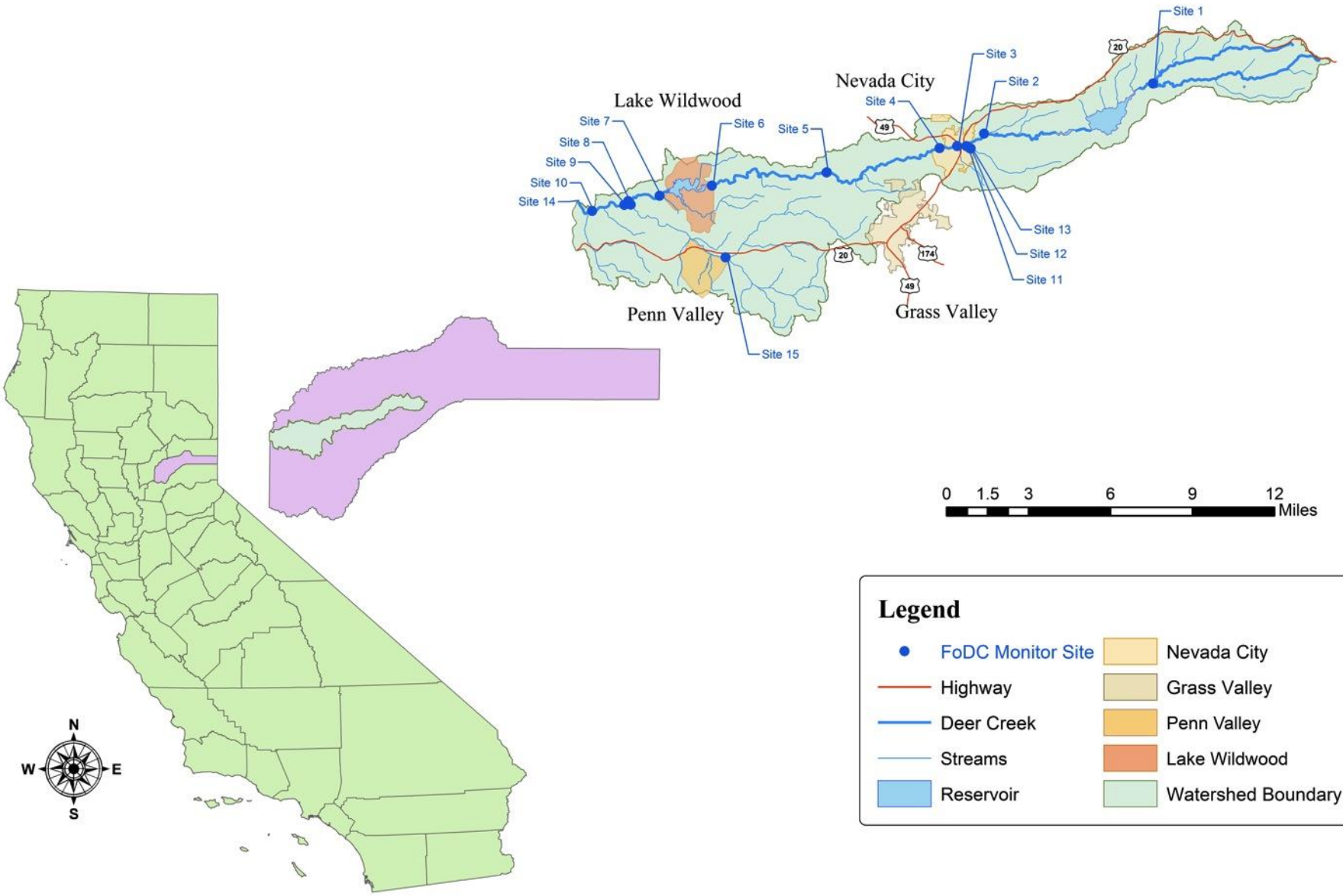
Bioassessment in Deer Creek: Long-term and Case-specific Variation using an IBI and a Multivariate Approach

Andy Bell & Jeff Lauder

Sierra Streams Institute

Nevada City, CA

Deer Creek Watershed



Deer Creek Bioassessment

Step 1:

Assess biological condition

Step 2:

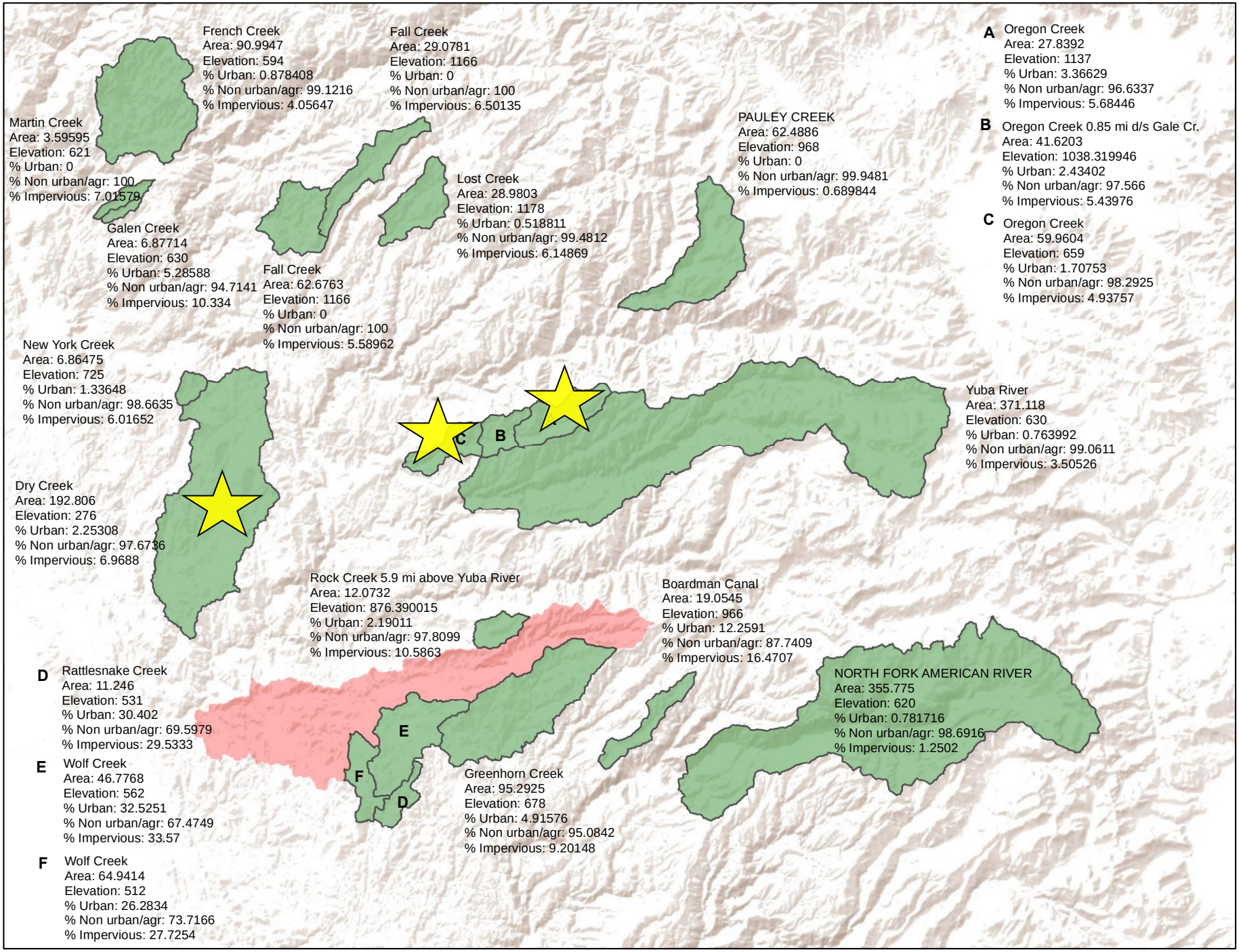
What changed and why?

Index of Biotic Integrity

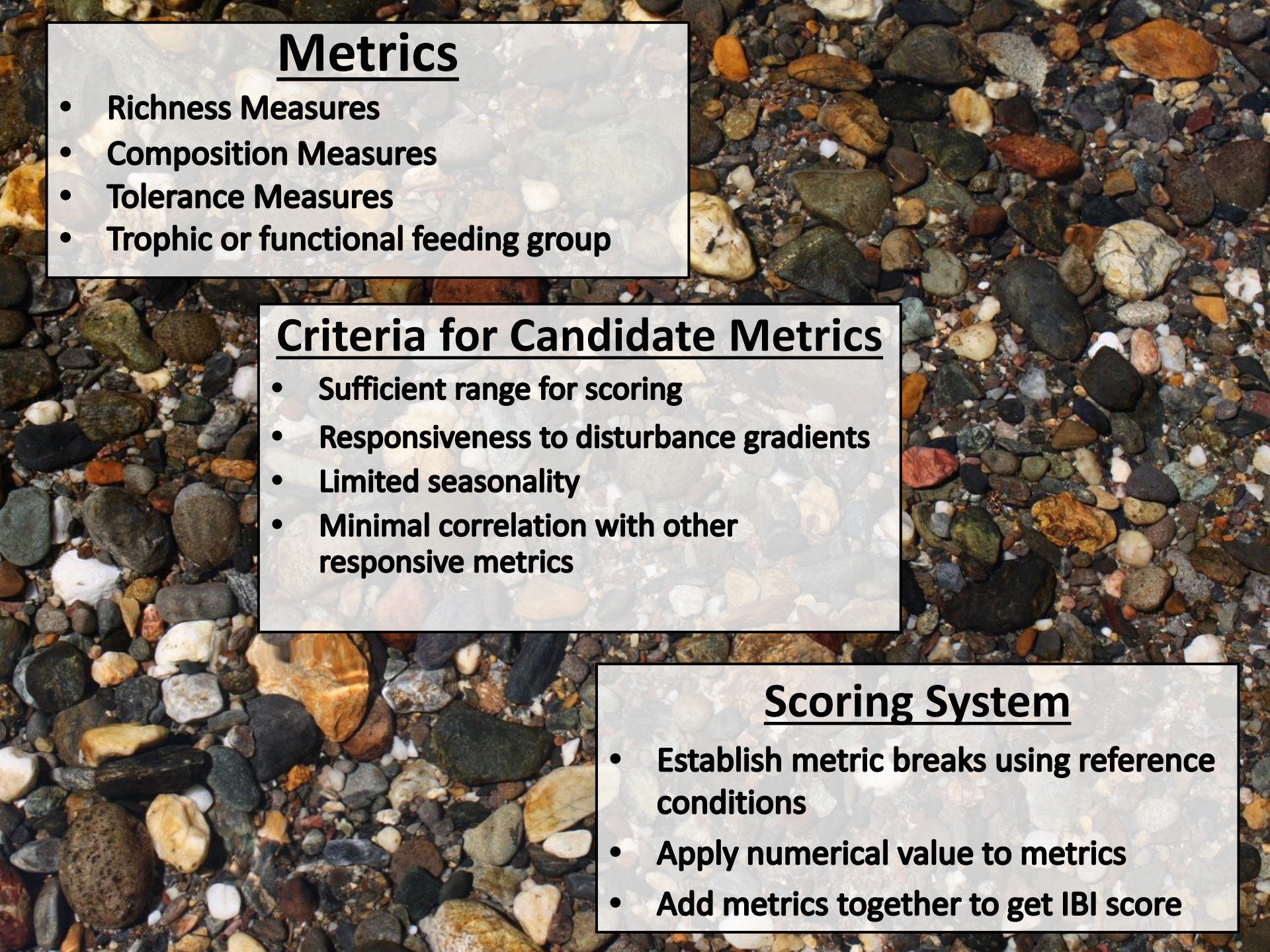
- The composition of the benthic macroinvertebrate assemblages provide a direct measure of the integrity of the stream's ecological condition
- Family-level IBI
  - Utilizes citizen science data
  - Affordable for non-profit watershed groups
  - Facilitates communication to the public about ecological conditions
- Macroinvertebrate families have varying responses to anthropogenic disturbance gradients

The search for the reference condition……

- Streams within a 25 mile buffer of the Deer Creek watershed
- Watershed area & elevation
- Quantitative GIS land cover analysis
  - Urban Development (<5% of watershed)
  - Impervious Surfaces (<10% of watershed)
  - Density of Roads (<2km roads/km^2)
  - Riparian Development (2km by 200m upstream)
- Ground truthing
  - Field visits, water quality, physical habitat assessment, site access


French Creek
Area: 90.9947
Elevation: 594
% Urban: 0.878408
% Non urban/agr: 99.1216
% Impervious: 4.05647
Fall Creek
Area: 29.0781
Elevation: 1166
% Urban: 0
% Non urban/agr: 100
% Impervious: 6.50135
A
Oregon Creek
Area: 27.8392
Elevation: 1137
% Urban: 3.36629
% Non urban/agr: 96.6337
% Impervious: 5.68446
Martin Creek
Area: 3.59595
Elevation: 621
% Urban: 0
% Non urban/agr: 100
% Impervious: 7.01579
PAULEY CREEK
Area: 62.4886
Elevation: 968
% Urban: 0
% Non urban/agr: 99.9481
% Impervious: 0.689844
B
Oregon Creek 0.85 mi d/s Gale Cr.
Area: 41.6203
Elevation: 1038.319946
% Urban: 2.43402
% Non urban/agr: 97.566
% Impervious: 5.43976
Lost Creek
Area: 28.9803
Elevation: 1178
% Urban: 0.518811
% Non urban/agr: 99.4812
% Impervious: 6.14869
Galen Creek
Area: 6.87714
Elevation: 630
% Urban: 5.28588
% Non urban/agr: 94.7141
% Impervious: 10.334
C
Oregon Creek
Area: 59.9604
Elevation: 659
% Urban: 1.70753
% Non urban/agr: 98.2925
% Impervious: 4.93757
Fall Creek
Area: 62.6763
Elevation: 1166
% Urban: 0
% Non urban/agr: 100
% Impervious: 5.58962
New York Creek
Area: 6.86475
Elevation: 725
% Urban: 1.33648
% Non urban/agr: 98.6635
% Impervious: 6.01652
A
B
C
Yuba River
Area: 371.118
Elevation: 630
% Urban: 0.763992
% Non urban/agr: 99.0611
% Impervious: 3.50526
Dry Creek
Area: 192.806
Elevation: 276
% Urban: 2.25308
% Non urban/agr: 97.6736
% Impervious: 6.9688
Rock Creek 5.9 mi above Yuba River
Area: 12.0732
Elevation: 876.390015
% Urban: 2.19011
% Non urban/agr: 97.8099
% Impervious: 10.5863
Boardman Canal
Area: 19.0545
Elevation: 966
% Urban: 12.2591
% Non urban/agr: 87.7409
% Impervious: 16.4707
D
Rattlesnake Creek
Area: 11.246
Elevation: 531
% Urban: 30.402
% Non urban/agr: 69.5979
% Impervious: 29.5333
NORTH FORK AMERICAN RIVER
Area: 355.775
Elevation: 620
% Urban: 0.781716
% Non urban/agr: 98.6916
% Impervious: 1.2502
E
Wolf Creek
Area: 46.7768
Elevation: 562
% Urban: 32.5251
% Non urban/agr: 67.4749
% Impervious: 33.57
E
F
D
Greenhorn Creek
Area: 95.2925
Elevation: 678
% Urban: 4.91576
% Non urban/agr: 95.0842
% Impervious: 9.20148
F
Wolf Creek
Area: 64.9414
Elevation: 512
% Urban: 26.2834
% Non urban/agr: 73.7166
% Impervious: 27.7254

	Reference Sites			Deer Creek
	Oregon Creek: Tippe Canoe	Oregon Creek: Camptonville	Dry Creek	
Watershed Area (sq. mi.)	12.40	23.06	72.67	84.50
Elevation (ft)	3,678	2,194	950	4,800-300
% Urban	2.92	1.71	2.31	10.04
% Impervious	6.01	4.93	7.05	14.51
Road Density (km/km^2)	2.00	2.12	2.24	3.31
Dams	-	-	1	3



Metrics

- Richness Measures
- Composition Measures
- Tolerance Measures
- Trophic or functional feeding group

Criteria for Candidate Metrics

- Sufficient range for scoring
- Responsiveness to disturbance gradients
- Limited seasonality
- Minimal correlation with other responsive metrics

Scoring System

- Establish metric breaks using reference conditions
- Apply numerical value to metrics
- Add metrics together to get IBI score

IBI Development Details

- 48 candidate metrics
- BMIs ID'ed to family by volunteers (with QA/QC)
- Disturbance stressor gradients:
  - % of watershed urban development
  - % of riparian area (2km x 200m upstream) impervious surfaces
  - Dissolved Oxygen (mg/L)
  - pH
  - Turbidity (ntu)
  - Nitrate (mg/L)

Richness Measures

Total Taxa
Insect Taxa
Non-insect Taxa
Ephemeroptera Taxa
Plecoptera Taxa
Trichoptera Taxa
Diptera Taxa
Coleoptera Taxa
Plecoptera& Trichoptera Taxa
EPT Taxa

Tolerance Measures

% Tolerant
% Intolerant
Tolerant Taxa
Intolerant Taxa
Beck's Biotic Index
Hilsenhoff's Biotic Index

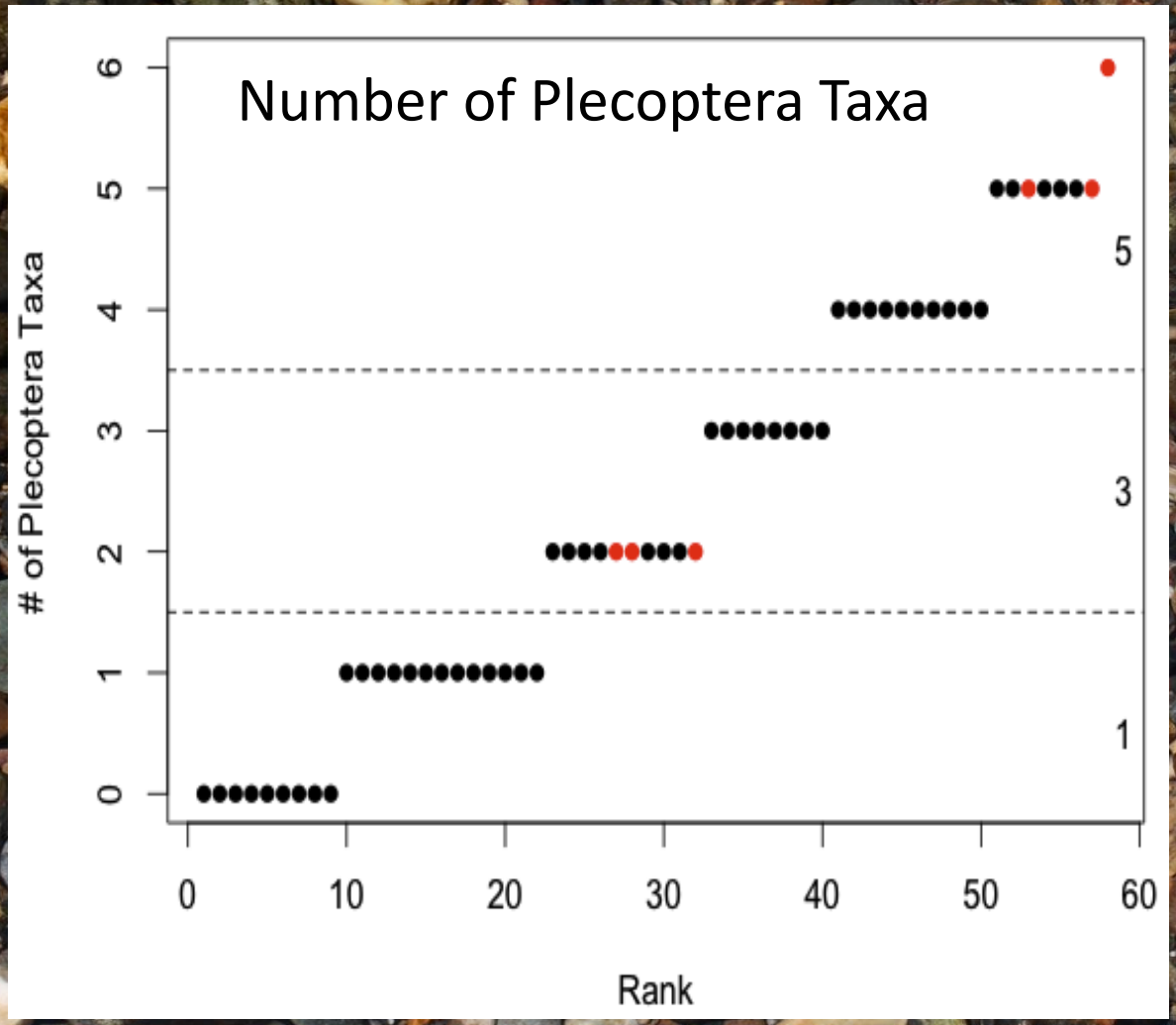
Trophic or Functional Feeding Group Measures

% Collector/gatherers
% Filterers
% Predators
% Scrapers
% Shredders
Collector/gatherers Taxa
Filterer Taxa
Predator Taxa
Scraper Taxa
Shredder Taxa

Composition Measures

% Non-insect
% EPT
% EPT excluding Baetidae
% Ephemeroptera
% Ephemeroptera (w/oBaetidae)
% Plecoptera
% Trichoptera
% Plecoptera & Trichoptera
% Coleoptera
% Odonata
% Diptera
% Chironomidae
% Amphipoda
% Gastropoda
% Isopoda
% Oligochaeta
Shannon-Wiener Index
Margaleff's Index
Simpson's Index
% Dominant Taxon
% 3 Most Dominant Taxa

Insufficient range for scoring
Unresponsive to disturbance
Obvious seasonality
Correlated with other metrics



Metric Scoring

Scores:

5 (Healthy)

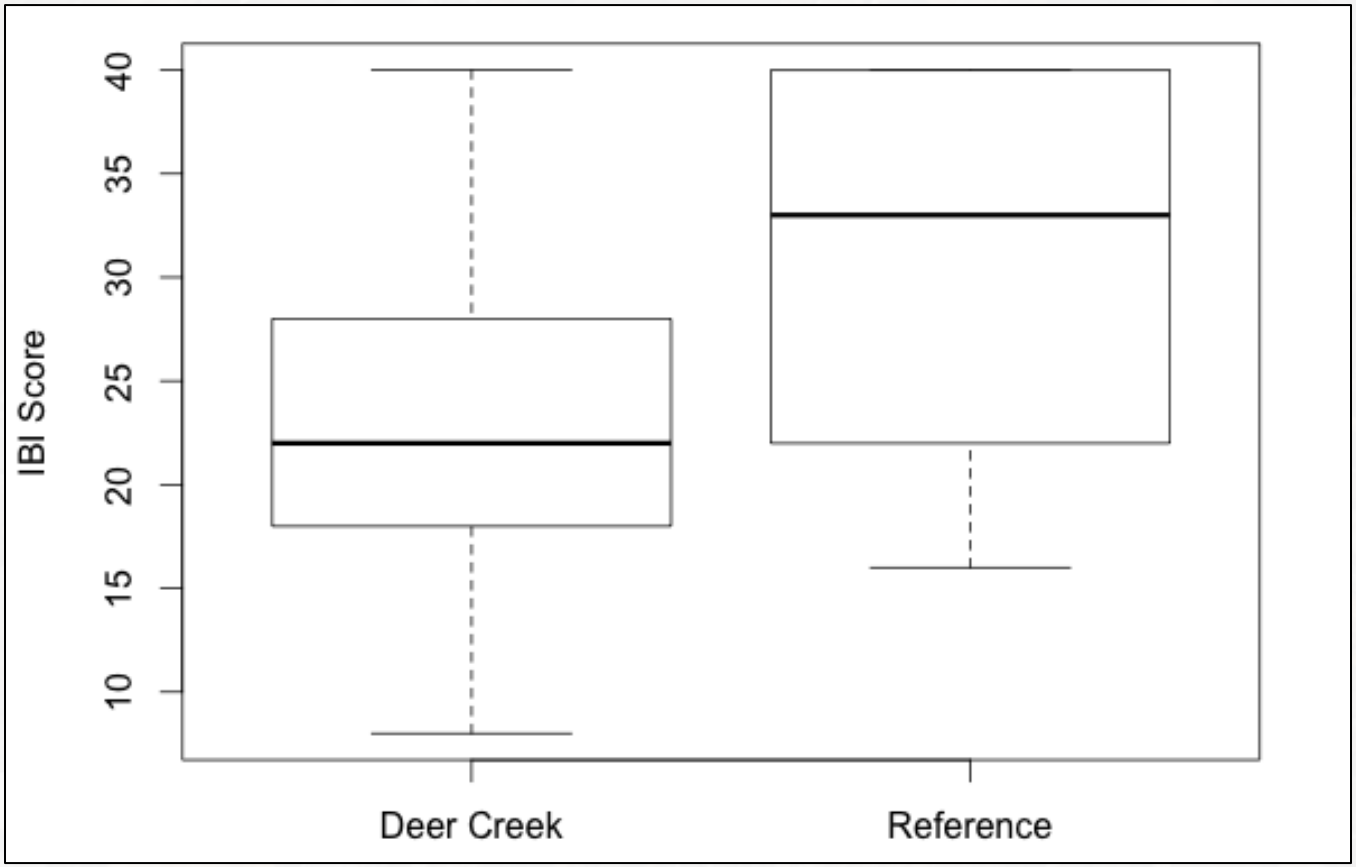
3

1 (Impaired)

Total IBI score out of 40

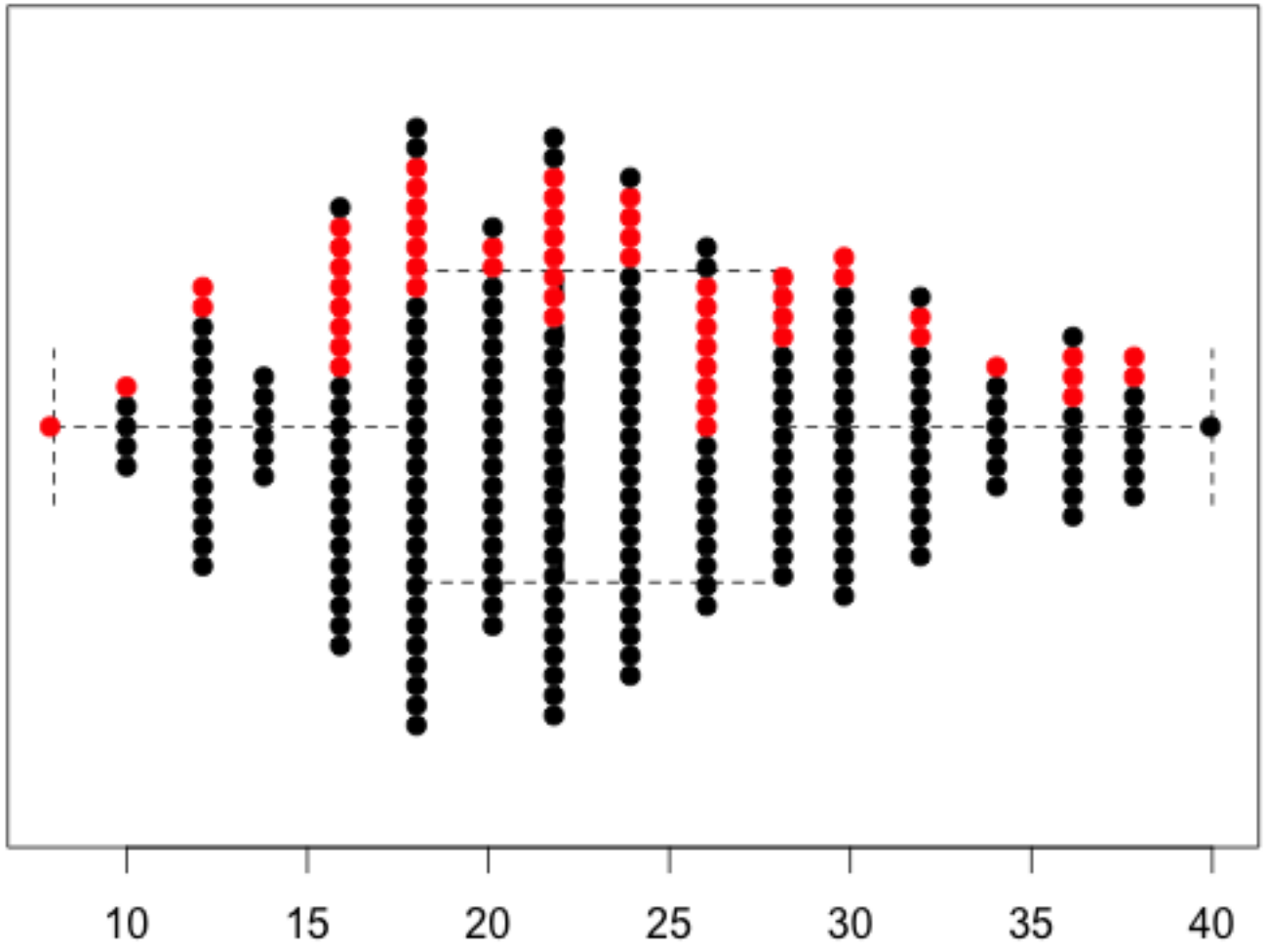
- Development set (2009 & 2010, June and October)
- Reference Sites (2012, June and October)

Reference IBI Score



Watershed Area	Reference	Deer Creek
Upper	40	32.7
Middle	32	21.5
Lower	18	16.6

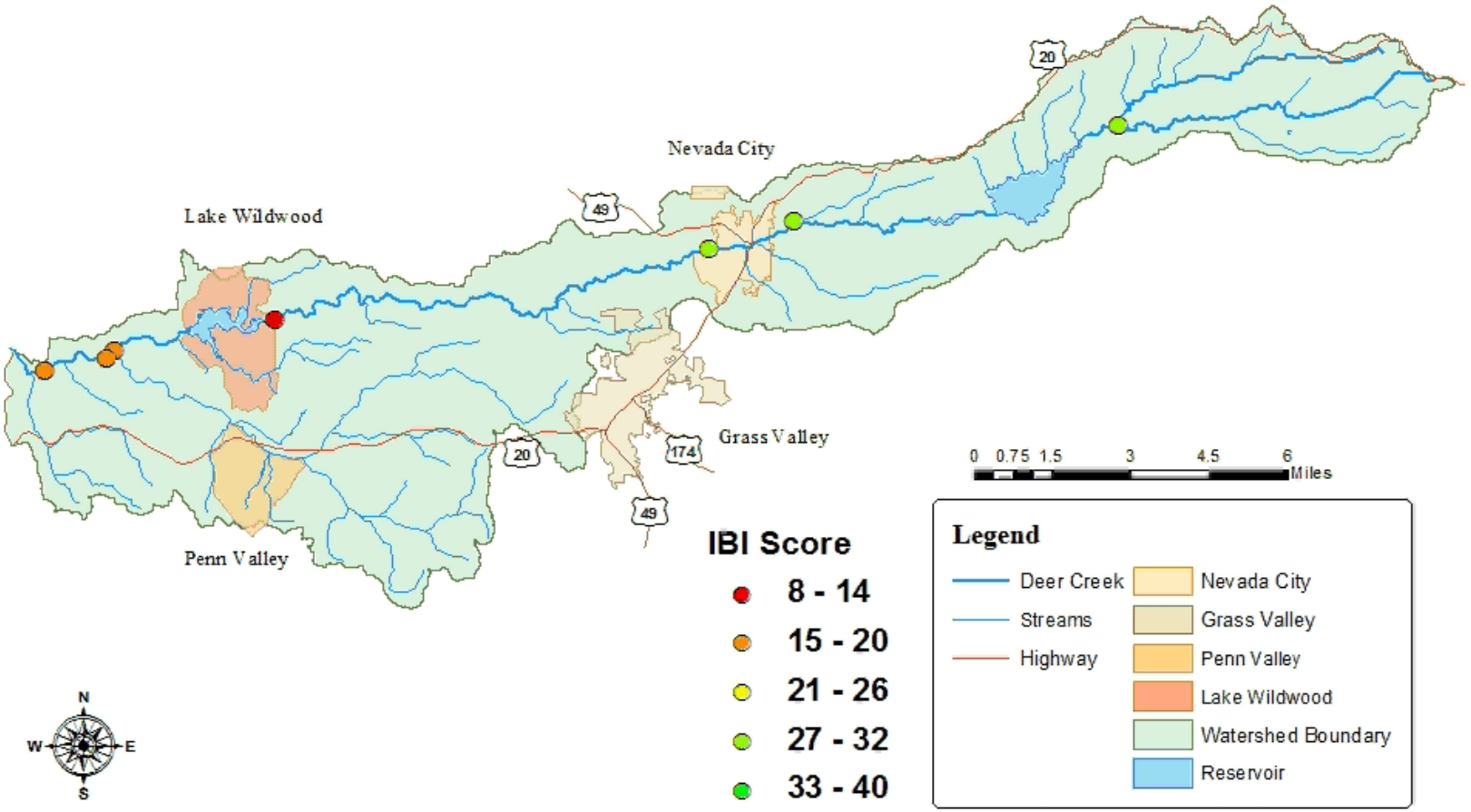
Full Dataset Distribution of IBI Scores

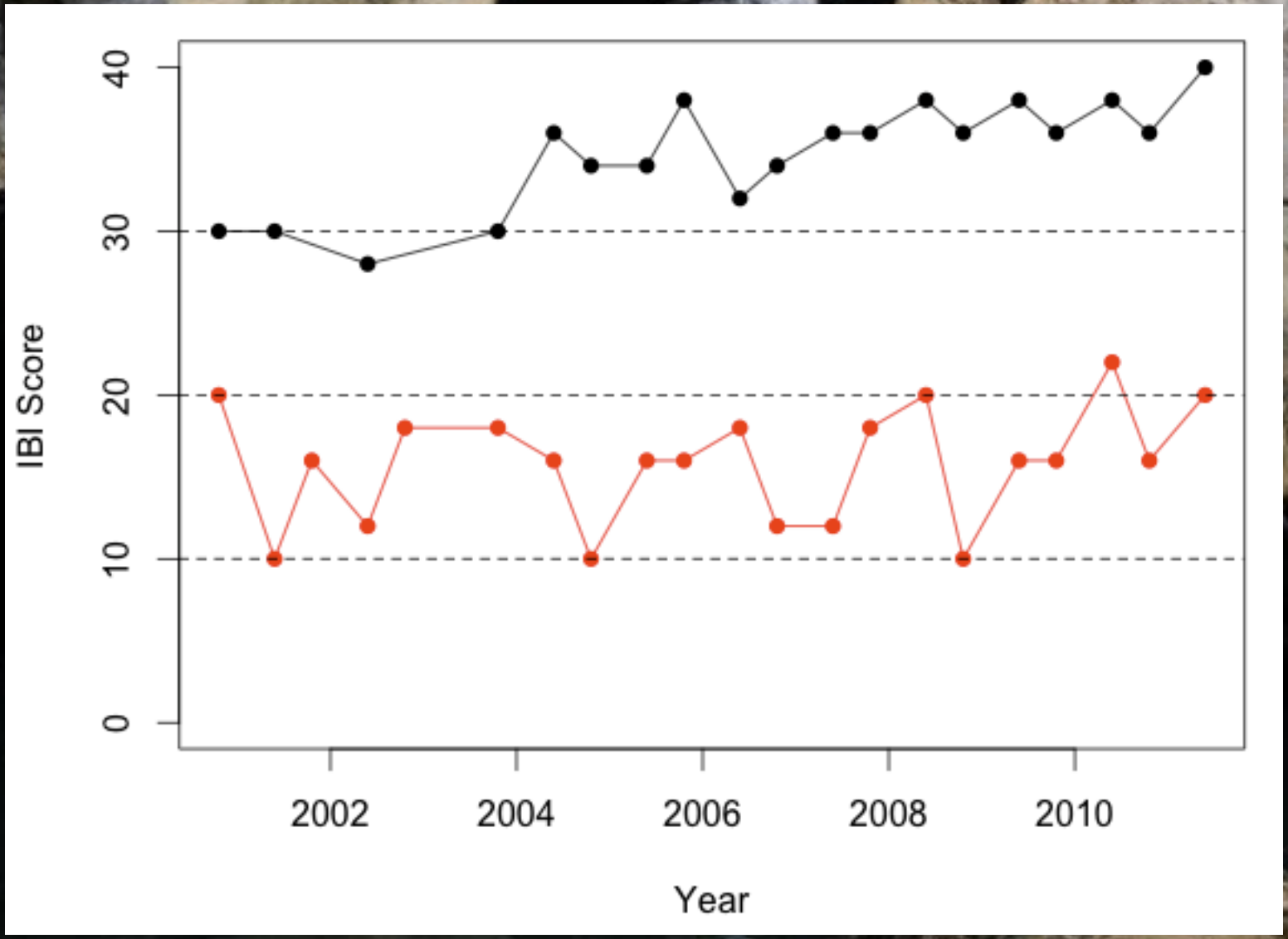


- Full Dataset
- Development Set

Deer Creek Index of Biotic Integrity

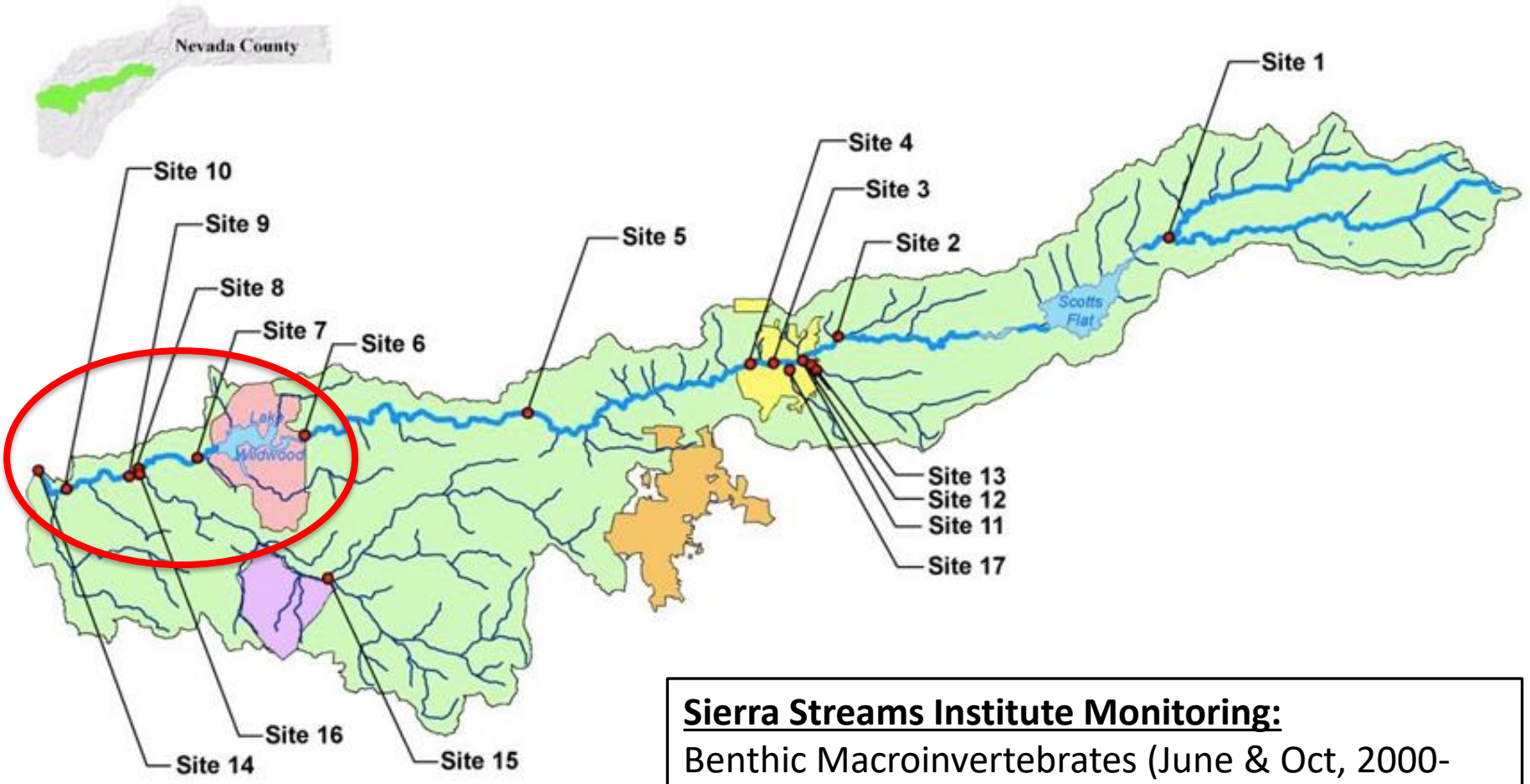
Oct 2000





- Upper Watershed (Site 1) Urban development = 2.29%
- Lower Watershed (Site 10) Urban development = 10.04%

Deer Creek Monitoring Sites



Legend

- Monitoring Sites
- Deer Creek
- Tributary
- Reservoir
- Watershed Boundary
- Nevada City
- Grass Valley
- Penn Valley
- Lake Wildwood

Sierra Streams Institute Monitoring:

Benthic Macroinvertebrates (June & Oct, 2000-present)

Water Quality (Monthly, 2000-present)

Algae (May-Oct, 2004-present)

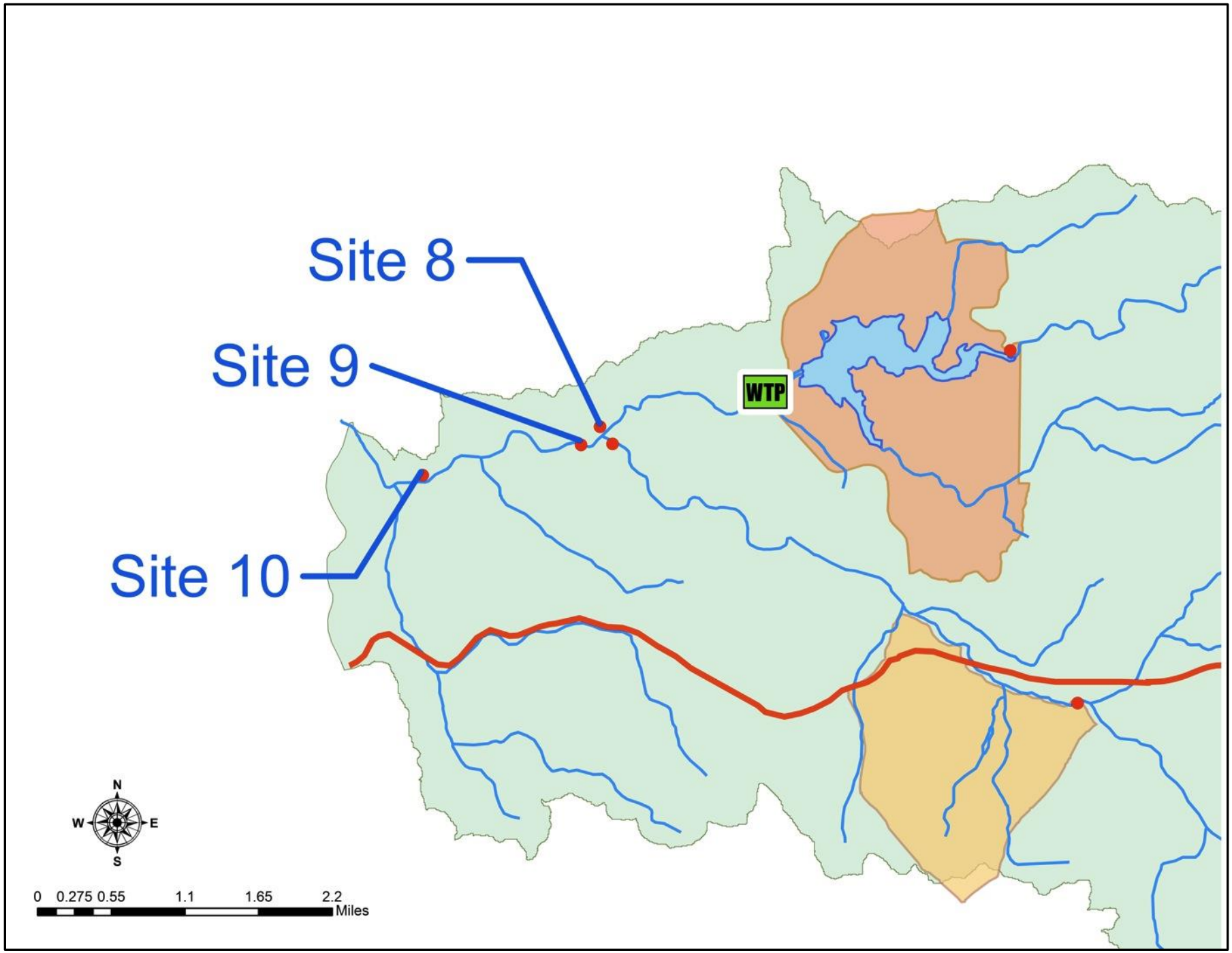
0 2.5 5 10 Miles

0 3.75 7.5 15 Kilometers

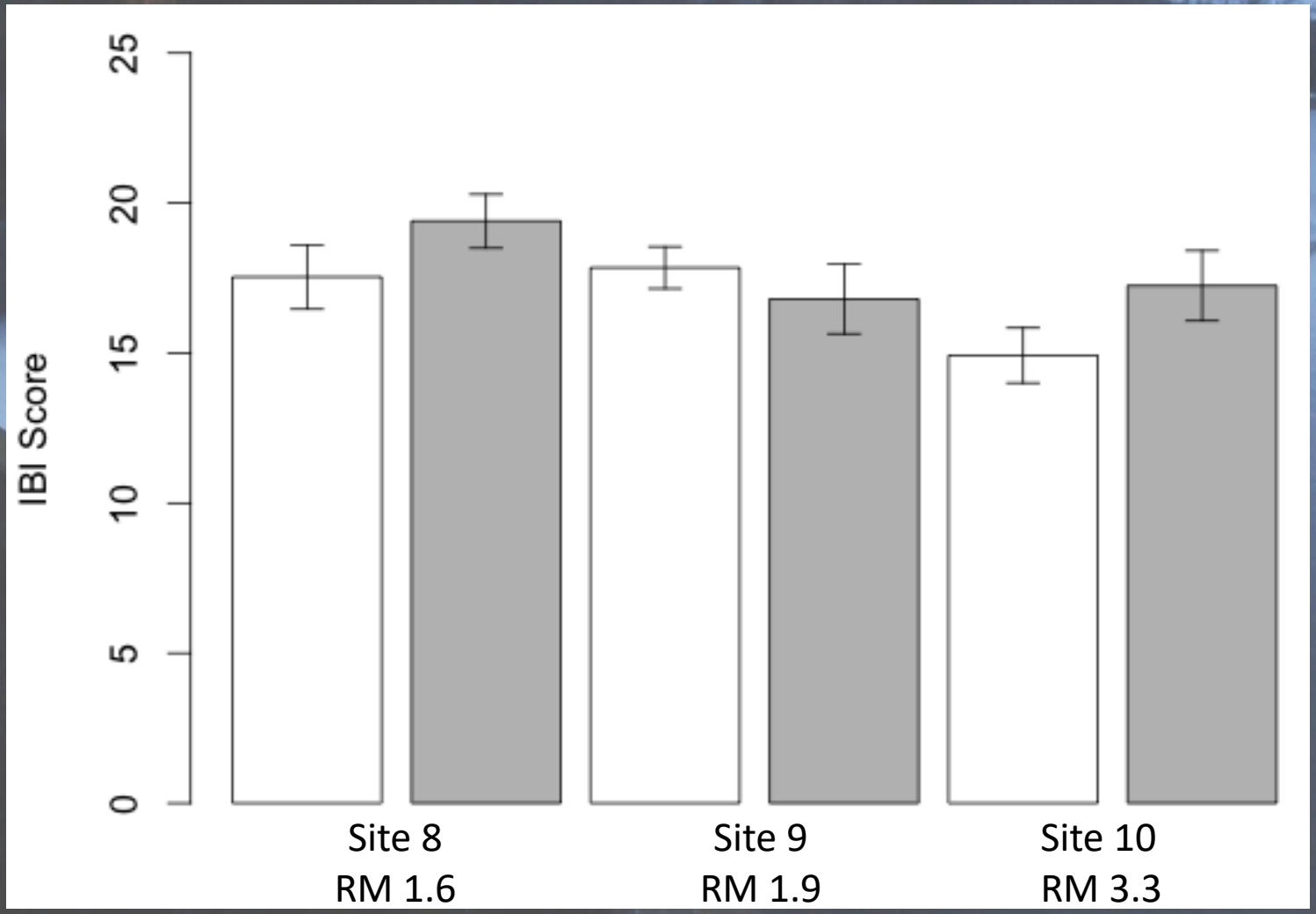
N W E S

Lake Wildwood Waste Water Treatment Plant (LWW WWTP)

- Recreational dam in lower Deer Creek watershed
- Immediately downstream of dam is WWTP
- Government mandate in 2007
  - Upgrade to fully denitrify wastewater, produce more consistent, contained flows

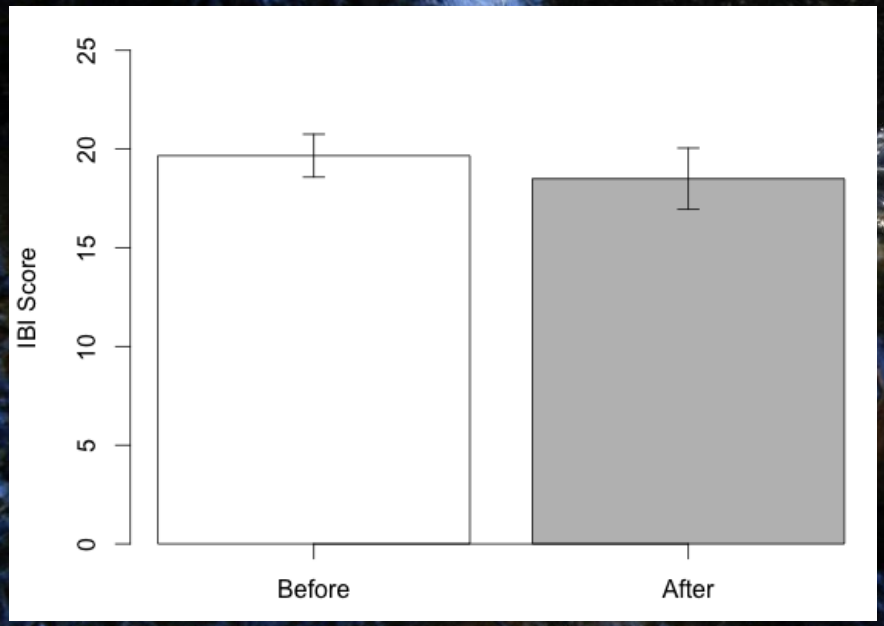

Site 8
Site 9
Site 10
WTP
N
W
E
S
0 0.275 0.55 1.1 1.65 2.2
Miles

IBI Scores below treatment plant:



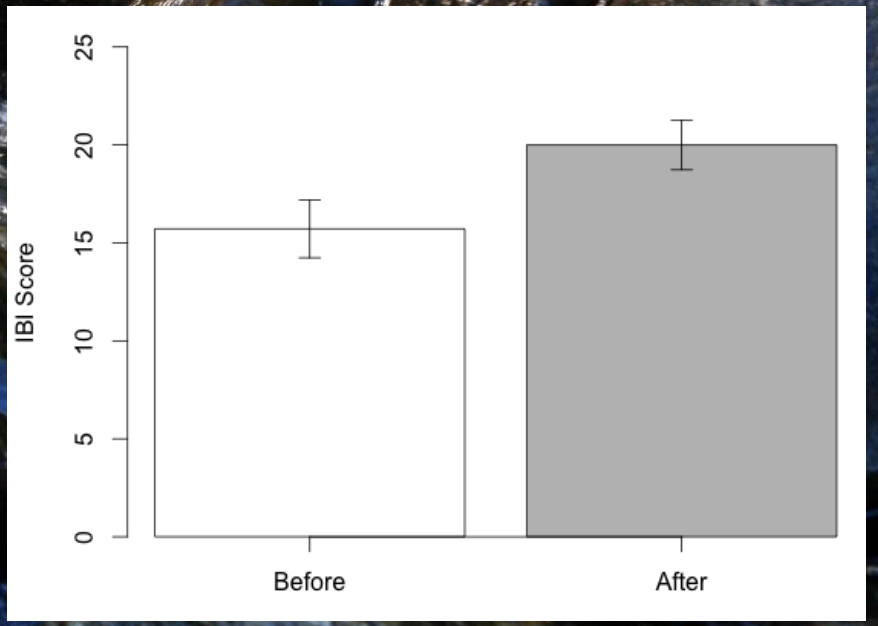
Site 8 seasonality after upgrade

June



P=0.5058

October



P=0.04972

Deer Creek Bioassessment

Step 1:

Assess biological condition

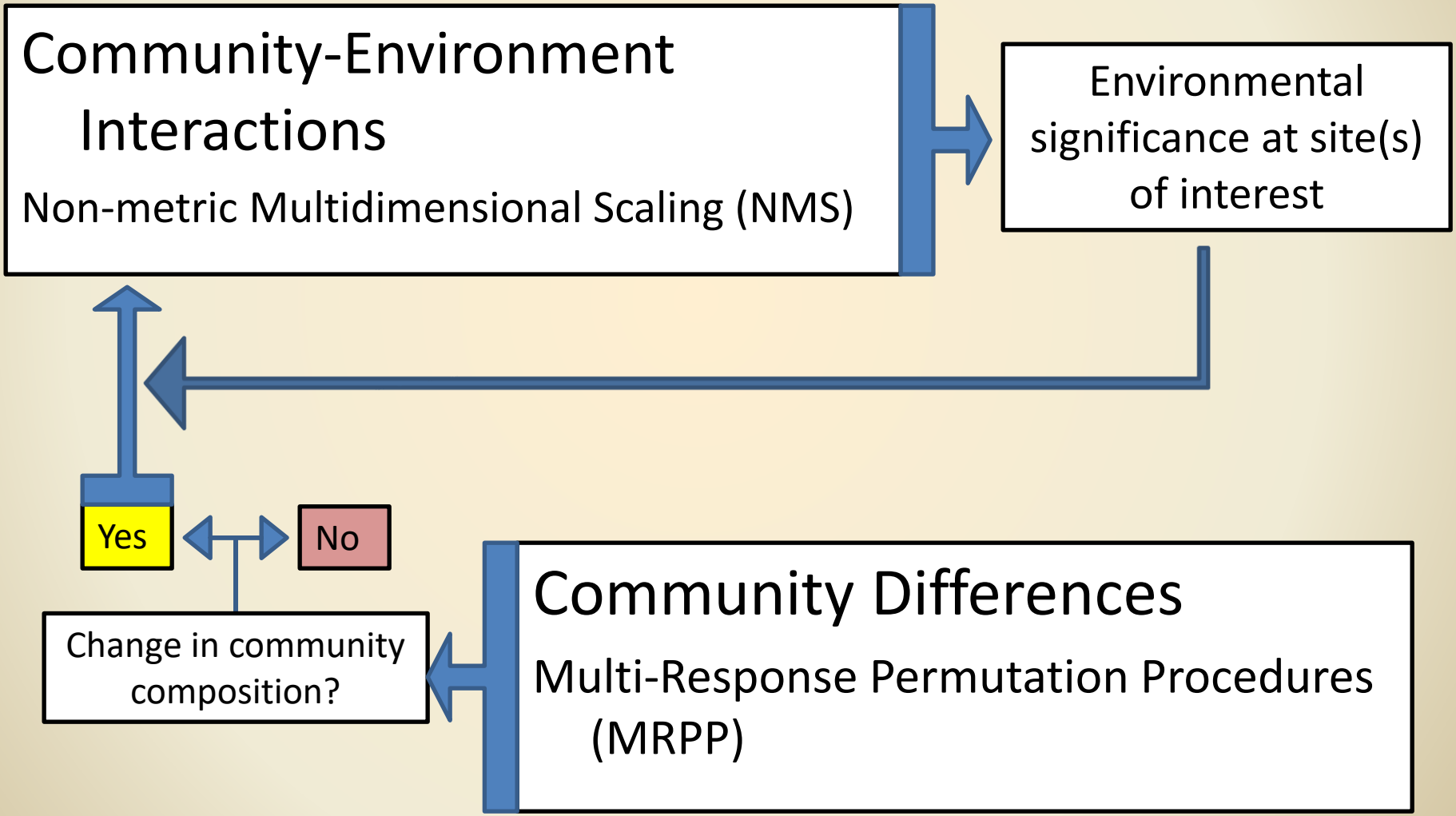
Step 2:

What changed and why?

Objectives

- Dynamics of community-disturbance interactions
  - Before and After WWTP upgrade
    - Changes in community.
    - Changes in disturbance variable significance.

Methods


Community-Environment Interactions
Non-metric Multidimensional Scaling (NMS)
Environmental significance at site(s) of interest
Yes
No
Change in community composition?
Community Differences
Multi-Response Permutation Procedures (MRPP)

NMS

Pros

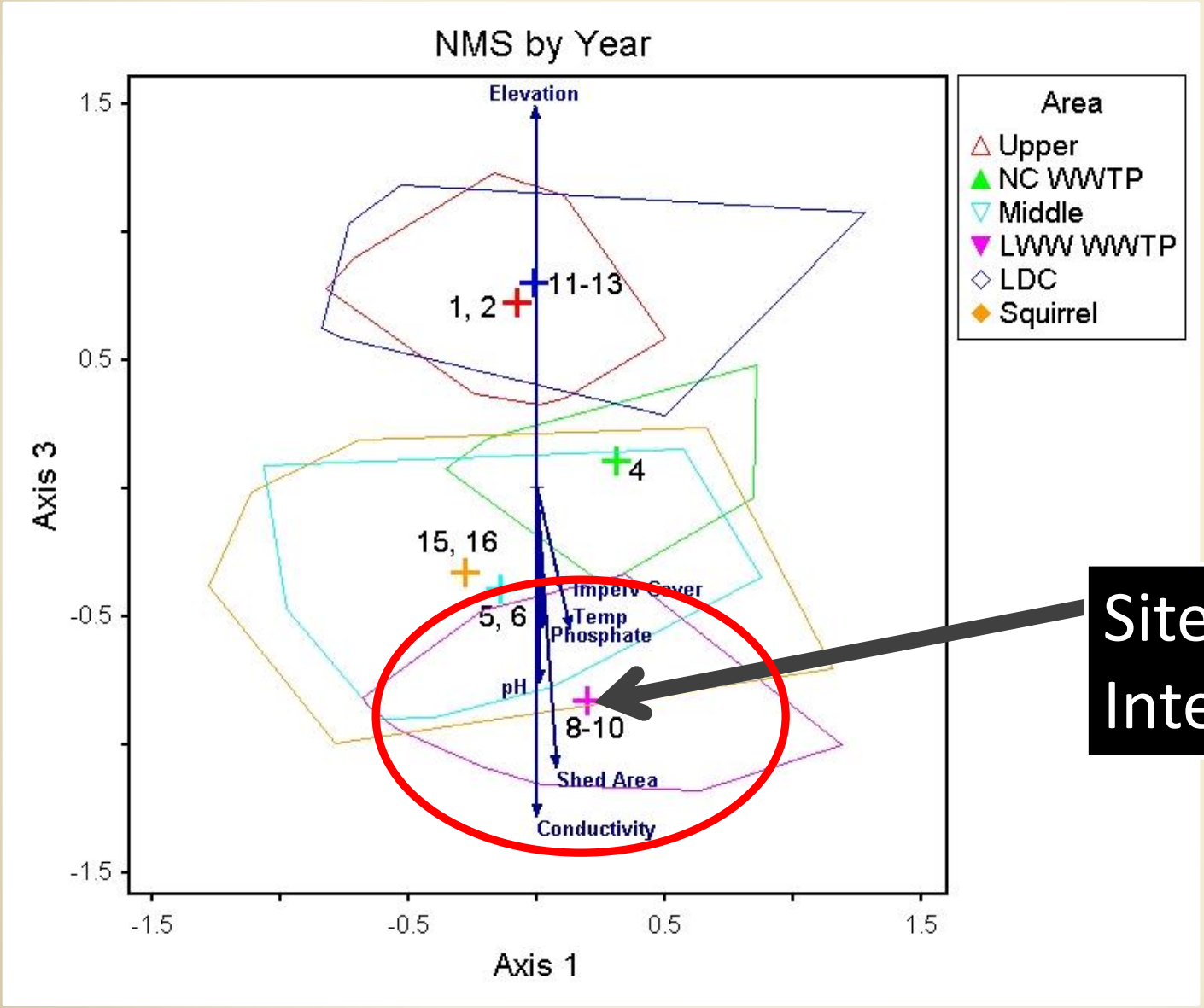
- Non-parametric technique
- Unlike PCA, does not depend on linear relationships among variables.
- Unlike CCA, does not depend on linear combinations of variables for environmental correlations.

Cons

- Not a “constrained” ordination; environmental correlations may require more interpretation.

McCune & Grace (2002)

Overall Site Summary



Stress: 14.16
Instability: 0.00
R^2: 0.804
Axis 3 variance: 0.450

Sites of Interest

LWW WWTP

Significant Variables (r>0.20) along Axis 3 in overall NMS:

Correlations	Axis 3 variance
Phosphate	-0.558
Nitrate	-0.451
pH	-0.652
Conductivity	-0.843
Water Temperature	-0.571
Shed Area Above	-0.789
Urban Cover	-0.413
Impervious Cover	-0.486

LWW WWTP

- Did Nitrate inputs actually decrease?
- What other water quality parameters changed?

Parameter	W	p
Phosphate	286.5	0.4108
Nitrate	421.5	<0.01
pH	243	0.8819
Conductivity	266.5	0.7148
Turbidity	210.5	0.3729
D.O.	195	0.2131
Water Temp.	292.5	0.3373

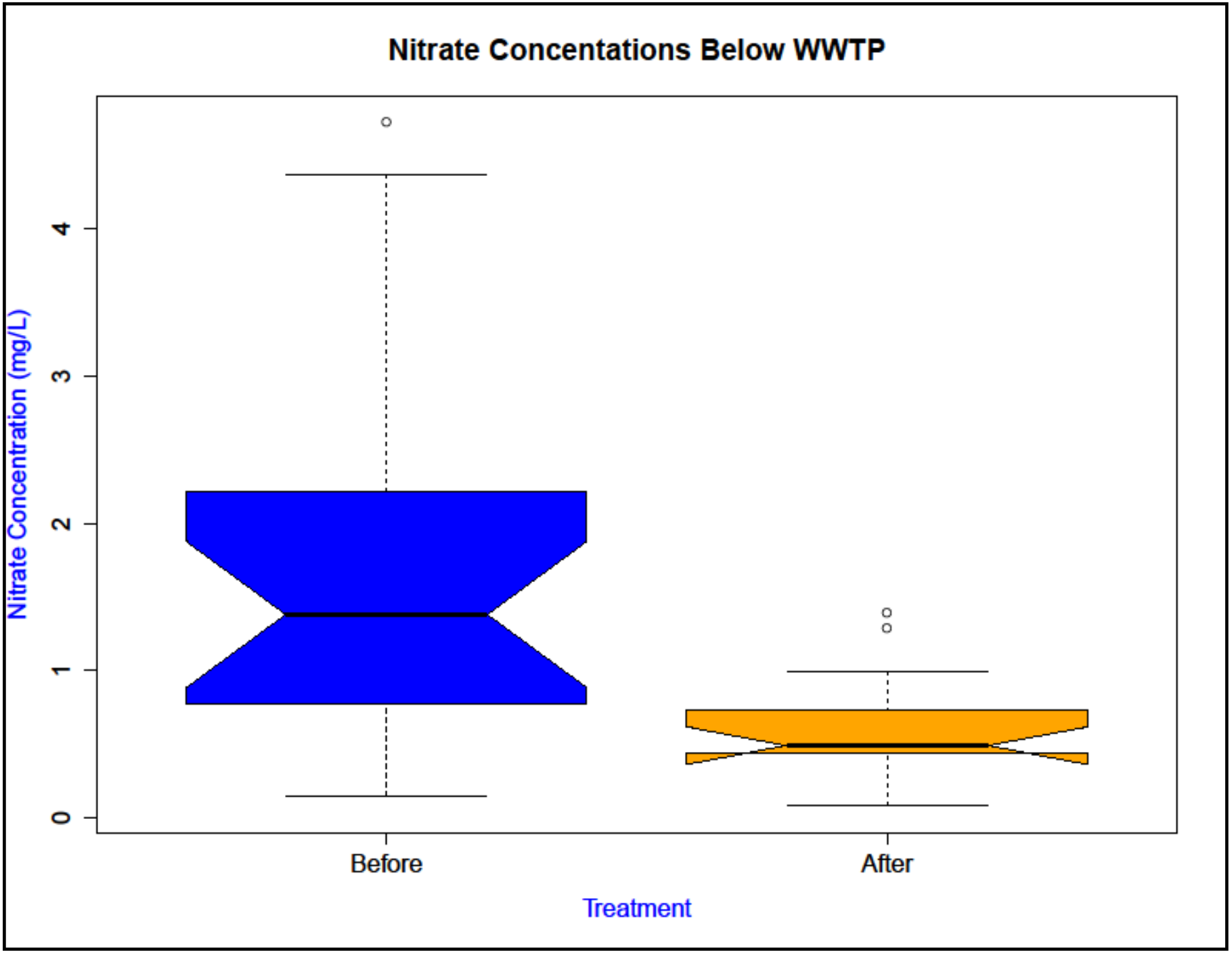
LWW WWTP

- Did Nitrate inputs actually decrease?
- What other water quality parameters changed?

Parameter	W	p
Phosphate	286.5	0.4108
Nitrate	**421.5**	**<0.01**
pH	243	0.8819
Conductivity	266.5	0.7148
Turbidity	210.5	0.3729
D.O.	195	0.2131
Water Temp.	292.5	0.3373

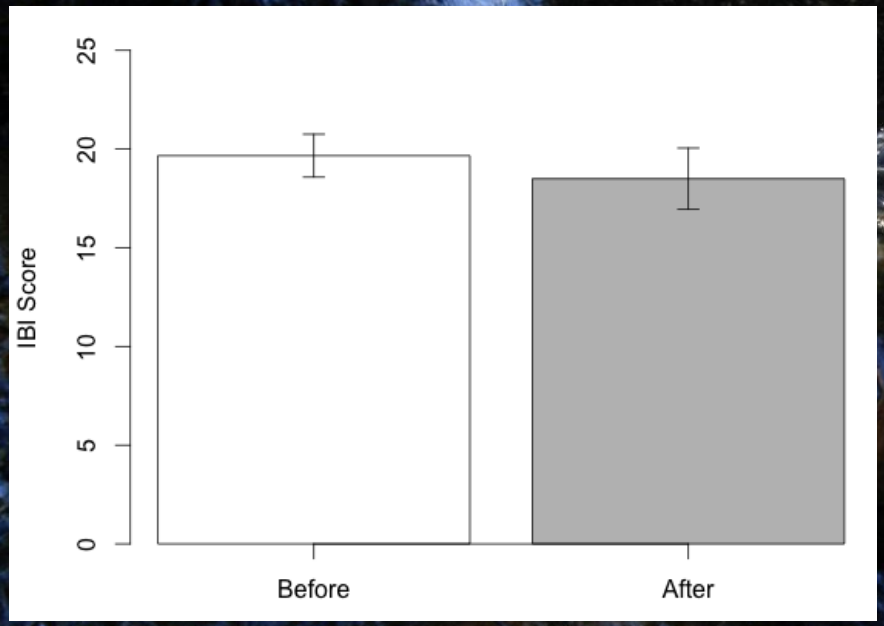
Reduced NO_3 from μ= 1.085 mg/L to 0.67 mg/L

(SE $\pm$ 0.18, z= -440.5, p= 0.03)


Nitrate Concentations Below WWTP
Nitrate Concentration (mg/L)
0
1
2
3
4
Before
After
Treatment

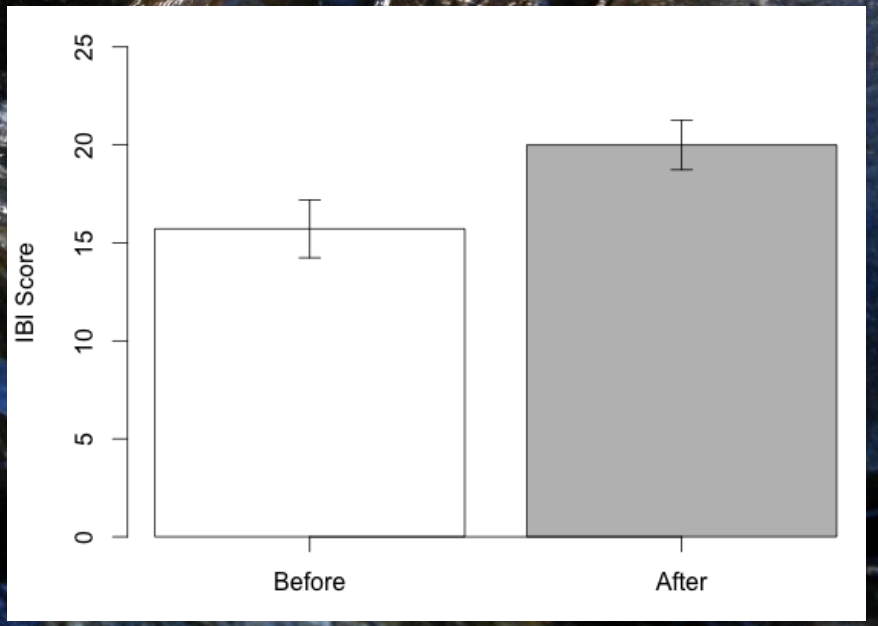
Site 8 seasonality after upgrade

June



P=0.5058

October



P=0.04972

LWW WWTP

MRPP of BMI Composition

Treatment

T = -0.890

A = 0.014

p = 0.173

Season/Treatment

T = -5.47

A = 0.151

p = <0.01

Before vs After	T	A	p
June	-1.93	0.07	0.04
October	-6.72	0.19	<0.01

LWW WWTP

MRPP of BMI Composition

Treatment

T = -0.890

Season/Treatment

T = -5.47

A = 0.151

p = <0.01

MRPP Statistics	T	A	p
Before	-2.21	0.12	0.02
8 vs 9	-2.32	0.13	0.02
8 vs 10	-1.74		
9 vs 10	-0.77		

Statistics	T	A	p
After	0.32	0.013	0.59
8 vs 9	-0.03	0.001	0.44
			0.01
			-0.06

Before vs After	T	A	p
June	-1.93	0.07	0.04
October	-6.72	0.19	<0.01

0.35

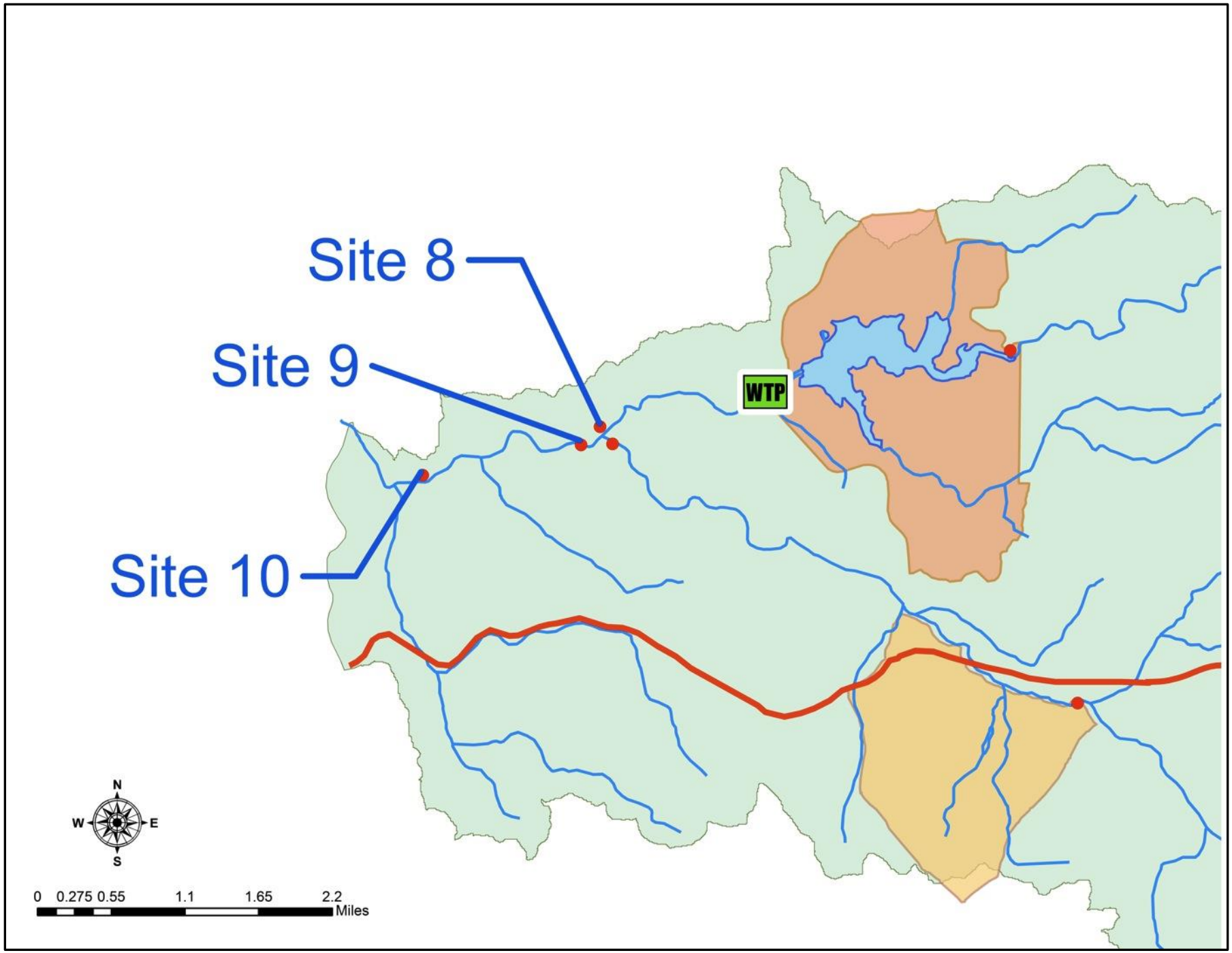
0.91

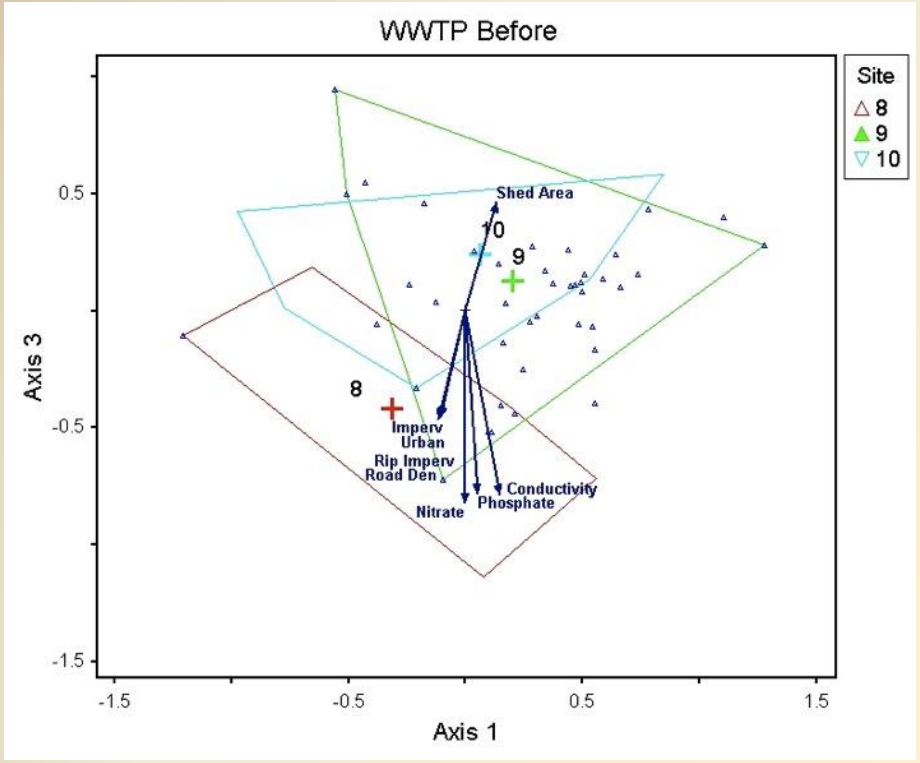
LWW WWTP

MRPP of BMI Composition

MRPP Statistics	T	A	p
Before	-2.21	0.12	0.02
8 vs 9	-2.32	0.13	0.02
8 vs 10	-1.74	0.11	0.06
9 vs 10	-0.77	0.04	0.21

MRPP Statistics	T	A	p
After	0.32	-0.013	0.59
8 vs 9	-0.03	0.001	0.44
8 vs 10	-0.26	0.01	0.35
9 vs 10	1.2	-0.06	0.91

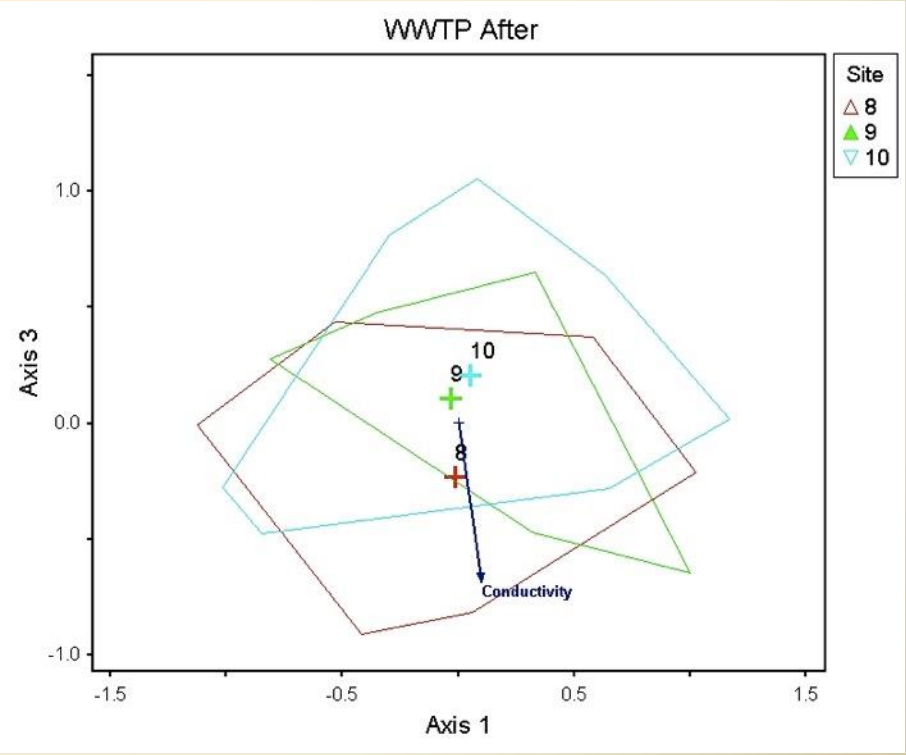

Site 8
Site 9
Site 10
WTP
N
W
E
S
0 0.275 0.55 1.1 1.65 2.2
Miles

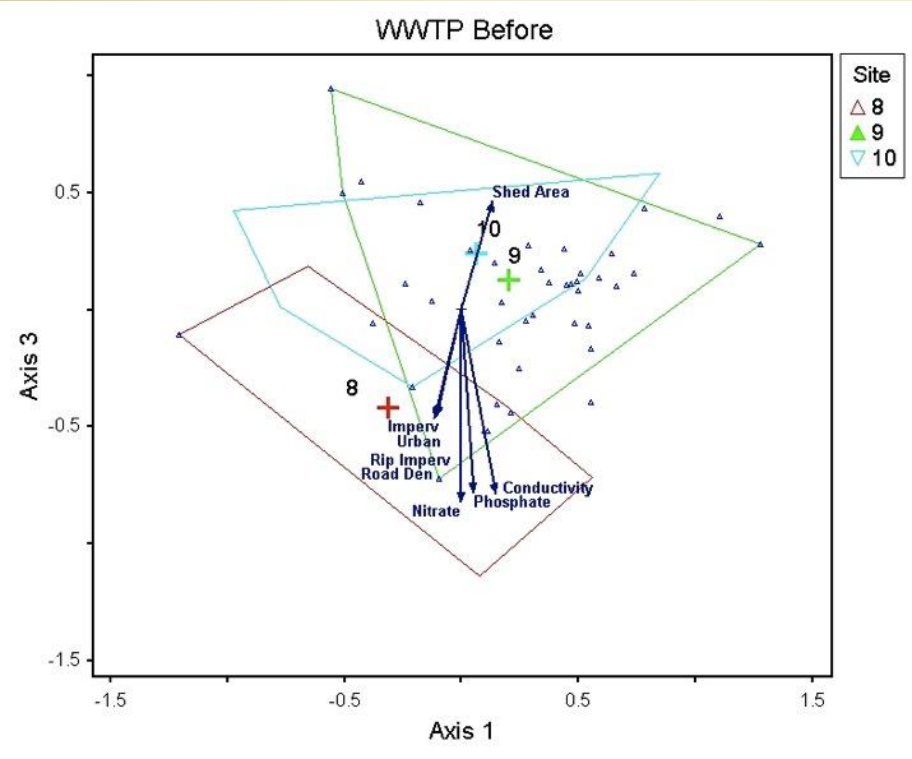


Stress: 13.19 **Instability: 0.00**
R^2: 0.769 **Axis 3 R^2: 0.330**

Stress: 13.19 **Instability: 0.00**
R^2: 0.769 **Axis 3 R^2: 0.211**

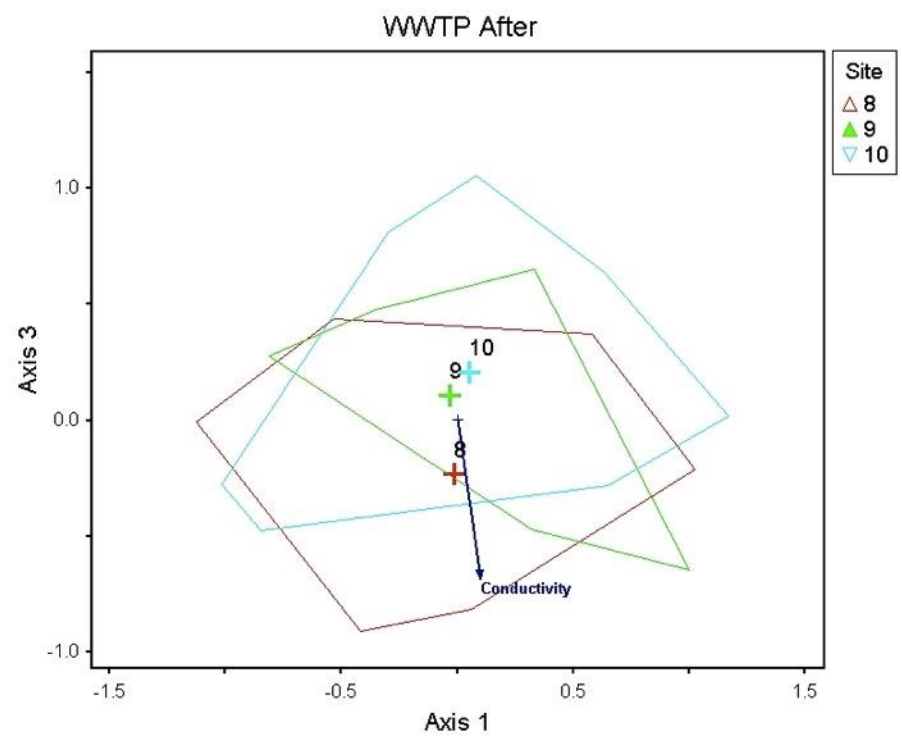
Correlations	r	τ
Phosphate	-0.723	-0.639
Nitrate	-0.740	-0.547
pH	0.369	0.326
Conductivity	-0.726	-0.484
Dissolved Oxygen	-0.289	-0.284





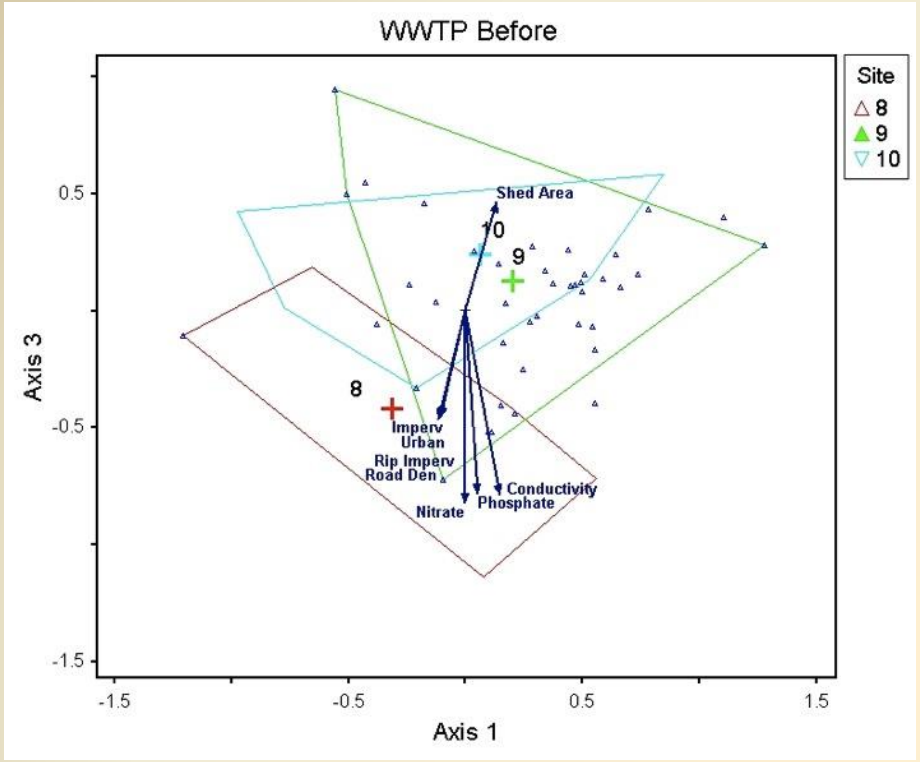
Stress: 13.19 **Instability: 0.00**
R^2: 0.769 **Axis 3 R^2: 0.211**

Correlations	r	τ
Phosphate	**-0.723**	**-0.639**
Nitrate	**-0.740**	**-0.547**
pH	0.369	0.326
Conductivity	**-0.726**	**-0.484**
Dissolved Oxygen	-0.289	-0.284



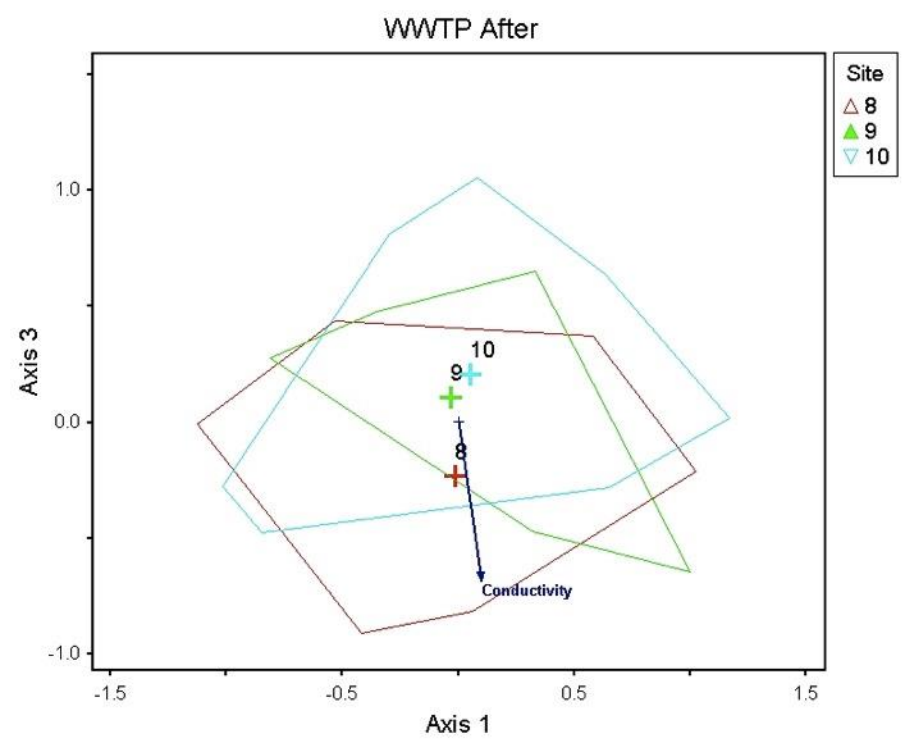
Stress: 13.19 **Instability: 0.00**
R^2: 0.769 **Axis 3 R^2: 0.330**

Correlations	r	τ
Phosphate	**-0.40**	**-0.26**
Nitrate	**-0.44**	**-0.33**
Conductivity	**-0.57**	**-0.29**
Turbidity	0.37	0.33
Water Temperature	0.20	0.03



Stress: 13.19 **Instability: 0.00**
R^2: 0.769 **Axis 3 R^2: 0.211**

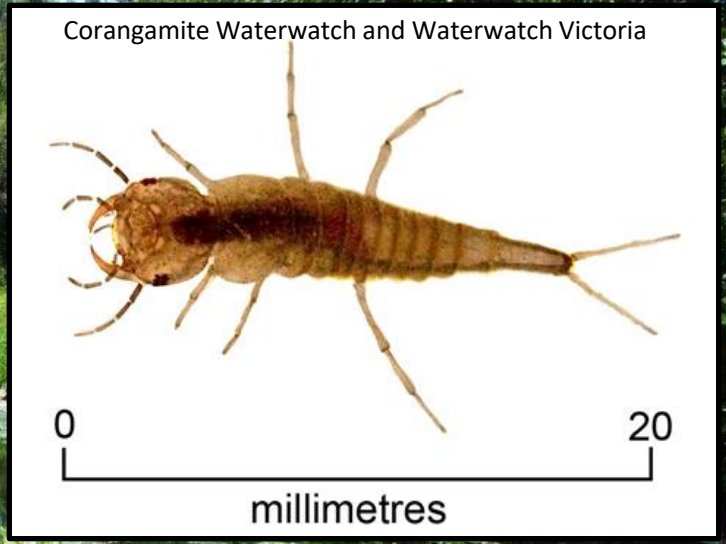
Stress: 13.19 **Instability: 0.00**
R^2: 0.769 **Axis 3 R^2: 0.330**



Indicator Species Analysis

Before

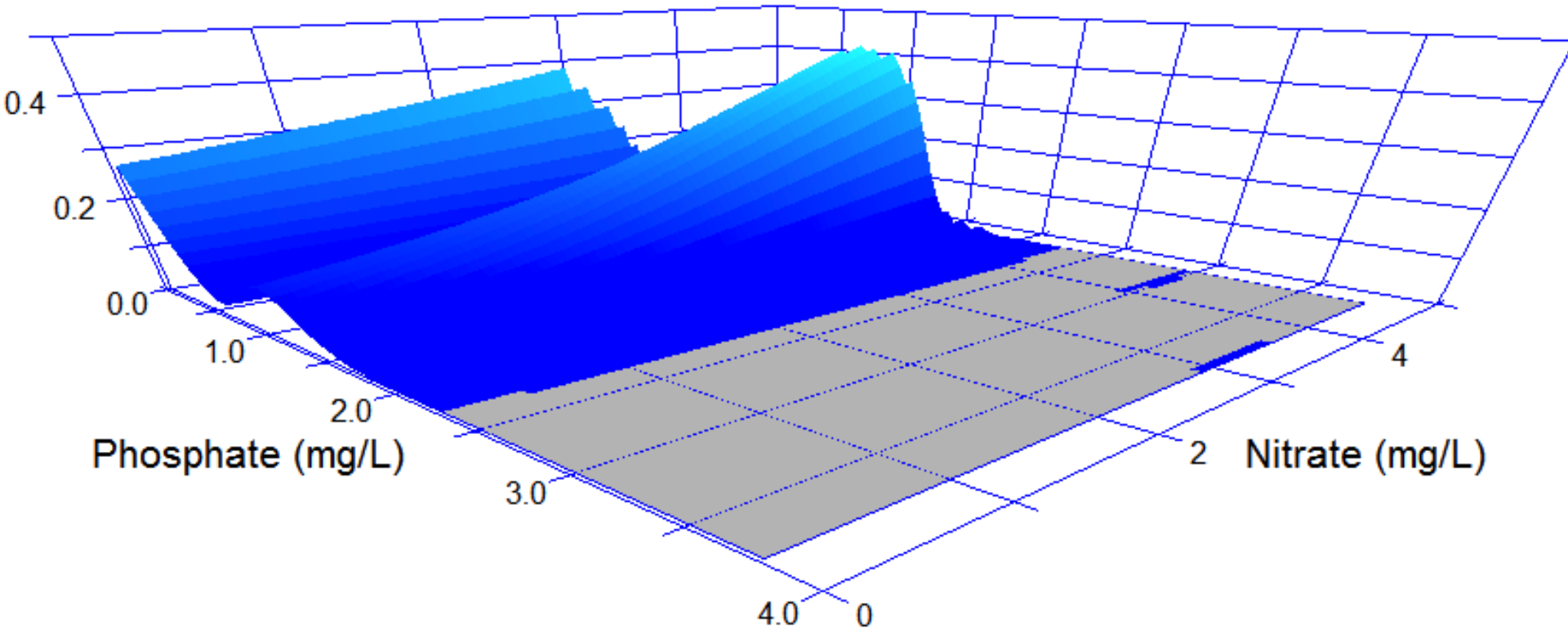
Coleoptera, Dytiscidae
"Water Tiger", Diving Beetle
IV = 20.0, p = 0.0340
Tolerance Value 5, Predator



After

Diptera, Tipulidae
Crane Flies
IV = 32.9, p = 0.0382
Tolerance Value 3, Shredder/Collector

Coleoptera, Dytiscidae



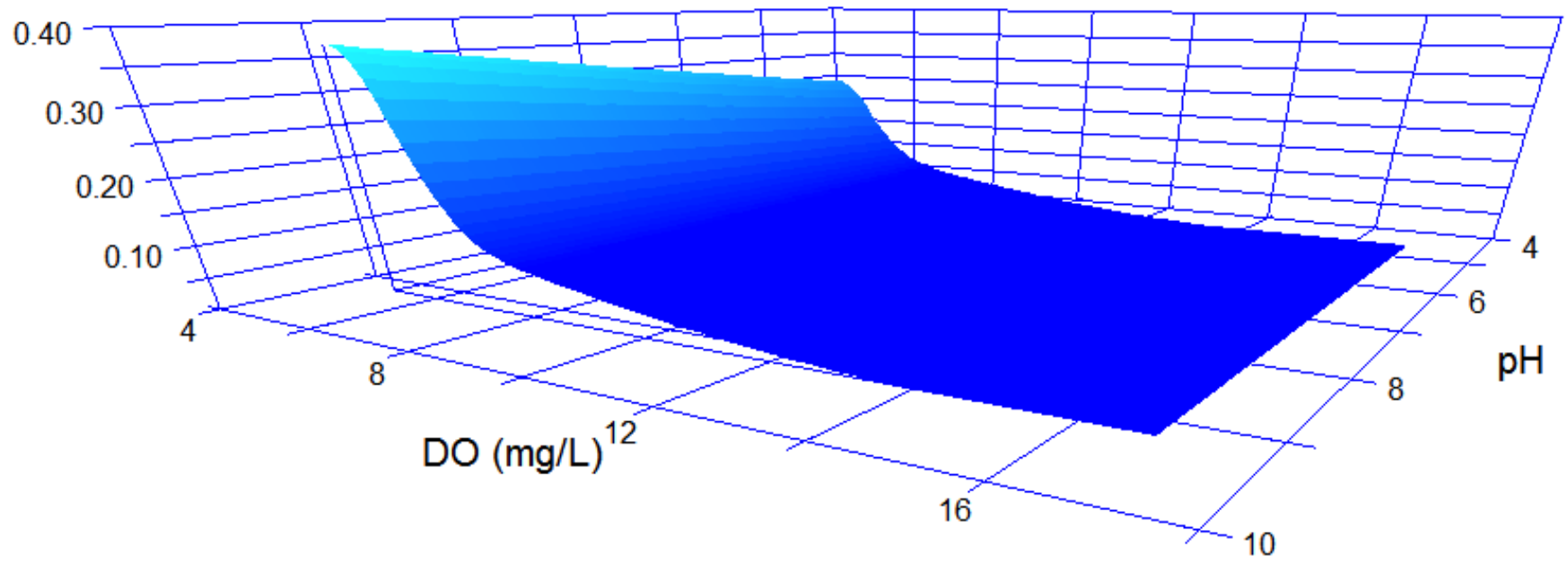
Before

IV = 20.0, p = 0.0340

Tolerance Value 5,

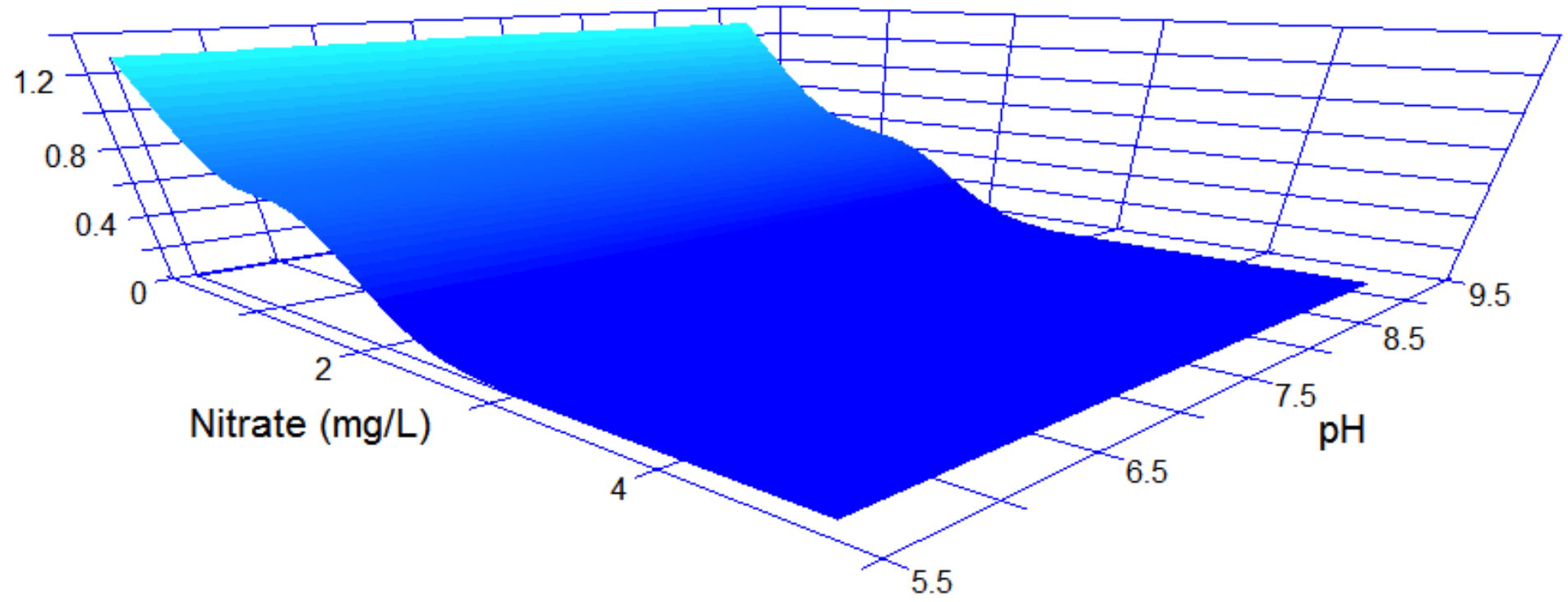
Predator

Coleoptera, Dytiscidae



Model for all observations

Diptera, Tipulidae

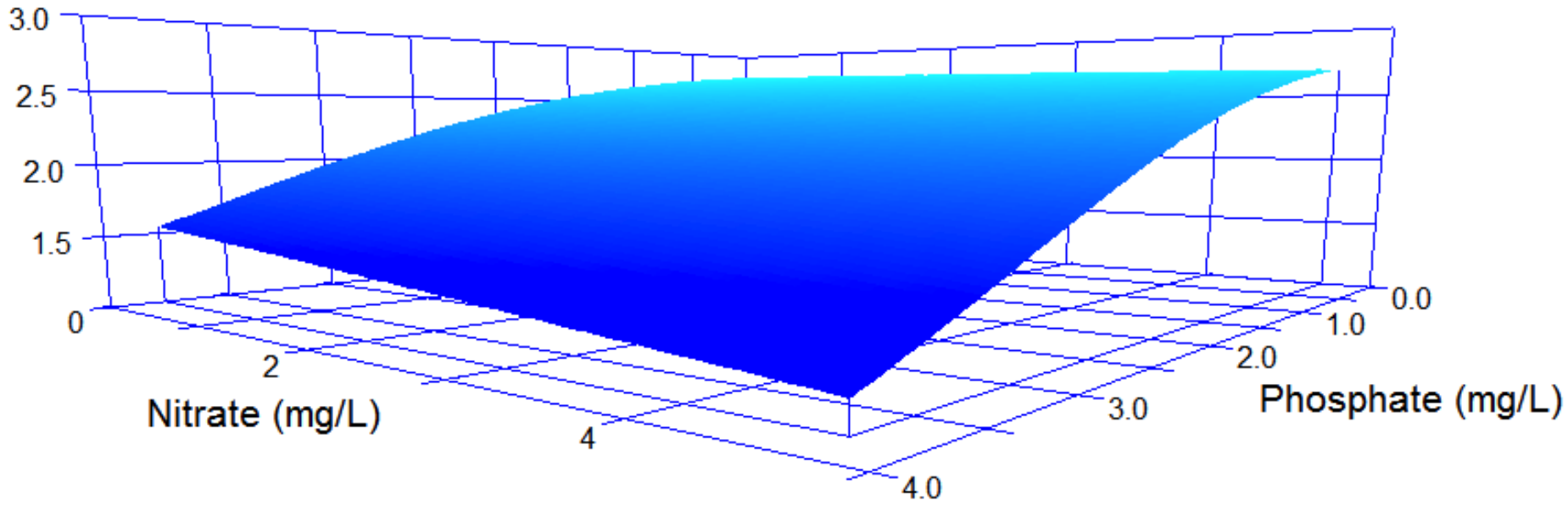


After

IV = 32.9, p = 0.0382

Tolerance Value 3,

Shredder/Collector



Model for all observations

Conclusions

- Nitrate load decreased below the WWTP
- Community composition changed downstream of the WWTP
  - IBI showed increase in score between Oct. before and after at site 8.
  - Multivariate analysis did show seasonality, and that site 8 changed the most significantly.

IBI / Multivariate Methods

	IBI	Multivariate
Change in community	✓	✓
Change in health	✓	
Environmental Correlations		✓
Changes through time	✓	+/-
Clear dissemination to Stakeholders	✓	

Note: Not a comparison! Simply shows that both methods should be used together.

But what does this all mean?

- Citizen-science data can successfully be used for robust bioassessments.
- Multi-metric methods can be amenable to smaller watersheds with varied disturbances conditionally.
- Family level IBI is sensitive enough for analysis.
- The “causal analysis” can also be used as a validation step for the IBI scores when using smaller datasets.

Future Directions

- Collect more data points at the reference sites
- Carry out more inclusive multivariate analysis including reference sites and IBI scores for more direct validation.
- Expand dataset to include citizen science data from other watersheds

Andy Bell:
Andy@sierrastreamsinstitute.org
Jeff Lauder:
Jeff@sierrastreamsinstitute.org
www.sierrastreamsinstitute.org

SIERRA Streams INSTITUTE