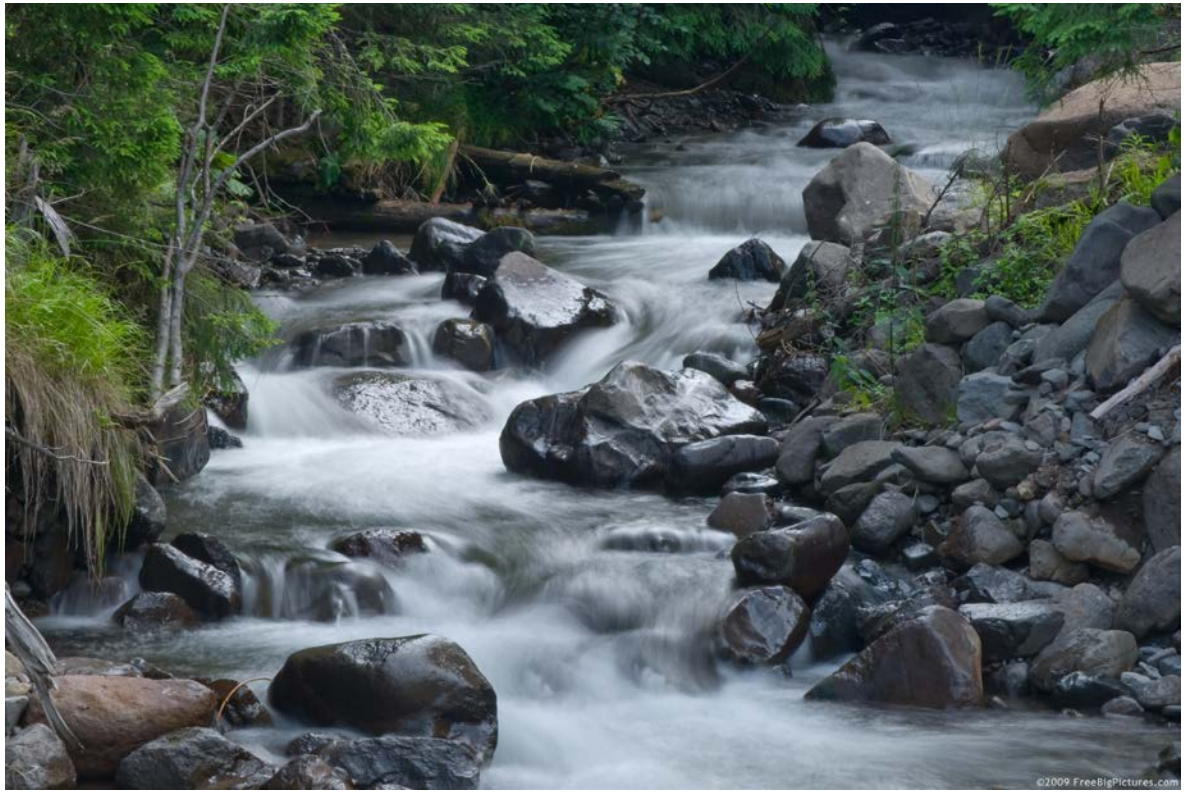
Using Biological Indicators to Assess Water Quality of Freshwater Streams

Dessie L. A. Underwood, Director
Stream Ecology and Assessment Laboratory

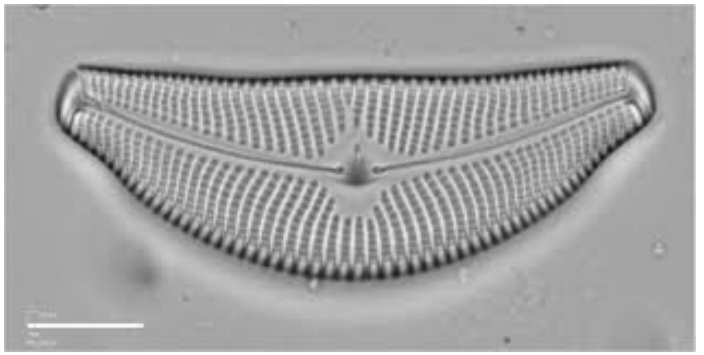
Interim Associate Dean for Research
College of Natural Sciences and Mathematics
California State University Long Beach

Water Quality



Assessing Water Quality

- Chemical analyses
- Biotic analyses
  - Microbes
  - Periphyton
  - Fish
  - Benthic Macroinvertebrates (BMIs)



Added Value of Biotic Measures

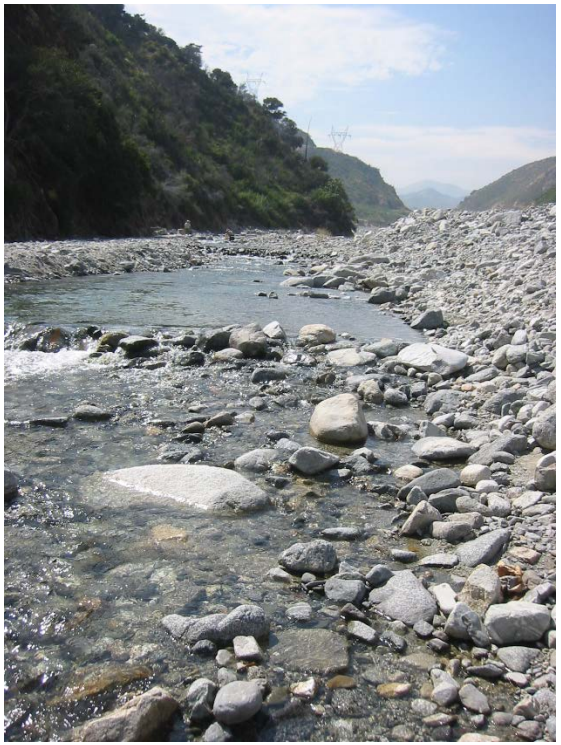
- Many BMIs are long-lived in the water and interact with the surrounding riparian habitat as adults
- Biological indicators of current and recent past impacts on a stream system
- Impacts upstream may be detected in the downstream BMI community

BMIs as Bioindicators

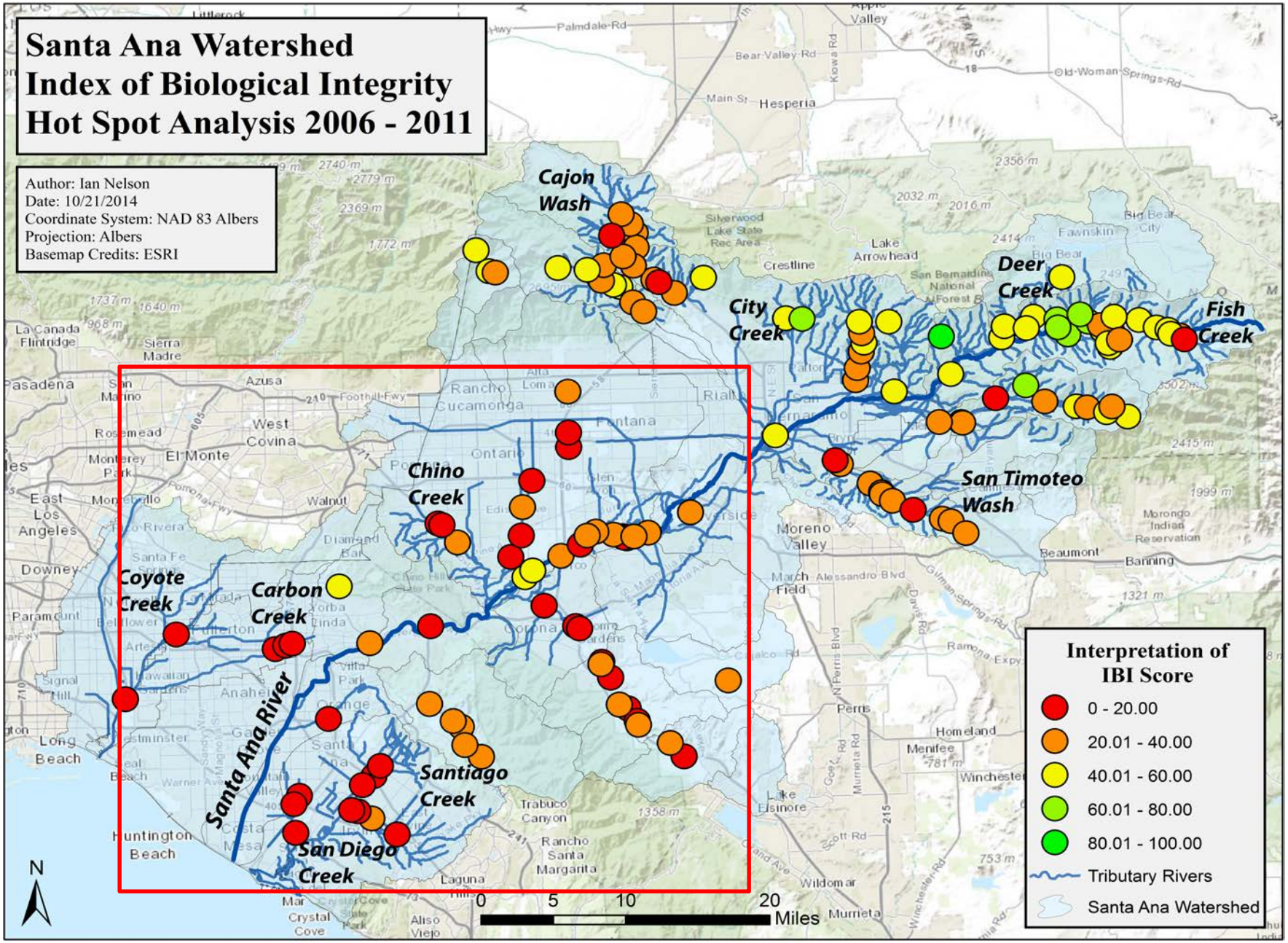
- Many organisms are sensitive to specific impacts
  - The presence or absence of certain organisms indicates specific conditions
- Complexity of the BMI community indicates the temporal stability of stream health
  - Trophic relationships
- A change in the BMI community over time implies a change within the system
- While we cannot measure every possible stressor, the state of the BMI community can act as the first alarm when stream health declines.

Southern California Index of Biotic Integrity (IBI)

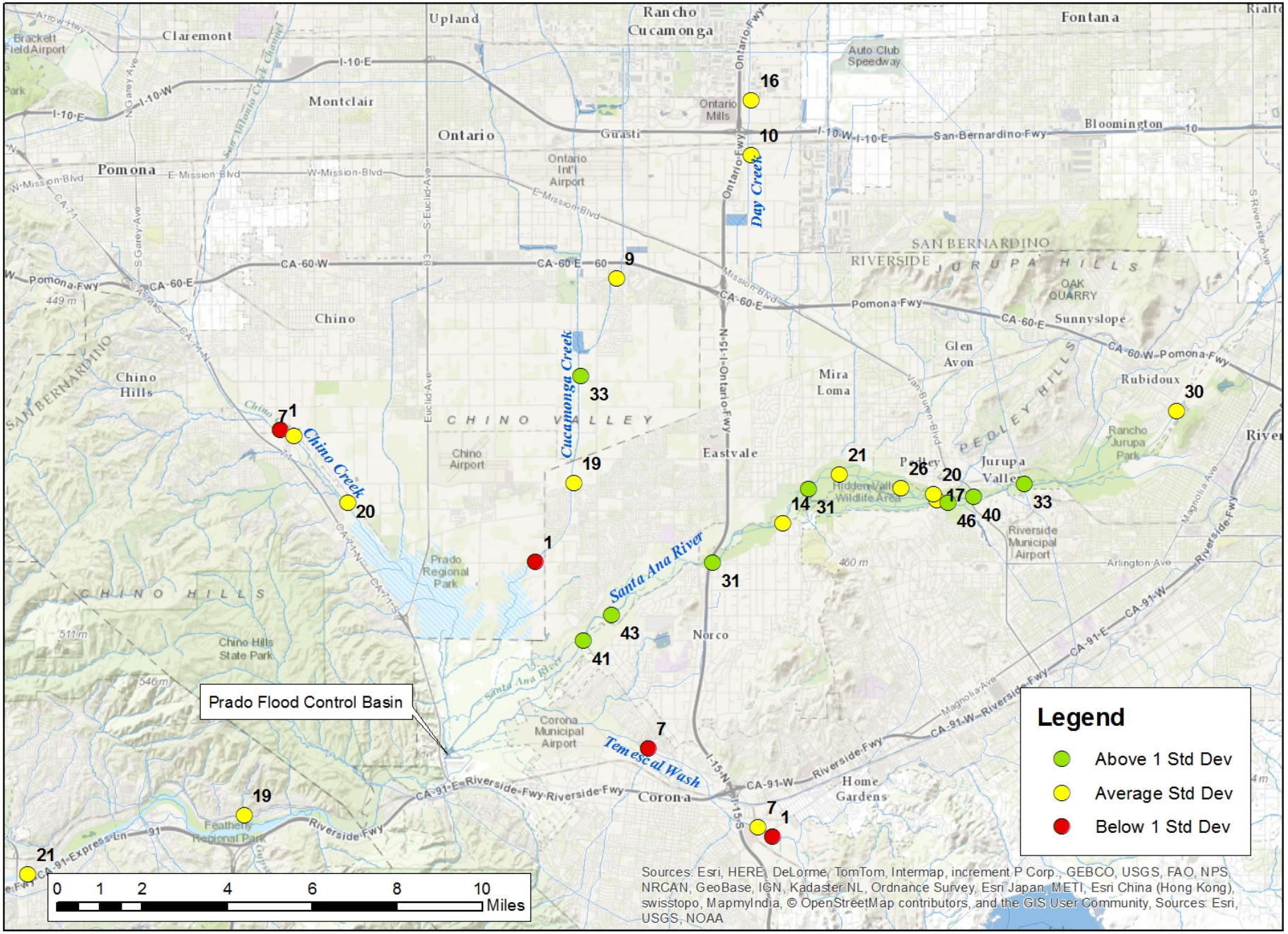
- Ode et al. 2005
- Based on 275 sites in Southern California Ecoregions 6 & 8
- Based on 500 count of BMIs
- Screened 61 candidate metrics
- Identified seven metrics for inclusion in the IBI



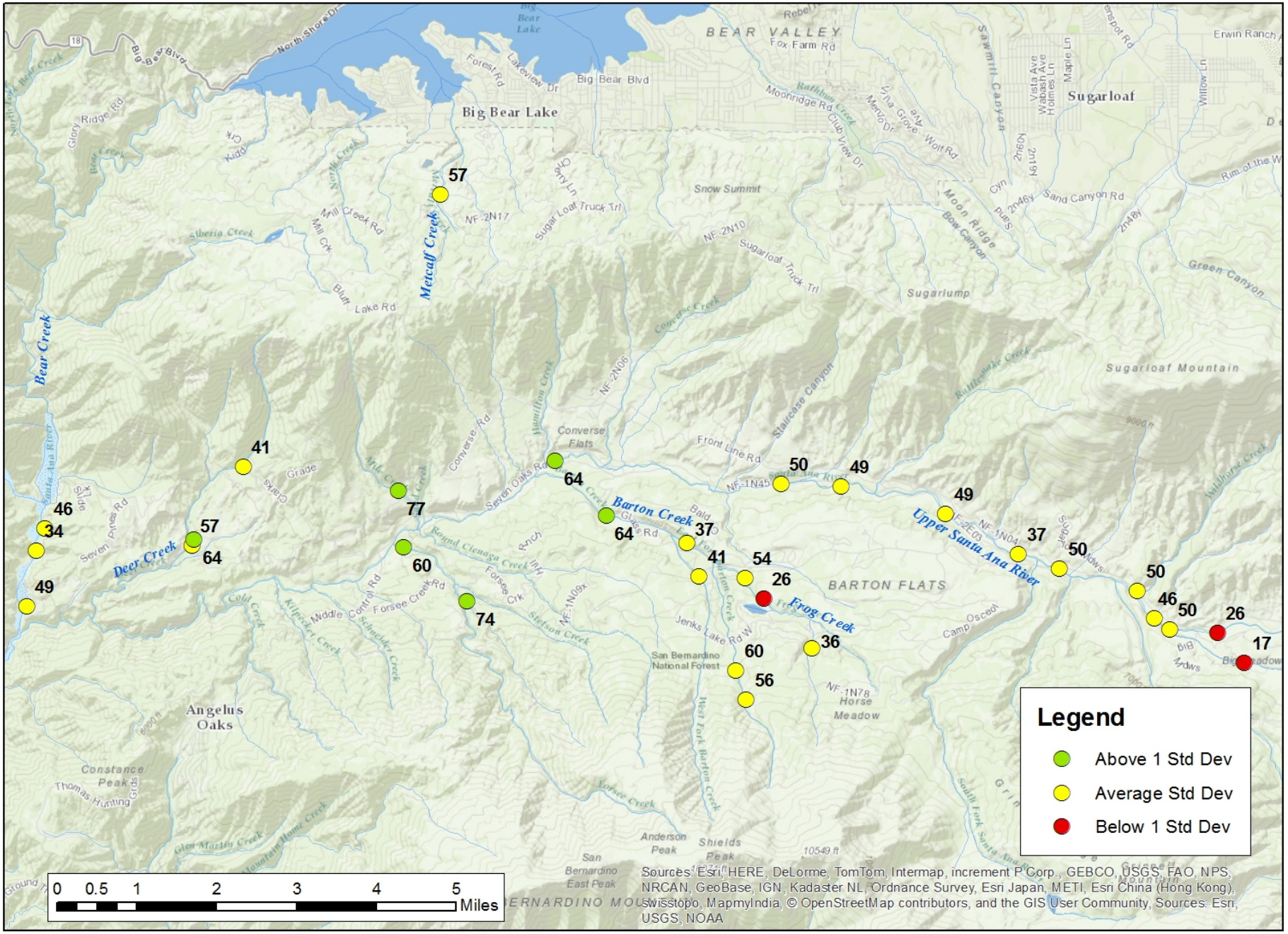
BMIs

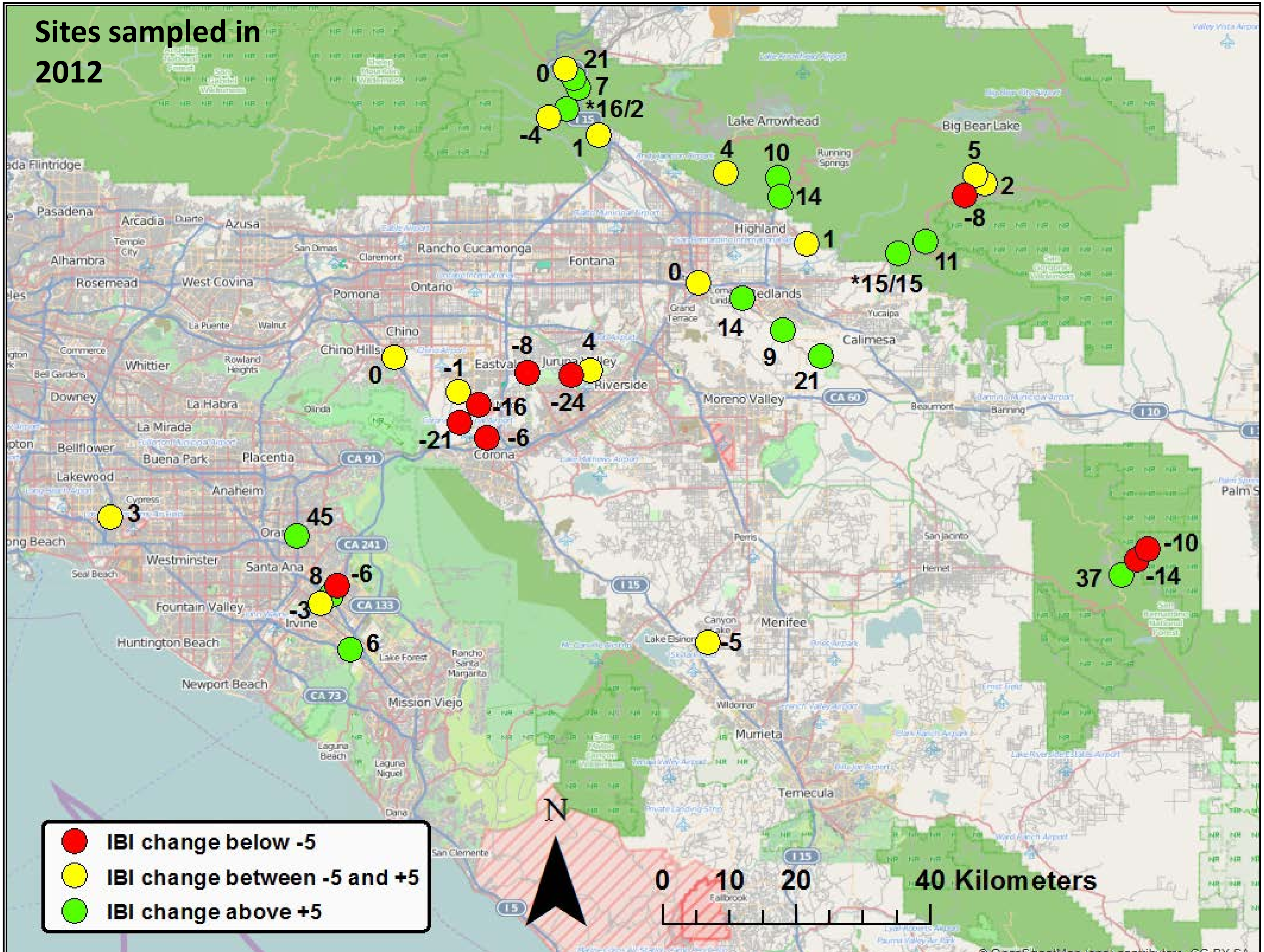

Santa Ana Watershed
Index of Biological Integrity
Hot Spot Analysis 2006 - 2011
Author: Ian Nelson
Date: 10/21/2014
Coordinate System: NAD 83 Albers
Projection: Albers
Basemap Credits: ESRI
Cajon Wash
City Creek
Deer Creek
Fish Creek
Chino Creek
San Timoteo Wash
Coyote Creek
Carbon Creek
Santa Ana River
Santiago Creek
San Diego Creek
Interpretation of IBI Score
0 - 20.00
20.01 - 40.00
40.01 - 60.00
60.01 - 80.00
80.01 - 100.00
Tributary Rivers
Santa Ana Watershed
N
0 5 10 20
Miles

Adjusted IBI Scores Upstream of Prado Flood Control Basin (2006-2011)

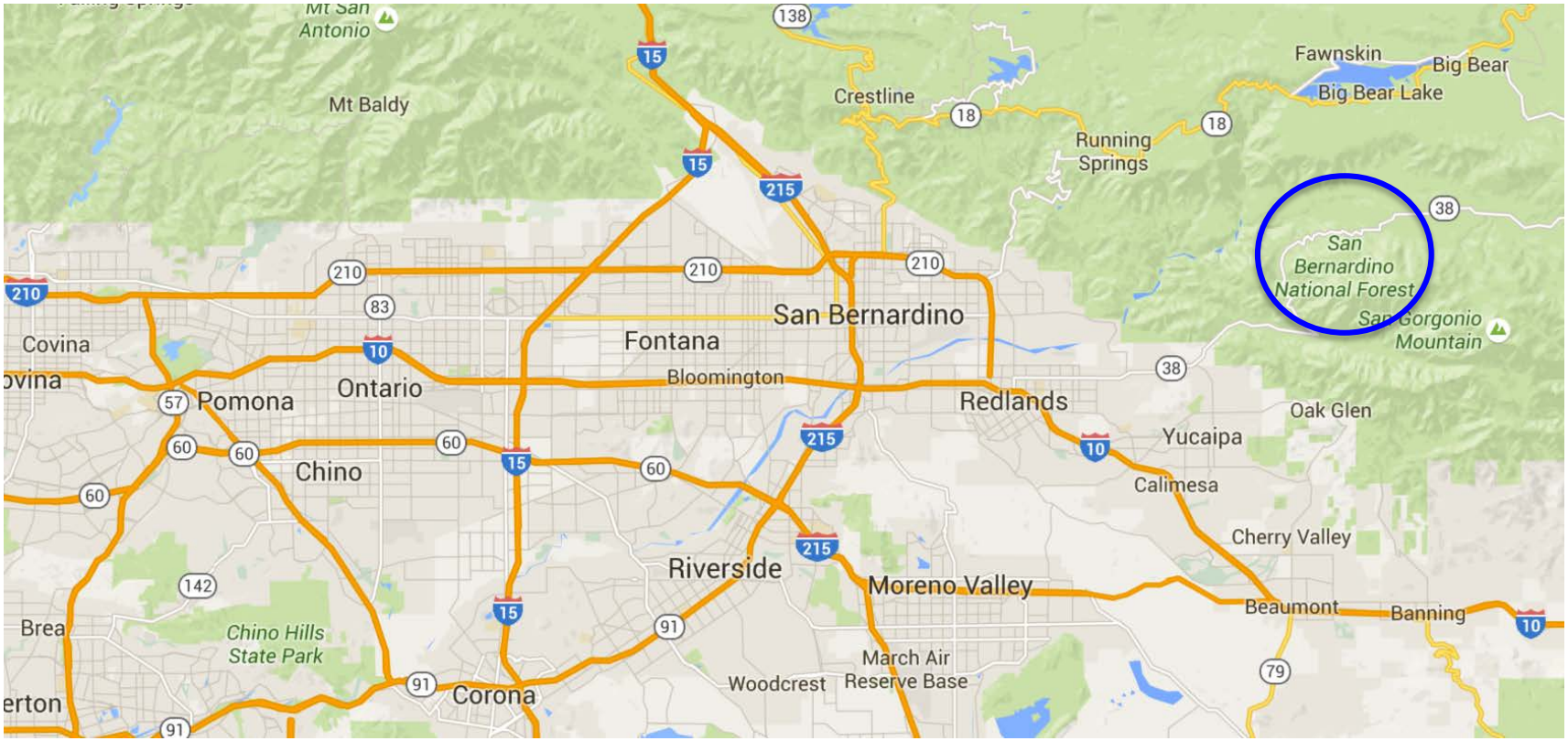


Adjusted IBI Scores in the Upper Santa Ana River Watershed (2006-2011)




Sites sampled in 2012
IBI change below -5
IBI change between -5 and +5
IBI change above +5
0 10 20 40 Kilometers
N
21
0
7
*16/2
-4
1
4
10
14
5
2
-8
1
11
*15/15
0
14
9
21
-8
4
0
-1
-16
-24
-21
-6
3
45
8
-6
-3
6
-5
-10
37
-14
© OpenStreetMap (and) contributors, CC-BY-SA

Cold Creek


Mt San Antonio
Mt Baldy
Crestline
Fawnskin
Big Bear
Big Bear Lake
Running Springs
San Bernardino National Forest
San Gorgonio Mountain
Covina
Pomona
Ontario
Fontana
San Bernardino
Bloomington
Redlands
Oak Glen
Yucaipa
Calimesa
Cherry Valley
Chino
Riverside
Moreno Valley
Beaumont
Banning
Brea
Chino Hills State Park
Corona
Woodcrest
March Air Reserve Base

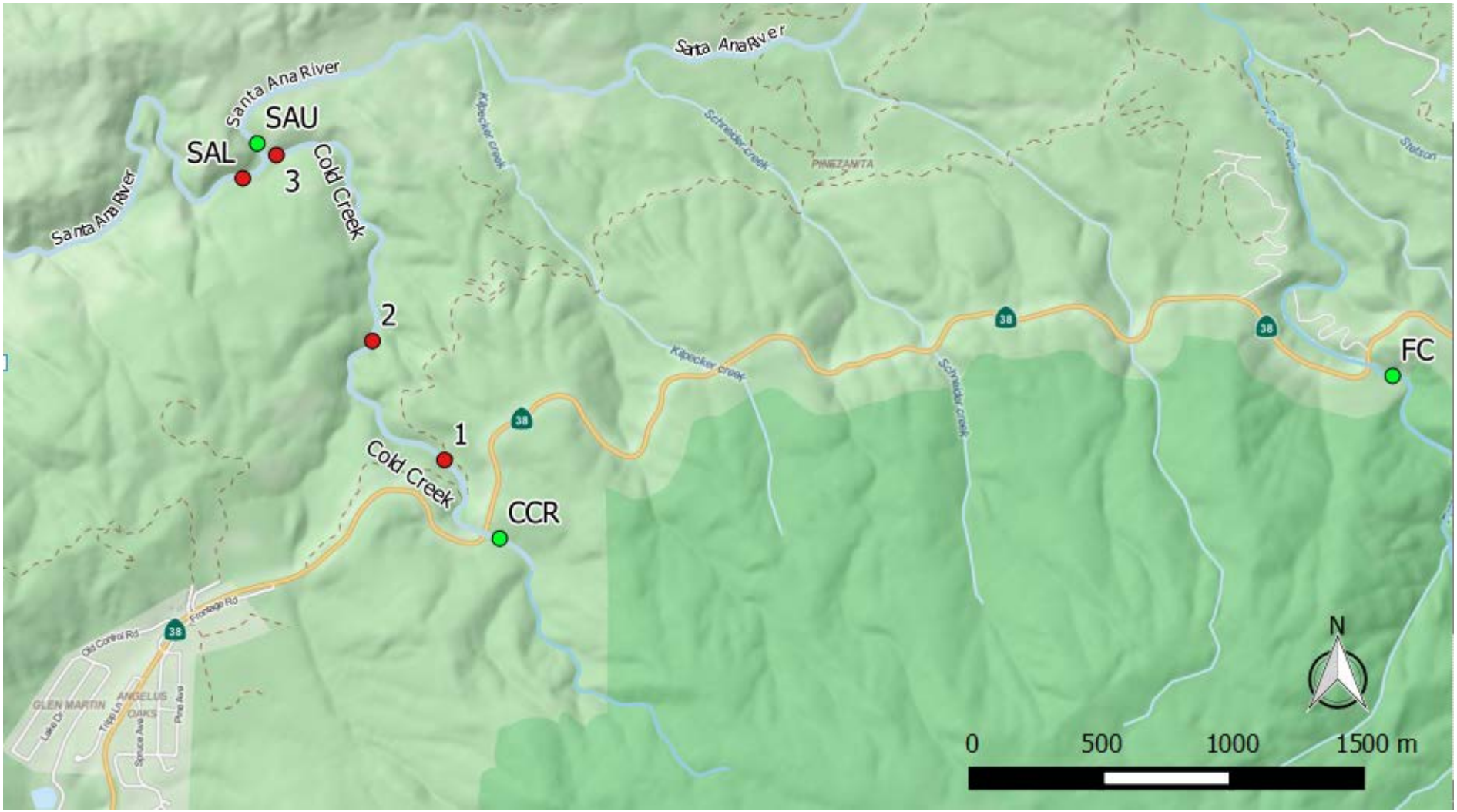
Cold Creek Fuel Spill

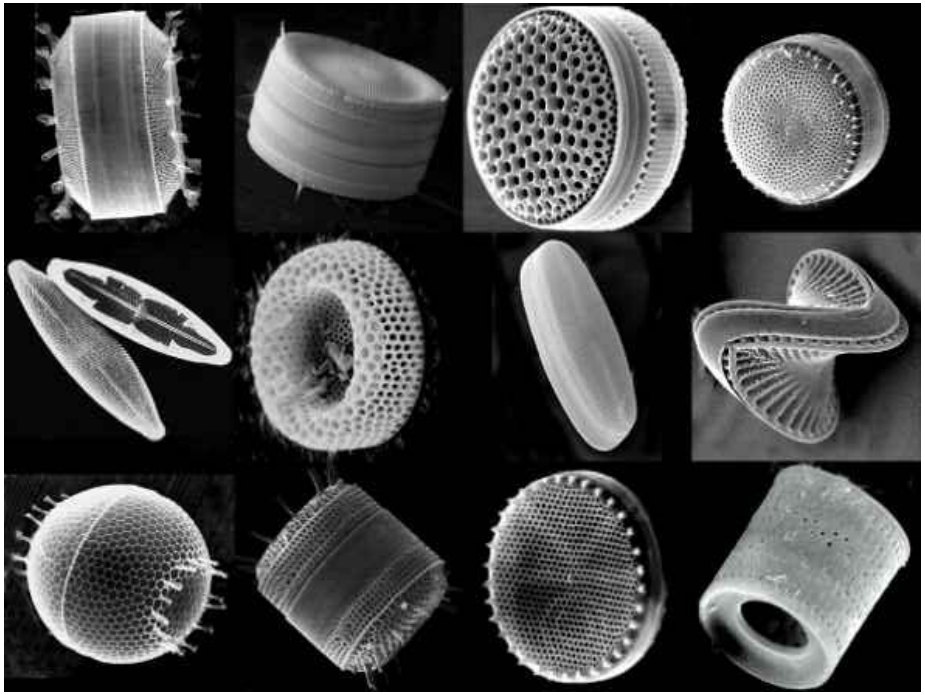
- Cold Creek a small tributary of the Santa Ana River
- Relatively large spill, April 2013
  - 6,435 liters of diesel fuel and 14,558 liters of gasoline spilled into Cold Creek
- Clean-up response 24 hours after the spill
- Bioassessment contracted to the Stream Ecology and Assessment Laboratory at CSULB, Nov 2013

Clean-up efforts

- Containment dams with absorbent booms and pads
  - 0.2, 0.4, and 1.2 km downstream from the spill site
- Flushing of diesel and gasoline from the creek bed into containment dams
- Vacuuming of diesel and gasoline at the first containment dam
- Absorbent booms and pads changed out at the lower two containment dams

Cold Creek Sampling Design



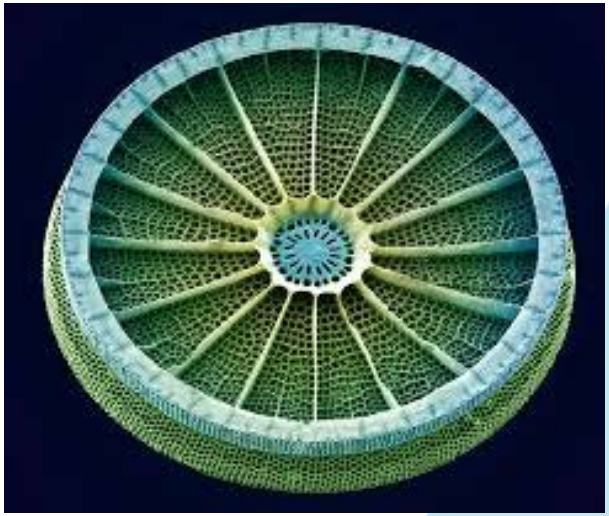


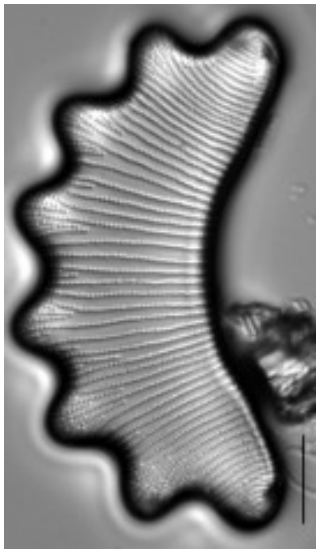
Biological Indicators

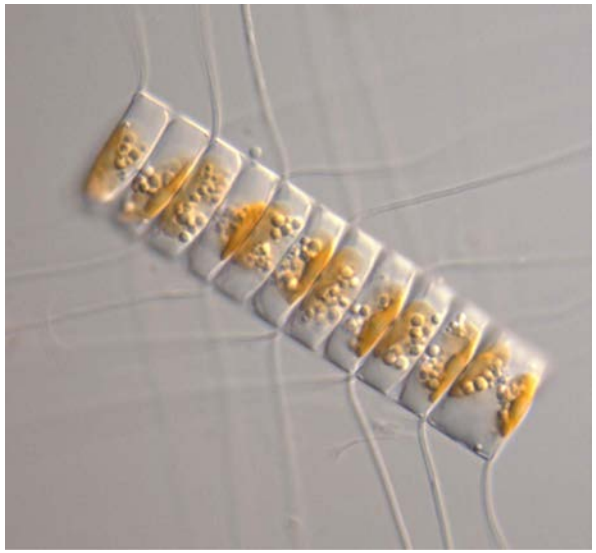
Diatoms

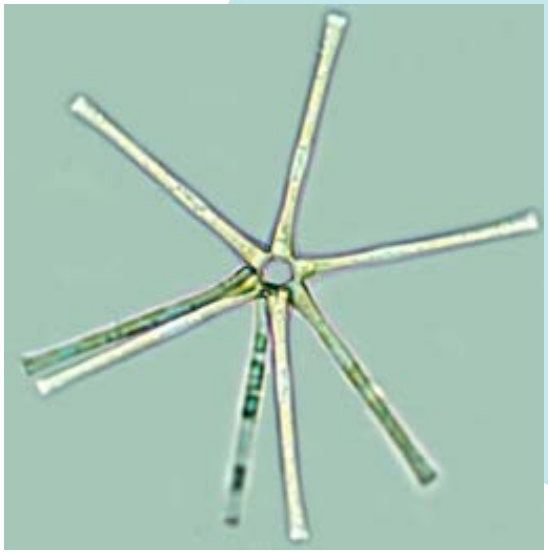
Benthic Macroinvertebrates (BMIs)

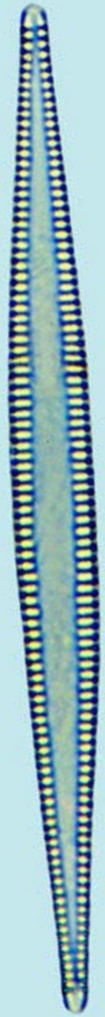
Diatoms!!



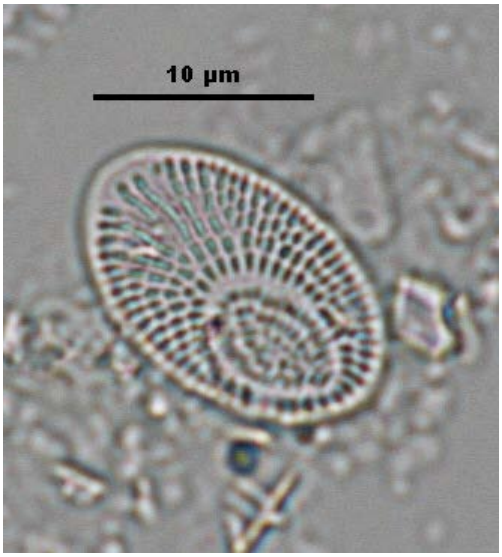


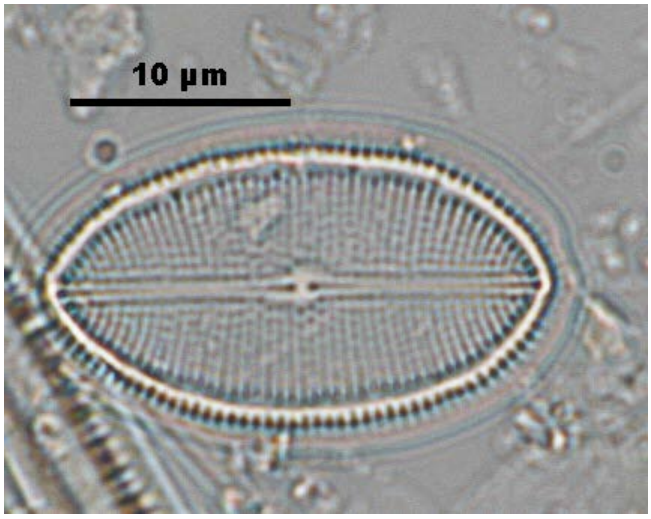


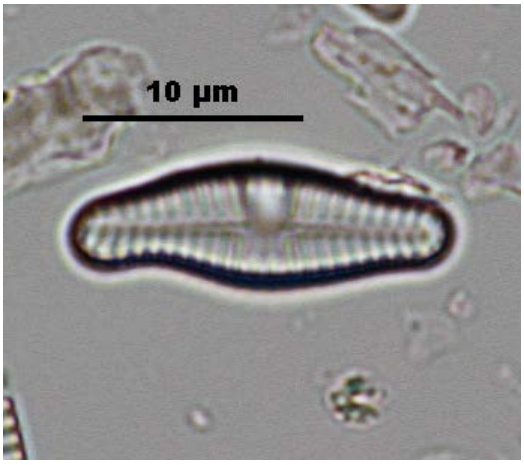


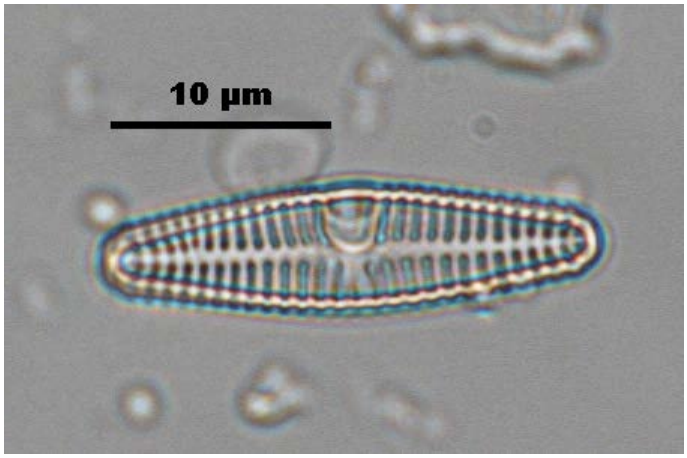


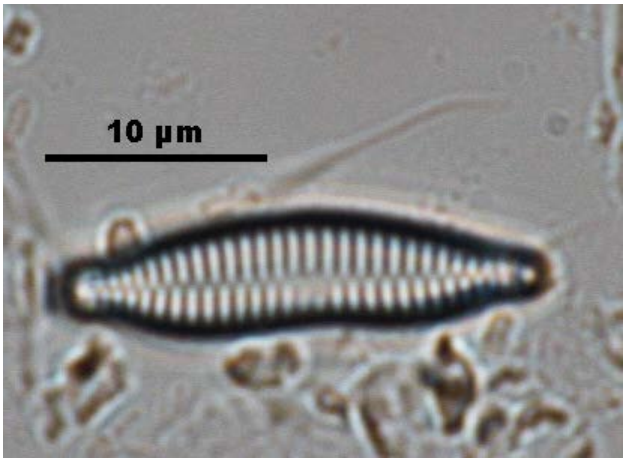
Diatomaceous Earth

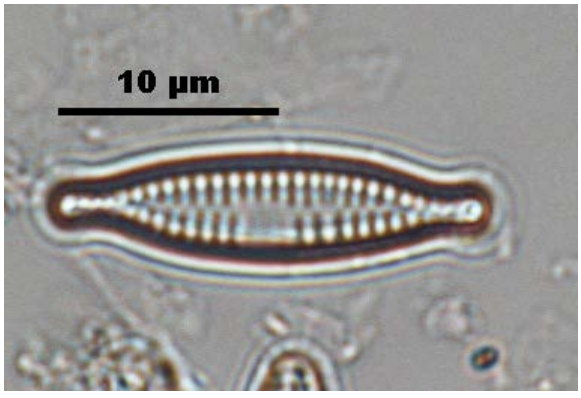

10 µm

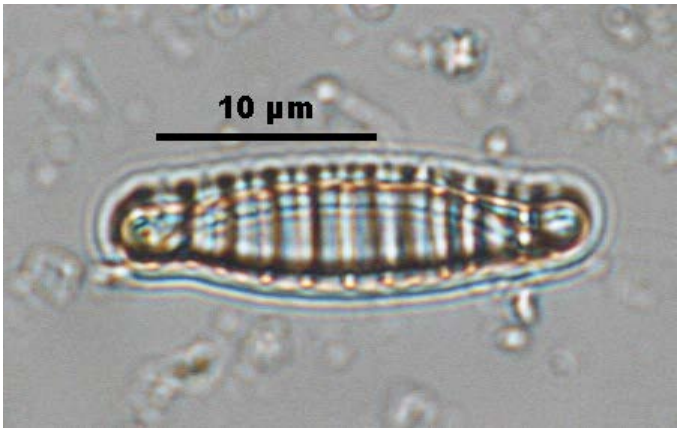

10 µm

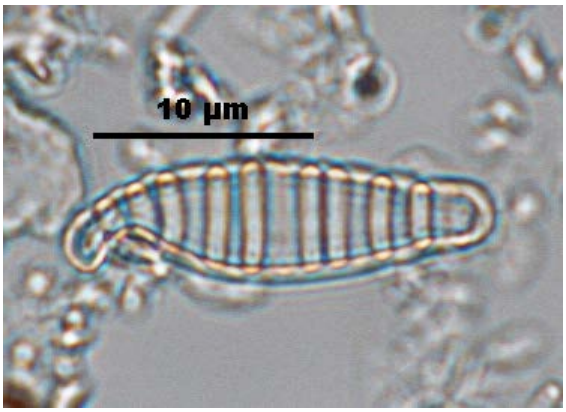

10 µm

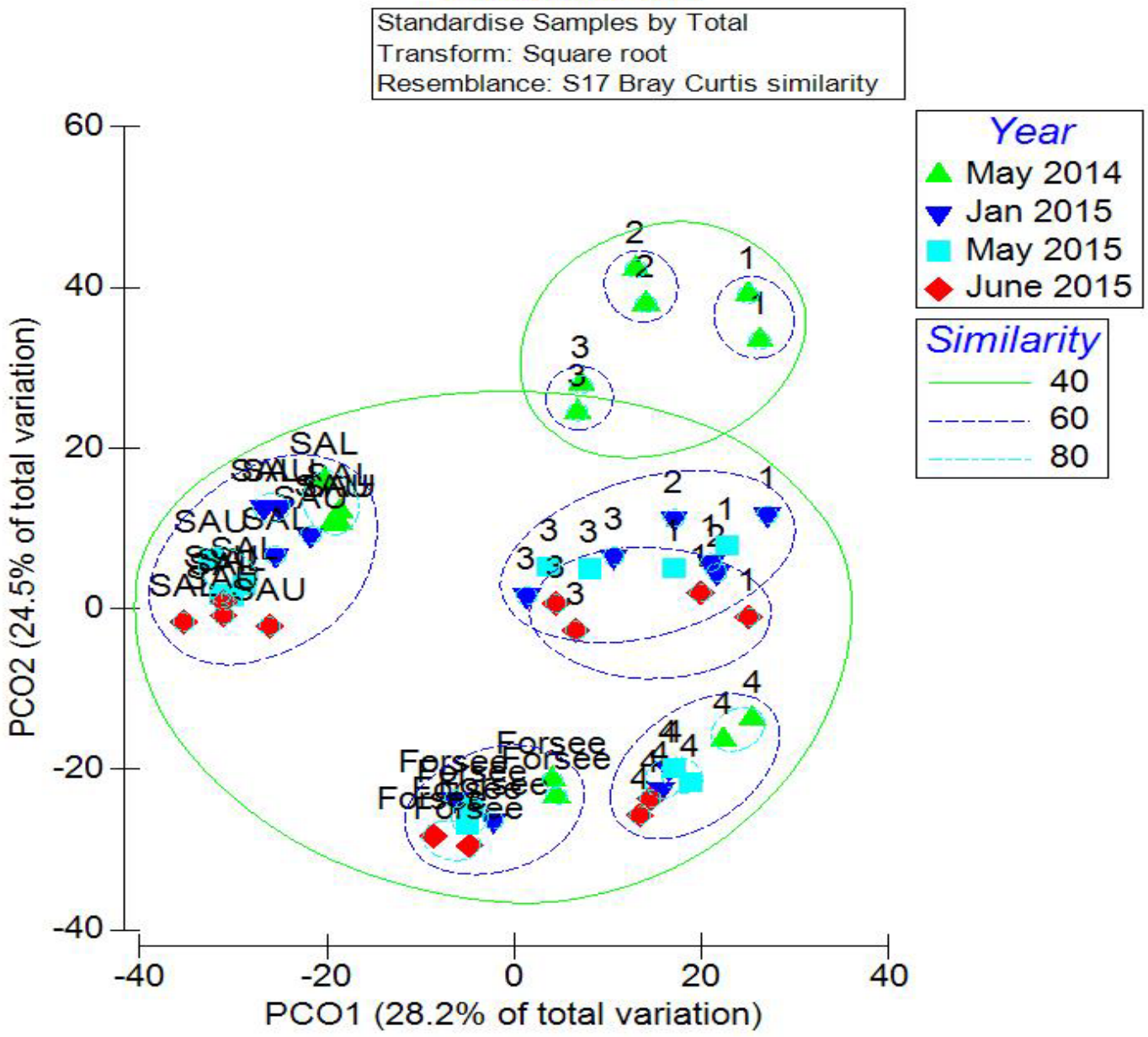

10 µm

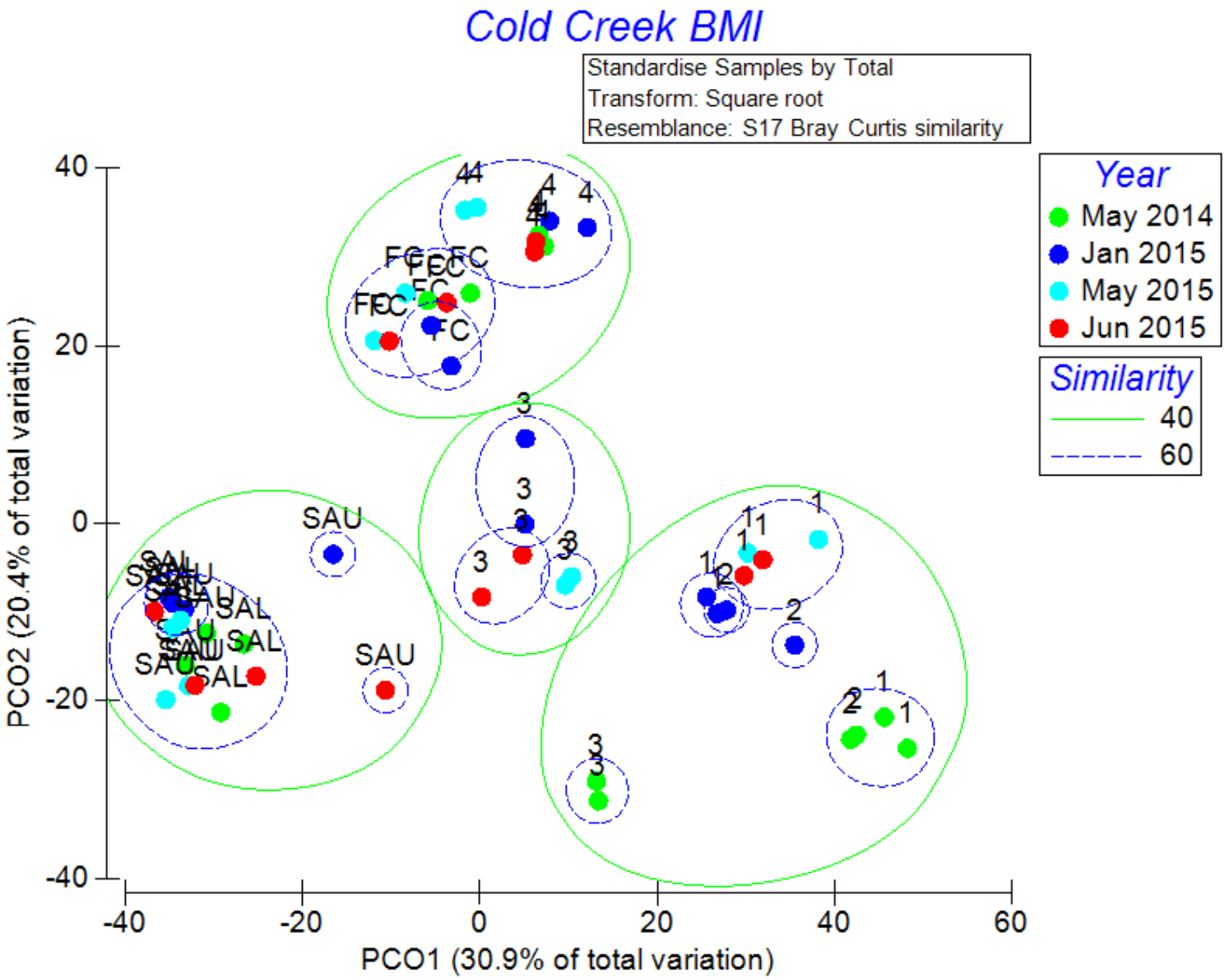

10 µm


10 µm


10 µm


10 µm


Diatoms SA
Standardise Samples by Total
Transform: Square root
Resemblance: S17 Bray Curtis similarity
Year
May 2014
Jan 2015
May 2015
June 2015
Similarity
40
60
80
PCO2 (24.5% of total variation)
PCO1 (28.2% of total variation)
60
40
20
0
-20
-40
-40
-20
0
20
40
SAL
SAU
Forsee


Cold Creek BMI
Standardise Samples by Total
Transform: Square root
Resemblance: S17 Bray Curtis similarity
Year
May 2014
Jan 2015
May 2015
Jun 2015
Similarity
40
60
PCO2 (20.4% of total variation)
PCO1 (30.9% of total variation)
40
20
0
-20
-40
-40
-20
0
20
40
60
SAU
SAL
FC
1
2
3
4

Acknowledgements

SWAMP
Surface Water Ambient Monitoring Program

Maryanne Horton and Raquel Santos (CNSM)
Stream Ecology and Assessment Laboratory
Past Graduate Students
Marty Lewis and Lauren Fah
Current Graduate Students
Robert Esquivel, Matt Schliebe, Eilleen Salas
Jose Caprile, Fritz Rieman
Undergraduate Students
Sergio Mendoza, Brina Kamae

Heather Boyd, Santa Ana Regional Water Quality Control Board

Nationwide®

CALIFORNIA
Water Boards
STATE WATER RESOURCES CONTROL BOARD
REGIONAL WATER QUALITY CONTROL BOARDS

Table 3. Scoring ranges for seven component metrics in the SoCal B-IBI

Metric score	Coleoptera taxa (all sites)	EPT taxa		Predator taxa (all sites)	% Collector individuals		% Intolerant individuals		% Noninsect taxa (all sites)	% Tolerant taxa (all sites)
		6	8		6	8	6	8		
10	>5	>17	>18	>12	0–59	0–39	25–100	42–100	0–8	0–4
9		16–17	17–18	12	60–63	40–46	23–24	37–41	9–12	5–8
8	5	15	16	11	64–67	47–52	21–22	32–36	13–17	9–12
7	4	13–14	14–15	10	68–71	53–58	19–20	27–31	18–21	13–16
6		11–12	13	9	72–75	59–64	16–18	23–26	22–25	17–19
5	3	9–10	11–12	8	76–80	65–70	13–15	19–22	26–29	20–22
4	2	7–8	10	7	81–84	71–76	10–12	14–18	30–34	23–25
3		5–6	8–9	6	85–88	77–82	7–9	10–13	35–38	26–29
2	1	4	7	5	89–92	83–88	4–6	6–9	39–42	30–33
1		2–3	5–6	4	93–96	89–94	1–3	2–5	43–46	34–37
0	0	0–1	0–4	0–3	97–100	95–100	0	0–1	47–100	38–100

Note: Three metrics have separate scoring ranges for the two Omernik Level III ecoregions in southern coastal California region (6 = chaparral and oak woodlands, 8 = Southern California mountains).

Example for a site in Ecoregion 6

Coleoptera	EPT	Predator	%Collectors	%Intolerant	%Noninsect	%Tolerant
5	11	7	89	7	7	2
8	6	4	2	3	10	10

These individual metric scores are summed = 43.
This value is out of 70 and represents the raw score.
The raw scored is adjusted to a value between 0 and 100. 43 X 10/7 = 61

Bray-Curtis Similarity Indices

$$S = 100\left(1 - \frac{\sum |y_{i1} - y_{i2}|}{\sum y_{i1} + \sum y_{i2}}\right)$$

	Site 1	Site 2	Site 3
Sp. A	10	10	10
Sp. B	50	5	5
Sp. C	3	30	0
Sp. D	1	40	1
Sp. E	7	70	0

	Site 1	Site 2	abs (y1-y2)	
Sp. A	10	10	0	
Sp. B	50	5	45	
Sp. C	3	30	27	
Sp. D	1	40	39	
Sp. E	7	70	63	
sumYi	71	155	174	23.01

	Site 1	Site 2
Site 2	23.01	
Site 3	36.78	18.71