Benthic macroinvertebrate communities of the lower Sacramento River watershed: Measuring relative community health without reference sites

Daniel A. Markiewicz[1], Kevin M. Goding[1], Robert Holmes[2], Tom Kimball[3], and Victor de Vlaming[1]

1) University of California, Davis; 2) Central Valley Regional Water Quality Control Board, Sacramento; 3) Moss Landing Marine Laboratories

Objectives

Characterize the range of benthic macroinvertebrate (BMI) communities in wadeable streams in the southeastern Sacramento River watershed

Evaluate associations of environmental factors with BMI community composition.

Extended original focus:
     Examine relative health of BMI communities

Background

In studies of California's Central Valley, environmental variables associated with differences in BMI communities included (Brown and May 2000, Griffith et al. 2003):

Substrate

Stream gradient

Conductivity

Channel morphology

Study Sites and Sampling Events

- 4 sampling events:
  Fall 2000, Spring 2001, Fall 2001, Spring 2002

- Sites included low gradient valley floor (LG) sites and higher gradient sierra foothill (HG) sites.

- California Stream Bioassessment Protocol (CSBP) sampling 3 data points (transects) per sampling event at each site

- Habitat and land use data collected concurrently with BMI samples

- Water quality data collected monthly

Analysis Methods

- Calculated 28 BMI community metrics for each transect
- Examined community composition, BMI metrics, and environmental parameters using multivariate techniques.

  Pairwise Correlation
  Nonmetric Multidimensional Scaling (NMS) Ordination
  Cluster Analysis

- Modified IBI construction methods to develop measures of relative BMI community health (Biotic Indices -- BIs)

Sites sampled:

| Water Body	Code	Type
•Auburn Ravine	AR	HG Native/Urban
•Butte Creek	BC	HG Native/Agriculture
•Dry Creek	DC	HG Urban
•Coon Creek SMD1 WWTF	WW	HG bracketing WWTF
•Pleasant Grove	PG	LG Agriculture/Urban
•Jack Slough	JS	LG Agriculture
•Wadsworth Canal	WC	LG Agriculture
•Main Drainage Canal	MD	LG Agriculture
•Gilsizer Slough	GS	LG Agriculture
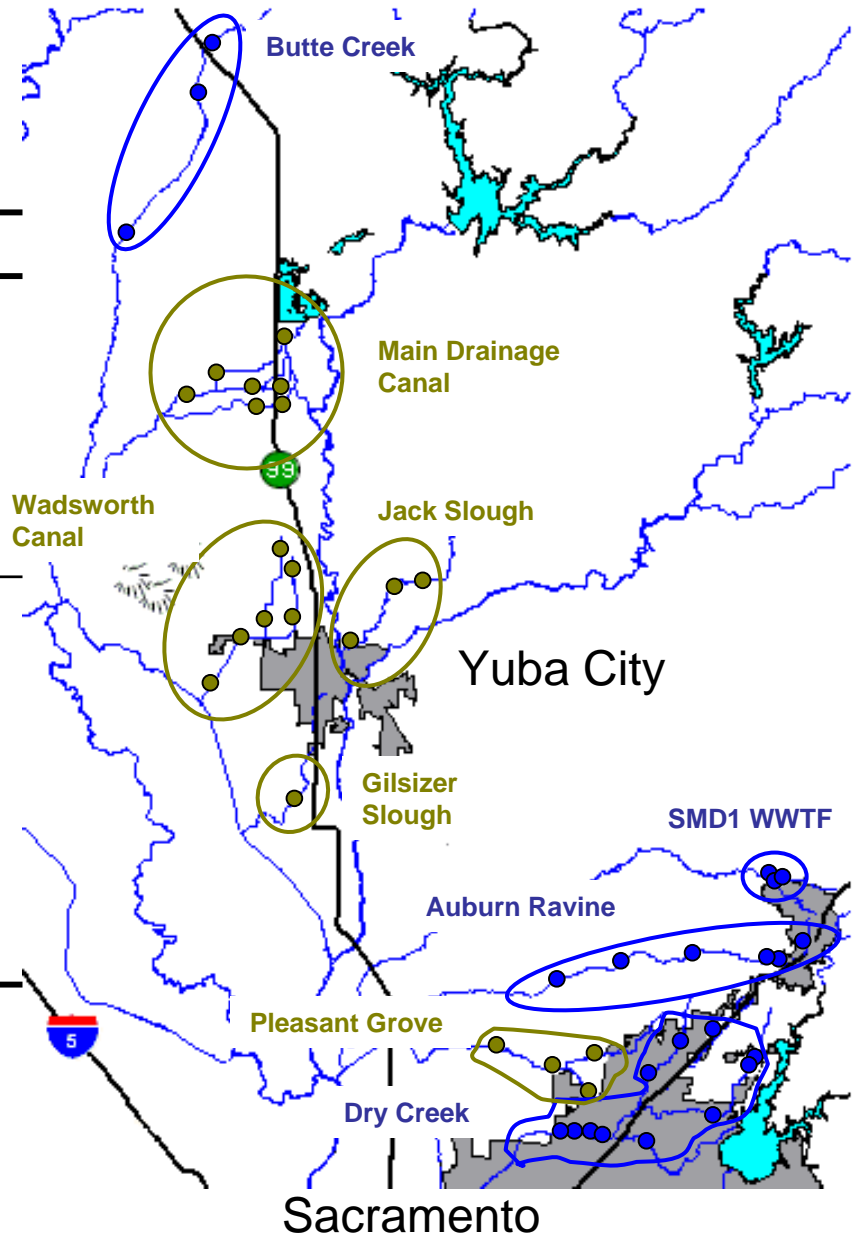
Ranges of Environmental Variables

	Low Gradient		High Gradient	
	Range	Mean	Range	Mean
Temperature (^{o}C)	4.6 – 29.0	15.8	4.8 – 29.2	15.6
SpC (µS/cm)	48 – 991	295	47 – 465	165
DO (mg/L)	0.7 – 19.0	7.8	5.3 – 14.0	9.5
pH (pH units)	5.1 – 9.9	7.6	5.8 – 9.1	7.6
Hardness (mg/L of $CaCO_3$)	16 – 480	135	12 – 408	68
Alkalinity (mg/L of $CaCO_3$)	20 – 332	126	20 – 175	63
Ammonia (mg/L)	0.0 – 30.0	0.6	0.0 – 0.5	0.02
Turbidity (NTU)	0 – 97	15	0 – 32	5
Reactive Phosphorus (mg/L)	0.27 – 5.0	0.86	0.18 – 5.0	0.69
Nitrate Nitrogen (mg/L)	0 – 4.1	0.74	0 – 6.5	0.83
% Fine Substrates	0 – 100	84	1 – 78	31
Habitat Score	29 – 153	85	107 – 185	142

Ranges of BMI Metrics

	Low Gradient		High Gradient	
	Range	Mean	Range	Mean
Taxonomic Richness	7 – 20	14	9 – 31	19
EPT Taxa	**0 – 6**	**1**	**2 – 15**	**6**
% EPT	0 – 62	4	2 – 83	36
% Sensitive EPT	0 – 8	1	0 – 26	4
% Insects	**3 – 92**	**38**	**18 – 98**	**77**
Tolerance Value	4 – 10	7	4 – 7	5
% Oligochaetes	2 – 88	38	0 – 38	9

Metrics in Red increase in value at impacted sites.

Range of BMI Community Composition
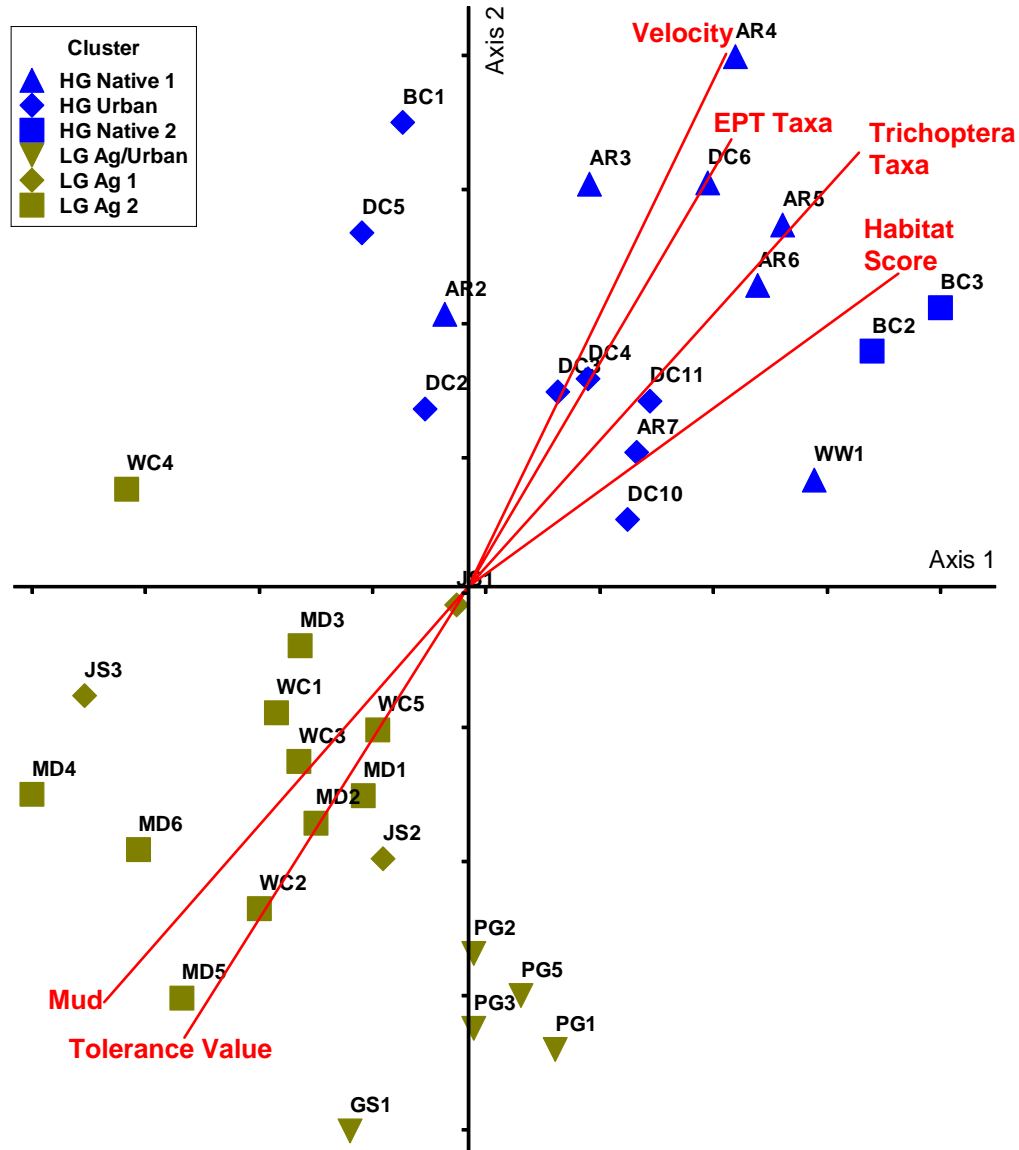
Correlations with environmental variables: $r^2 > 0.800$

BMI Community Health

Goal: Which sites show the most severe impacts from human activity?

Generally:

Index of Biotic Integrity (IBI) is constructed using the best available sites as "Reference" sites.

Sites are compared to "Reference" sites to identify the degree of community impairment at a site.

Central Valley problem:

Reference sites not yet characterized, and difficult to identify

Therefore, IBI construction not yet possible

Solution:

Modify IBI construction method

Create a Relative ranking of BMI community health

Original Method - IBI

1 | Classify Reference Sites

↓

2 | Identify metrics which are highly variable and show site–site differences

↓

3 | Select metrics able to identify impairment

↓
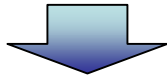
4 | Standardize chosen metrics and combine into IBI score

↓
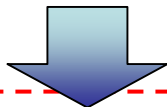
5 | Establish thresholds of impairment status

Modified Method - BI

1 | Classified all sites using cluster analysis and NMS ordination

↓

Chose metrics based on:

2 | High Signal/Noise Ratio
ANOVA by Site: F ratio > 3.0

↓

Low correlations between metrics chosen
Pearson correlation coefficient < 0.70

↓

3 | Correlations with:
Minimum DO
Specific Conductivity
Epifaunal Substrate
% Fine Substrates

↓

4 | Standardize chosen metrics and combine into BI score

Metrics included in Biotic Indices (BIs)

Low Gradient	High Gradient
Taxonomic Richness	Shannon Diversity
EPT Taxa	EPT Taxa
ETO Index	EPT Index
	Plecoptera Taxa
	% Hydropsychidae
% Insects	% Insects
% Intolerant	
Tanytarsini / Chironomini	
% Multivoltine *	% Multivoltine *
Tolerance Value *	Tolerance Value *
% Dominant Taxon *	
% Collectors *	% Grazers
	% Oligochaeta *
	% Chironomidae *

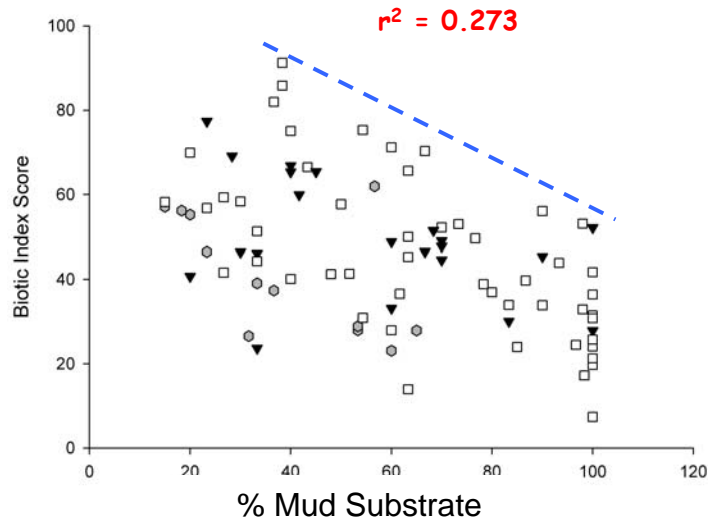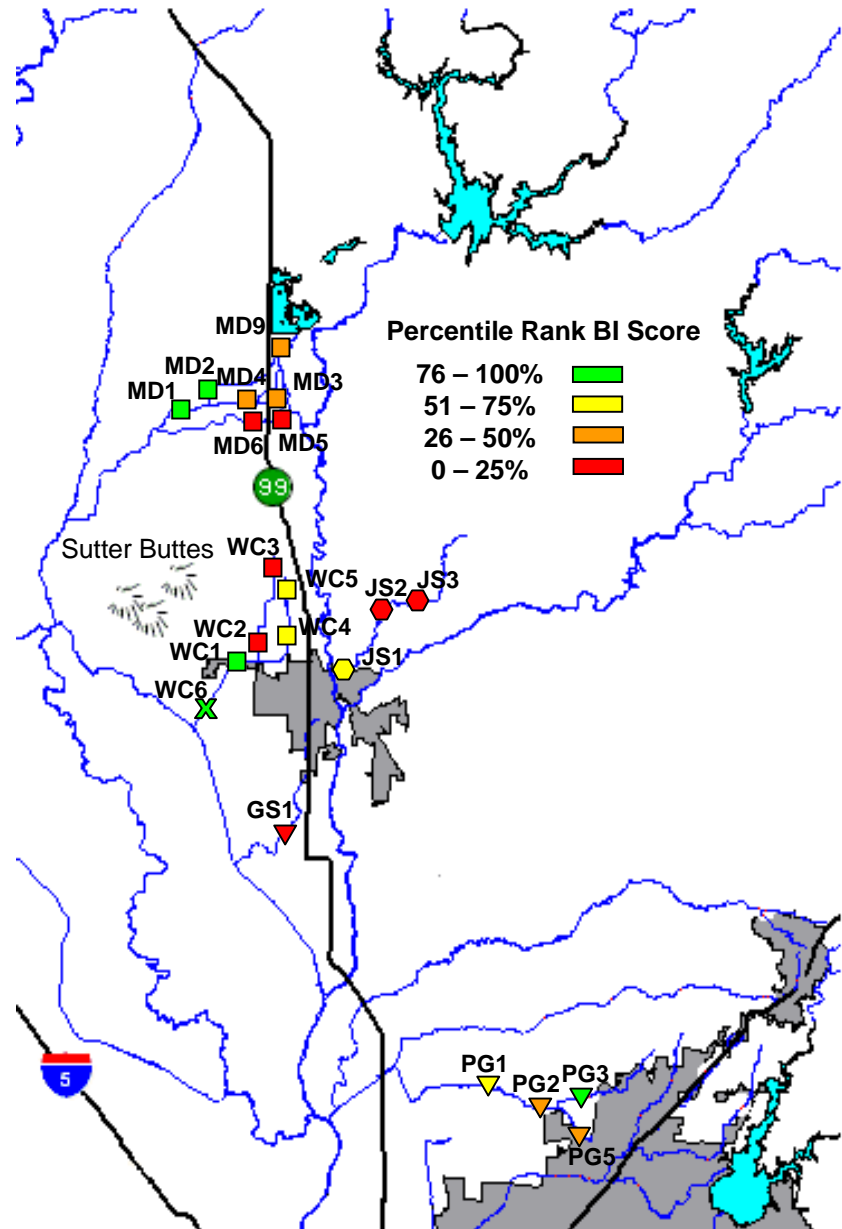Metrics in Red indicated impacted conditions.

Low Gradient BI scores

Three agricultural waterways (Main Drain, Wadsworth Canal, and Jack Slough) showed a clear pattern of increased BI scores at downstream sites.

Sites within the same tributaries in the Main Drain and Wadsworth Canal showed similar BI scores.


Percentile Rank BI Score

76 – 100%	🟩
51 – 75%	🟨
26 – 50%	🟧
0 – 25%	🟥

Low Gradient Biotic Index - Correlations with Environmental Variables

$r^2 = 0.273$ — % Mud Substrate vs Biotic Index Score

$r^2 = 0.087$ — Physical Habitat Score vs Low Gradient BI Score

$r^2 = 0.042$ — Turbidity (NTU) vs Biotic Index Score

$r^2 = 0.001$ — Minimum DO (mg/L) vs Biotic Index Score
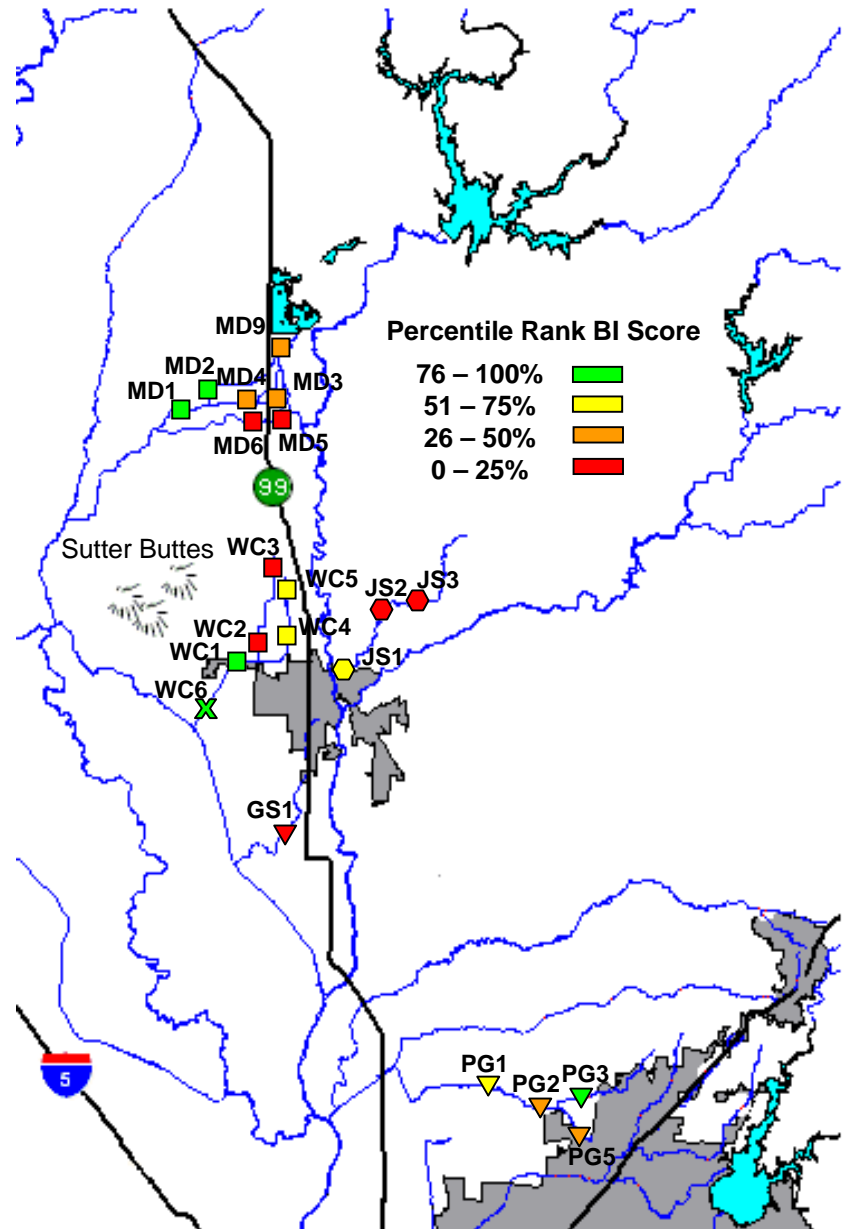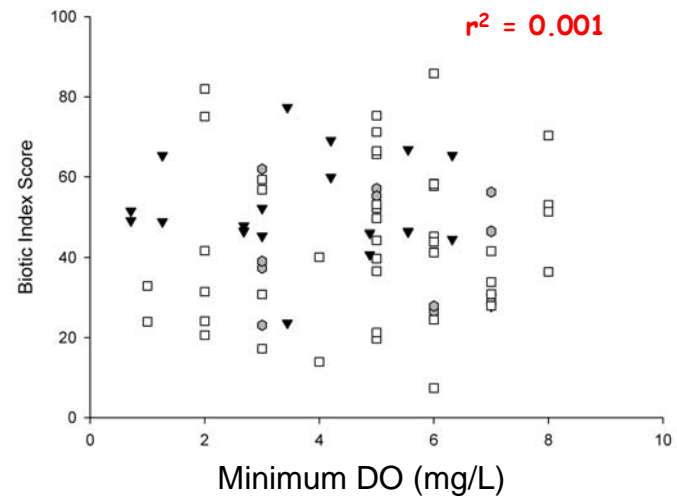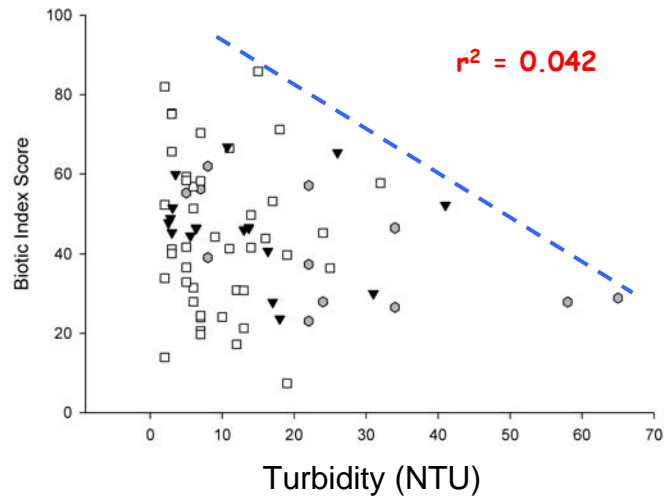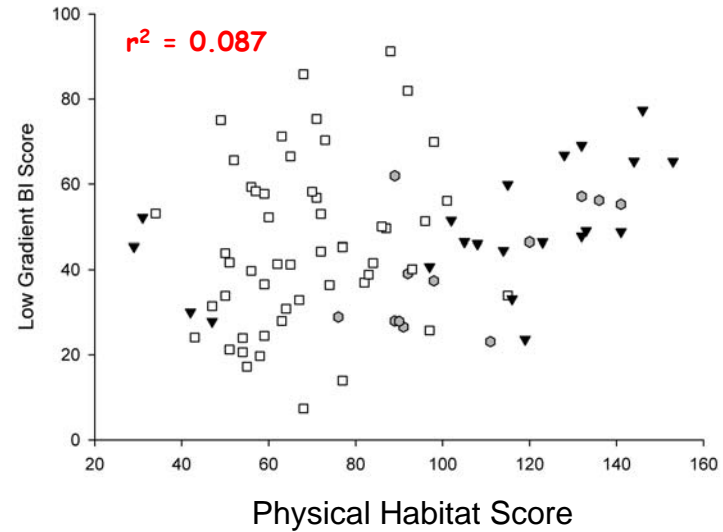
Low Gradient BI scores

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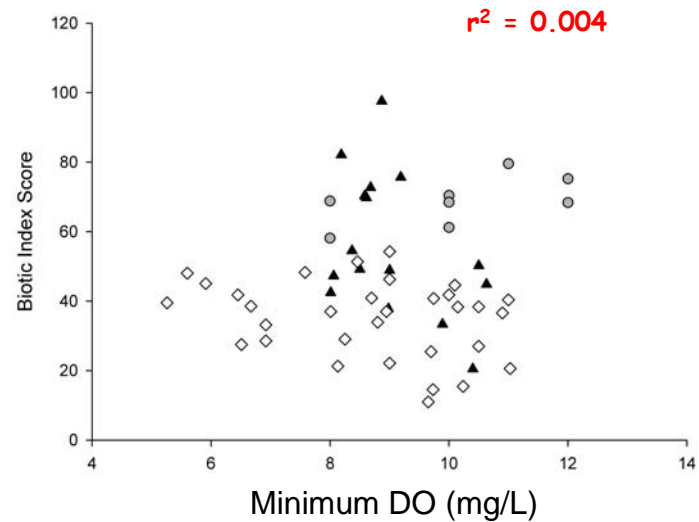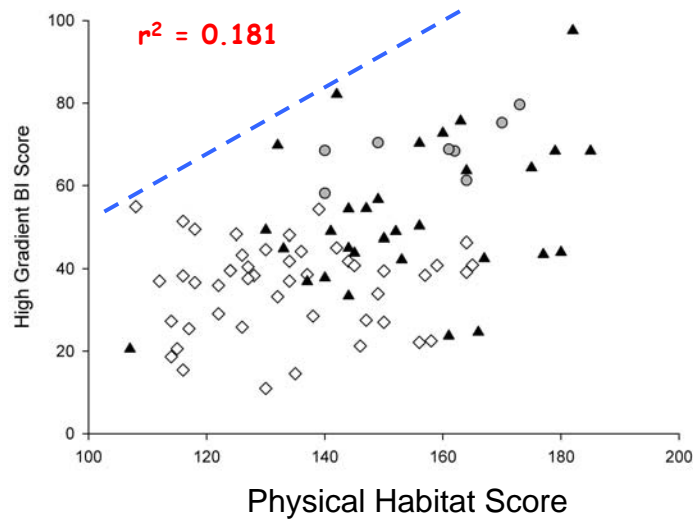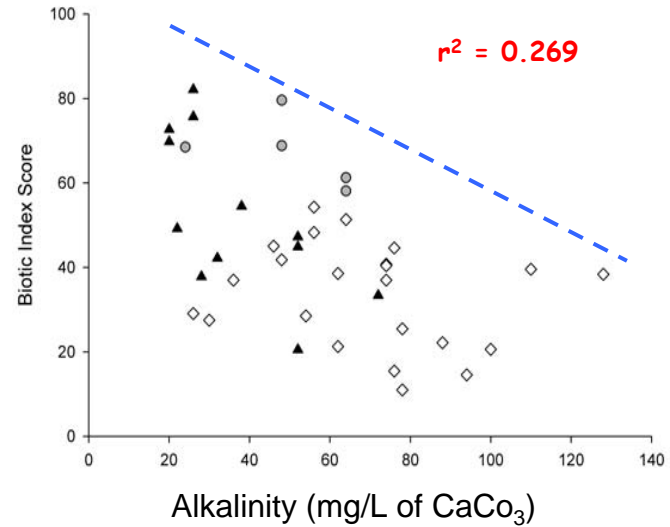BI Scores were correlated with:

Mud (-)

Turbidity? (-)

MD9

MD2 MD4 MD3
MD1

MD6 MD5

Percentile Rank BI Score

76 – 100%
51 – 75%
26 – 50%
0 – 25%

99

Sutter Buttes   WC3

WC5   JS2   JS3

WC2   WC4
WC1   JS1

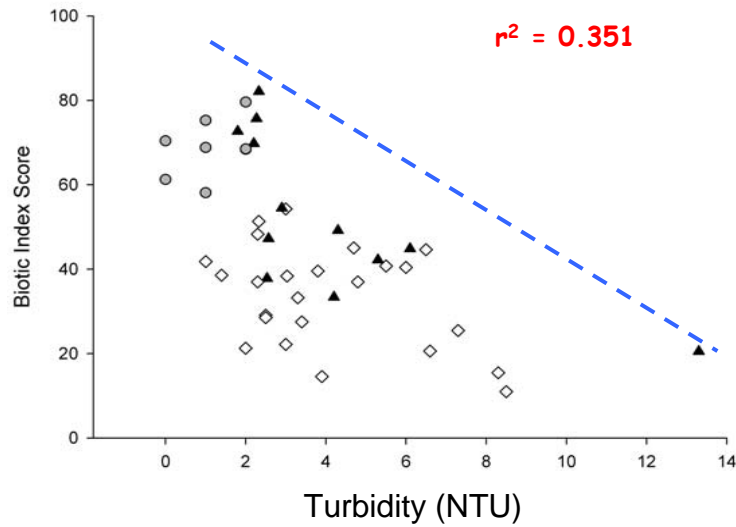WC6

GS1

PG1
        PG2 PG3

PG5

High Gradient BI scores

Sites closer to the center of urban areas, or in an agricultural area (BC1), showed lower BI scores.
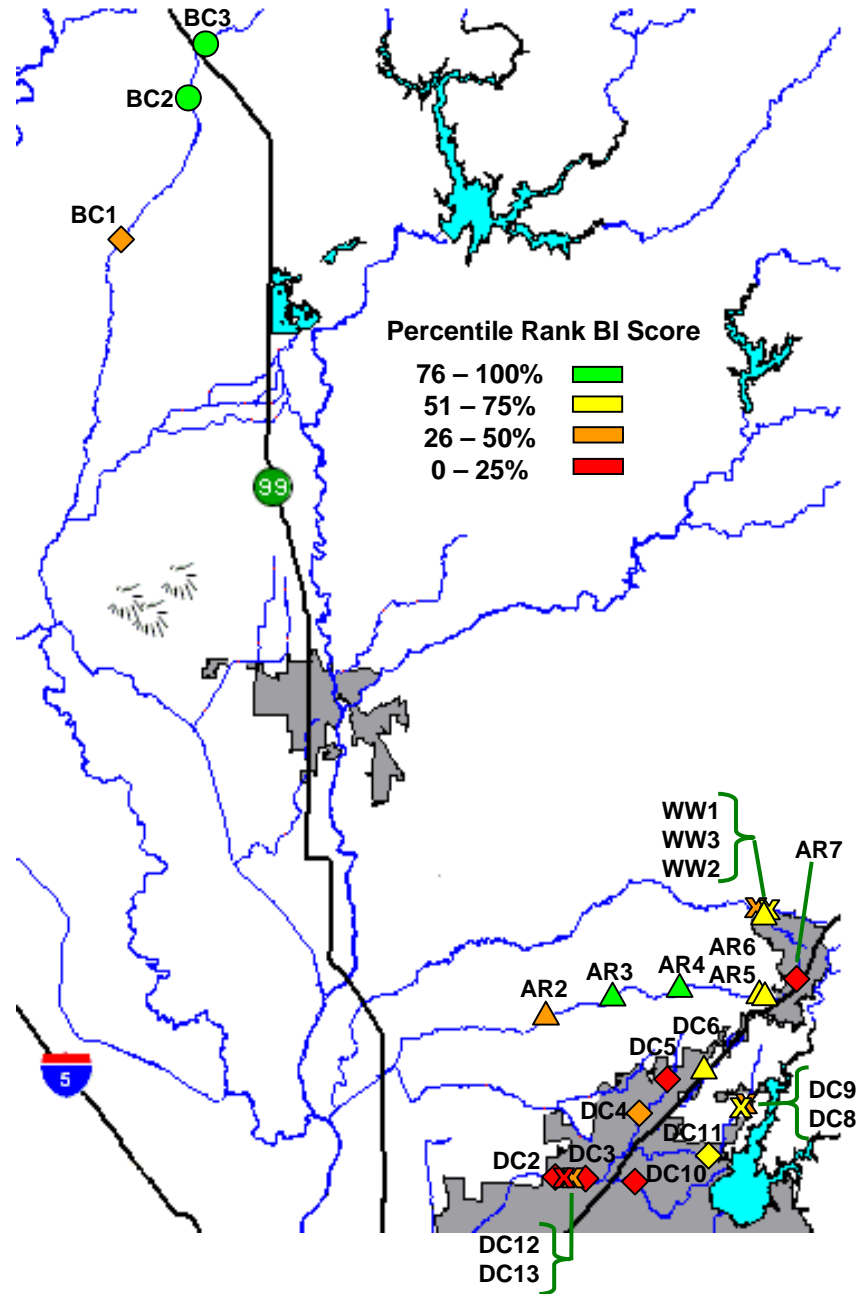
High Gradient Biotic Index - Correlations with Environmental Variables
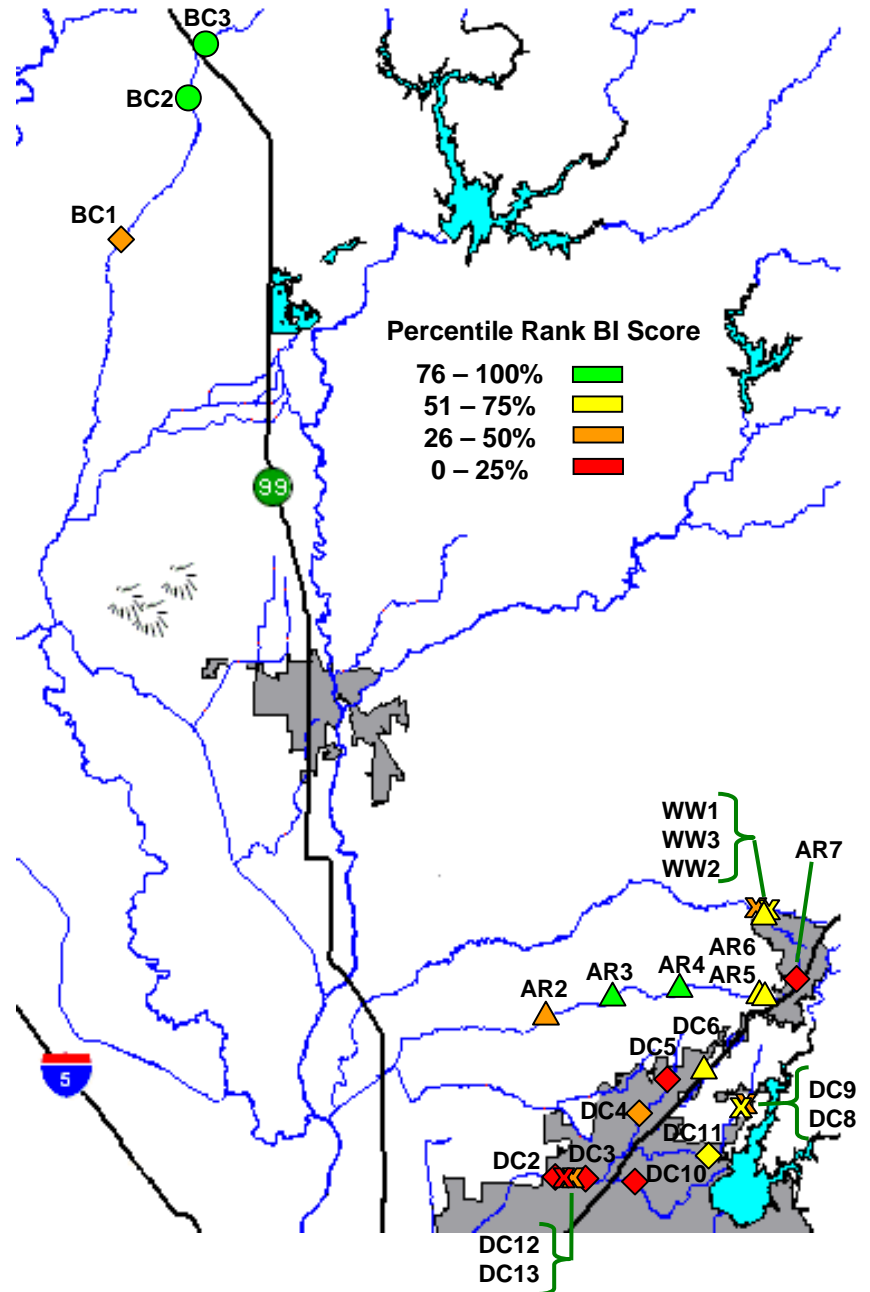
High Gradient BI scores

Sites closer to the center of urban areas, or in an agricultural area (BC1), showed lower BI scores.

BI scores were correlated with:

Turbidity (-)

Alkalinity (-)

Habitat Score (+)

Percentile Rank BI Score

76 – 100%
51 – 75%
26 – 50%
0 – 25%

Conclusions

A range of BMI communities is present at both high gradient and low gradient sites.

BMI community health cannot be fully explained by quality of habitat, substrate grain size, or measured water quality variables.

Biotic Index analyses successfully:

Highlighted sites containing the most impacted BMI communities.

Showed spatial patterns of BMI community health.

Gave preliminary indications of likely stressors in sites subject to multiple stressors.

Acknowledgements