Southern California Coastal Index of Biotic Integrity (IBI)

Peter R. Ode, Andrew C. Rehn and Jason T. May

Aquatic Bioassessment Laboratory
Water Pollution Control Laboratory
California Department of Fish and Game
California State University, Chico

Aquatic Bioassessment Laboratory

Why a southern California IBI?

- Southern California coastal region is of interest because it is both arid and densely populated (~½ CA pop)

- With increasing demands on watershed resources, there is a strong need to monitor the condition of watersheds and waterbodies in this region

- Biological data offer an efficient and highly defensible method for assessing these conditions

Why a **new** southern California IBI?

Reasons to expand the San Diego IBI:

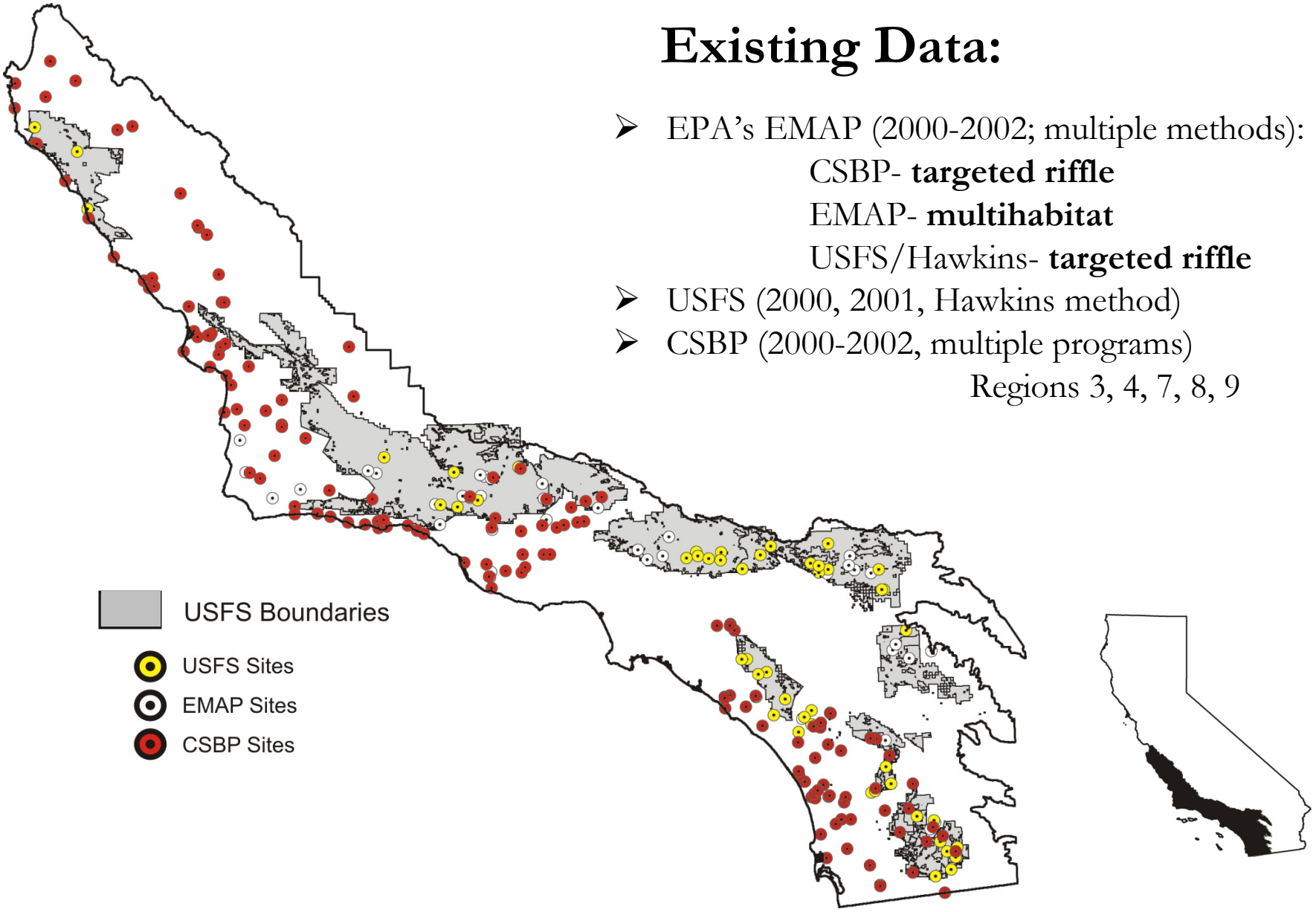
- We reasoned that geology and climate are similar throughout this region and we might be able to make one IBI for the region
- Many state and federal agencies collect invertebrate samples from streams in this region, but almost no sharing of data and still no regional context for interpreting results
- Opportunity to incorporate new developments in bioassessment (particularly in the interface between metric based and community ordination based methods)

Enhancements in Southern California Coastal IBI

	San Diego 2002	SoCal 2003
Geographic Extent	• San Diego Regional Board	• San Diego to Monterey
Number of Sites/ Sampling Methods	• **93 sites** (CSBP only)	• **238 Sites** (EMAP, CSBP, USFS)
Reference Criteria	• Semi-quantitative local and watershed condition measures (David Gibson's criteria)	• GIS-based local and watershed scale landuse criteria and site specific phab/chemistry
Metrics Screening	• **21 metrics** tested, test-reference discrimination, dose-response	• **61 metrics** tested, quantitative landuse screens and tested for redundancy
Gradient Selection	• 1 gradient: Gibson Score	• 7 local and watershed scale gradients screened for redundancy
Other Features		• Increased integration of ordination and multivariate techniques • Distinct **validation** dataset to test IBI performance

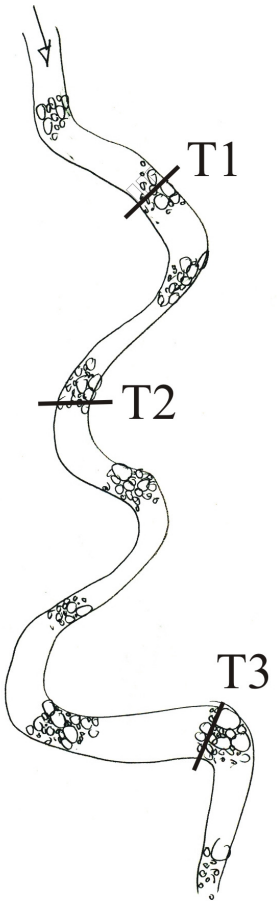
Existing Data:

- EPA's EMAP (2000-2002; multiple methods):
  - CSBP- **targeted riffle**
  - EMAP- **multihabitat**
  - USFS/Hawkins- **targeted riffle**
- USFS (2000, 2001, Hawkins method)
- CSBP (2000-2002, multiple programs)
  - Regions 3, 4, 7, 8, 9

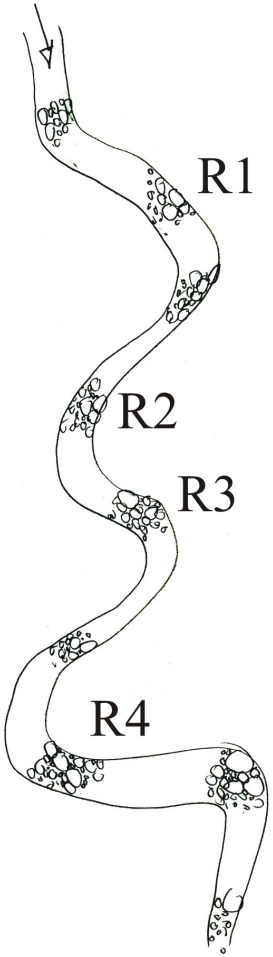


Differences Between Two Targeted Riffle Methods

CSBP



Hawkins (USFS)



CSBP

- **3 separate samples/ site, 300 organisms each**
- **Total = 900 organisms, 18 ft^2 sampled**

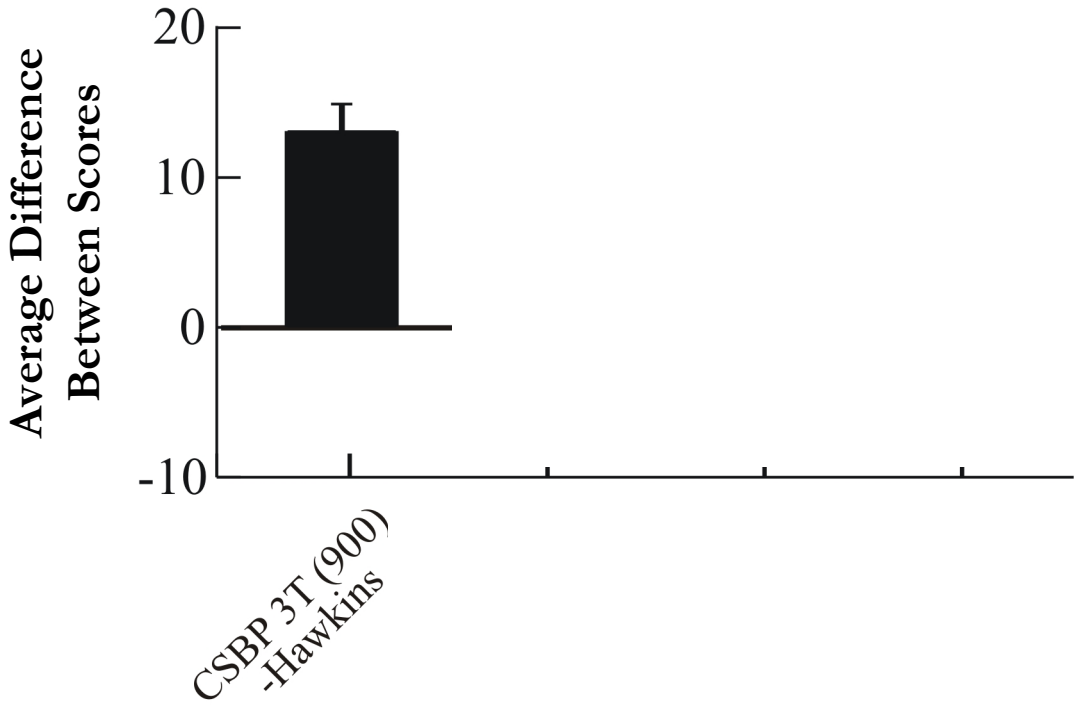
Hawkins (USFS)

- **1 composited sample/ site – 500 organisms**
- **Total = 500 organisms, 8 ft^2 sampled**

Combining Data from Different Methods

To combine different protocols into an IBI we need to make them equivalent.

…adjust the average site scores for each method to the same value



Conclusion: CSBP and Hawkins/USFS are comparable with two modifications to CSBP

1. Combine all 3 CSBP transects into one cumulative taxa list for calculating metrics
2. Subsample 500 organisms from 900 organism (3*300) CSBP composite

Interpreting Biotic Condition from Community Data: the IBI Concept

Premise of Bioassessment:

A great deal of information about stream condition can be obtained by studying the community of organisms found a site.

Primary Challenges:

1. Translating a list of species into numbers that water quality managers can use
2. Accounting for natural biological variability

Goal of IBI: Control for natural variability in order to maximize detection of environmental degradation

Strategy: Determine the best measures (metrics) of biotic condition and use them to calculate an index score for stream reaches (Index of Biotic Integrity-IBI)

Creating an Index of Biotic Integrity (IBI)

5 step process: (modified from methods developed by: Karr *et al.* 1986, Kerans and Karr 1992, Hughes *et al.* 1998, Barbour *et al.* 1999, and McCormick *et al.* 2001)

I. **Preliminary steps**
   a. Divide sites into reference and test groups
   b. Evaluate need to create separate IBIs for different stream classes
II. **Select stressor gradients** and **potential metrics**
III. **Screen metrics** to select the most robust ones
IV. **Assemble IBI**
   a. Score metrics
   b. Combine scores into a composite index
   c. Assign rating categories to IBI score ranges
V. **Test the IBI** and measure its performance characteristics

Preliminary Step 1a: Selecting Reference Sites

Critical to all bioassessment techniques (multivariate and multimetric)

Our definition: Reference sites are the **least disturbed sites** in a region of interest (not necessarily pristine)

We need to understand the range of variability at reference sites before we can understand how biology responds to impairment

Assigning sites to either a reference group or a non-reference group helps in several ways:

- Establishes range of expected conditions
- Enables us to select metrics that are minimally sensitive to natural variation
- Helps us evaluate need for separate IBIs for different stream types

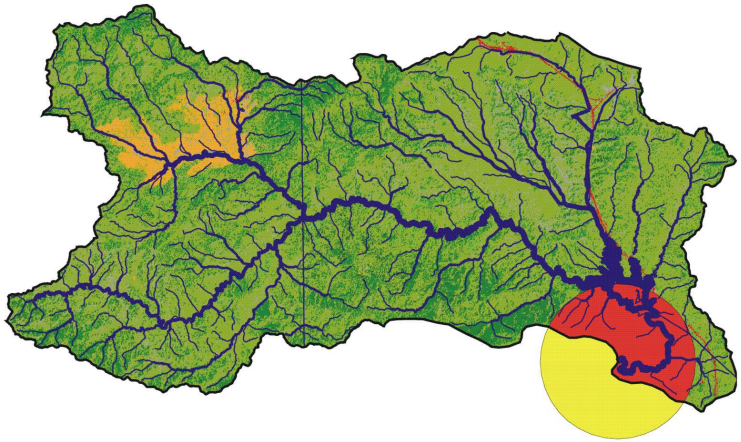
Assigning Sites to Reference and Test Groups

We classified all 238 sites as reference or test following an objective and quantitative method developed by DFG-ABL and SNARL

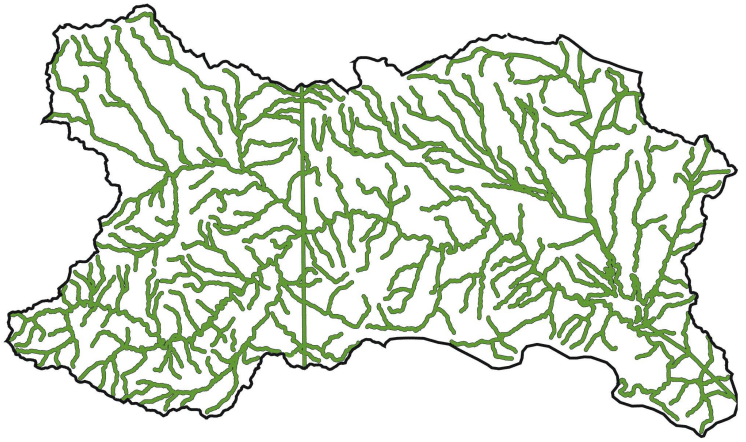
3 Basic Steps:

1. Delineate watershed boundaries for all sites
2. Use GIS techniques to calculate quantitative landuse metrics at several spatial scales
3. Subject candidate sites to further screens with local physical habitat and chemistry data

GIS Landuse Analysis at 4 Spatial Scales

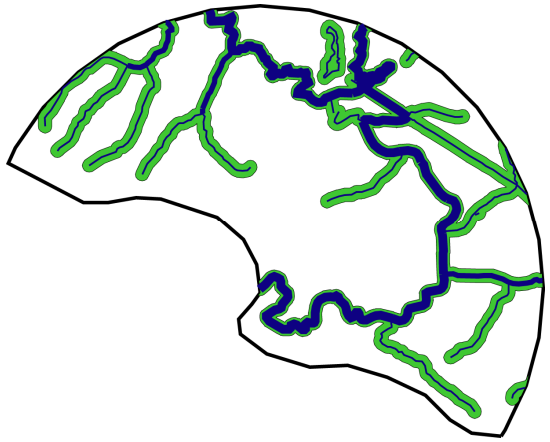


Watershed



Watershed Stream Buffer (120m)

5 km Buffer



5 km Stream Buffer

Available Landuse Datasets

CalVEG (California Land Cover Mapping and Monitoring Program, LCMMP 1993-1997) –used for most sites

Central Coast Watershed Group (CCoWS, 2001)

Used for all counties north of San Luis Obispo

Data were more current, but had less detail in landuse activities

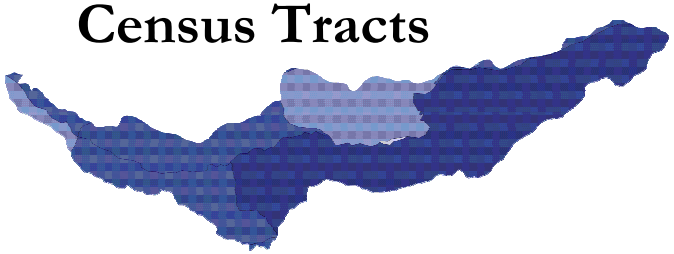
LandCover Change

LCMMP 1993-1998 Landcover change was used to calculate change in vegetative cover within each watershed

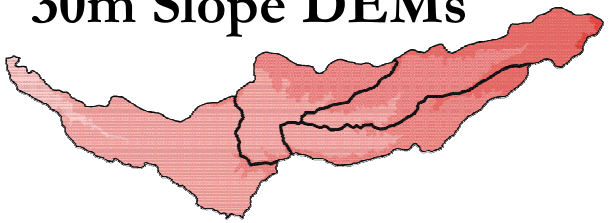
No one dataset had complete coverage,
so we used the most current available for each site

ATtILA Components

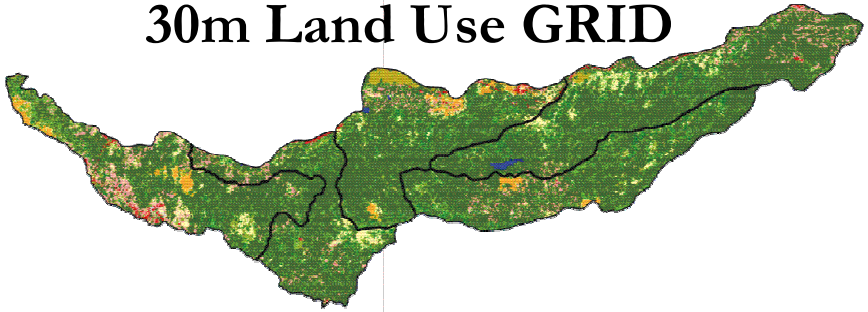
Census Tracts



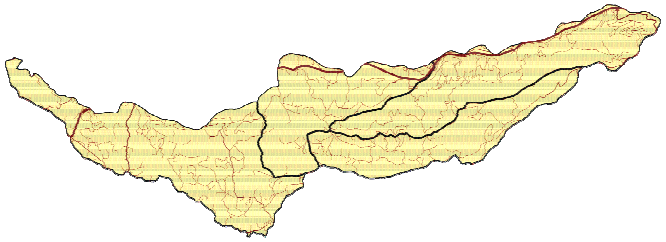
30m Slope DEMs



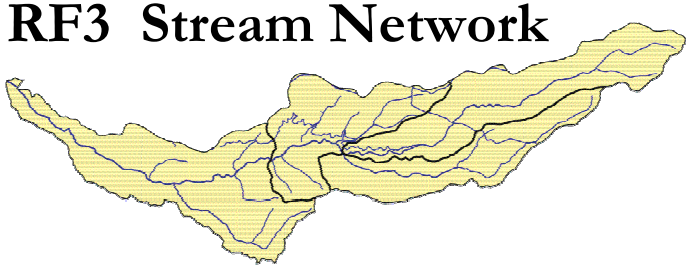
30m Land Use GRID



Road Network

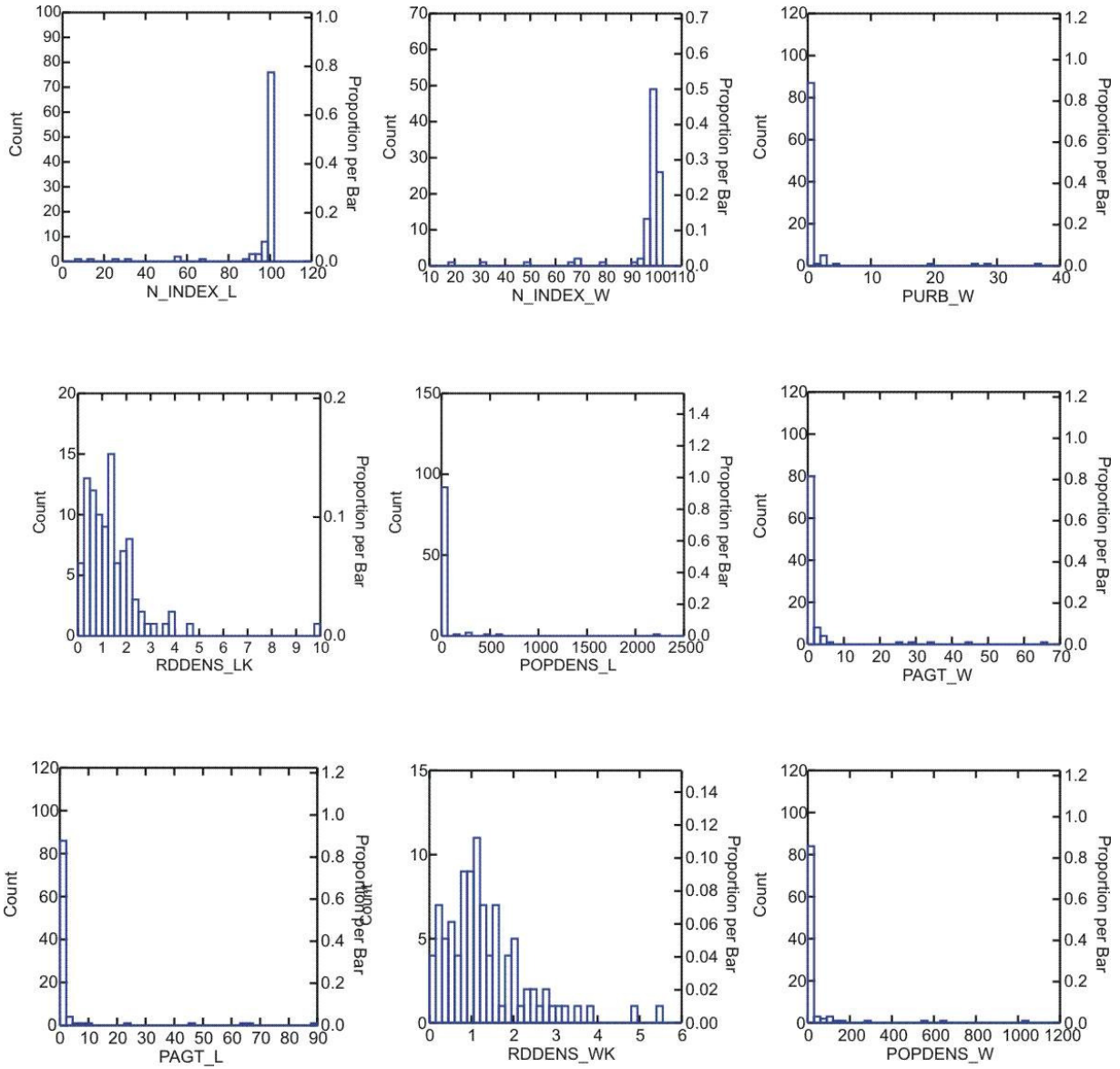


RF3 Stream Network



ATtILA Products:

Frequency Histograms of Watershed Metrics for all 238 sites in IBI



Rejected from Reference Pool if:

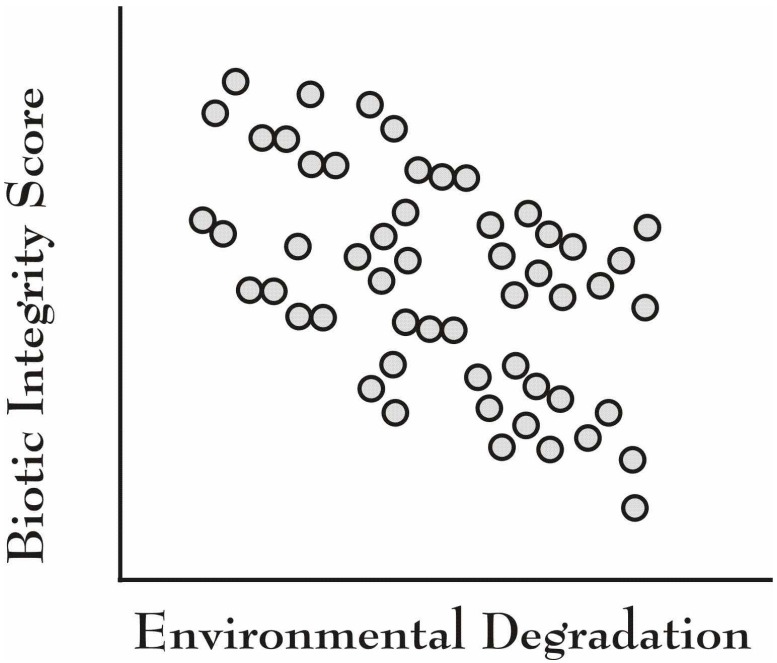
- N_index_L <95%
- Purb_L >0.5%
- Pagt_L >0.7%
- Rddens_L >2.0 km/ km^2
- PopDens_L >15ind./ km^2
- N_index_W <95%
- Purb_W >0.6%
- Pagt_W >2%
- Rddens_W > 2 km/ km^2
- PopDens_W >20 ind./ km^2

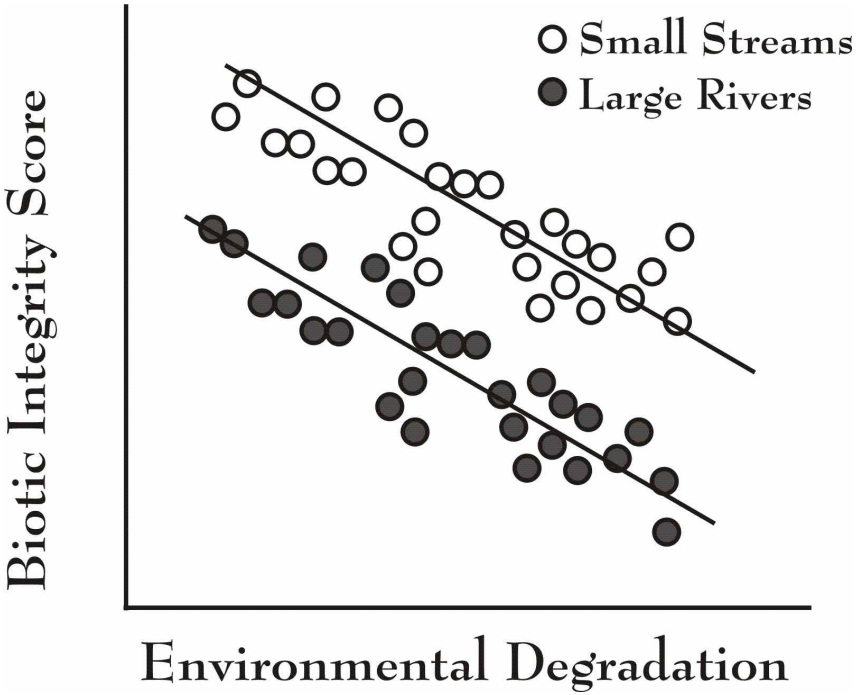
Additional Local Condition Screens:

- Obvious bank stability, erosion problems
- Sedimentation problems
- Evidence of mining, dams, grazing, recent fire, recent timber harvest

Final Breakdown: 73 Reference Sites/ 165 Test Sites

Preliminary Step 1b: Evaluating the Need to Classify

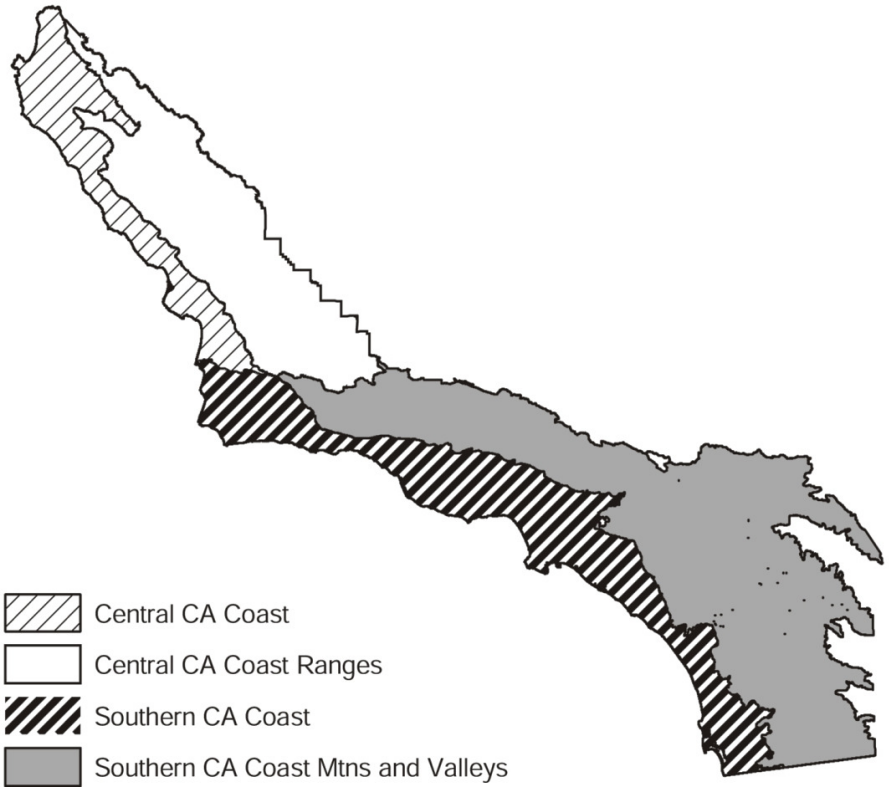




Can we find ways of partitioning this variation so that signals become clearer?

Solution: Develop two IBIs for the region

Evaluating the Need to Classify



Examples of Class Categories:

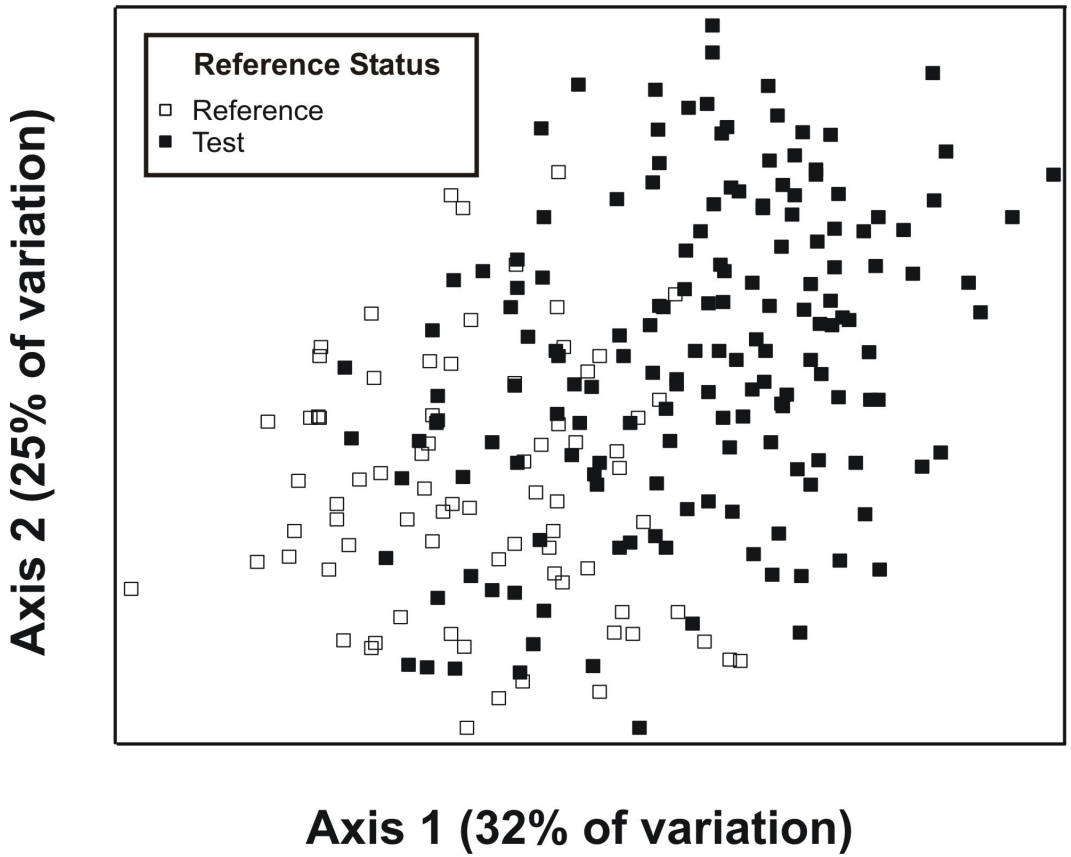
- Ecoregion
- Elevation
- Stream Size (Strahler order, watershed area etc.)
- Season

TradeOff: Too many IBIs are impractical for regional watershed management programs

Goal:

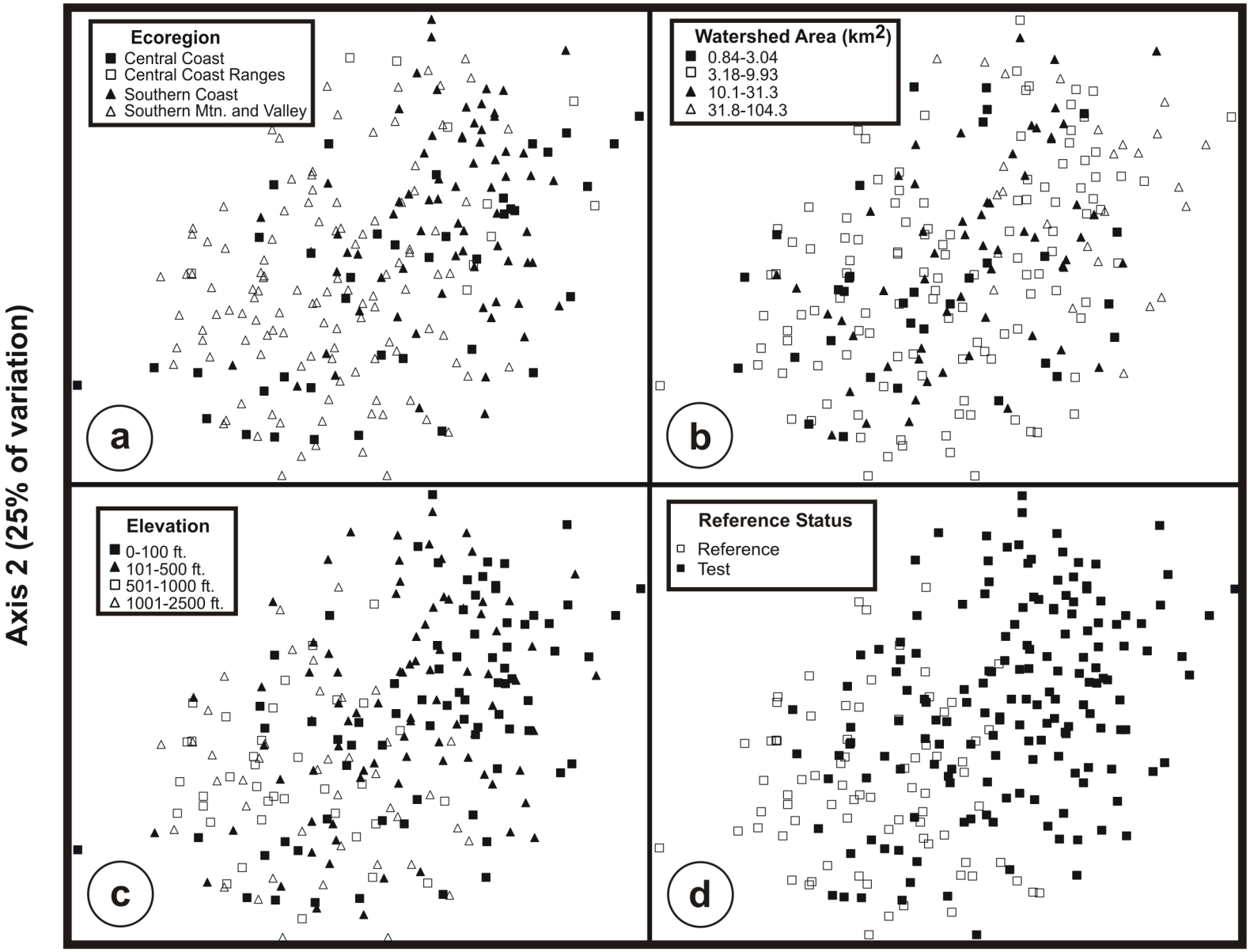
Use the fewest categories necessary to partition natural variation

NMS (Non-metric multidimensional scaling): Is variation at sites explained by stream class?

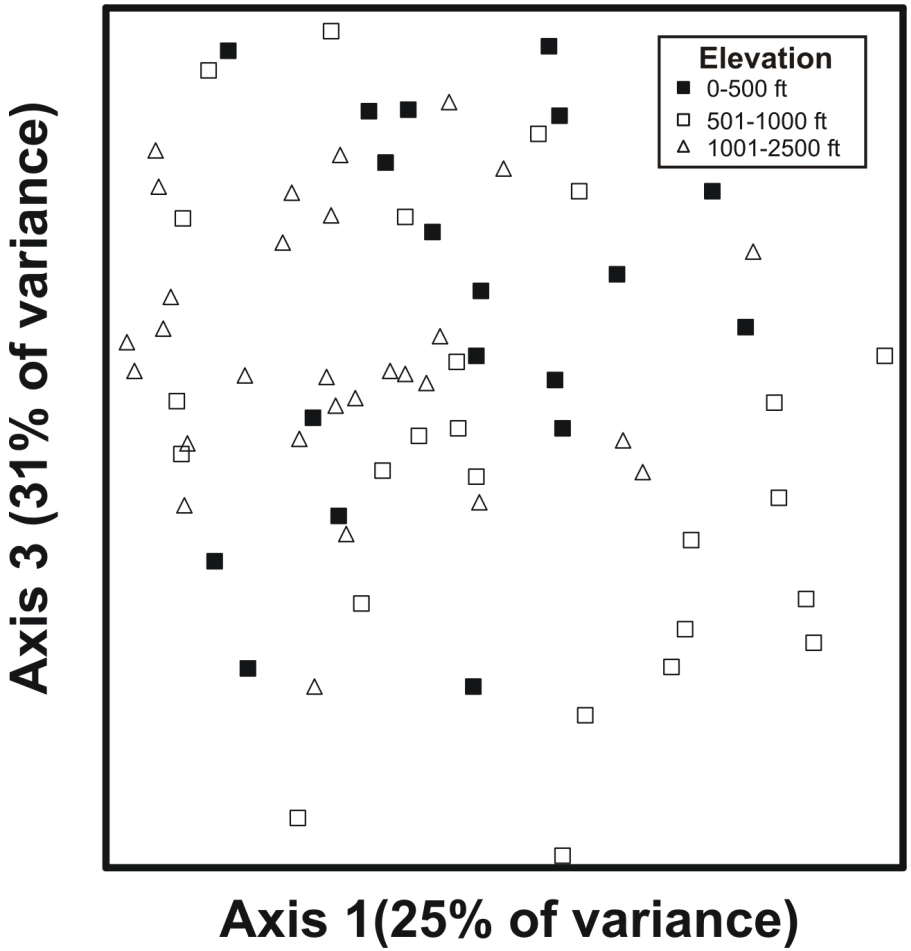


If classes explain a lot of the variation at sites, then we'd expect to see sites form "clouds" based on these classes and then we'd need to develop separate IBIs

We evaluated **elevation**, **ecoregion** and **watershed area** to see if communities clustered according to any of these classes.


Ecoregion
Central Coast
Central Coast Ranges
Southern Coast
Southern Mtn. and Valley
a
Watershed Area (km2)
0.84-3.04
3.18-9.93
10.1-31.3
31.8-104.3
b
Elevation
0-100 ft.
101-500 ft.
501-1000 ft.
1001-2500 ft.
c
Reference Status
Reference
Test
d
Axis 2 (25% of variation)
Axis 1 (32% of variation)

NMS Plot of Elevation at reference sites only



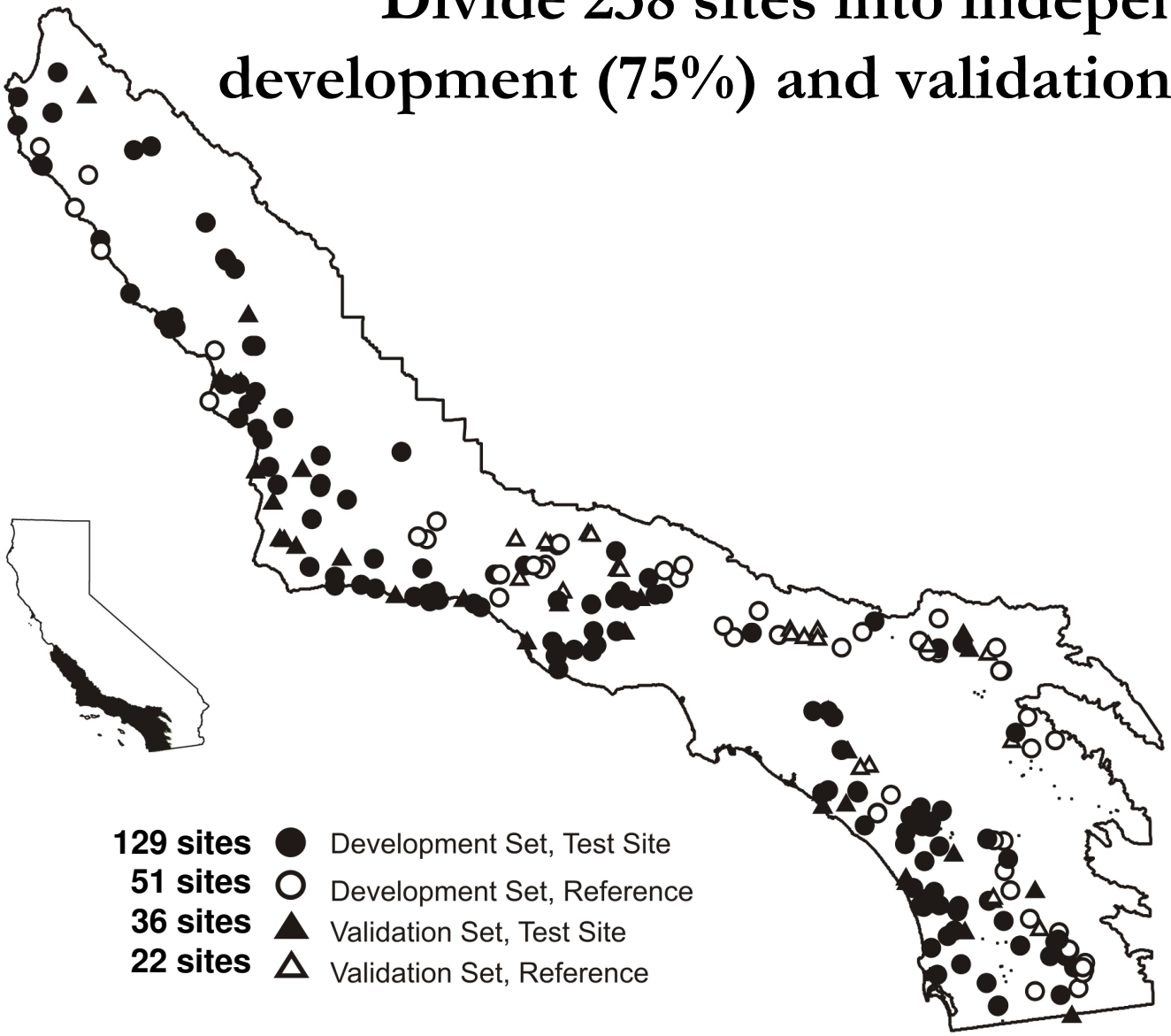
No clustering of reference communities based on elevation

Reveals that apparent clustering was influenced by the abundance of test sites at low elevations

Conclusion:

No need for separate IBIs with respect to ecoregion, watershed area or elevation

Divide 238 sites into independent development (75%) and validation sets (25%)



Creating an Index of Biotic Integrity (IBI)

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Screening Biological Metrics: Step One

Select uncorrelated stressor variables:

Pearson Product-Moment Correlation														
	U_index_W	Pagt_W	Purb_L	RdDens_L	EMBEDDEI	CHANNEL A	BANK ST	VEG PRO	RIPARIA	% FINES	TDS	TOTAL	TOTAL I	TURBID
U_index_W	1													
Pagt_W	0.75	1												
Purb_L	-0.04	-0.03	1											
RdDens_L	0.502	0.156	0.239	1										
EMBEDDEDNESS	-0.218	-0.092	0.091	-0.243	1									
CHANNEL ALT	-0.492	-0.332	-0.172	-0.523	0.312	1								
BANK STABILITY	-0.131	-0.072	0.06	-0.25	0.372	0.394	1							
VEG PROTECTIO	-0.189	-0.078	-0.013	-0.193	0.186	0.48	0.571	1						
RIPARIAN WIDTH	-0.39	-0.286	-0.151	-0.466	0.227	0.814	0.417	0.449	1					
% FINES	0.396	0.279	-0.012	0.297	-0.711	-0.378	-0.386	-0.151	-0.339	1				
TDS	0.589	0.365	0.006	0.391	-0.381	-0.502	-0.459	-0.35	-0.468	0.465	1			
TOTAL P	-0.008	-0.009	0.228	0.187	-0.01	-0.138	-0.129	-0.027	-0.154	0.035	0.038	1		
TOTAL N	0.524	0.483	0.07	0.16	-0.128	-0.361	-0.226	-0.205	-0.271	0.389	0.51	0.133	1	
TURBIDITY	0.052	0.052	-0.008	0.164	-0.237	-0.246	-0.192	-0.048	-0.21	0.187	0.159	0.196	0.208	1

Screening Biological Metrics: Step One

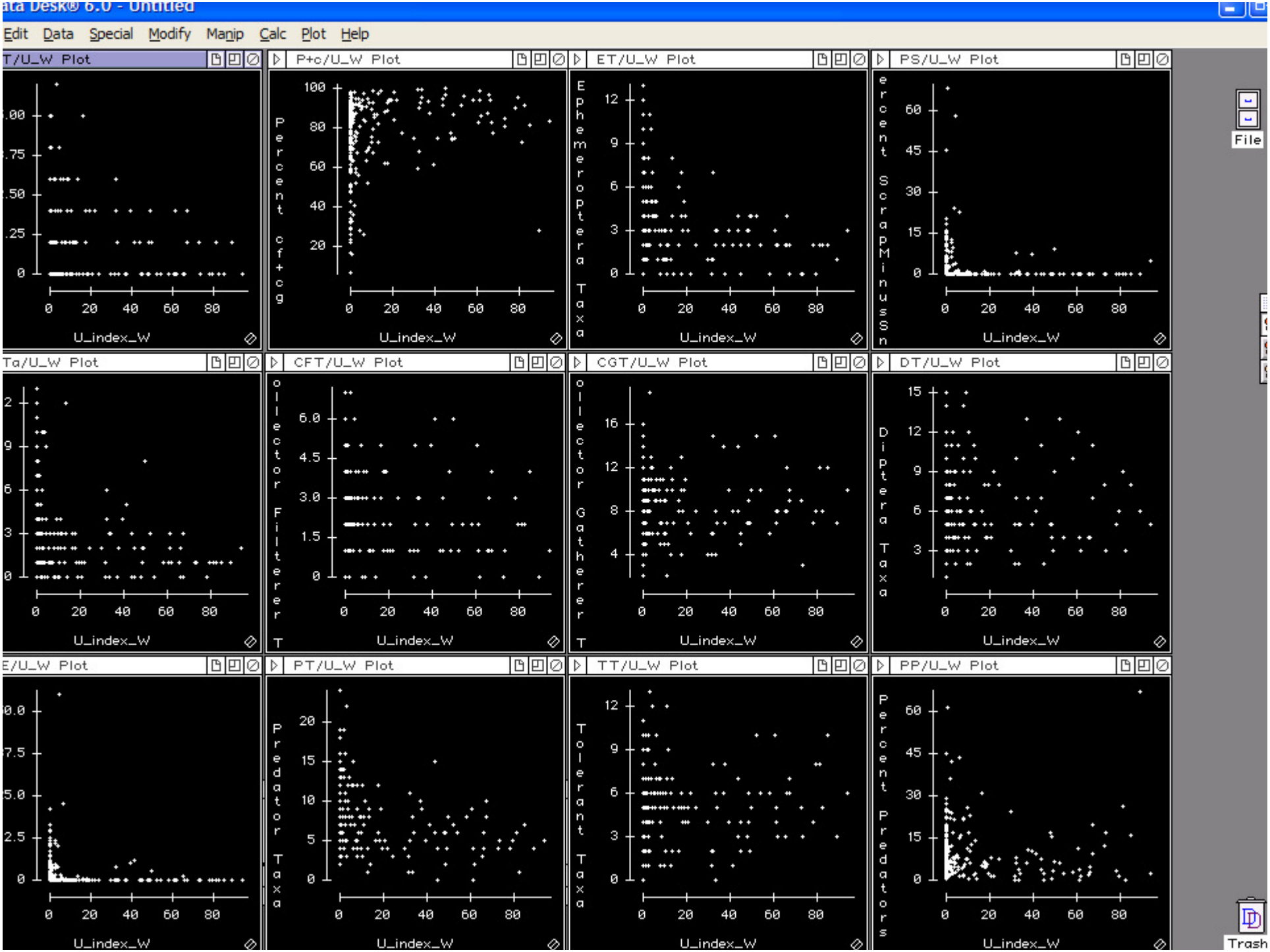
Select uncorrelated stressor variables:

4 land use stressors
Percent watershed unnatural
Percent watershed in agriculture
Road density
Percent urban local scale

6 reach scale stressors
Qualitative channel alteration score
Qualitative bank stability score
Percent fines and sands
Total Dissolved Solids
Total Nitrogen
Total Phosphorous

Screening Biological Metrics: Step Two

Determine which bug metrics are correlated with disturbance.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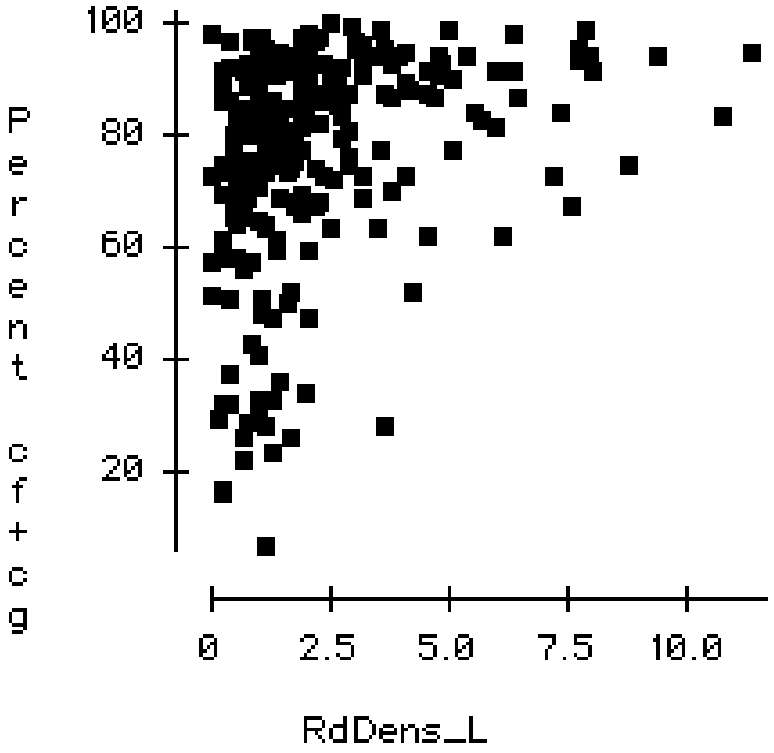
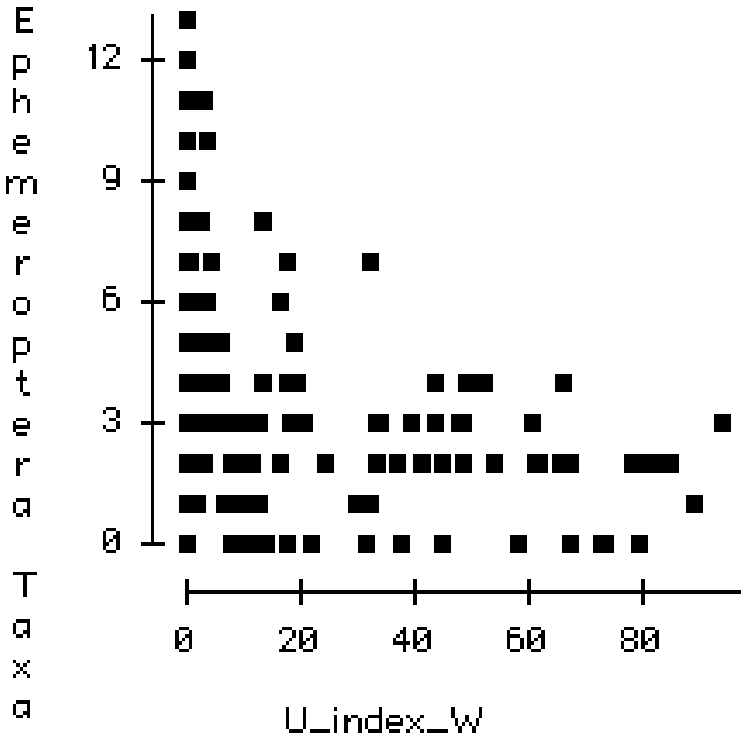
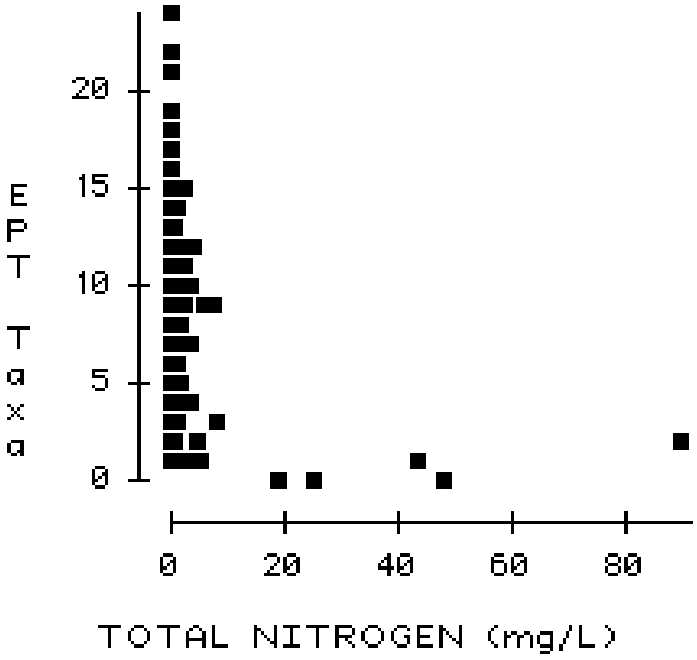
Edit Data Special Modify Manip Calc Plot Help
T/U_W Plot
P+c/U_W Plot
ET/U_W Plot
PS/U_W Plot
Percent c+c+g
Ephemeroptera Taxa
Percent ScrapMinusSn
U_index_W
Ta/U_W Plot
CFT/U_W Plot
CGT/U_W Plot
DT/U_W Plot
Collector Filterer T
Collector Gatherer T
Diptera Taxa
E/U_W Plot
PT/U_W Plot
TT/U_W Plot
PP/U_W Plot
Predator Taxa
Tolerant Taxa
Percent Predators
File
Trash

Responsive metrics

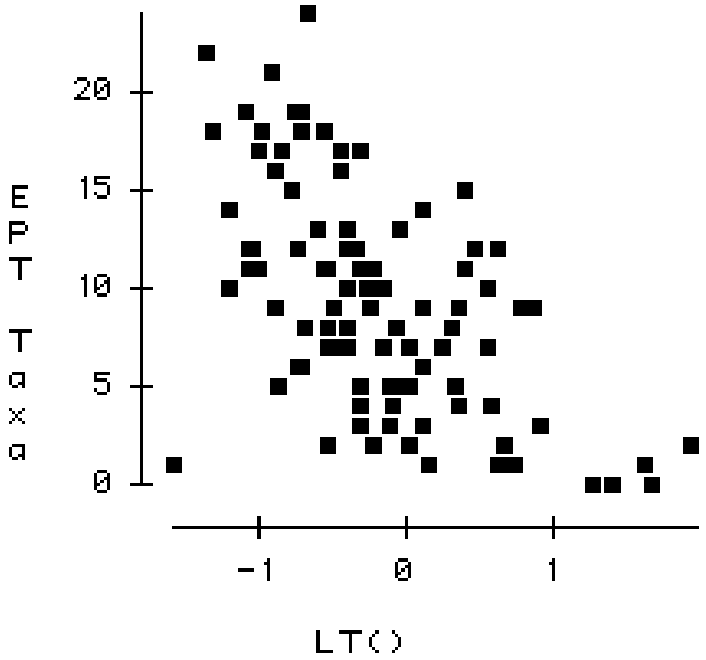




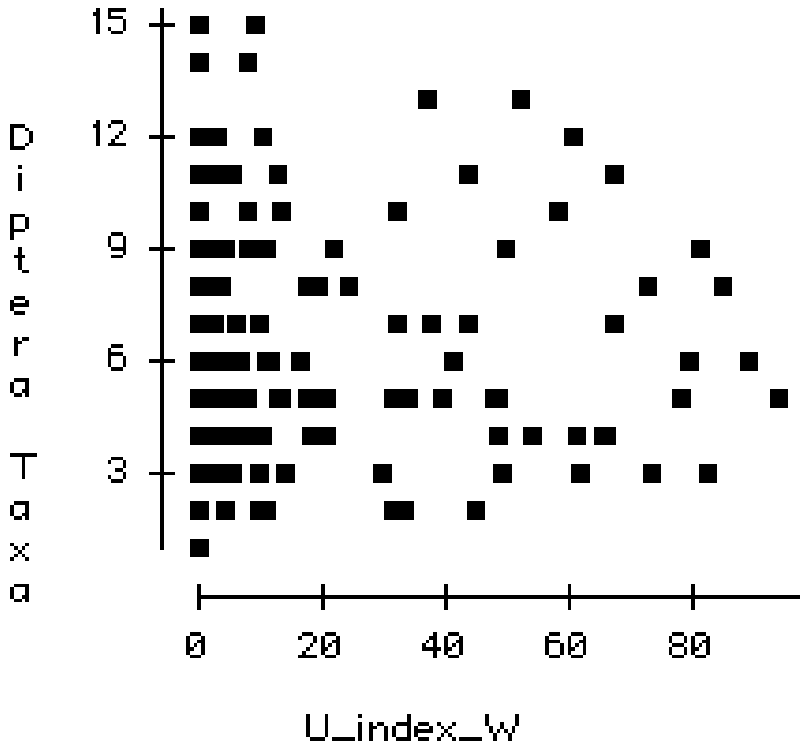
Untransformed

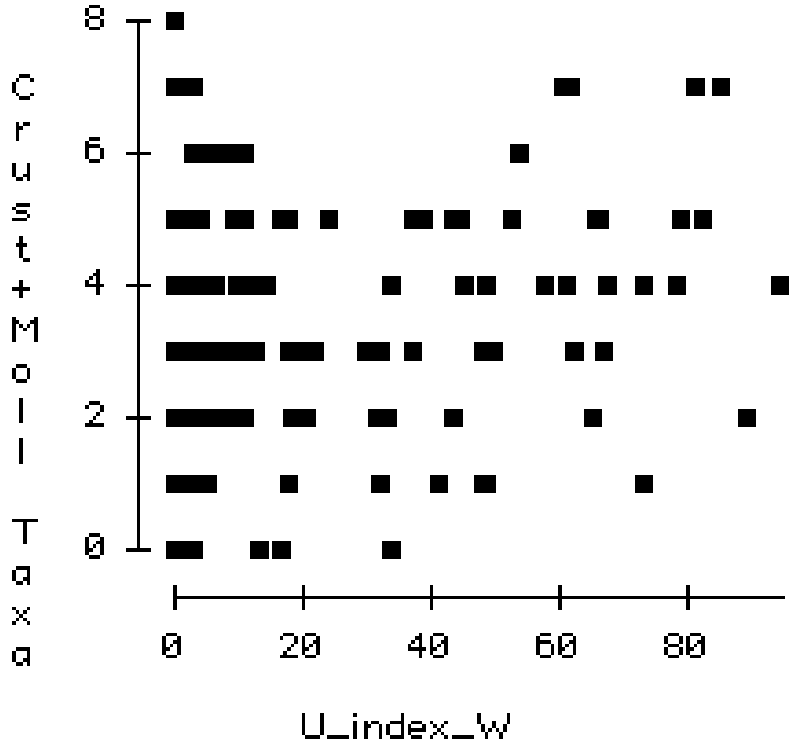


Log Transformed



Not so responsive metrics





Screening Biological Metrics: Step Three

Select responsive biotic metrics that are uncorrelated with each other:

Pearson Product-Moment correlations between biological metrics.

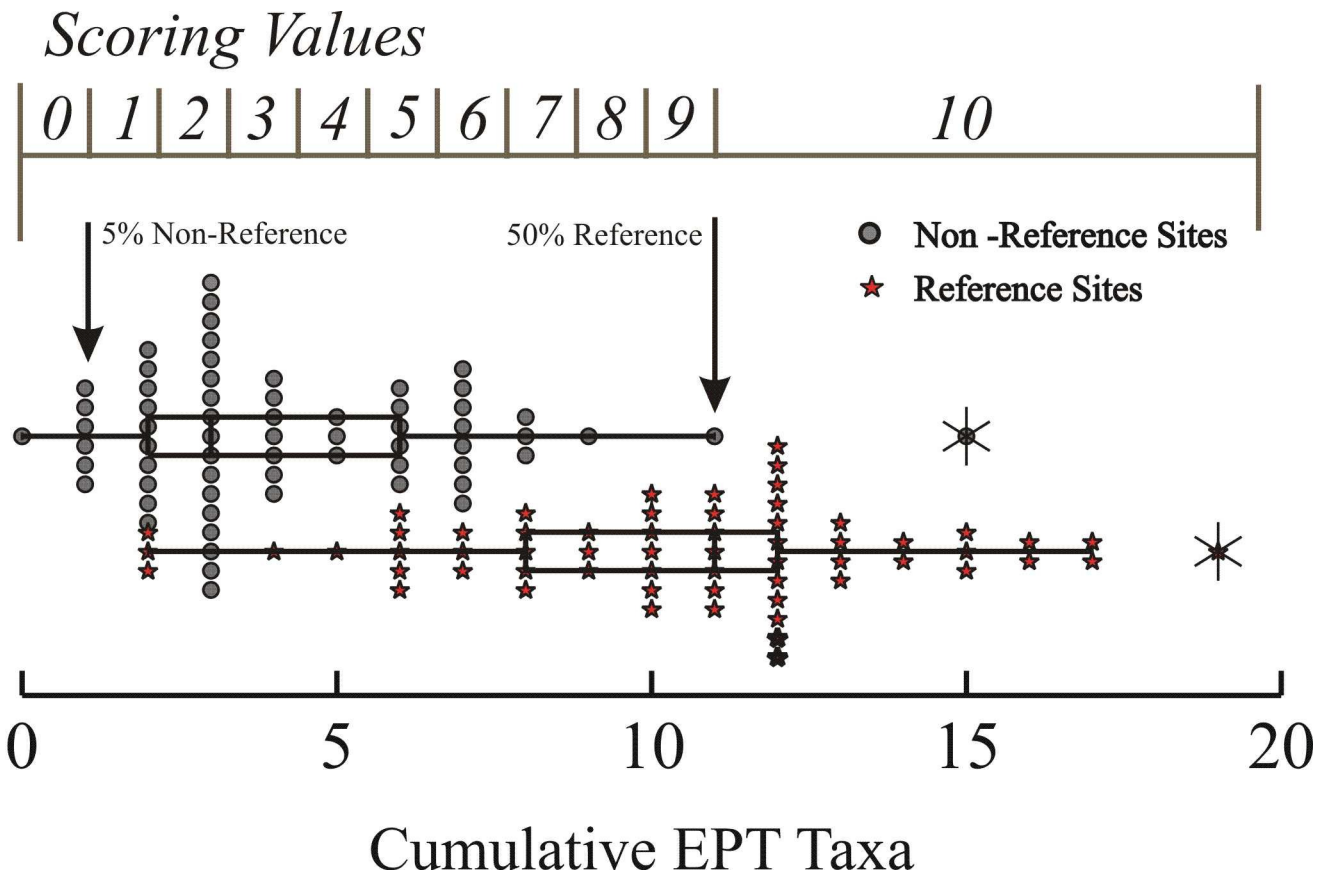
	Sensitive EPT Index (%)	EPT Index (%)	Percent Plecoptera	Percent Trichoptera	Percent Non-Insect Taxa	Percent NonHydroCheumTrichops	Taxonomic Richness	Plecoptera Taxa	Trichoptera Taxa	Ephemeroptera Taxa	EPT Taxa	Tolerance Value
Sensitive EPT Index (%)	1											
EPT Index (%)	0.6	1										
Percent Plecoptera	0.471	0.236	1									
Percent Trichoptera	0.688	0.661	0.077	1								
Percent Non-Insect Taxa	-0.446	-0.439	-0.221	-0.371	1							
Percent NonHydroCheumTrichops	0.816	0.506	0.12	0.819	-0.311	1						
Taxonomic Richness	0.472	0.392	0.248	0.338	-0.47	0.365	1					
Plecoptera Taxa	0.609	0.332	0.538	0.283	-0.489	0.385	0.582	1				
Trichoptera Taxa	0.571	0.545	0.19	0.643	-0.629	0.568	0.695	0.479	1			
Ephemeroptera Taxa	0.519	0.547	0.324	0.251	-0.555	0.27	0.694	0.557	0.512	1		
EPT Taxa	0.678	0.602	0.373	0.528	-0.692	0.521	0.807	0.745	0.879	0.818	1	
Tolerance Value	-0.831	-0.813	-0.372	-0.685	0.518	-0.675	-0.508	-0.541	-0.618	-0.588	-0.713	1
Intolerant Taxa	0.693	0.467	0.451	0.446	-0.642	0.483	0.747	0.875	0.717	0.702	0.9	-0.668
Intolerant EPT Taxa	0.721	0.484	0.47	0.459	-0.626	0.506	0.714	0.889	0.714	0.712	0.906	-0.689
Percent Tolerant Taxa	-0.485	-0.496	-0.254	-0.46	0.807	-0.366	-0.413	-0.514	-0.652	-0.526	-0.7	0.597
Percent Intolerant Indiv (0-2)	0.971	0.57	0.483	0.634	-0.425	0.77	0.466	0.611	0.52	0.526	0.653	-0.821
Percent Collectors	-0.463	-0.323	-0.239	-0.566	0.219	-0.504	-0.227	-0.311	-0.397	-0.139	-0.356	0.433
Percent Filterers	-0.049	0.186	-0.103	0.28	-0.094	0.023	-0.122	-0.103	0.125	-0.048	0.023	-0.084
Percent Scrapers	0.184	0.058	0.07	0.115	-0.083	0.155	0.162	0.225	0.211	0.103	0.216	-0.056
Percent cf+cg	-0.55	-0.204	-0.348	-0.393	0.164	-0.536	-0.349	-0.426	-0.334	-0.192	-0.372	0.407
ScraperTaxa	0.553	0.423	0.16	0.505	-0.407	0.51	0.722	0.511	0.757	0.562	0.772	-0.572
Predator Taxa	0.247	0.135	0.263	0.064	-0.239	0.148	0.776	0.469	0.288	0.438	0.453	-0.256

Screening Biological Metrics: Step Three

Select responsive biotic metrics that are uncorrelated with each other:

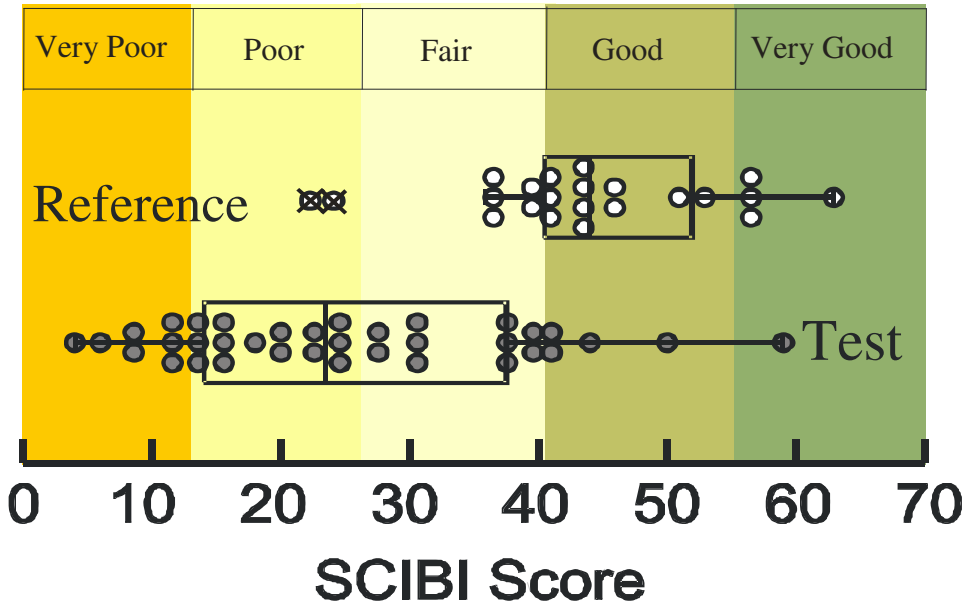
1. Percent collector filterer + collector gatherer individuals
2. Percent non-insect taxa
3. Percent tolerant taxa
4. Percent intolerant individuals
5. EPT richness
6. Coleoptera richness
7. Predator richness

Step Four: Score Final Metrics

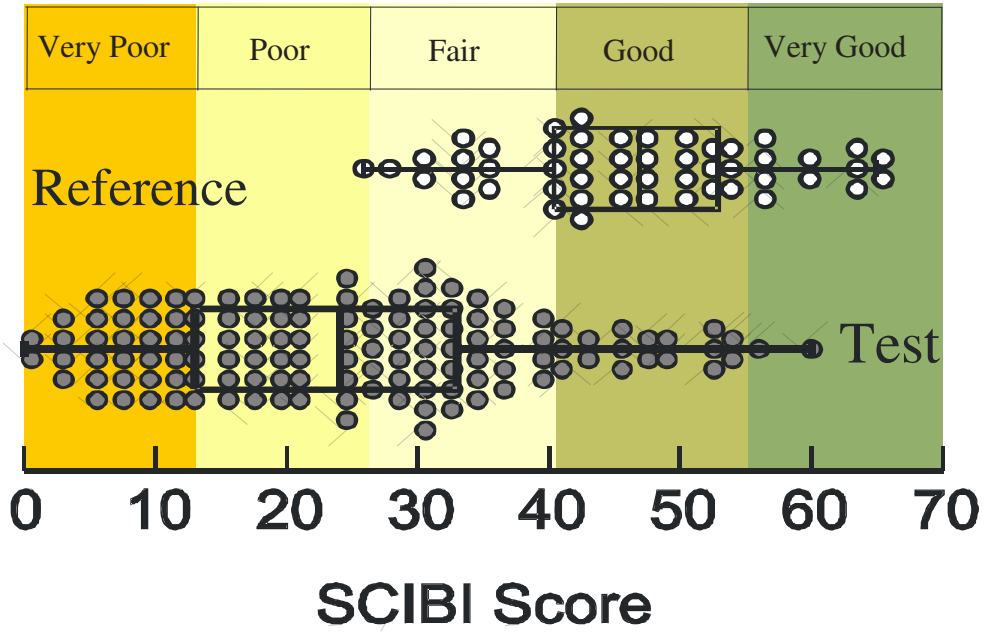


Metric Score	% CF+CG	% Non-Insect Taxa	% Tolerant Taxa	Coleoptera Taxa	Predator Taxa	% Intolerant Individuals	EPT Taxa
10	**0-51**	**0-8**	**0-5**	**>5**	**>12**	**32-100**	**>16**
9	**52-55**	**9-13**	**6-8**		**12**	**29-31**	**15-16**
8	**56-60**	**14-18**	**9-11**	**5**	**11**	**26-28**	**14**
7	**61-66**	**19-23**	**12-15**	**4**	**10**	**22-25**	**12-13**
6	**67-71**	**24-28**	**16-18**		**9**	**19-21**	**10-11**
5	**72-76**	**29-33**	**19-21**	**3**	**8**	**15-18**	**9**
4	**77-81**	**34-38**	**22-25**	**2**	**7**	**12-14**	**7-8**
3	**82-86**	**39-43**	**26-28**		**6**	**8-11**	**5-6**
2	**87-91**	**44-48**	**29-32**	**1**	**5**	**5-7**	**4**
1	**92-95**	**49-53**	**33-36**		**4**	**1-4**	**2-3**
0	**96-100**	**54-100**	**37-100**	**0**	**0-3**	**0**	**0-1**

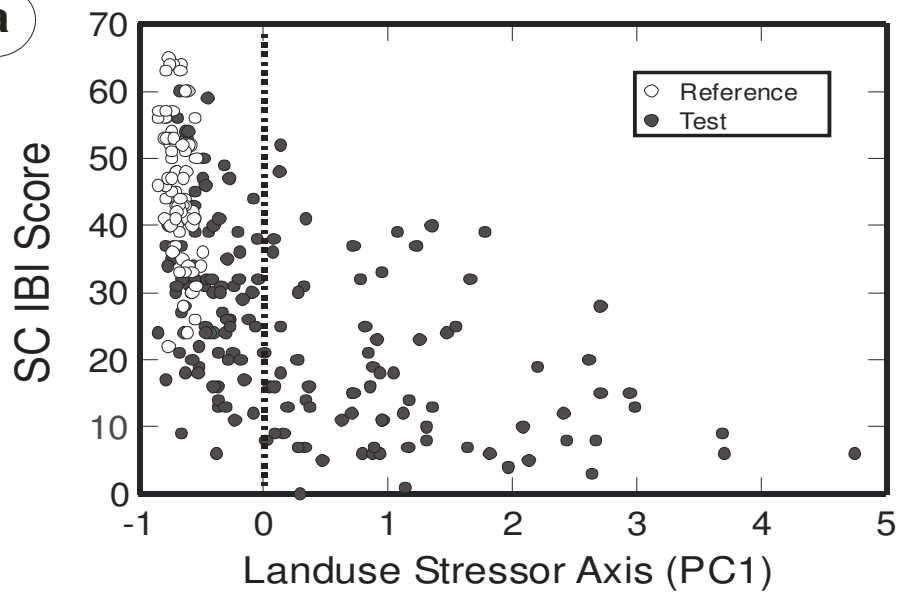
Validation Set



Development Set



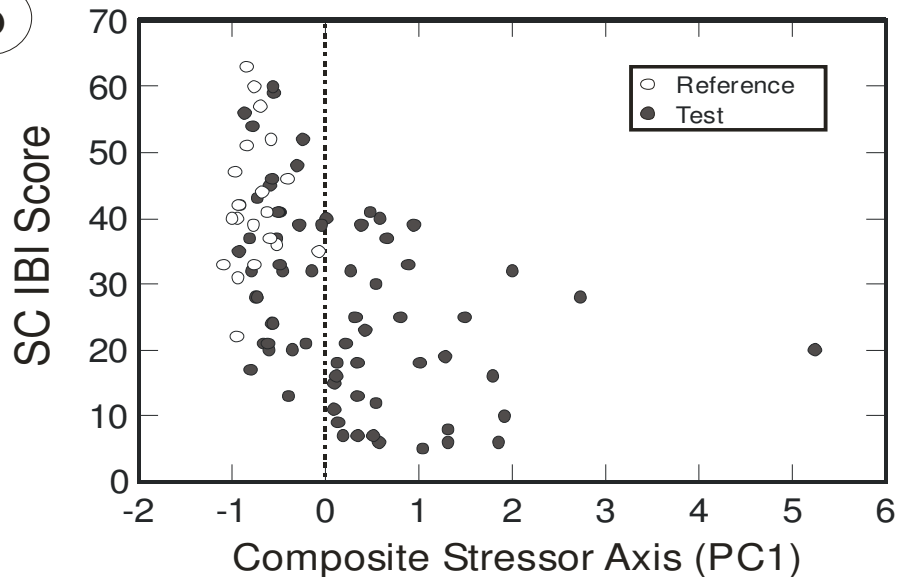
a



LOADINGS ON PCA1	
UINDEX_W	**0.870**
%AGT_W	**0.622**
%URB_L	0.548
RDNS_L	**0.804**

52% of Variance Explained

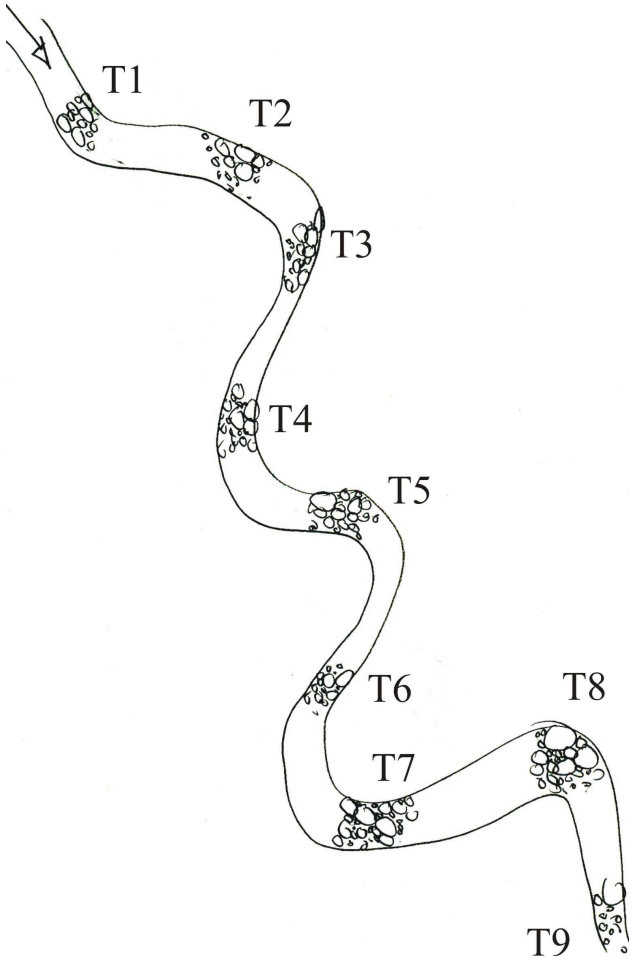
b



LOADINGS ON PCA1	
UINDEX_W	**0.836**
%AG_W	**0.607**
%URB_L	0.127
RDNS_L	**0.622**
CH ALT	**-0.740**
BK STAB	-0.561
%F&S	**0.602**
TDS	**0.901**
TOT P	0.137
TOT N	**0.659**

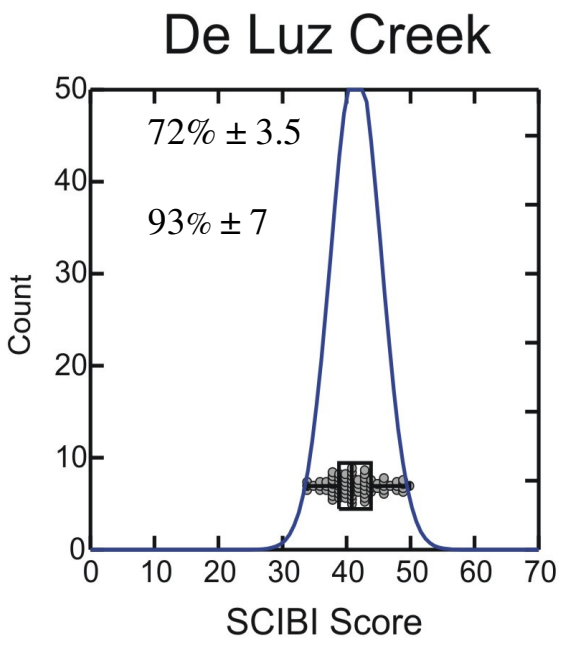
40% of Variance Explained

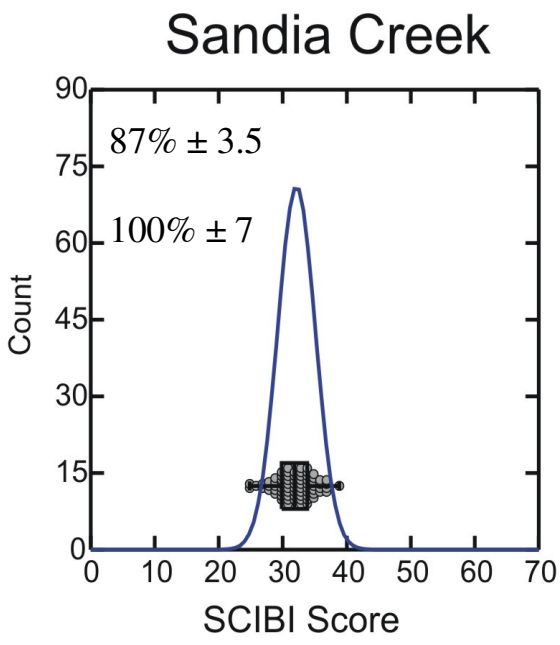
San Diego Sampling Repeatability Study

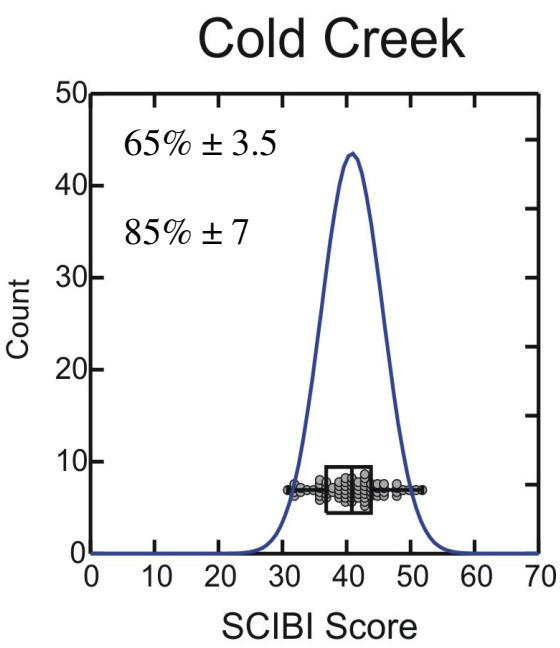


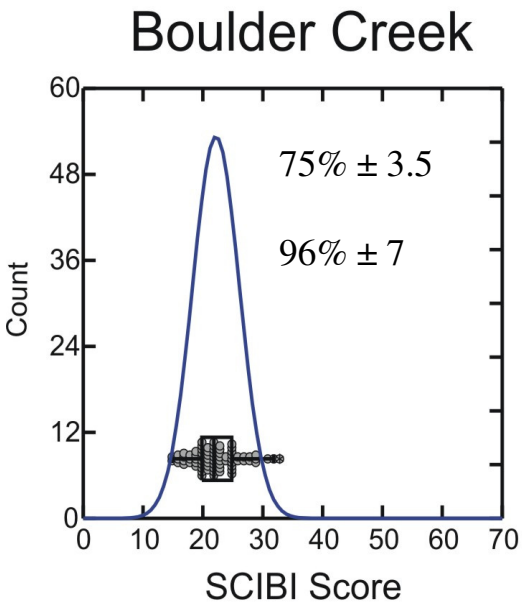
Methodology:

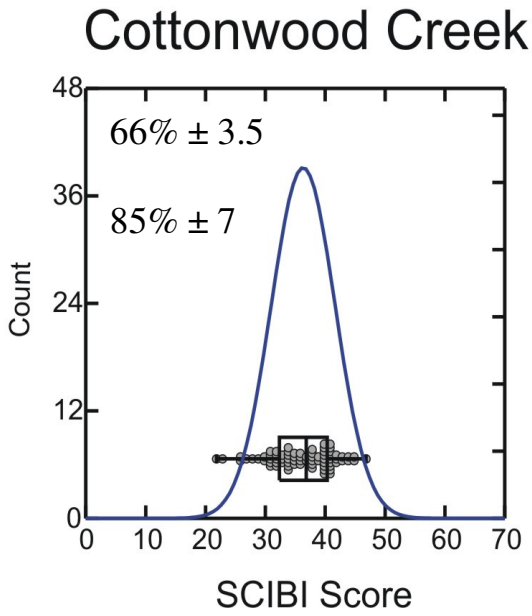
- Sampling sites were reference sites from San Diego IBI
- 9 riffles identified at each site, and one transect sampled from each riffle
- Each sample processed separately at ABL
- 75 replicates of 3 samples each were repeatedly subsampled and composited to calculate SoCal IBI metrics
- IBI scores were calculated for all iterations and plotted to infer distribution of IBI scores possible at each site (i.e. estimate of natural variation in IBI scores at a point in time)

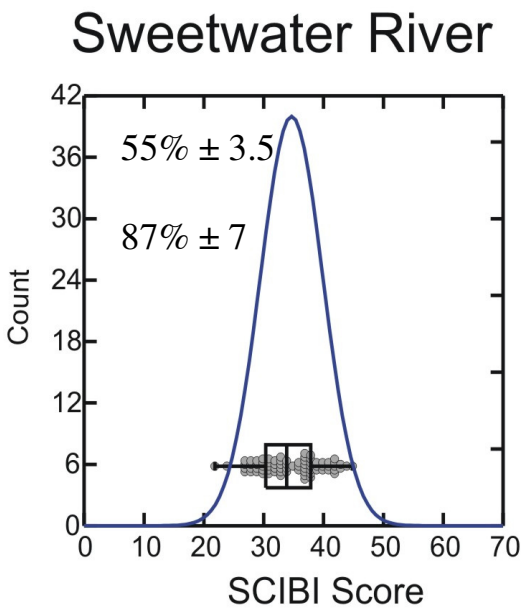

De Luz Creek
72% ± 3.5
93% ± 7
Count
SCIBI Score


Sandia Creek
87% ± 3.5
100% ± 7
Count
SCIBI Score


Cold Creek
65% ± 3.5
85% ± 7
Count
SCIBI Score

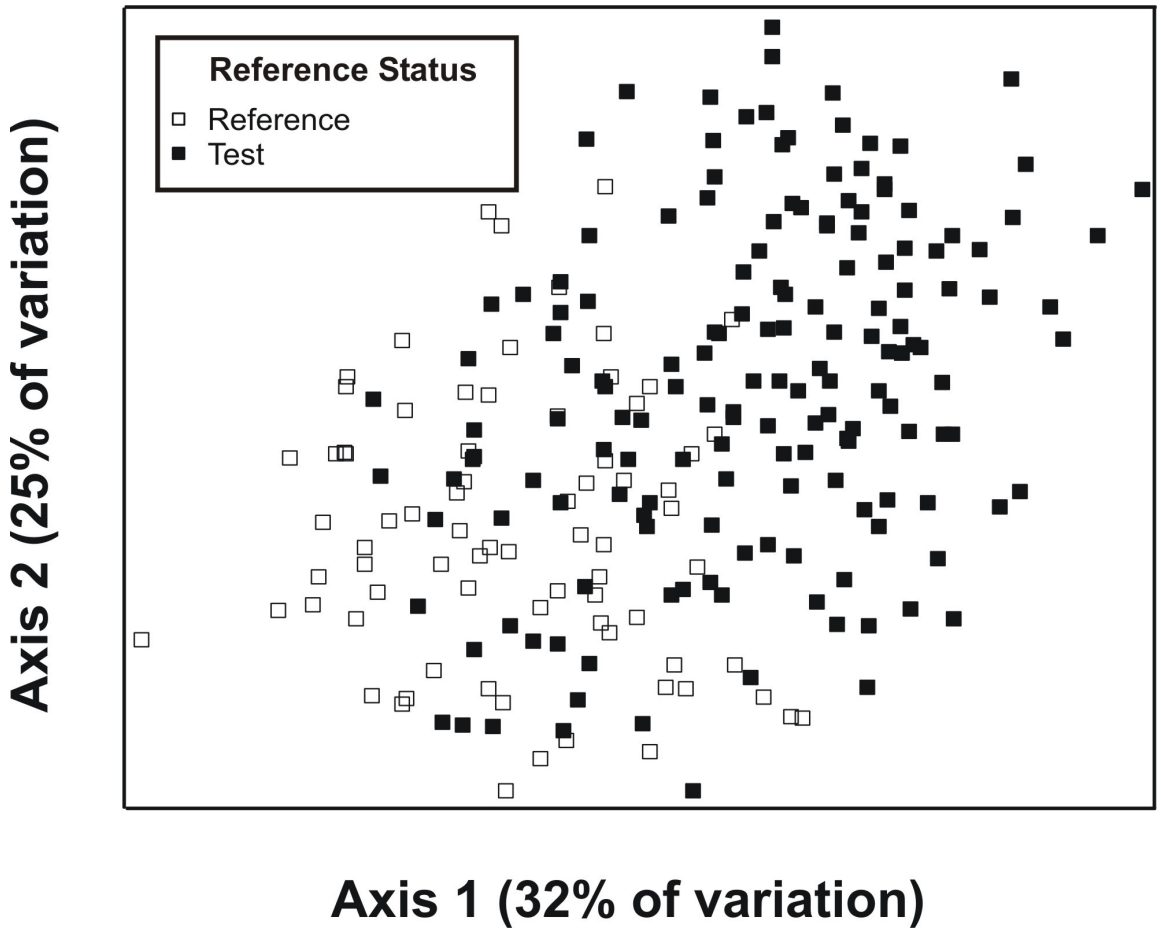

Boulder Creek
75% ± 3.5
96% ± 7
Count
SCIBI Score


Cottonwood Creek
66% ± 3.5
85% ± 7
Count
SCIBI Score


Sweetwater River
55% ± 3.5
87% ± 7
Count
SCIBI Score

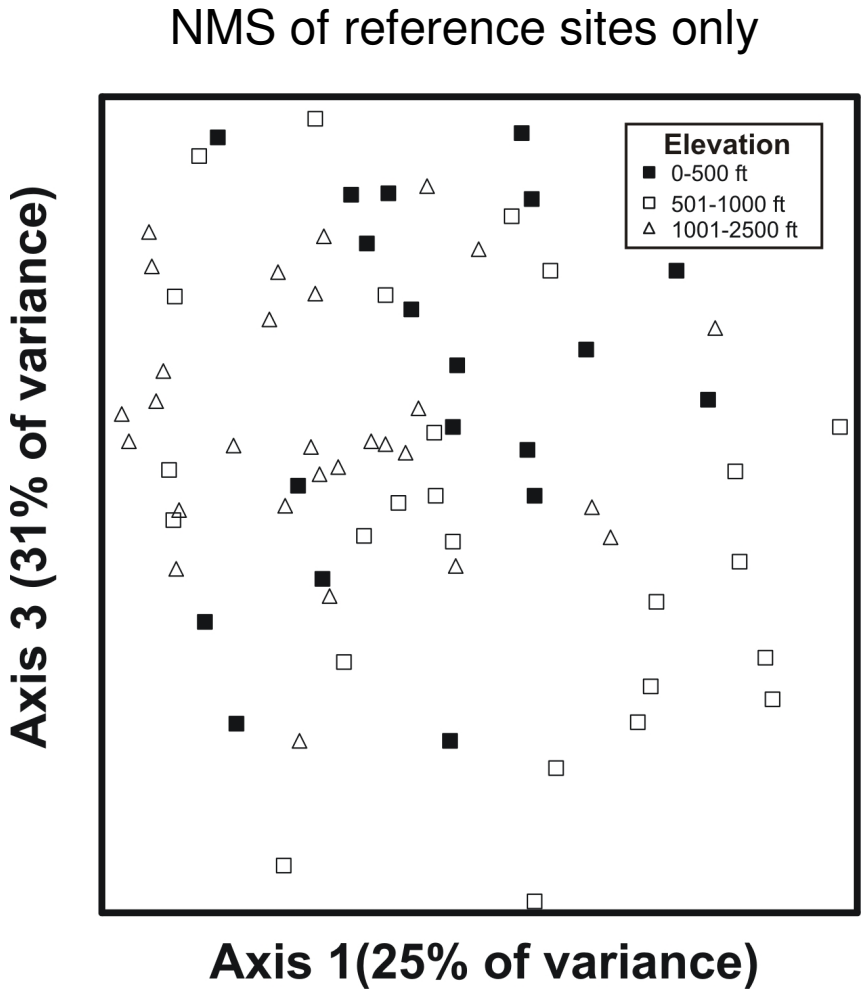
Putting It All Together

Ordination revealed a strong disturbance gradient



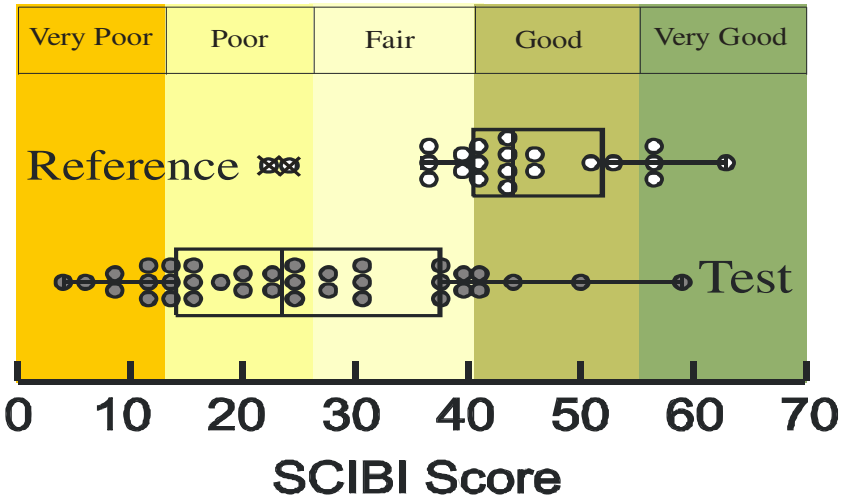
Putting It All Together

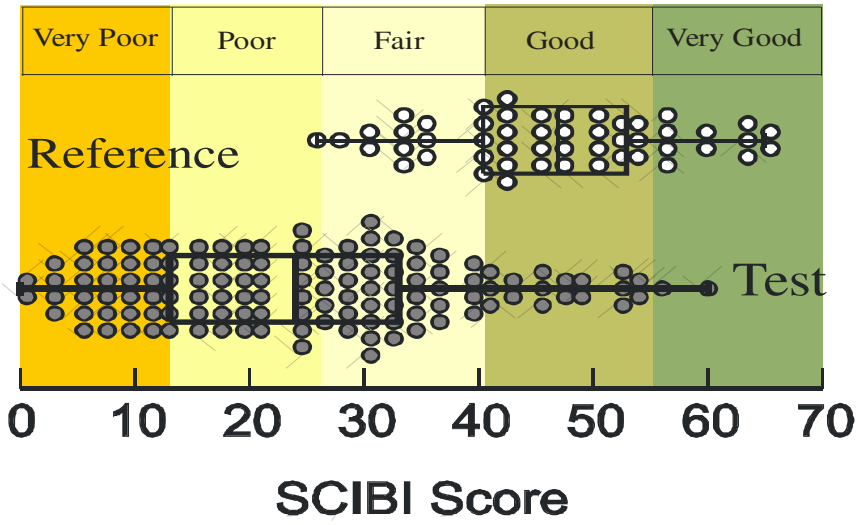
Disturbance gradient is independent of elevation



Putting It All Together

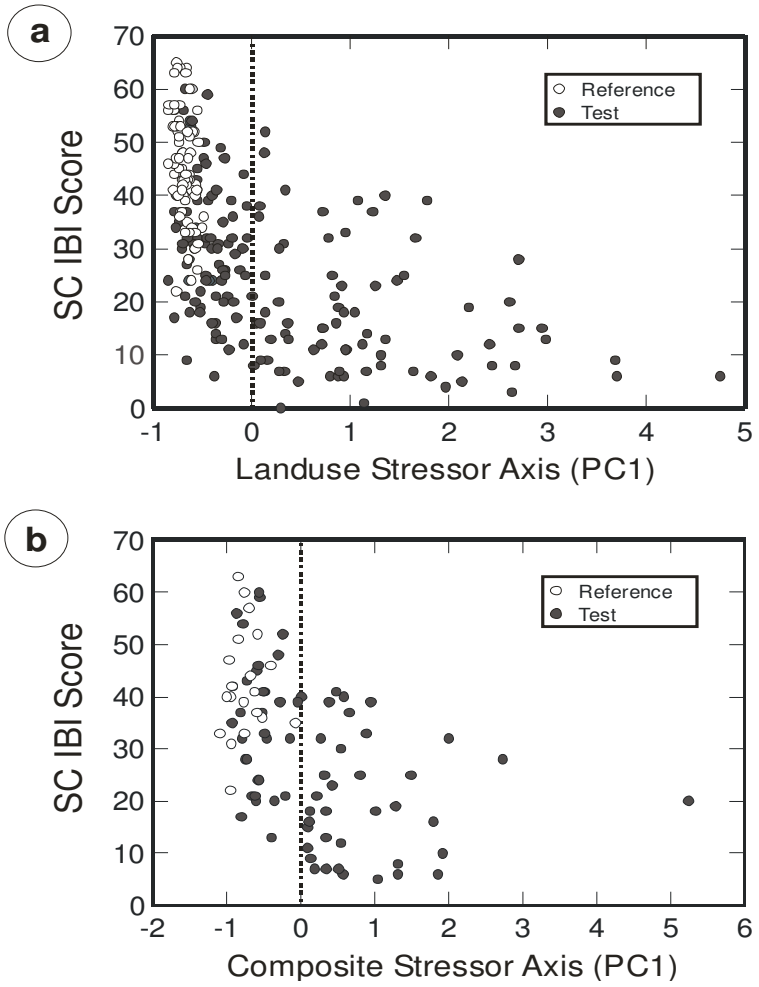
IBI quantifies impairment on a linear scale





Putting It All Together

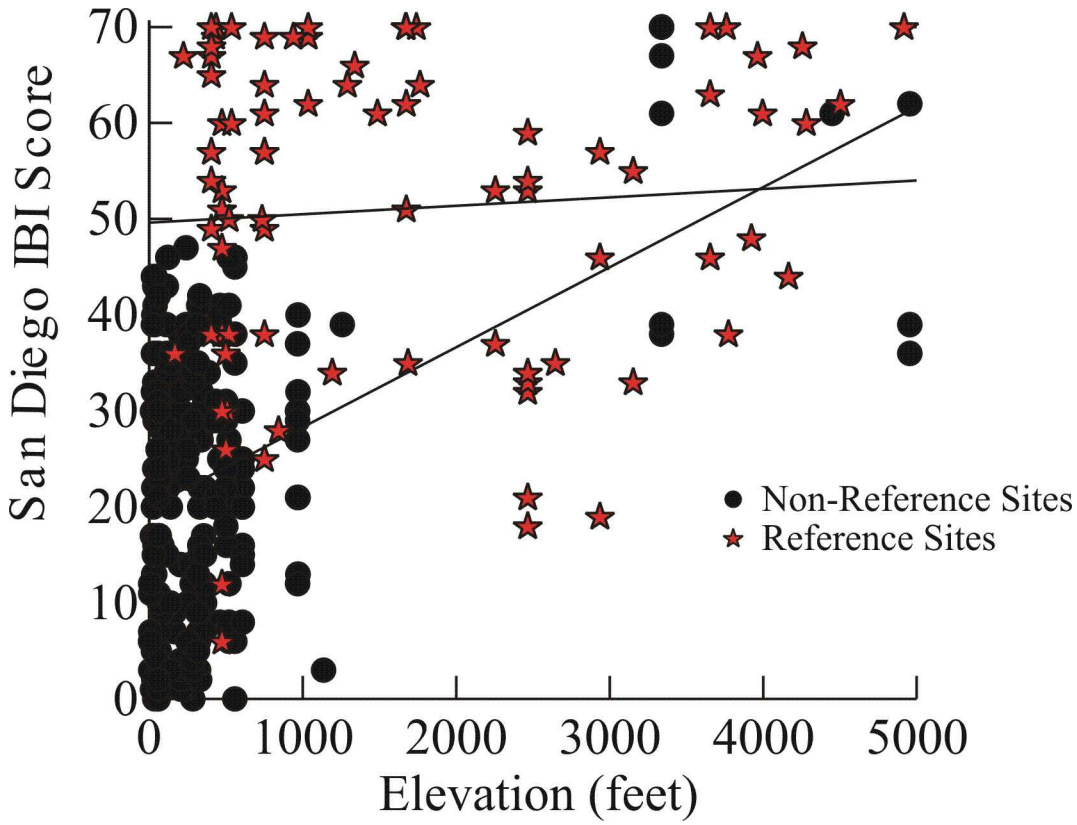
IBI responds well to stressors of interest in region



the

end

San Diego Dataset: Classifying based on elevation

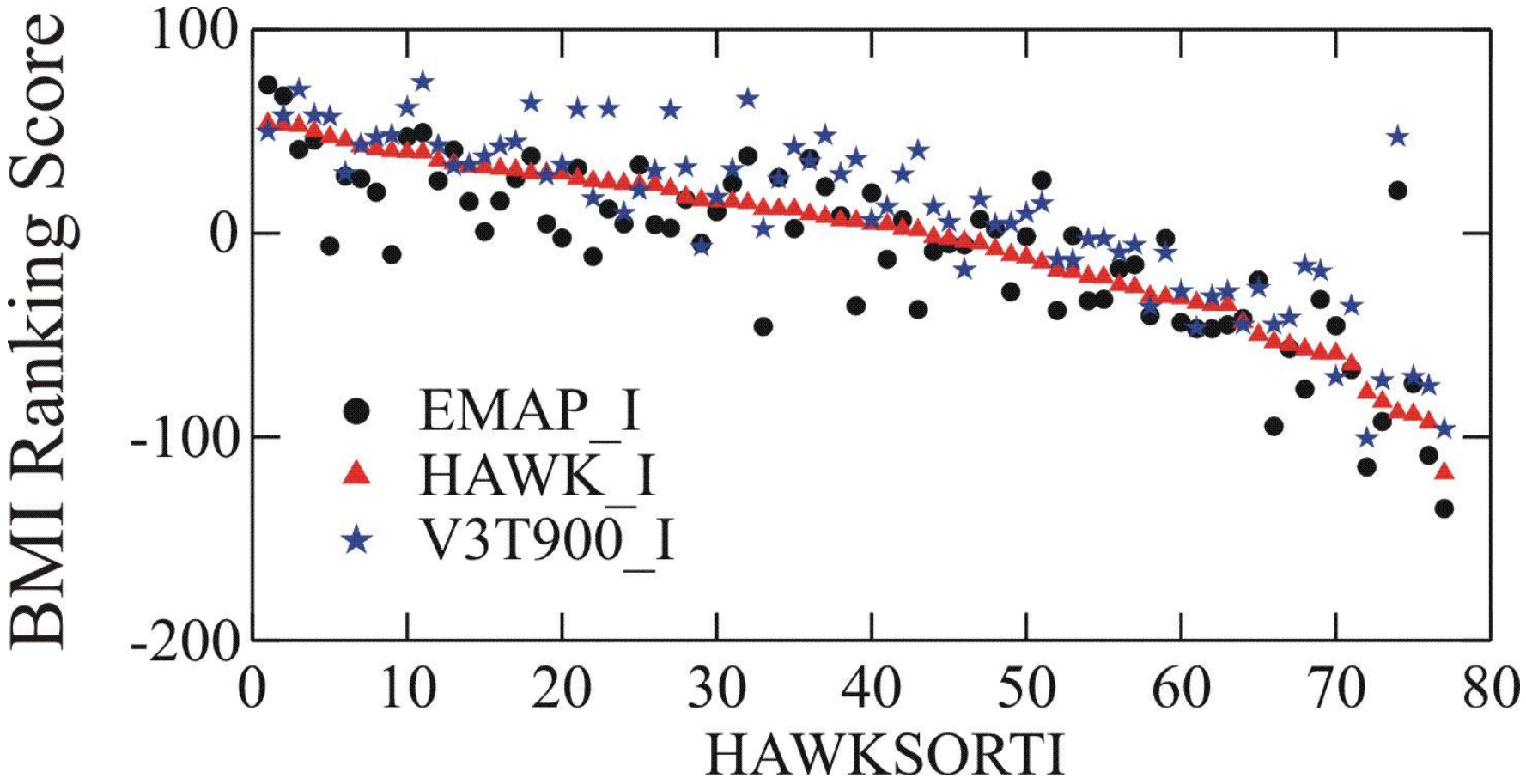


Future Directions + Discussion Topics

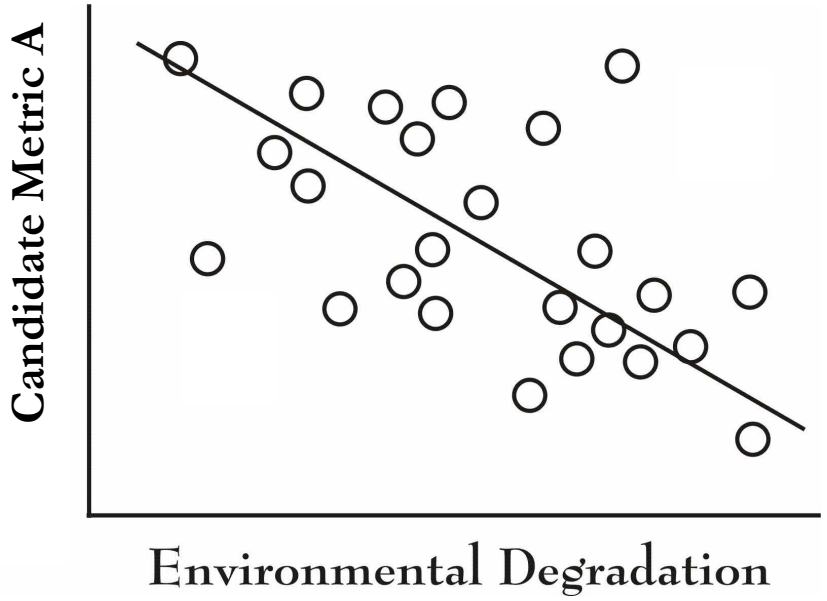
- Potential for combining O/E and multimetric approaches
- Potential use in 305(b) reporting
- Future needs of bioassessment
  - Tolerance values
  - IBIs for difficult regions (e.g. Central Valley, intermittent streams)
  - Integrating multiple communities (e.g. fish and algae)

Future Directions

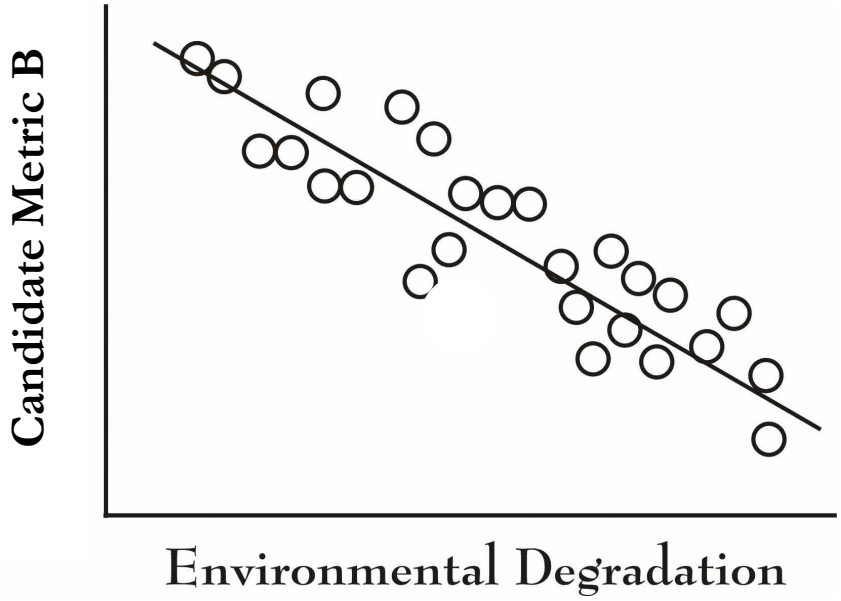
- We are currently evaluating the potential for expanding the scope of this IBI to the Southern California Coastal Region
- We plan to integrate data from USFS, EMAP and Regional Boards (Regions 3,4,7,8,9) ….currently have data from ~250-300 sites
- Most of the effort needed is in metrics development (which metrics respond to which gradients) and classification of stream types


BMI Ranking Score
100
0
-100
-200
0
10
20
30
40
50
60
70
80
HAWKSORTI
EMAP_I
HAWK_I
V3T900_I

Biological communities are inherently variable; IBI Goal is to find metrics that are sensitive to human disturbance, but insensitive to natural variation



More sensitive to natural variation



Less sensitive to natural variation