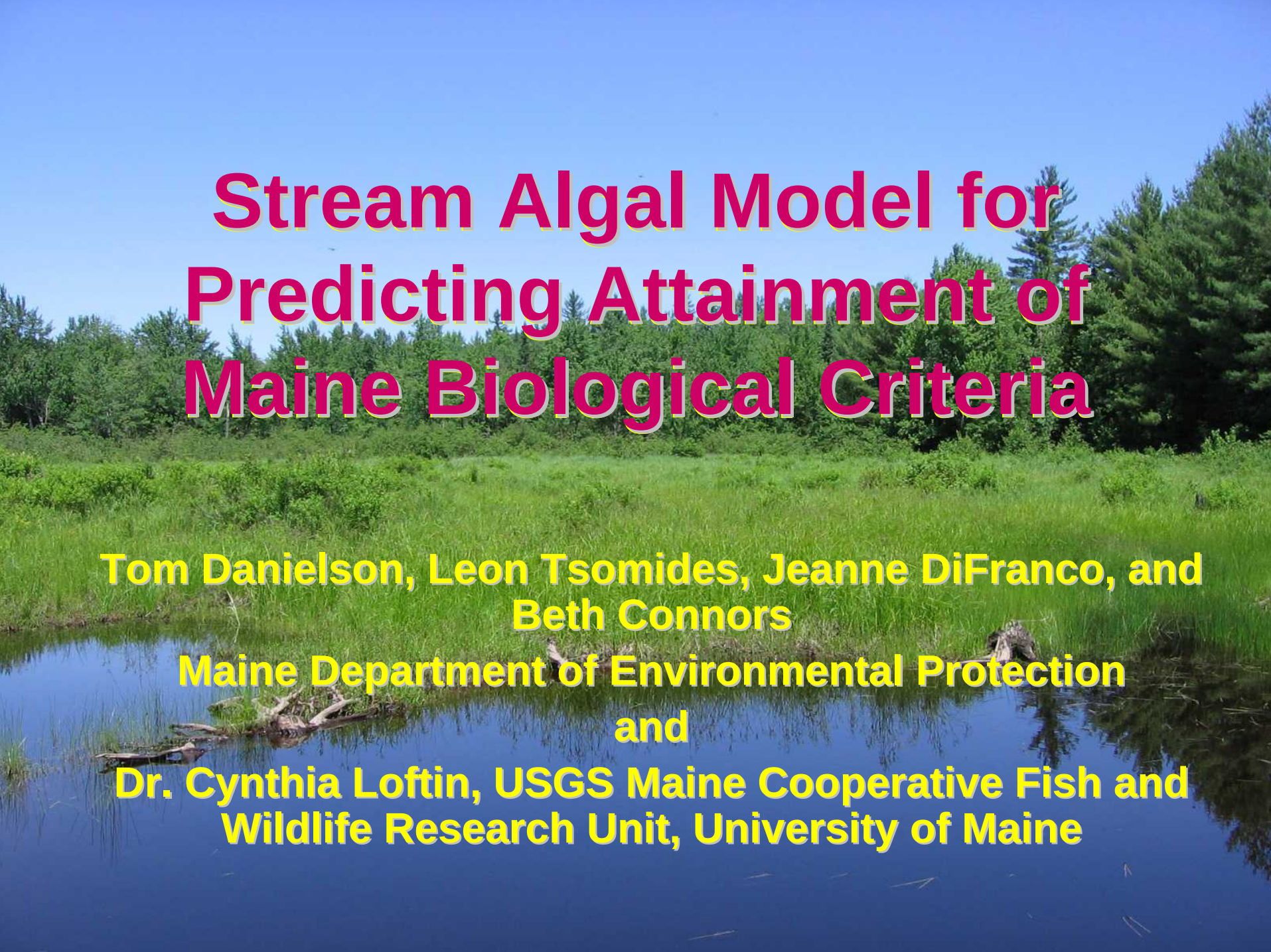


Stream Algal Model for Predicting Attainment of Maine Biological Criteria

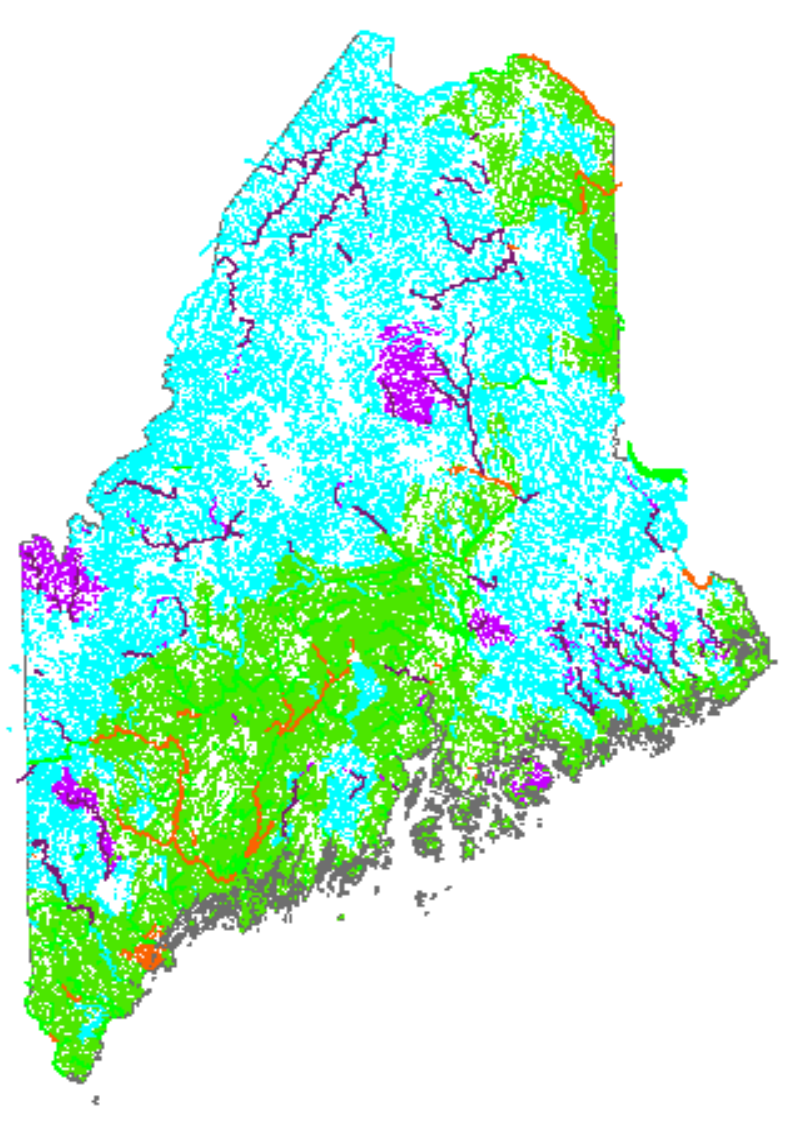
Tom Danielson, Leon Tsomides, Jeanne DiFranco, and Beth Connors

Maine Department of Environmental Protection

and

Dr. Cynthia Loftin, USGS Maine Cooperative Fish and Wildlife Research Unit, University of Maine

Stream Classes



% OF LINEAR MILES OF STATUTORY CLASSIFICATIONS

Class AA = 6%

Class A = 45%

Class B = 47%

Class C = 2%

(Class C ~8-10% for large rivers and urban streams)

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Maine DEP's Biological Monitoring Unit

- **Determine if streams, rivers, and wetlands are attaining aquatic life criteria**
- **Provide water quality data for many other programs**
- **>25 years with stream macroinvertebrates.**
- **10 years with stream and wetland algae and wetland macroinvertebrates.**

Leon Tsomides

Beth Connors

Jeanne DiFranco

Tom Danielson

Sampling

Macroinvertebrate Sample

Taxa List

Pteronarcys	2
Acroneuria	7
Epeorus	23
Baetis	14
Leucrocuta	10
Chimarra	25
Psilotreta	8
. . .	

Statistical Model

Predicts probability of a sample attaining Class A, Class B, or Class C

Compare Result to Assigned Class

1. Attains assigned class or is better ☺
2. Does not attain assigned class ☹

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Foundations of Algal Model

- **Maine's narrative aquatic life criteria (aka, biocriteria)**
- **U.S. Environmental Protection Agency's Biological Condition Gradient (BCG)**
  - **Davies, S.P. and S.K. Jackson (2006) The Biological Condition Gradient: A Descriptive Model for Interpreting Change in Aquatic Ecosystems. *Ecological Applications* 16(4):1251–1266**

Aquatic Life Criteria

Class AA **Class A**	as naturally occurs
Class B	support all aquatic species indigenous to the receiving water; no detrimental changes to the resident biological community
Class C	maintain the structure and function of the resident biological community

Non-attainment (NA) stream does not meet minimum criteria

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BCG Tolerance Groups

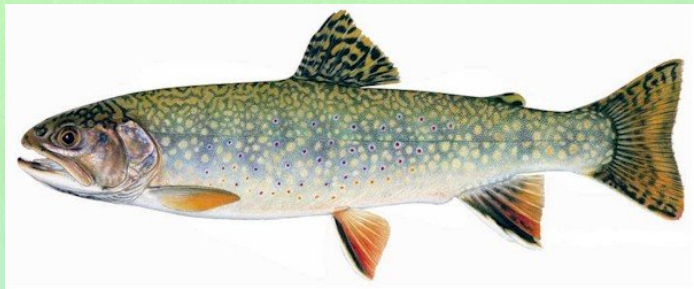
- **Sensitive-rare taxa**

Pteronarcys

Slimy Sculpin

- **Sensitive-ubiquitous**

Stenonema



Brook Trout

BCG Tolerance Groups

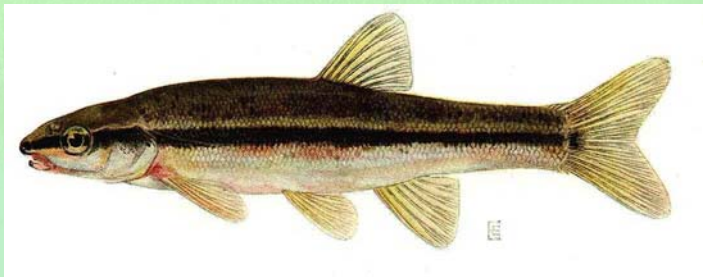
- **Taxa of intermediate tolerance**

Neureclipsis

Common Shiner

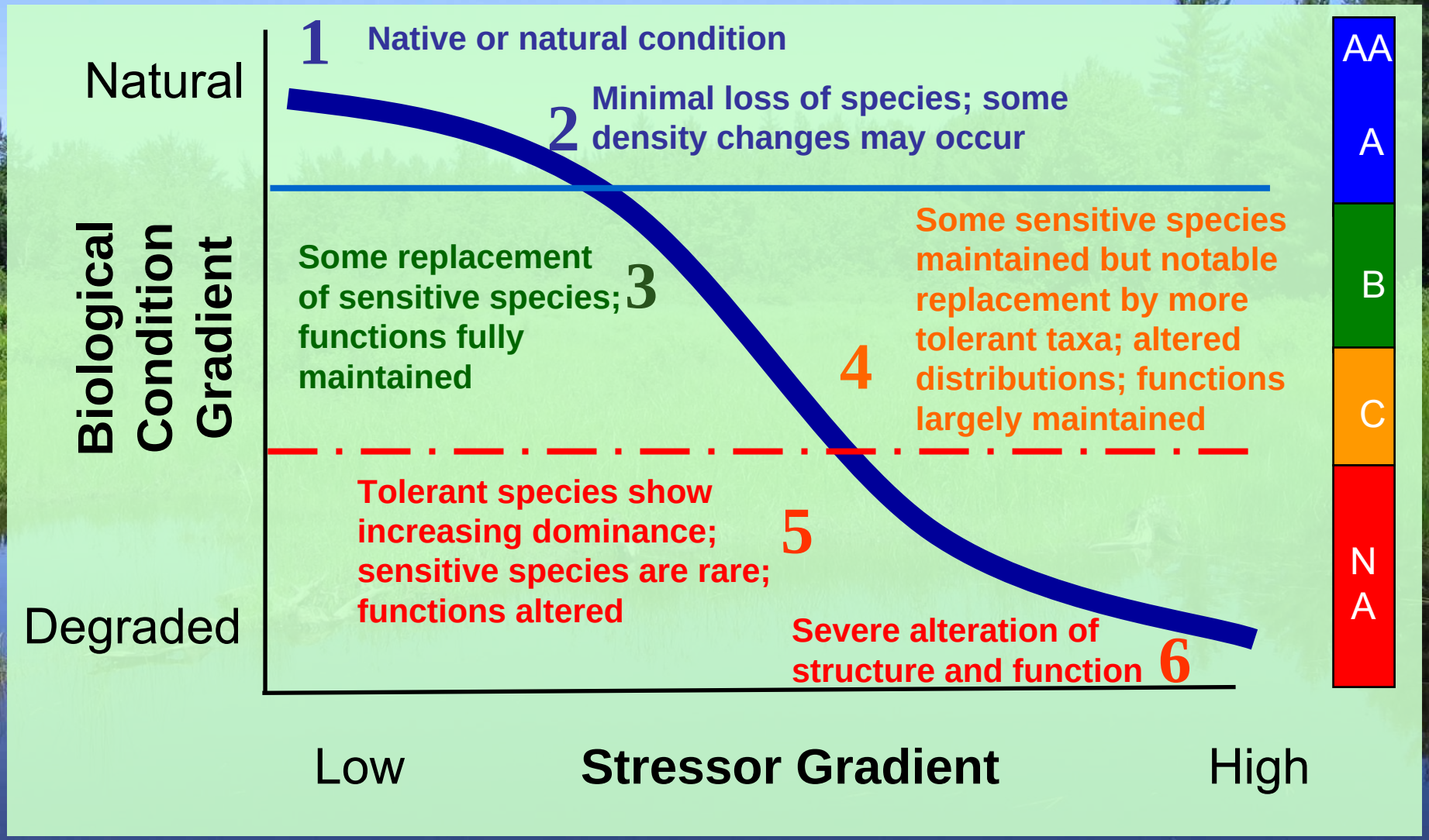
- **Tolerant taxa**

Chironomus



Blacknose Dace

Biological Condition Gradient (BCG) and Tiered Aquatic Life Use (TALU)



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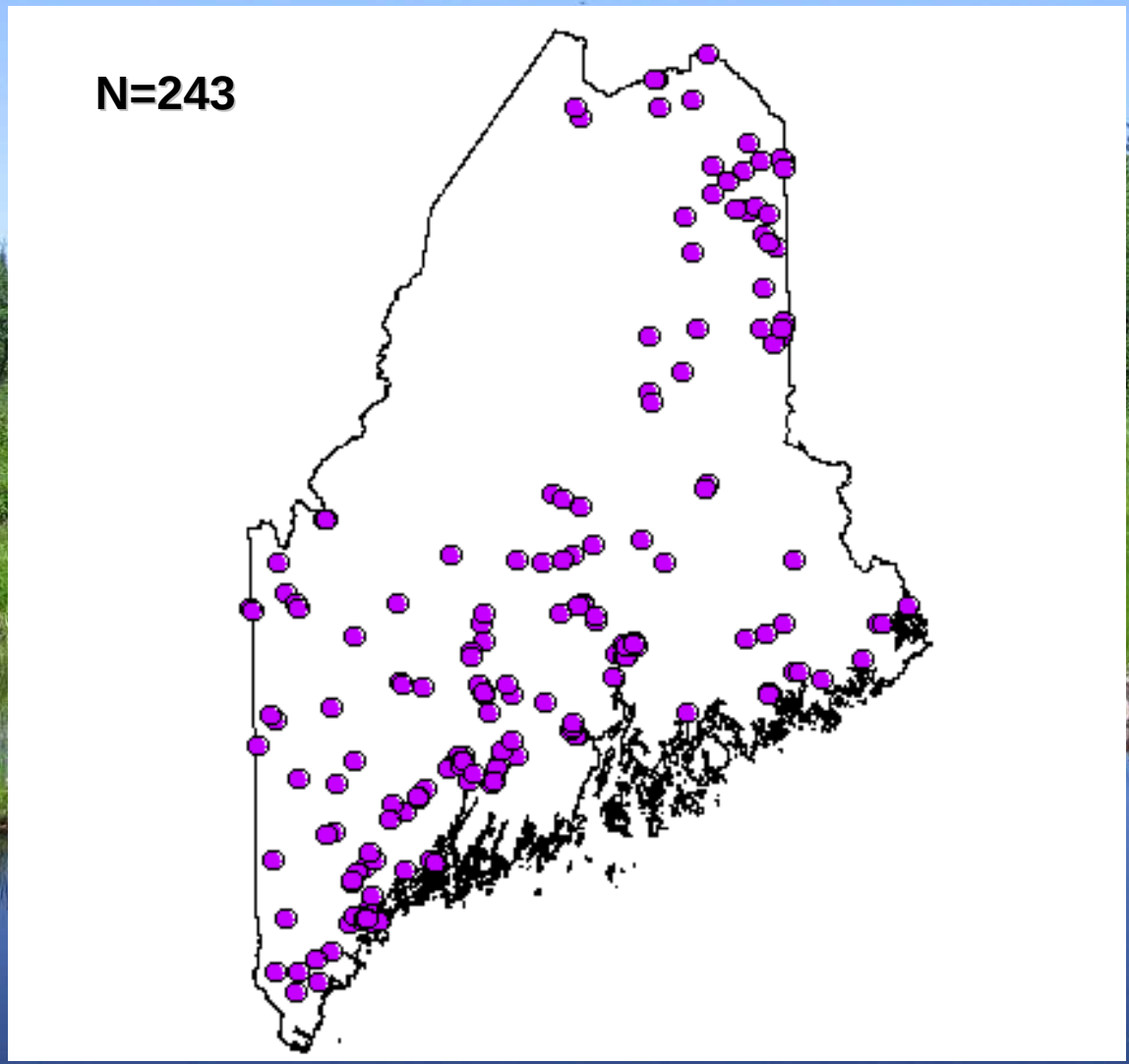
Developing Algal Model

- **Phase 1 – Collected data**
- **Phase 2 - Revised the BCG for Maine stream algae**
  - **What is a "natural" algal community?**
  - **Which algae are sensitive, intermediate, or tolerant?**
- **Phase 3 - Interpreted algal samples and assigned Maine classes and BCG tiers.**
- **Phase 4 – Built and tested model.**

Sample Locations



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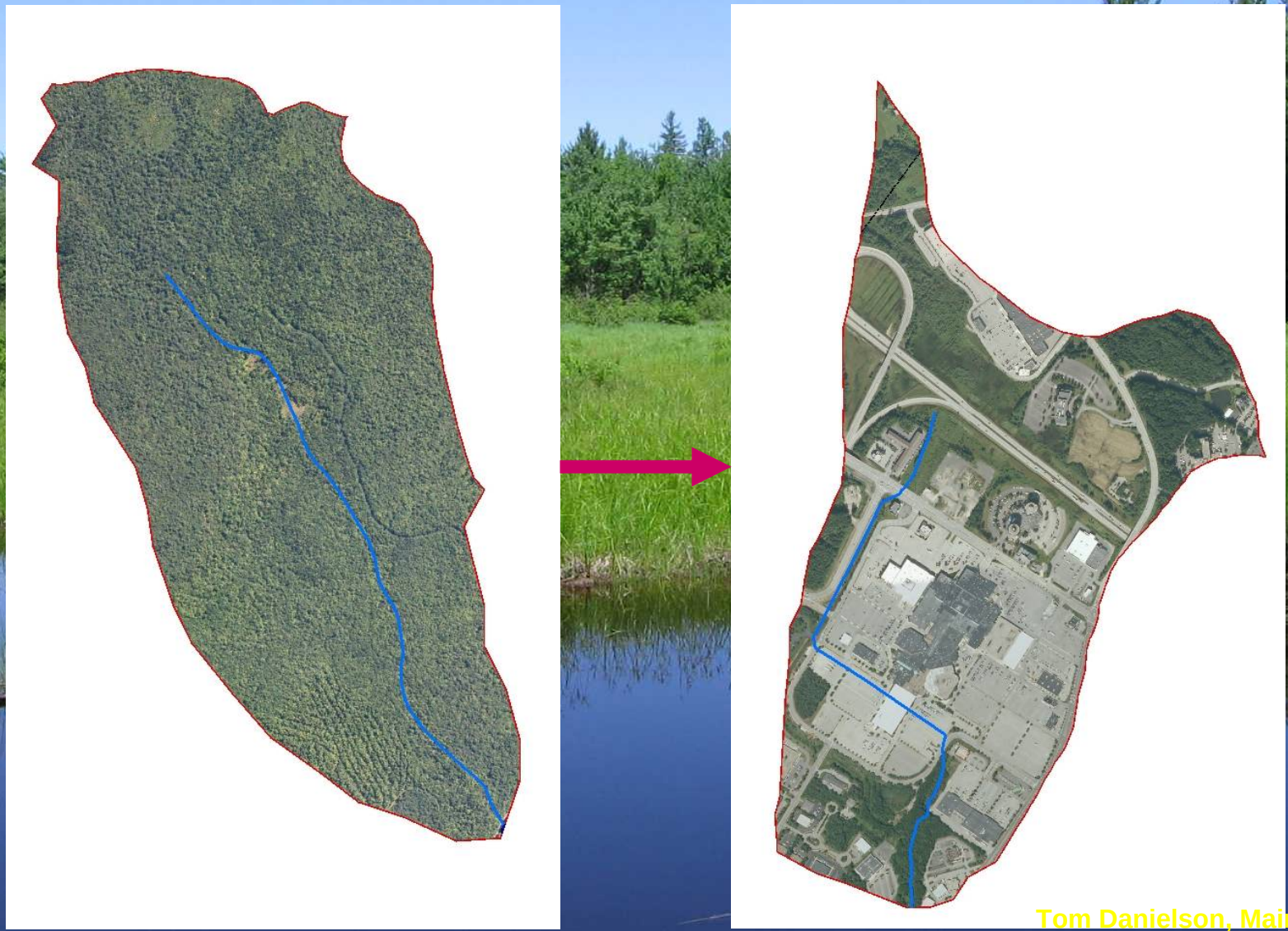
Range of Condition



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Minimally Disturbed Reference Sites

- **>95% of upstream watershed is forest & wetlands**
- **No point source discharges**
- **No dams**
- **No atypical source of pollution (e.g., iron mining)**

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Natural Substrate Samples

- Establish 6 transects
- Collect 3 rocks per transect
- Total of 18 rocks
- Scrape area of rocks within circle with a brush
- Composite sample

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Natural Substrate Samples

- Establish 6 transects
- Collect 3 rocks per transect
- Total of 18 rocks
- Scrape area of rocks within circle with a brush
- Composite sample

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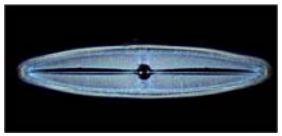
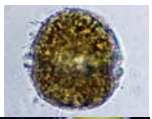
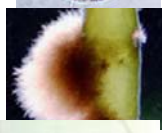
Taxonomic Diversity

1999-2008 Stream Samples	Genera	Species/ Forms
 Diatoms	90	806
 Green Algae	59	226
 Cyanobacteria	51	122
 Euglenoids	4	13
 Yellow-green Algae	5	7
 Dinoflagellates	2	3
 Red Algae	4	2
 Chrysophytes	5	4

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Weighted Average Optima

$$\theta_k = \frac{\sum_{i=1}^{n} y_{ik} x_i}{\sum_{i=1}^{n} y_{ik}}$$

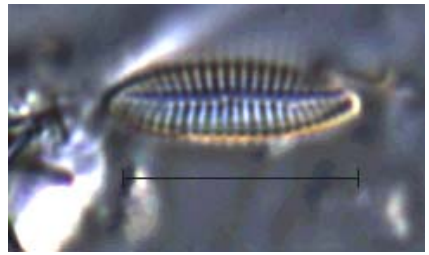
where:

θ_k **= optima of species k**

y_{ik} **= abundance of species *k* in sample *i***

x_i **= value of environmental parameter in sample *i***

A Simple Example (*Achnanthes conspicua*)



Sample	Abundance*	TP (ppb)	Log (TP)	Log(TP) x Abundance
Sucker Brook	16,273	21	1.322	21,512.9
Rocky Brook	7,018	20	1.301	9,130.4
Little Ossippee River	1,048	10	1.000	1,048.0
Togus Stream	29	77	1.886	54.7
Penjajawoc Stream	6	21	1.322	7.9
Carrabassett River	5	6	0.778	3.9
	Sum = 24,379			Sum = 31,757.8

*** This example is with abundances, but we used square root percent abundances for the project.**

Optimum log(TP) = $\frac{31,758}{24,379}$ = 1.303

Optimum TP = $10^{(1.303)}$ **= 20ppb**

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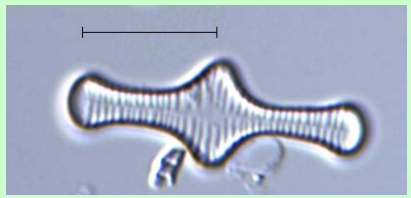
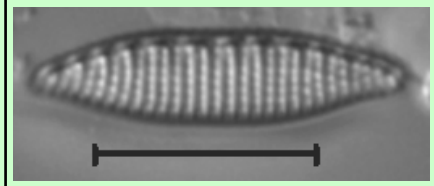
Weighted Average Optima

Environmental Variable	*Tabellaria flocculosa* 	*Nitzschia amphibia* 
Percent of Watershed that is Forest or Wetland	98%	16%
Percent of Watershed that is Impervious Surface	1%	40%
Specific Conductance	22 μS/cm	475 μS/cm
Total Nitrogen	331 ppb	711 ppb
Total Phosphorous	8 ppb	39 ppb

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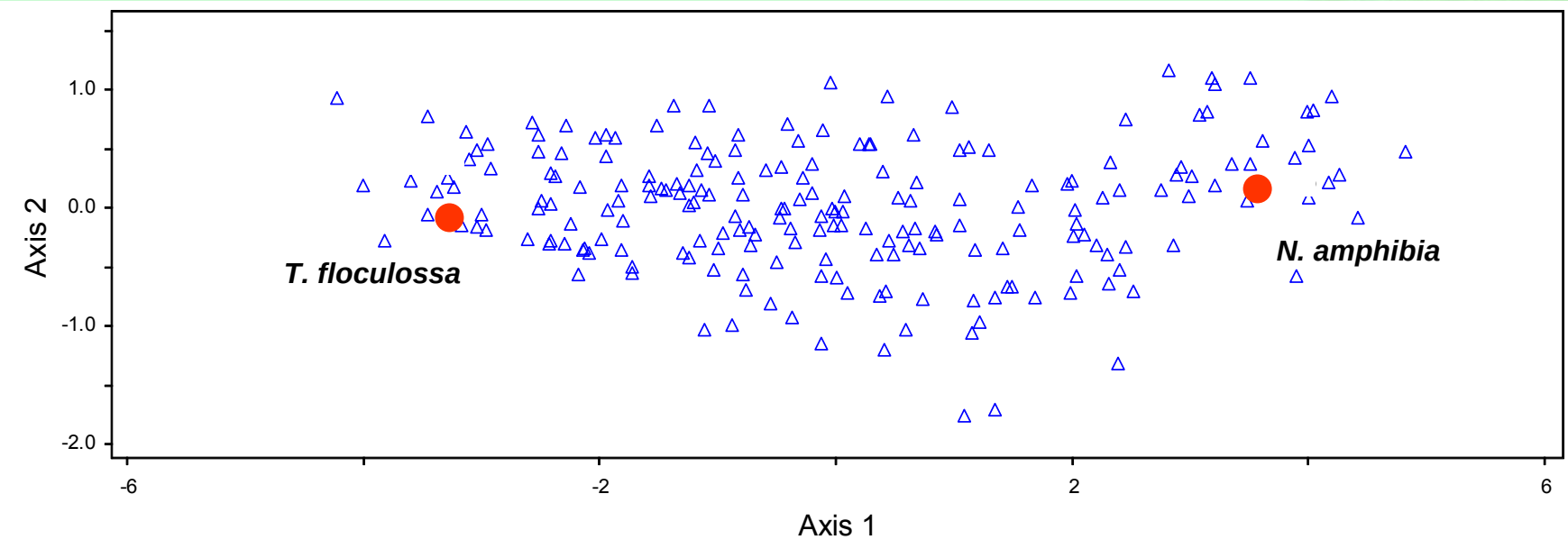
PCA Identified Major Pattern in Species Optima



- **Axis 1 represents 86% of variance**
- **Rescaled axis to 1 (most sensitive) to 100**
- **Grouped taxa into Sensitive (<32.2), Intermediate (32.2-60), and Tolerant (>60).**

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Tested Attributes

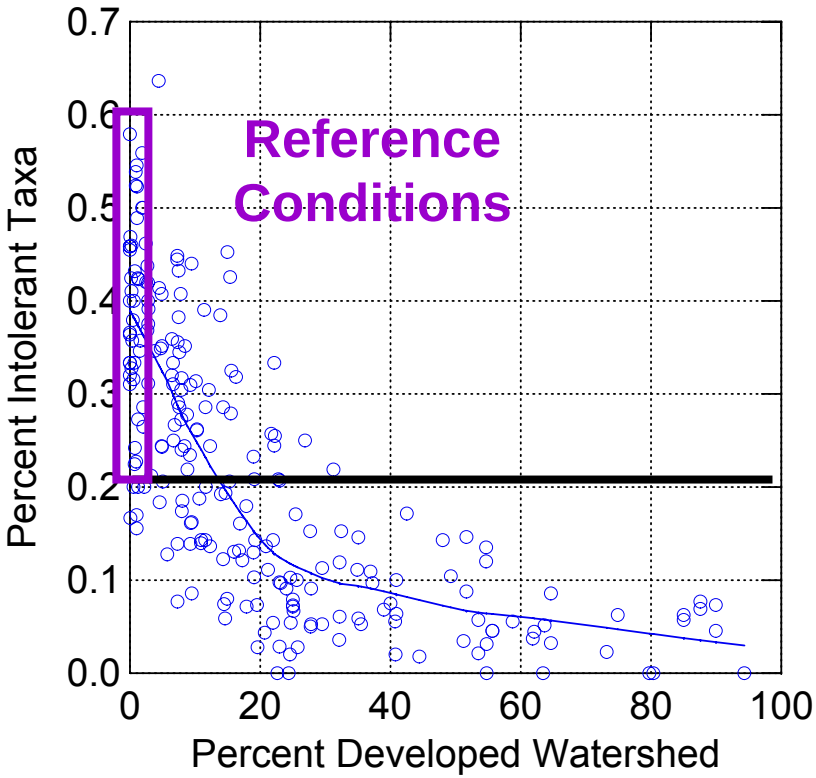
FROM LITERATURE (Examples)

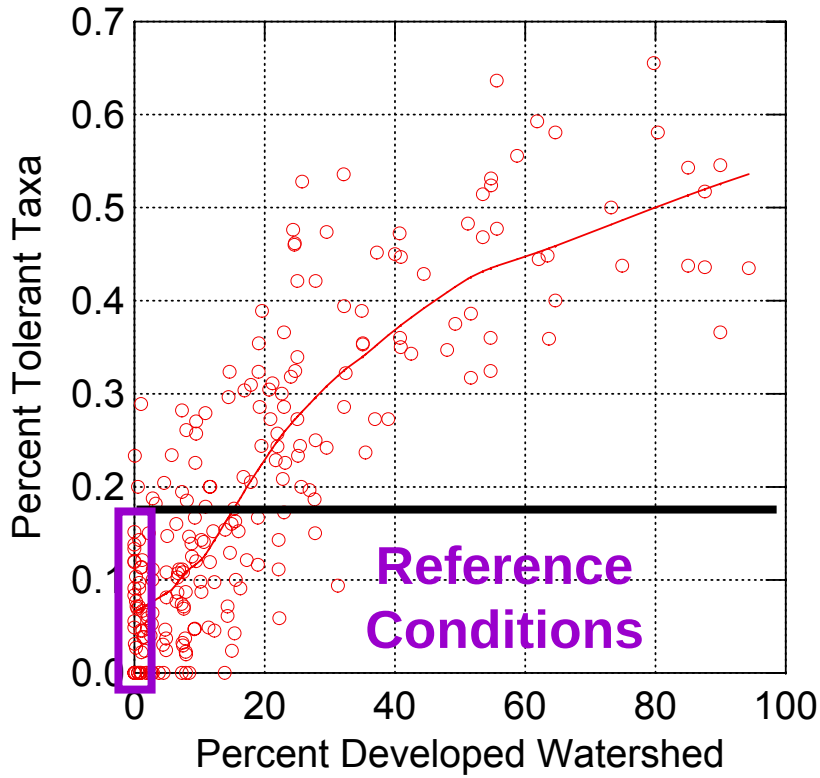
- Relative abundance
  - motile diatoms
  - polysaprobic diatoms
  - eutraphentic diatoms
  - low oxygen diatoms
  - salt tolerant diatoms
  - dominant species
- Total Richness
- Shannon-Wiener Diversity

NOVEL (Examples)

- Relative richness
  - Sensitive taxa
  - Tolerant taxa
  - *Brachysira, Eunotia, Tabellaria, and Anomoneis (*BETA)
  - Bacillariaceae, Catenulaceae, Rhoicospheniaceae, and Surirellaceae (BCRS)
- Relative biovolume
  - Sensitive taxa
  - Tolerant taxa

Algal Metrics





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Class Assignments

- 5 biologists in the DEP Biomonitoring Unit
  - Beth Connors
  - Tom Danielson
  - Jeanne DiFranco
  - Caitlin Kersten
  - Leon Tsomides
- Independently interpreted metrics and community structure in relation to:
  - Maine narrative aquatic life criteria
  - Stream algal BCG framework

Materials given to biologists

- Summary variables and metrics for each sample (n=230)
- Taxa lists with abundances, relative abundances, tolerances, etc. for each sample
- Samples identified by random number
- Only biological data provided
- Report with metric graphs and descriptions

Class Assignments

- **Biologists independently evaluated samples**
  - **Maine class (A, B, C, NA)**
  - **BCG Tier (1-6)**
- **Biologists later compared results and made consensus assignments.**

Biologist Class Assignments

- **105 Class A, 46 Class B, 46 Class C, and 33 non-attainment.**
  - **53% unanimous**
  - **22% 4 vs. 1 (differed by one class)**
  - **20% 3 vs. 2 (differed by one class)**
  - **5% differed by more than one class**

Discriminant Analysis Model

- **Predicts group membership (i.e., A, B, C, NA) based on linear combination of metrics**
- **230 samples**
  - **150 used to build the model (training set)**
  - **80 used to test the model (test set)**

Discriminant Analysis Model

Variable	Transformation	A	B	C	NA
Constant		-402.743	-345.655	-271.173	-212.396
BCRS_RD	4th root	103.154	101.749	99.952	112.145
EREC_RD	4th root	-22.778	-20.192	-21.129	-14.504
HIGH_R	square root	-0.355	0.008	0.269	-2.056
INT_RB	arcsine	64.054	63.318	53.664	30.441
INT_RR	arcsine	52.328	73.567	47.320	25.235
INTTOL	4th root	540.168	488.664	444.500	408.181
SEN_RB	4th root	87.324	86.118	74.211	45.088
SEN_RR	arcsine square root	1749.161	1580.800	1394.386	1244.261
SENTOL	4th root	-631.965	-576.899	-519.906	-468.459

Linear Discriminant Model

Probability of belonging to the Class A group =

constant +

variable1 * coefficient1 +

variable2 * coefficient2 +

variable3 * coefficient3 +

. . .

variable9 * coefficient9

95% Correct Model Performance with Training Data (n=150)

(Row percents with number of samples in parentheses)

	Algal LDM Predicted Class			
	A	**B**	**C**	**NA**
***a priori* Class A**	**97% (67)**	3% (2)	--	--
***a priori* Class B**	3% (1)	**90% (27)**	7% (2)	--
***a priori* Class C**	--	--	**93% (28)**	7% (2)
***a priori* NA**	--	--	--	**100% (21)**

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91% Correct Model Performance with Validation Data (n=80)

(Row percents with number of samples in parentheses)

	Algal LDM Predicted Class			
	A	**B**	**C**	**NA**
***a priori* Class A**	**97% (35)**	3% (1)	--	--
***a priori* Class B**	13% (2)	**81% (13)**	6% (1)	--
***a priori* Class C**	--	13% (2)	**88% (14)**	--
***a priori* NA**	--	--	9% (1)	**91% (10)**

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Comparison of Algal LDM with Macroinvertebrate LDM (n=147)

(Row percents with number of samples in parentheses)

	Macroinvertebrate LDM Class			
	A	B	C	NA
Algae Class A	82% (67)	10% (2)	6% (4)	2% (1)
Algae Class B	29% (8)	54% (15)	14% (4)	4% (1)
Algae Class C	28% (9)	28% (9)	28% (9)	16% (5)
Algae NA	12% (3)	16% (4)	24% (6)	48% (12)

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Diagnosing Stressors and Tracking Incremental Improvements

- **Conflicting algal and macroinvertebrate model predictions can provide information about likely stressors.**
- **Diagnostic metrics**
  - **Percent motile diatoms (sedimentation)**
  - **Percent salt tolerant diatoms**
  - **Percent acidobiontic diatoms**
- **Inference models**
  - **Predict environmental conditions based on diatom community composition**
  - **TP, TN, specific conductance, % developed in watershed, % impervious surfaces**

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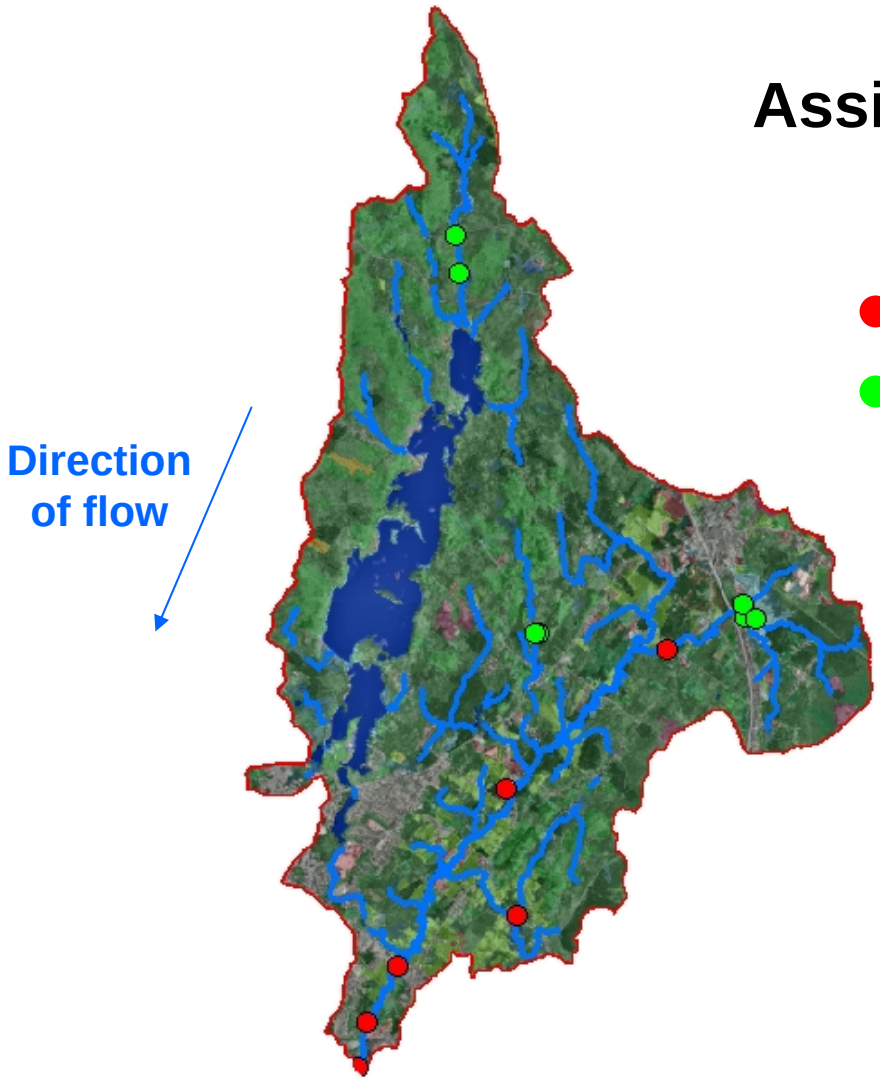
Watershed Assessment Pleasant River, Windham



Assigned Goal is Class B

- Stream sample
- Wetland sample

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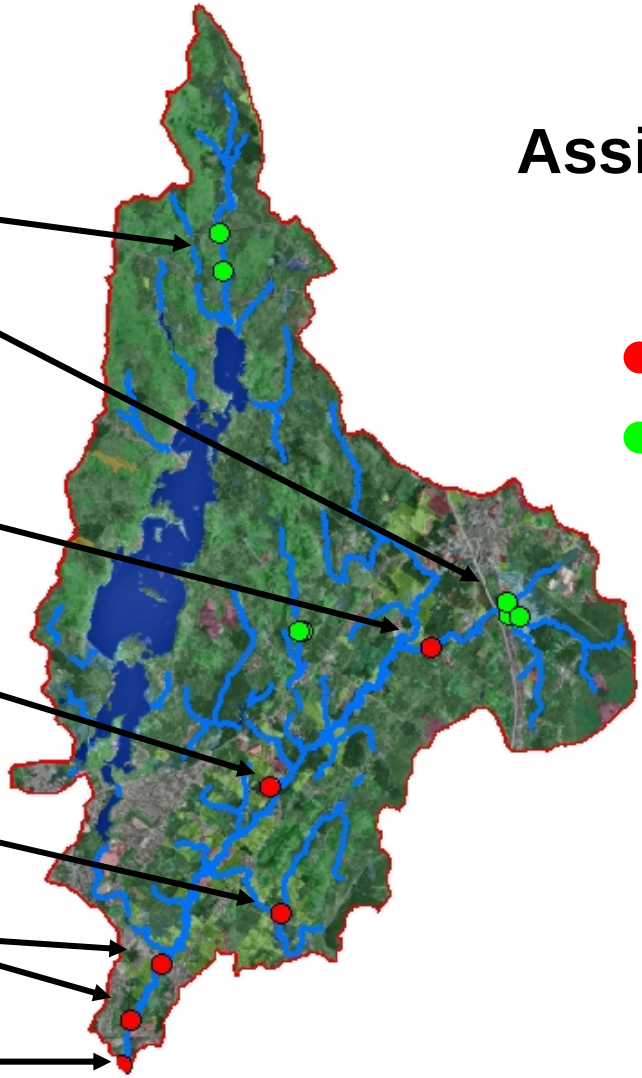
BCG is a Crosswalk



Wetland Bugs: A

Wetland Bugs: A/B

Bugs: B
Algae: B

Algae: B

Bugs: B

Algae: C

Bugs: B

Assigned Goal is Class B

- Stream sample
- Wetland sample

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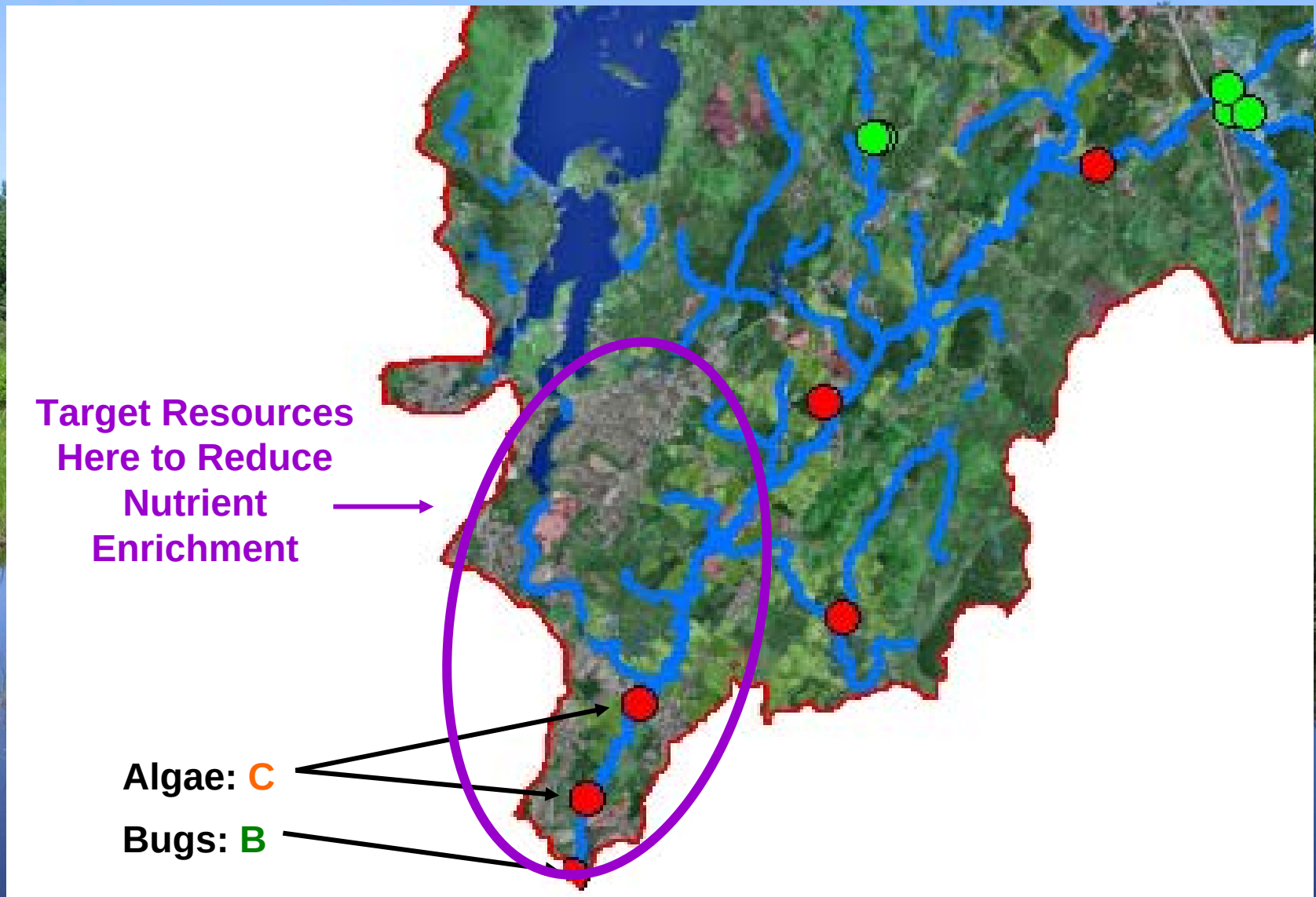
BCG Helps Targets Resources



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  - U.S. Environmental Protection Agency
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- DEP Staff
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  - Leon Tsomides
  - Jeanne DiFranco
  - Beth Connors
  - Susanne Meidel
  - Chris Halsted
  - Mike Smith (now with OGIS)
  - >50 interns, conservation aides, Americorps, and volunteers
- Partners
  - Houlton Band of Maliseet Indians
  - Manomet Center for Conservation Sciences
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  - Dr. Francis Drummond
  - Dr. Susan Brawley
  - Dr. R. Jan Stevenson (Michigan State University)
  - Dr. Dave Courtemanch (Maine DEP)