An Introduction to SWAMP's Perennial Streams Assessment (PSA)

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SWAMP's Perennial Streams Assessment (PSA):

a statistical survey designed to support and enhance statewide monitoring efficiency and effectiveness

- Background and Rationale
- Technical Overview
- Highlights from first 8 years
- Current and Future Efforts

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Need For Perspective Met By Statistical Surveys

In late 1980's, U.S. Congress expressed frustration that (despite billions spent on WQ monitoring programs) EPA couldn't answer basic questions about national aquatic resources:

- What is the condition of the nation's waters?
- Is it getting better? Is it getting worse?
- Are we allocating $$$$ wisely?

EPA's Environmental Monitoring and Assessment Program (EMAP) – a strategy for optimizing use of monitoring resources

1. Use probability (random) survey design to select sites

   Each site represents a known stream length with known statistical precision …. permits assessment of entire resource with limited sampling effort

2. Collect extensive biological, chemical and physical data at sites

3. Analyze data to make objective condition assessments:
   - *49 ±5% of CA streams have degraded invertebrate assemblages*
   - *76 ±5% of biologically degraded north coast streams are also degraded by fine sediments*

4. Use survey results to help interpret existing monitoring data and guide management of monitoring resources

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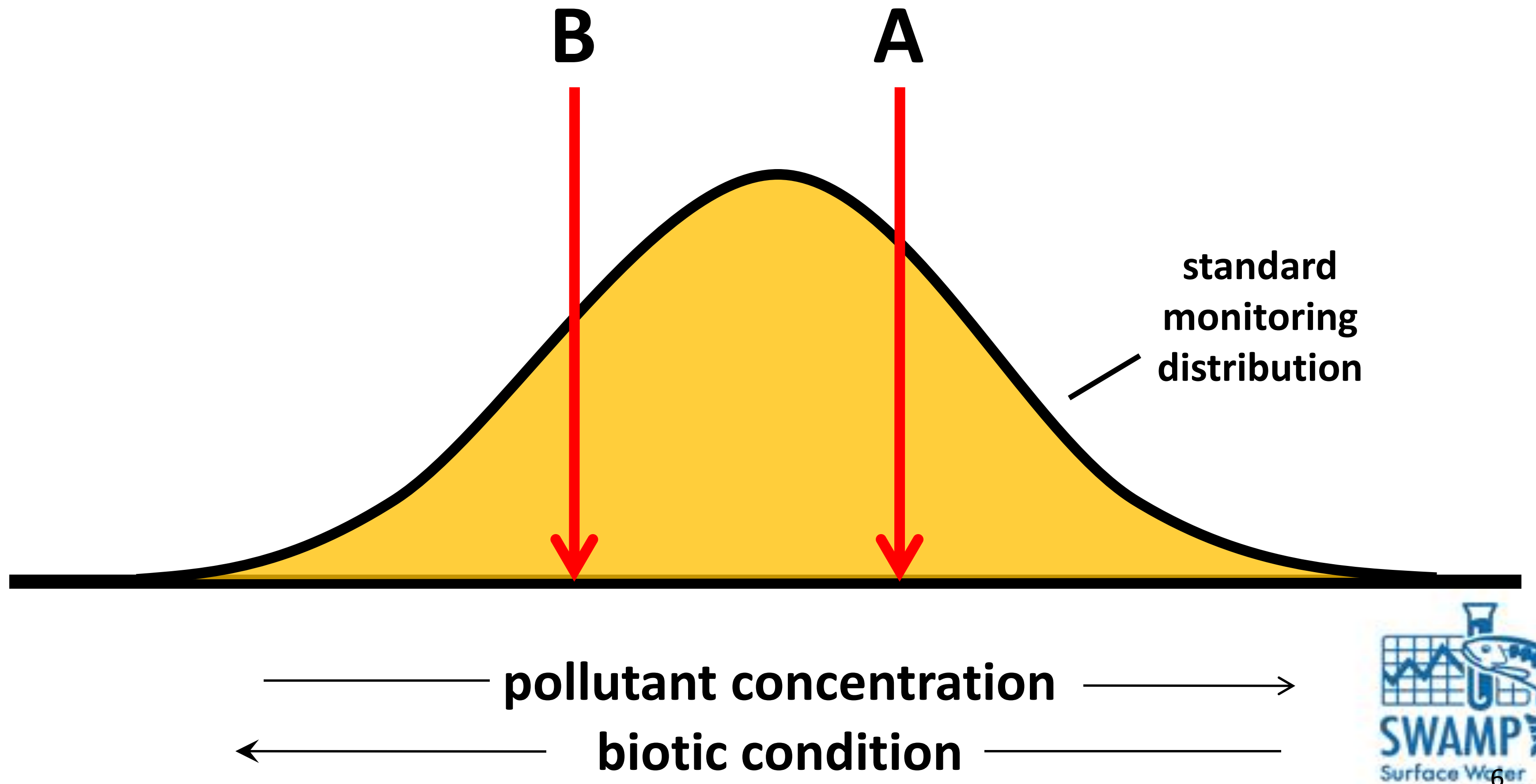
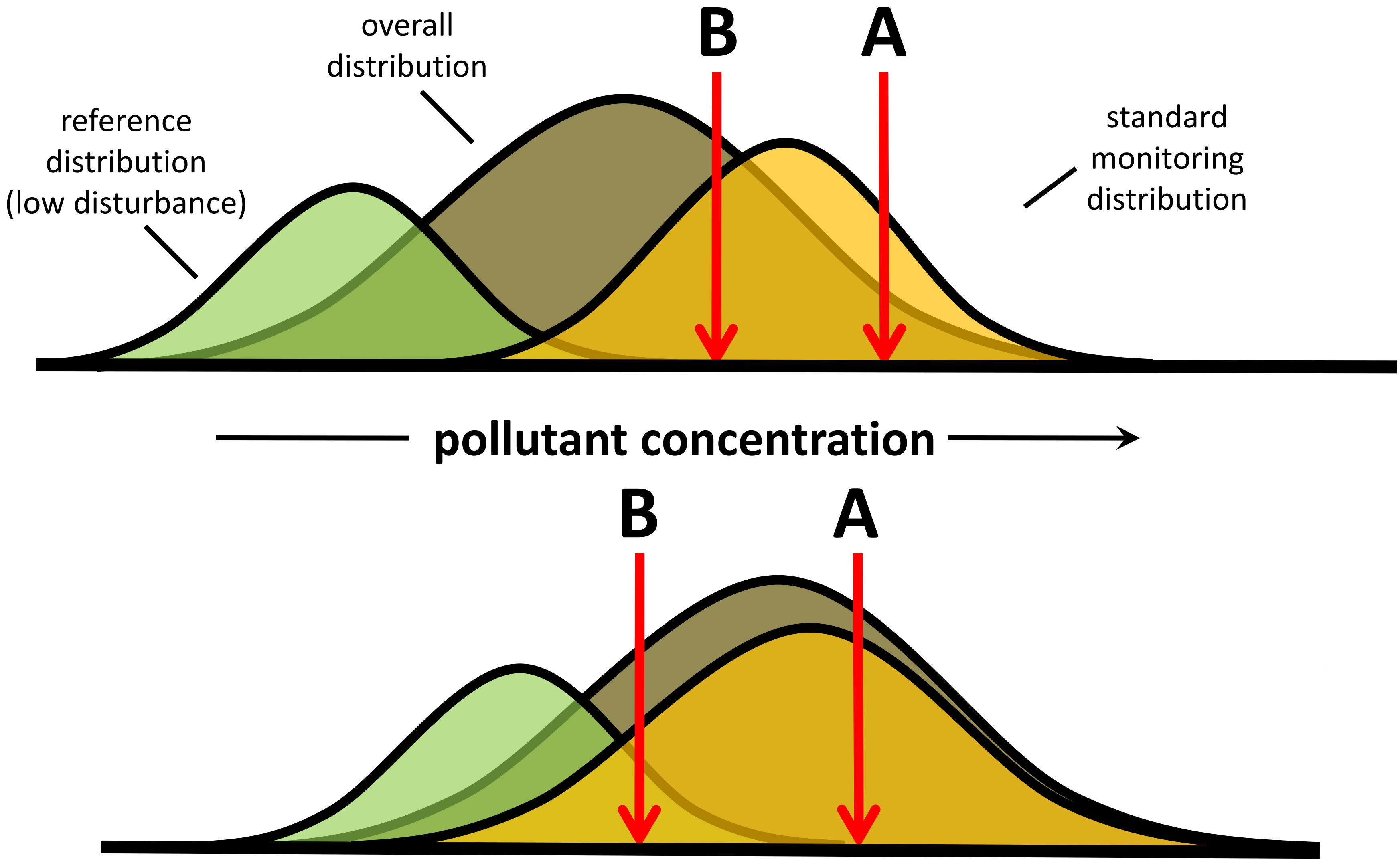
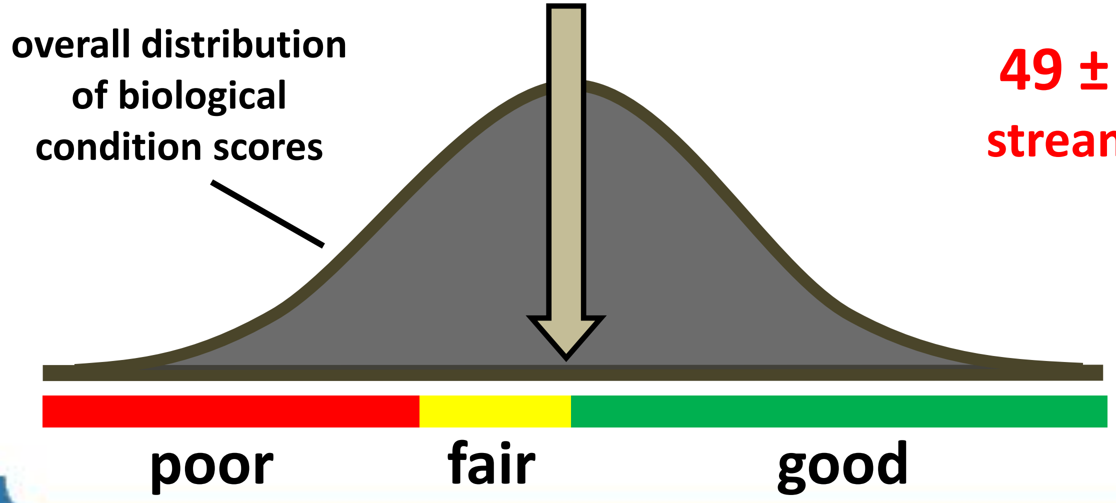
Probability surveys provide context for interpreting targeted monitoring data




overall
distribution
B
A
reference
distribution
(low disturbance)
standard
monitoring
distribution
pollutant concentration
B
A

Probability surveys provide an unbiased picture of the overall distribution

- Statistical surveys (like political polls) allow us to estimate the characteristics of a large population with relatively small sampling effort
- Knowledge of an overall distribution allows us to produce objectives estimates of resource extent and condition with known statistical precision



49 ± 5% of California streams have degraded biology

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Probability surveys are widely adopted…

- ~35 U.S. states currently use in WQ programs
- Used by several federal agencies
  - **EPA, USFS, NPS**

… and used for many different resources:

- Wetlands
- Lakes
- Rivers and Streams
- Coastal Bays and Estuaries

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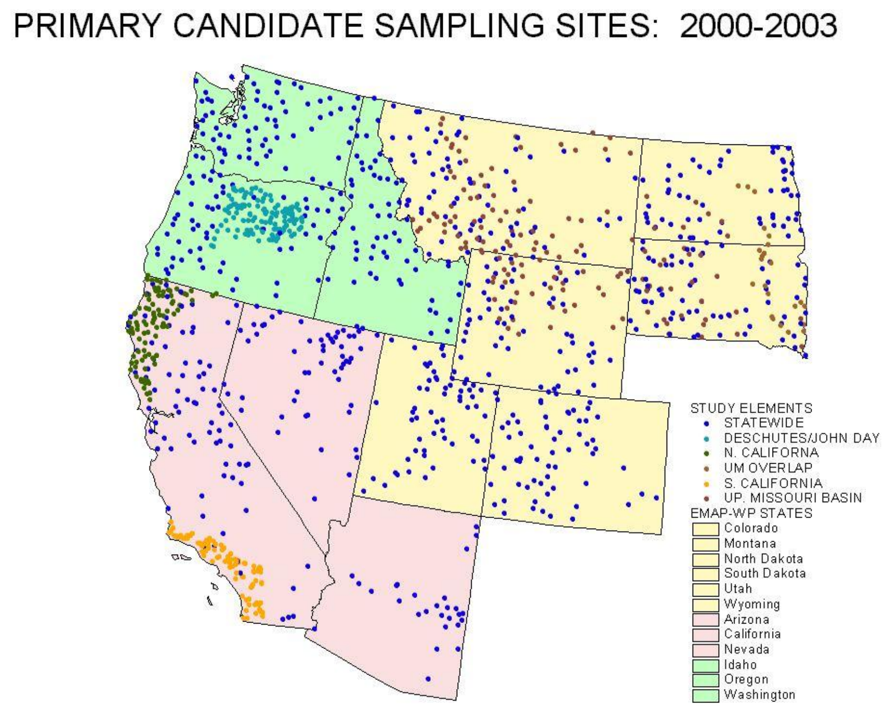
The Beginning: Western EMAP (2000-2003)



- ~ 200 sites in CA
- Northern CA and Southern CA intensification areas
- CA added another 30 in Central Coast in 2003

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EMAP	CMAP	PSA
2000 2001 2002 2003 **Statewide** + North Coast South Coast (Central Coast)*	2004 2005 2006 2007 **Statewide** + integration with NPS program (stratified by land use) + modified channels	2008 2009 2010 2011 **Statewide** + 7 subregions + integration with NPDES (SMC, R2?) + link to reference plan + link to targeted sites?
STATUS (+ stressor extent/ relative risk)	**STATUS** (+ stressor extent/ relative risk)	**STATUS** (+ stressor extent/ relative risk)
	TRENDS	**TRENDS**
	Landuse	**Landuse** *(modified)*

- ***PSA built on previous designs + added several enhancements***
- ***All 3 projects are now referred to collectively as PSA***

Technical Overview

PSA Technical Approach

Step 1. Define and map the population of interest (e.g., all perennial and wadeable streams in CA)

This mapped network of all potential sampling sites is the **sampling frame**

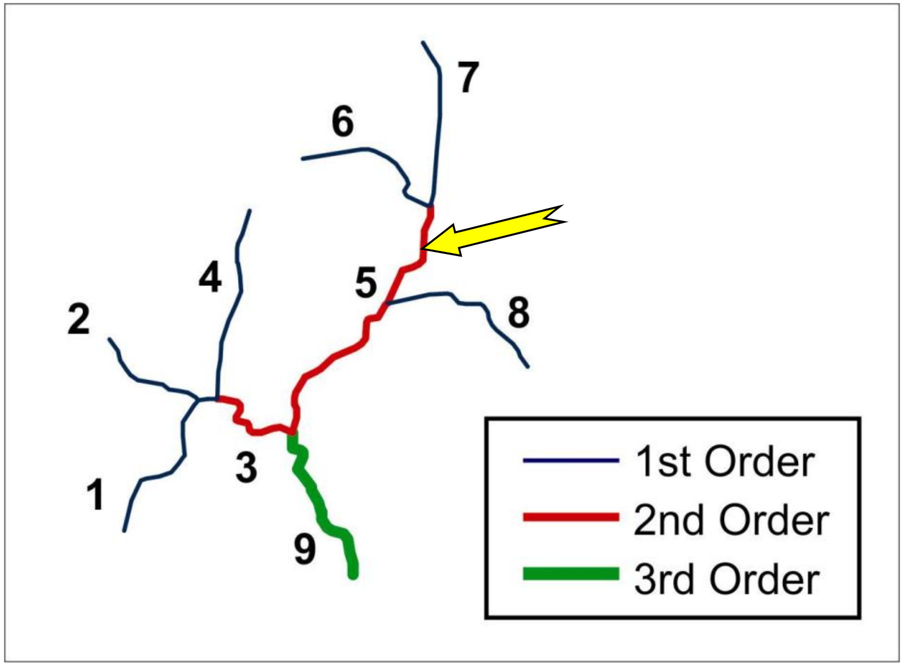
California's frame is based on the National Hydrography Dataset (NHD) medium resolution map (1:100,000 scale)

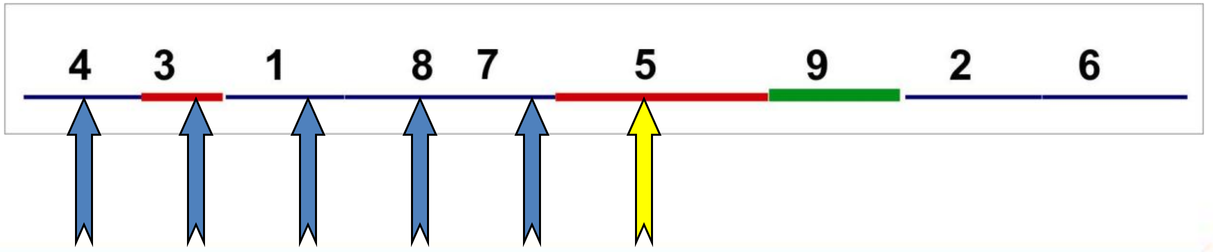
For design details, see summaries by Tony Olsen (EPA-ORD):

http://www.epa.gov/nheerl/arm/designpages/design&analysis.htm

Step 2: Select a Geographically Balanced Set of Sampling Points from a Stream Network (GRTS)

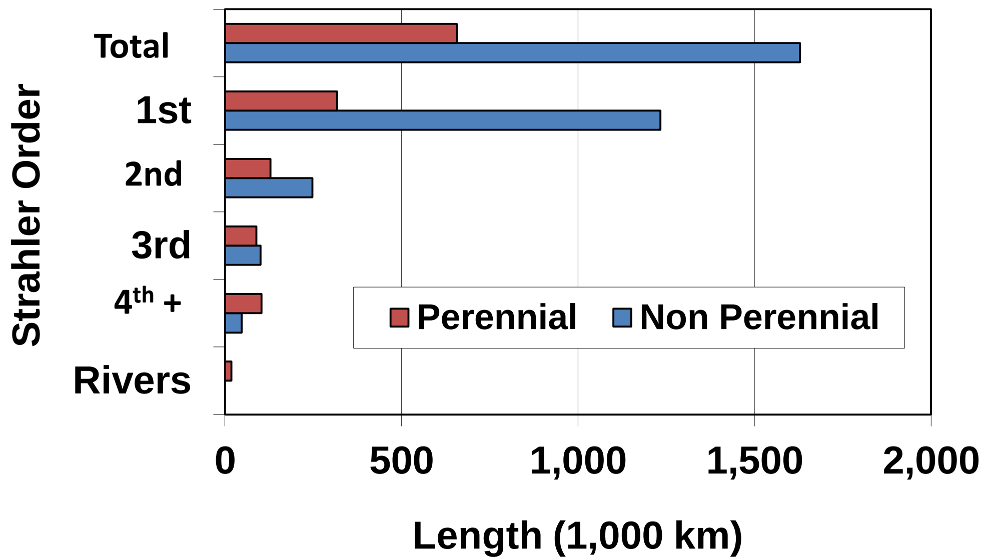
- Stream network is converted into a line
  - Segments all given IDs
  - Segment lengths are preserved
  - Segment arrangement is re-arranged to create a spatial balance in the region of interest (i.e., California)
- Sample locations placed systematically on line and then translated back to geographic coordinates

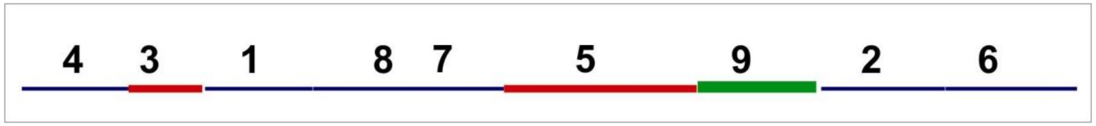


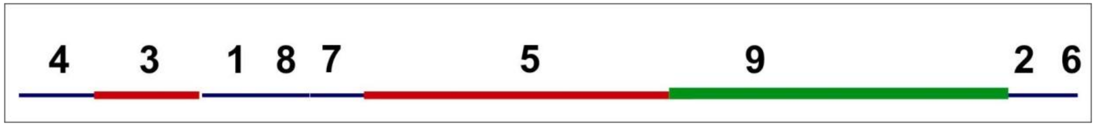


sampling locations

Key Concept: Unbalanced Site Selection







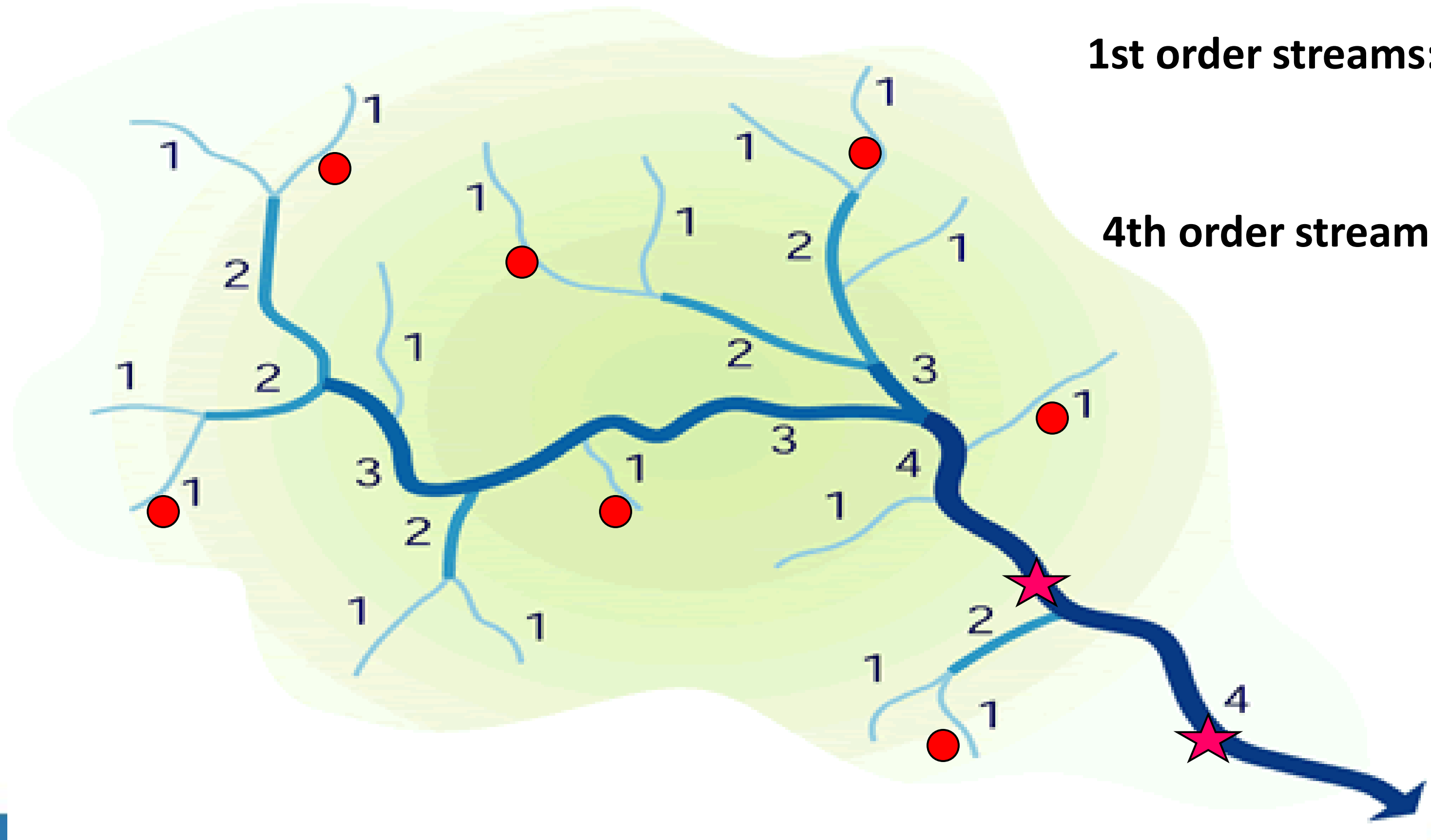
EXAMPLE: Small streams make up the majority of stream segments … a simple random selection of sites would give imprecise assessments for larger streams

SOLUTION:

1) Increase the probability of sampling large streams by increasing the relative segment length,
2) back-adjust weights to compensate for this during analysis

Putting it all together, this process creates a set of spatially-balanced, yet randomly-selected sites

Each sampling site represents a known portion of the total stream length (i.e., each site has a *design weight*)



1st order streams: $\frac{10{,}000\text{km}}{7\text{ sites}}$ =1428.5

4th order streams: $\frac{1{,}000\text{km}}{2\text{ sites}}$ = 500

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Step III. Reconnaissance

Field crews get a list of candidate sites and spend most of winter evaluating site list with desk work and field reconnaissance:

- **visit county assessor's offices for ownership info**
- **obtain permits for sampling public sites, attempt to get permission for private sites…**
- **use field visits to evaluate sites and determine access**


Highlights of First 8 Years
(2000-2007)

Reconnaissance Fates

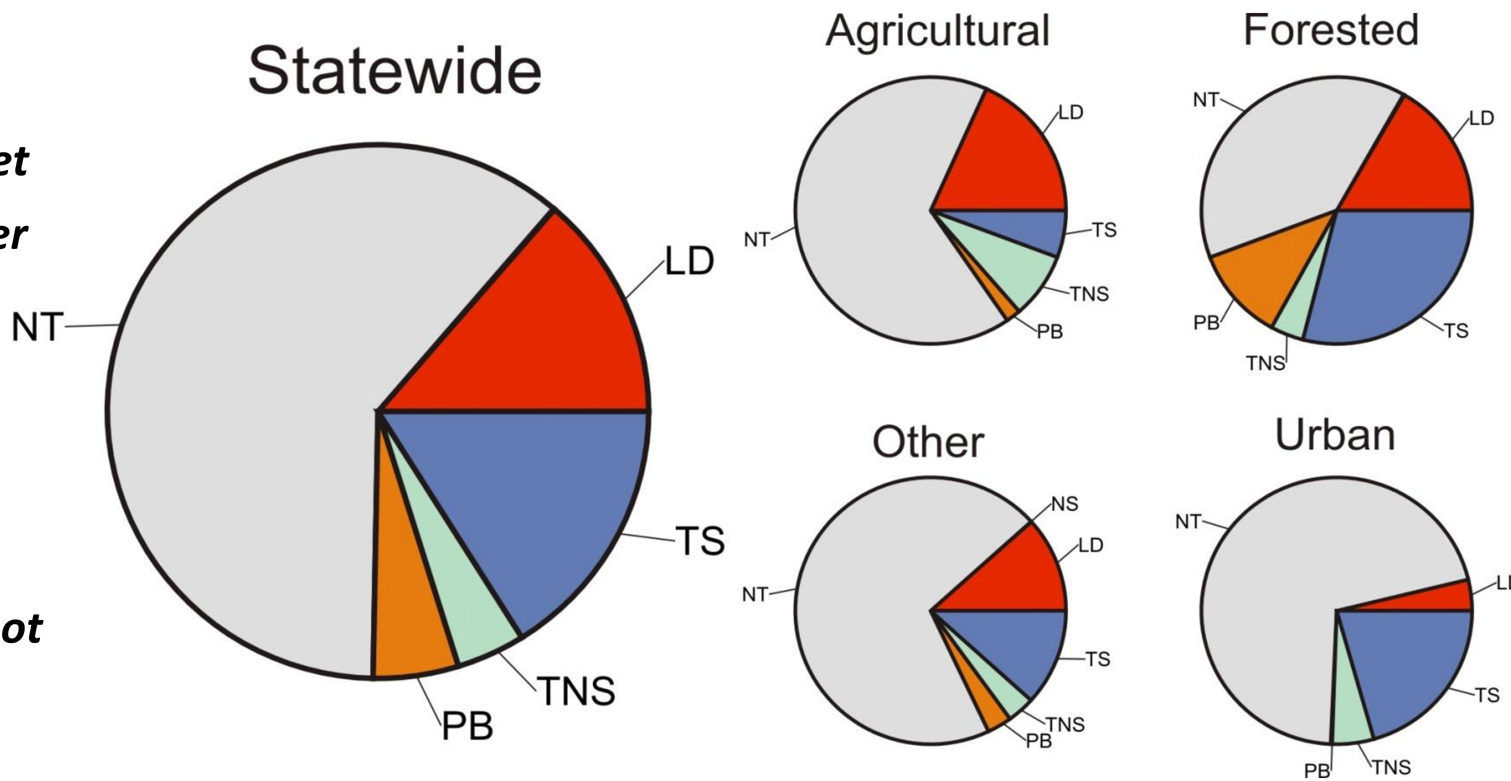
NT = non target

LD = landowner denial

PB = physical barrier

TS = target sampled

TNS = target not sampled



- ➢ Vast majority of non-target sites were non-perennial
- ➢ Large proportion of landowner denials, especially in agricultural lands, relatively few in urban regions

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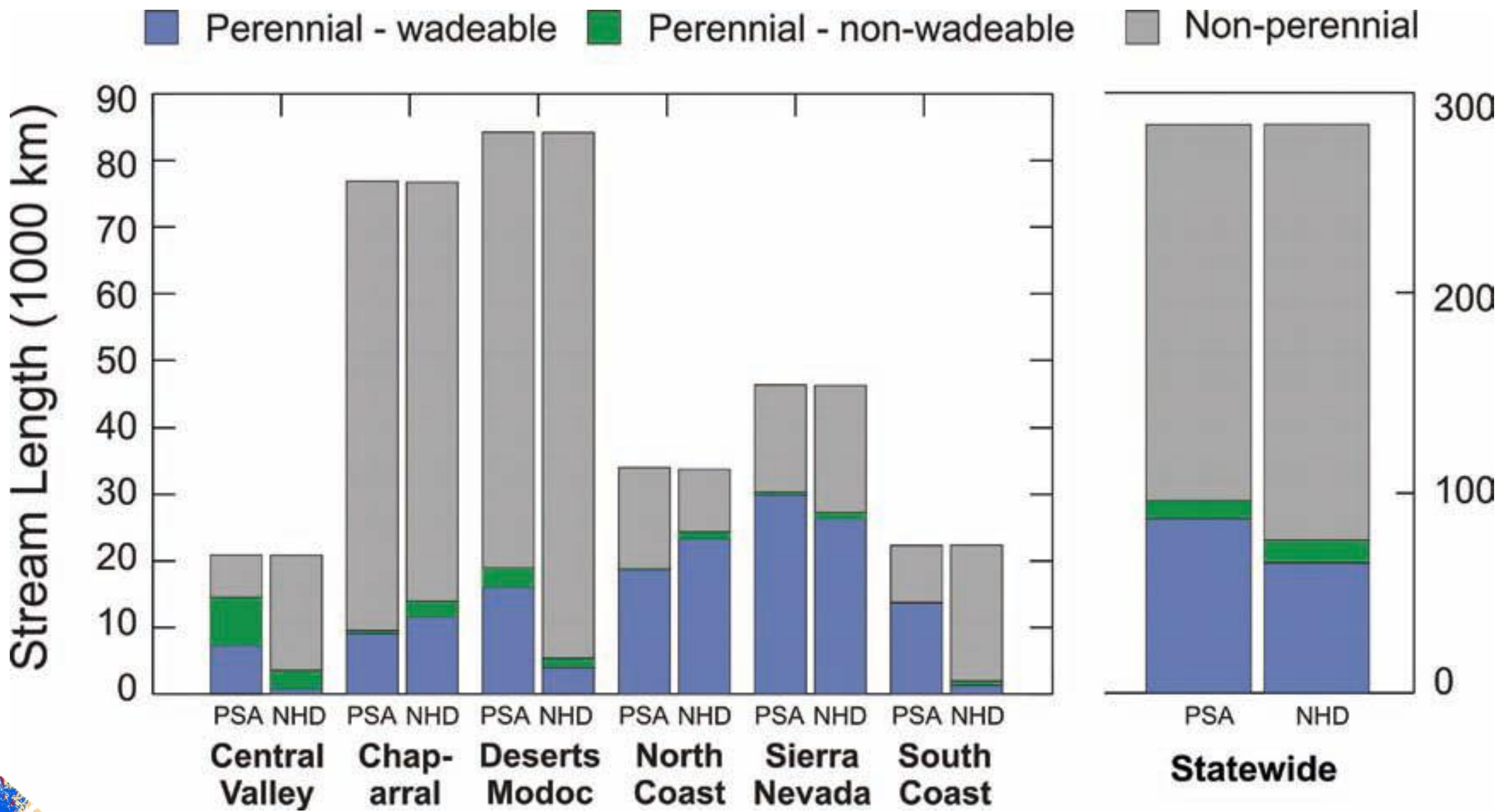
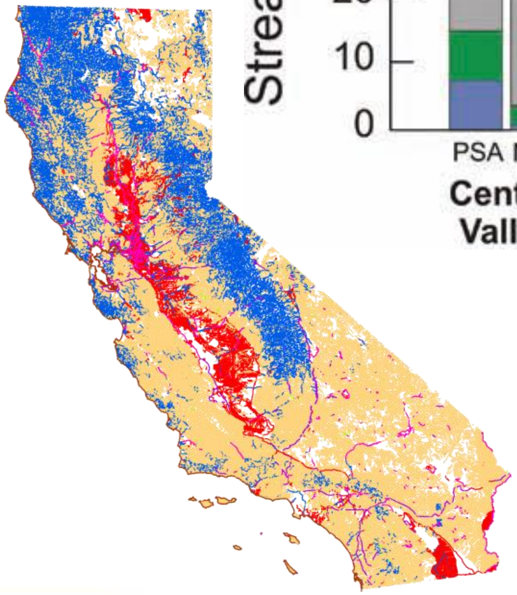
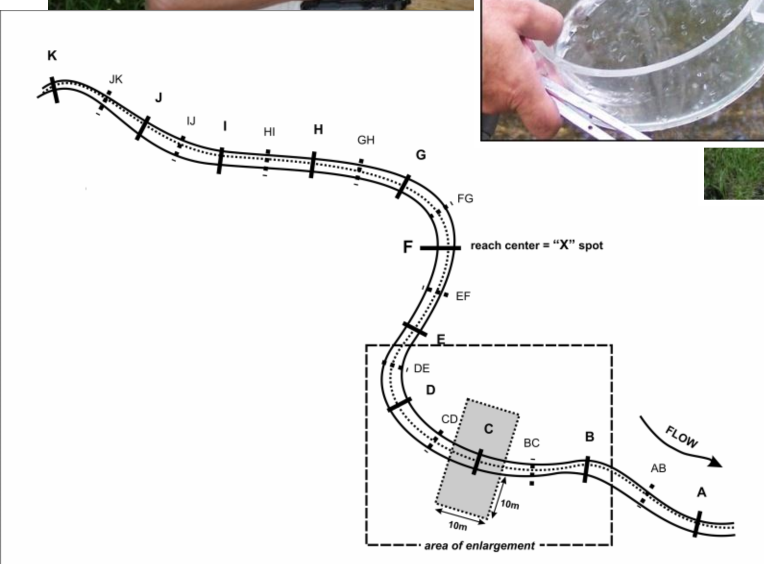
Resource extent estimates:





- ~75% of CA stream length is non-perennial
- current maps are frequently inaccurate
- neglected target for monitoring and protection

Sites that meet sampling criteria are sampled for biological, chemical and habitat condition indicators following SWAMP SOPs



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Indicators

Category	Indicator	EMAP	CMAP	PSA
Physical Habitat	Instream habitat condition	x	x	x
	Riparian vegetative condition	x	x	x
	Human activities within reach	x	x	x
Biological Indicators	**Benthic macroinvertebrates**	x	x	x
	Algae	x	x	x
	Fish	x	-	-
	CRAM Wetland Condition	-	-	x
Chemical Indicators/ Stressors	SSC/TSS, turbidity, pH, conductance, DO	x	x	x
	Major ions (Cl^-, SO_4)	x	x	x
	Nutrients (N, P, Si)	x	x	x
	DOC	x	x	x

Benthic Macroinvertebrates (BMIs)

Bottom-dwelling invertebrates, not microscopic

- DIVERSE and ABUNDANT: Dozens to > 100 BMI species present at a site, thousands of individuals/m^2
- Unique preferences for different micro-habitats: physical settings, but also different sensitivities to stresses (pollutants, sediments, flow conditions, climate, etc.)

Scoring Biological Condition with Bugs

(Observed/ Expected Models)

Developed in UK (Wright and others 1970s-1980s, RIvPACS), adapted in Australia (AusRivAS) and US (Chuck Hawkins, Utah State… source of most of these slides)

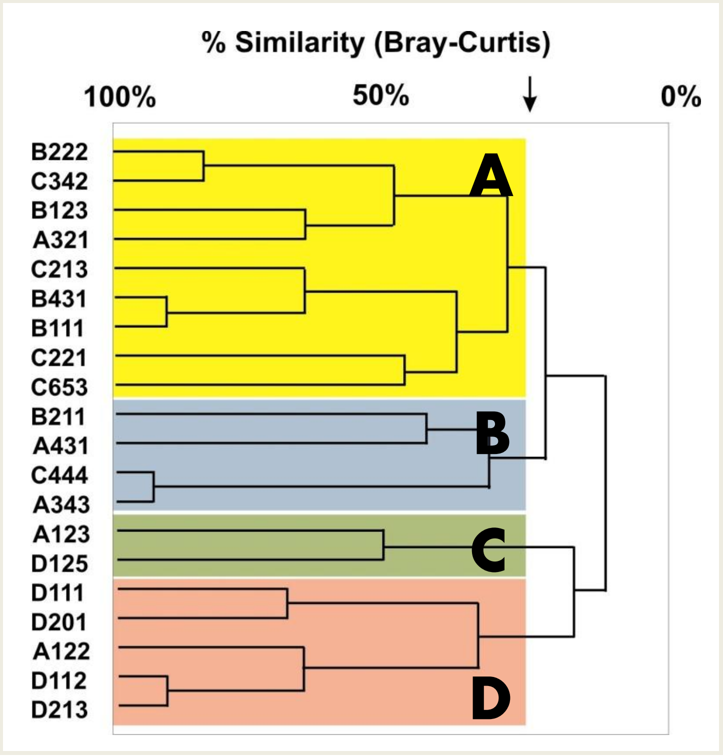
Species-based approach: Compare number of **observed** ("O") taxa to number of **expected** ("E") taxa

"Expected" taxa derived from predictive modeling techniques, using data from "reference sites" (sites with low levels of human activity)

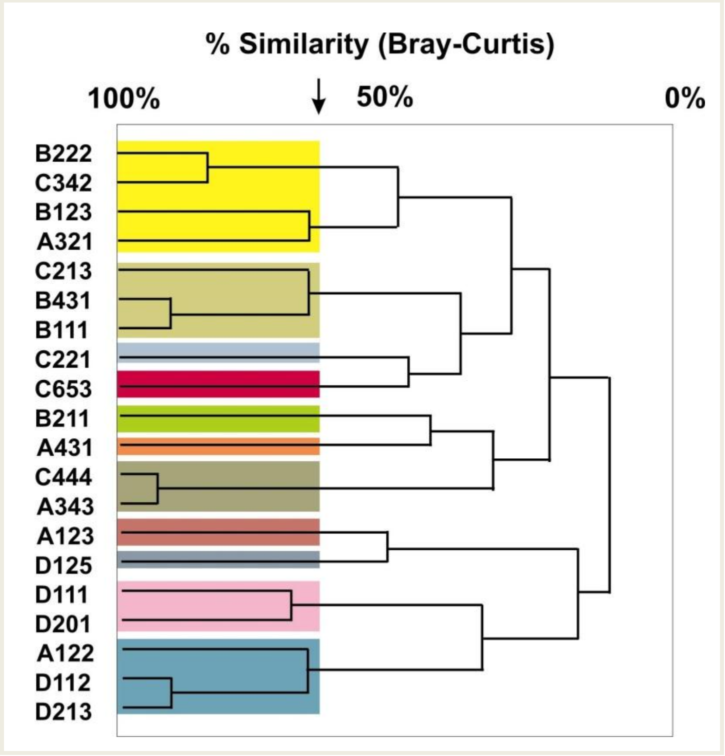
Estimating "E"

Step 1. Classify reference sites based on biological similarity

Clustering techniques used to identify groups of reference sites with similar species composition



4 classes



11 classes

Estimating "E"

Step 2. Develop model that will predict class membership for new sites

Cluster Natural
Predictor Variables:

Watershed Area
Geology
Latitude/ Longitude
Elevation
Temperature
Precipitation

Biologically Defined Reference Clusters:

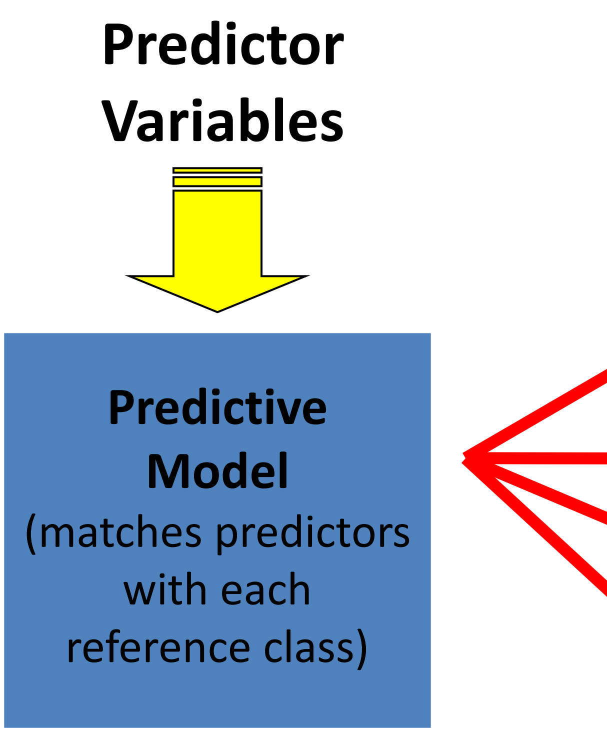
- Cluster A
- Cluster B
- Cluster C
- Cluster D

Predictive Model (Random Forests/ Discriminant Functions)
matches best predictors with each reference cluster

Estimating "E"

Step 3. Estimate capture probabilities

Use discriminant model output + frequencies of occurrence within each class to estimate **probabilities of capture (PC)** for each taxon at a given test site



Cluster	Site's probability of cluster membership	Frequency of species X (*Farula sp.*) in cluster	Expected contribution to PC
A	0.5	0.6	0.30
B	0.4	0.2	0.08
C	0.1	0.0	0.00
D	0.0	0.0	0.00
Probability of *Farula sp.* being in sample if site is in reference condition			**0.38**

Estimating "E"

Step 4. Sum of taxon occurrence probabilities is an estimate of the number of native taxa (E) that should be observed (O)

Taxon	pc	O
Atherix	0.70	*
Baetis	0.92	*
Caenis	0.86	
Drunella	0.63	
Epeorus	0.51	*
Farula	**0.38**	
Gyrinus	0.07	
Hyalella	0.00	*
E	4.07	3

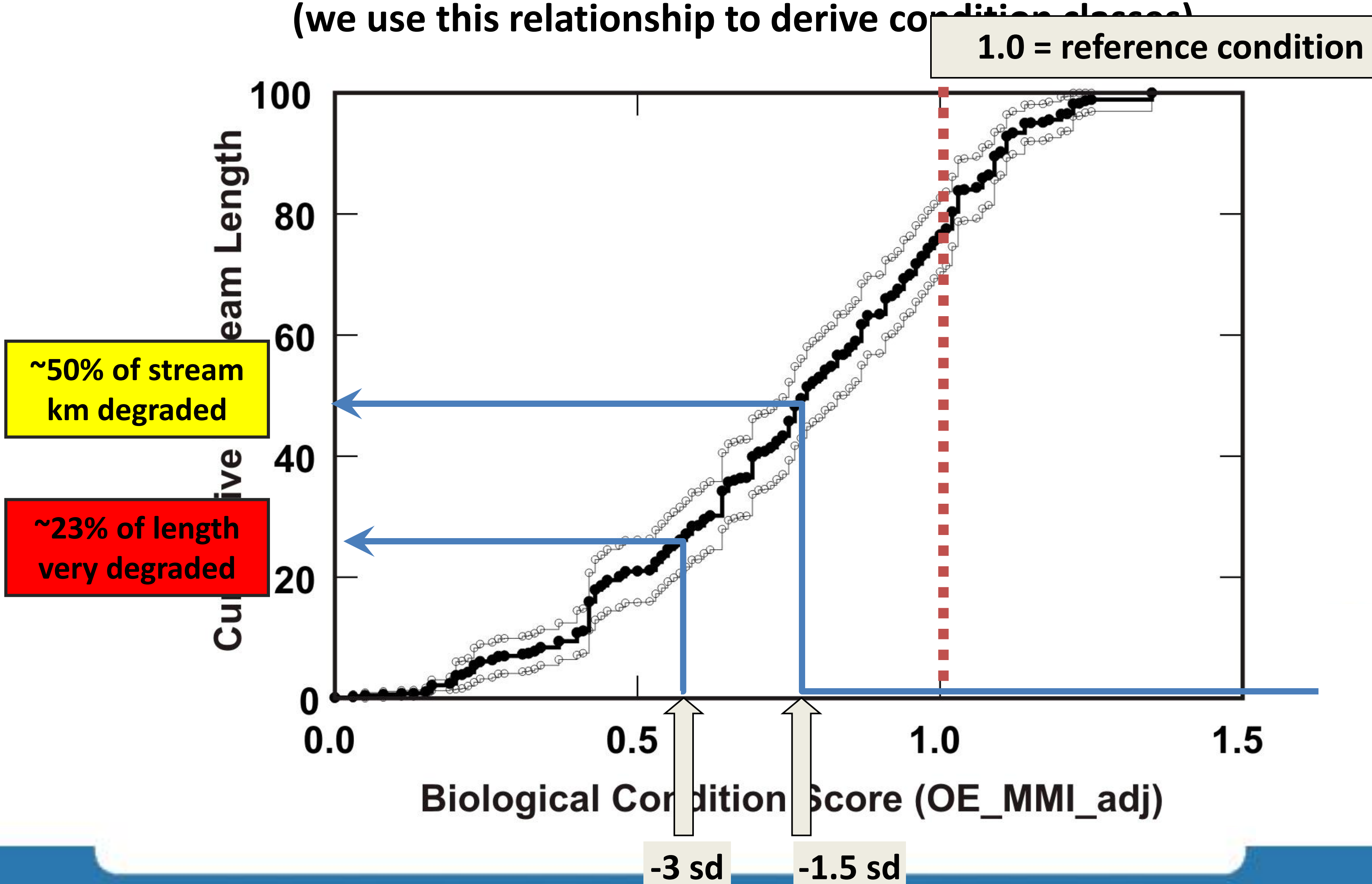
O/E = 3 / 4.07

O/E = 0.74

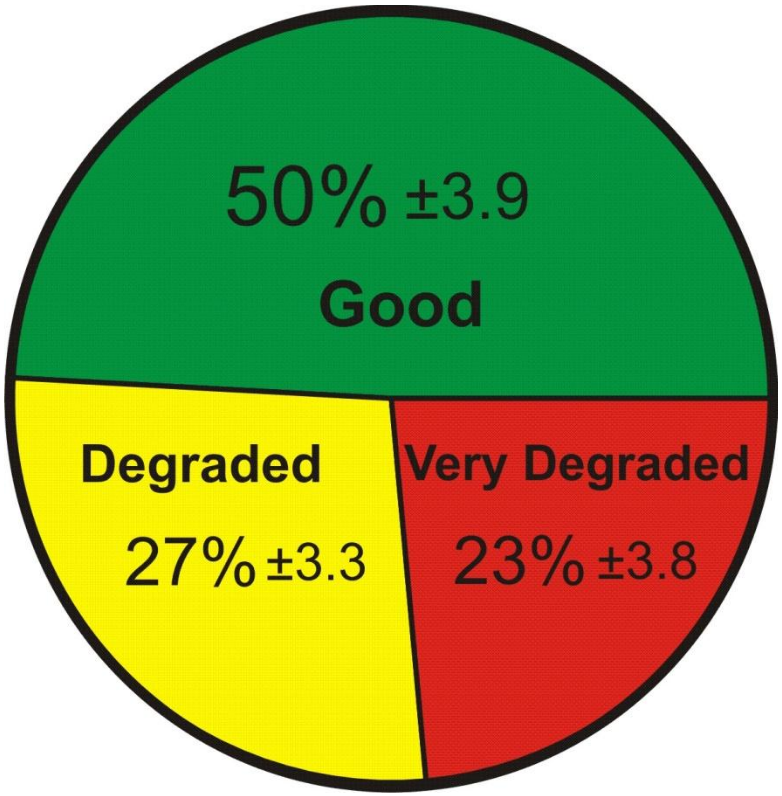
O/E (scaled 0.0 to 1.0): represents proportion of native assemblage present at test site

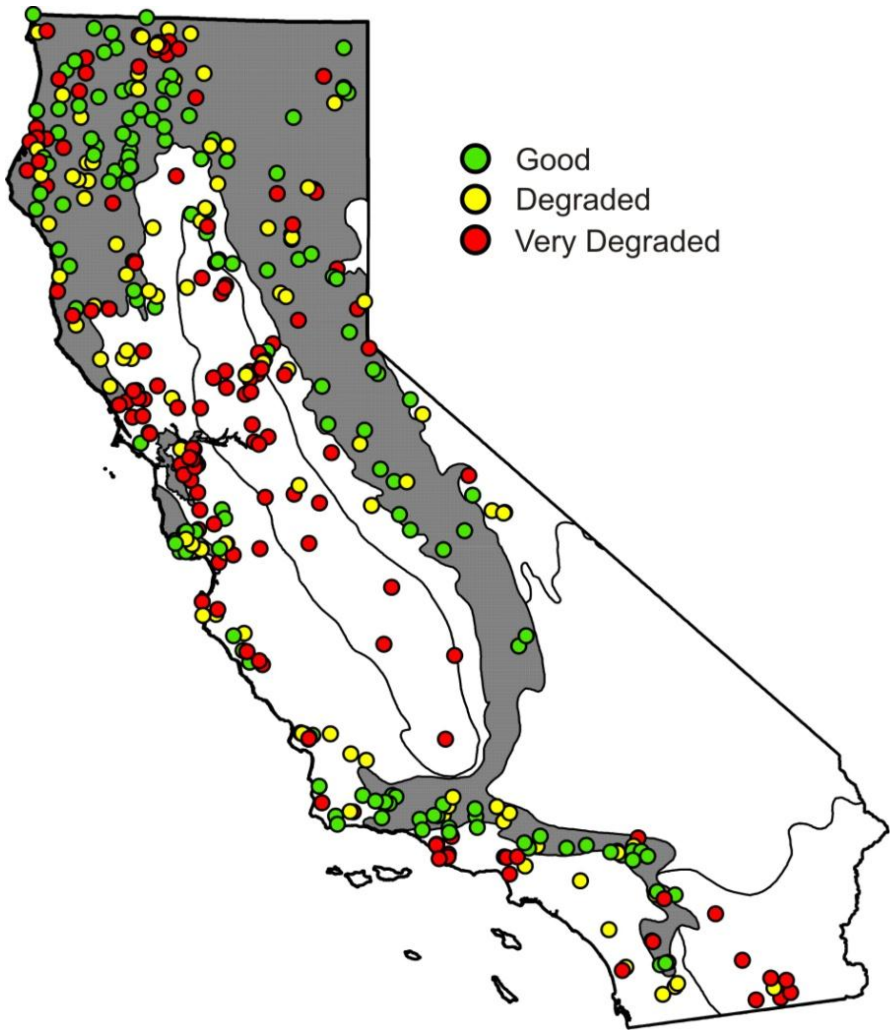
Biological condition scores vs. cumulative stream length assessed =the condition assessment

(we use this relationship to derive co

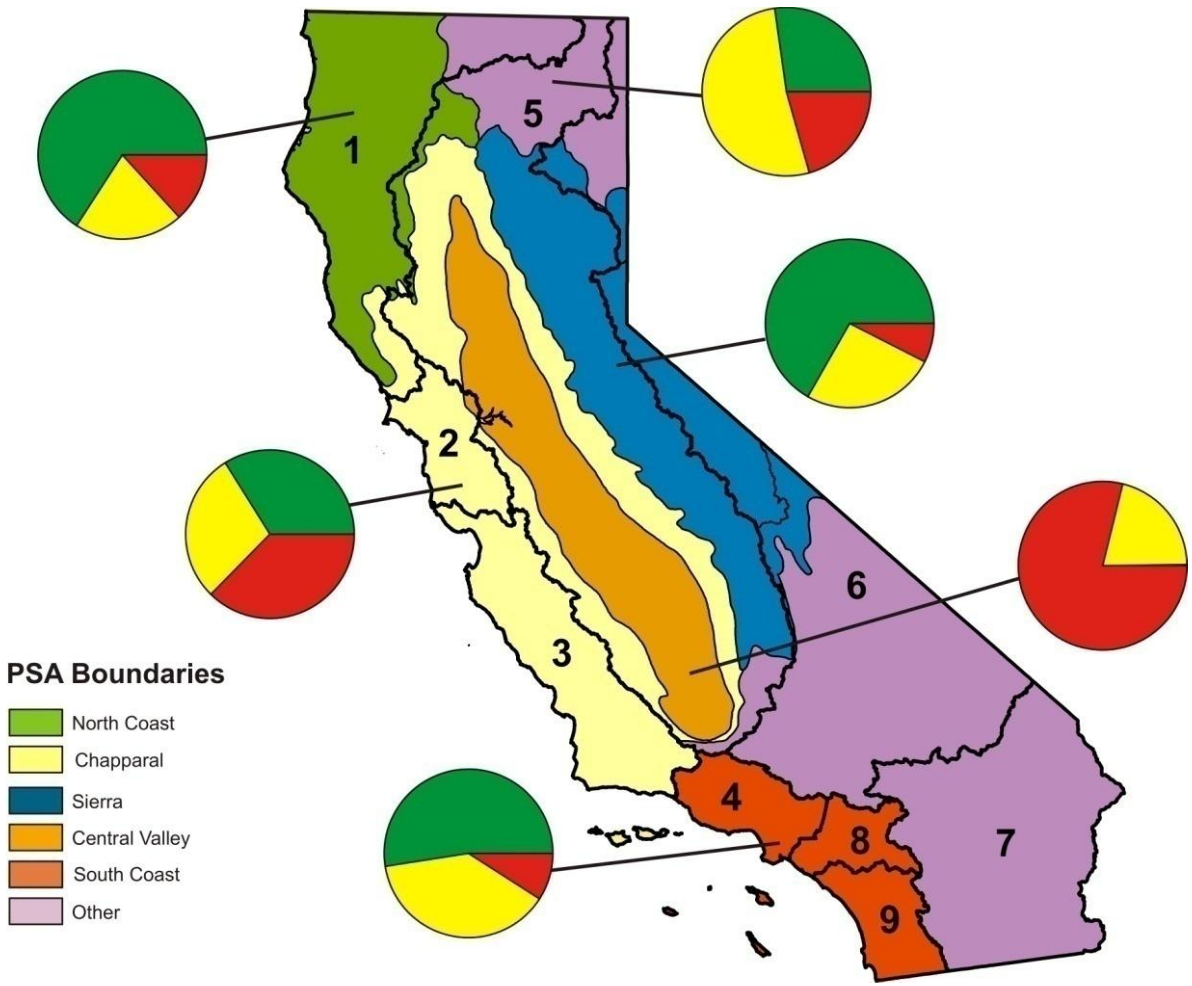


Biological Condition of California's Wadeable Perennial Streams



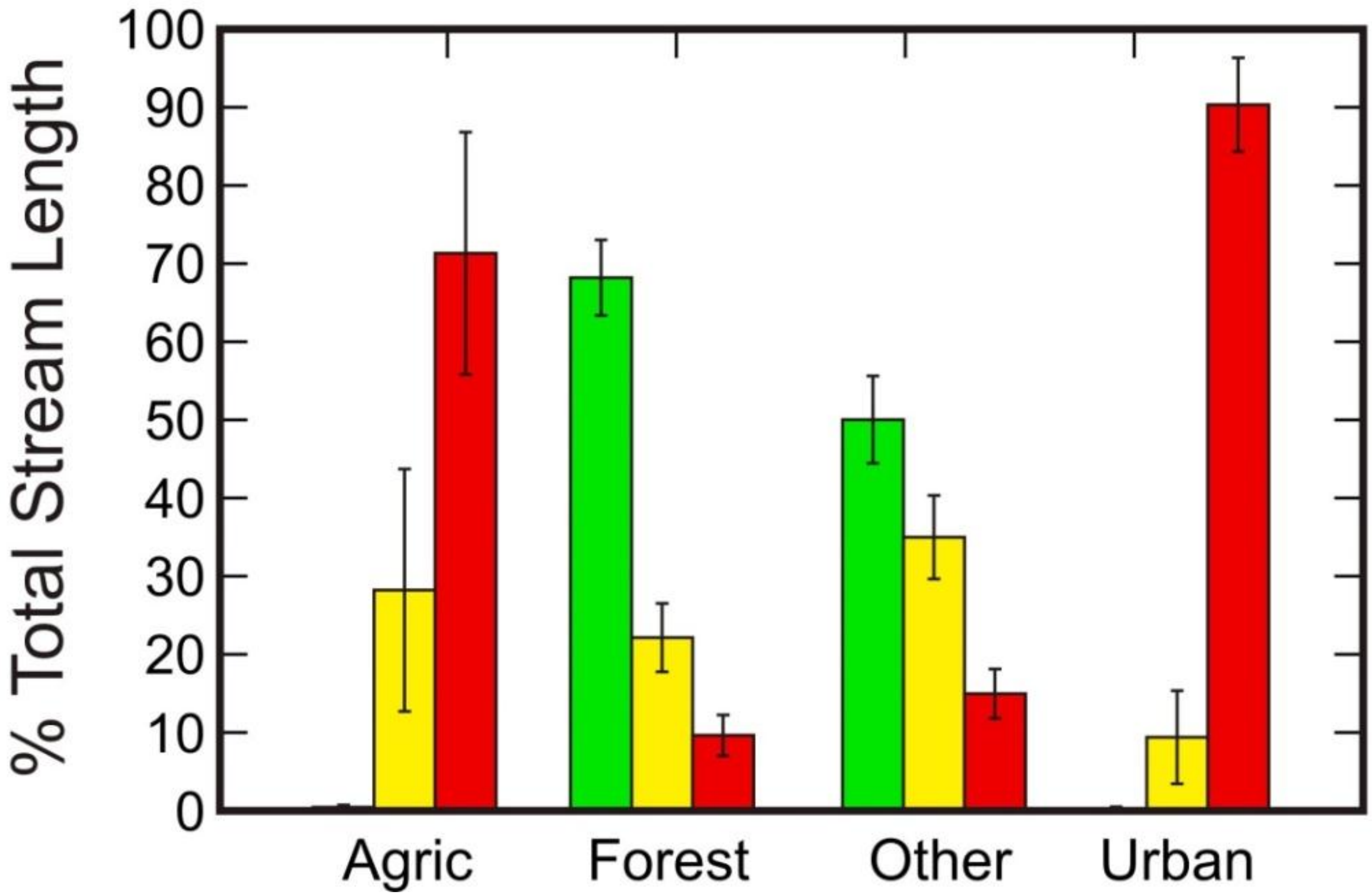


Condition Assessments by Region (8 years)



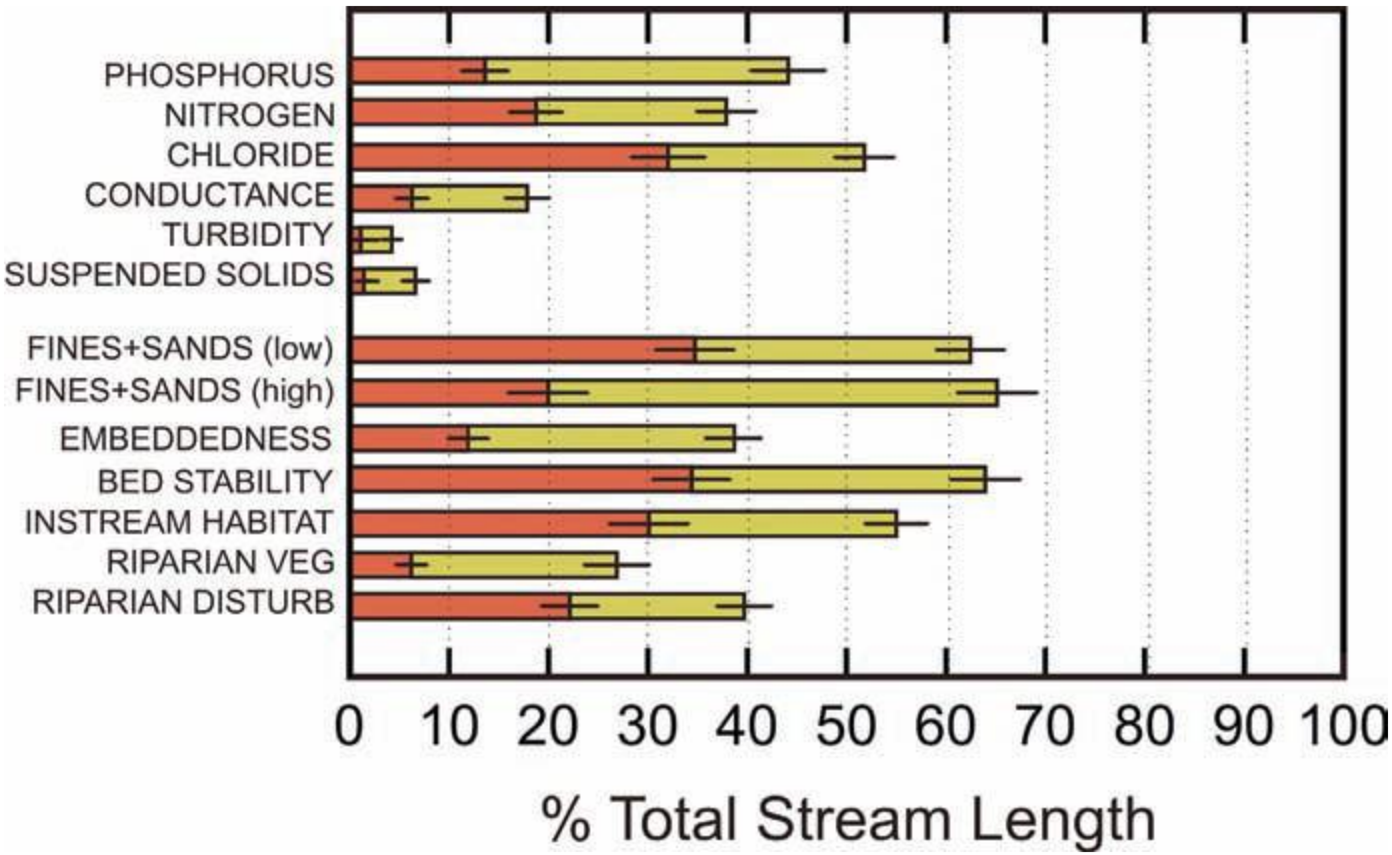
31

Condition Assessments by Landuse



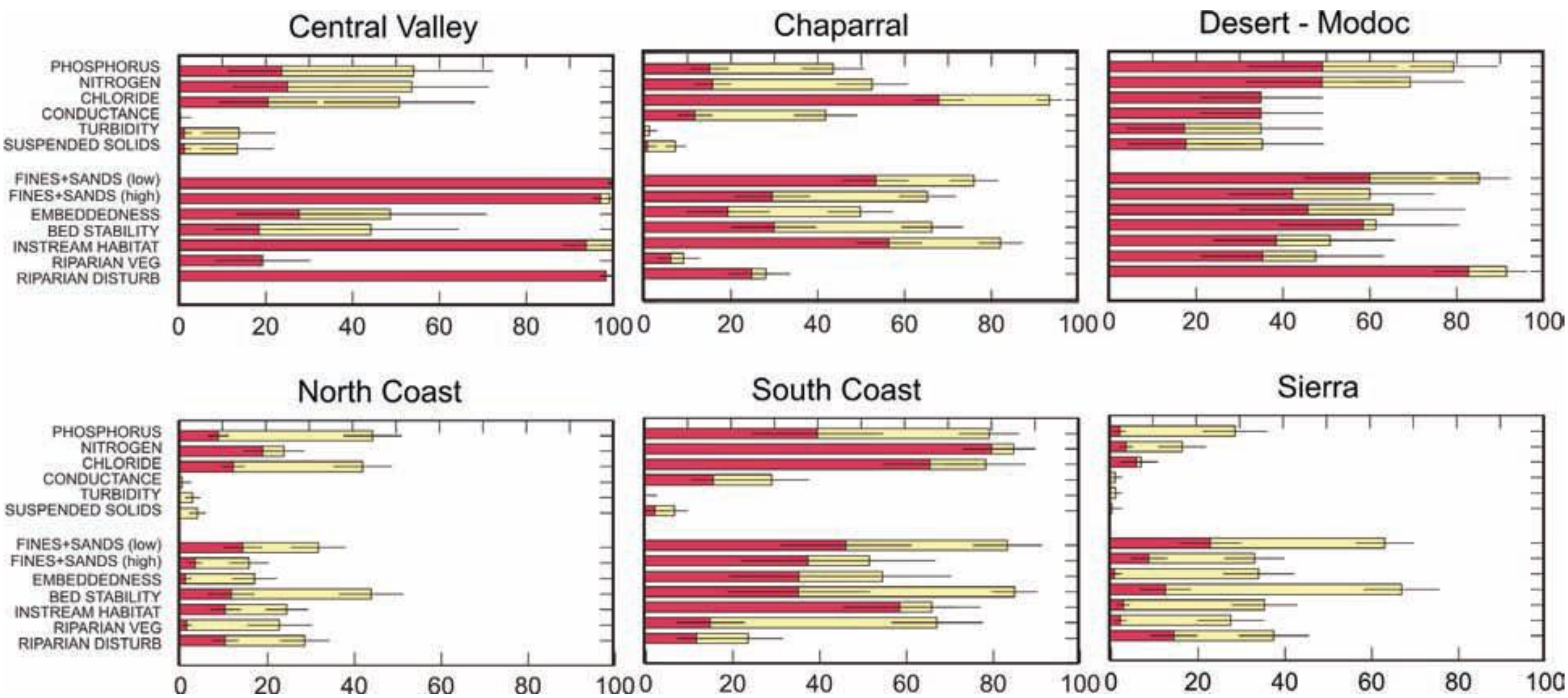
Stressor Extent Estimates:

% of stream length with high (red) or moderate (red + yellow) levels of various stressors



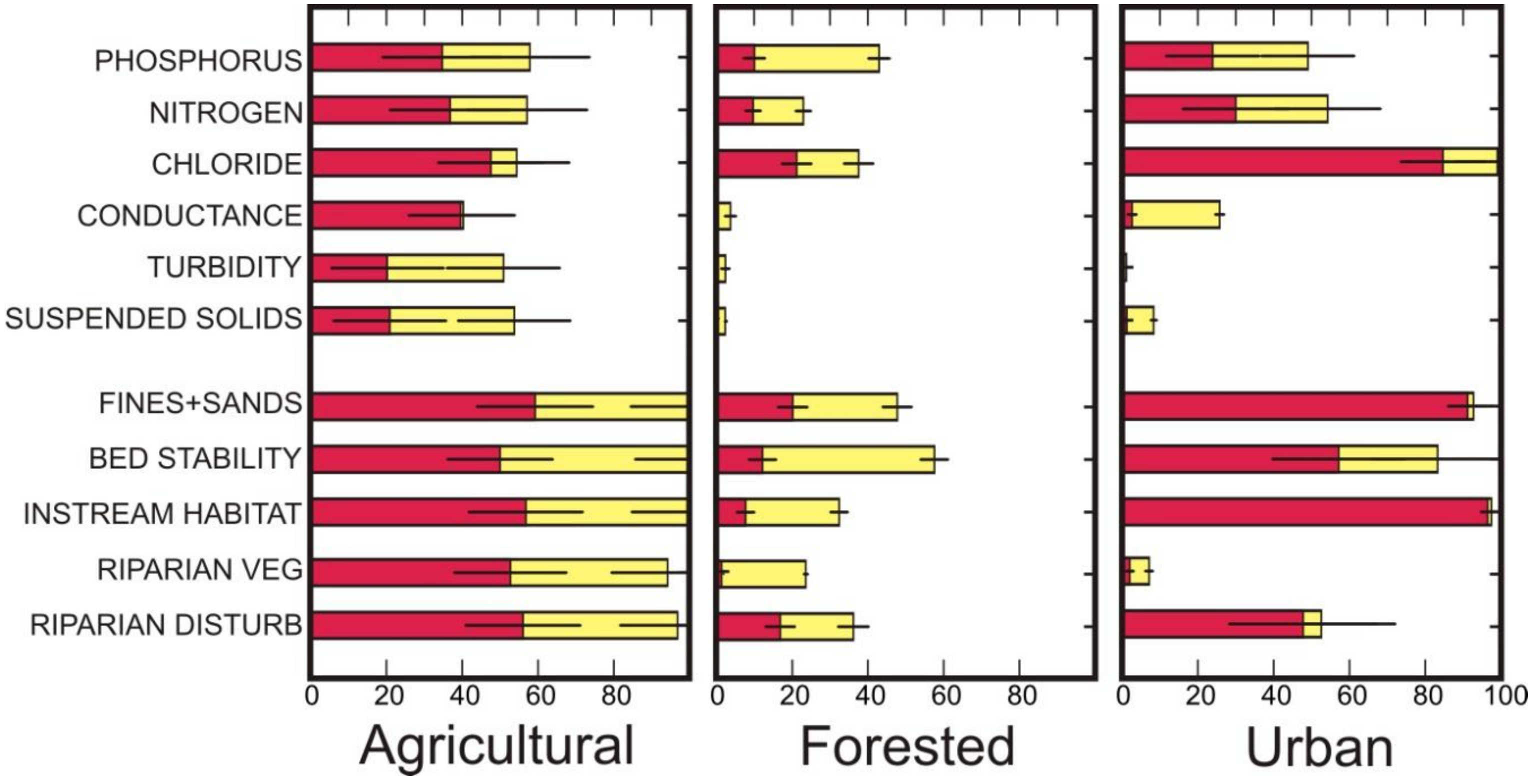
Stressor Extent Estimates by Region:

% of stream length with high (red) or moderate (red + yellow) levels of various stressors



Stressor Extent Estimates by Landuse:

% of stream length with high (red) or moderate (red + yellow) levels of various stressors

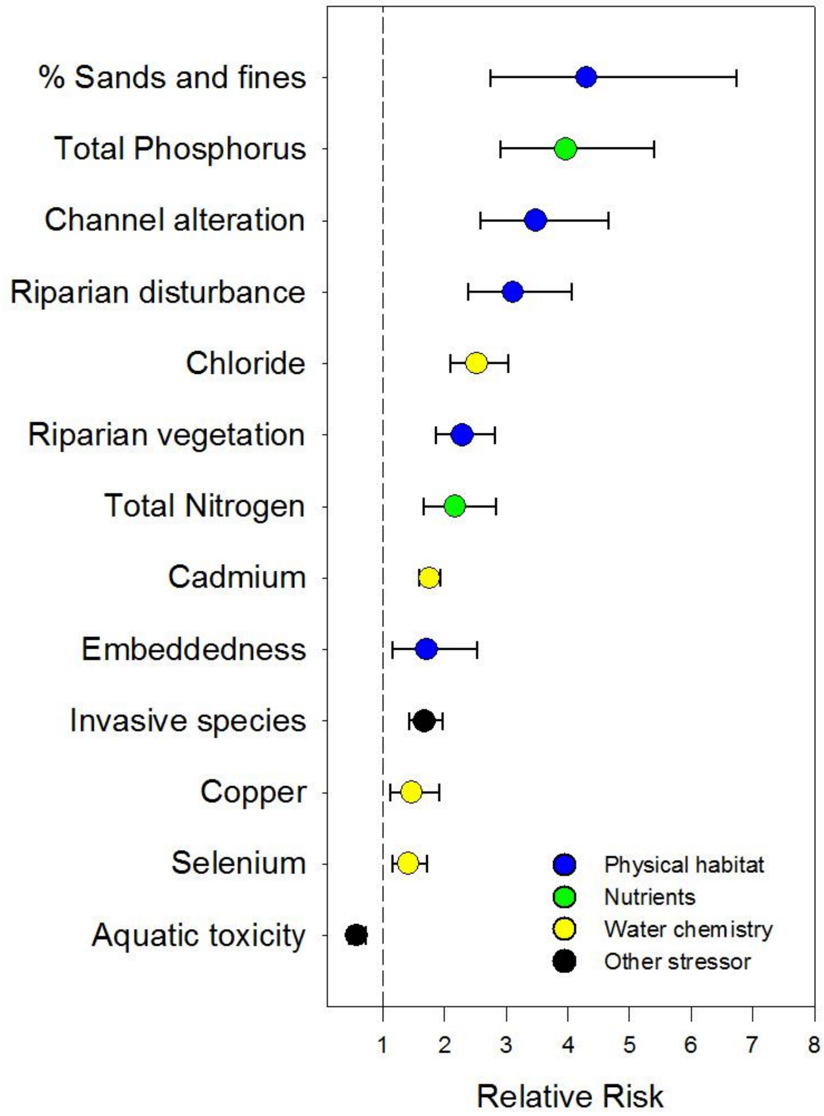


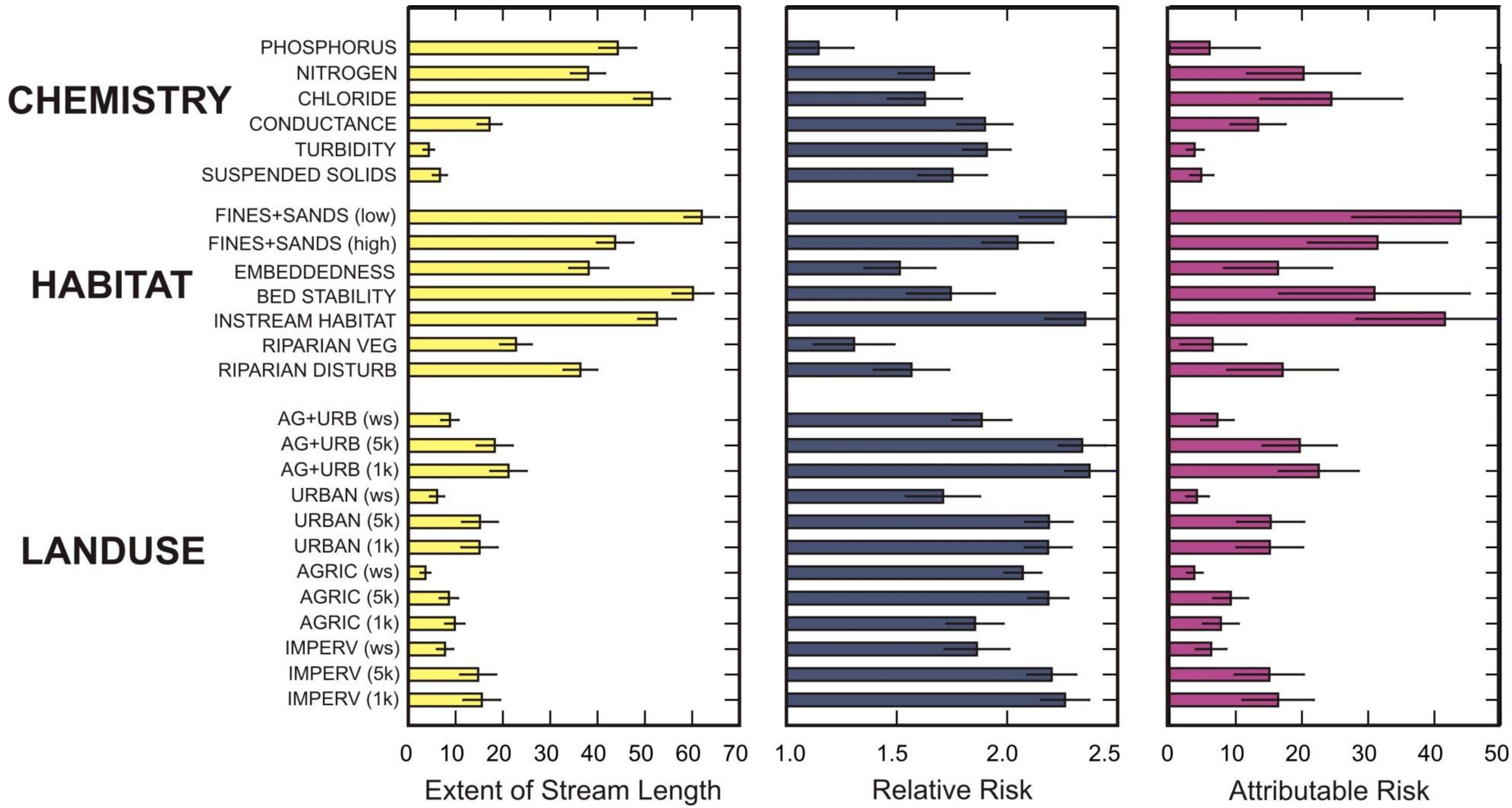
35

Relative Risk

Increased risk of biological impairment in presence of high stressor levels *(analogous to medical risk advisories – e.g., 10x higher risk of emphysema associated with smoking)*

Data from SMC probability survey (Mazor et al. 2011)





Stressor Extent = % of streams with high stressor levels

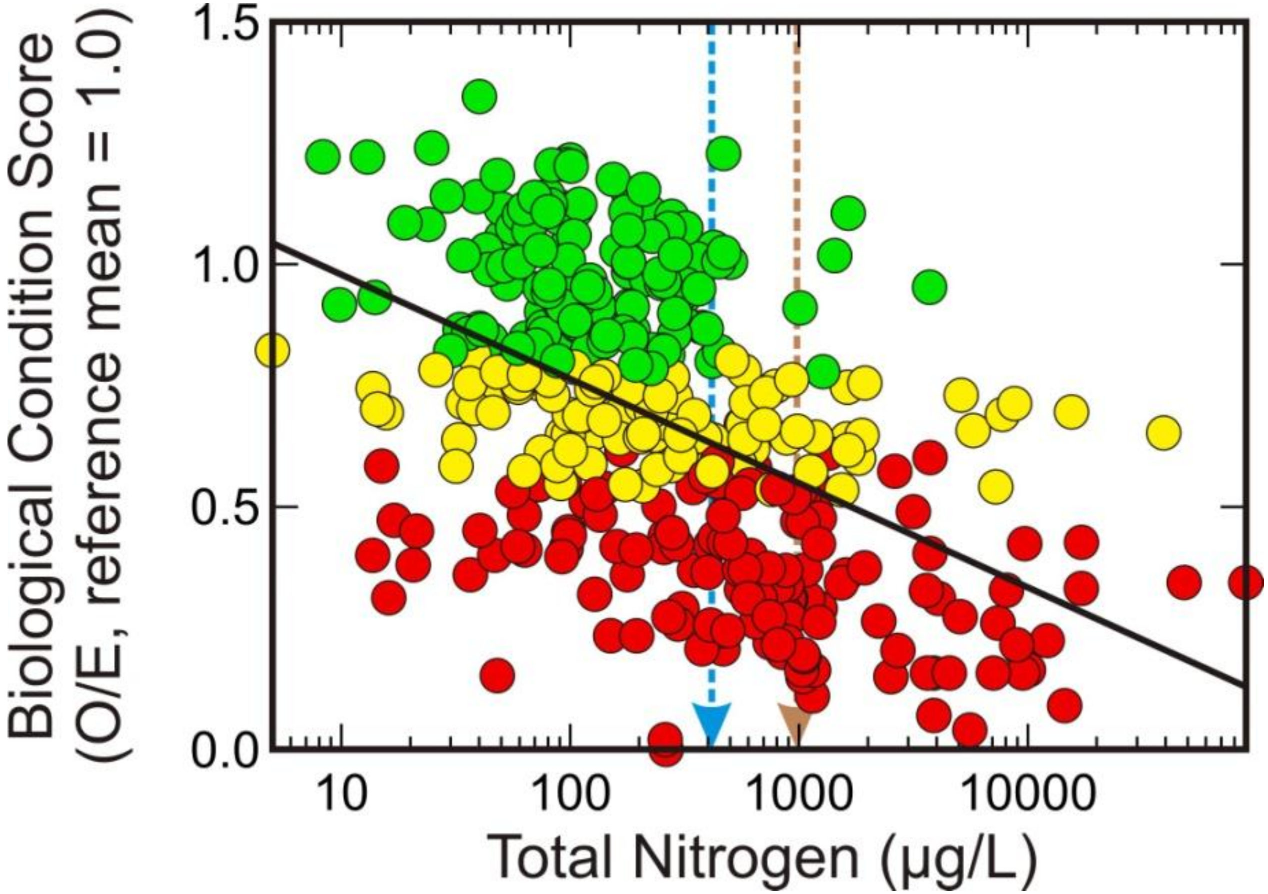
Relative Risk = increased risk to biology associated with high stress

Attributable Risk = impact factor, integrates extent and risk

37

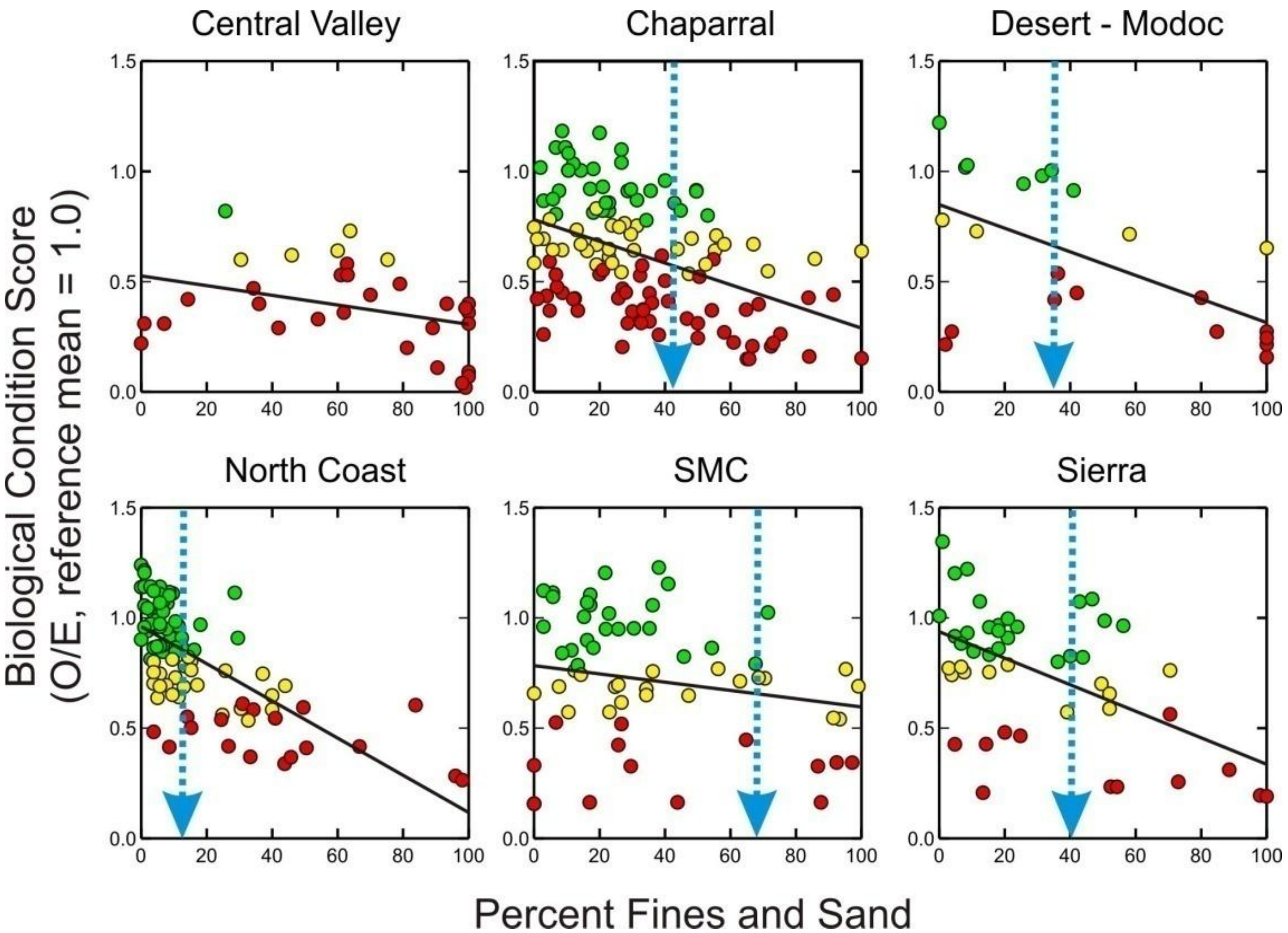
Other Applications

Biology-based stressor thresholds



38

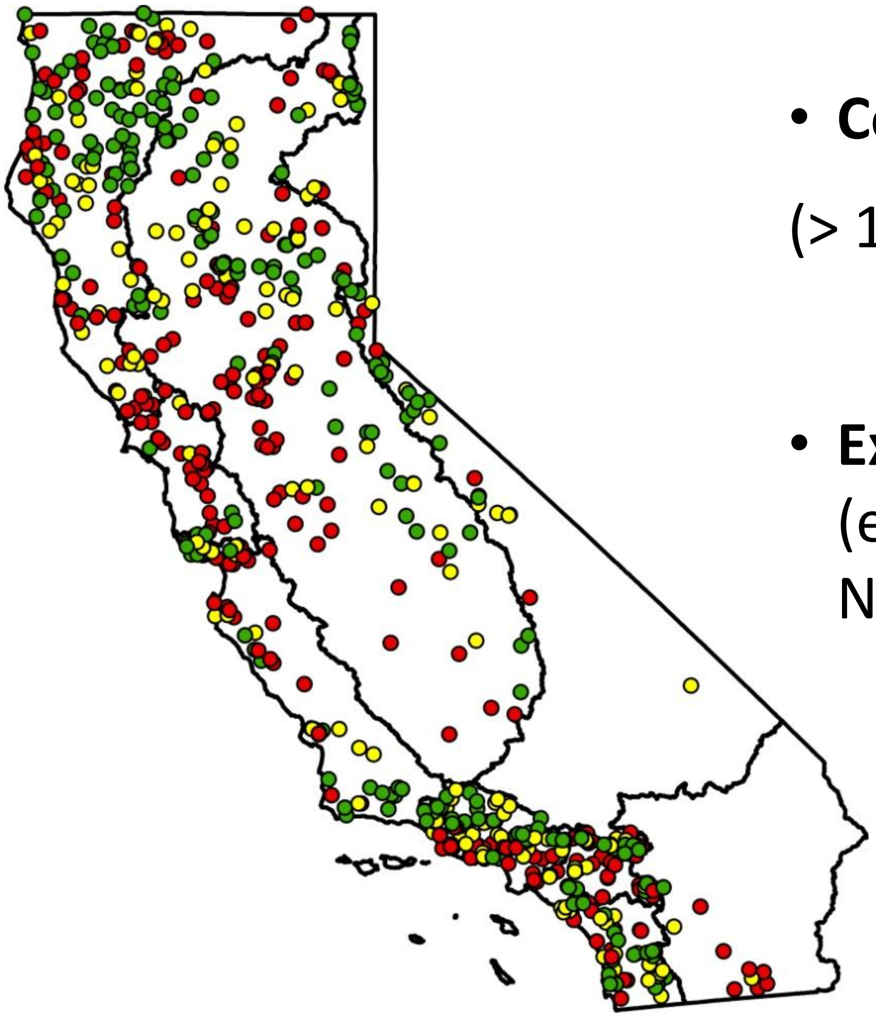
Biology-based stressor thresholds



regionally calibrated thresholds

39

Current and Future Efforts



- **Combine multiple surveys**

(> 1000 sites through 2011)

- **Expand cost-sharing partnerships** (e.g., SoCal-SMC, BayArea-RMC, NRSA, USFS, TRPA)

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Combining Statewide and Regional Surveys

Program	Number of Sites	Geographic Distribution	Notes	Design Elements
EMAP	230	Statewide	Western EMAP	
CMAP	200	Statewide	California EMAP	Landuse
PSA	300	Statewide	Perennial Streams Assessment	Weighted landuse
NRSA	61	Statewide	National Rivers and Streams Assessment	
SMC	400	SoCal coast	Coalition of regional boards and regulated stakeholders	Landuse + watersheds
SoCal (other)	100-200	SoCal coast	Multiple designs and scales	
USFS	40	Sierra Forests		
Garcia River	90	Garcia River	The Nature Conservancy	
TRPA	75	Tahoe Basin	Tahoe Regional Planning Agency	Urban/Non

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(programs in black have been combined)

Current and Future Efforts

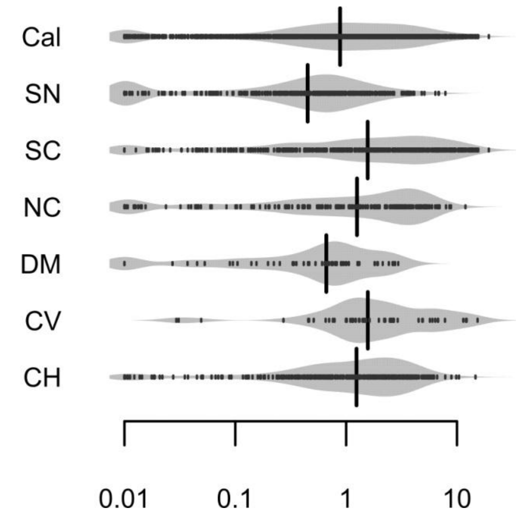
- **Incorporate new BMI scoring tools** (O/E models built for bio-objectives)

- **Multiple indicators**
  - Biology- BMIs, algae
  - Instream and Riparian Habitat – (SWAMP PHAB, CRAM)

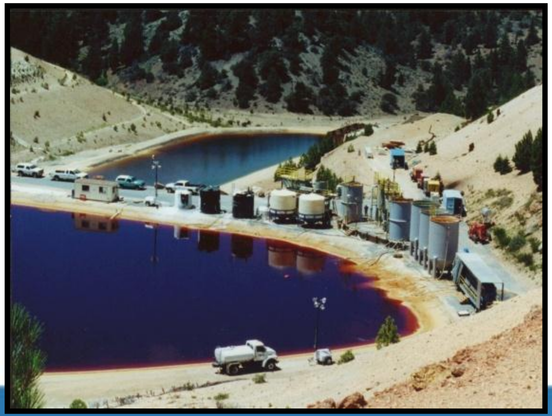
algae photos courtesy Robert Sheath

Current and Future Efforts

- **Emphasis on Regional Assessments**
- **Document Stressor Distribution Patterns**
    - Instream habitat
    - Riparian habitat
    - Landcover
    - Infrastructure
    - Mines, etc.
- **Expand focus to non-perennial streams**



Road density distributions in each PSA region (log+1 km/km^2)



Take Home Messages

- Probability surveys provide critical perspective that can't be obtained from traditional survey designs … results will support more efficient and effective use of monitoring dollars
- Multiple benefits beyond general condition assessments – SWAMP's PSA will continue to produce a large public data set that can be mined to meet many needs
- Partnerships can greatly extend value

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Questions?

For more information:

PSA Summary Report on SWAMP website:

http://www.swrcb.ca.gov/water_issues/programs/swamp/docs/reports/psa_smmry_rpt.pdf