Bugs, Fish & Algae: An Overview of California's Bioassessment Program

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Aquatic Bioassessment Laboratory

Water Boards

SWAMP Surface Water Ambient Monitoring Program

What is bioassessment?

An evaluation of the condition, or health, of a waterbody based on the organisms living within it.

Benthic Macroinvertebrates (BMIs)

Bottom-dwelling invertebrates, not microscopic

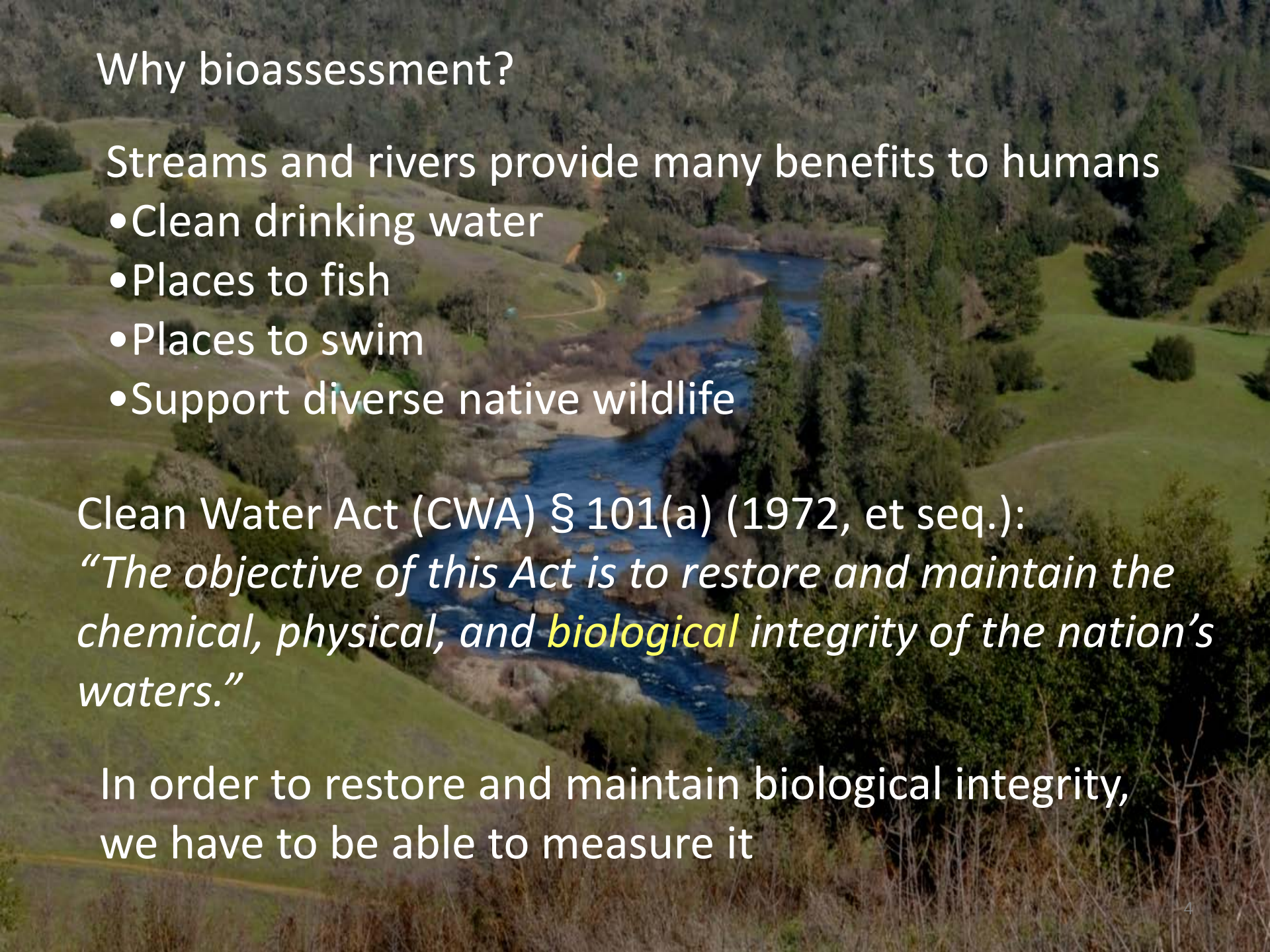
Diverse and abundant: Dozens to > 100 BMI species present at a site, thousands of individuals/m2

Unique preferences for different micro-habitats: physical settings, but also different sensitivities to pollutants, sediment, flow alteration, etc.







Why bioassessment?

Streams and rivers provide many benefits to humans

- Clean drinking water
- Places to fish
- Places to swim
- Support diverse native wildlife

Clean Water Act (CWA) § 101(a) (1972, et seq.):
"The objective of this Act is to restore and maintain the chemical, physical, and biological integrity of the nation's waters."

In order to restore and maintain biological integrity, we have to be able to measure it

Key Components of How We Measure and Assess Biological Integrity:

- **Standard field and lab methods** (plus other infrastructure components like data management & quality assurance)
- **The Reference Condition Monitoring Program (RCMP)**: reference conditions help us set benchmarks and are the core of building interpretive indices
- **The Perennial Streams Assessment (PSA):** statewide stream survey that allows biological condition estimates for all wadeable stream length in CA.

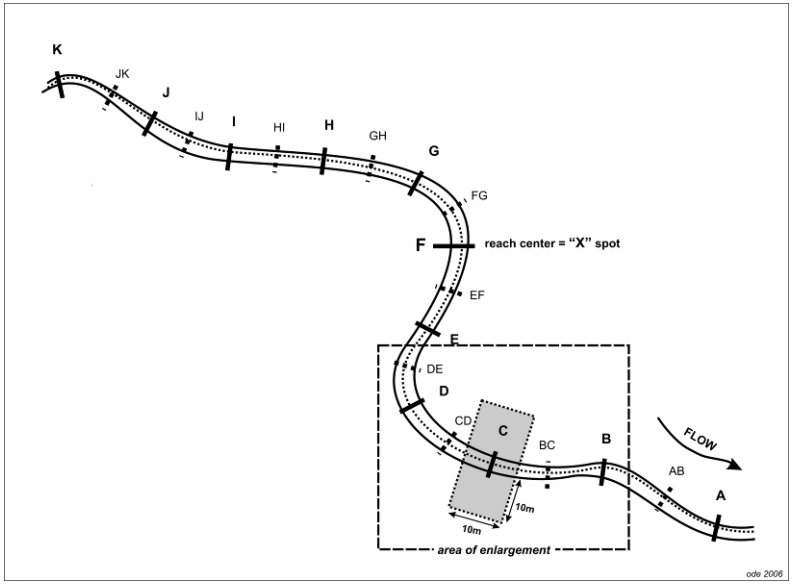
Standard field methods: every bioassessment site is sampled for **biological**, **chemical** and **physical** habitat indicators.

Biological Indicators:
- Benthic macroinvertebrates
- Diatoms
- Non-diatoms (i.e., “soft” algae)

Chemical Indicators:
- Nitrogen
- Phosphorous
- Chloride
- Total Suspended Solids
- etc.

Physical Habitat Indicators:
- Riparian vegetation complexity
- In-stream habitat complexity
- Substrate composition
- Local riparian disturbance
- Canopy density
- etc.

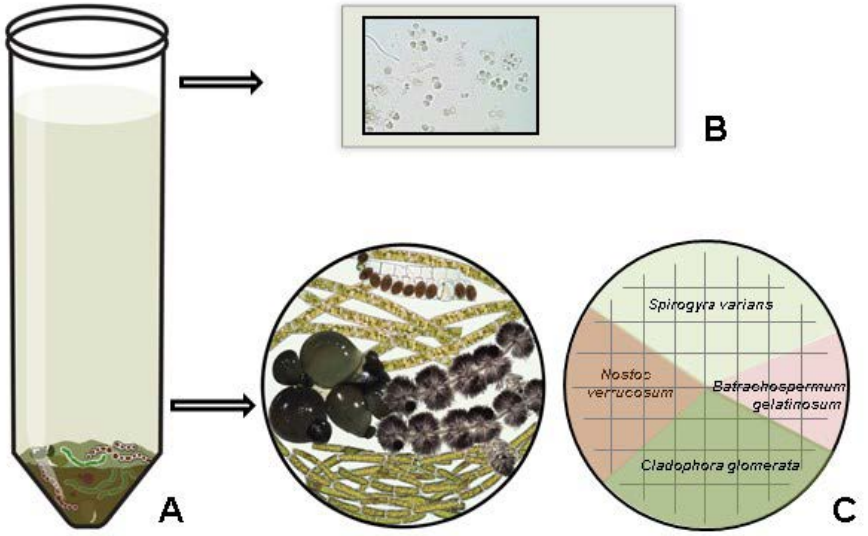
Standardized sampling reach divided into equally-spaced transects



Standard lab methods:

For both BMIs and algae, we have standard methods for:

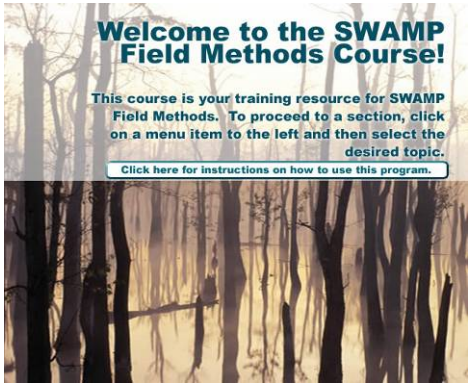
- Washing and preparing samples for identification
- Subsampling the original "total" sample into the portion that will be identified
- Recommended levels of taxonomic identification (i.e., "Standard Taxonomic Effort")
- Suggested literature best suited for identification of different groups



All of these methods are well-supported and well-documented in numerous Standard Operating Procedures (SOPs)

…well supported by extensive quality control (QC) measures

- External QC for BMIs
- External QC for algae (under development but not far off)
- Field audits and calibrations for field crews



…well supported by online resources

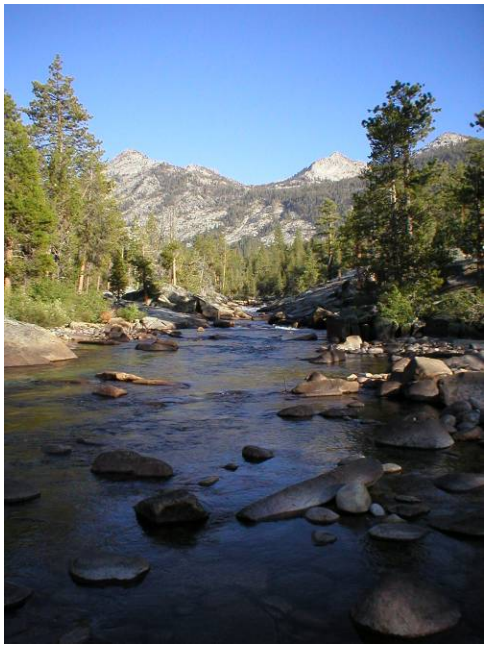
- Video modules that demonsrate field protocols
- Photographic libraries of taxonomic identifications

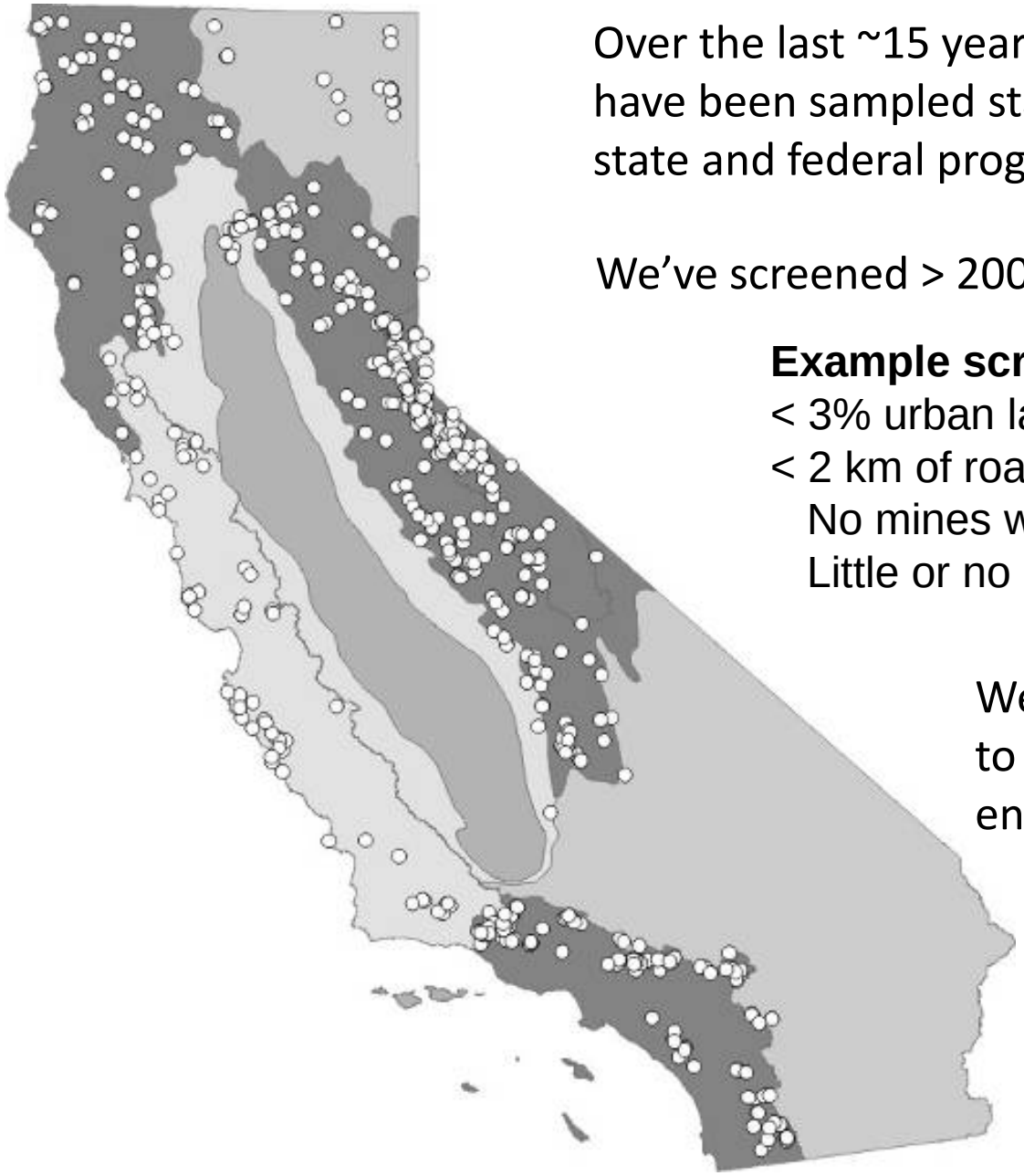
The Reference Condition Monitoring Program (RCMP)

Reference sites are healthy stream reaches that define a benchmark of expected biological, chemical and physical conditions when human disturbance in the environment is absent or minimal.

This benchmark, known as **the reference condition**, is the foundation of any bioassessment program:

- sets the standard for evaluating results from compliance and ambient monitoring
- provides meaningful objectives for stream restoration
- establishes a framework for protecting our healthiest streams and rivers
- provides a basis for assessing potential effects of climate change on streams





Over the last ~15 years, thousands of sites have been sampled statewide by various regional, state and federal programs

We've screened > 2000 "pre-existing"sites

Example screening criteria:
< 3% urban land use in upstream watershed
< 2 km of roads/km^2 in upstream watershed
No mines w/in 5km upstream
Little or no human activity in riparian zone

We've also targeted high-quality sites to improve geographic and environmental coverage

Result: > 600 reference sites statewide that represent California's diverse physiography

The California Stream Condition Index (CSCI)

EXPECTED

Natural environmental variables…



Elevation | **Climate** | **Geology** | **Watershed Size**

…are used to predict the species and metric values expected at a site if it's healthy.






OBSERVED

The site is sampled and species are identified in the lab.



CSCI Ecological Indicators

Taxonomic Completeness	Species
Measures of ecological structure and function	# Species
	# Shredders
	% Clingers
	% Coleoptera
	% EPT*
	% Intolerant

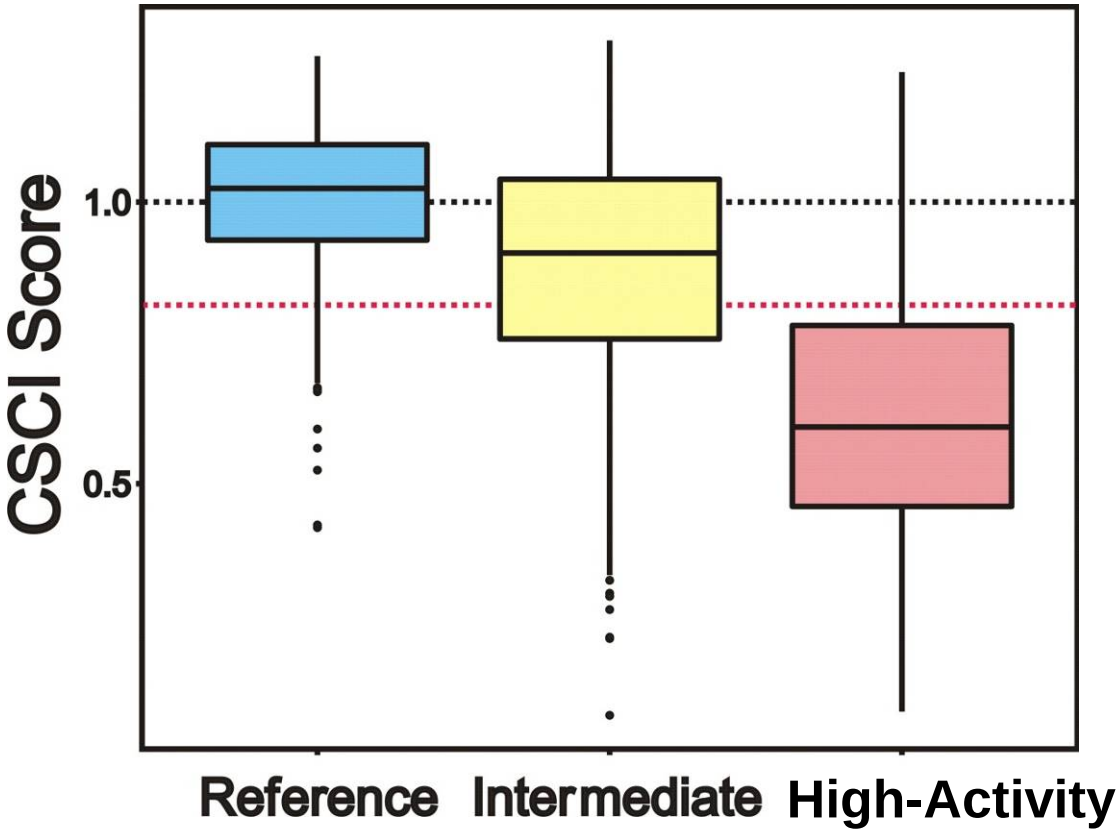
**EPT = Ephemeroptera + Plecoptera + Trichoptera*

Observed Species & Metrics

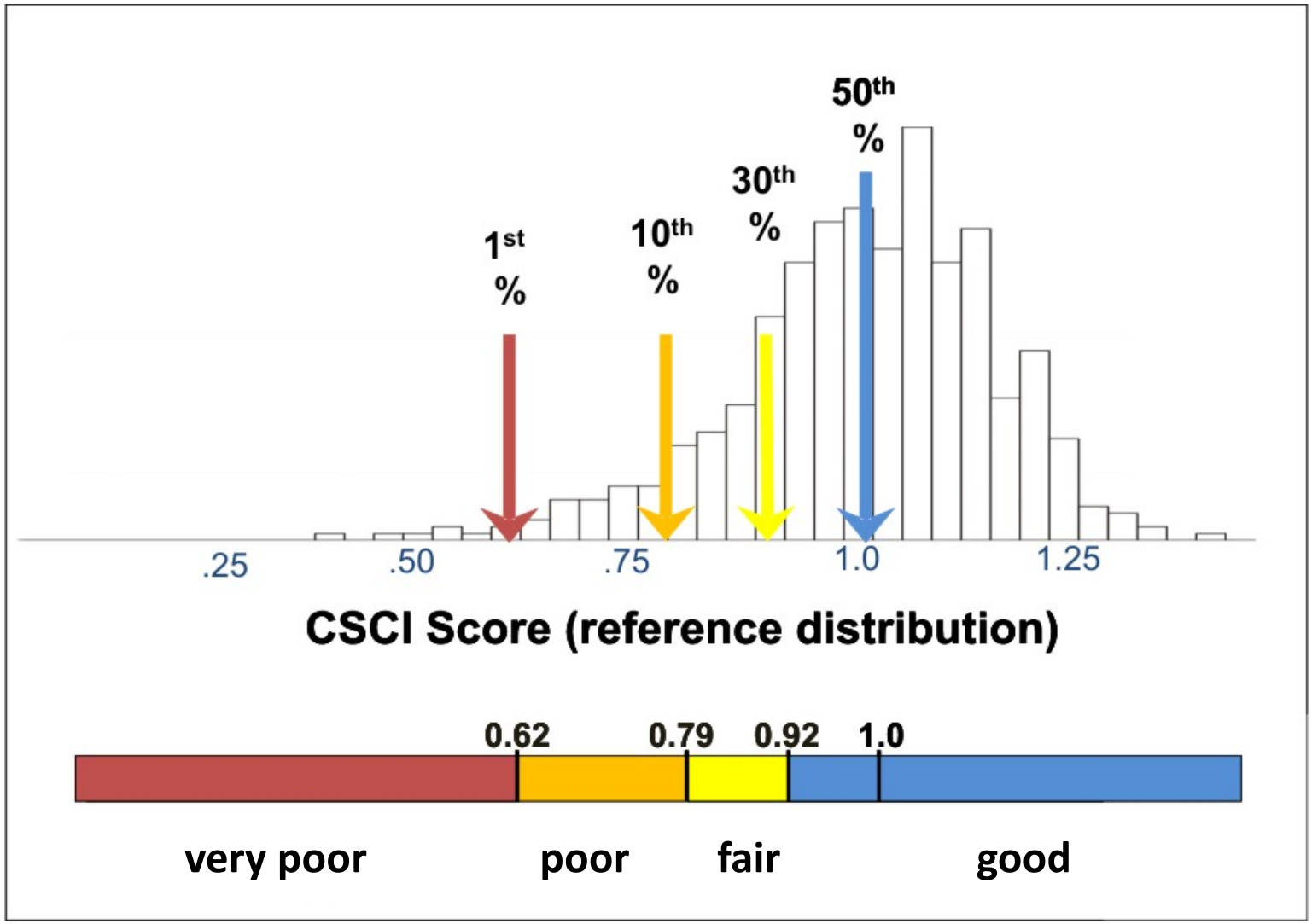
Expected Species & Metrics

= **CSCI SCORE**

The CSCI is responsive to human activity



The distribution of scores at reference sites is used to establish condition categories for all sites:



The Perennial Streams Assesssment (PSA)

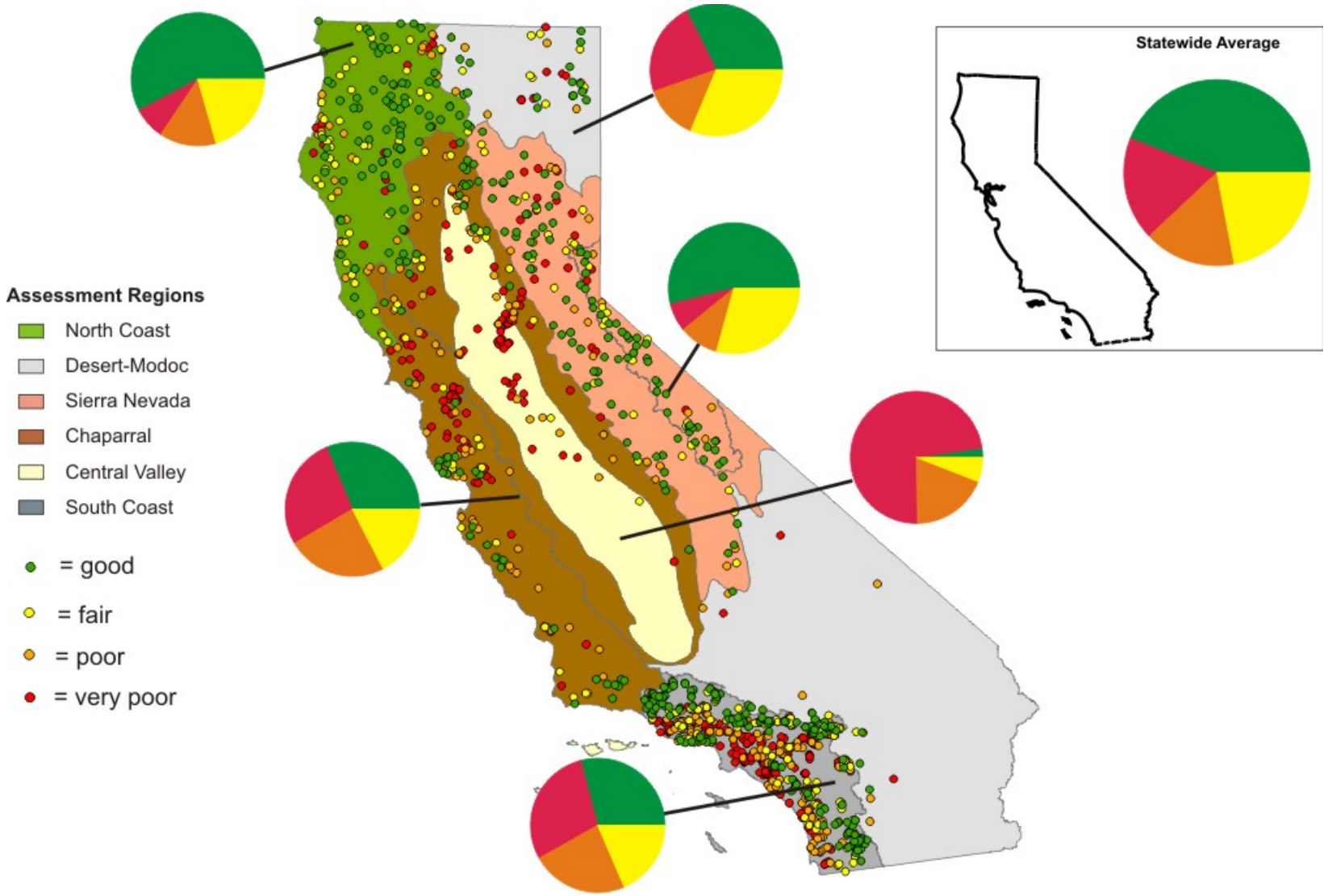
The PSA is a statewide survey where sampling sites are selected according to a probability (random) survey design:

- each random site represents a known portion of total stream length (i.e., each site has a statistical “weight”)
- permits assessment of the entire resource of interest with relatively limited sampling effort
- works similarly to political or opinion polls

Allows us to provide objective answers to several core questions with known statistical precision:

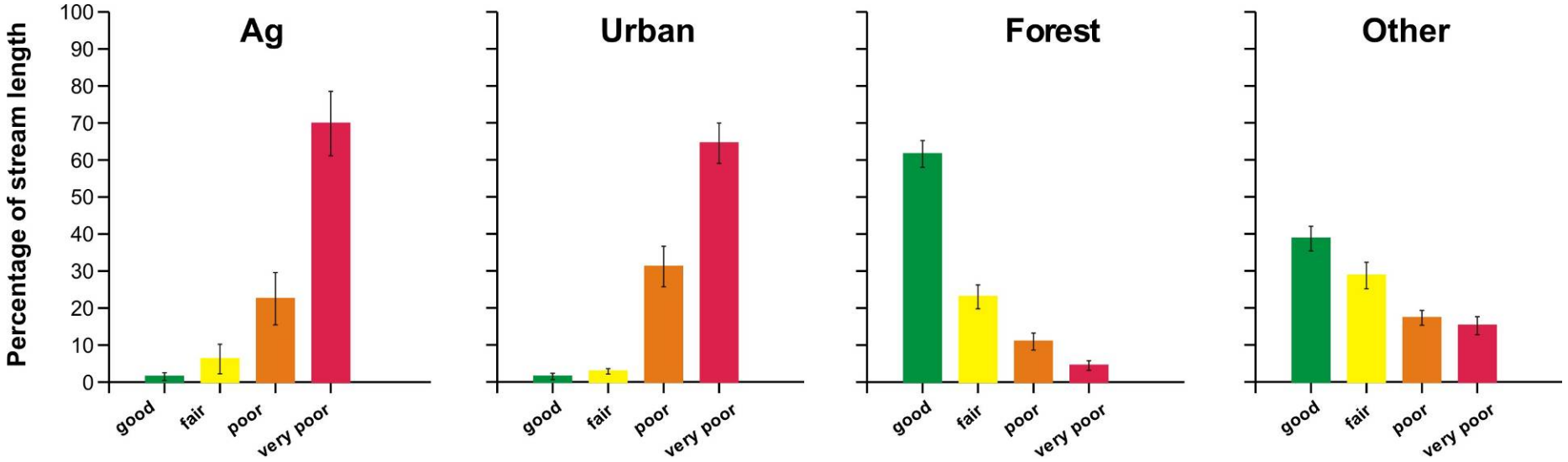
- What is the biological condition of California streams?
- Is condition getting better or worse?
- How does condition differ among streams draining agricultural, urban and forested watersheds?
- What chemical and physical stressors have the strongest association with biological condition?

Results from recent PSA 13-year report: >1300 sites sampled 2000-2012

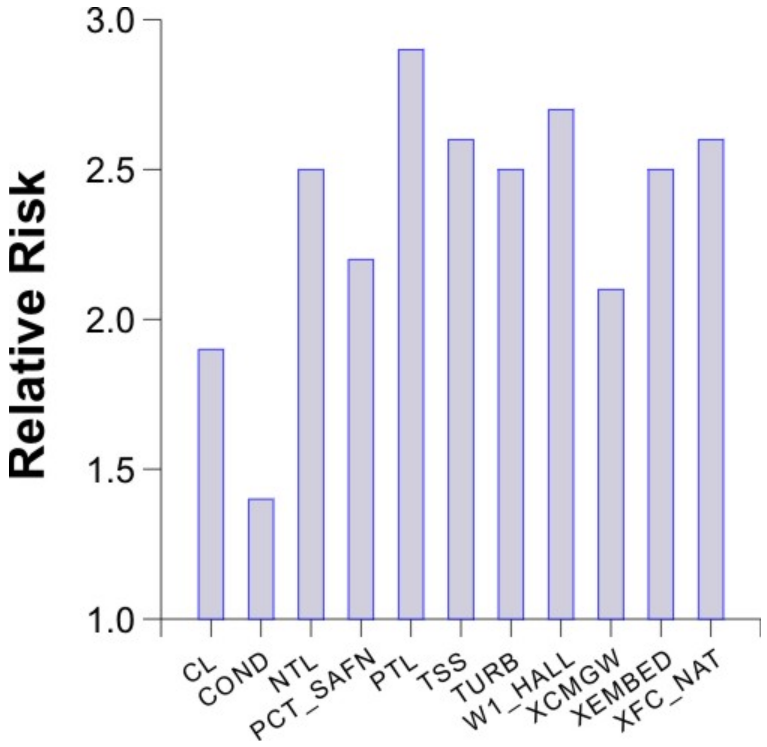


- Streams in ag or urban dominated watersheds were mosty in poor condition
- Streams in forested watersheds were mostly in good condition
- Streams with mixed land use/land cover were more variable in condition



<u>Relative Risk</u>: the increased risk of biological impairment when stressors exceed a critical threshold



CL =Chloride
COND = Conductivity
NTL = Total Nitrogen
PCT_SAFN = % sand and fines
PTL = Total Phosphorous
TSS= Total Suspended Solids
TURB = Turbidity
W1_HALL = Riparian Disturbance
XCMGW = Woody Riparian Cover
XEMBED = Mean Embeddedness
XFC_NAT = Instream Habitat Diversity

The scope and robust design of our core programs (RCMP and PSA) have attracted outside investment and collaboration from many non-SWAMP entities:

- **US Forest Service-** Sierra Nevada Management Indicator Species Program
- **USGS/SCCWRP/Colorado State-** ecohydrology and the influence of stream flow on ecological integrity
- **Private Timber Lands-** previous gap in our datasets that's now being filled in
- **The Nature Conservancy-** Aquatic biodiversity mapping and freshwater conservation blueprint;
- All of these collaborations greatly expand our datasets and our scientific understanding

The distributions of biological and stressor values from PSA and RCMP sites provide a complete context for interpreting data from sites that are targeted because they're known (or thought) to have problems.

- put results from site-specific projects into a regional perspective
- help set meaningful and objective restoration targets

Moving into other habitat types:

- **Depressional wetlands**: ~100 sites sampled 2011-2014
- **Nonperennial streams**: pilot studies in San Diego and Colorado Desert regions, now moving into northern CA

Part 2:

Using Biological and Habitat Indices Together for Bioassessment of California Streams

BMIs are powerful indicators of stream health because of their integrated response to multiple stressors over time and space.

However…
Other assemblages, such as fish or algae, often respond differently to various stressors, and over different time scales.

A primary long-term goal of SWAMP's bioassessment program has been to develop multiple indices of stream condition so that results from different assemblages can be used in conjunction to produce more complete and rigorous assessments of stream condition than provided by any single assemblage alone.

- where multiple assemblages are all in agreement about condition, inference of human-caused alteration to the system, or lack thereof, is strengthened

- where multiple assemblages are in disagreement, it may be possible to take advantage of their different sensitivities to elucidate the effects of different stressors

Indices Used:

The California Stream Condition Index (CSCI) based on benthic macroinvertebrates (Mazor et al. 2016)

The “H20” algae index: a hybrid index based on diatoms and non-diatom (i.e., “soft”) algae in conjunction (Fetscher et al. 2014)

The California Rapid Assessment Method (CRAM): an index not based on a particular taxonomic assemblage, but that combines in-stream and riparian measures to indicate overall condition of habitat (*cramwetlands.org*)

First step was to compare performance characteristics of H20 and CRAM with performance characteristics of CSCI (namely, **bias, precision, sensitivity and responsiveness**).

Goal: to evaluate whether cases of disagreement among indices might indicate moderate levels of stress, to which some indices have responded but not others, or whether disagreement among indices was more likely to be "noise" due to poor performance in one or more index

Why was this important?

The H20 index was developed for use in southern coastal California, so it was important to evaluate its performance statewide

CRAM developed for statewide use, but performance evaluations were not completely parallel with CSCI evaluations

Conclusion: H20 and CRAM performed reasonably well on a statewide scale. Patterns of agreement/disagreement among indices were considered to be real signal and not just noise due to poor performance in one or more indices

Second step was to compare the frequency with which the three indices agreed and disagreed about site condition to identify whether cases of agreement and disagreement occurred in systematic and predictable ways according to which stressor(s) affect sites.

Data set: 628 probabilistic sites sampled 2008-2012 for all 3 indicators

- some of these pass reference screens
- used same criteria as CSCI to establish condition categories for H20 and CRAM (i.e, 30th, 10th and 1st percentiles of reference sites)

Results: Full agreement between all 3 indicators at 55% of sites; chi-square goodness-of-fit test highly significant ($p < 0.0001$)

Condition	*n*	Ag	Urban	Forest	Other	Reference	Moderate-activity	High-activity
All 3 degraded	159	24	108	0	27	0	20	139
All 3 not degraded	185	0	2	67	116	77	98	10
Sites w/ disagreement	284	16	78	40	150	34	141	109

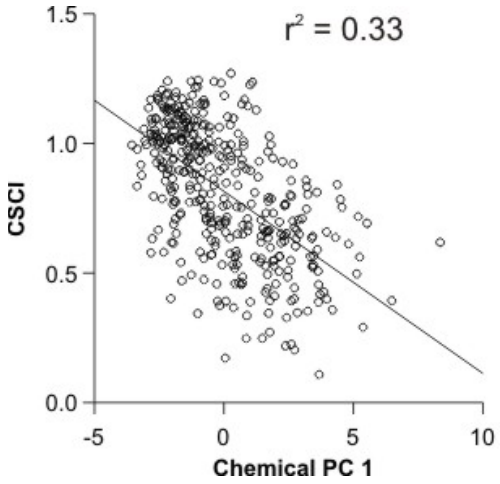
Results: focusing on the 284 sites that had some form of disagreement:

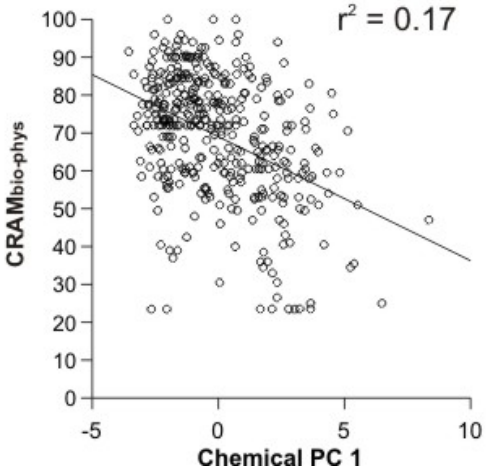
At sites where CSCI indicated degradation, but H20 indicated fair or good condition (and ignoring CRAM), exceedence of PHAB thresholds was far more likely than exceedence of chemical thresholds.

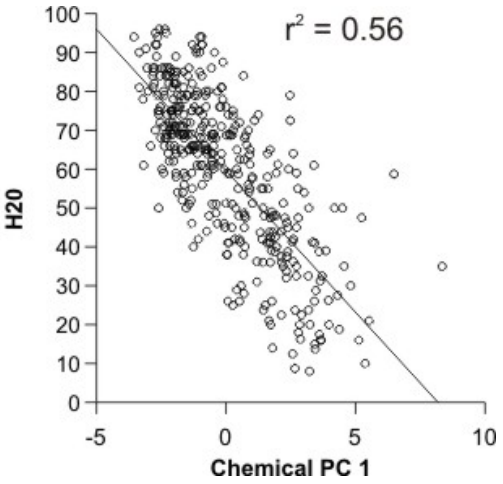
At sites where H20 indicated degradation, but CSCI indicated fair or good condition (and ignoring CRAM), exceedence of chemical thresholds was far more likely than exceedence of PHAB thresholds.

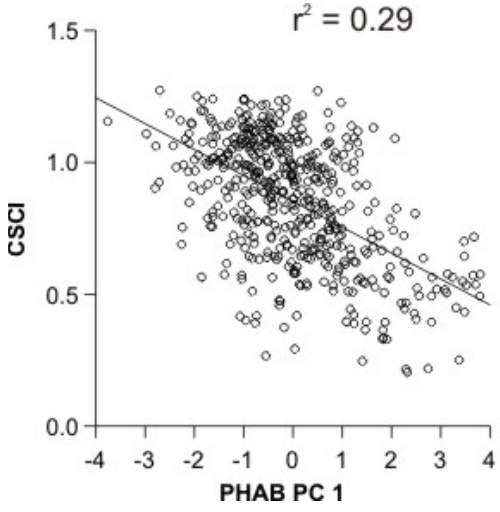
		Number of exceedences				
Summary	***n***	**Chem**	**PHAB**	**Chem & PHAB**	**Only Chem**	**Only PHAB**
CSCI degraded, H20 not	**69**	26	51	21	**5**	**30**
H20 degraded, CSCI not	**93**	65	49	35	**30**	**14**
CRAM degraded	**110**	41	64	33	**8**	**31**

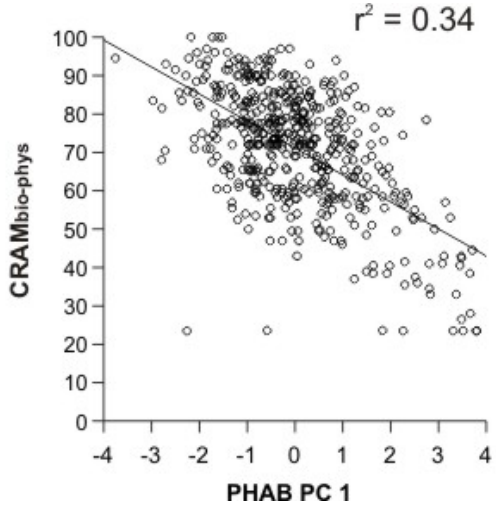
Results: Principal Components Analysis (PCA)

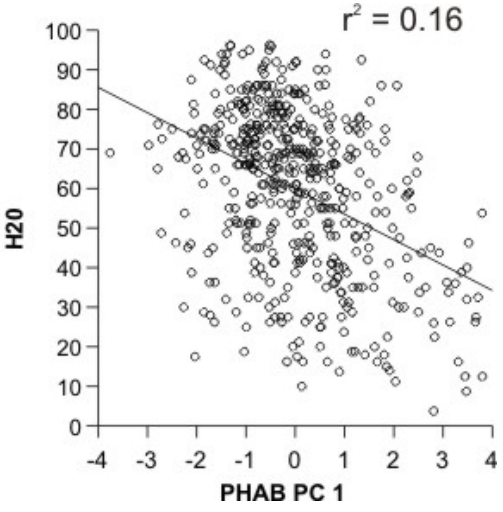




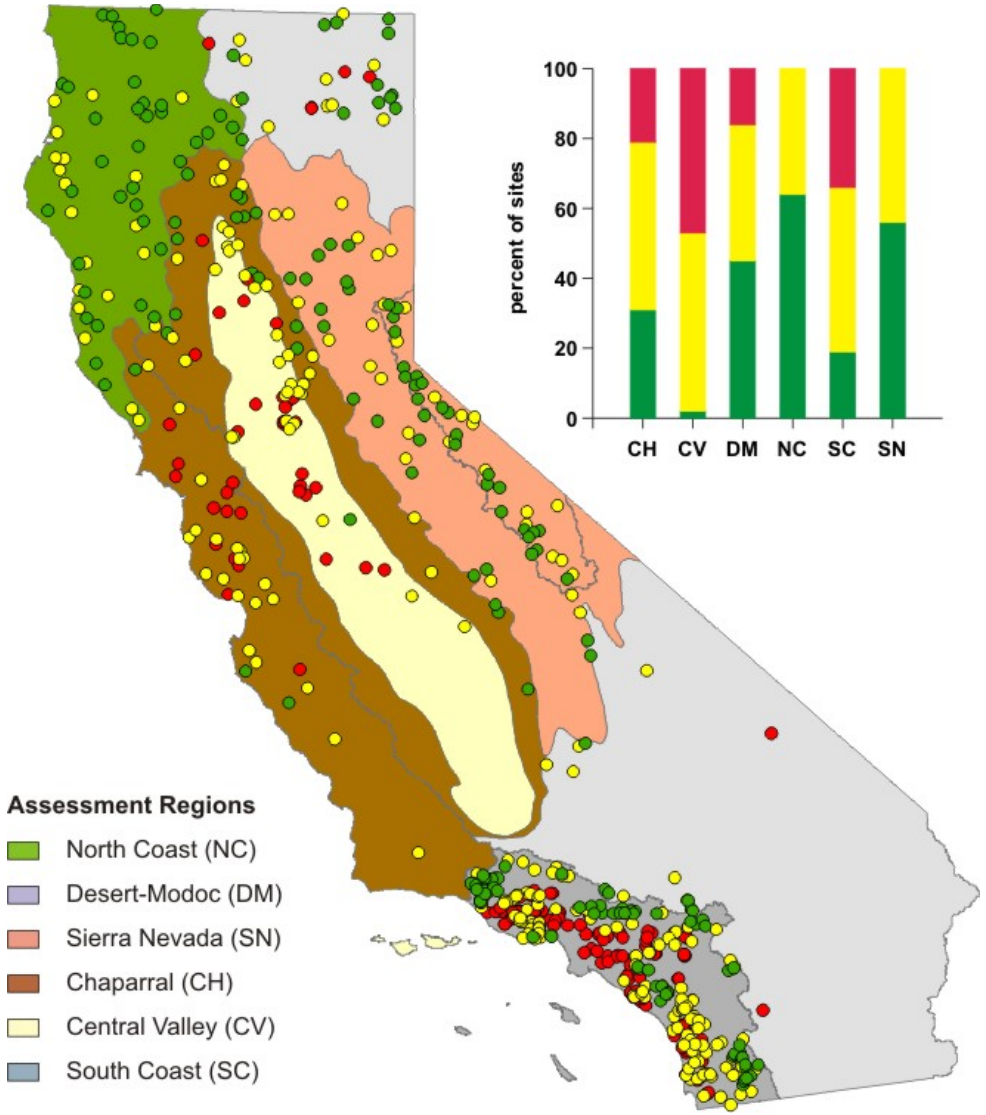








Results: Regional patterns of agreement/disagreement



CONCLUSIONS:

CRAM and H20 performed reasonably well on a statewide scale despite being "unmodeled" indices

Disagreement between indices was more likely to indicate moderate levels of stress, to which some indices have responded but not others, rather than "noise" due to one or more index performing poorly

Patterns of agreement/disagreement were highly non-random

- the indices frequently agreed that reference sites were unimpaired, and that high-activity sites were impaired
- CRAM and CSCI were more sensitive to PHAB stressors
- H20 was more sensitive to chemical stressors

Where multiple assemblages are all in agreement about condition, inference of human-caused alteration to the system, or lack thereof, is strengthened.

Where multiple assemblages are in disagreement, the different sensitivities of the indices to different kinds of stressors can potentially help us diagnose causes of degradation.

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

Question must be answered in two steps:

- first step is to define stressor thresholds, i.e., “exceedence”
- we used biology-based thresholds