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**New England Association of Environmental  
Biologists**

**Hotel Viking  
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# Application of the Index of Biotic Similarity (B) to the Analysis of the Data Generated by the



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# Outline

- Vermont Streams Project
- Index of Biotic Similarity, BioSim2, & the statistical test
- Results
- Conclusions

# Outline

- Vermont Streams Project
  - Concept
  - Participants
  - Drainage Basins in the Project
  - Macroinvertebrate Techniques

# Vermont Streams Project

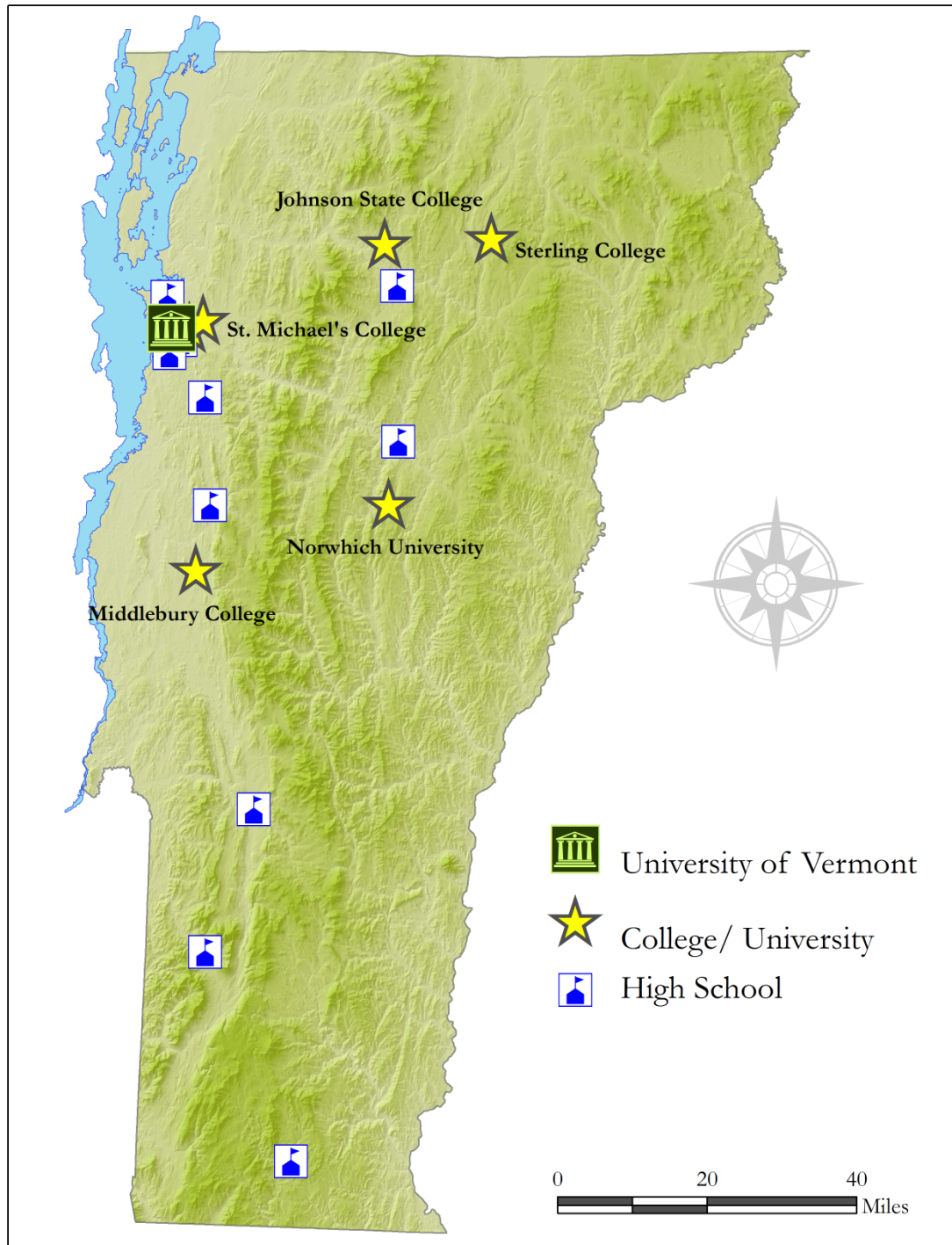
## Concept

The Streams Project is a **collaborative** effort involving **Universities, Colleges, VT DEC, and high schools**, managed by **VT EPSCoR** (Experimental Programs to Stimulate Competitive Research). It is dedicated to collecting **high-quality data** on **streams in the Champlain basin** while training the **next generation of scientists**.

Ultimately this database will be instrumental in **understanding watershed dynamics** around the state.

# Vermont Streams Project

## Participants

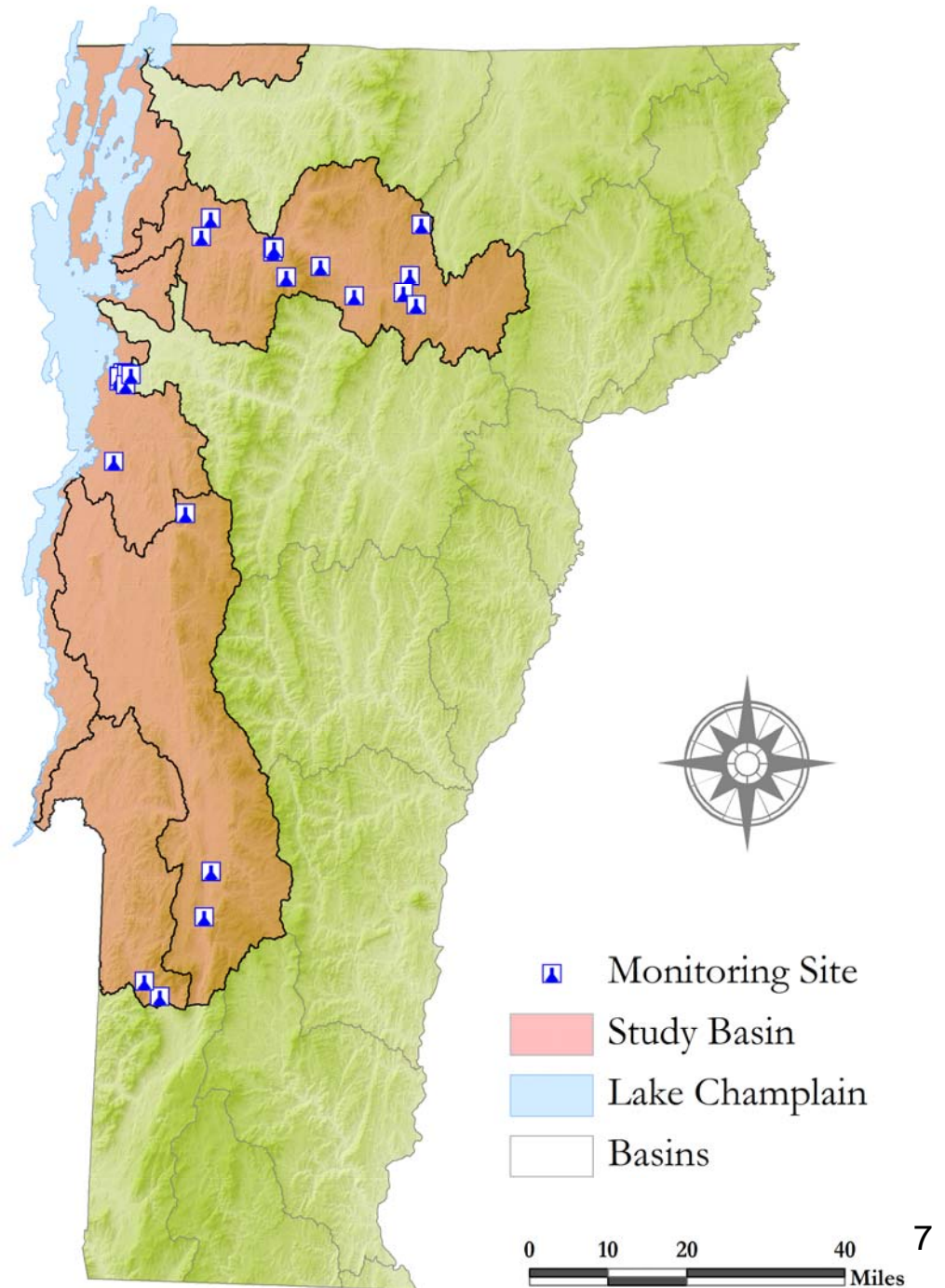


# Vermont Streams Project

2008, College Baseline Study:

33 sites

6 drainage basins



# Vermont Streams Project

## Macroinvertebrate Techniques

### Sampling



- Collected in summer-early fall (June & July up to October)
- Collected from representative locations in a riffle in the stream
- Substrate in an area about 1 square meter upstream of a 500 micron mesh D-net is thoroughly disturbed by hand
- Four replicates collected each replicate lasting about 30 seconds
- Replicates preserved individually in 75% alcohol

# Vermont Streams Project

## Macroinvertebrate Techniques

### Processing



- 1) Sample is washed and spread evenly over a white, gridded tray with 16 squares.
- 2) Starting with random grid, it and the next 3 consecutive squares are picked clean of macroinvertebrates using a 3 diopter magnifying headset and separate light.
- 3) Process is continued if necessary until 300 organisms are picked.
- 4) Total number of squares picked is recorded.
- 5) Picked macroinvertebrates are preserved in 75% alcohol.
- 6) Macroinvertebrates are identified to genus, except Oligochaetes and Chironomids (Family).

# Outline

- Index of Biotic Similarity, BioSim2, & the Statistical Test
  - Brief Review
  - What is a Sector?
  - Statistically Valid Sectors

# Index of Biotic Similarity, BioSim2, & the Statistical Test (Pinkham-Pearson Index) Brief Review

$$B = \frac{1}{k} \sum_{i=1}^k \frac{\text{Min} (X_{ia}, X_{ib})}{\text{Max} (X_{ia}, X_{ib})}$$

Barbour *et al.* (1992) in a systematic comparison of the metrics proposed in EPA's rapid bioassessment protocol (Pfalkin *et al.*, 1989), concluded that  $B$  "may be the most appropriate metric to serve as a measure of community similarity."

# Index of Biotic Similarity, BioSim2, & the Statistical Test

## Brief Review

$$B = \frac{1}{k} \sum_{i=1}^k \frac{\text{Min} (X_{ia}, X_{ib})}{\text{Max} (X_{ia}, X_{ib})}$$

|                  | Taxon 1         | Taxon 2            | Taxon 3           | Taxon 4           | Taxon 5             | Taxon 6            |          |
|------------------|-----------------|--------------------|-------------------|-------------------|---------------------|--------------------|----------|
| Site 1           | 10              | 0                  | 0                 | 5                 | 30                  | 2                  |          |
| Site 2           | 10              | 0                  | 0                 | 5                 | 30                  | 2                  |          |
| Site 3           | 0               | 10                 | 20                | 0                 | 0                   | 0                  |          |
| Site 4           | 1               | 50                 | 2                 | 3                 | 15                  | 12                 |          |
| Site1w<br>Site 2 | $\frac{10}{10}$ | $+$ $\frac{0}{0}$  | $+$ $\frac{0}{0}$ | $+$ $\frac{5}{5}$ | $+$ $\frac{30}{30}$ | $+$ $\frac{2}{2}$  | $= 1$    |
|                  | 6               |                    |                   |                   |                     |                    |          |
|                  | 1               | $+$ 1              | $+$ 1             | $+$ 1             | $+$ 1               | $+$ 1              | $= 1$    |
|                  | 6               |                    |                   |                   |                     |                    |          |
| Site1w<br>Site 3 | $\frac{0}{10}$  | $+$ $\frac{0}{10}$ | $+$ $\frac{0}{0}$ | $+$ $\frac{0}{5}$ | $+$ $\frac{0}{30}$  | $+$ $\frac{0}{2}$  | $= 0$    |
|                  | 6               |                    |                   |                   |                     |                    |          |
|                  | 0               | $+$ 0              | $+$ 0             | $+$ 0             | $+$ 0               | $+$ 0              | $= 0$    |
|                  | 6               |                    |                   |                   |                     |                    |          |
| Site1w<br>Site 4 | $\frac{1}{10}$  | $+$ $\frac{0}{50}$ | $+$ $\frac{0}{2}$ | $+$ $\frac{3}{5}$ | $+$ $\frac{15}{30}$ | $+$ $\frac{2}{12}$ | $= 0.23$ |
|                  | 6               |                    |                   |                   |                     |                    |          |
|                  | 0.1             | $+$ 0              | $+$ 0             | $+$ 0.6           | $+$ 0.5             | $+$ 0.17           | $= 0.23$ |
|                  | 6               |                    |                   |                   |                     |                    |          |

# Index of Biotic Similarity, **BioSim2**, & the Statistical Test

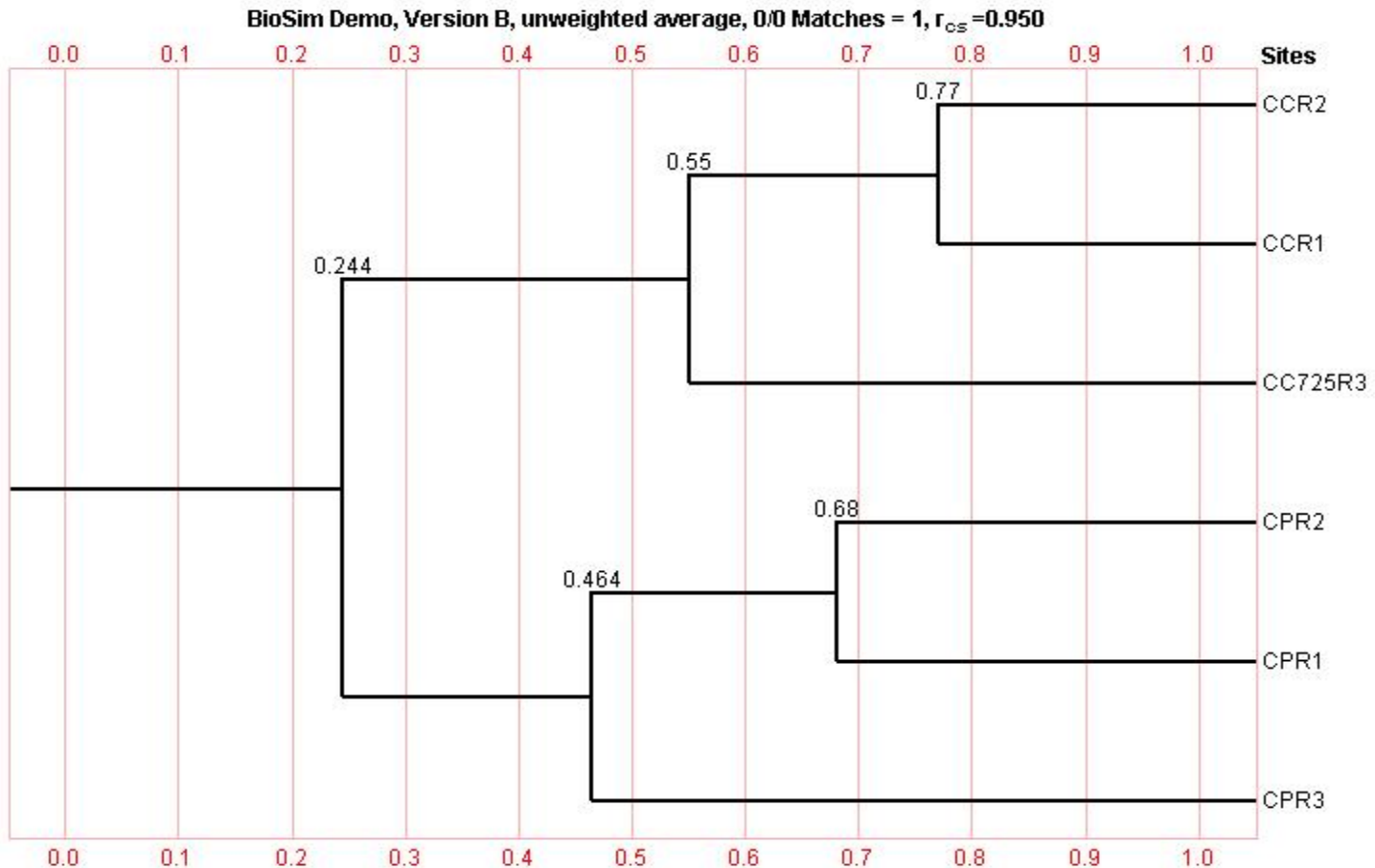
## Brief Review

Matrix of B's Between 11 Parameters

|                   | SiltRating | PcBoulder% | PcCobble% | PcCoarseGravel% | PcGravel% | PcSilt% | PcClay% | Embeddedness | Canopy% | Width  | FilamentousGreen% |
|-------------------|------------|------------|-----------|-----------------|-----------|---------|---------|--------------|---------|--------|-------------------|
| SiltRating        | 1          | 0.4531     | 0.5797    | 0.5264          | 0.4447    | 0.1188  | 0.1122  | 0.568        | 0.5953  | 0.3926 | 0.2854            |
| PcBoulder%        | 0.4531     | 1          | 0.5296    | 0.4035          | 0.4725    | 0.0701  | 0.1184  | 0.444        | 0.3985  | 0.4775 | 0.3455            |
| PcCobble%         | 0.5797     | 0.5296     | 1         | 0.6305          | 0.4283    | 0.0661  | 0.0198  | 0.7029       | 0.5629  | 0.4591 | 0.3132            |
| PcCoarseGravel%   | 0.5264     | 0.4035     | 0.6305    | 1               | 0.4844    | 0.0868  | 0.0521  | 0.6775       | 0.6     | 0.5009 | 0.2734            |
| PcGravel%         | 0.4447     | 0.4725     | 0.4283    | 0.4844          | 1         | 0.1437  | 0.0397  | 0.5284       | 0.4558  | 0.5761 | 0.3737            |
| PcSilt%           | 0.1188     | 0.0701     | 0.0661    | 0.0868          | 0.1437    | 1       | 0.7736  | 0.1345       | 0.0905  | 0.0832 | 0.3793            |
| PcClay%           | 0.1122     | 0.1184     | 0.0198    | 0.0521          | 0.0397    | 0.7736  | 1       | 0.0305       | 0.0483  | 0.0411 | 0.3153            |
| Embeddedness      | 0.568      | 0.444      | 0.7029    | 0.6775          | 0.5284    | 0.1345  | 0.0305  | 1            | 0.653   | 0.459  | 0.2853            |
| Canopy%           | 0.5953     | 0.3985     | 0.5629    | 0.6             | 0.4558    | 0.0905  | 0.0483  | 0.653        | 1       | 0.4149 | 0.2304            |
| Width             | 0.3926     | 0.4775     | 0.4591    | 0.5009          | 0.5761    | 0.0832  | 0.0411  | 0.459        | 0.4149  | 1      | 0.3314            |
| FilamentousGreen% | 0.2854     | 0.3455     | 0.3132    | 0.2734          | 0.3737    | 0.3793  | 0.3153  | 0.2853       | 0.2304  | 0.3314 | 1                 |

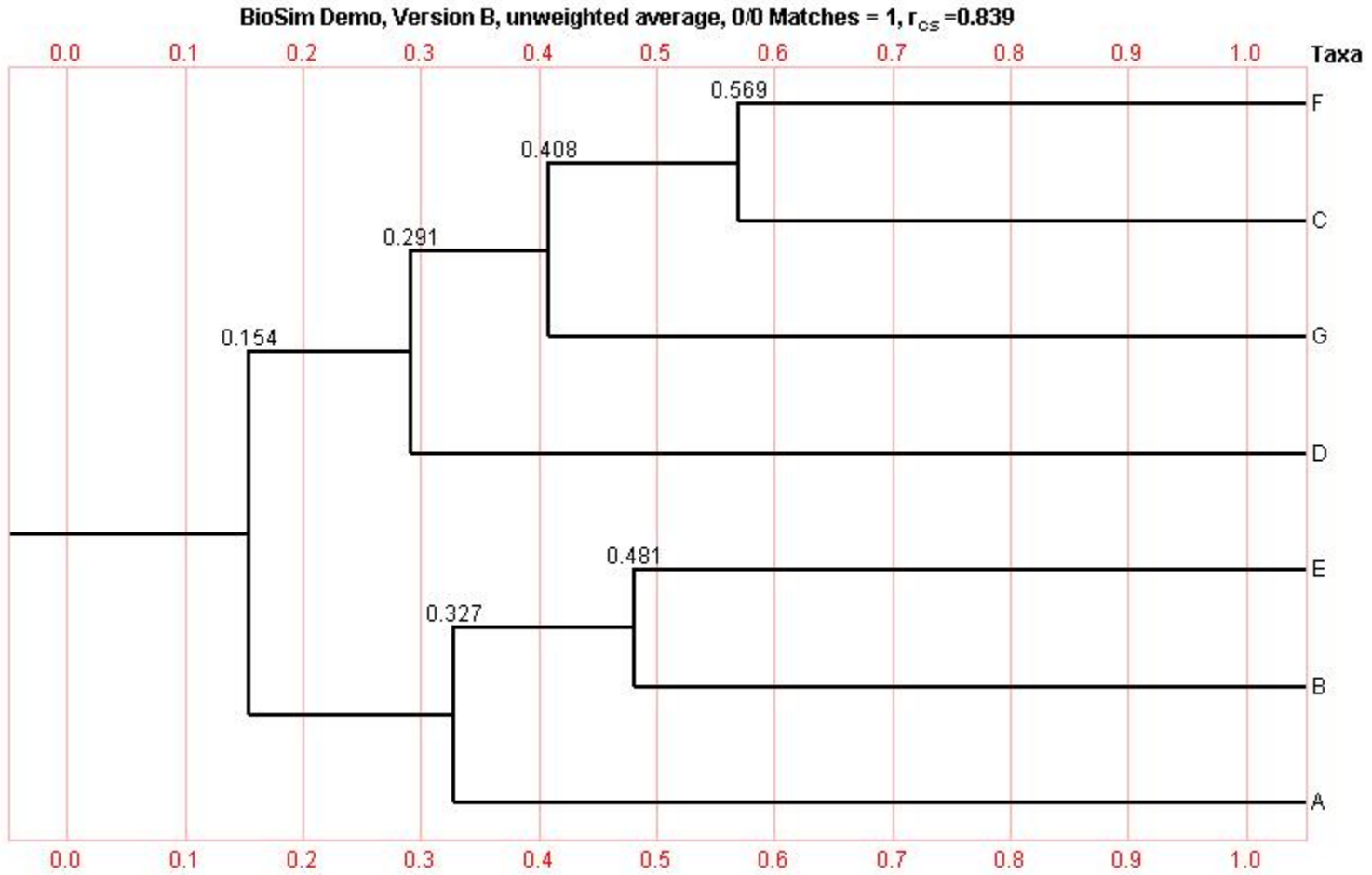
# Index of Biotic Similarity, **BioSim2**, & the Statistical Test

## Brief Review Site Dendrogram



# Index of Biotic Similarity, **BioSim2**, & the Statistical Test

## Taxa Dendrogram



# Index of Biotic Similarity, BioSim2, & the Statistical Test

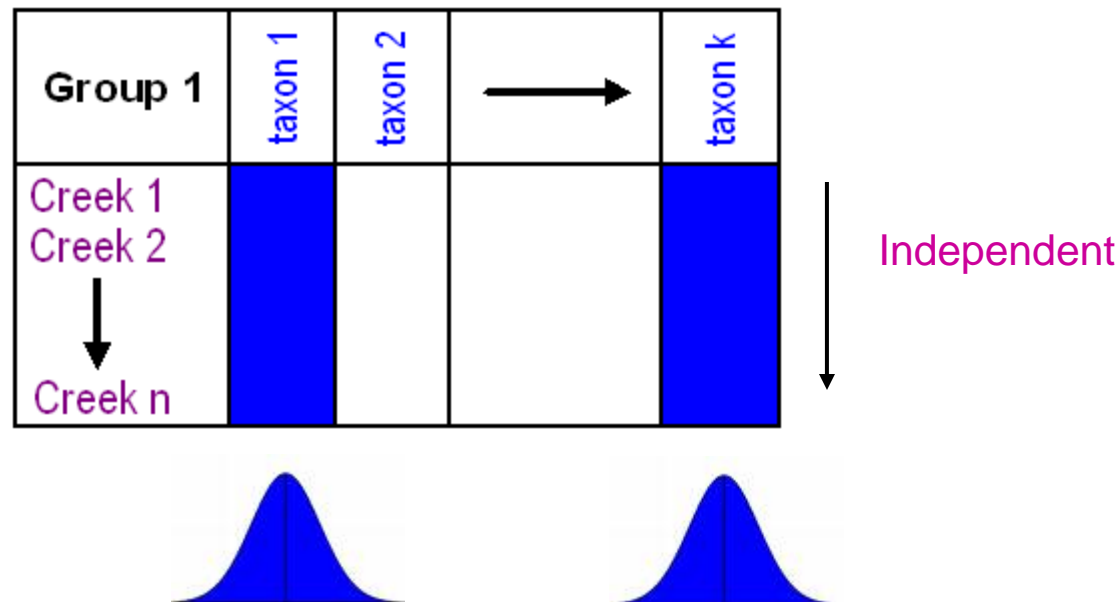
## What is a Sector?

|      | F   | C   | G   | D     | E     | B   | A     |       |
|------|-----|-----|-----|-------|-------|-----|-------|-------|
| CCR2 | 0   | 0   | 0   | 1.1   | 1.8   | 2.1 | 7.7   |       |
| CCR1 | 0   | 0   | 0   | 0     | 1.8   | 3.2 | 5.7   |       |
| CCR3 | 0   | 0   | 0.2 | 0.5   | 5     | 4.7 | 9.5   | 0.55  |
| CPR2 | 8.7 | 0.7 | 0   | 12.5  | 6.4   | 0.7 | 3.8   | 0.244 |
| CPR1 | 6.9 | 0.9 | 0   | 15.7  | 0.7   | 0.2 | 3.8   |       |
| CPR3 | 9.6 | 2   | 1.5 | 22    | 3.8   | 0.5 | 8.4   | 0.464 |
|      |     |     |     | 0.291 | 0.154 |     | 0.327 |       |

# Index of Biotic Similarity, BioSim2, & the Statistical Test

## Statistically Valid Sectors

- Assumptions
  - The measurements in each site are independent
  - The % composition of taxa follow a normal distribution



# Index of Biotic Similarity, BioSim2, & the Statistical Test

## Statistically Valid Sectors

- Calculations

| Group 1 | taxon 1 | taxon 2 | → | taxon k |
|---------|---------|---------|---|---------|
| Creek 1 |         |         |   |         |
| Creek 2 |         |         |   |         |
| ↓       |         |         |   |         |
| Creek n |         |         |   |         |

$$\bar{x}_{1,1} \quad \bar{x}_{1,2} \quad \bar{x}_{1,k}$$

$$s_{1,1} \quad s_{1,2} \quad s_{1,k}$$

| Group 2 | taxon 1 | taxon 2 | → | taxon k |
|---------|---------|---------|---|---------|
| Creek 1 |         |         |   |         |
| Creek 2 |         |         |   |         |
| ↓       |         |         |   |         |
| Creek m |         |         |   |         |

$$\bar{x}_{2,1} \quad \bar{x}_{2,2} \quad \bar{x}_{2,k}$$

$$s_{2,1} \quad s_{2,2} \quad s_{2,k}$$

$$d_i = \frac{\bar{x}_{1,i} - \bar{x}_{2,i}}{\sqrt{\frac{s_{1,i}^2}{n} + \frac{s_{2,i}^2}{m}}}$$

# Index of Biotic Similarity, BioSim2, & the Statistical Test

## Statistically Valid Sectors

- Calculations

$H_0$ : There is not a significant difference between the percent compositions of taxa in the sites making up Sector 1 & Sector 2.

$H_a$ : There is a significant difference between the percent compositions of taxa in the sites making up Sector 1 & Sector 2.

Given  $H_0$  is true then

$$d_i \sim N(0,1)$$

$$\text{so } \sum_{i=1}^k d_i^2 \sim \chi^2(k-1).$$

The  $p$ -value is calculated using the chi-square distribution.

# Outline

- Results
  - Original Macroinvertebrate Data Matrix
  - Macroinvertebrate % Composition Data
  - Statistically Valid Sector Analysis
  - Abundance Values for Each Sector

# Results

## Original Macroinvertebrate Data Matrix

- 208 taxa collected at 33 sites comprising 24,677 organisms...
- compressed to 83 taxa at 33 sites comprising 23,987 organisms (<97% of original) by eliminating
  - taxa which appeared in only one site with 30 or fewer organisms (82 taxa).
  - taxa which appeared in only two sites with total of 30 or fewer organisms (25 taxa).
  - taxa which appeared in only three sites with a total of 30 or fewer organisms (18 taxa).

# Results

## Macroinvertebrate % Composition Data

- These **83 taxa** at **33 sites** comprising **23,987 organisms...**
- further compressed to **65 taxa** at **33 sites** by eliminating those taxa with a sum of their % compositions over all sites that did not exceed 4%.  
**23,454 organisms** remained (>95% of the original)

# Results

## Statistically Valid Sectors

| Year       | Healthcare | Technology | Consumer Discretionary | Consumer Staples | Energy | Financials | Industrials | Materials | Real Estate | Utilities | Communication Services | Other |
|------------|------------|------------|------------------------|------------------|--------|------------|-------------|-----------|-------------|-----------|------------------------|-------|
| 1980-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1980-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1980-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1980-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1981-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1981-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1981-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1981-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1982-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1982-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1982-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1982-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1983-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1983-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1983-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1983-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1984-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1984-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1984-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1984-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1985-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1985-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1985-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1985-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1986-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 1986-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
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| 1999-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
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| 2000-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
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| 2000-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2001-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2001-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2001-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2001-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2002-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2002-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2002-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
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| 2003-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2003-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
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| 2004-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2004-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
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| 2007-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2008-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
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| 2009-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2009-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2009-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2010-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2010-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2010-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2010-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2011-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2011-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2011-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2011-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2012-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2012-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2012-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2012-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2013-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2013-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2013-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2013-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2014-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2014-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2014-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2014-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2015-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2015-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2015-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2015-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2016-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2016-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2016-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2016-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2017-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2017-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2017-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2017-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2018-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2018-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2018-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2018-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2019-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2019-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2019-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2019-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2020-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2020-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2020-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2020-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2021-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2021-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2021-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2021-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2022-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2022-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2022-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2022-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2023-01-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2023-04-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2023-07-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |
| 2023-10-01 |            |            |                        |                  |        |            |             |           |             |           |                        |       |







# Results

## Major Conclusions

- Four major site sets (clusters of sites) were identified.
- These four site sets could be **distinguished** on the basis of as few as 25 taxa.
- These 25 taxa included taxa sets (clusters of taxa) of pollution intolerant, intermediate and tolerant organisms,

thus...

- These four site sets could be **assessed for impact** on the basis of as few as 25 taxa.
- It is not at all unreasonable to have HS students master the consistent identification of these 25 taxa and thus be in a position to assist the professional effort by state DEC/DCEMs to assess stream quality on an ongoing basis.

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# Questions



<http://thestartingfive.wordpress.com/2008/01/29/five-questions-to-take-advantage-of-a-black-sense-of-urgency/>

For more information, go to:  
<http://www2.norwich.edu/pinkhamc/>