# Scoring Biological Integrity

*the California Stream Condition Index (CSCI)*

Resources Agency California Department Fish & Game

Aquatic Bioassessment Laboratory

California Water Boards

SWAMP Surface Water Ambient Monitoring Program

- **Scoring Tool Enhancements**
  - Update to O/E component
  - Integrating predictive MMI techniques
  - Our recommendations
- **Setting Thresholds**
- **Statewide and Regional Extent Estimates**

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# Technical Team

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****** Scientific Review Panel***


How do we convert a list of species
into a condition score?

# Qualities of a good scoring tool

Technical Qualities

- precise
- accurate
- responsive

Regulatory Qualities

- universally applicable
- easy to relate to ecological condition
- easy to compare to a standard

# Two common approaches for quantifying biotic condition

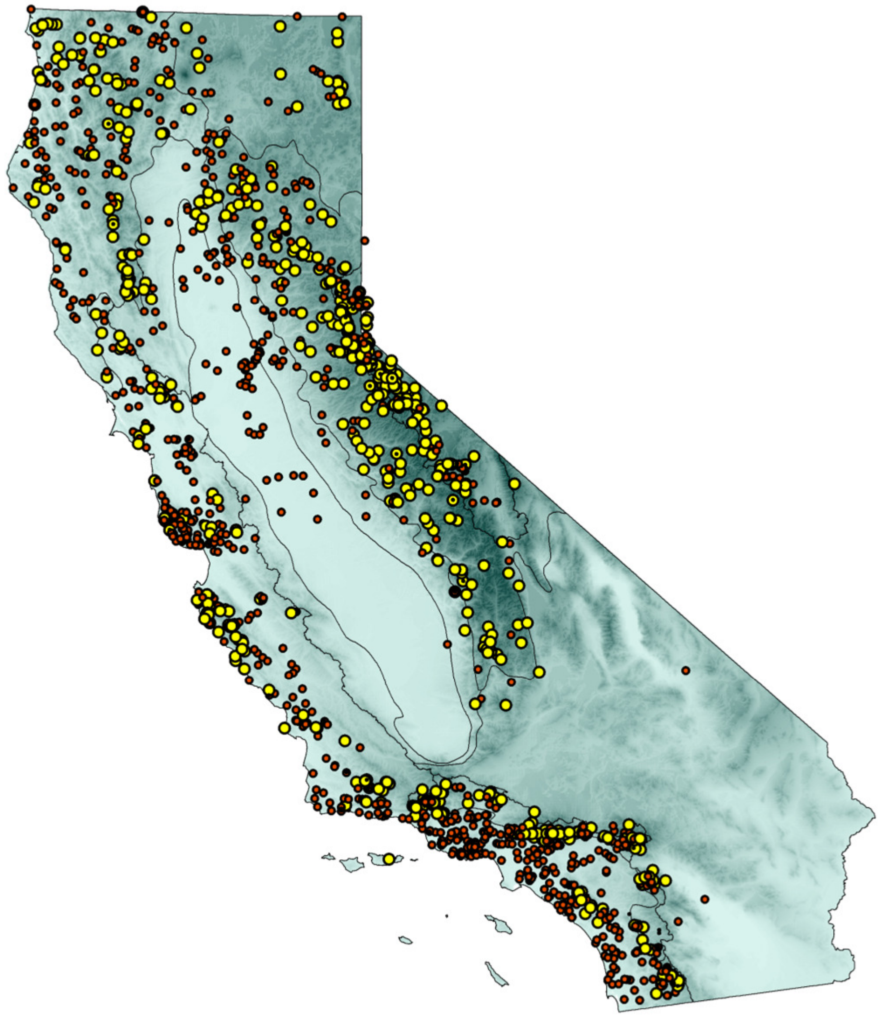
**Species loss indices** (e.g., O/E indices)

**Ecological structure indices** (e.g., multi-metric indices including IBIs)

# Scoring Tools Rely on Reference Sites to Establish Expected Conditions

- 485 reference sites used to develop scoring models

- Excellent coverage of CA's natural stream diversity



# Species Loss Index (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.** Identify natural gradients that best explain clusters (=predictors)

**Step 3.** Use predictor values at test sites to predict species expected to be observed

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# O/E Update

- April index performed well and science panel liked it
- **Reference pool adjustments:**
  - added sites to target under-represented areas
  - dropped sites based on stakeholder feedback
- Created new model

## Final Model (Random Forests, 10 clusters, 4 predictors):

- Average Monthly Temperature (2000-2009)
- Average Monthly Precipitation (2000-2009)
- Log Watershed Area
- Site Elevation

**Performance was very similar to our April O/E index**

# Multi-metric Indices (MMIs)

Species list is converted into metrics representing diversity, ecosystem function, and sensitivity to stress

| Taxon | Count |
|---|---|
| Mayfly species 1 | 43 |
| Mayfly species 2 | 12 |
| Mayfly species 3 | 2 |
| Beetle species 1 | 1 |
| Beetle species 2 | 1 |
| Midge genus 1 | 65 |
| Midge species 1 | 3 |
| Midge species 2 | 10 |
| Midge genus 2 | 3 |
| Dragonfly species 1 | 2 |
| Stonefly species 1 | 1 |
| Stonefly species 2 | 14 |
| Worm species 1 | 9 |
| Worm species 2 | 2 |

- # mayfly taxa
- # predator taxa
- % sediment tolerant taxa
- % herbivore taxa
- % mayfly individuals


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# Why develop an MMI?

- Science panel recommended exploring MMI
- MMIs have useful qualities
  - Measure ecological attributes other than species loss
  - Very responsive to stress
  - May work well where species-specific predictions are tricky
- **New techniques available** (*see Hawkins and Vander Laan presentation at 2011 CABW*)
  - Adds site-specific adjustments to traditional MMIs

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# Building a predictive MMI (pMMI)

*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 pMMI

# Step 1. Calculate metrics at reference sites and stressed sites

- **Sample Information:**
  - 1520 sites had “adequate” samples (i.e., >450 bugs)
  - 514 are reference (same definition as O/E)
  - 175 are highly stressed

- **Calculate Metrics**
  - Used SWAMP’s new bioassessment reporting module
  - Subsample to 500 organisms, calculate at SAFIT Level 1 (midges to family)

- **Use 80% for model development, 20% to validate**

# Metrics: the usual suspects

| Class | Abundance-based | # Taxa | % Taxa |
|---|---|---|---|
| Taxonomic | % EPT | EPT taxa | % EPT taxa |
| | [not considered] | Coleoptera taxa | % Coleoptera taxa |
| | [not considered] | Diptera taxa | % Diptera taxa |
| | % Chironomidae | [NA] | [NA] |
| | [not considered] | Non-insect taxa | % Non-insect taxa |
| | Shannon Diversity | Taxonomic richness | |
| FFG | % Collectors | Collector taxa | % Collector taxa |
| | % Predators | Predator taxa | % Predator taxa |
| | % Scrapers | Scraper taxa | % Scraper taxa |
| | % Shredders | Shredder taxa | % Shredder taxa |
| Tolerance | % Intolerant | Intolerant taxa | % Intolerant taxa |
| | % Tolerant | Tolerant taxa | % Tolerant taxa |
| | Weighted tolerance value | | |

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

- Models allow us to predict site-specific reference expectation for each metric
- Most influential gradients:

| | | |
|---|---|---|
| • Latitude | • Soil Erodability | • MgO_Mean |
| • Longitude | • Soil Bulk Density | • Surfur_Mean |
| • Elevation Range | • Soil Permeability | • SumAve_Phos |
| • Site Elevation | • Hydraulic Conductivity | • CaO_Mean |
| • Precipitation | | • Mean Phosphorus |
| • Temperature | | • Mean Nitrogen |
| • log Watershed Area | | |

# Step 3. Select most responsive metrics

- Select metrics with the best ability to discriminate reference from stressed (i.e., highest t-value)

- Avoid selecting redundant metrics

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

- **Score each metric** by comparing observed value to reference expectation

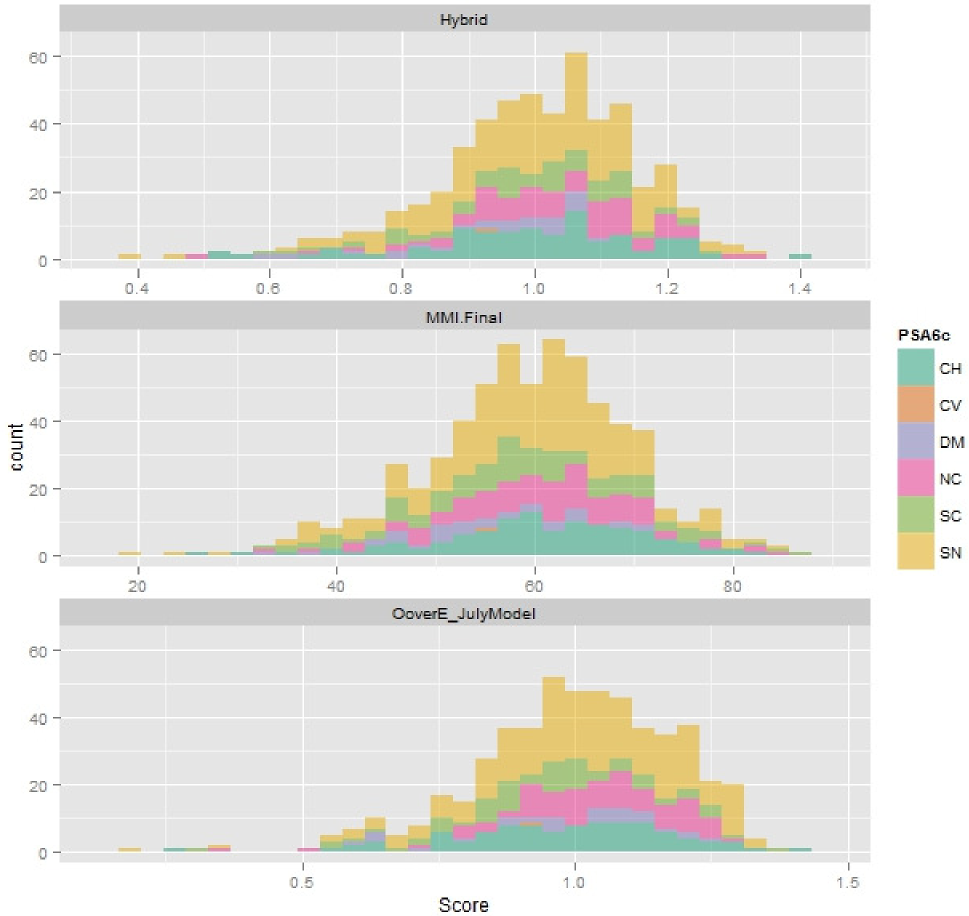
- **Sum** 10 metrics and **adjust** scale to be equivalent to O/E (divide score by mean of reference)

# Final Metrics

| Metric | Mod v Null | % explained by RF model | \|t\| | Response |
|---|---|---|---|---|
| Collector taxa | Modeled | 11 | 13.2 | Decrease |
| Coleoptera taxa | Modeled | 40 | 17.6 | Decrease |
| Diptera taxa | Null | 7 | 13.5 | Decrease |
| Intolerant taxa | Modeled | 53 | 32.2 | Decrease |
| Predator taxa | Modeled | 11 | 13.6 | Decrease |
| Scraper taxa | Modeled | 38 | 20.0 | Decrease |
| Shredder taxa | Modeled | 42 | 19.1 | Decrease |
| % Non-Insect Taxa | Modeled | 15 | 18.1 | Increase |
| Shannon diversity | Modeled | 16 | 10.7 | Decrease |
| Tolerance value | Modeled | 32 | 12.4 | Increase |

# Comparing Performance of 3 Scoring Tools

1. Species Loss Index (O/E)
2. Ecological Structure Index (pMMI)
3. Combined Index (“hybrid”)



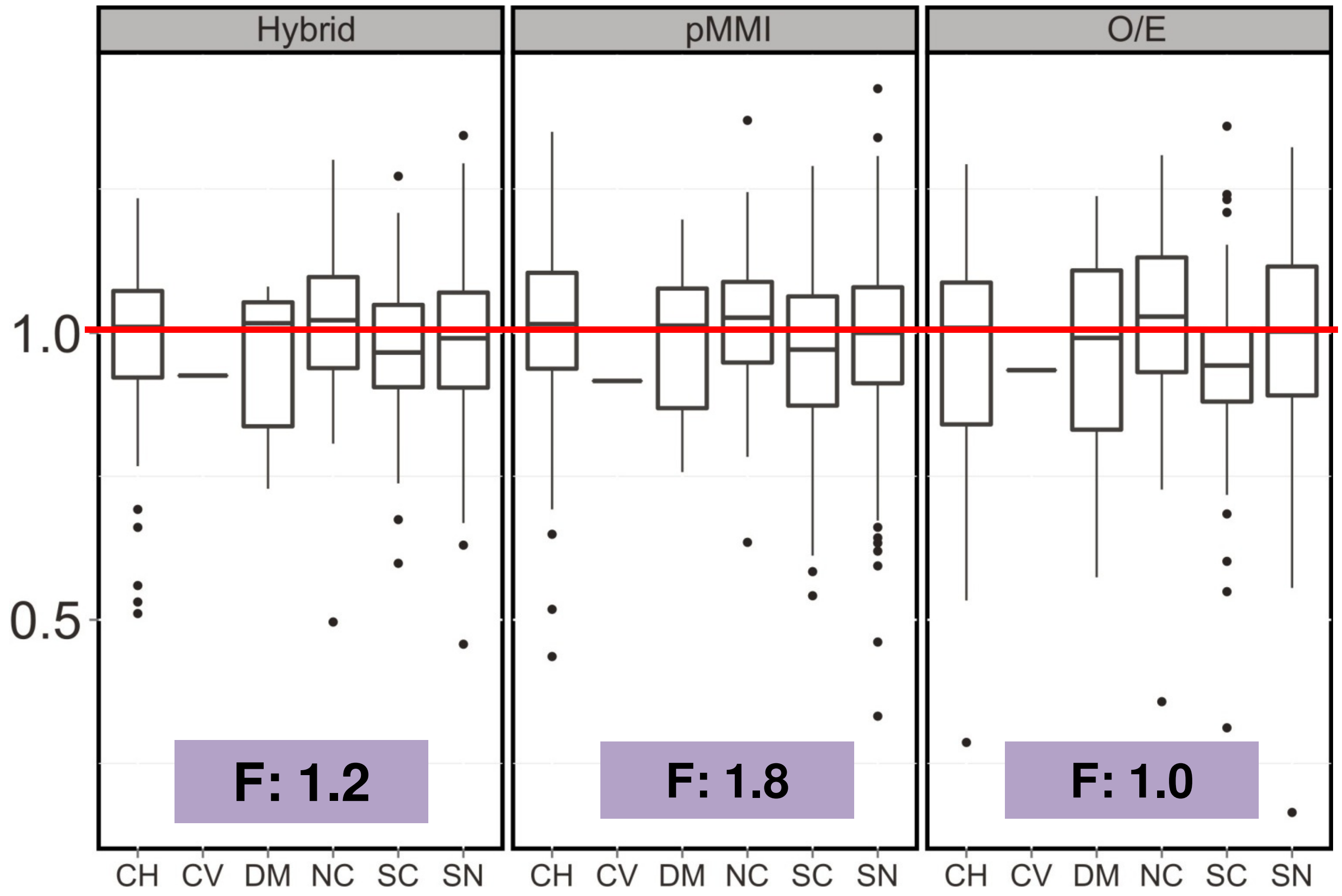
# Measuring Performance

All evaluations used a common dataset

| Class | Property | Measure | O/E | pMMI | Hybrid |
|---|---|---|---|---|---|
| **Precision** | Variance of reference sites | SD | **0.19** | **0.15** | **0.14** |
| **Sensitivity/ Responsiveness** | Discrimination | t-test | **9.5** | **17.6** | **15.3** |
| | Variance explained by stress | Random forest model | **25%** | **56%** | **49%** |
| **Accuracy/ Bias** | Variance explained by natural gradients (ref sites) | Random forest model | **-7%** | **-9%** | **-8%** |
| | Difference among PSA regions (ref sites) | ANOVA | **1.0** | **1.8** | **1.2** |
| **Replicability** | Within-site variability | Mean within-site SD | **0.10** | **0.10** | **0.08** |

# Statewide Consistency

## Distribution of reference scores by PSA region

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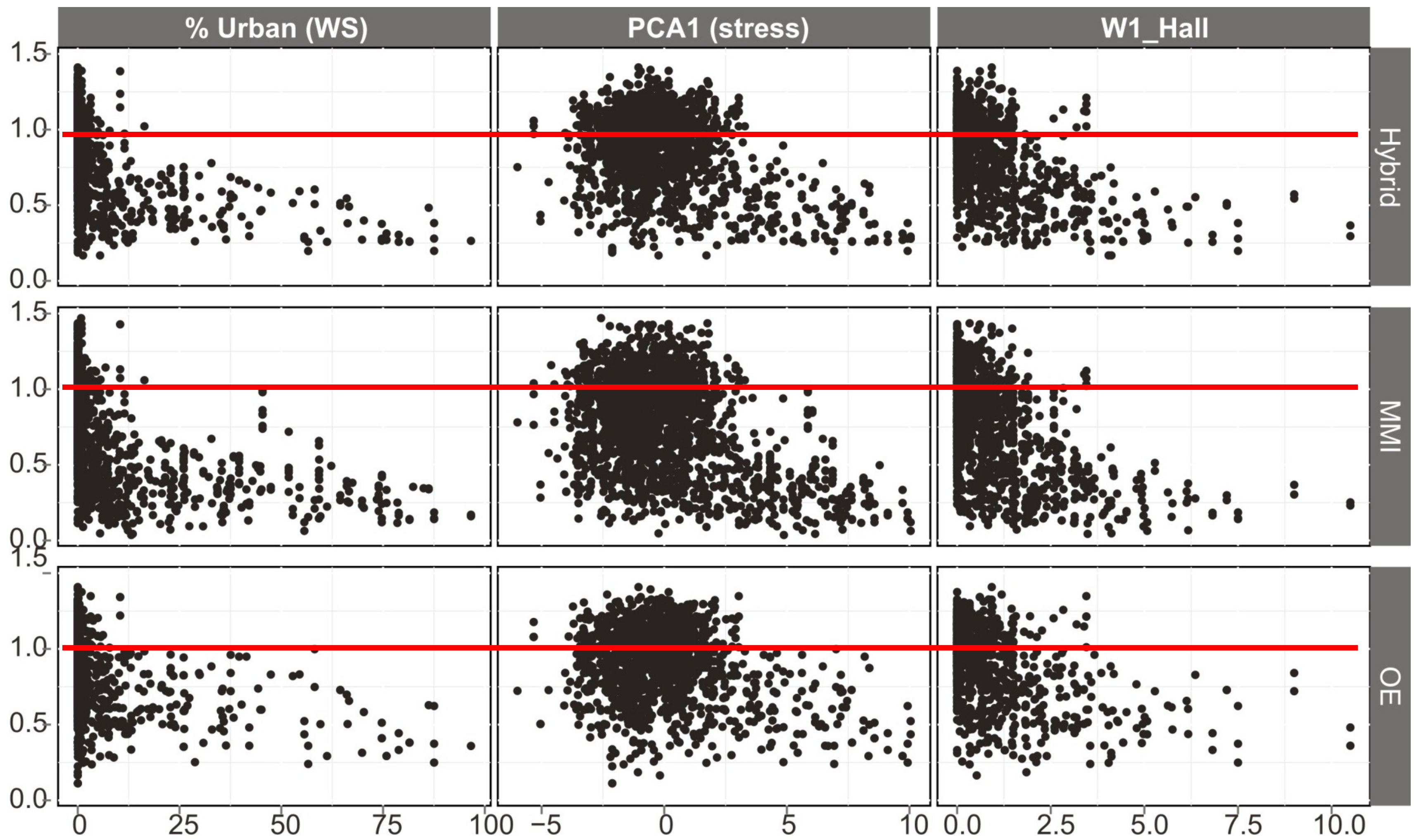
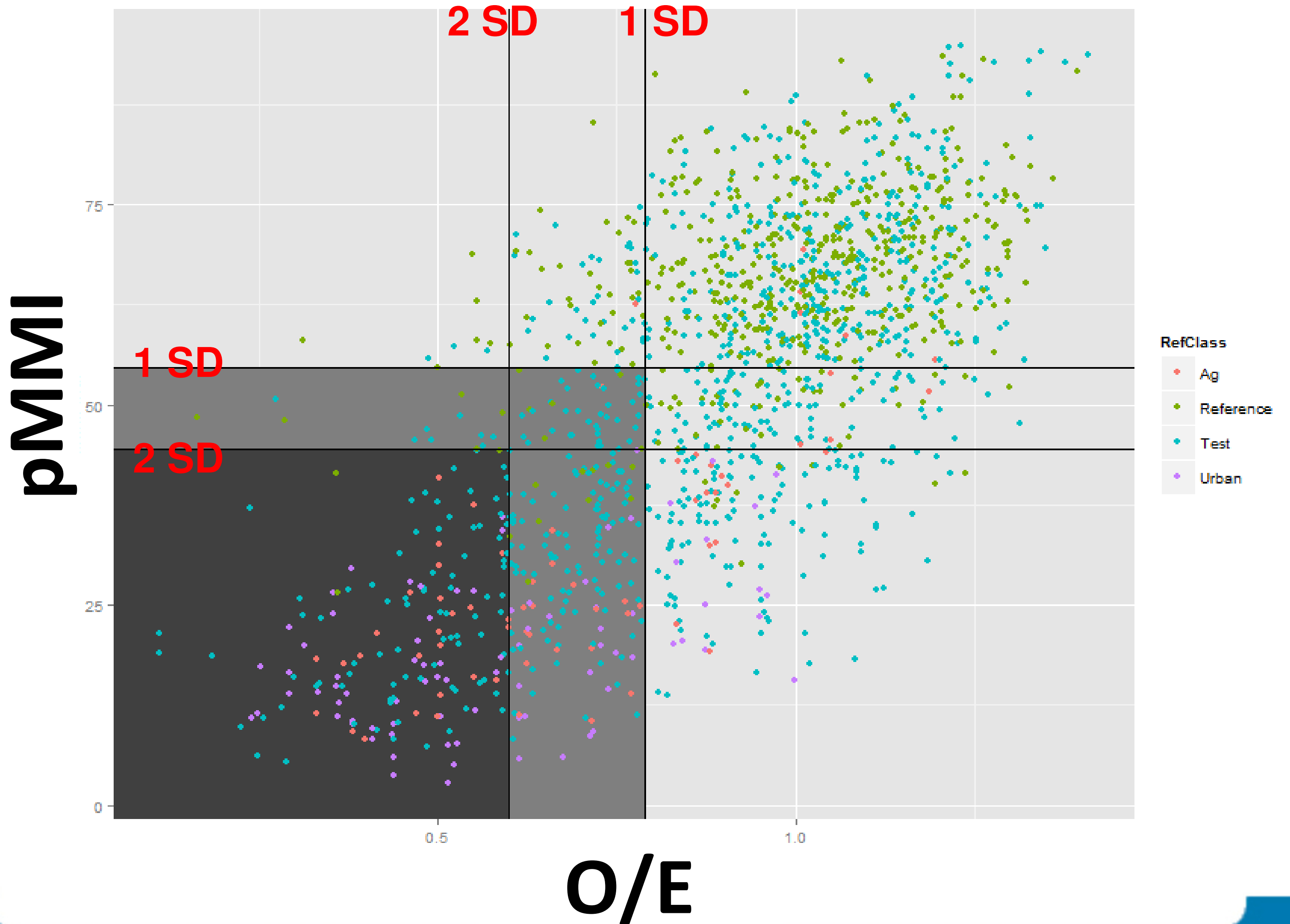
# Responsiveness to stress



# pMMI and O/E have general agreement, but tell us somewhat different things



# Both pMMI and O/E have desirable qualities

- pMMI is precise and very responsive to stress (but it was designed to be)
- % species loss is an intuitive, meaningful measure of condition
- Both are accurate and applicable throughout state
- Potential for complementarity is great -- we explored a few options (see Science Panel)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# We recommend a combined index

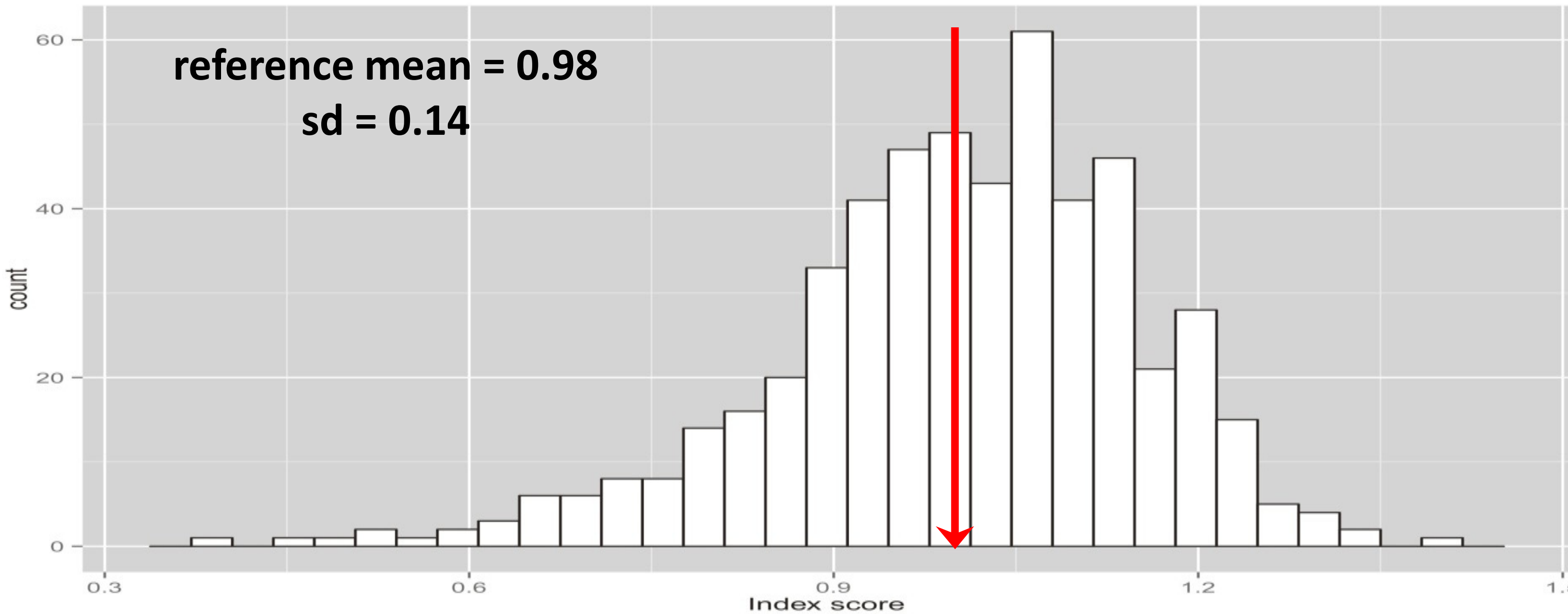
- Retains some of the better qualities of both indices, tempers weaknesses
- Can be disaggregated into component MMI and O/E (i.e., you don't lose information by combining)
- Implementation is easier with a single score

# California Stream Condition Index (CSCI)

Part A: Ecological Structure Component (pMMI)

Part B: Taxonomic Loss Component (O/E)

**CSCI is a simple average of the two scores**



# Options for setting thresholds

- Statistical criteria
  - Standard deviation
  - %-ile of reference distribution
- Ecological criteria
  - Acceptable species loss or change in community structure

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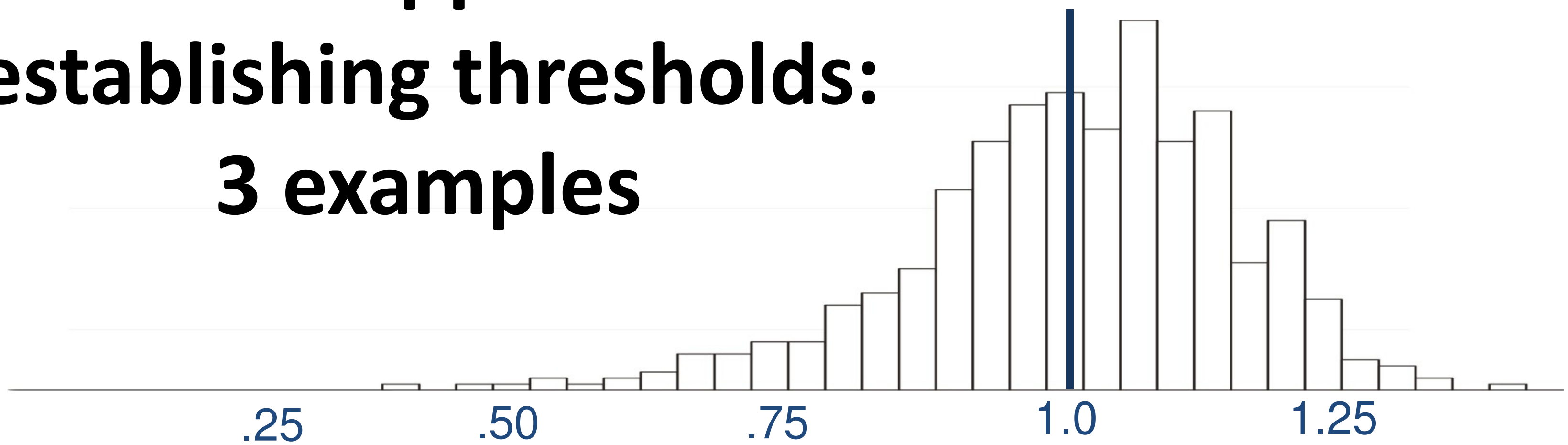
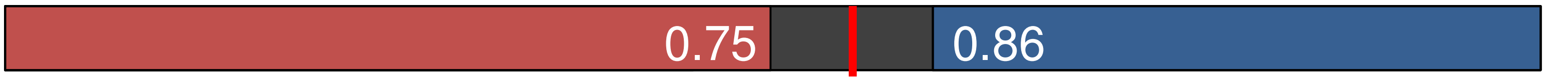
# We recommend statistically defined thresholds

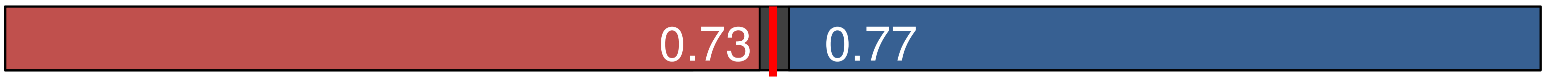
- Widely accepted practice
- Setting objective ecological benchmarks is complex
- No technical objections from the science panel

# Statistical approaches to establishing thresholds: 3 examples



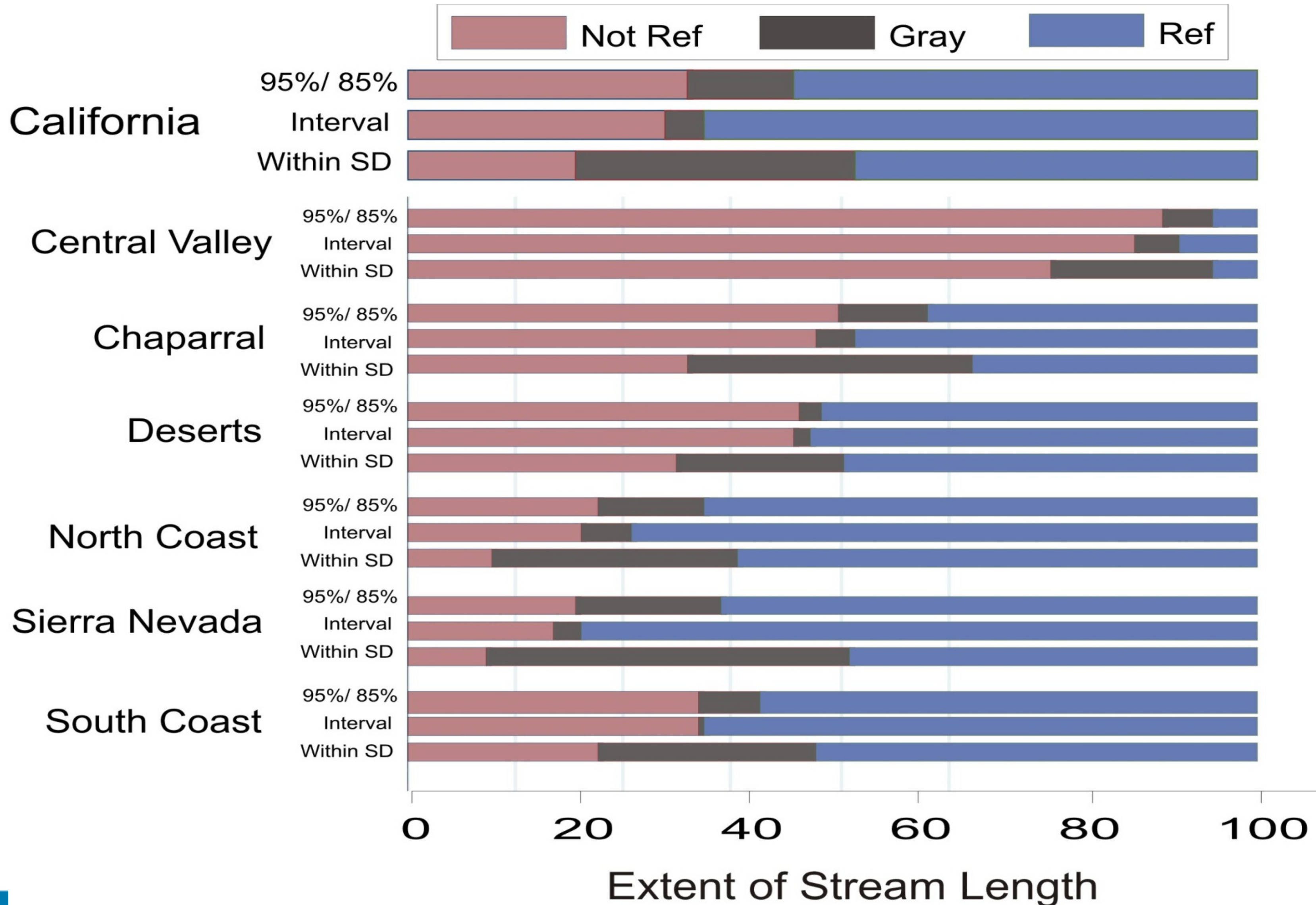

95% and 85% confidence that site is not equivalent to reference




95% confidence that the 95% threshold is where we think it is

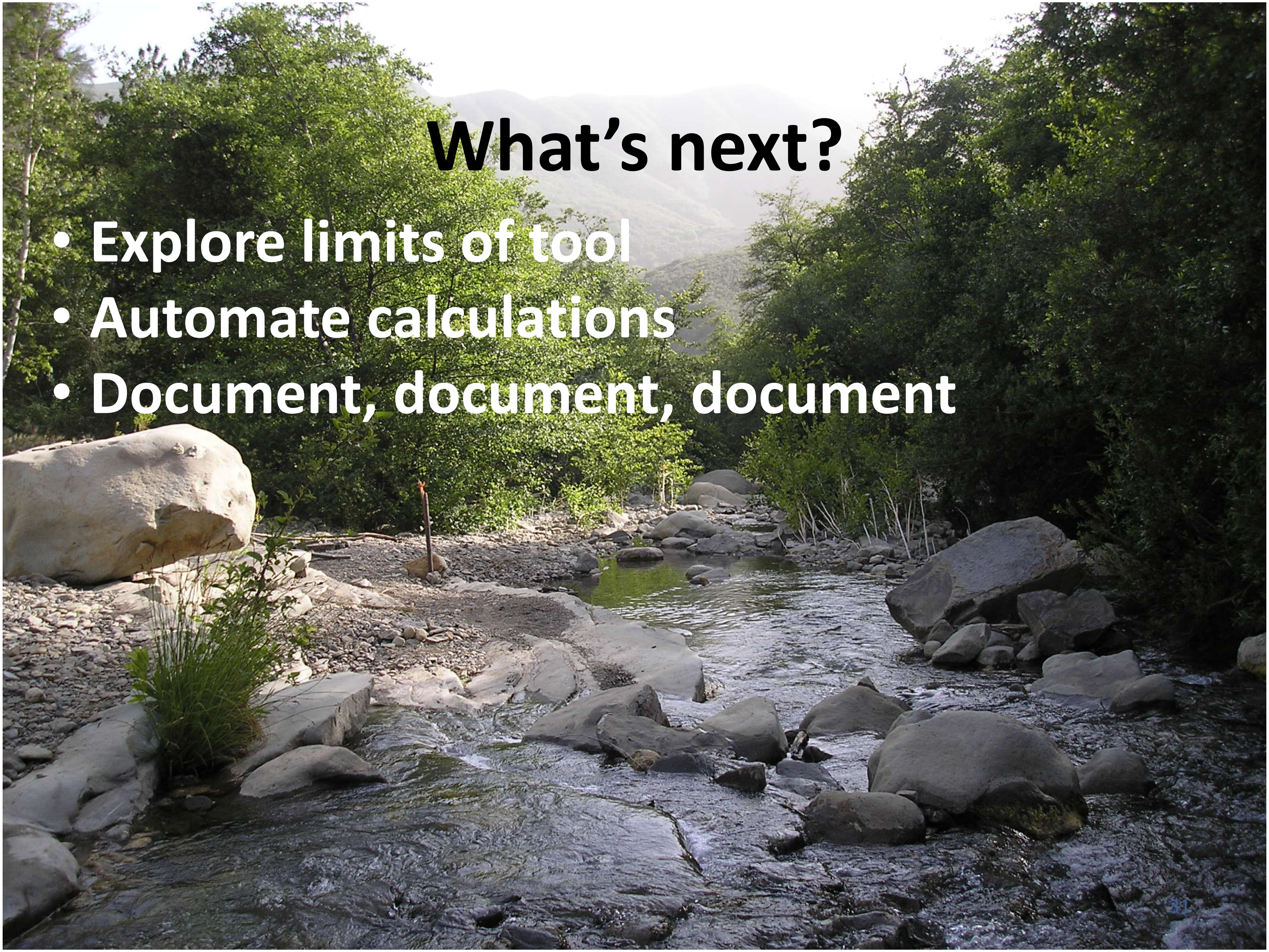

Use within-site error rate to establish uncertainty around threshold

# Extent of stream length by region

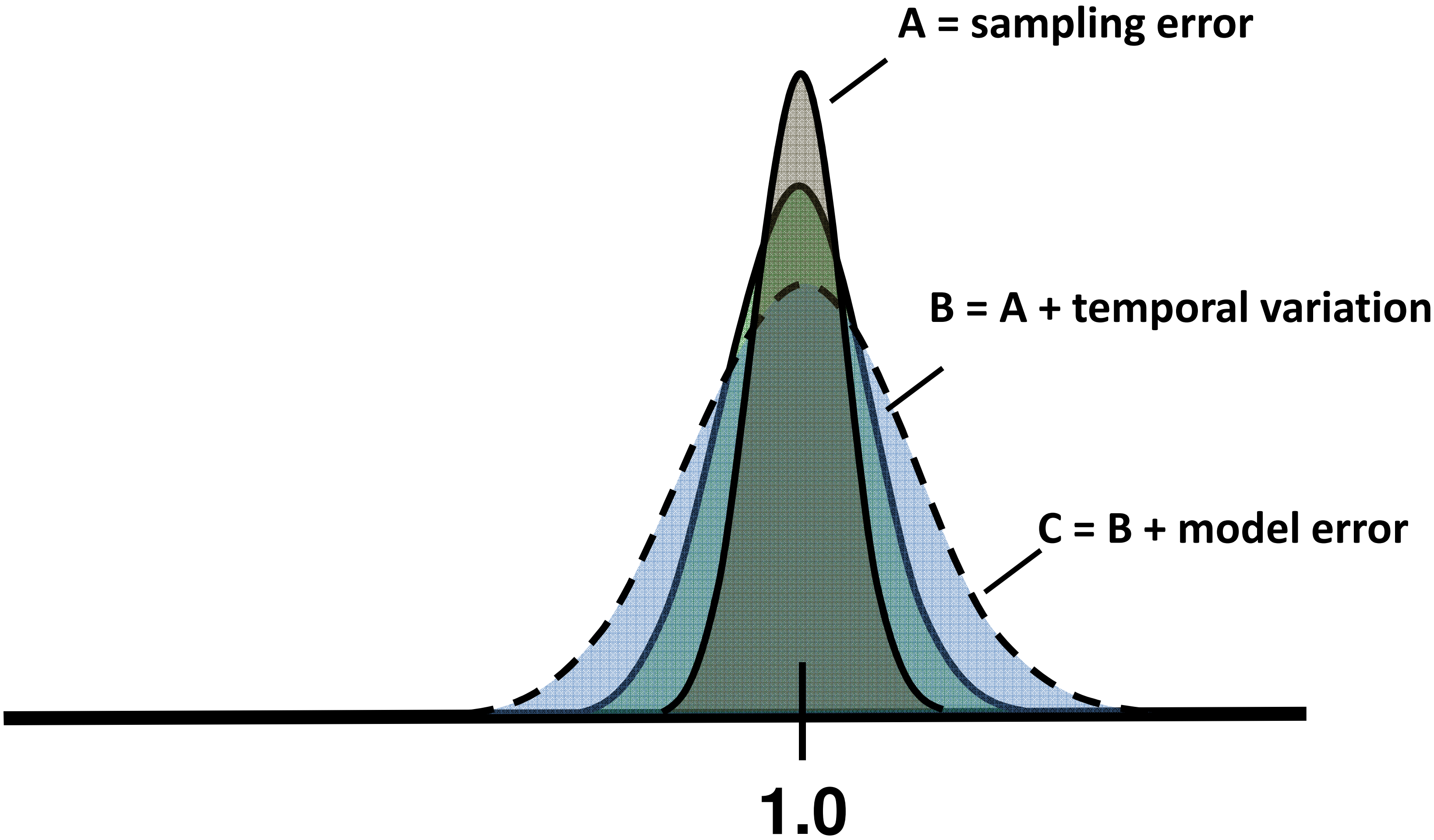


# What's next?

- Explore limits of tool
- Automate calculations
- Document, document, document



# Sources of variation in O/E scores




*(after Hawkins et al. 2010)*