.01	126	0.25	0.54	125	106	132	143	718	586
Santa Clara	174	1.12	1.09	209	0.15	0.22	211	167	300	233	704	382
Santa Cruz	1	0.43	NA	NA	NA	NA	1	18	NA	NA	NA	NA
Solano	26	0.75	0.63	34	0.24	0.74	21	430	622	23	901	628
Sonoma	16	1.17	0.58	18	0.65	0.76	13	56	41	21	557	295
Water Board Region 2	678	1.18	1.25	779	0.26	0.43	717	255	524	889	790	581

Table 13 (continued)

	Temperature			Dissolved Oxygen			Chlorophyll a		
County	N	Mean (°C)	SD	N	Mean (mg/L)	SD	N	Mean (mg/m²)	SD
Alameda	237	17.5	3.6	224	9.4	3.6	182	93	144
Contra Costa	130	16.6	3.2	120	8.8	3.3	103	70	70
Marin	58	14.3	1.9	51	9.1	1.1	47	33	33
Napa	186	14.9	2.6	177	9.1	1.6	19	64	74
San Francisco	1	18.1	0.0	1	8.0	0.0	NA	NA	NA
San Mateo	143	14.0	2.8	130	9.6	1.4	119	45	75
Santa Clara	234	16.7	3.9	224	9.3	2.6	208	60	75
Santa Cruz	NA	NA	NA	NA	NA	NA	NA	NA	NA
Solano	23	17.1	2.2	21	7.5	2.0	21	51	44
Sonoma	21	15.6	2.9	16	7.4	2.6	13	49	31
Water Board Region 2	1,033	16.0	3.5	964	9.2	2.7	712	65	96

Table 14. Summary of water quality sampling effort and measured values at reference and non-reference sites by county and all of Water Board Region 2. NA = no data available.

	Total Nitrogen (Reference)			Total Nitrogen (Non-reference)			Total Phosphorus (Reference)			Total Phosphorus (Non-reference)		
County	N	Mean (mg/L)	SD	N	Mean (mg/L)	SD	N	Mean (mg/L)	SD	N	Mean (mg/L)	SD
Alameda	2	0.80	0.91	189	1.76	1.62	3	1.23	2.06	194	0.21	0.19
Contra Costa	1	0.38	0.00	102	1.20	1.07	4	0.28	0.19	111	0.42	0.37
Marin	7	0.19	0.10	38	0.57	0.55	11	0.10	0.07	47	0.44	0.73
Napa	3	0.13	0.09	13	0.72	0.47	4	0.18	0.08	17	0.16	0.08
San Francisco	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	0.16	0.00
San Mateo	7	0.48	0.59	99	0.77	1.03	11	0.12	0.11	115	0.26	0.56
Santa Clara	10	0.32	0.26	164	1.17	1.10	26	0.06	0.05	183	0.16	0.23
Santa Cruz	NA	NA	NA	1	0.43	0.00	NA	NA	NA	NA	NA	NA
Solano	NA	NA	NA	26	0.75	0.63	1	0.28	NA	33	0.24	0.75
Sonoma	1	0.20	0.00	15	1.24	0.54	1	0.15	NA	17	0.68	0.78
Water Board Region 2	31	0.34	0.39	647	1.23	1.27	61	0.16	0.46	718	0.26	0.43

Table 14 (continued)

	AFDM (Reference)			AFDM (Non-reference)			Specific Conductivity (Reference)			Specific Conductivity (Non-reference)		
County	N	Mean (g/m^2)	SD	N	Mean (g/m^2)	SD	N	Mean (µS/cm)	SD	N	Mean (µS/cm)	SD
Alameda	3	14.0	1.6	177	415.7	652.5	7	579	251	228	1007	735
Contra Costa	2	50.2	7.6	102	480.3	855.1	4	650	208	127	1049	499
Marin	9	13.3	12.4	34	27.8	28.2	12	299	74	46	327	334
Napa	4	8.6	9.5	15	40.9	36.8	7	318	188	37	330	187
San Francisco	NA	NA	NA	NA	NA	NA	NA	NA	NA	1	479	0
San Mateo	14	68.6	90.4	111	111.2	136.1	15	468	228	128	748	609
Santa Clara	31	27.2	25.9	180	191.3	318.1	31	492	152	202	737	396
Santa Cruz	NA	NA	NA	1	17.9	0.0	NA	NA	NA	NA	NA	NA
Solano	1	15.5	NA	20	450.5	630.9	1	236	NA	22	932	625
Sonoma	1	13.2	NA	12	59.4	40.3	3	264	50	18	605	291
Water Board Region 2	65	32.7	49.2	652	277.1	544.1	80	447	198	809	824	595

Table 14 (continued)

	Temperature (Reference)			Temperature (Non-reference)			Dissolved Oxygen (Reference)			Dissolved Oxygen (Non-reference)		
County	N	Mean (°C)	SD	N	Mean (°C)	SD	N	Mean (mg/L)	SD	N	Mean (mg/L)	SD
Alameda	7	14.9	2.8	230	17.6	3.6	7	8.7	1.0	217	9.4	3.7
Contra Costa	4	13.6	2.5	126	16.7	3.1	2	9.9	0.3	118	8.7	3.3
Marin	12	13.3	1.4	46	14.6	1.9	11	9.4	1.0	40	9.0	1.1
Napa	19	14.9	2.9	167	14.9	2.6	18	8.8	1.3	159	9.2	1.6
San Francisco	NA	NA	NA	1	18.1	0.0	NA	NA	NA	1	8.0	0.0
San Mateo	15	12.0	0.9	128	14.2	2.9	14	9.7	1.5	116	9.6	1.4
Santa Clara	31	15.7	3.7	203	16.9	3.9	31	9.2	1.1	193	9.3	2.8
Santa Cruz	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Solano	1	13.1	NA	22	17.3	2.1	1	9.5	0.0	20	7.4	2.0
Sonoma	3	14.2	1.0	18	15.8	3.1	1	8.9	0.0	15	7.3	2.6
Water Board Region 2	92	14.4	3.0	941	16.2	3.5	85	9.2	1.2	879	9.2	2.8

Table 14 (continued)

	Chlorophyll a (Reference)			Chlorophyll a (Non-reference)		
County	N	Mean (mg/m²)	SD	N	Mean (mg/m²)	SD
Alameda	3	21.6	14.6	179	94.4	144.5
Contra Costa	2	14.2	1.6	101	71.6	70.7
Marin	11	19.4	27.8	36	37.7	33.8
Napa	4	17.3	5.1	15	77.0	78.7
San Francisco	NA	NA	NA	NA	NA	NA
San Mateo	14	9.7	6.6	105	49.2	79.1
Santa Clara	30	28.4	31.4	178	65.7	78.7
Santa Cruz	NA	NA	NA	NA	NA	NA
Solano	1	8.1	0.0	20	53.1	43.7
Sonoma	1	47.1	0.0	12	48.9	32.0
Water Board Region 2	66	21.5	25.4	646	69.9	99.1

Association between Index Scores and Water Quality Stressors

Correlation analysis

Index scores decreased with increasing levels of TN, TP, AFDM, specific conductivity, temperature and chlorophyll a, and increased with increasing levels of dissolved oxygen (Figures 88 to 90, Table 15). Each of the correlations were statistically significant ($p<0.001$), and for TN, AFDM and specific conductivity the relationship was relatively strong (rho < -0.50). Temperature was strongly associated with ASCI scores (rho -0.51), and less with CSCI scores (rho = -0.44). Dissolved oxygen was positively correlated with CSCI and ASCI scores, with rho = 0.28 for each comparison.

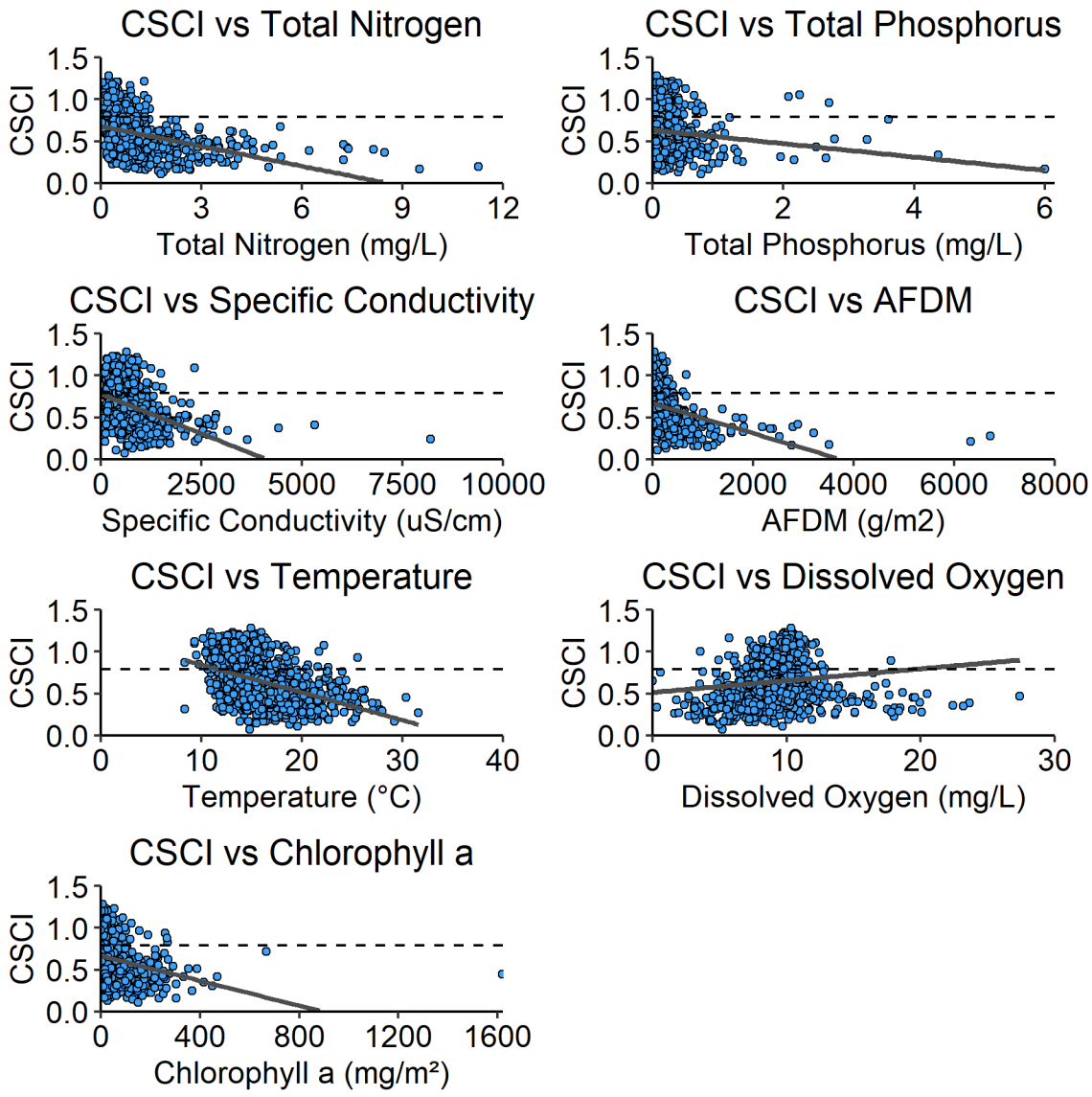


Figure 88. CSCI vs chemistry stressors. The dashed horizontal line is the 10th percentile reference threshold, and the grey line indicates the linear regression line.

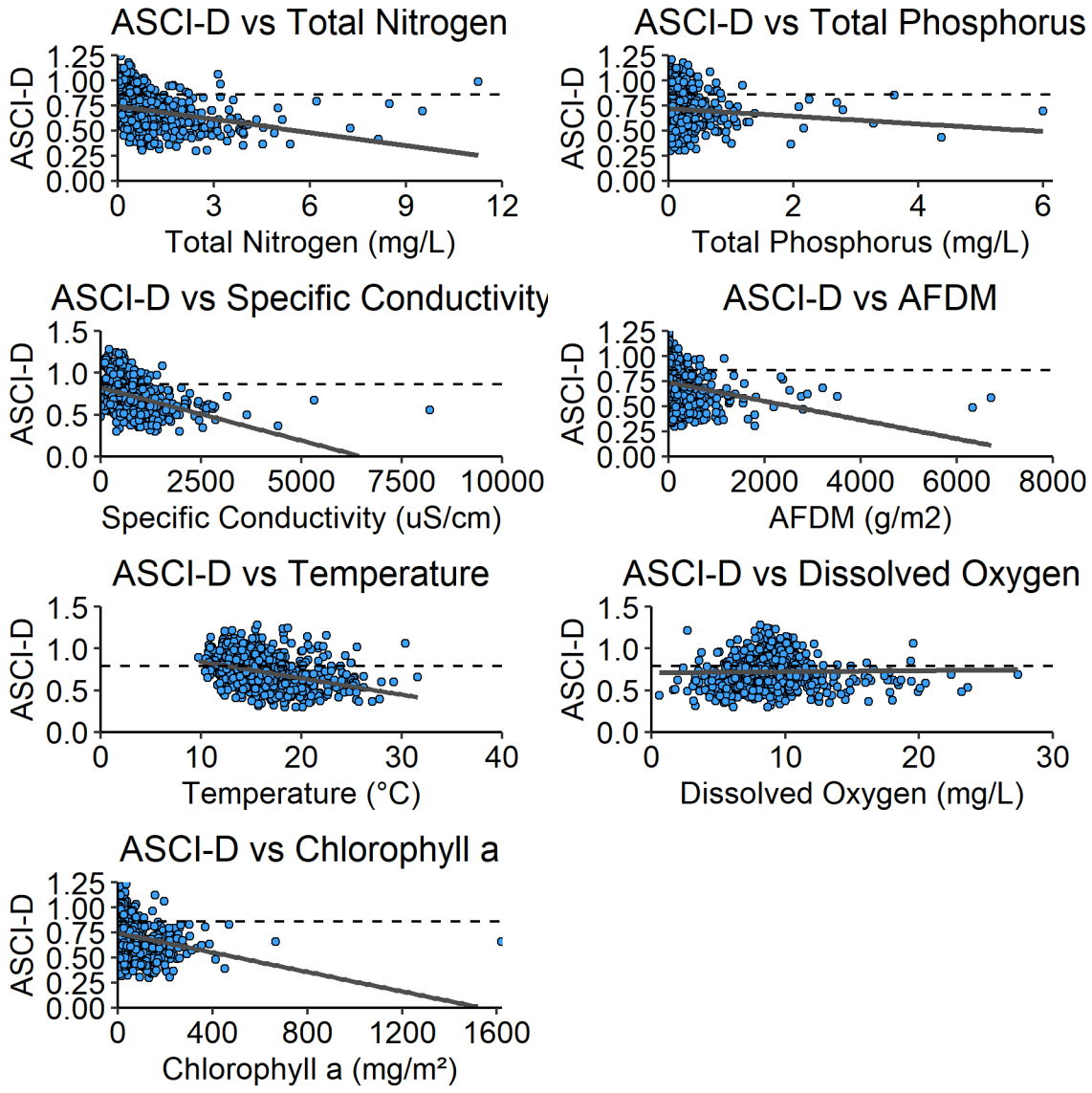


Figure 89. ASCI-D vs chemistry stressors. The dashed horizontal line is the 10th percentile reference threshold, and the grey line indicates the linear regression line.

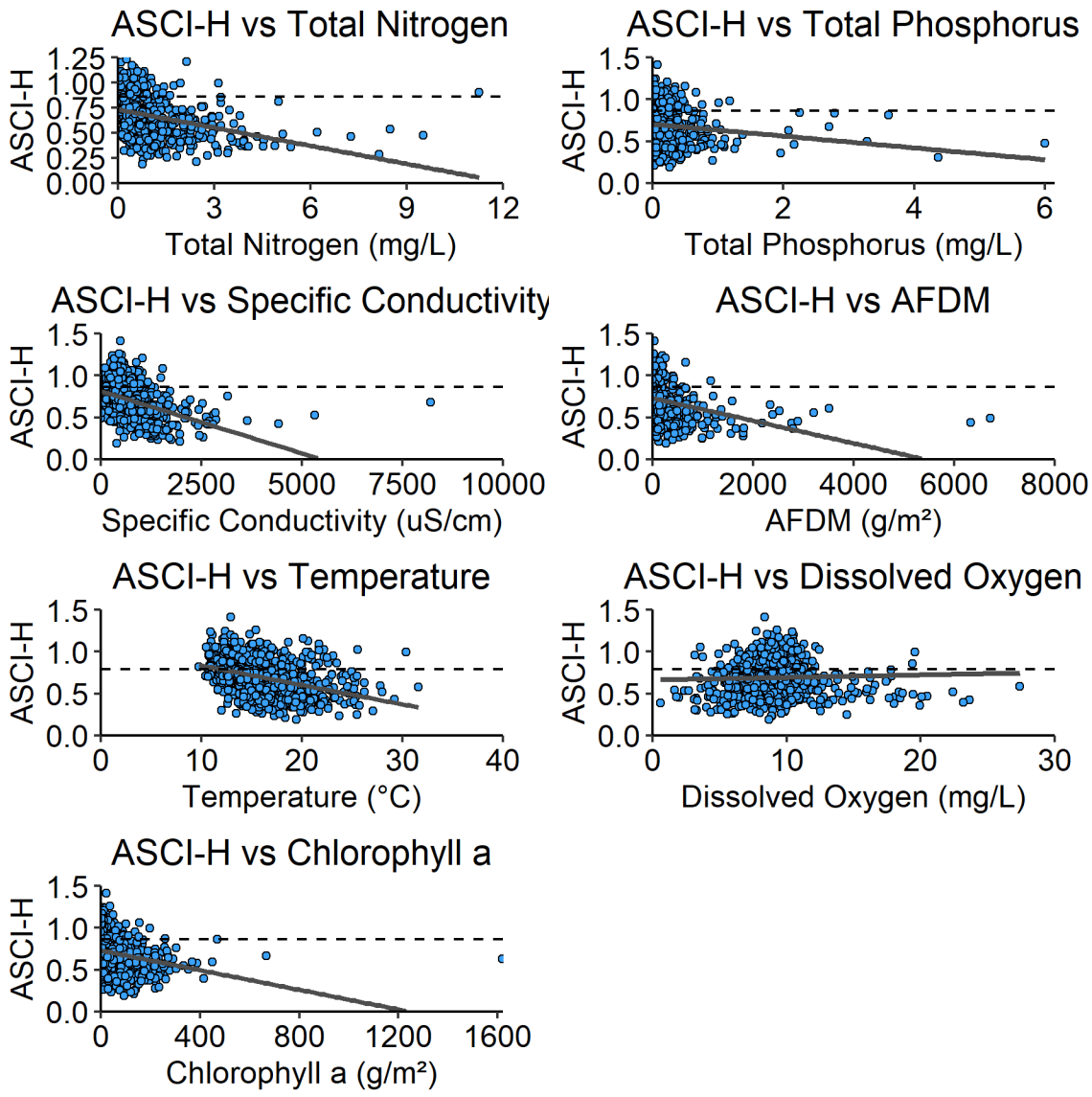


Figure 90. ASCI-H vs chemistry stressors. The dashed horizontal line is the 10th percentile reference threshold and the grey line indicates the linear regression line.

Table 15. Spearman rank correlation analysis of index scores and water quality parameters.

Index	Parameter	N	Spearman p	Spearman rho	Rho squared
CSCI	TN	671	<0.001	-0.51	0.26
CSCI	TP	768	<0.001	-0.18	0.03
CSCI	Specific Conductance	875	<0.001	-0.53	0.32
CSCI	AFDM	705	<0.001	-0.57	0.28
CSCI	Temperature	1,019	<0.001	-0.44	0.20
CSCI	Dissolved Oxygen	953	<0.001	0.28	0.08
CSCI	Chlorophyll a	700	<0.001	-0.41	0.16
ASCI-D	TN	592	<0.001	-0.52	0.27
ASCI-D	TP	682	<0.001	-0.18	0.03
ASCI-D	Specific Conductance	762	<0.001	-0.55	0.33
ASCI-D	AFDM	703	<0.001	-0.58	0.30
ASCI-D	Temperature	763	<0.001	-0.51	0.26
ASCI-D	Dissolved Oxygen	746	<0.001	0.28	0.08
ASCI-D	Chlorophyll a	698	<0.001	-0.40	0.16
ASCI-H	TN	584	<0.001	-0.52	0.27
ASCI-H	TP	669	<0.001	-0.18	0.03
ASCI-H	Specific Conductance	726	<0.001	-0.55	0.33
ASCI-H	AFDM	689	<0.001	-0.58	0.31
ASCI-H	Temperature	726	<0.001	-0.51	0.26
ASCI-H	Dissolved Oxygen	709	<0.001	0.28	0.08
ASCI-H	Chlorophyll a	684	<0.001	-0.40	0.16

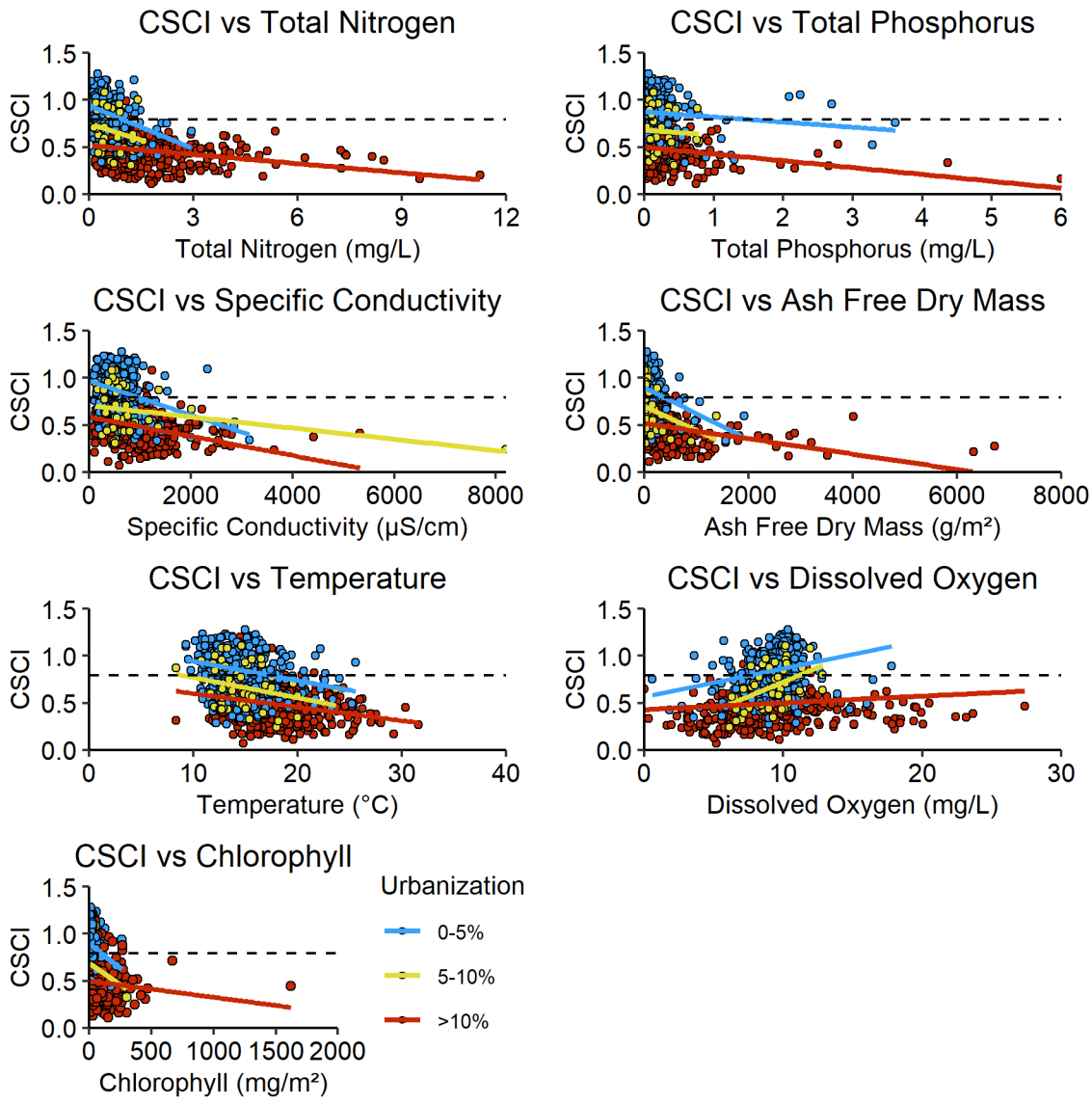


Figure 91. CSCI vs chemistry stressors, by level of urbanization within 1km. The dashed horizontal line is the 10th percentile reference threshold, and the other lines indicate the linear regression lines.

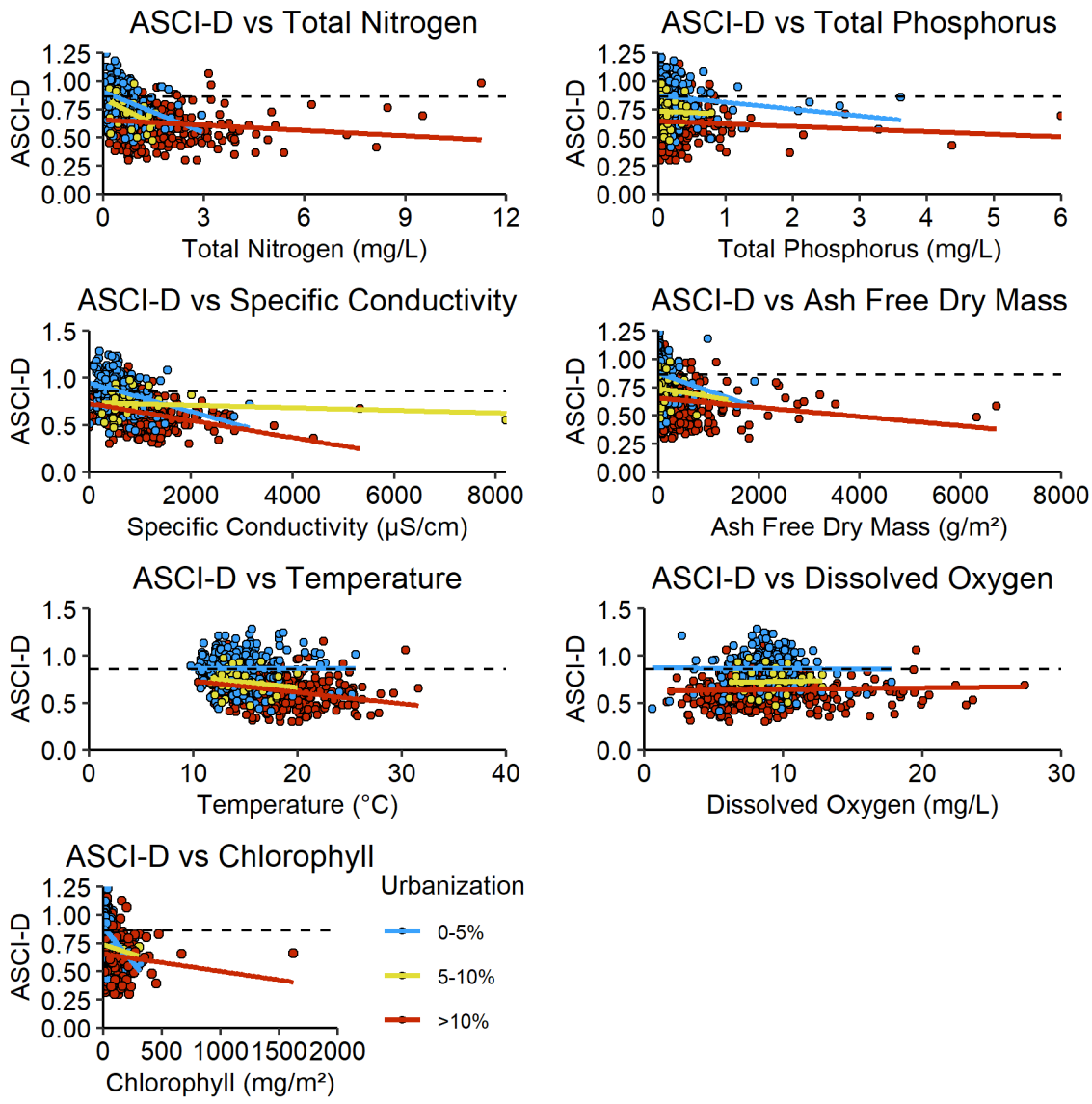


Figure 92. ASCI-D vs chemistry stressors, by level of urbanization within 1km. The dashed horizontal line is the 10th percentile reference threshold, and the other lines indicate the linear regression lines.

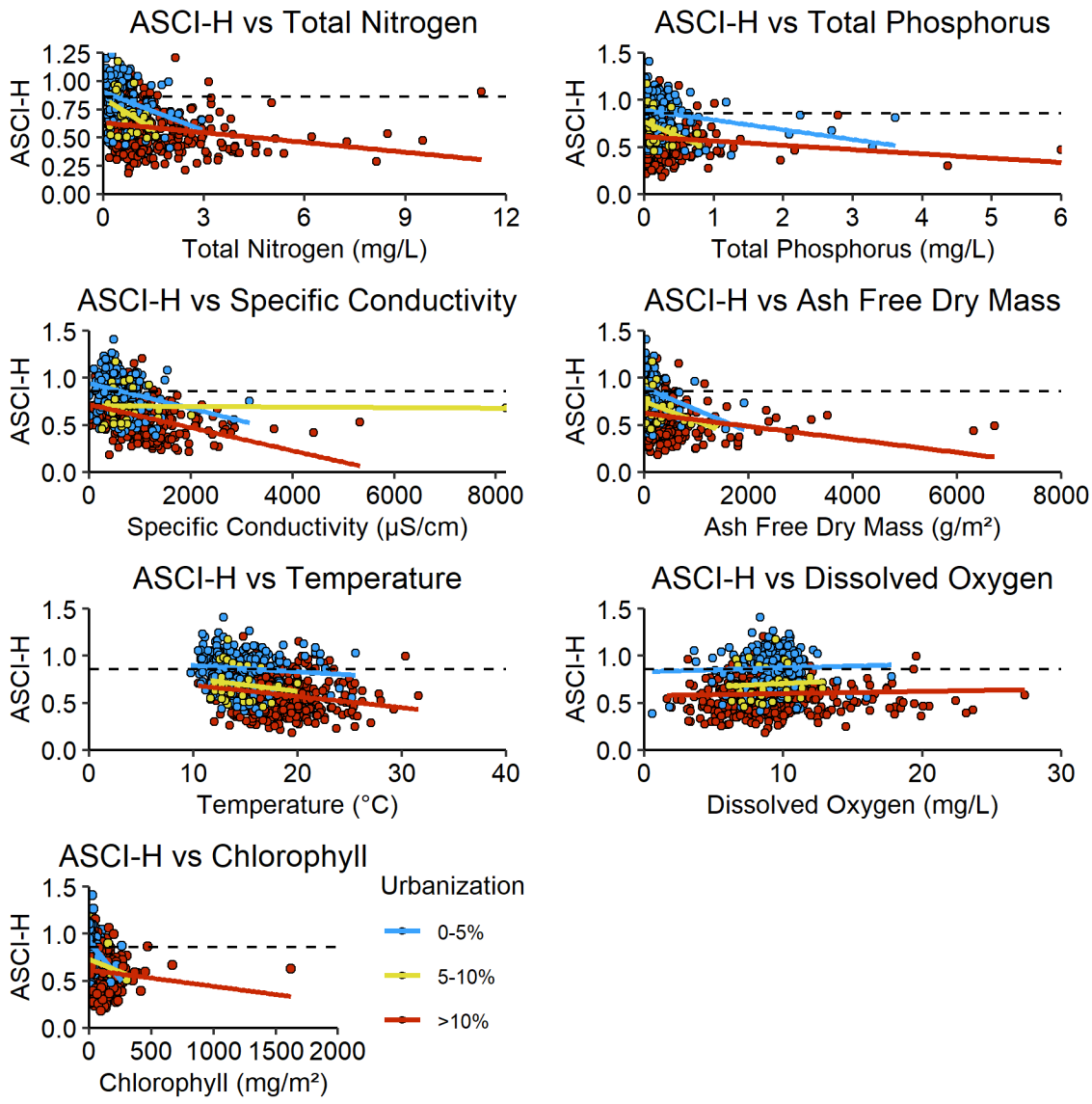


Figure 93. ASCI-H vs chemistry stressors, by level of urbanization within 1km. The dashed horizontal line is the 10th percentile reference threshold, and the other lines indicate the linear regression lines.

Table 16. Spearman rank correlation analysis of index scores and water quality parameters, by level of urbanization. Low = 0 – 5%, Medium = 5 – 10%, High = >10%.

Index	Parameter	Urbanization	N	Spearman p	Spearman rho	Rho squared
CSCI	TN	Low	183	<0.001	-0.32	0.10
CSCI	TN	Medium	34	0.20	-0.22	0.05
CSCI	TN	High	457	<0.001	-0.31	0.10
CSCI	TP	Low	244	0.68	-0.03	<0.001
CSCI	TP	Medium	42	0.67	-0.07	<0.001
CSCI	TP	High	485	<0.001	-0.18	0.03
CSCI	AFDM	Low	241	<0.001	-0.30	0.09
CSCI	AFDM	Medium	35	0.09	-0.30	0.09
CSCI	AFDM	High	440	<0.001	-0.42	0.18
CSCI	Specific Conductance	Low	296	<0.001	-0.26	0.07
CSCI	Specific Conductance	Medium	47	0.11	-0.24	0.06
CSCI	Specific Conductance	High	535	<0.001	-0.41	0.17
CSCI	Temperature	Low	406	<0.001	-0.24	0.06
CSCI	Temperature	Medium	56	0.14	-0.20	0.04
CSCI	Temperature	High	560	<0.001	-0.27	0.07
CSCI	Dissolved Oxygen	Low	382	<0.001	0.28	0.08
CSCI	Dissolved Oxygen	Medium	50	0.001	0.45	0.20
CSCI	Dissolved Oxygen	High	524	<0.001	0.25	0.06

Index	Parameter	Urbanization	N	Spearman p	Spearman rho	Rho squared
CSCI	Chlorophyll	Low	230	0.05	-0.13	0.02
CSCI	Chlorophyll	Medium	34	0.16	-0.25	0.06
CSCI	Chlorophyll	High	439	<0.001	-0.19	0.03
ASCI-D	TN	Low	160	<0.001	-0.35	0.12
ASCI-D	TN	Medium	27	0.02	-0.46	0.21
ASCI-D	TN	High	408	<0.001	-0.26	0.07
ASCI-D	TP	Low	213	0.007	-0.18	0.03
ASCI-D	TP	Medium	32	0.36	-0.17	0.03
ASCI-D	TP	High	440	0.08	-0.08	0.01
ASCI-D	AFDM	Low	235	<0.001	-0.27	0.08
ASCI-D	AFDM	Medium	33	0.68	-0.07	0.01
ASCI-D	AFDM	High	438	<0.001	-0.30	0.09
ASCI-D	Specific Conductance	Low	257	<0.001	-0.30	0.09
ASCI-D	Specific Conductance	Medium	36	0.07	0.30	0.09
ASCI-D	Specific Conductance	High	472	<0.001	-0.41	0.17

Index	Parameter	Urbanization	N	Spearman p	Spearman rho	Rho squared
ASCI-D	Temperature	Low	259	0.97	0.002	<0.001
ASCI-D	Temperature	Medium	36	0.27	-0.19	0.04
ASCI-D	Temperature	High	471	<0.001	-0.35	0.13
ASCI-D	Dissolved Oxygen	Low	256	0.23	-0.08	0.01
ASCI-D	Dissolved Oxygen	Medium	36	0.85	0.03	<0.001
ASCI-D	Dissolved Oxygen	High	457	0.09	0.08	0.01
ASCI-D	Chlorophyll	Low	229	<0.001	-0.23	0.05
ASCI-D	Chlorophyll	Medium	32	0.04	-0.37	0.13
ASCI-D	Chlorophyll	High	440	<0.001	-0.21	0.04
ASCI-H	TN	Low	158	<0.001	-0.29	0.09
ASCI-H	TN	Medium	25	0.07	-0.37	0.14
ASCI-H	TN	High	404	<0.001	-0.29	0.09
ASCI-H	TP	Low	208	<0.001	-0.28	0.08
ASCI-H	TP	Medium	30	0.01	-0.46	0.21

Index	Parameter	Urbanization	N	Spearman p	Spearman rho	Rho squared
ASCI-H	TP	High	434	0.004	-0.14	0.02
ASCI-H	AFDM	Low	230	<0.001	-0.29	0.08
ASCI-H	AFDM	Medium	31	0.08	-0.32	0.10
ASCI-H	AFDM	High	431	<0.001	-0.41	0.17
ASCI-H	Specific Conductance	Low	235	0.002	-0.20	0.04
ASCI-H	Specific Conductance	Medium	34	0.81	0.04	<0.001
ASCI-H	Specific Conductance	High	460	<0.001	-0.48	0.23
ASCI-H	Temperature	Low	236	0.07	-0.12	0.01
ASCI-H	Temperature	Medium	34	0.36	-0.16	0.03
ASCI-H	Temperature	High	459	<0.001	-0.28	0.08
ASCI-H	Dissolved Oxygen	Low	233	0.91	0.01	<0.001
ASCI-H	Dissolved Oxygen	Medium	34	0.31	0.18	0.03
ASCI-H	Dissolved Oxygen	High	445	0.01	0.12	0.01
ASCI-H	Chlorophyll	Low	224	<0.001	-0.26	0.07

Index	Parameter	Urbanization	N	Spearman p	Spearman rho	Rho squared
ASCI-H	Chlorophyll	Medium	30	0.13	-0.28	0.08
ASCI-H	Chlorophyll	High	433	<0.001	-0.21	0.04

Logistic regressions

The probability of having an intact index score (i.e., scores $\geq$10th percentile reference threshold) decreased with increasing levels of TN, TP, AFDM, specific conductivity, temperature and chlorophyll (Figures 94 to 96, Table 17). The relationship was significant for most index:parameter combinations, with the exception of CSCI:TP (p=0.06), ASCI-D:dissolved oxygen (p=0.95) and ASCI-H:dissolved oxygen (p=0.90).

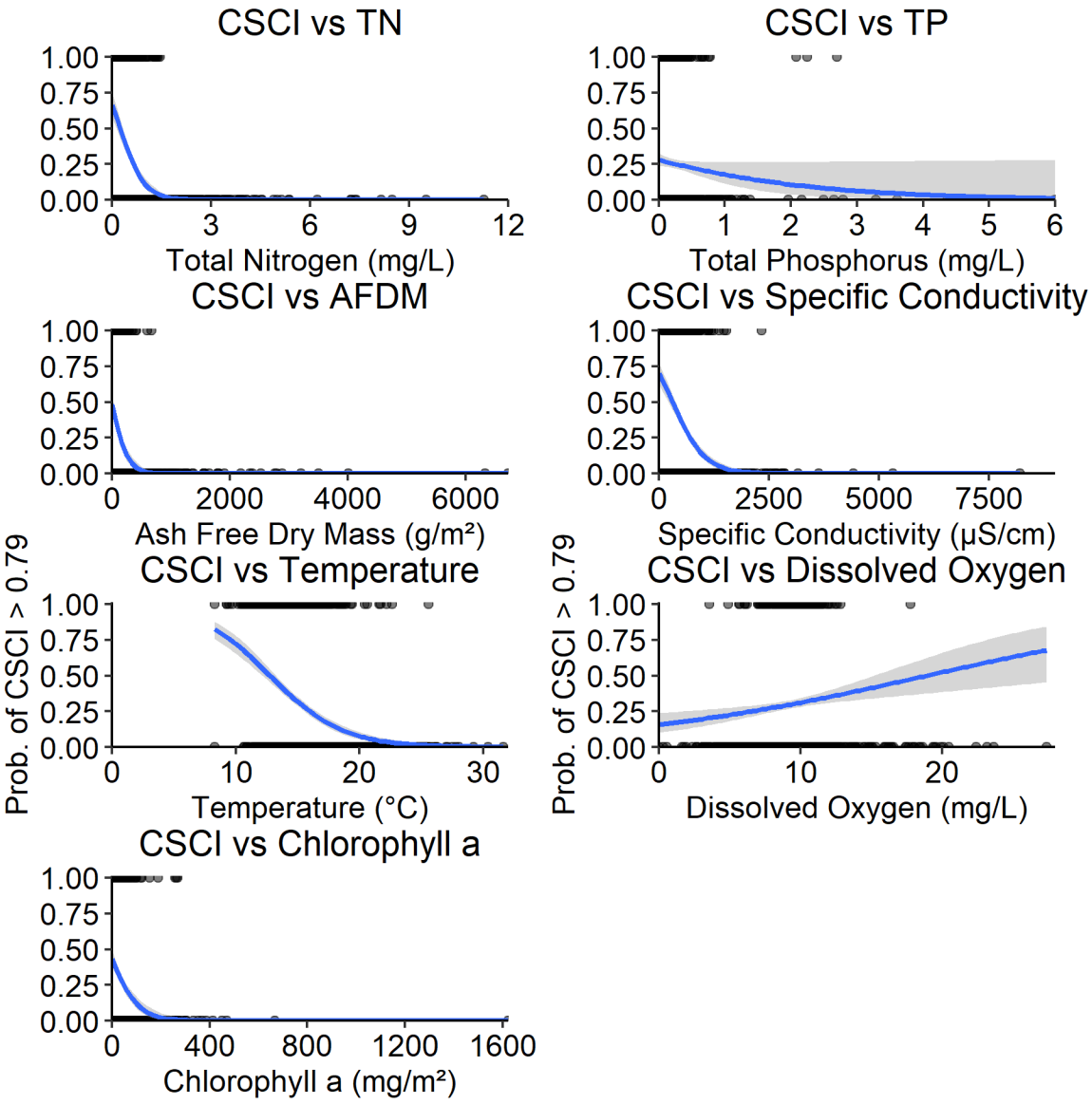


Figure 94. Logistic regression of the probability of CSCI scores above 0.79 with water quality parameter concentrations.

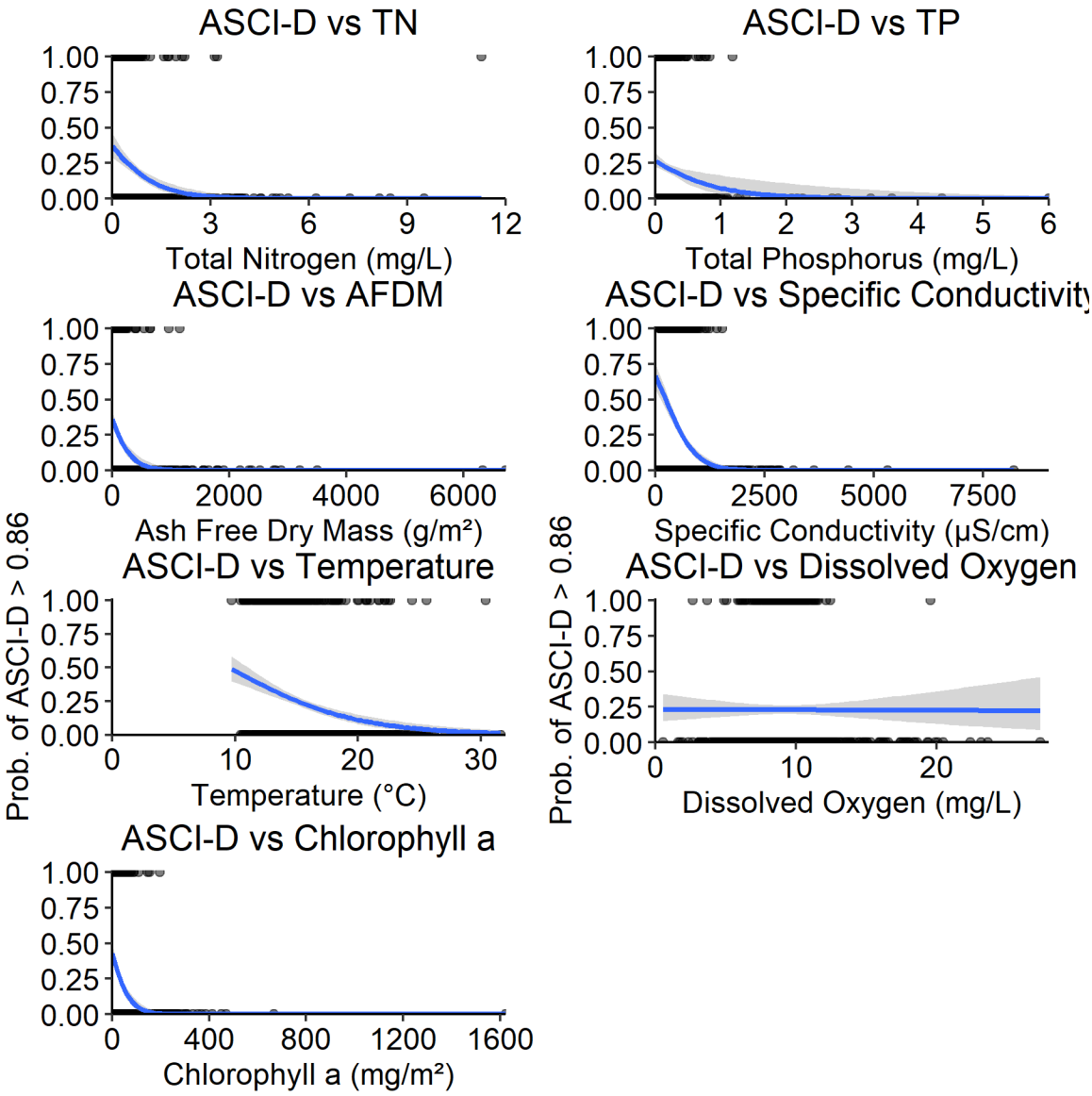


Figure 95. Logistic regression of the probability of ASCI-D scores above 0.86 with water quality parameter concentrations.

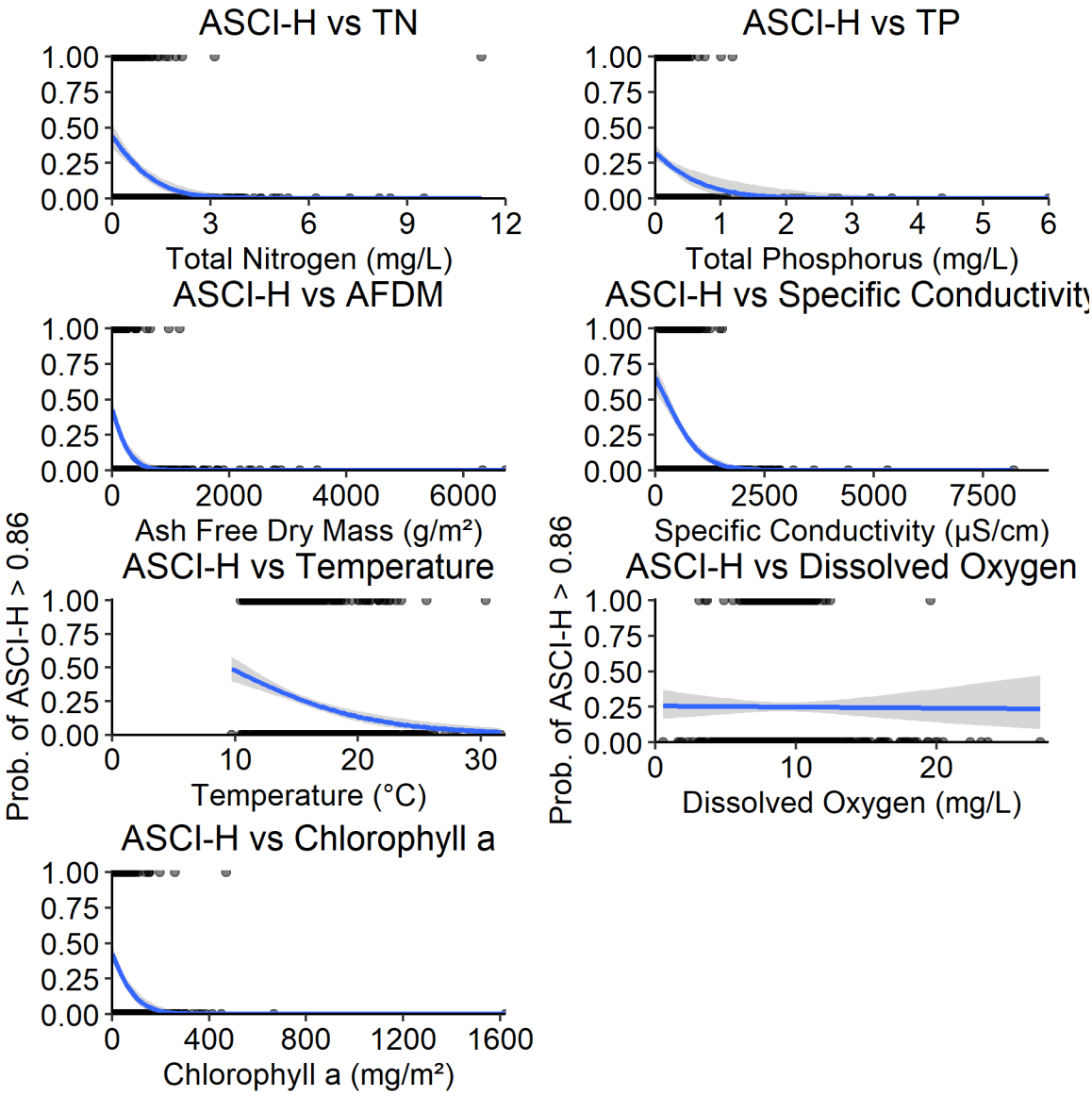


Figure 96. Logistic regression of the probability of ASCI-H scores above 0.86 with water quality parameter concentrations.

Table 17. Simple logistic regression summary statistics for CSCI, ASCI-D and ASCI-H scores based on the 10th percentile of reference threshold vs water quality parameters. The coefficient shows the change in the log odds for the outcome for a one unit increase in the predictor variable.

Index	Stressor	Coefficient	Std Error	p-value
CSCI	TN	-2.74	0.315	<0.001
CSCI	TP	-0.58	0.307	0.06
CSCI	AFDM	-0.007	0.001	<0.001
CSCI	Specific Conductance	-0.003	0.0003	<0.001
CSCI	Temperature	-0.34	0.03	<0.001
CSCI	Dissolved Oxygen	0.09	0.03	0.001
CSCI	Chlorophyll a	-0.02	0.003	<0.001
ASCI-D	TN	-1.20	0.23	<0.001
ASCI-D	TP	-1.51	0.53	0.005
ASCI-D	AFDM	-0.005	0.0008	<0.001
ASCI-D	Specific Conductance	-0.003	0.0003	<0.001
ASCI-D	Temperature	-0.20	0.03	<0.001
ASCI-D	Dissolved Oxygen	-0.002	0.03	0.95
ASCI-D	Chlorophyll a	-0.02	0.004	<0.001
ASCI-H	TN	-1.29	0.22	<0.001
ASCI-H	TP	-1.96	0.55	<0.001
ASCI-H	AFDM	-0.006	0.0008	<0.001
ASCI-H	Specific Conductance	-0.003	0.0003	<0.001
ASCI-H	Temperature	-0.18	0.03	<0.001
ASCI-H	Dissolved Oxygen	-0.004	0.03	0.90
ASCI-H	Chlorophyll a	-0.02	0.003	<0.001

Association between Index Scores and Geospatial Data

Index scores decreased with increasing levels of land use disturbances (agriculture, urbanization, Code21, road & railroad density) and increased with increasing levels of open space (Figures 97 to 105, Table 18). The relationship was significant ($p<0.001$) at all three landscape scales tested (1 km, 5 km, watershed). The land use attributes with the strongest relationship to CSCI, ASCI-D and ASCI-H was urbanization (rho ≤ -0.55) and open space (rho ≥ 0.56).

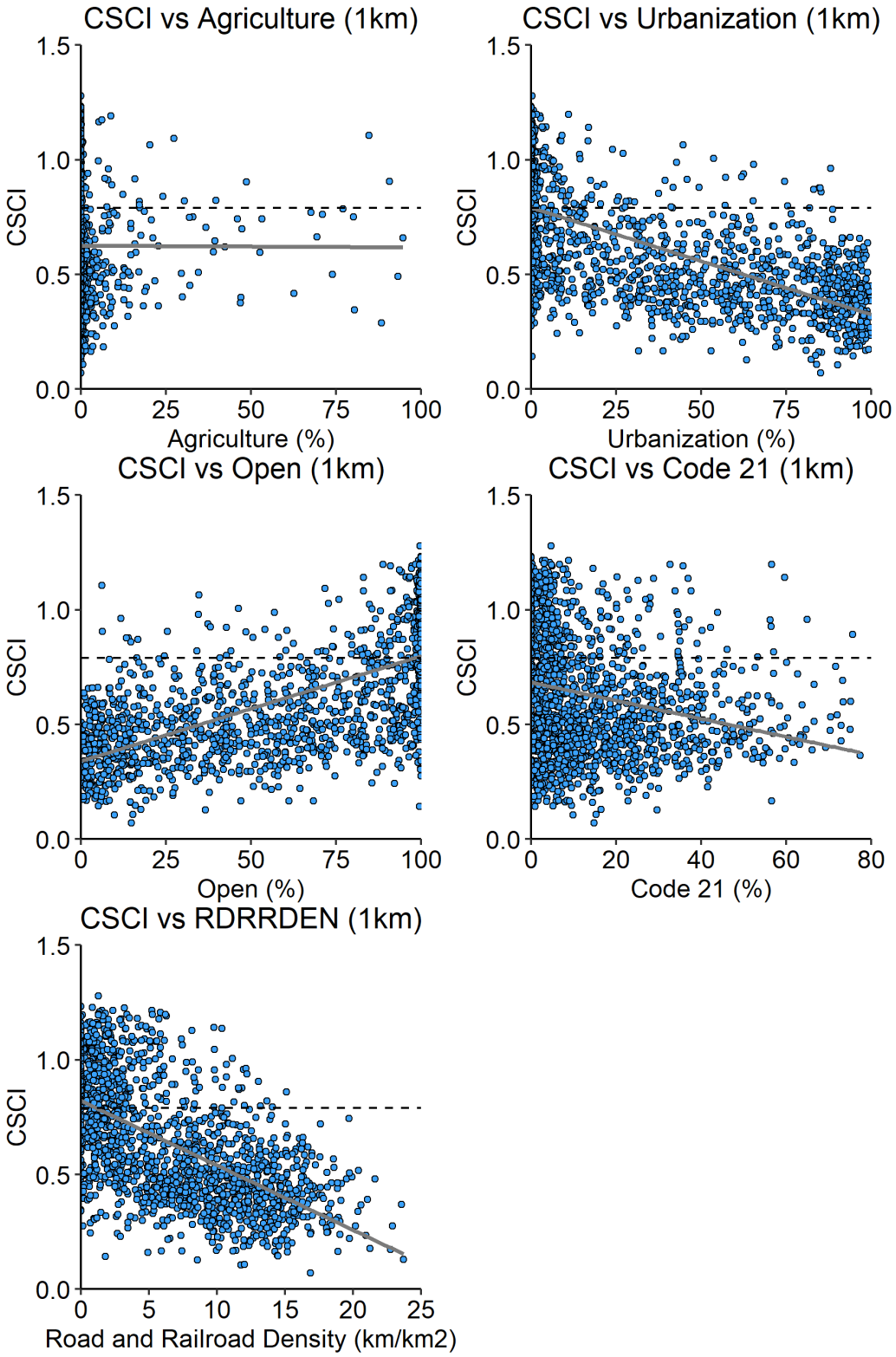


Figure 97. CSCI by landscape attributes at 1km upstream of sampling location. The horizontal dashed line is the 10th percentile reference threshold, and the grey line is the linear regression line.

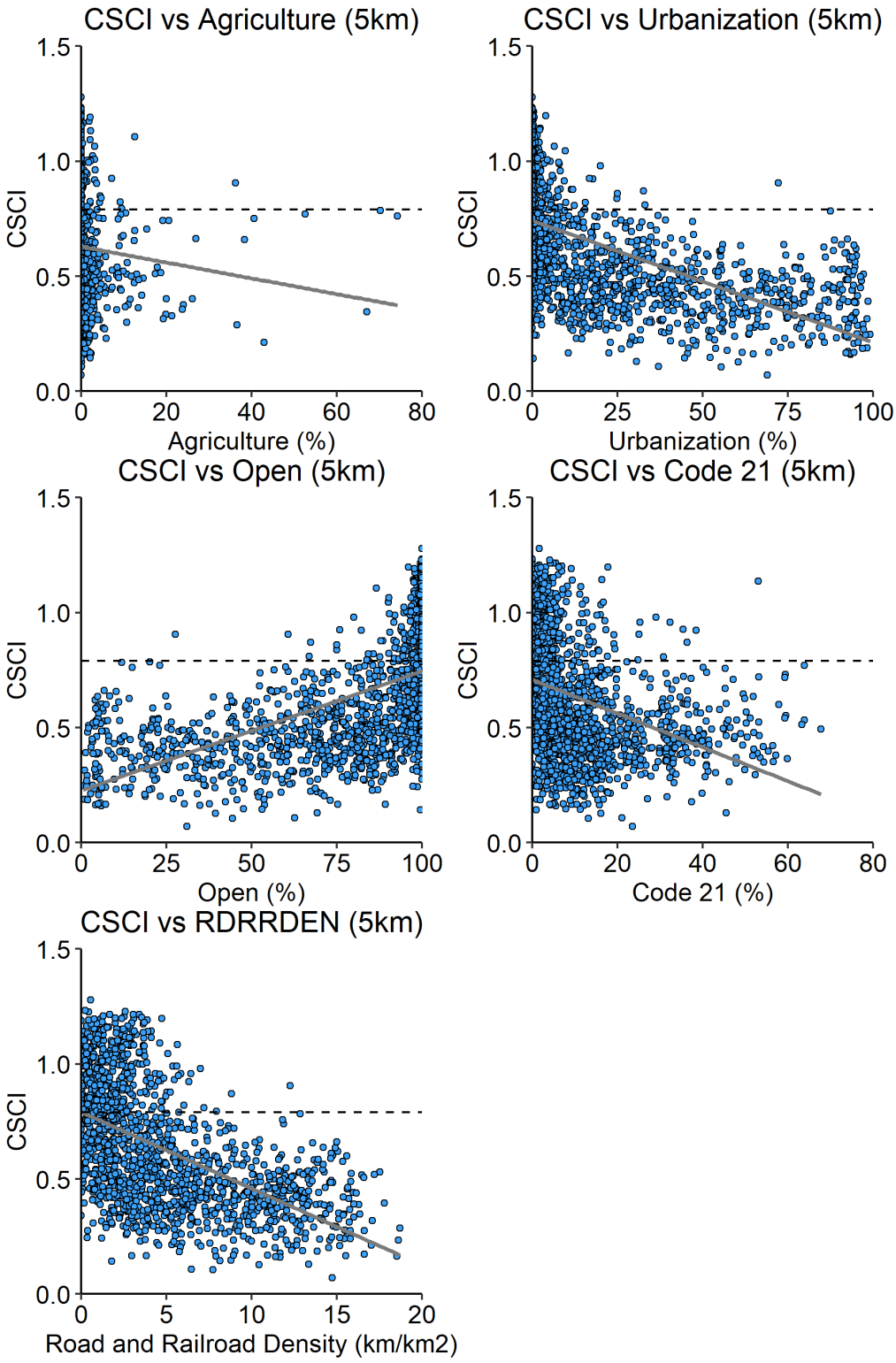


Figure 98. CSCI by landscape attributes at 5km upstream of sampling location. The horizontal dashed line is the 10th percentile reference threshold, and the grey line is the linear regression line.

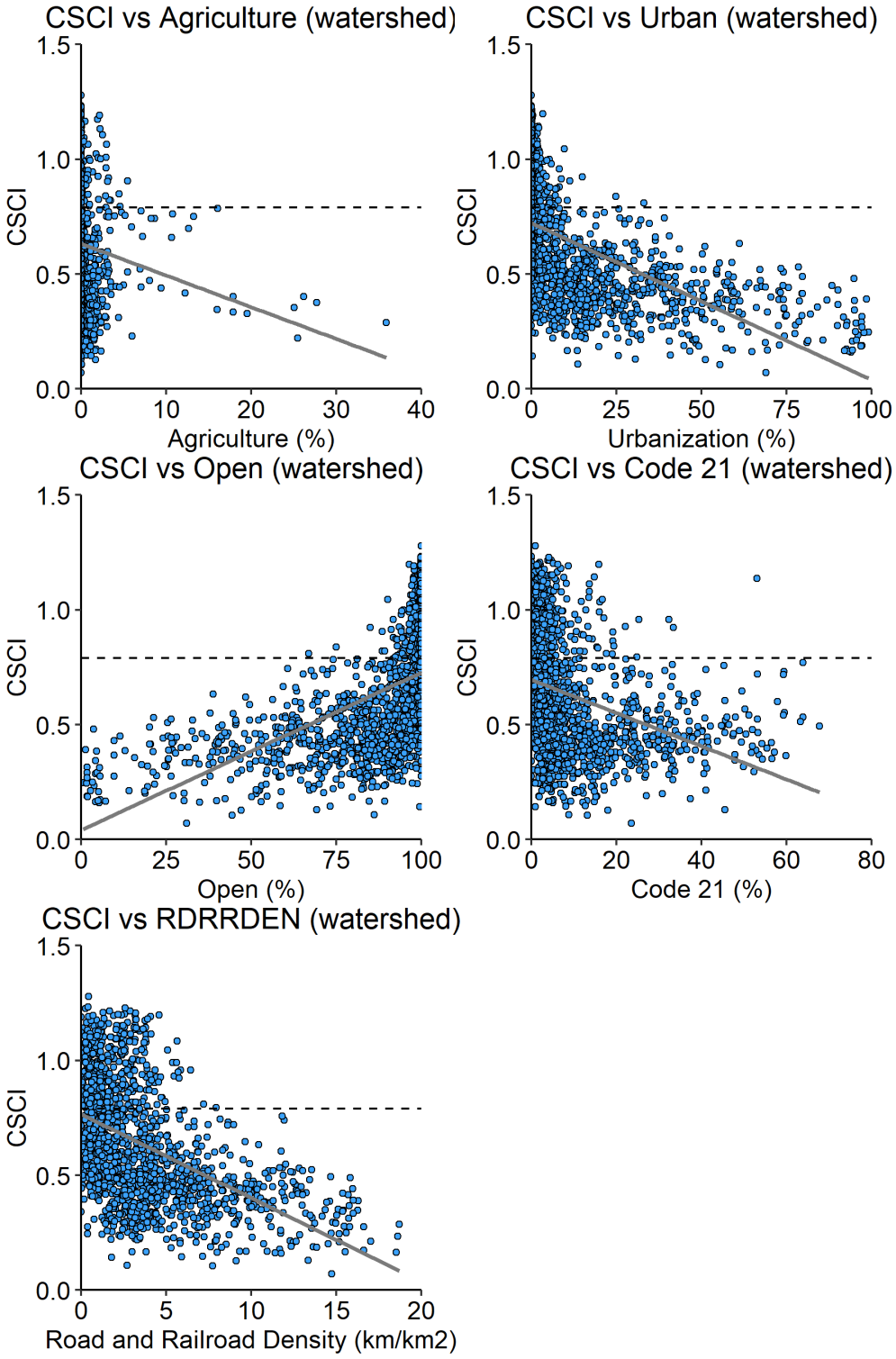


Figure 99. CSCI by landscape attributes for the watershed upstream of sampling location. The horizontal dashed line is the 10th percentile reference threshold, and the grey line is the linear regression line.

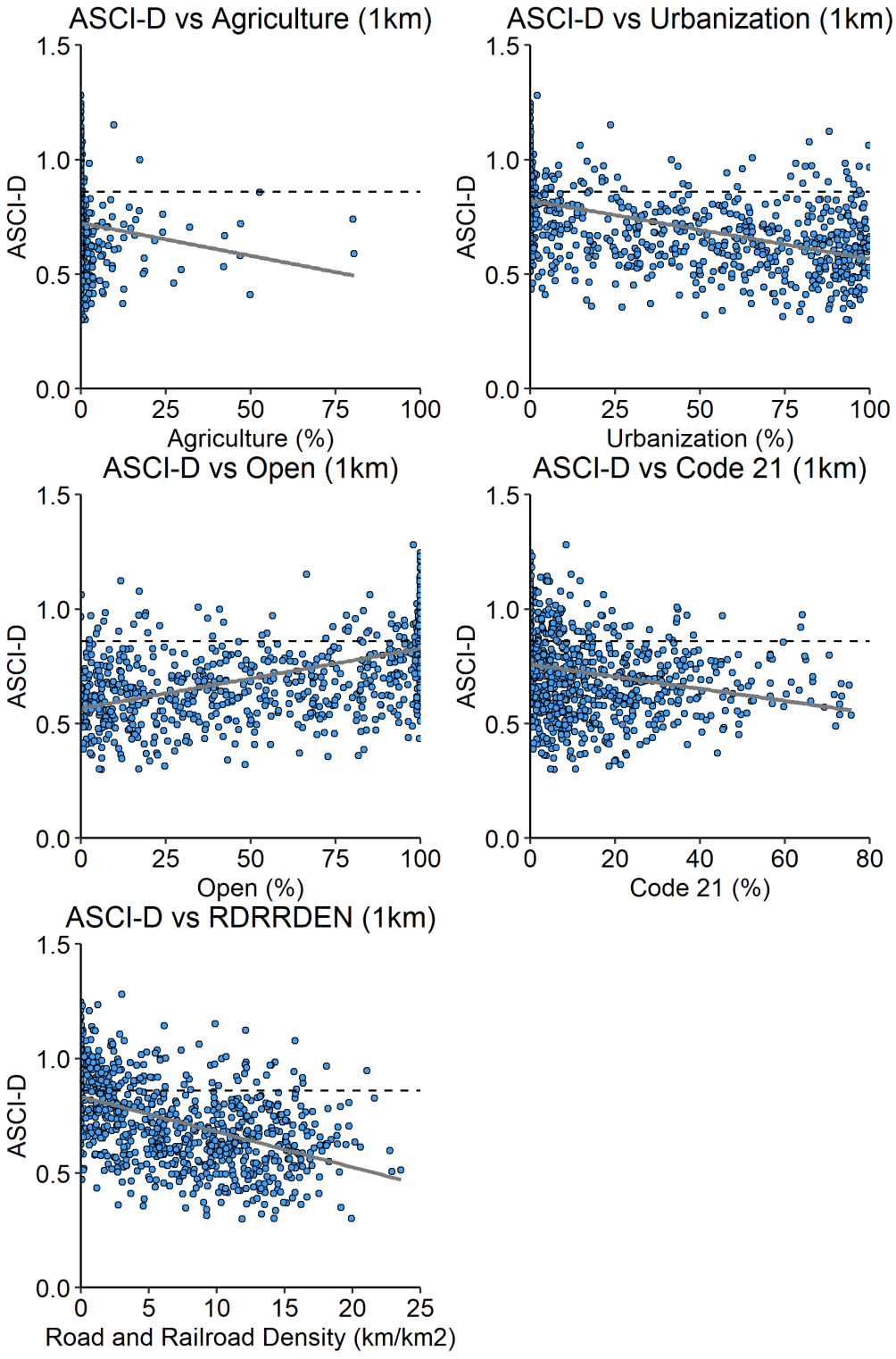


Figure 100. ASCI-D by landscape attributes at 1 km upstream of sampling location. The horizontal dashed line is the 10th percentile reference threshold, and the grey line is the linear regression line.

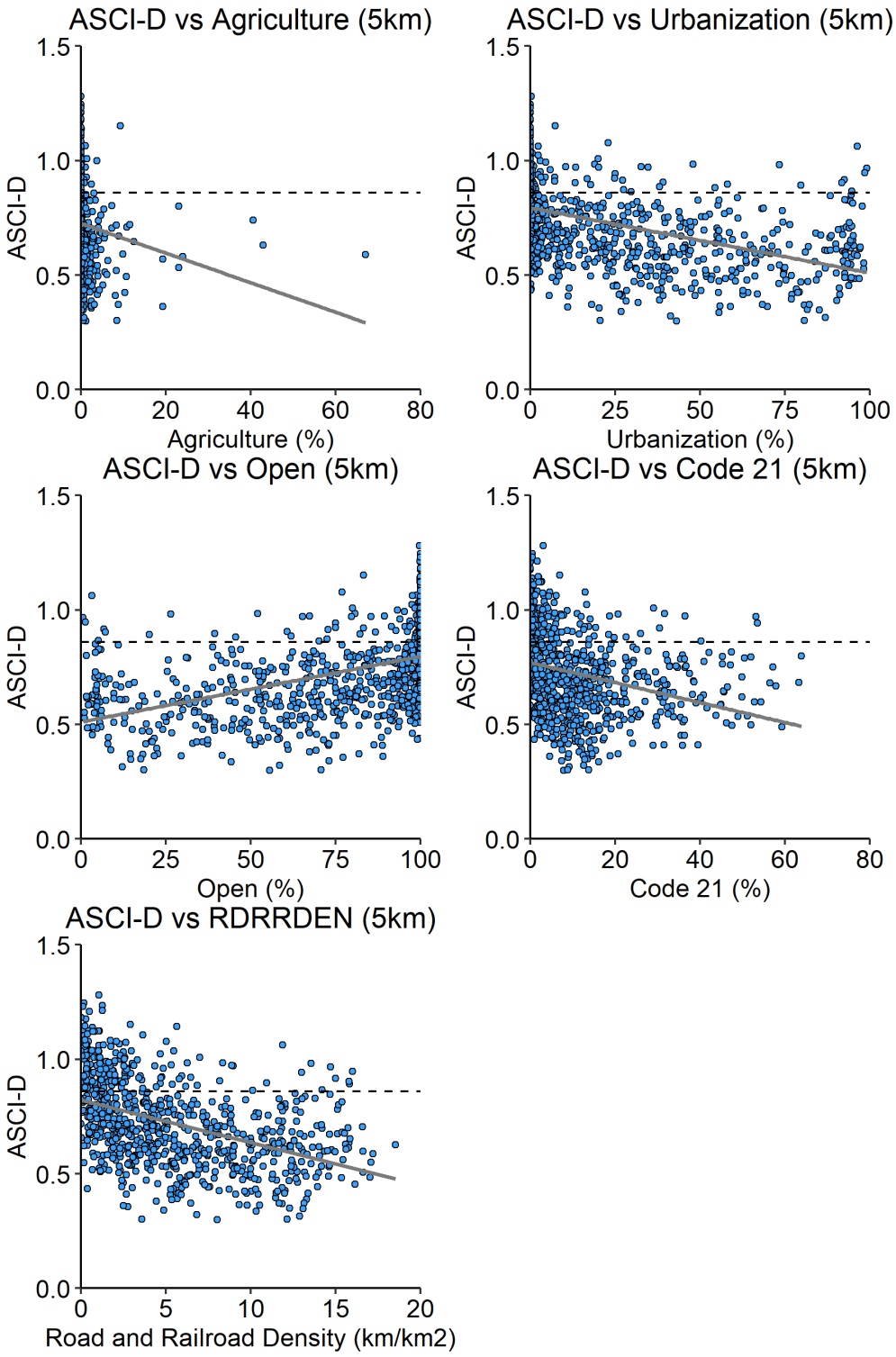


Figure 101. ASCI-D by landscape attributes at 1 km upstream of sampling location. The horizontal dashed line is the 10th percentile reference threshold, and the grey line is the linear regression line.

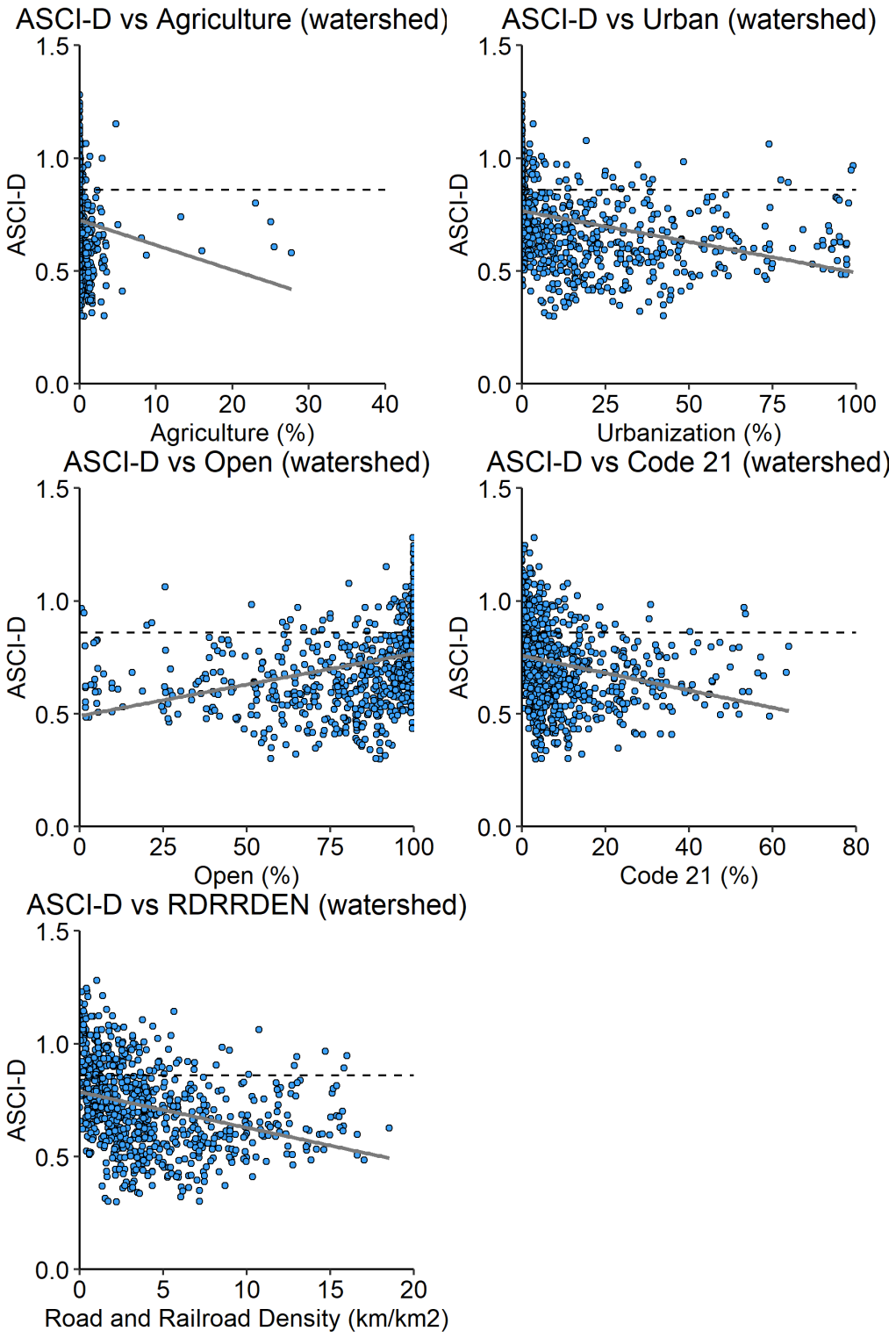


Figure 102. ASCI-D by landscape attributes for the watershed upstream of sampling location. The horizontal dashed line is the 10th percentile reference threshold, and the grey line is the linear regression line.

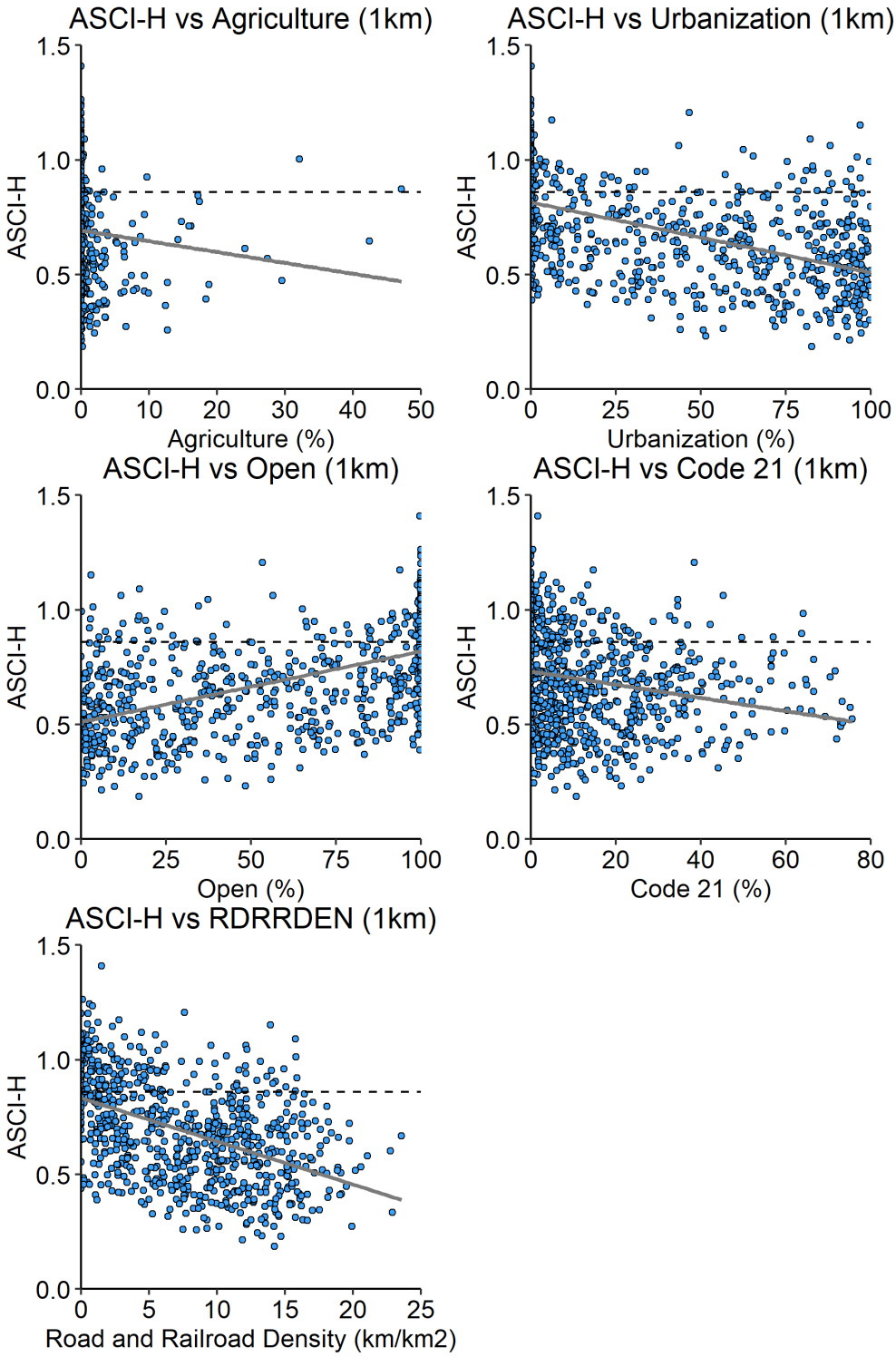


Figure 103. ASCI-H by landscape attributes at 1 km upstream of sampling location. The horizontal dashed line is the 10th percentile reference threshold, and the grey line is the linear regression line.

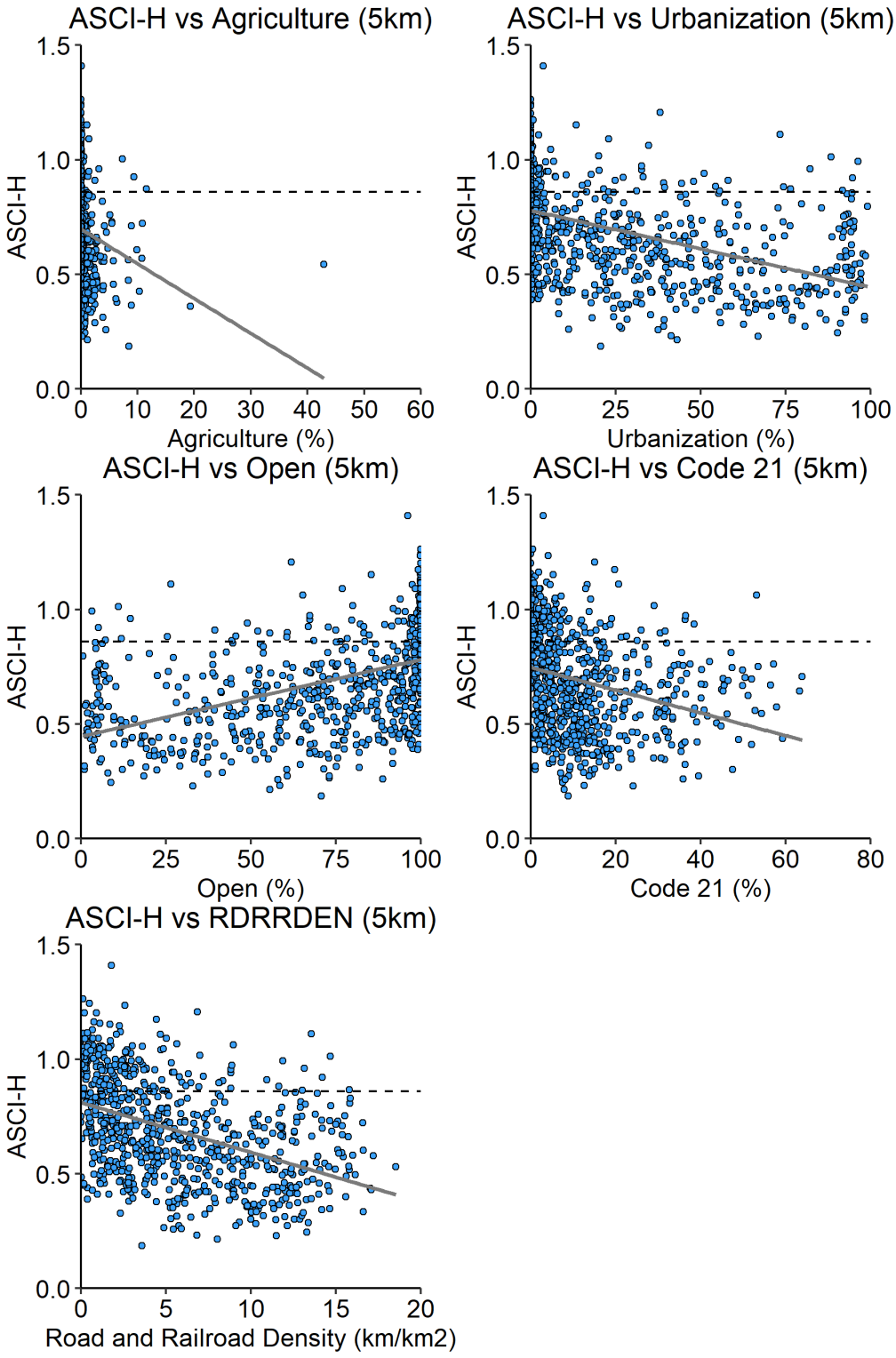


Figure 104. ASCI-H by landscape attributes at 5 km upstream of sampling location. The horizontal dashed line is the 10th percentile reference threshold, and the grey line is the linear regression line.

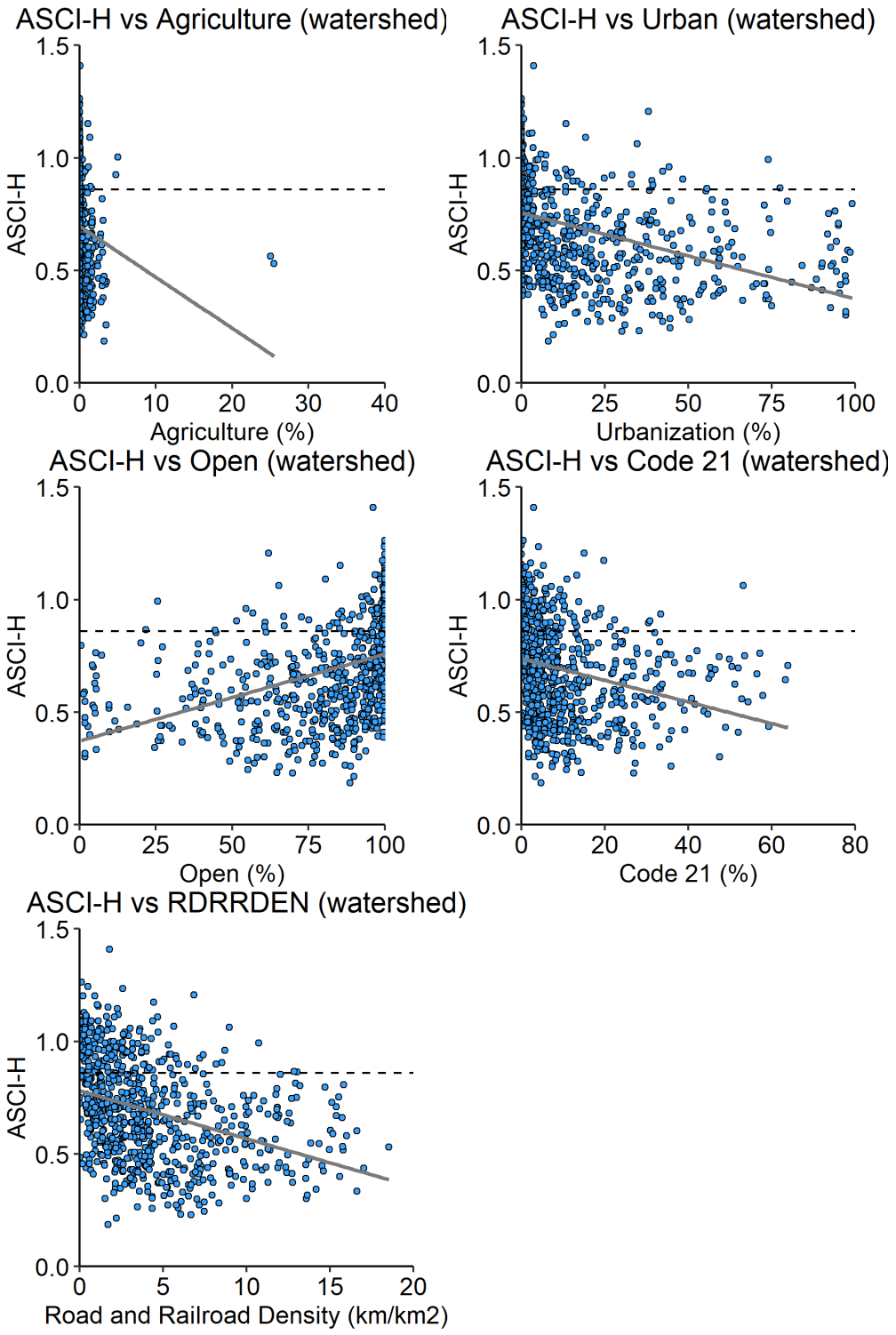


Figure 105. ASCI-H by landscape attributes for the watershed upstream of sampling location. The horizontal dashed line is the 10th percentile reference threshold, and the grey line is the linear regression line.

Table 18. Spearman rank correlation of index scores vs landscape attributes. WS = watershed.

Index	Stressor	Scale	N	Spearman p	Spearman rho
CSCI	Agriculture	1 km	1,492	<0.001	-0.17
CSCI	Agriculture	5 km	1,492	<0.001	-0.30
CSCI	Agriculture	WS	1,492	<0.001	-0.30
CSCI	Urban	1 km	1,492	<0.001	-0.68
CSCI	Urban	5 km	1,492	<0.001	-0.71
CSCI	Urban	WS	1,492	<0.001	-0.73
CSCI	Open	1 km	1,492	<0.001	0.67
CSCI	Open	5 km	1,492	<0.001	0.70
CSCI	Open	WS	1,492	<0.001	0.73
CSCI	Code 21	1 km	1,492	<0.001	-0.31
CSCI	Code 21	5 km	1,492	<0.001	-0.48
CSCI	Code 21	WS	1,492	<0.001	-0.47
CSCI	Road & railroad density	1 km	1,492	<0.001	-0.60
CSCI	Road & railroad density	5 km	1,492	<0.001	-0.59
CSCI	Road & railroad density	WS	1,492	<0.001	-0.54
ASCI-D	Agriculture	1 km	782	<0.001	-0.29
ASCI-D	Agriculture	5 km	782	<0.001	-0.42
ASCI-D	Agriculture	WS	782	<0.001	-0.43
ASCI-D	Urban	1 km	782	<0.001	-0.55
ASCI-D	Urban	5 km	782	<0.001	-0.59
ASCI-D	Urban	WS	782	<0.001	-0.56
ASCI-D	Open	1 km	782	<0.001	0.56
ASCI-D	Open	5 km	782	<0.001	0.59

Index	Stressor	Scale	N	Spearman p	Spearman rho
ASCI-D	Open	WS	782	<0.001	0.56
ASCI-D	Code 21	1 km	782	<0.001	-0.32
ASCI-D	Code 21	5 km	782	<0.001	-0.44
ASCI-D	Code 21	WS	782	<0.001	-0.40
ASCI-D	Road & railroad density	1 km	782	<0.001	-0.47
ASCI-D	Road & railroad density	5 km	782	<0.001	-0.50
ASCI-D	Road & railroad density	WS	782	<0.001	-0.41
ASCI-H	Agriculture	1 km	745	<0.001	-0.27
ASCI-H	Agriculture	5 km	745	<0.001	-0.39
ASCI-H	Agriculture	WS	745	<0.001	-0.39
ASCI-H	Urban	1 km	745	<0.001	-0.56
ASCI-H	Urban	5 km	745	<0.001	-0.58
ASCI-H	Urban	WS	745	<0.001	-0.59
ASCI-H	Open	1 km	745	<0.001	0.56
ASCI-H	Open	5 km	745	<0.001	0.59
ASCI-H	Open	WS	745	<0.001	0.60
ASCI-H	Code 21	1 km	745	<0.001	-0.31
ASCI-H	Code 21	5 km	745	<0.001	-0.42
ASCI-H	Code 21	WS	745	<0.001	-0.41
ASCI-H	Road & railroad density	1 km	745	<0.001	-0.48
ASCI-H	Road & railroad density	5 km	745	<0.001	-0.48
ASCI-H	Road & railroad density	WS	745	<0.001	-0.43

Stream Classification and Priority Explorer (SCAPE)

Most sites in Water Board Region 2 (70%) had predicted SCAPE values in the "possibly-" or "likely constrained" categories (Figures 106 to 107, Table 19). Alameda, Contra Costa, Solano, and Sonoma Counties exceeded the regional rate of constrained sites (86%, 77%, 89%, 78%, respectively), while Marin County had the highest rate of "likely-" or "possibly unconstrained" sites (66%). San Francisco and Santa Cruz Counties each had two sampling sites, with both sites in the constrained category for San Francisco County and both sites in the unconstrained category for Santa Cruz.

Almost half of the measured CSCI scores in Water Board Region 2 (49%) compared favorably with the predicted SCAPE categories, and thus were classified as "expected" (Figures 108 to 109, Table 20). Sonoma and Marin Counties had the highest proportion of sites with measured CSCI scores performing better than predicted (>30% of sites each). Contra Costa County and San Francisco County (two sites) had the highest proportion of measured CSCI scores performing worse than expected (50% of sites).

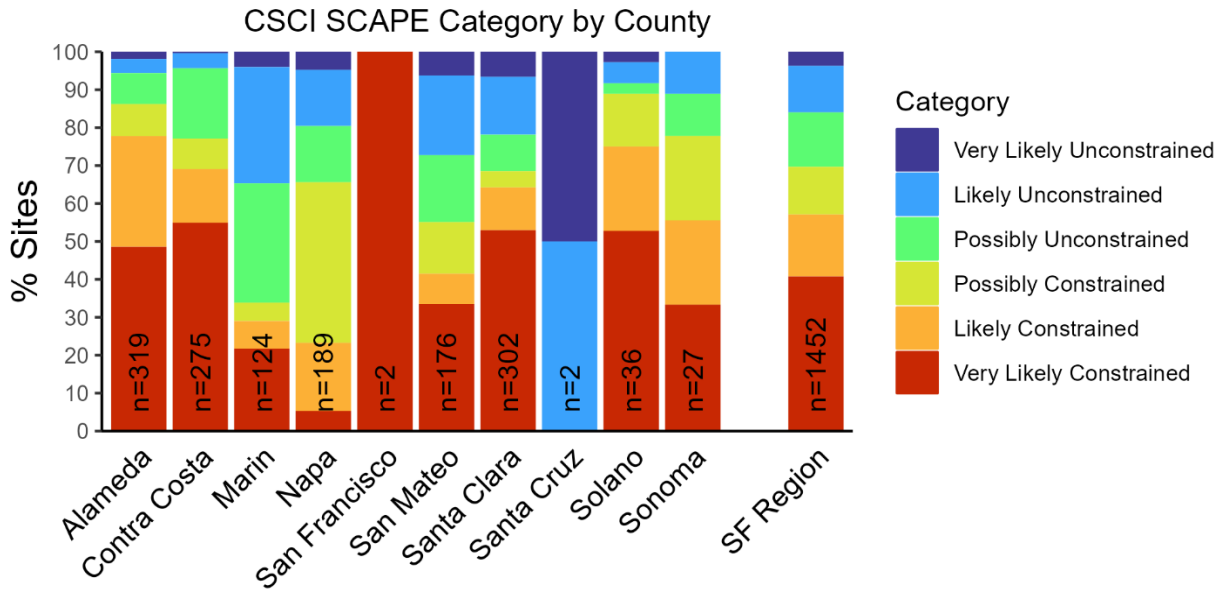


Figure 106. Proportion of sites predicted in each Stream Classification and Priority Explorer (SCAPE) category, by county and all of Water Board Region 2. The numbers in the plot indicate the total number of sites per county.

Table 19. Percentage of sites predicted in each Stream Classification and Priority Explorer (SCAPE) category, by county and Water Board Region 2.

Subpopulation	Very Likely Unconstrained	Likely Unconstrained	Possibly Unconstrained	Possibly Constrained	Likely Constrained	Very Likely Constrained
Water Board Region 2	3.7%	12.3%	14.3%	12.6%	16.3%	40.8%
Alameda	1.9%	3.8%	8.2%	8.5%	29.2%	48.6%
Contra Costa	0.4%	4.0%	18.5%	8.0%	14.2%	54.9%
Marin	4.0%	30.6%	31.5%	4.8%	7.3%	21.8%
Napa	4.8%	14.8%	14.8%	42.3%	18.0%	5.3%
San Francisco	0.0%	0.0%	0.0%	0.0%	0.0%	100.0%
San Mateo	6.3%	21.0%	17.6%	13.6%	8.0%	33.5%
Santa Clara	6.6%	15.2%	9.6%	4.3%	11.3%	53.0%
Santa Cruz	50.0%	50.0%	0.0%	0.0%	0.0%	0.0%
Solano	2.8%	5.6%	2.8%	13.9%	22.2%	52.8%
Sonoma	0.0%	11.1%	11.1%	22.2%	22.2%	33.3%

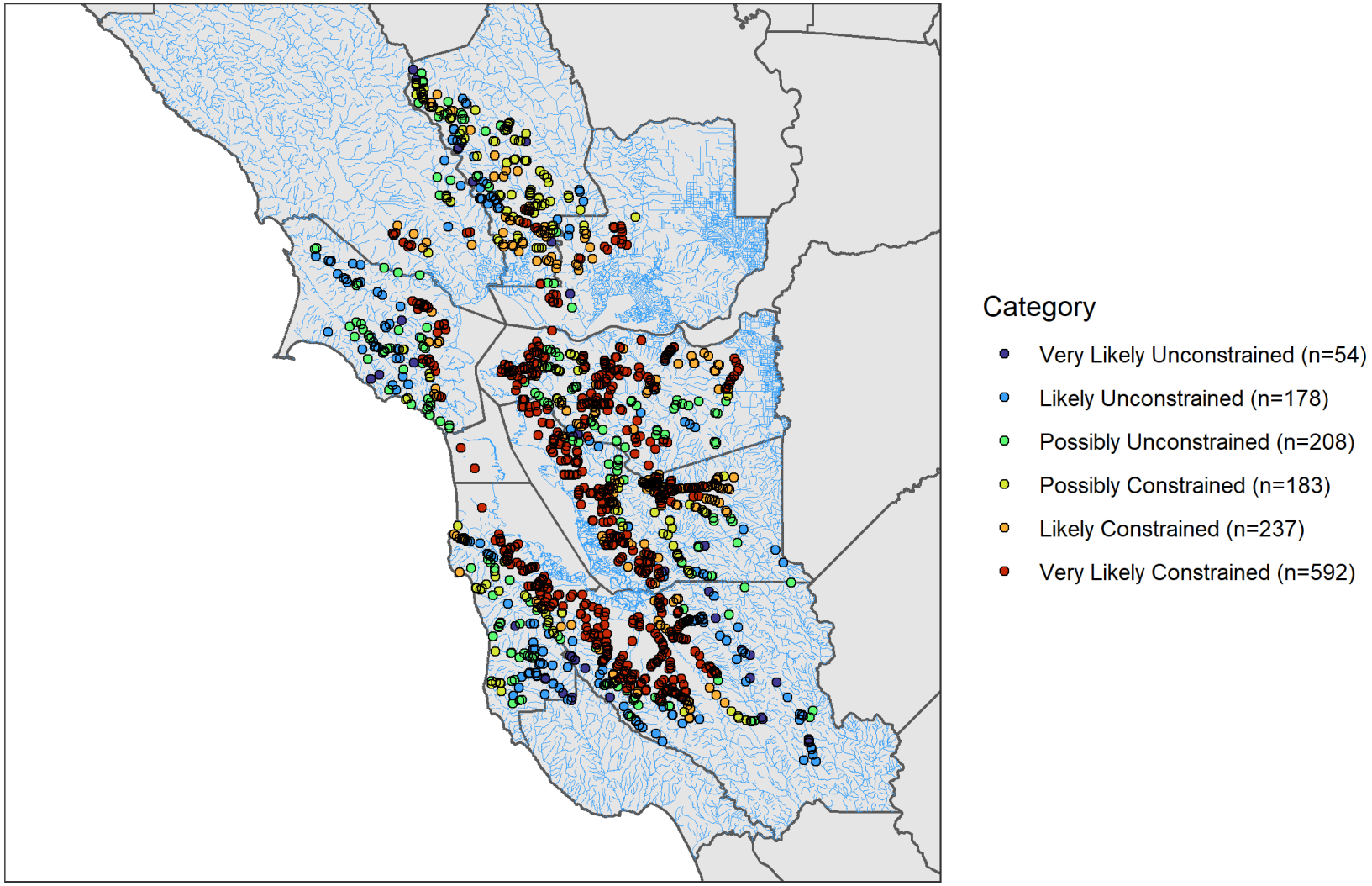


Figure 107. Map of CSCI Stream Classification and Priority Explorer (SCAPE) constrained/unconstrained sites by county.

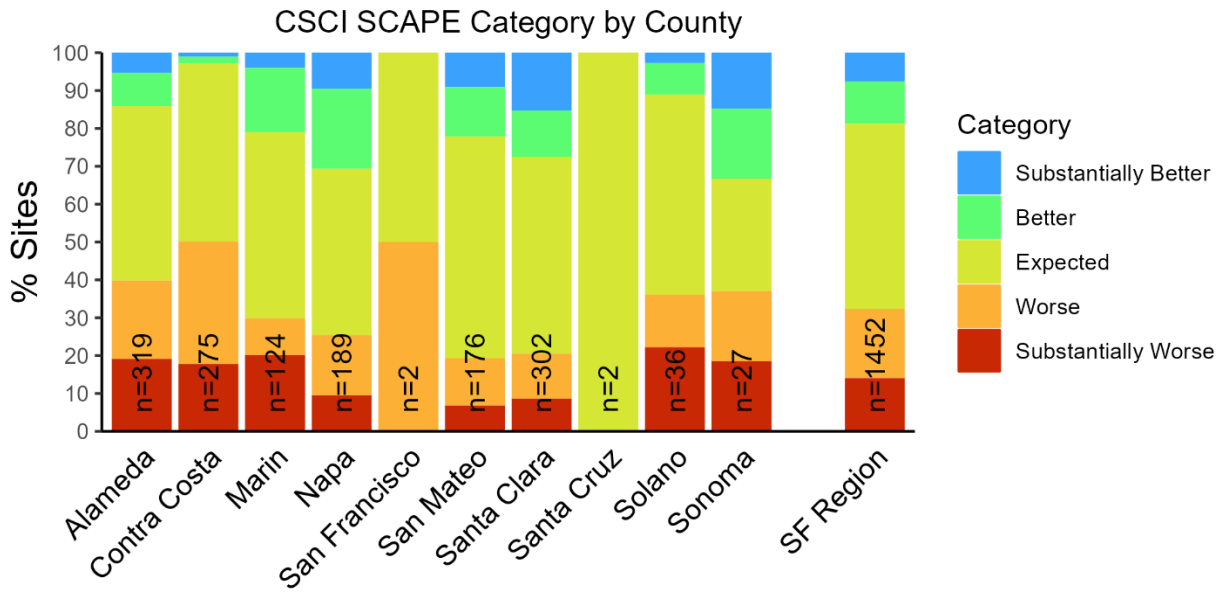
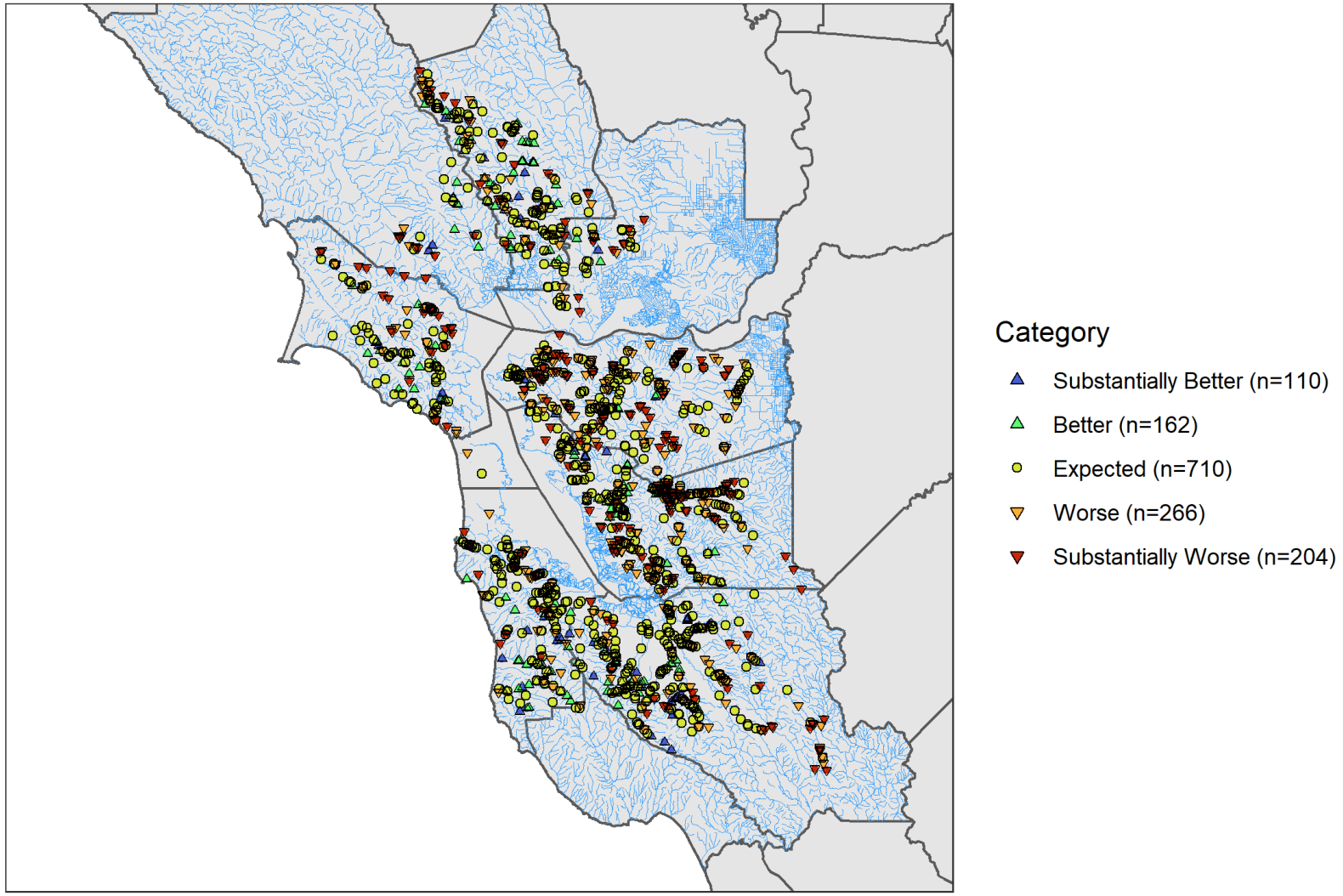


Figure 108. Measured CSCI score performance relative to predictions in Stream Classification and Priority Explorer (SCAPE), by county and all of Water Board Region 2.

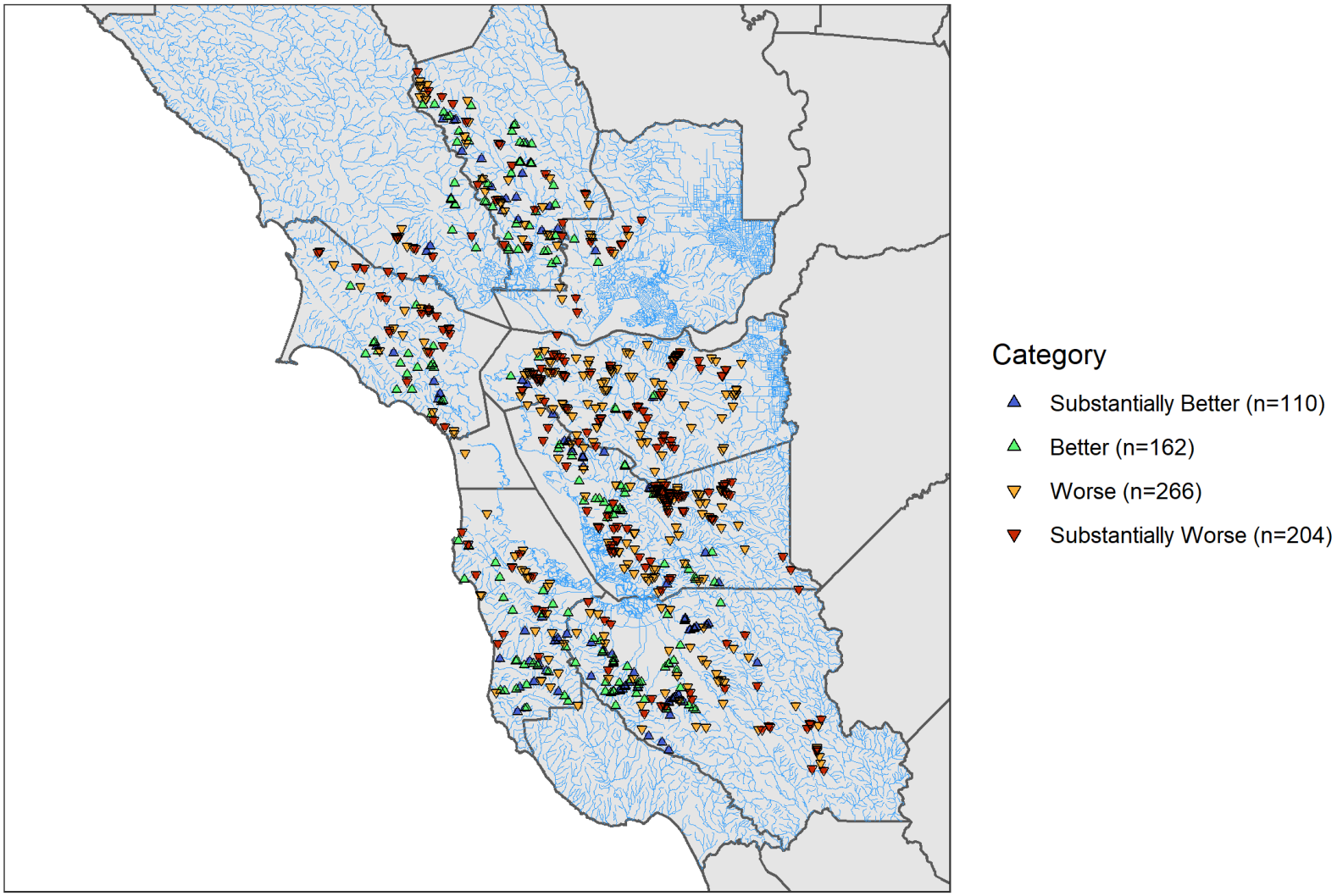
Table 20. Performance of measured CSCI scores relative to predictions in Stream Classification and Priority Explorer (SCAPE), by county and all of Water Board Region 2.

Subpopulation	Substantially Better %	Better %	Expected %	Worse %	Substantially Worse %
Water Board Region 2	8%	11%	49%	18%	14%
Alameda	5%	9%	46%	21%	19%
Contra Costa	1%	2%	47%	32%	18%
Marin	4%	17%	49%	10%	20%
Napa	10%	21%	44%	16%	10%
San Francisco	0%	0%	50%	50%	0%
San Mateo	9%	13%	59%	13%	7%

Subpopulation	Substantially Better %	Better %	Expected %	Worse %	Substantially Worse %
Santa Clara	15%	12%	52%	12%	9%
Santa Cruz	0%	0%	100%	0%	0%
Solano	3%	8%	53%	14%	22%
Sonoma	15%	19%	30%	19%	19%


Category
Substantially Better (n=110)
Better (n=162)
Expected (n=710)
Worse (n=266)
Substantially Worse (n=204)

A.



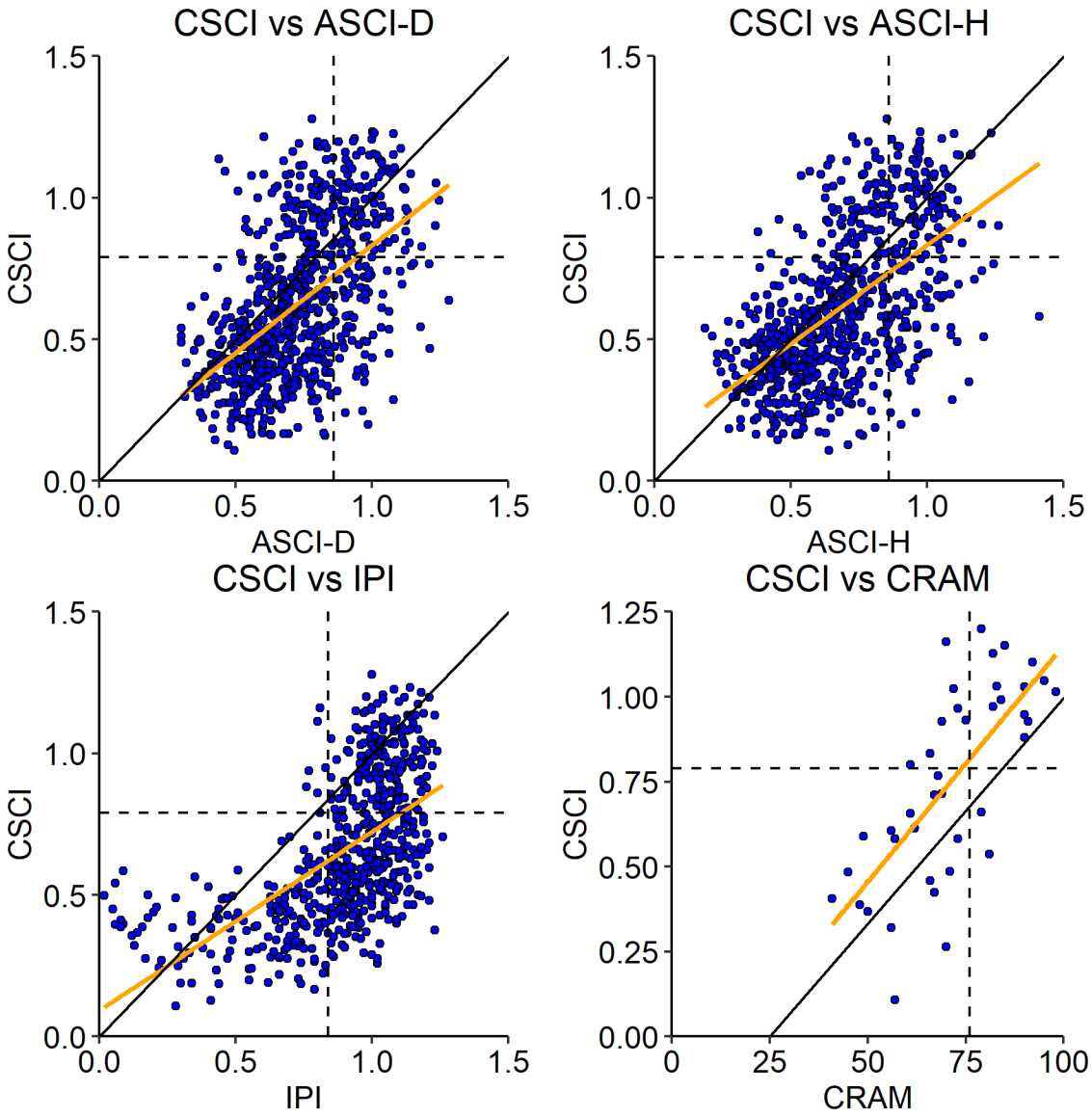
B.

Figure 109. Maps of measured CSCI score performance relative to predictions in SCAPE, by county. Bottom graph (B.) has the "Expected" category removed, to better see the other categories.

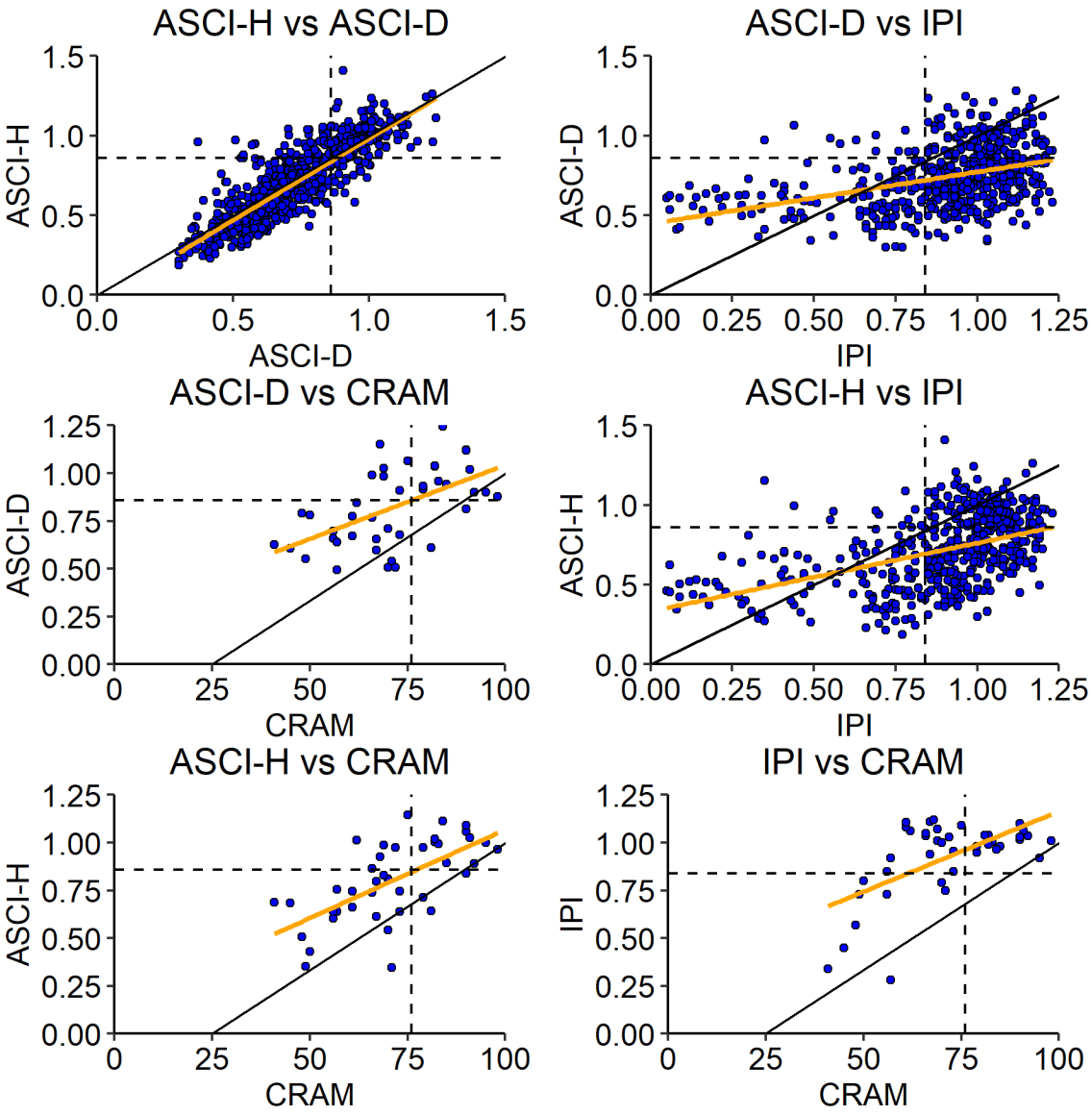
Concordance among Indices

There was a significant relationship between index scores for all indices ($p<0.05$) with relatively strong relationships identified for most index pairs (Figure 110 and Table 21). Concordance between IPI and CRAM was significant ($p=0.02$), but showed the weakest relationship among pairs (rho = 0.37).

The greatest concordance among condition categories for each index pair was for the “very likely altered” category, with at least 44% of the data for both indices in this category (Tables 22 to 24). The other condition category pairs had no more than 10% of the data. This is not surprising, given that most sites were in the “very likely altered” category for CSCI, ASCI-D and ASCI-H scores.


CSCI vs ASCI-D
CSCI
ASCI-D
CSCI vs ASCI-H
CSCI
ASCI-H
CSCI vs IPI
CSCI
IPI
CSCI vs CRAM
CSCI
CRAM

A.



B.

Figure 110. Concordance among CSCI, ASCI-D, ASCI-H, IPI and CRAM. The black line indicates the 1:1 relationship, while the orange line indicates the linear regression line. Dashed vertical and horizontal lines are the 10th percentile reference thresholds.

Table 21. Concordance among indices using Spearman rank correlation.

Indices	Number of Sites	Spearman p-value	Spearman rho
CSCI vs ASCI-D	771	<0.001	0.55
CSCI vs ASCI-H	744	<0.001	0.60
CSCI vs IPI	614	<0.001	0.64
CSCI vs CRAM	41	<0.001	0.73
ASCI-D vs ASCI-H	745	<0.001	0.85
ASCI-D vs IPI	533	<0.001	0.43
ASCI-D vs CRAM	41	<0.001	0.54
ASCI-H vs IPI	496	<0.001	0.49
ASCI-H vs CRAM	41	<0.001	0.66
IPI vs CRAM	41	0.02	0.37

Table 22. Concordance among CSCI and ASCI-D condition categories.

	CSCI Likely intact	CSCI Possibly altered	CSCI Likely altered	CSCI Very likely altered
ASCI-D Likely intact	51 (7%)	20 (3%)	23 (3%)	21 (3%)
ASCI-D Possibly altered	27 (4%)	15 (2%)	12 (2%)	18 (2%)
ASCI-D Likely altered	33 (4%)	21 (3%)	26 (3%)	61 (8%)
ASCI-D Very likely altered	29 (4%)	17 (2%)	55 (7%)	342 (44%)

Table 23. Concordance among CSCI and ASCI-H condition categories.

	CSCI Likely intact	CSCI Possibly altered	CSCI Likely altered	CSCI Very likely altered
ASCI-H Likely intact	65 (9%)	21 (3%)	20 (3%)	23 (3%)
ASCI-H Possibly altered	17 (2%)	10 (1%)	11 (1%)	24 (3%)
ASCI-H Likely altered	27 (4%)	12 (2%)	19 (3%)	32 (4%)
ASCI-H Very likely altered	24 (3%)	24 (3%)	61 (8%)	354 (48%)

Table 24. Concordance among ASCI-D and ASCI-H condition categories.

	CSCI Likely intact	CSCI Possibly altered	CSCI Likely altered	CSCI Very likely altered
ASCI-H Likely intact	76 (10%)	17 (2%)	7 (1%)	2 (0%)
ASCI-H Possibly altered	27 (4%)	20 (3%)	14 (2%)	7 (1%)
ASCI-H Likely altered	17 (2%)	16 (2%)	35 (5%)	69 (9%)
ASCI-H Very likely altered	9 (1%)	9 (1%)	34 (5%)	386 (52%)

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