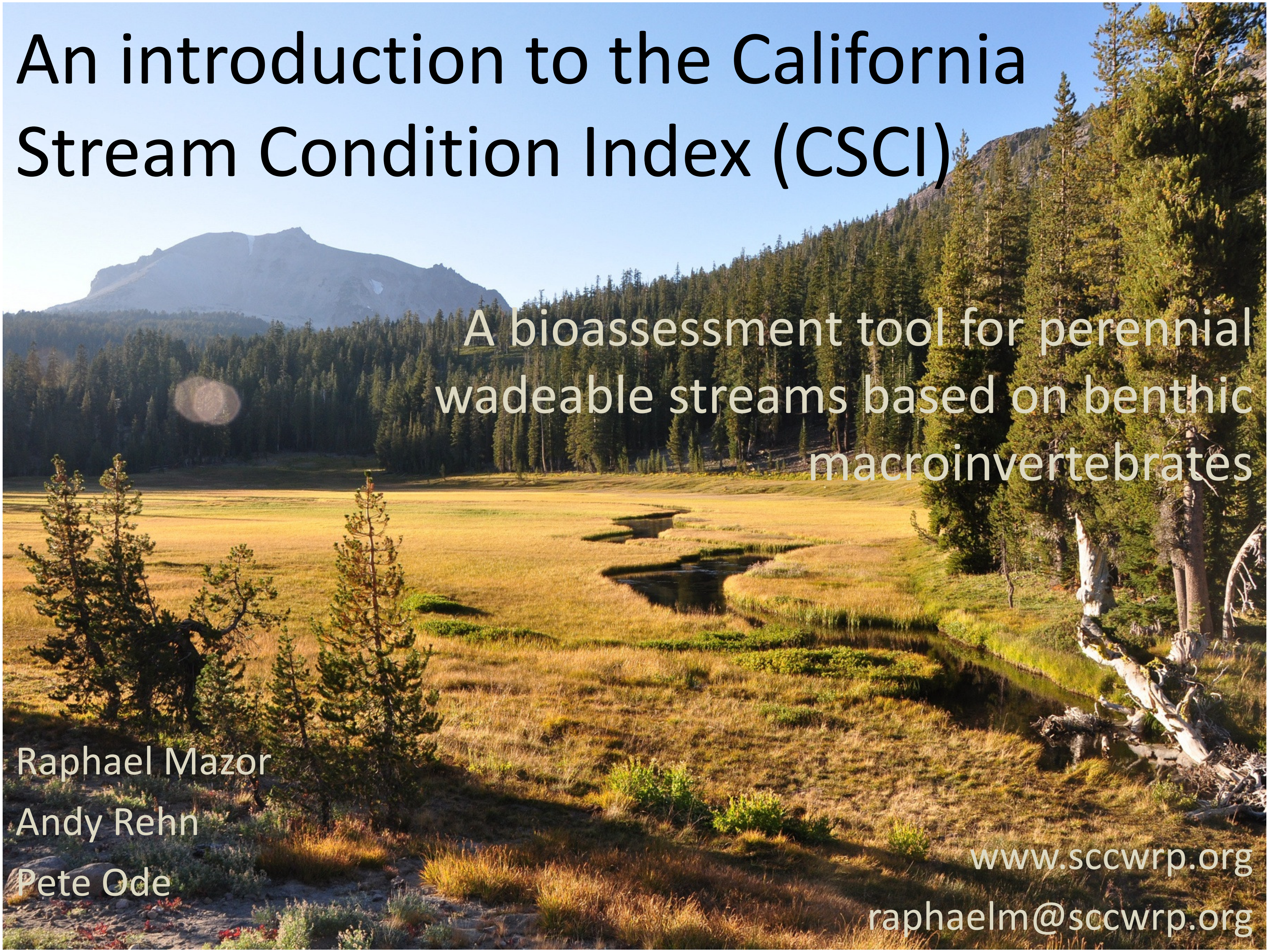
An introduction to the California Stream Condition Index (CSCI)



A bioassessment tool for perennial wadeable streams based on benthic macroinvertebrates

Raphael Mazor
Andy Rehn
Pete Ode

www.sccwrp.org
raphaelm@sccwrp.org

Outline

- What is the CSCI, and why is it better than previous assessment tools?
- How was it developed?
- How does it perform?
- What does the CSCI tell us about a site?

How is the CSCI better than previous indices?

- ***Much better reference*** data set
  - Bigger, broader, and more rigorously screened
- ***Site-specific expectations*** means that your site is held to appropriate standards
- A ***more comprehensive*** look at BMI communities
- ***Statewide applicability***, without regionalization
  - Nearly all perennial wadeable streams can be assessed
  - Consistent interpretability
  - Formal tests of applicability are possible

The CSCI has two components

- A measure of taxonomic completeness (O/E)
  - Similar to previous O/E models used in California
  - Compares taxa found at similar reference sites.
- A measure of ecological structure (MMI), made up of several metrics (e.g., % EPT taxa)
  - *Predictive* approach is different from previous IBIs used in California.
  - Compares metric values observed at similar reference sites.
  - Successful example for of a predictive MMI Nevada presented by Vander Laan and Hawkins at last year's CABW.

What do you need to calculate the CSCI?

- BMI data:
  - At least 450 bugs
  - At least 360 *unambiguous* bugs (i.e., identified with sufficient resolution: SAFIT Level 1, plus midges to subfamily)
  - SWAMP and SAFIT have already standardized BMI data production.
- Predictor data
  - All GIS-based (next slide)
  - Based mostly on site characteristics (+ a few catchment characteristics)
  - All predictors must be calculated using standard data sources.
  - State will develop protocols to support predictor calculation.

Predictor data

Location	Topography	Long-term climate	Soils	Minerology
Latitude	Watershed area*	Catchment precipitation*	Hydraulic conductance	MgO content
Longitude	Elevation range*	Local precipitation	Bulk density	CaO content
Elevation		Local temp	Erodibility	S content
			Permeability	N content
				P content

Major influences on bug community

Unaffected by most human activity

Development of the CSCI

- Identify reference sites
  - Divide into calibration (80%) and validation (20%) sets
  - Stratify so all subregions are represented (except for Central Valley)
- MMI component also requires stressed sites
  - At least 50% developed, high road density, or intensive riparian activity
  - Stratify so all subregions are represented

Taxonomic completeness component (O/E)

Compare number of **observed** (“O”) taxa to number of **expected** (“E”) taxa

Step 1: Cluster reference sites based on biological similarity

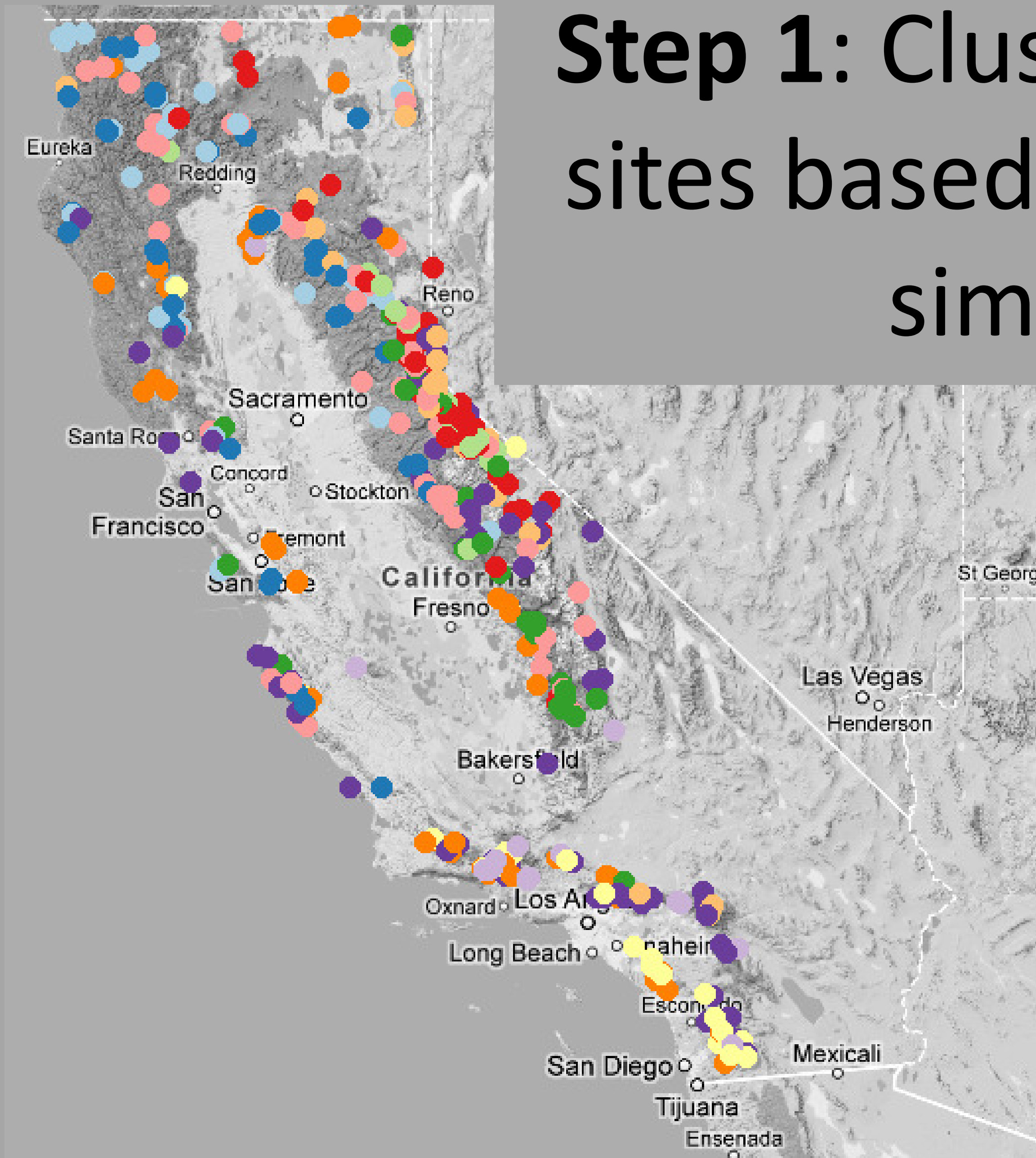
Step 2: Build model that predicts group membership based on natural gradients

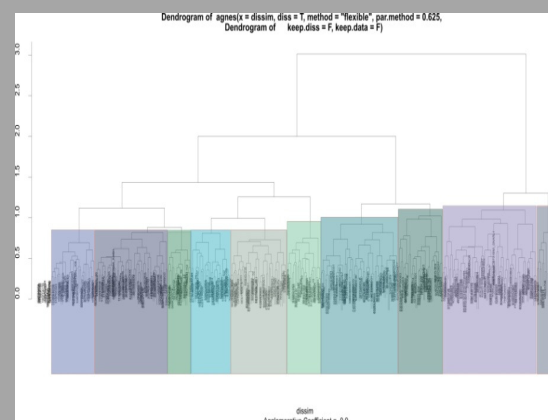
Step 3: Determine probability of observing a taxon at a site

Step 4: Score the site: Sum the probabilities (“E”) and count the taxa that are observed (“O”)

Component score is an estimate of taxonomic completeness

Step 1: Cluster reference sites based on biological similarity





Steps 2-4: Predict group membership, Calculate Taxon probabilities, and Score

- Use Random Forest to predict likelihood that a test site is a member of each reference group
- Probability of group membership * Frequency of taxon in each group = Probability of observing a taxon at a test site.
- Sum of all probabilities = Total number of expected taxa

Ecological structure component

follows methods of Hawkins and Vander Laan

Step 1. Calculate lots of metrics at reference and stressed sites

Step 2. Create models that adjust metric values to account for major natural sources of metric variation

Step 3. Select metrics based on ability to discriminate reference from stressed sites

Step 4. Score metrics (after Cao et al. 2007) and assemble into composite MMI

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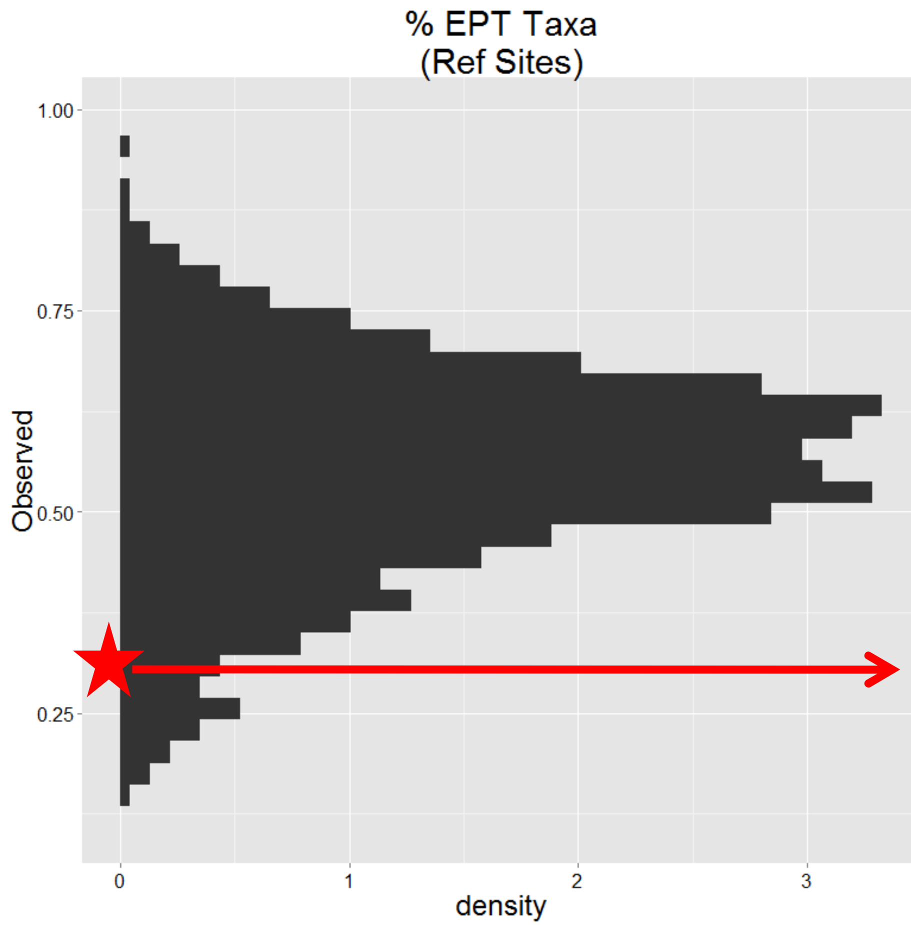
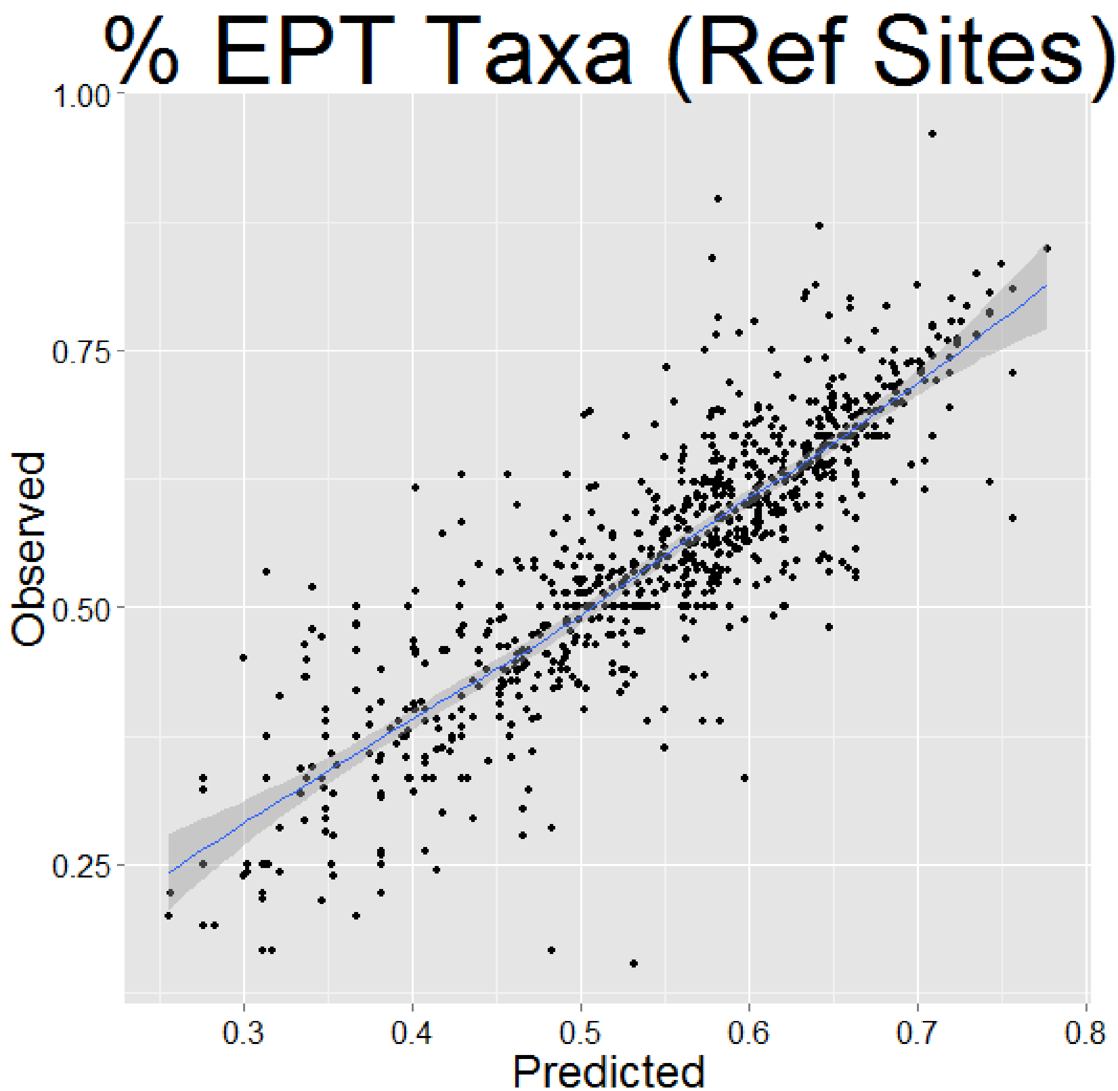
The old IBIs didn't address causes of variability at reference sites



All variability attributed to "noise"

30% EPT Taxa: Below reference expectations

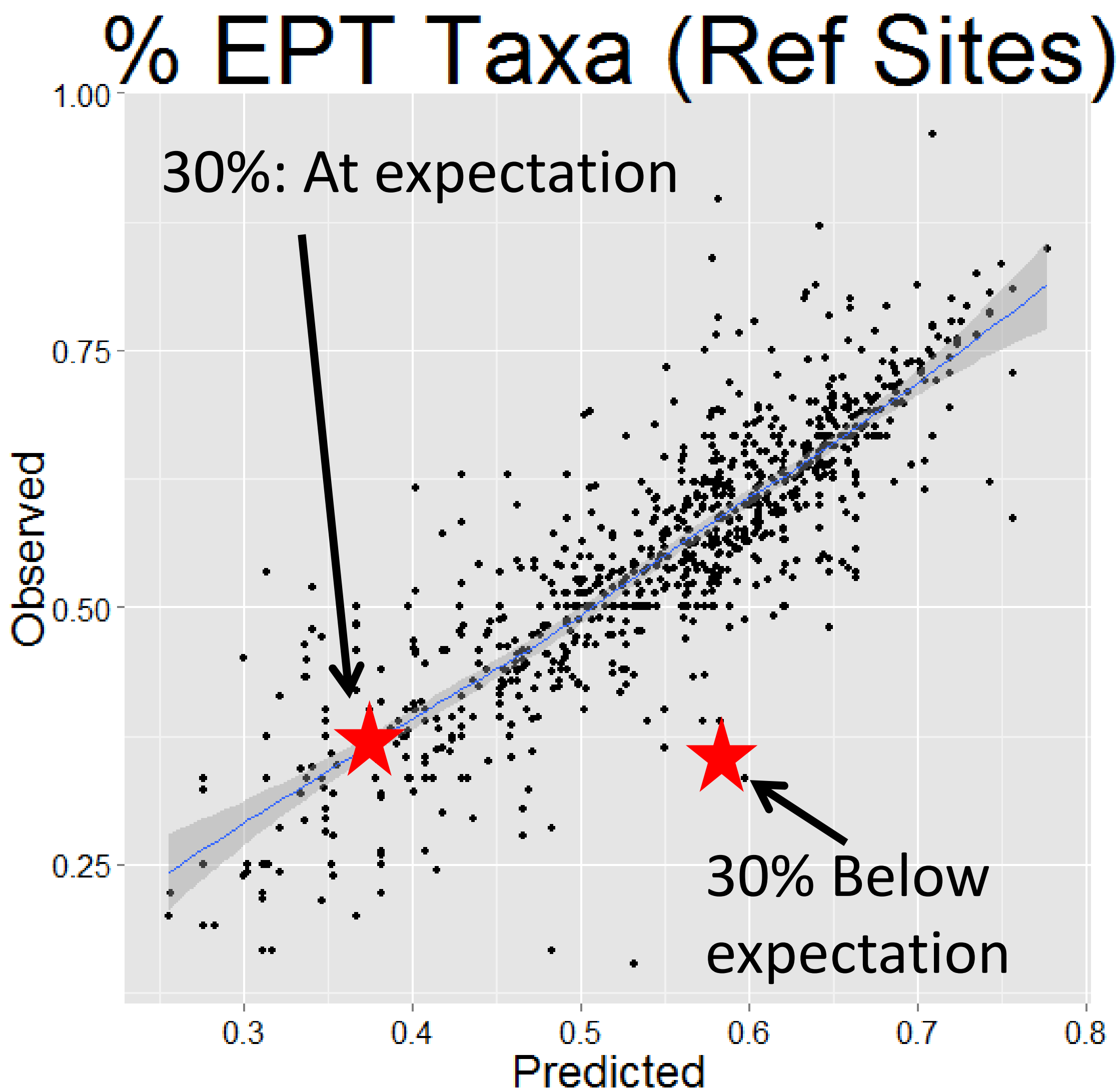
Now we model the variability in reference sites associated with natural gradients



Much of the variability attributed to environmental factors.

Environmental "noise" removed by models.

Now we model the variability in reference sites associated with natural gradients



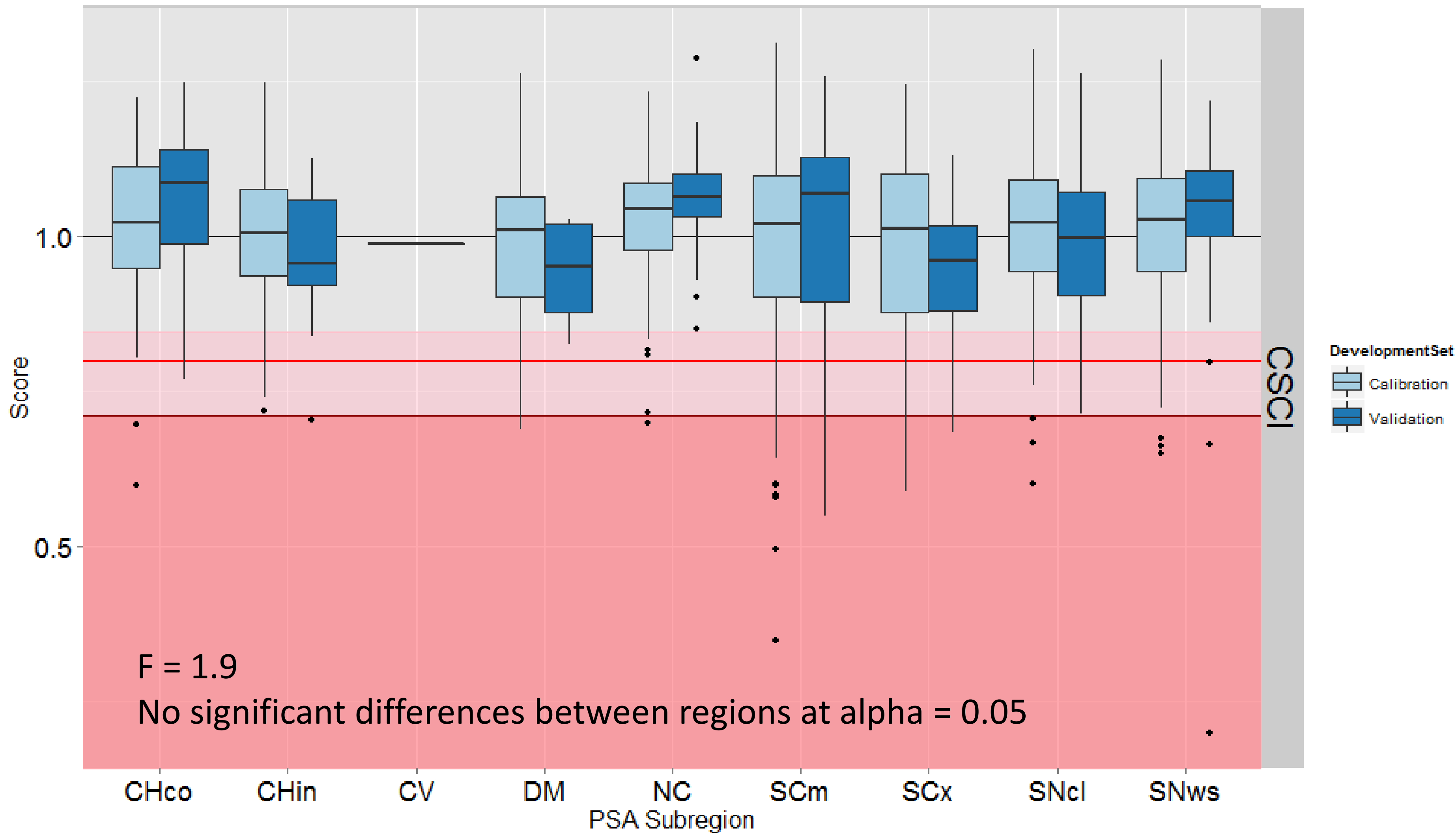
Score depends on the *environmental setting*, not just metric value.

Development of the CSCI

- Screen metrics that:
  - Respond strongly to stress
  - Are minimally correlated (statistically)
  - Nonredundant (philosophically)
- Each component standardized by reference mean and averaged together.
- Both components and CSCI have an expectation of 1.

Good performance overall

Scores at reference sites



Key performance measures

Good performance for CSCI and its components!

Performance aspect	How do we measure?
Accuracy	Ref Val means close to 1
Precision	Low SD for Ref sites
Sensitivity	Big differences between Ref and Stressed

	Reference				Stressed			
	Calibration		Validation		Calibration		Validation	
Index	Mean	SD	Mean	SD	Mean	SD	Mean	SD
CSCI	1.01	0.13	1.01	0.14	0.78	0.20	0.74	0.20
O/E	1.01	0.18	1.02	0.18	0.78	0.24	0.75	0.24
MMI	1.00	0.12	0.99	0.14	0.79	0.20	0.73	0.20

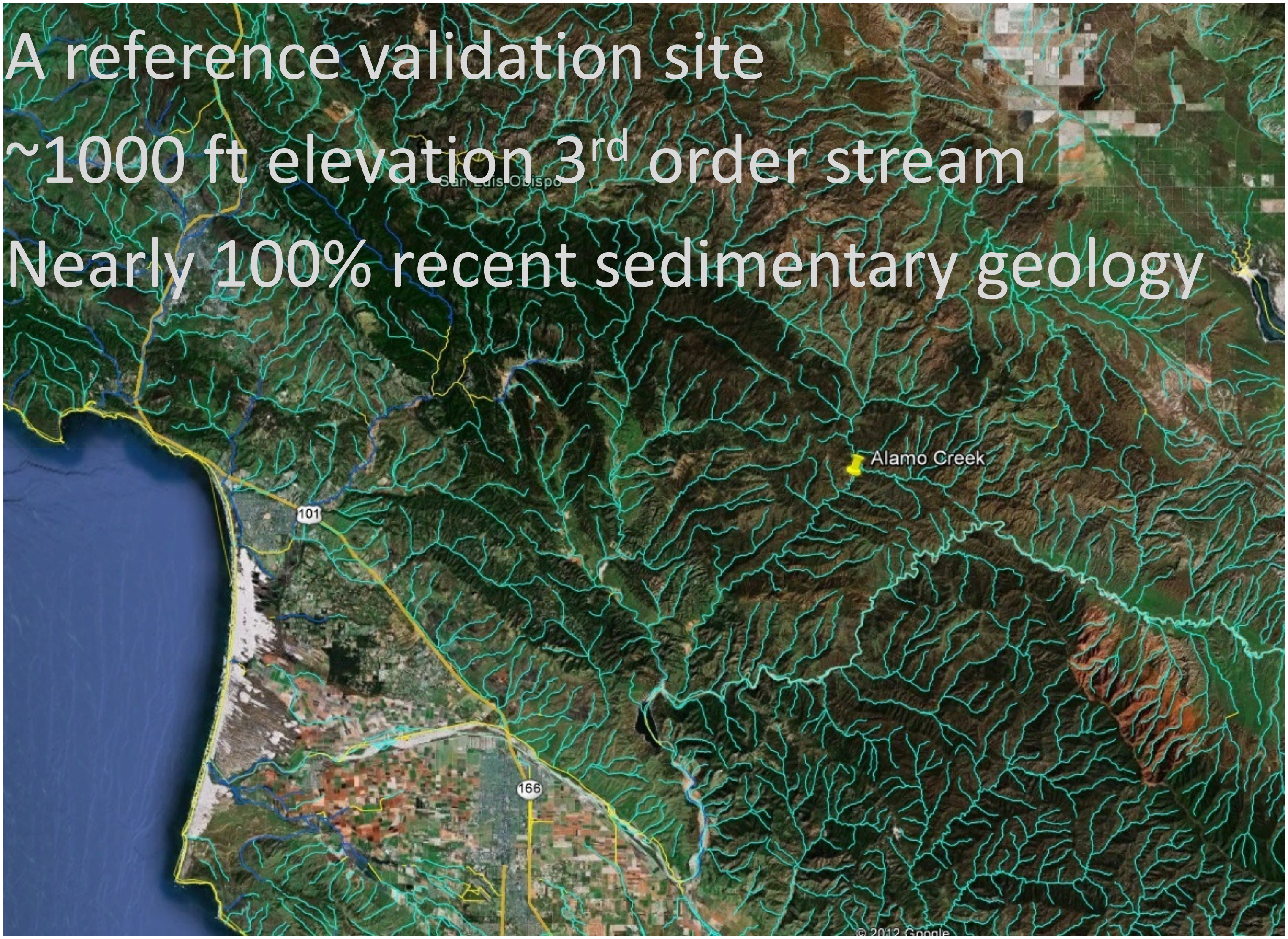
How does this play out at a “real” site?

Demonstration with an undeveloped site and a moderately stressed site

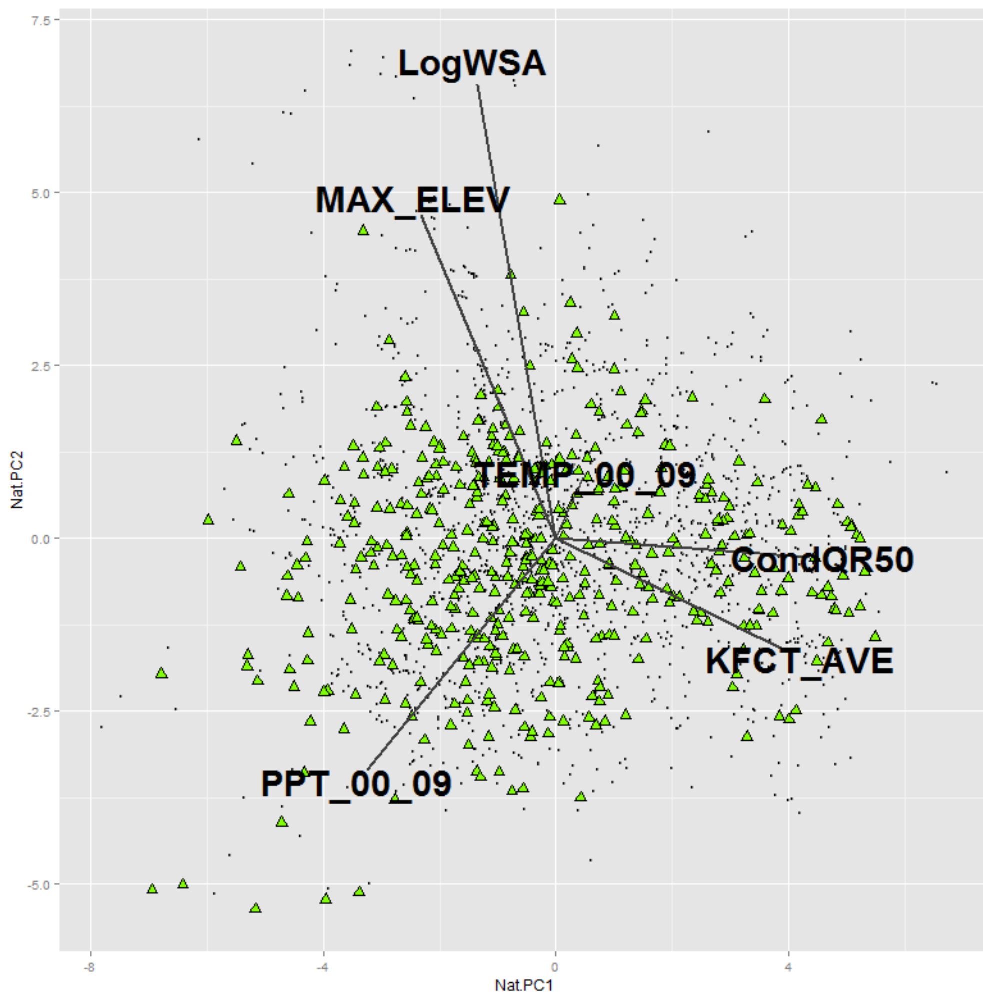
- What kind of information does the CSCI provide?
- Do the reference sites represent it well?
- Taxonomic completeness:
  - Which reference sites are important?
  - Which taxa are expected? Which are missing?
- Ecological structure:
  - Which metrics are close to expectations?

Alamo Creek
San Luis Obispo County

- A reference validation site
- ~1000 ft elevation 3rd order stream
- Nearly 100% recent sedimentary geology

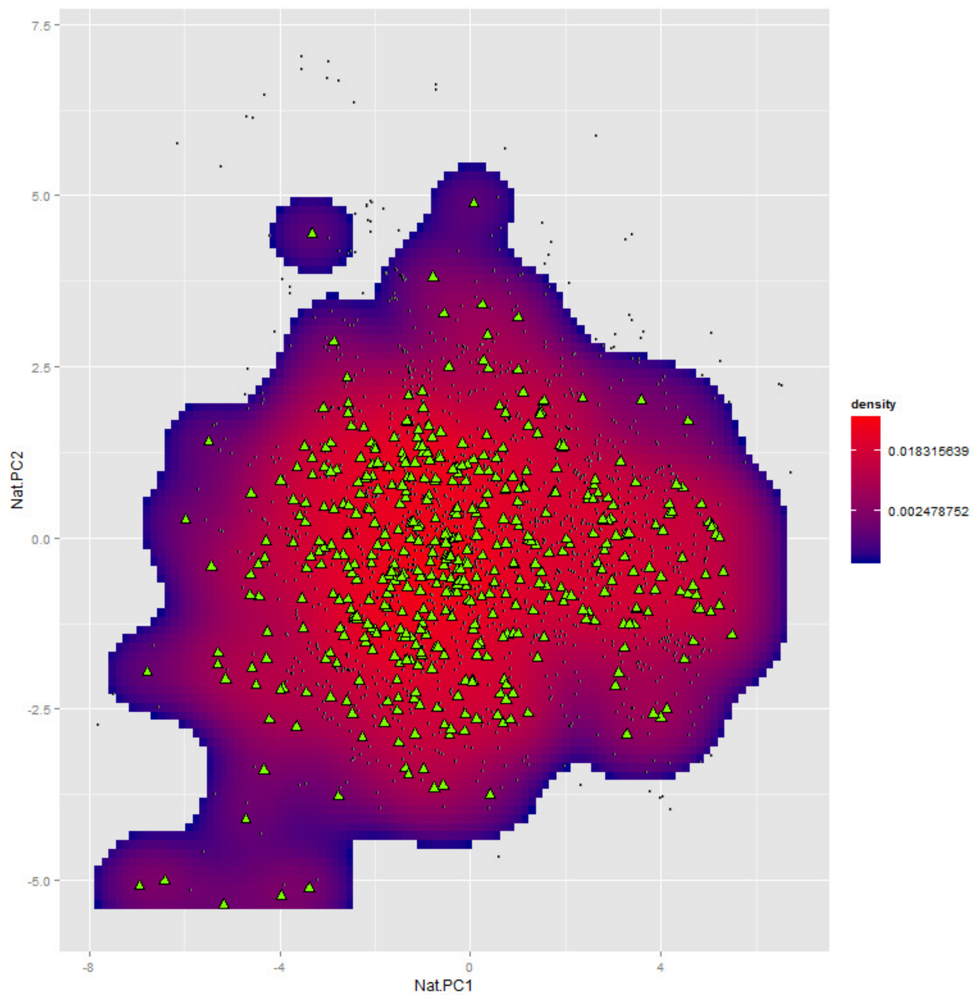


Alamo Creek
Comparison to reference sites



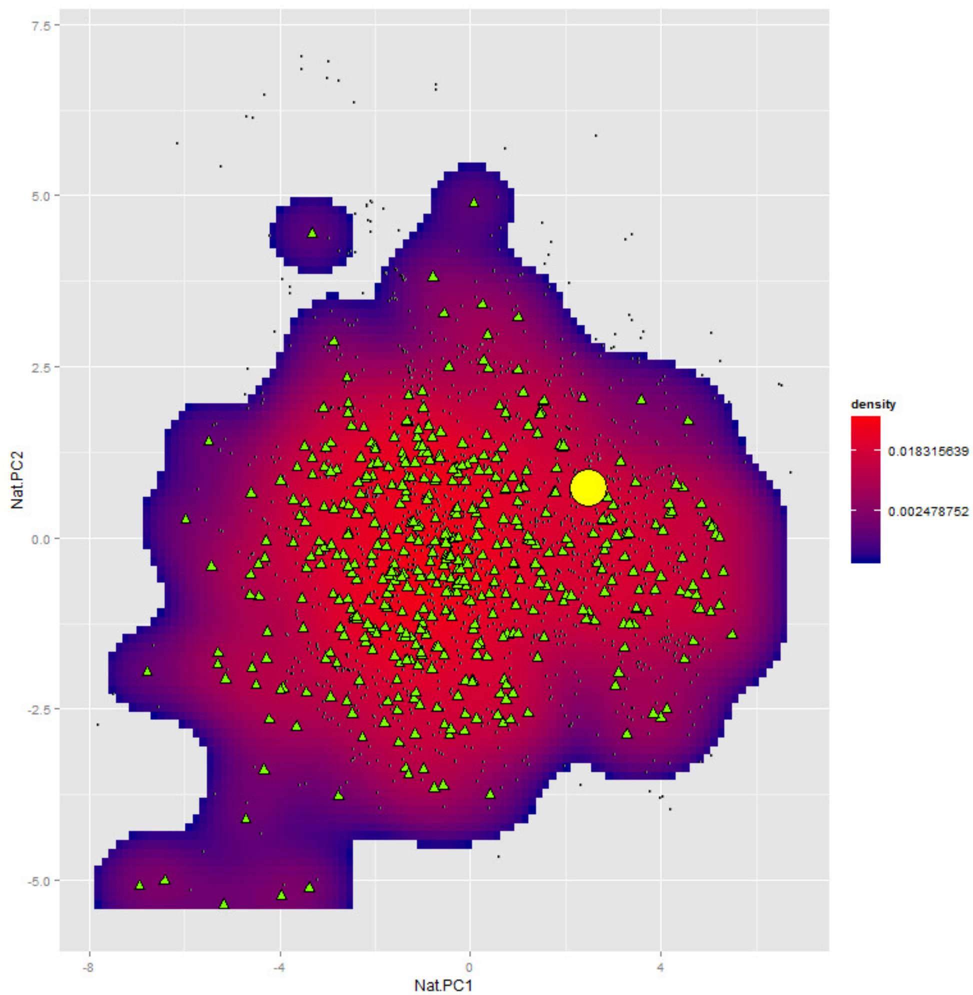
- Multivariate ordination of major environmental gradients (from Pete’s talk)

Alamo Creek
Comparison to reference sites



- Multivariate ordination of major environmental gradients (from Pete's talk)
- Map out density of reference sites in environmental space

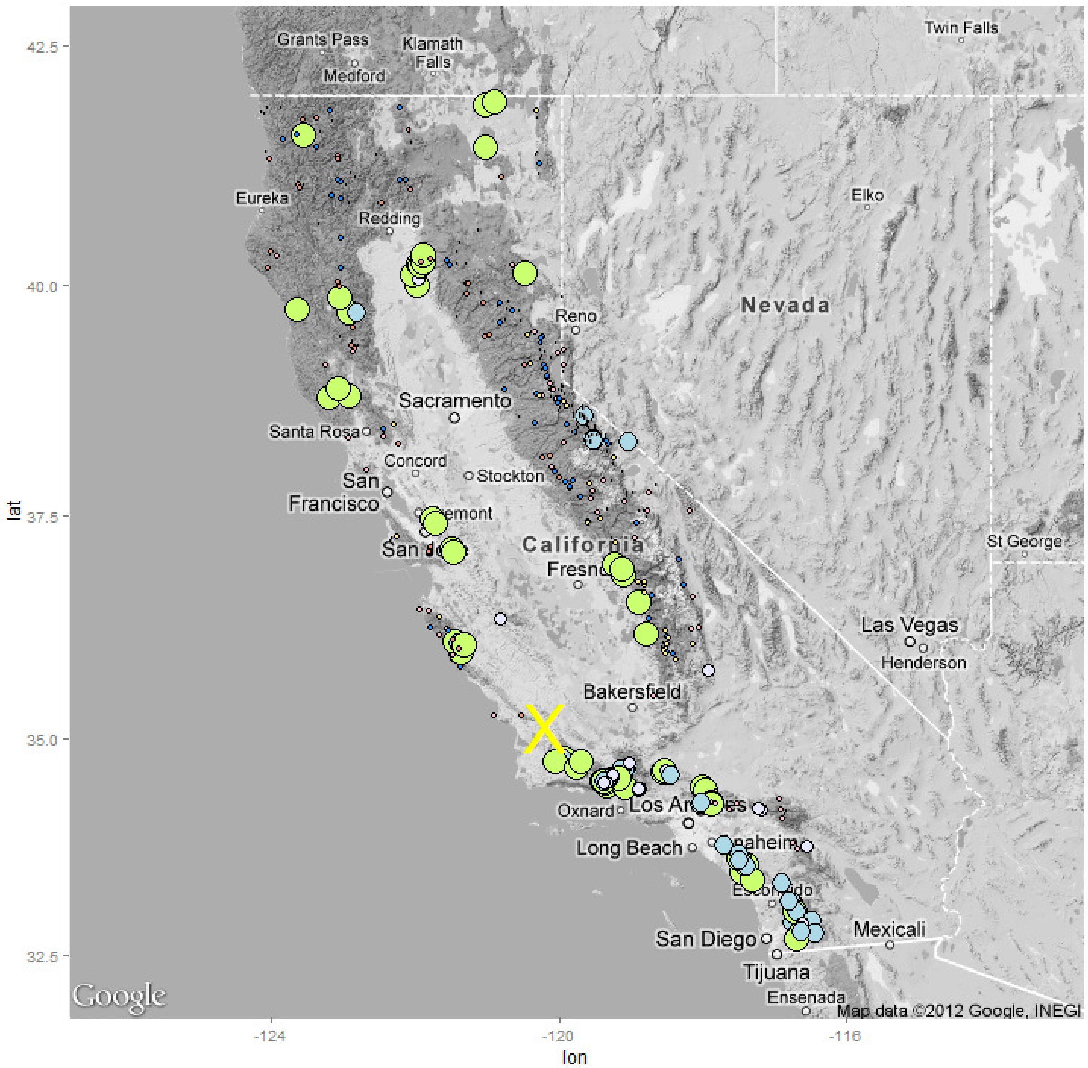
Alamo Creek
Comparison to reference sites



- Multivariate ordination of major environmental gradients (from Pete's talk)
- Map out density of reference sites in environmental space
- Alamo Creek plots well within the cloud of reference sites

Alamo Creek

Reference groups for assessing Taxonomic Completeness



- Mostly other mid-elevation sites across state
- Also, low-elevation so-cal sites
- Overall, 8 groups containing 356 ref sites provide at least some information

Alamo Creek
CSCI

Component	Obs1	Obs2	Expect
CSCI	0.98	0.94	1

Alamo Creek
Taxonomic completeness

Component	Obs1	Obs2	Expect
CSCI	0.98	0.94	1
O/E	1.01	1.01	1
O	9	9	8.92

A few taxa missing (mostly those with lower E)

Few "sensitive" taxa expected; these are all hardy bugs!

Taxon	Obs1	Obs2	Expect
Caloparyphus/ Euparyphus	1	1	0.52
Hydroptila	1	1	0.52
Bezzia/ Palpomyia	0	0	0.59
Oligochaeta	0	1	0.70
Simulium	1	0	0.80
Fallceon	1	1	0.81
Baetis	1	1	0.84
Chironominae	1	1	0.88
Orthocladiinae	1	1	0.88
Acari	1	1	0.90

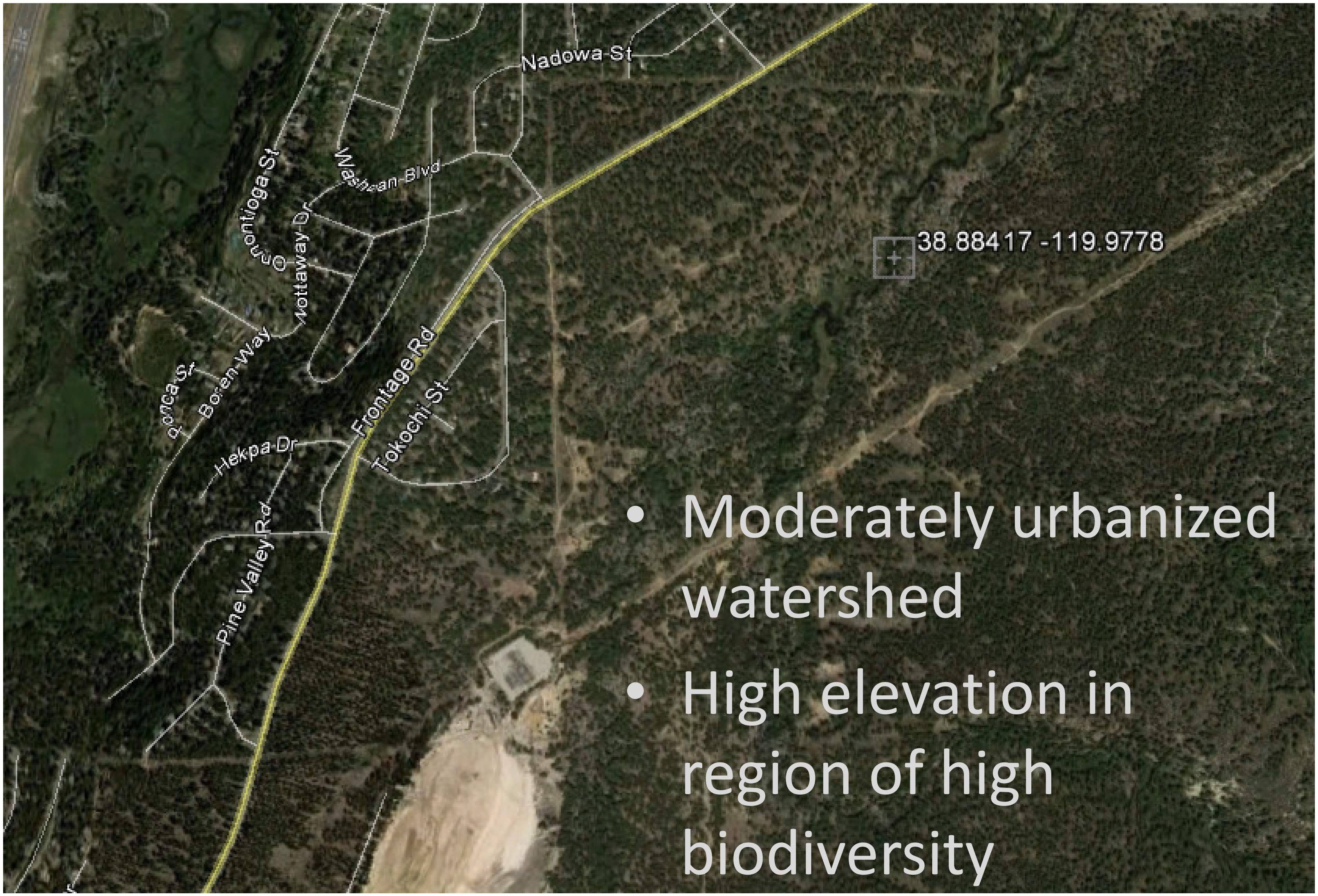
Alamo Creek
Ecological structure

Component	Obs1	Obs2	Expect
CSCI	0.98	0.94	1
O/E	1.01	1.01	1
O	9	9	8.92
MMI	0.95	0.88	1

Metrics indicate slight degradation, but not more than expected by noise.

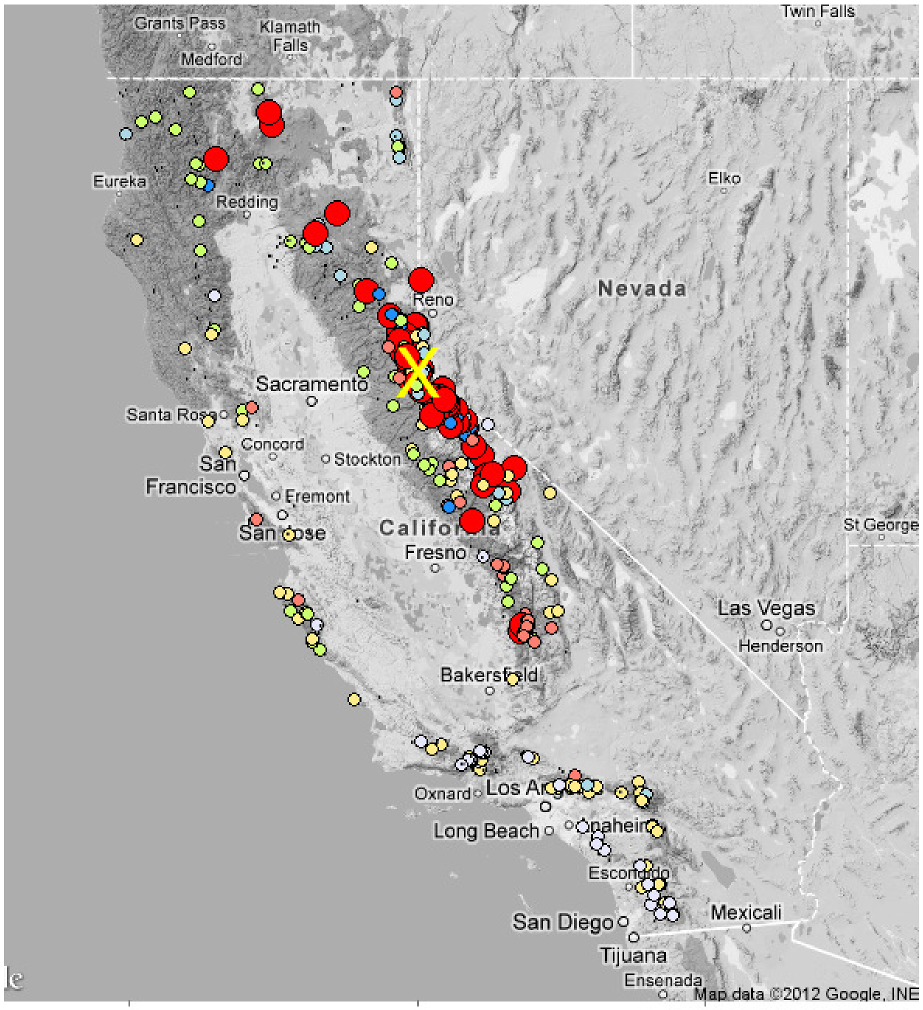
Metric	Obs1	Obs2	Expect
% Coleoptera taxa	7	0	10.4
Diptera taxa	9	7	5.3
% EPT taxa	25	35	40
% Intolerant	2	1	15
% Non-insect	11	21	11
% Predator taxa	33	15	33
% Scraper taxa	8	15	17
% Shredders	1	1	4.5
Simpson’s diversity	0.86	0.74	0.85
Tolerant taxa	24	20	4.8

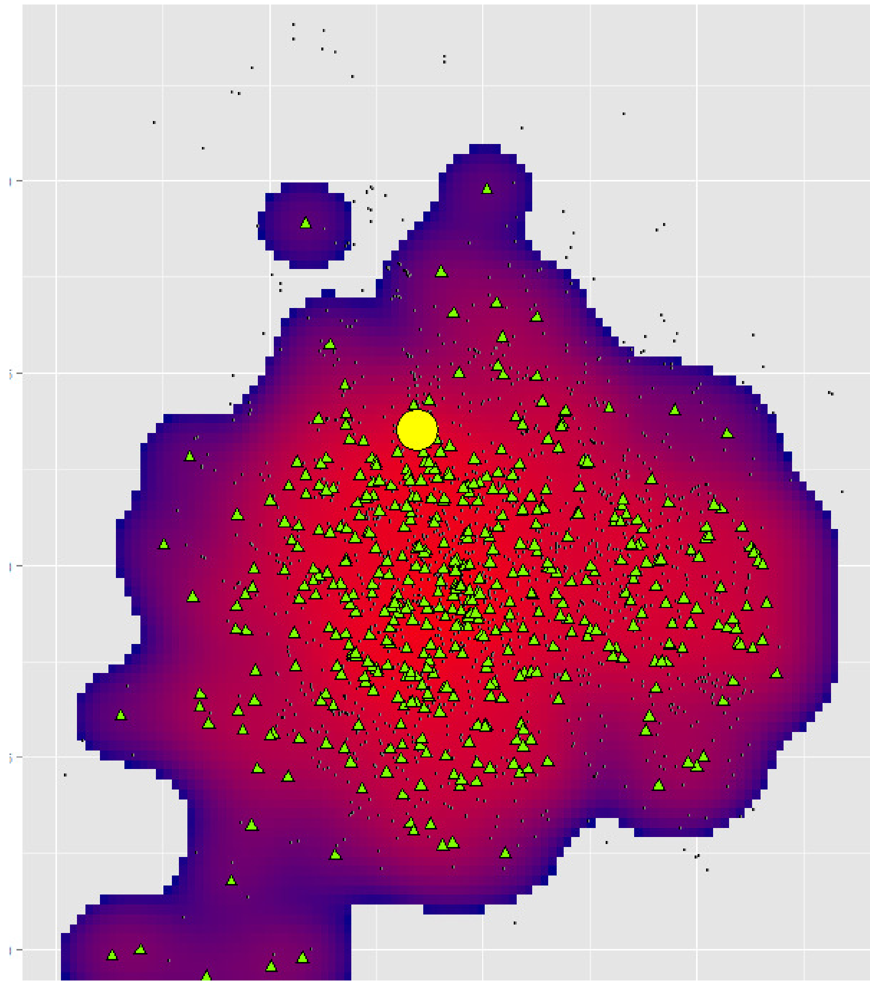
Trout Creek
Tahoe Basin



- Moderately urbanized watershed
- High elevation in region of high biodiversity

Trout Creek
Tahoe Basin





Trout Creek
Tahoe Basin

Component	Obs	Expect
CSCI	0.65	1
O/E	0.49	1
O	7	14.1
MMI	0.81	1

Metric	Obs	Expect
% Coleoptera taxa	3	4
Diptera taxa	5	5.3
% EPT taxa	24	63
% Intolerant	5	36
% Non-insect	35	3
% Predator taxa	65	26
% Scraper taxa	0	10
% Shredders	0	10
Simpson’s diversity	0.90	0.84
Tolerant taxa	6	5

Observed taxa	Missing taxa
Micrasema	Hydropsyche
Sweltsa	Diamesinae
Paraleptophlebia	Fallceon
Oligochaeta	Epeorus
Baetis	Rithrogena
Chironominae	Ameletus
Acari	Cinygmula
Orthocladiinae	Zapada
	Serratella
	Tanypodinae
	Rhyacophila
	Simulium
	Drunella

What does the final score mean?

- CSCI and both components are 1 if stream is undisturbed.
- Scores < 1 imply degradation.
- *But* scores can also vary because of:
  - Sampling error
  - Temporal variability
  - Model error
- Although management objective is 1, regulatory decisions need to account for these sources of error.

Remaining questions

- Should thresholds be established based on reference distribution?
- If so, should ALL ref sites be used for every test site?
- How should index applicability be formally tested?
  - Based on standard gradients (e.g., predictors)
  - Based on novel gradients (ad hoc)

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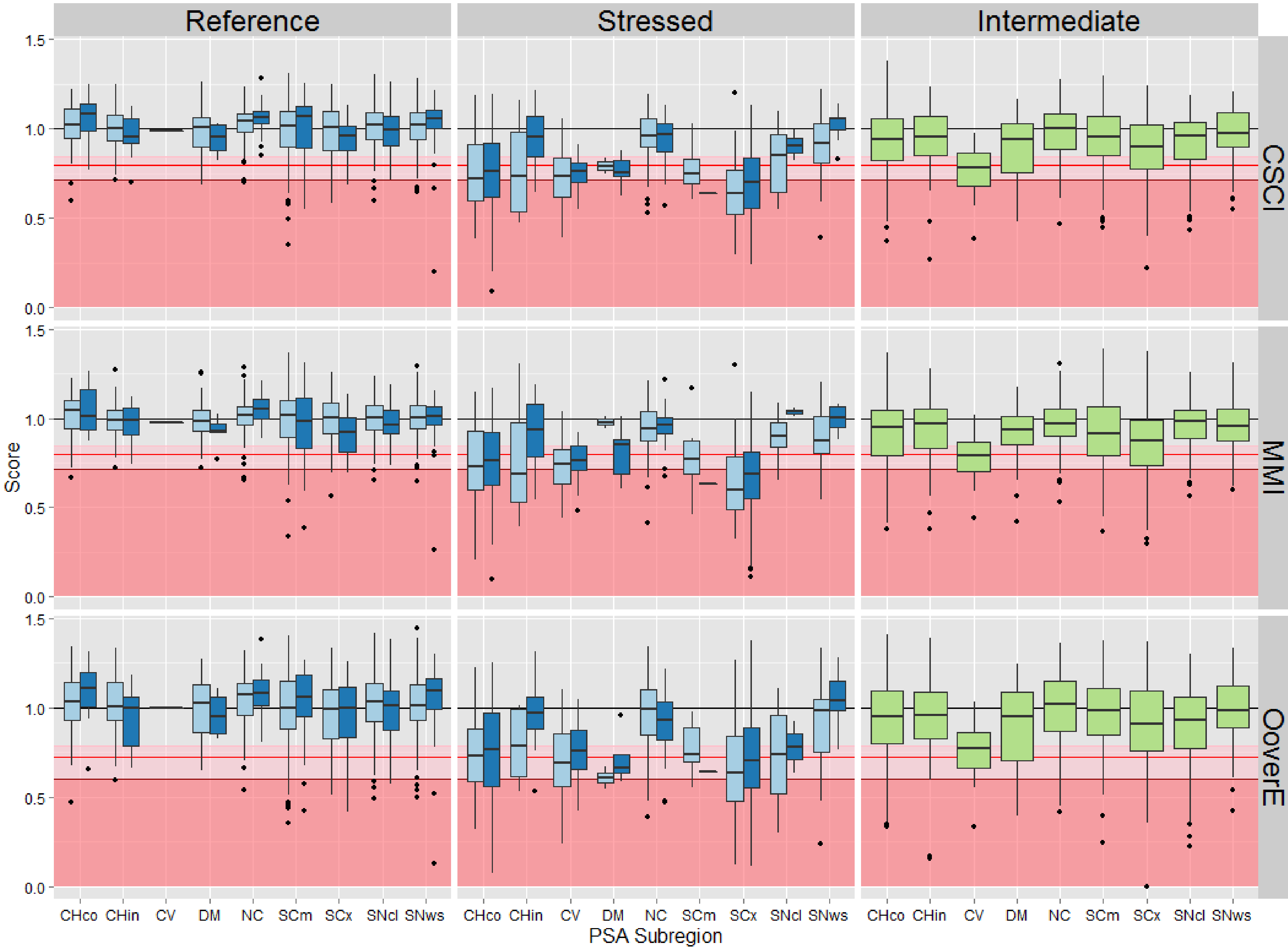

Reference
Stressed
Intermediate
CSCI
MMI
OoverE
Score
0.0
0.5
1.0
1.5
CHco
CHin
CV
DM
NC
SCm
SCx
SNcl
SNws
PSA Subregion

Key performance measures

Class	Parameter	How measured	CSCI	O/E	MMI
Sensitivity	Discrimination	t-test (ref vs. stressed)	25.2	20.4	25.0
	Variance explained by stress	Random forest	39%	27%	39%
Bias	Variance explained by natural gradients at reference sites	Random forest	-7%	-7%	-5%
	Difference among 9 PSA sub-regions at reference sites	ANOVA F-statistic	1.92	1.84	1.24
Replicability	Within-site variability at 826 replicated sites	Mean within-site SD	0.08	0.11	0.09

Again, good overall performance

Selected Metrics

Metric	% explained by RF model	Modeled?	Response
% Coleoptera taxa	24%	Yes	Decrease
Diptera taxa	4%	No	Decrease
% EPT Taxa	43%	Yes	Decrease
% Intolerant	22%	Yes	Decrease
% Non-insect	13%	Yes	Increase
% Predator taxa	10%	Yes	Decrease
% Scraper taxa	18%	Yes	Decrease
% Shredders	17%	Yes	Decrease
Simpson’s diversity	2%	No	Decrease
Tolerant taxa	7%	No	Increase

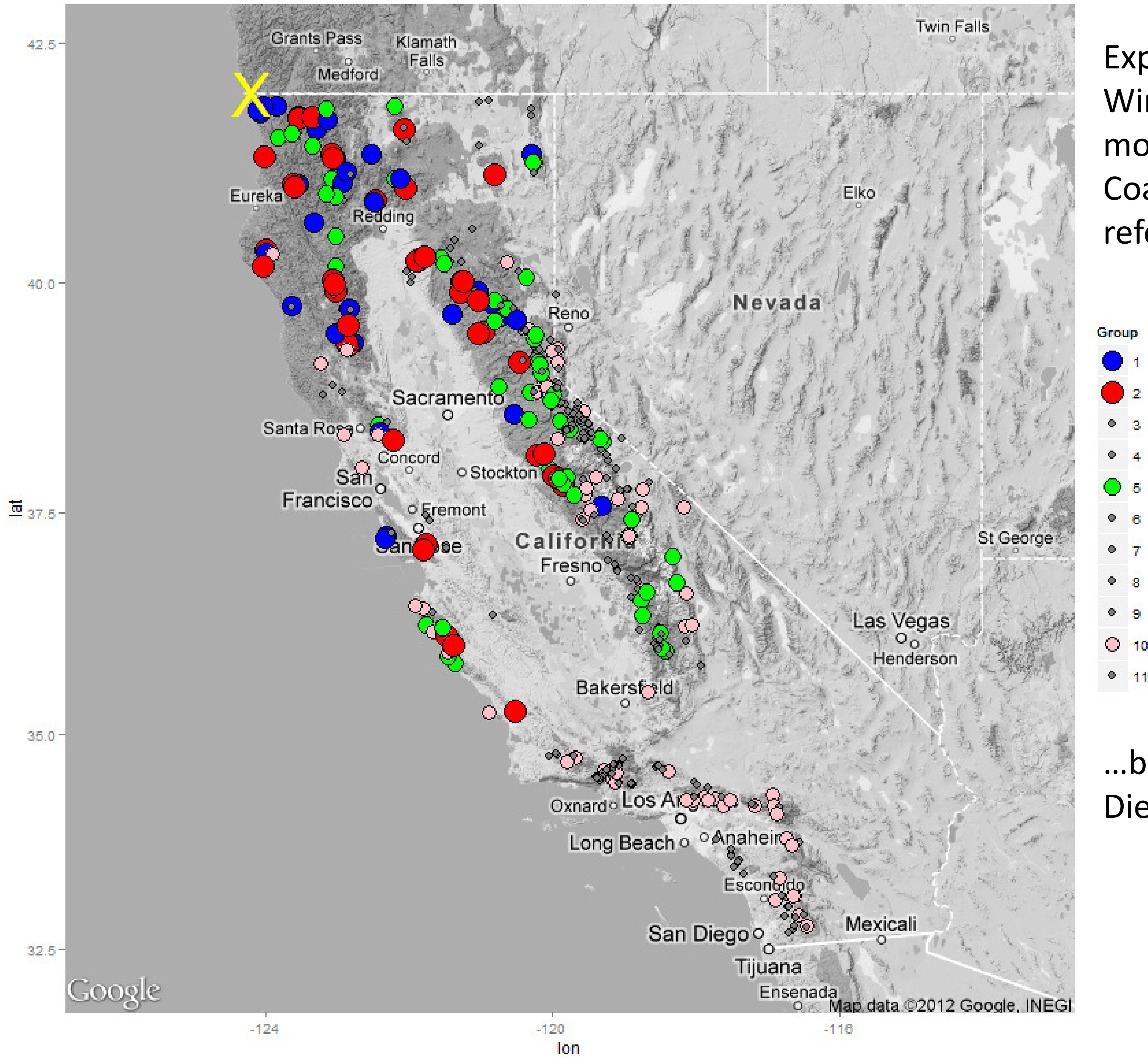
What else is different?

- Two components provide different ways of assessing the BMI community.
- Uses several predictive models (specifically, random forest) to develop site-specific expectations
- Expectations derived entirely from continuous natural gradients

Step 2: Build a model to predict group membership

- Random Forest model ("classification mode") calculates affinity for a test site with each reference group based on natural gradients (e.g., latitude, precipitation, watershed area).

Group	Probability of membership South Fork Winchuk River
Group 1	0.3
Group 2	0.4
Group 5	0.2
Group 10	0.1



Expectations for Winchuk River derived mostly from North Coast and Sierra reference sites…

…but even sites in San Diego are relevant

Step 2: Build a model to predict group membership

- Random Forest model ("classification mode") calculates affinity for a test site with each reference group based on natural gradients (e.g., latitude, precipitation, watershed area).

Step 3: Calculate probability of observing each taxon

Probability of observing a taxon at a site (“E”):

Environmental similarity between test site and each reference group times the frequency of a taxon in that group

Group	Frequency of *Eubrianax* in group	Probability site is in this group
1	0.3	0.85
2	0.4	0.91
5	0.2	0.69
10	0.1	0.11

Probability of observing *Eubrianax*:
0.77 =
(0.3*0.85) +
(0.4*0.91) +
(0.2*0.69) +
(0.1*0.11)

Step 4: Score the site

Total E: Sum of probabilities of all taxa

- Use only “common” taxa by summing only where prob ≥ 0.5

Total O: Count of expected taxa

Step 1: Calculate metrics

Class	Abundance	# Taxa	% Taxa
Taxonomy	% EPT	EPT taxa	% EPT taxa
	% Coleoptera	Coleoptera taxa	% Coleoptera taxa
	% Diptera	Diptera taxa	% Diptera taxa
	% Chironomidae		
	% Non-insect	Noninsect taxa	% Noninsect taxa
	Shannon diversity Simpson's diversity	Total richness	
FFG	% Collectors	Collector taxa	% Collector taxa
	% Predators	Predator taxa	% Predator taxa
	% Scrapers	Scraper taxa	% Scraper taxa
	% Shredders	Shredder taxa	% Shredder taxa
Tolerance	Tolerance value		
	% Tolerant	Tolerant taxa	% Tolerant taxa
	% Intolerant	Intolerant taxa	% Intolerant taxa

Step 2. Adjust metric values to account for influence of natural gradients

- Random forests models (1000 trees) allow us to predict site-specific reference expectation for each metric
- If Rsq $\geq$ 10%, use metric residuals (observed – predicted). Otherwise, use raw value
- No classification step—ALL calibration reference sites are used to develop expectations for each test site.

Step 3. Select most responsive metrics

- Select metrics with the best ability to discriminate reference from stressed (i.e., highest t-values – $|t|>10$)
- Avoid selecting redundant metrics
  - If R^2 with any previously selected metric > 0.5, do not select
  - Avoid "philosophical redundancy"(e.g., EPT taxa and % EPT)

Step 4. Score metrics and assemble into composite MMI *(follows Cao et al. 2007)*

- **Score metrics**
  - Decreasing metrics:(Obs – Min)/(Max– Min)
  - Increasing metrics:(Obs – Max)/(Min– Max)
    - Max = 95th percentile of reference
    - Min = 5th percentile of stressed

- **Sum** 10 metrics and **adjust** scale by dividing by mean of reference sites