TMDL Development for Biology Impairments In Virginia Waters

DEQ
VIRGINIA DEPARTMENT OF ENVIRONMENTAL QUALITY

Presentation Goals

Increase understanding of Virginia's benthic stressor methodology

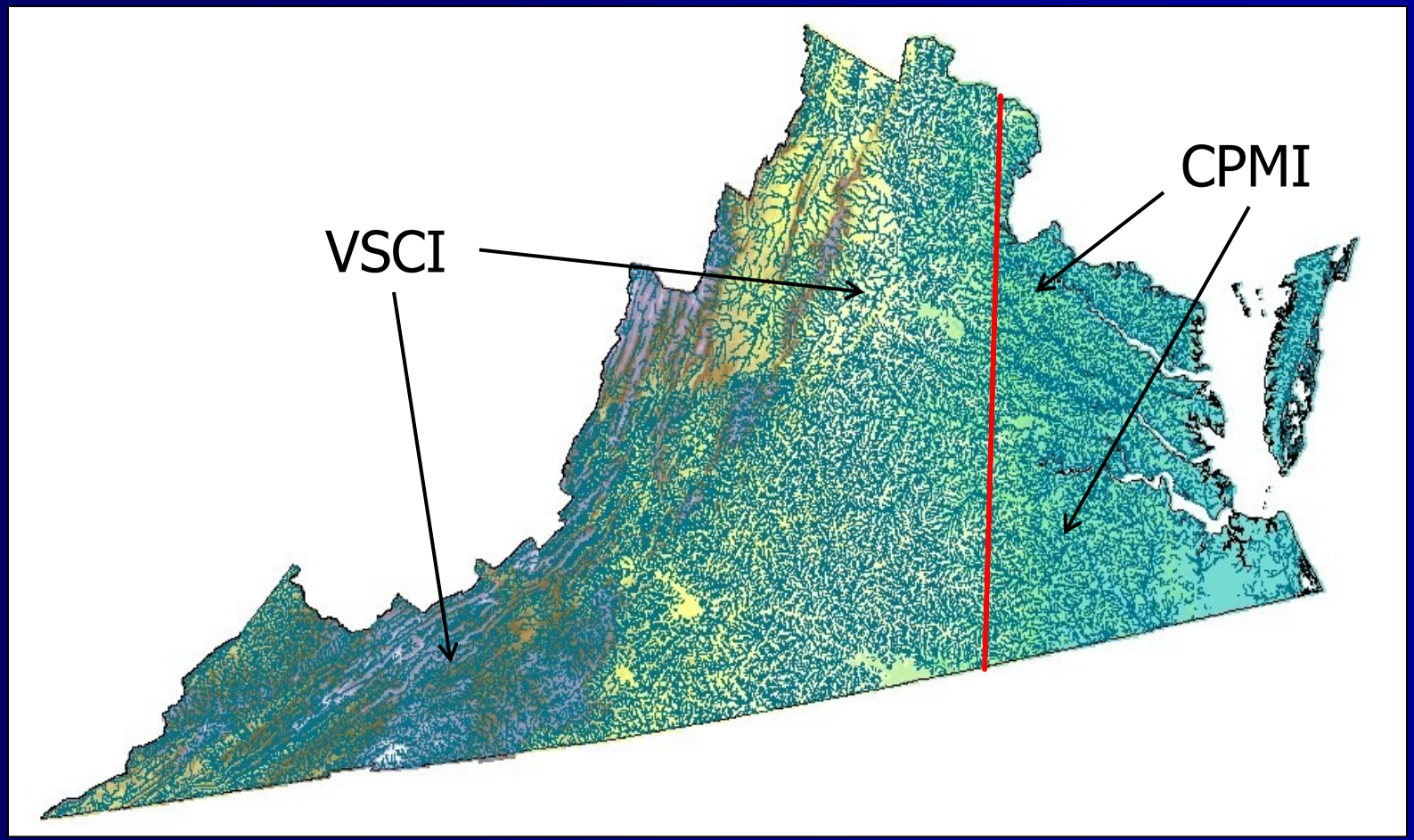
- Aquatic life standards and biological assessment tools
- Example of stressor analysis using Jackson River TMDL
- Improving stressor analysis with new tools and stressor screening values

Biological Assessment

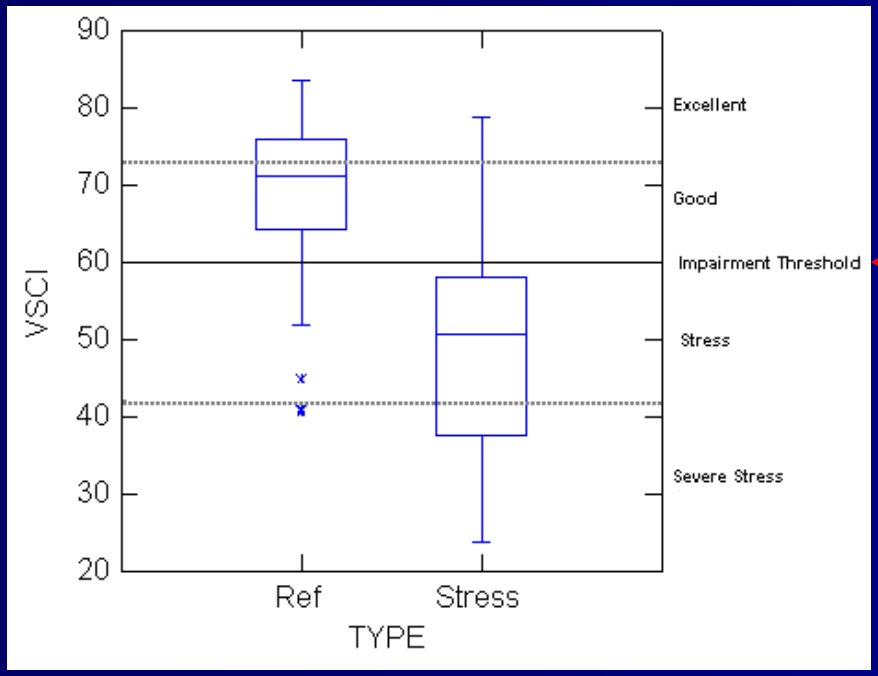
The General Water Quality Standard: "All state waters shall be free from substances [...] which are harmful to human, animal, plant or aquatic life." (9 VAC 25-260-20).

- Virginia Stream Condition Index (VSCI) used in non-coastal ecoregions to assess ecological health
- Coast Plain Macroinvertebrate Index (CPMI) used in coastal ecoregions to assess ecological health

Biological Assessment



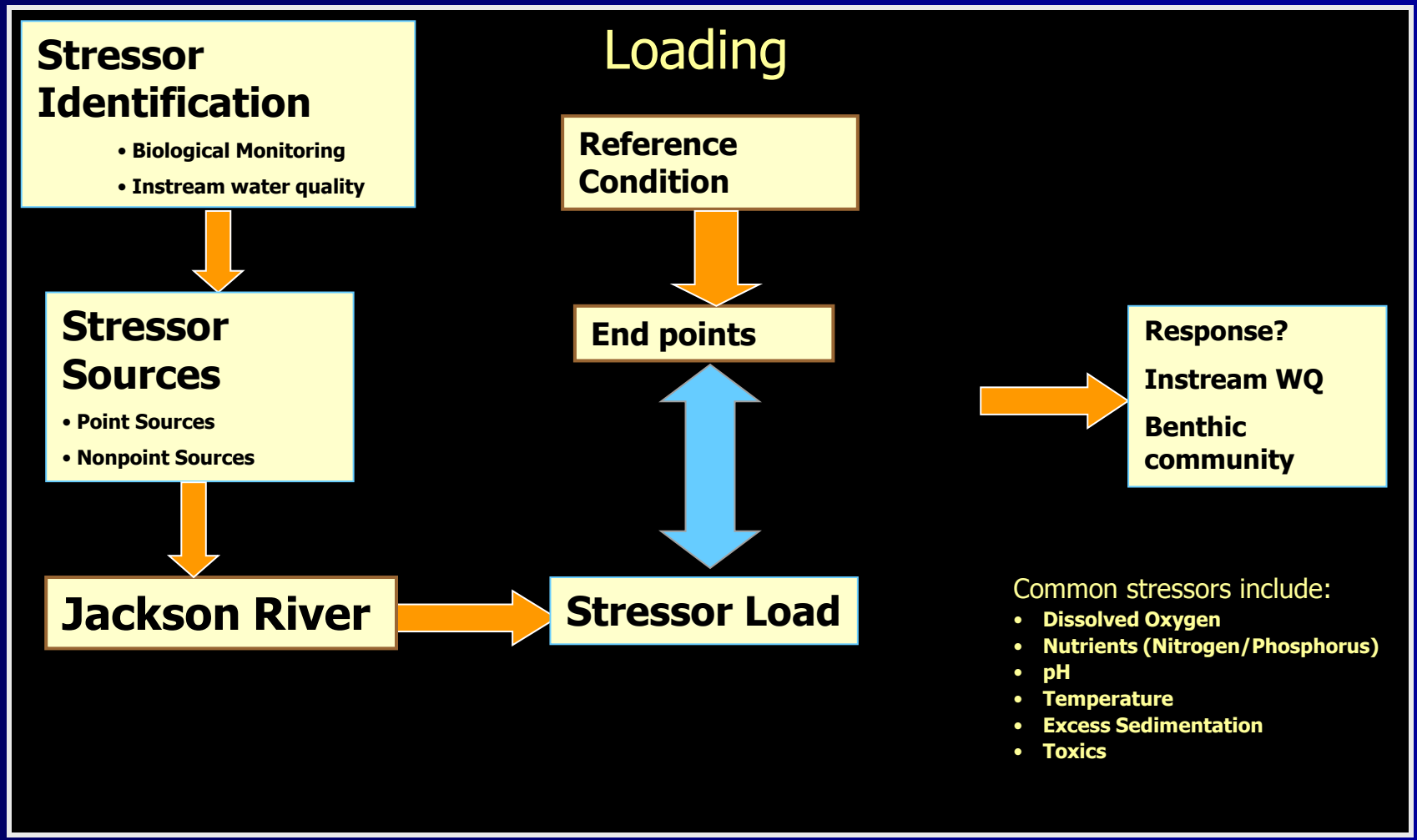
Biological Assessment



TMDL required ☹

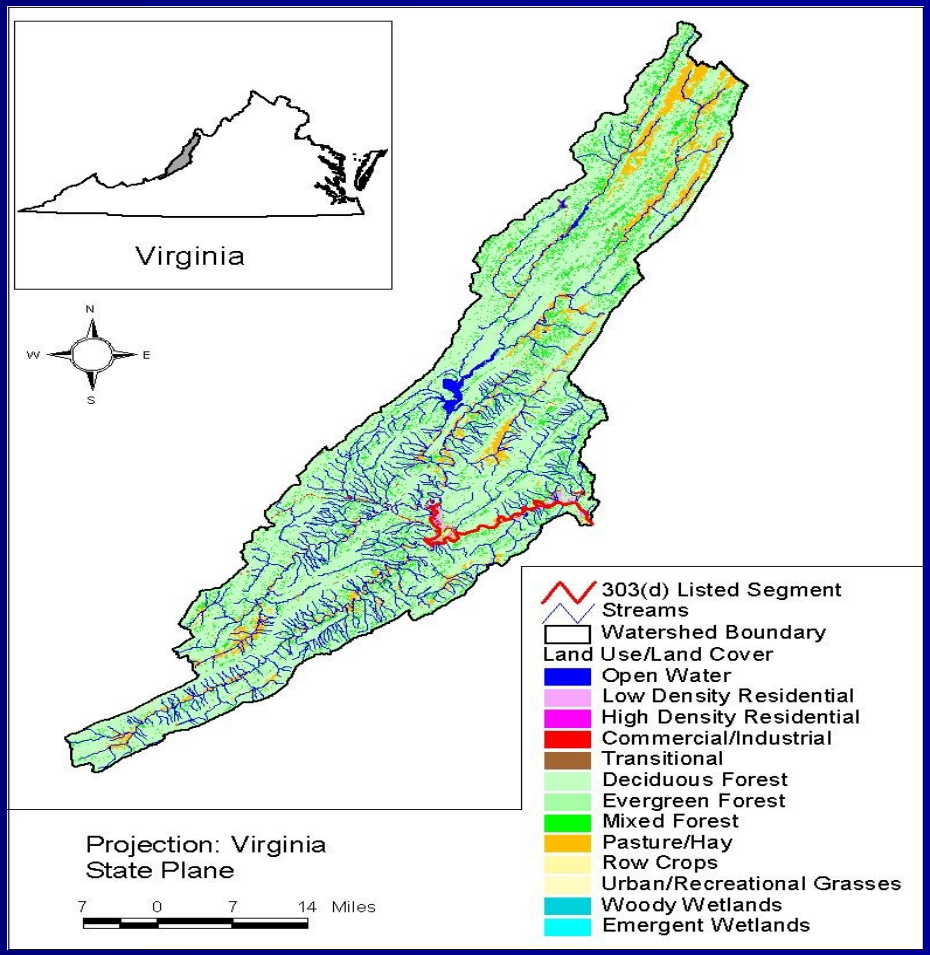
Virginia biological assessment tools are an ecoregional calibrated set metrics that detect and integrate a gradient of anthropogenic stressors

TMDL Process for Benthic Impairment



Example of Stressor Identification

- **Watershed Area is 584,686 acres**
- **Dominant land uses**
  - **89.3% Forested**
  - **8.5% Agriculture**
  - **2.2% Developed**



Benthic Stressor Identification

- What pollutant(s) is causing the impairment of the benthic community?

- Common stressors include:
  - Dissolved Oxygen
  - Nutrients (phosphorus and nutrients)
  - pH
  - Temperature
  - Excessive Sedimentation / habitat alteration
  - Toxics

Stressor Identification

- Each candidate stressor was evaluated based on available monitoring data, field observations, and consideration of potential sources in the watershed
- Potential stressors were further classified as a *non-stressor*, *possible stressor*, or *most probable stressor.*

Data Used in Stressor Identification

Environmental Data

1. **Instream Water Quality Data**
2. **Biological and Habitat Assessment Data**
3. **Acute and Chronic Toxicity Testing**
4. **Field notes and observations**
5. **Discharge Monitoring Reports (DMR), Nutrient Monitoring Reports (NMR), WET toxicity testing**
6. **Stream flow**

Sources

VADEQ

- Instream water quality data
- Habitat Data
- Biological monitoring data

Mead Westvaco

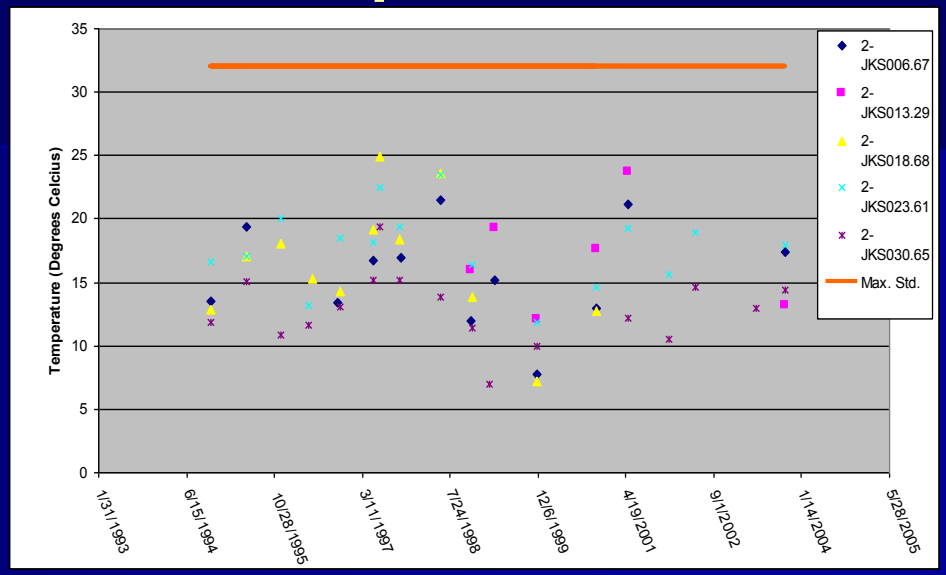
- Instream water quality data
- Biological monitoring data
- Nutrient data
- Metals data
- Periphyton data
- Periphyton studies conducted by Patrick Center for Environmental Research

pH and Temperature

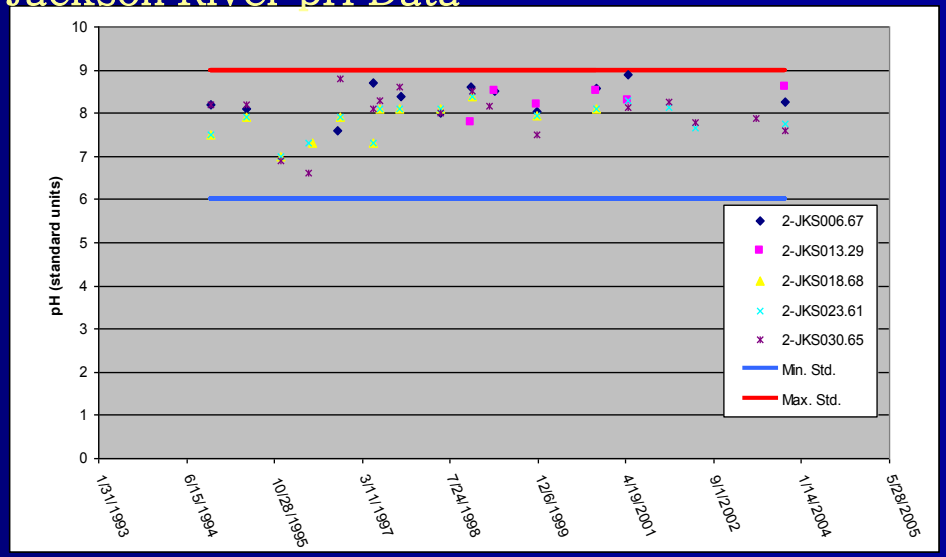
- Field monitoring data indicate adequate pH and temperature values in the Jackson River (within water quality standards)

Therefore, pH and temperature are considered as non-stressors in the Jackson River

Jackson River Temperature Data



Jackson River pH Data



Metals

- DEQ water quality data indicated
  - no dissolved metals parameters exceeded Virginia's established water quality standards
  - no sediment metals exceeded the Virginia's established sediment screening value
  - low metal CCU (<2)
- Metals sampled:
  - **Arsenic, Cadmium, Chromium, Copper, Lead, Mercury, Nickel, Selenium, Zinc**

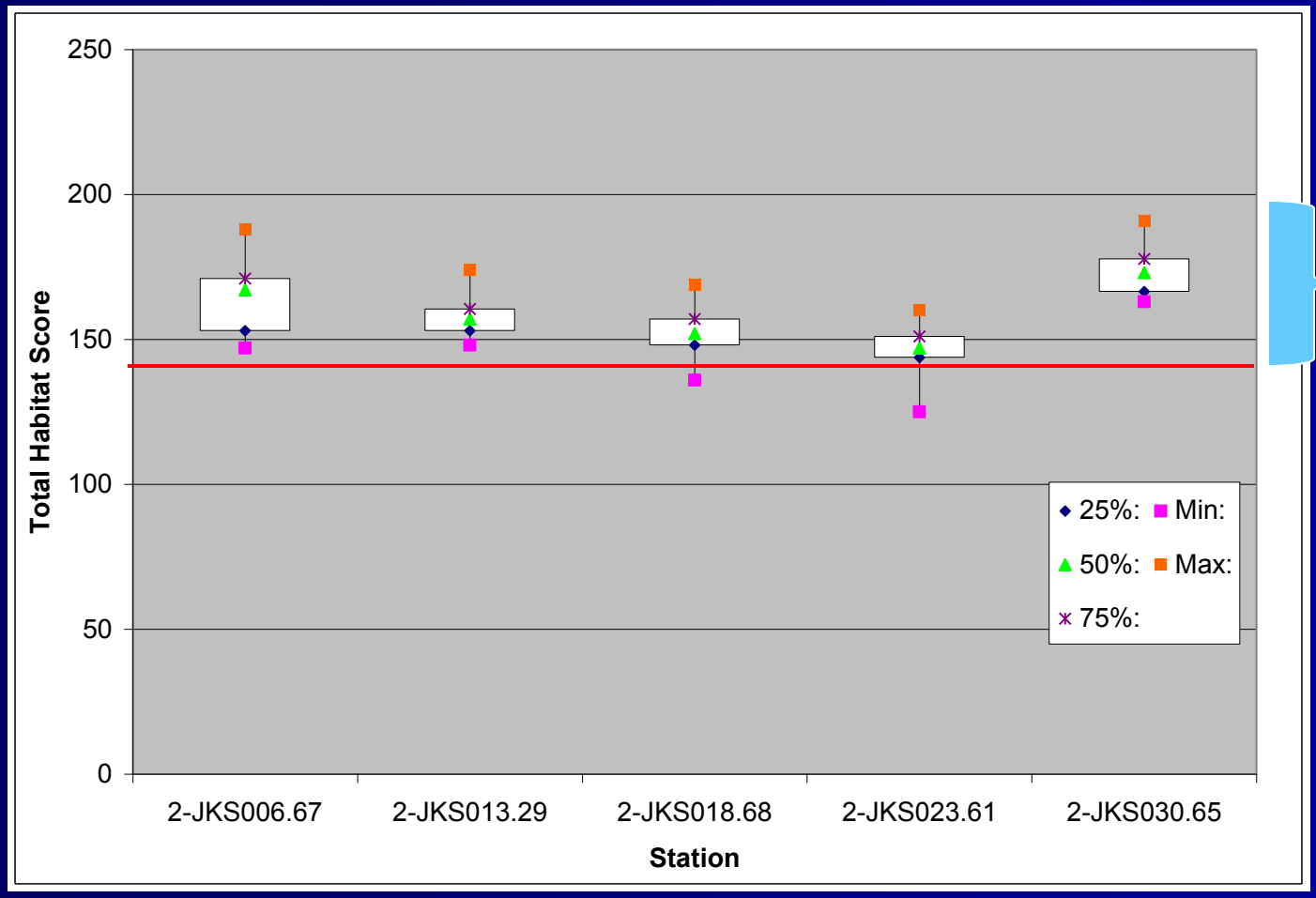
Therefore, metals are considered as non-stressors in the Jackson River

Organics

- DEQ water quality data indicated
  - no dissolved organics parameters exceeded Virginia's established water quality standards
  - no sediment organics exceeded the Virginia's established sediment screening value
- Organics sampled:
  - **Chlordane, DDD, DDE, Endrin, Endosulfan, Heptachlor Epoxide, Total PCBs**

Therefore, organic chemicals are considered as non-stressors in the Jackson River

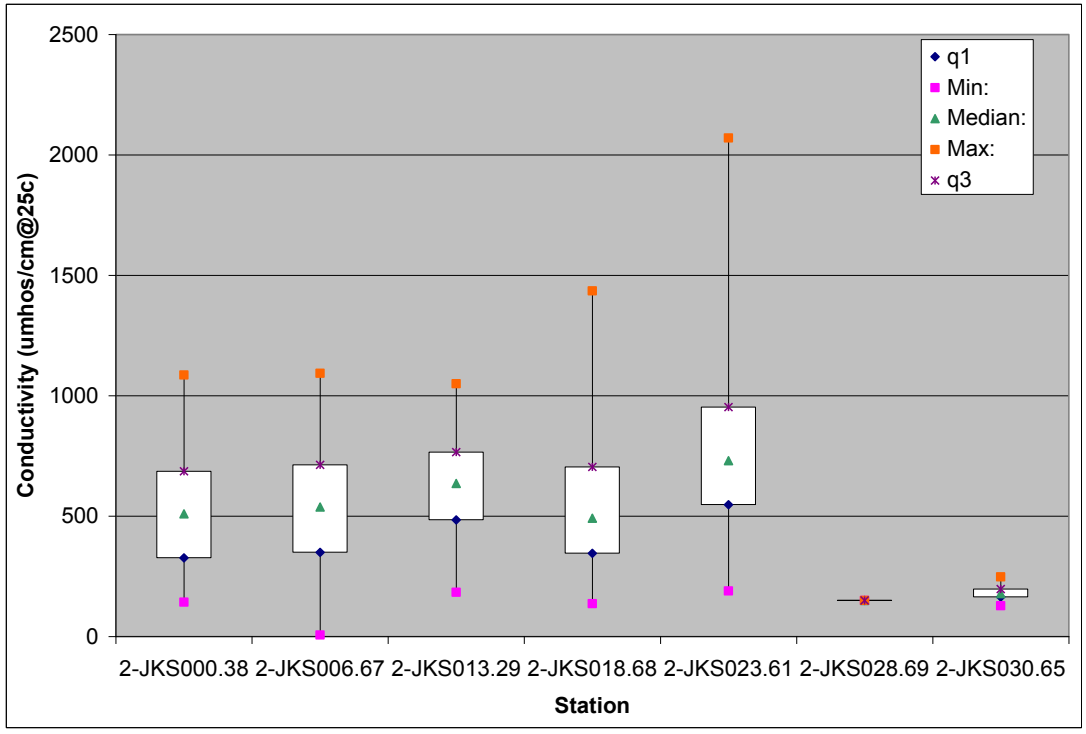
Habitat Assessment Scores
Total Habitat Scores



Conductivity/Total Dissolved Solids

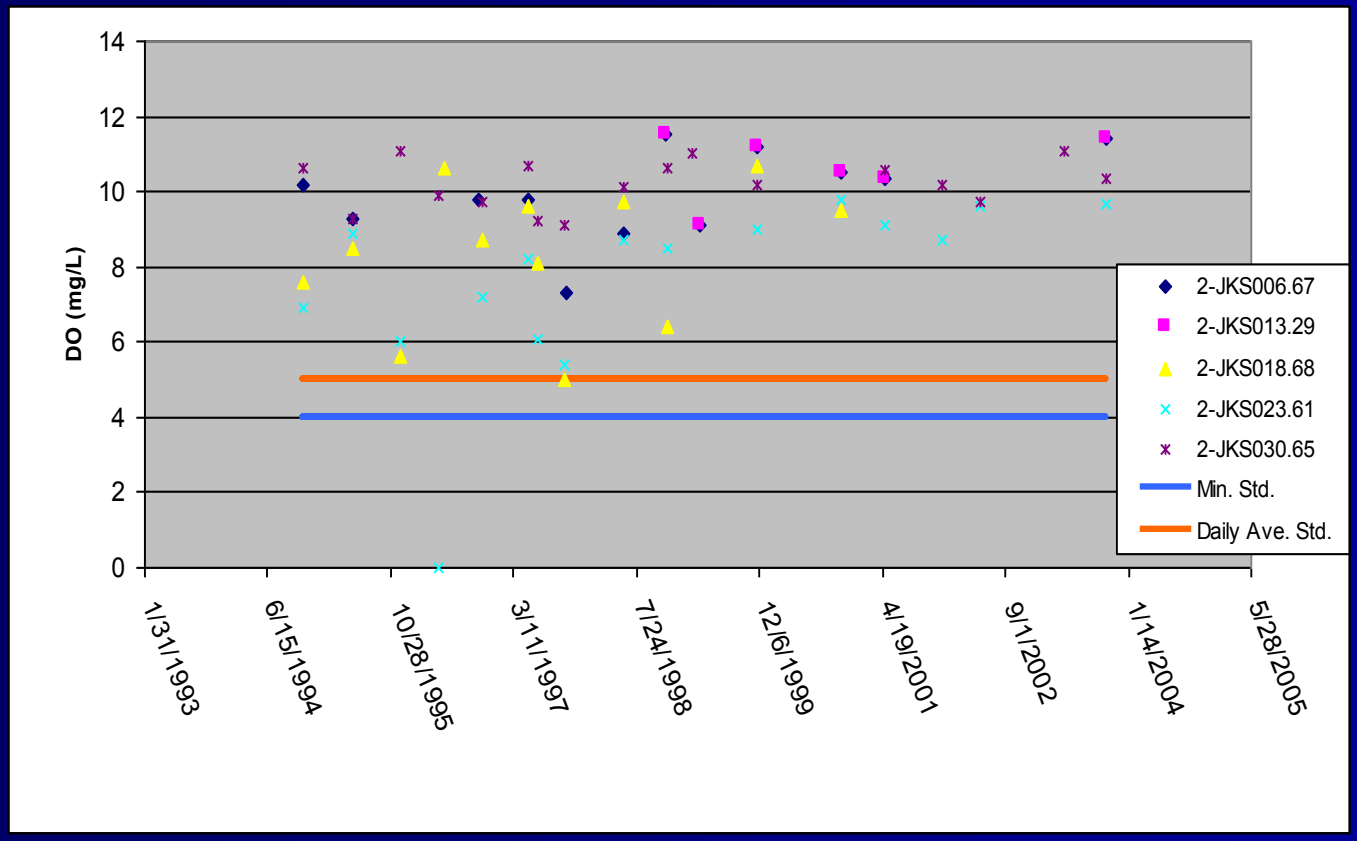
- Field monitoring shows elevated conductivity at most of the monitoring stations
- Conductivity is commonly used as a surrogate for TDS
- Aquatic organisms are sensitive to elevated TDS concentrations

Jackson River Conductivity Data



Therefore, TDS is considered as a possible stressor in the Jackson River

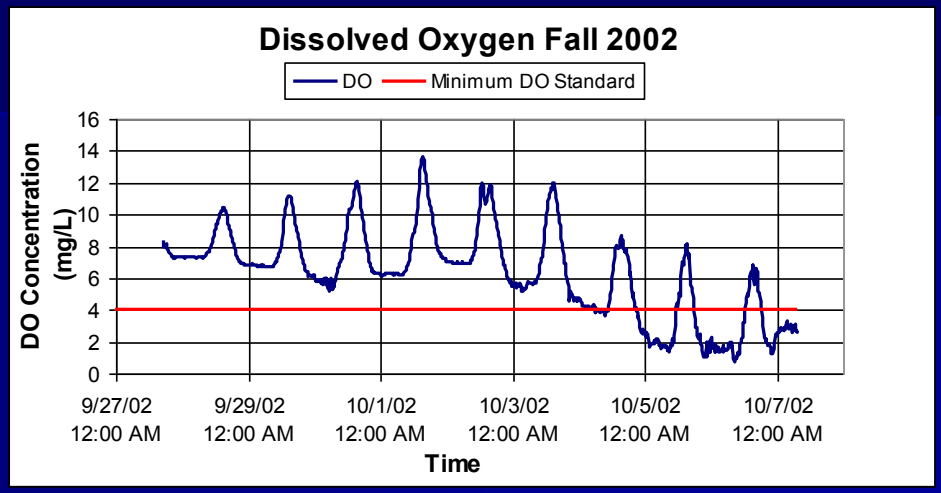
Dissolved Oxygen

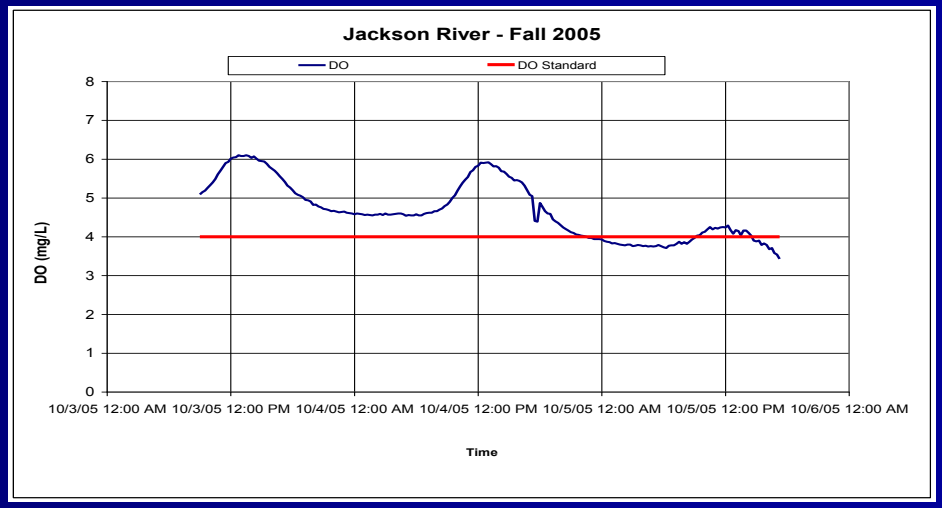


- Field dissolved oxygen concentrations indicate adequate DO levels above the standards

Diurnal Dissolved Oxygen

- Low instream dissolved oxygen concentrations are a problem in the Jackson River
- This problem is in part the result of the excessive nutrient loading to the river and subsequent periphyton growth that occurs because of this nutrient enrichment.





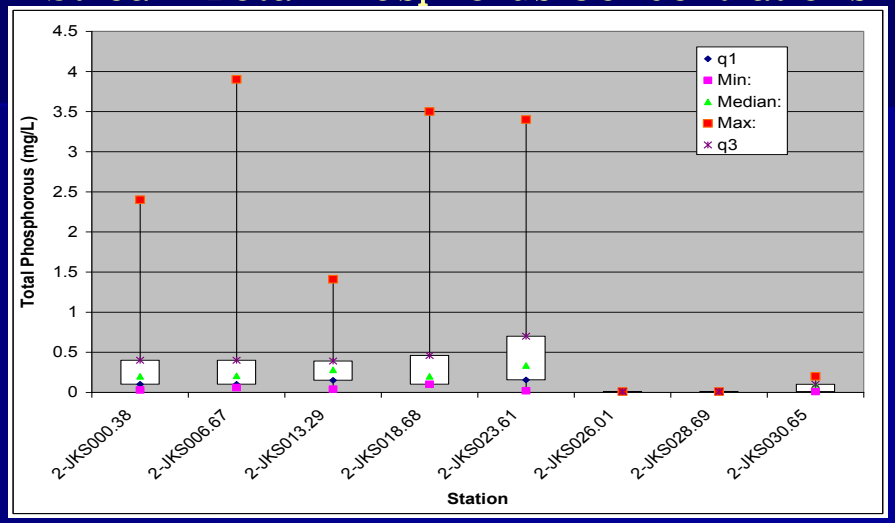
Low Dissolved Oxygen conditions are considered to be a most probable stressor

Phosphorous and Nitrogen

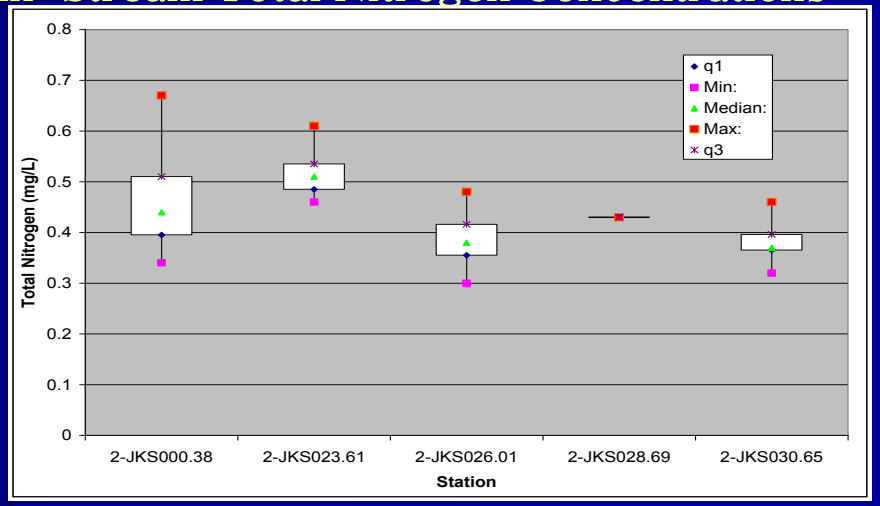
- High nutrient concentrations were observed in the Jackson River
- High nutrient concentrations appear to be resulting in significant periphyton growth (10 X higher than normal)
- DEQ ambient instream monitoring indicates that total phosphorus concentrations increase significantly in the Jackson River at station 2JKS023.61, below the MeadWestvaco facility and at the upstream end of the biologically impaired segment

Excessive nutrient loading leading to eutrophic conditions is considered to be a most probable stressor

In-Stream Total Phosphorus Concentrations



In-Stream Total Nitrogen Concentrations



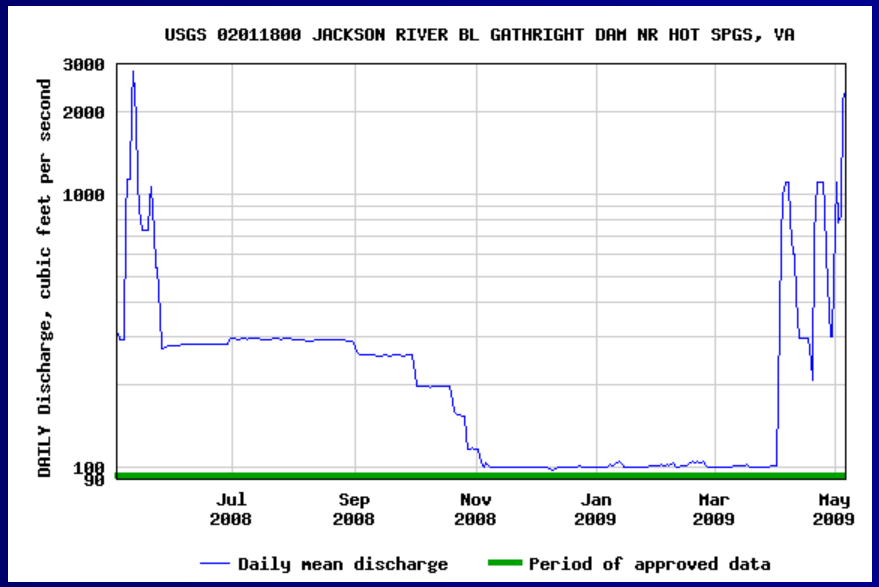
Field Observations- Periphyton Growth

Stressor Identification Summary

- Non Stressors
  - Temperature and pH
  - Metals
  - Organics
  - Excess Sedimentation/Habitat
- Possible Stressors
  - TDS
  - Toxicity
  - Flow Modification
- Most Probable Stressors
  - Low Dissolved Oxygen
  - Nutrients (Nitrogen and Phosphorus)

TMDL Implementation

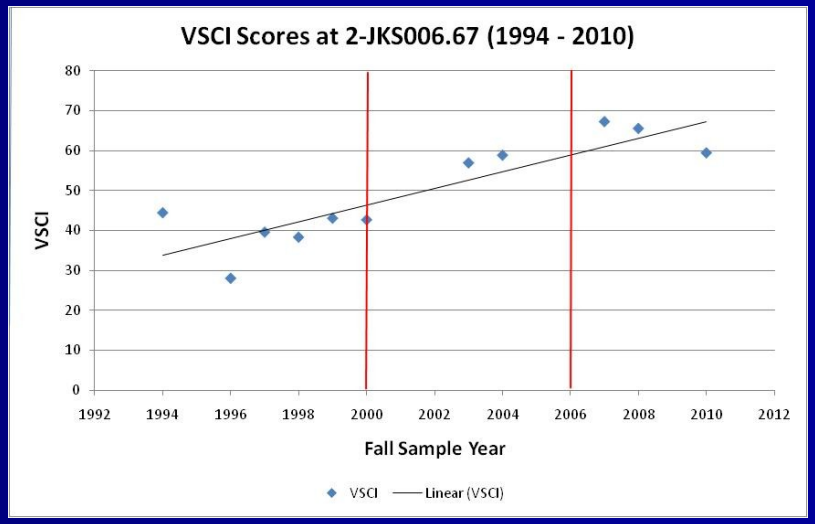
- Nutrient limits put into 1 major industrial facility, 2 major municipal facilities, and 1 minor municipal facility
- 89% Reduction in Phosphorus in impaired reach
- 20% Reduction in Nitrogen in impaired reach
- 216 study to alter growing season hydrology



Significant Improvement

Using reference site revisit data (over multiply years and season), we can calculate interannual variability due to natural conditions (using following equation):

$$x_a - x_b > Z_{(1-\alpha)} * S_{ann} \sqrt{\frac{1}{n_a} + \frac{1}{n_b}}$$



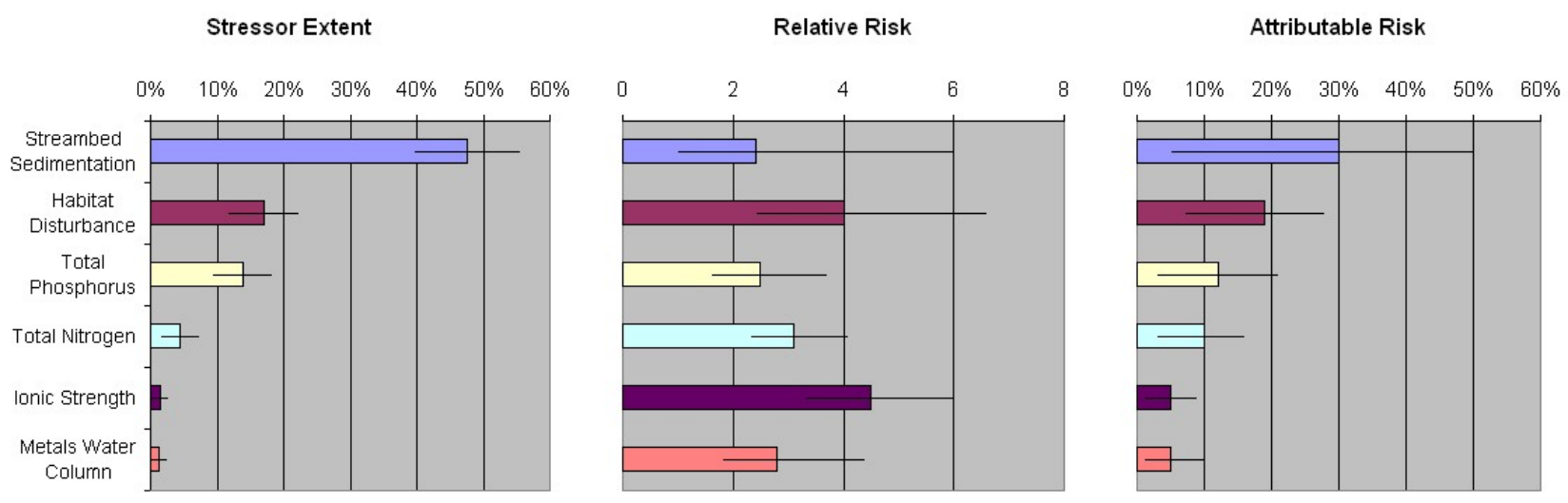
- VSCI increase in 9.7 points is considered significant improvement
- VSCI decrease in 9.7 points is considered significant degradation

Significant Improvement

Jackson River Fall Data (1994-2010)

Station	Years	Average	Point	Significant Increase/Decrease
Clearwater	1994-1999	77.3		reference site
Clearwater	2000-2005	78.5	+1.2	no significant increase/decrease
Clearwater	2006-2010	76.0	-2.6	no significant increase/decrease
City Park	1994-1999	25.1		needs TMDL
City Park	2000-2005	37.4	***+12.4***	***significant increase***
City Park	2006-2010	35.5	-1.9	no significant increase/decrease
Rt 18	1994-1999	45.7		needs TMDL
Rt 18	2000-2005	50.2	+4.5	no significant increase/decrease
Rt 18	2006-2010	48.7	-1.4	no significant increase/decrease
Low Moor	1994-1999	36.6		needs TMDL
Low Moor	2000-2005	39.7	+3.1	no significant increase/decrease
Low Moor	2006-2010	58.4	***+18.7***	***significant increase***
DLCC	1994-1999	38.7		needs TMDL
DLCC	2000-2005	52.8	***+14.1***	***significant increase***
DLCC	2006-2010	64.0	***+11.3***	***significant increase (de-list)***

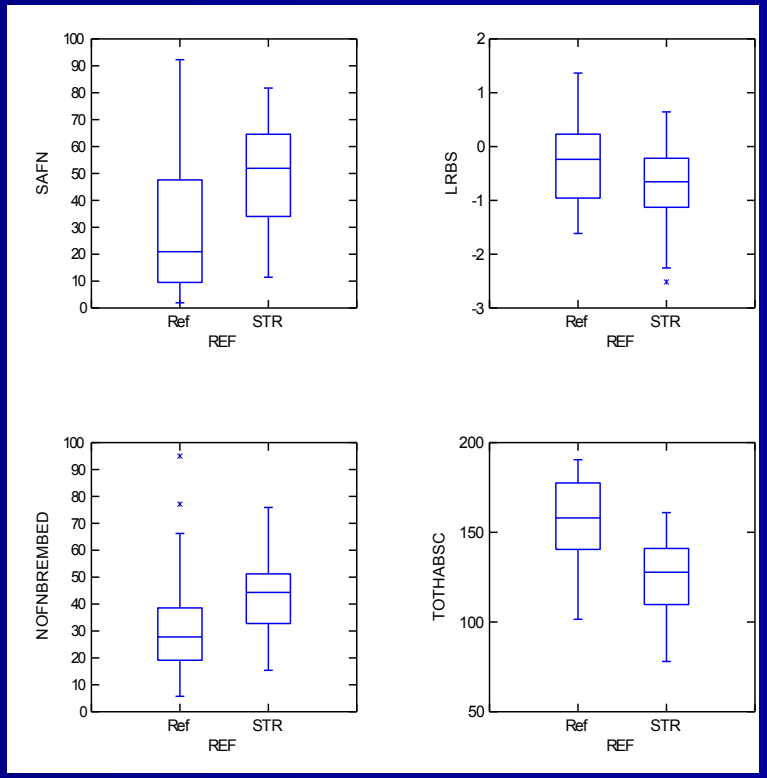
2010 ProbMon 305(b) Results



Stressor Parameters	Optimal	Suboptimal	Classification Reference
Total Nitrogen (mg/L)	<1	>2	(VDEQa 2006)
Total Phosphorus (mg/L)	<0.02	>0.05	(VDEQa 2006)
Habitat Degradation (unitless)	>150	<120	(USEPA 1999)
Streambed Sedimentation (unitless)	>-0.5	<-1.0	(Kaufmann 1999)
Ionic Strength (TDS mg/L)	<100	>350	(VDEQb 2006b)
Metals Water Column (unitless)	<1	>2	(Clements 2000)

New Screening Tools

Metrics that increase with stress	Best standard value (X_5)	X_{max}	Standardization equation. X=metric value
NoFNBRembed	12.6	100	score=100 x [(100-x)/100-12.6)]
SA+FN	8.7	100	score=100 x [(100-x)/100-8.7)]
Metrics that decrease with stress	**Best standard value (X_{95})**	**Xmin**	**Standardization equation. X=metric value**
tLRBS (converted to 0-100 scale) using y=16.667x+66.667	75.7	0	score = 100 x (x/75.7)
TOTHABSC	176.2	0	score = 100 x (x/176.2)



New Screening Tools

Figure 7. Box plot of Motile Diatom metric and PHAB siltation index. Category 1 = Motile diatom <=20% (n=95), Category 2 = Motile diatom between 20% and 40% (n=60), Category 3 = Motile diatom >=40% (n=60).

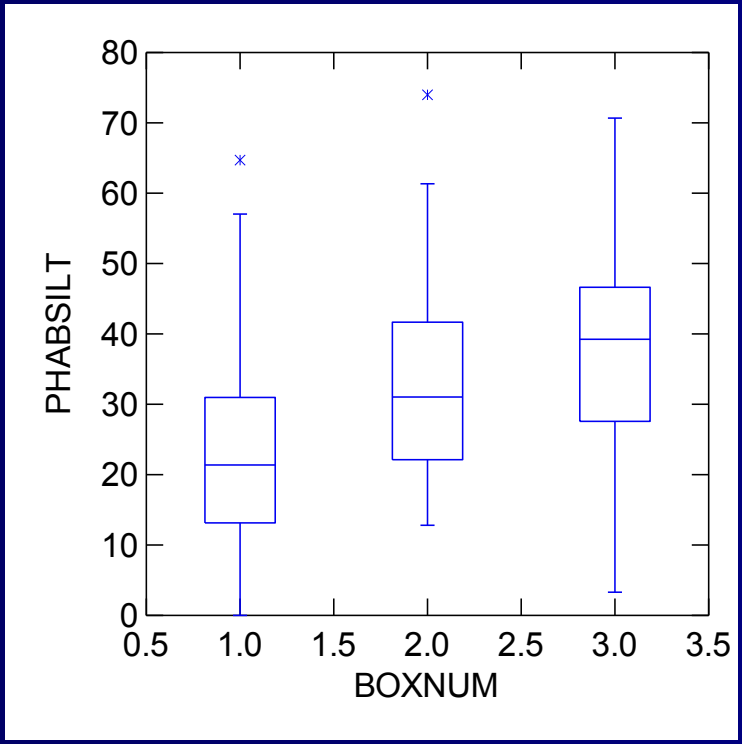
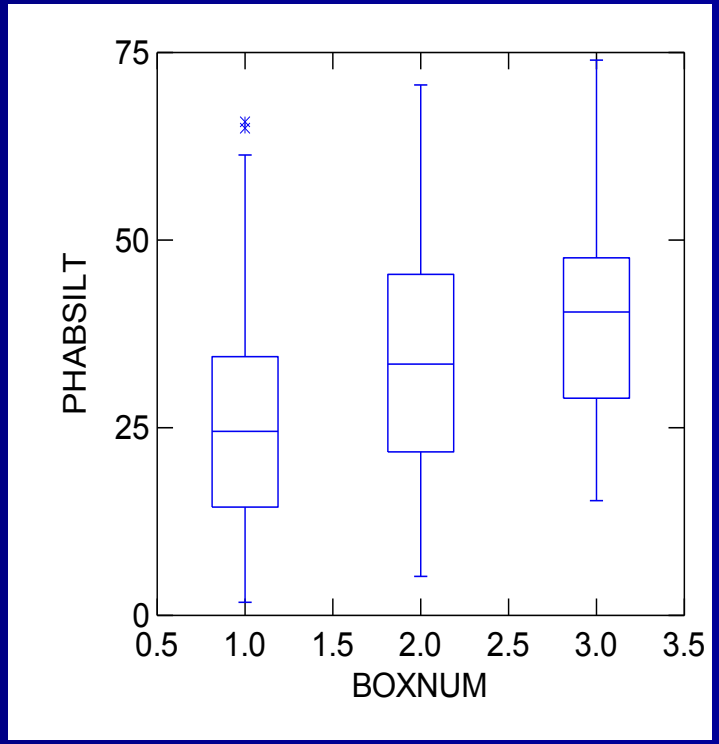
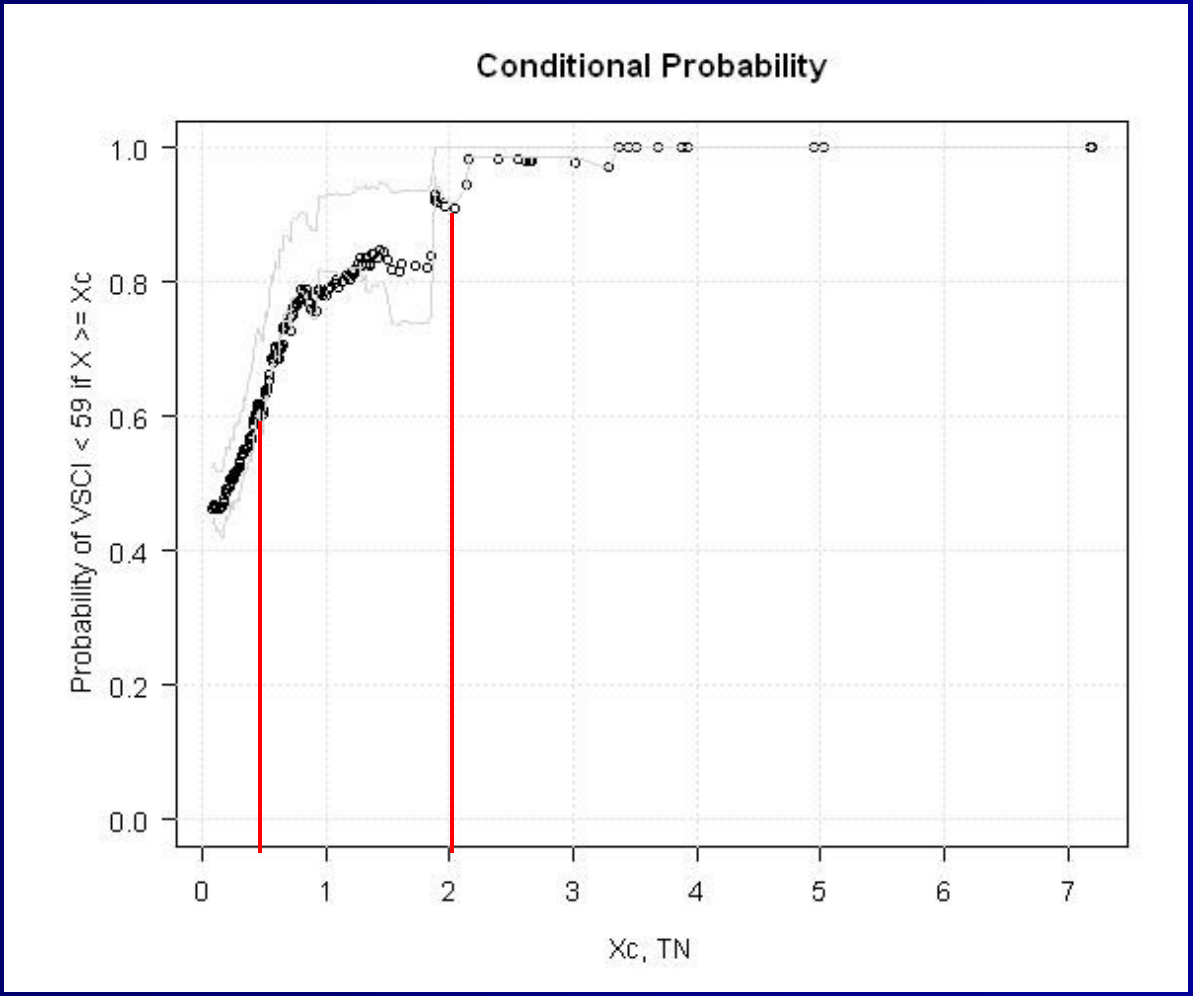


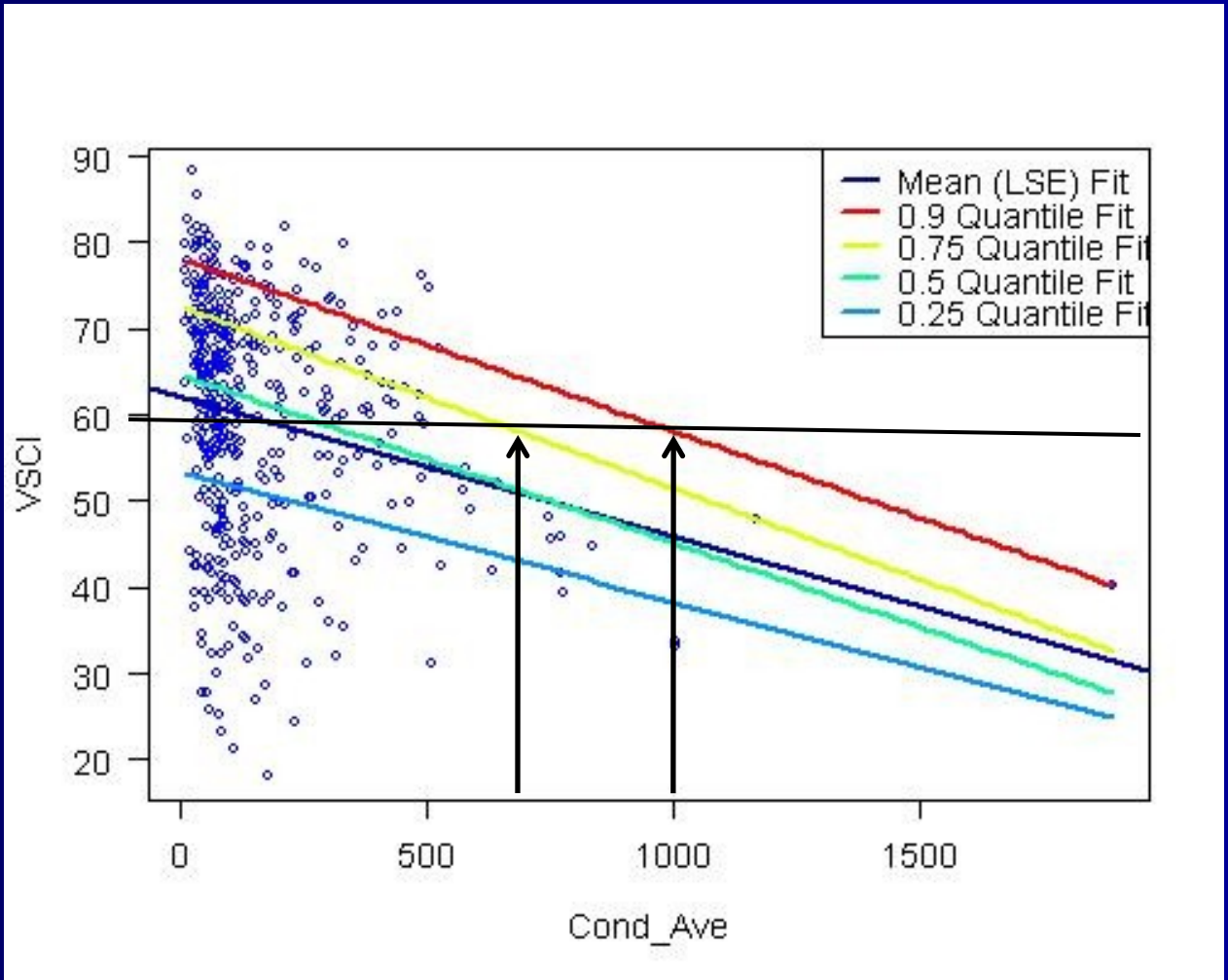
Figure 6. Box polt of VSCI and PHAB siltation index. Category 1 = VSCI >=65 (n=82), Category 2 = VSCI between 65 and 50 (n=64), Category 3 = VSCI <=50 (n=33)



Stressor Screening Results



Stressor Screening Results



Stressor Screening Results

Field Data and Nutrient Stressors Conditional Probability and Quantile Regression Results (n=505)

Field Data	Low Stress (<0.5)	Change Point	High Stress (>0.9)	Quantile 0.90	Quantile 0.75
DO	>10	<9.9	<7	6.2	8.0
pH	6.5 to 9	6.0 to 6.5	<5.5	NA	NA
Sp Cond	<200	>400	>500	1000.0	600.0

Nutrient Data	Low Stress (<0.5)	Change Point	High Stress (>0.9)	Quantile 0.90	Quantile 0.75
TN	<0.6	>0.6	>2.0	4.0	2.2
TP	<0.02	>0.04	0.2	0.4	0.2

Stressor Screening Results

Habitat and Metal Stressors Conditional Probability and Quantile Regression Results (n=343)

Habitat Data	Low Stress (<0.5)	Change Point	High Stress (>0.9)	Quantile 0.90	Quantile 0.75
RPB Habitat	>160	<145	<75	50	75
LRBS	>-0.5 to +1	<-0.9	<-2.2	-3.5	-2.5
PHABsilt	<20	>35	>70	80	60

Metals Data	Low Stress (<0.5)	Change Point	High Stress (>0.9)	Quantile 0.90	Quantile 0.75
ACCCLMNSSZ	<2.5	>3.5	>4	8	8
All Metals	<4	>4.1	>7	10	8

Stressor Screening Results

Review All Stats Results and Set Screening Values

Stress Category	Total Nitrogen (mg/L)
Probable Stressor	>2.0
Possible Stressor	1.0 to 2.0
Low Stress	0.6 to 1.0
Non-Stressor	<0.6

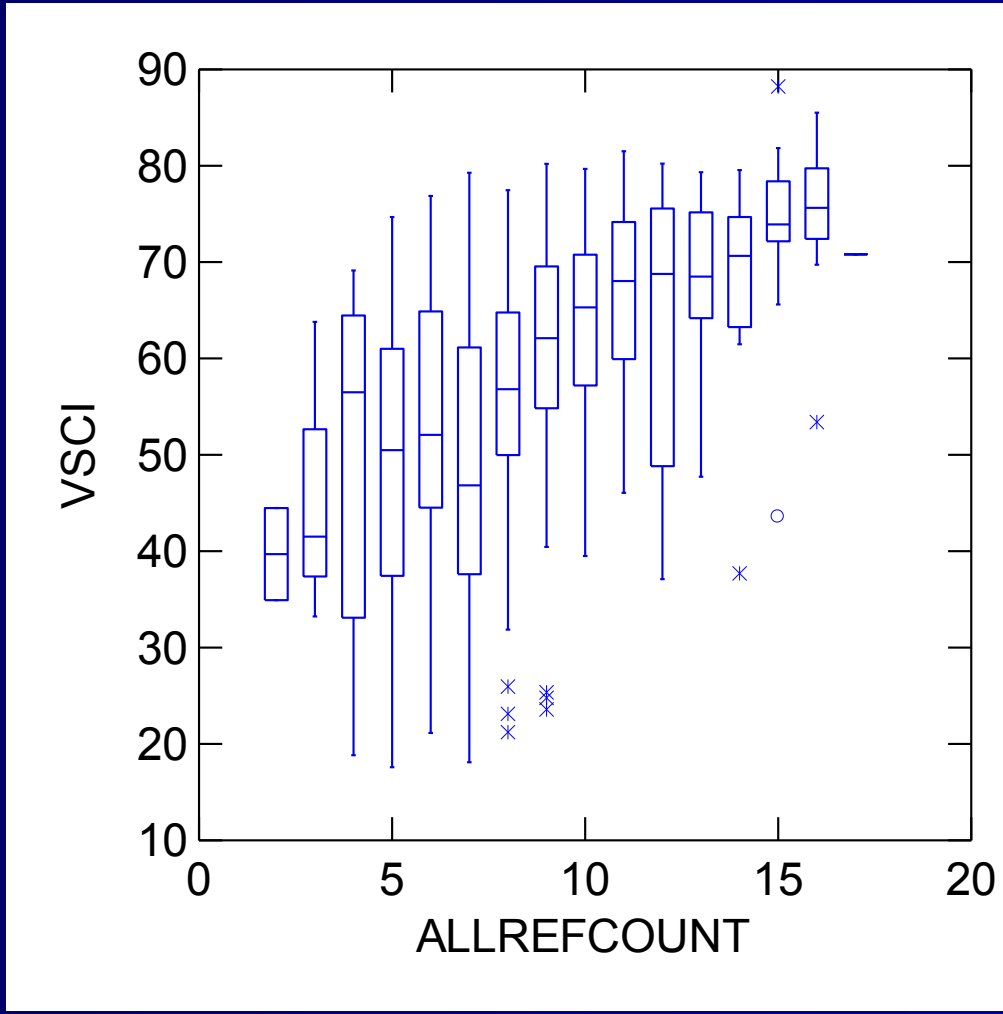
Reference Filter

DO >6 mg/L
pH >6,<9
Sp Cond < 250 uS/cm
TN <= 1 mg/L
TP <= 0.02 mg/L
Total Habitat > 150
LRBS >= -0.5
PHAB Silt Index <= 20
TSS < 5 mg/L

Missing Toxicity and Hydrology Filters

Embed >12
RipVeg >12
All Metal CCU <= 3.0
ACCLMSSZ CCU <= 1.5
% W Urban <= 4%
% W Ag <=15%
Pop Dens (km) <= 15
Road Dens (km) <= 1.5
% W Rfor120 >= 70%

Reference Screening Results

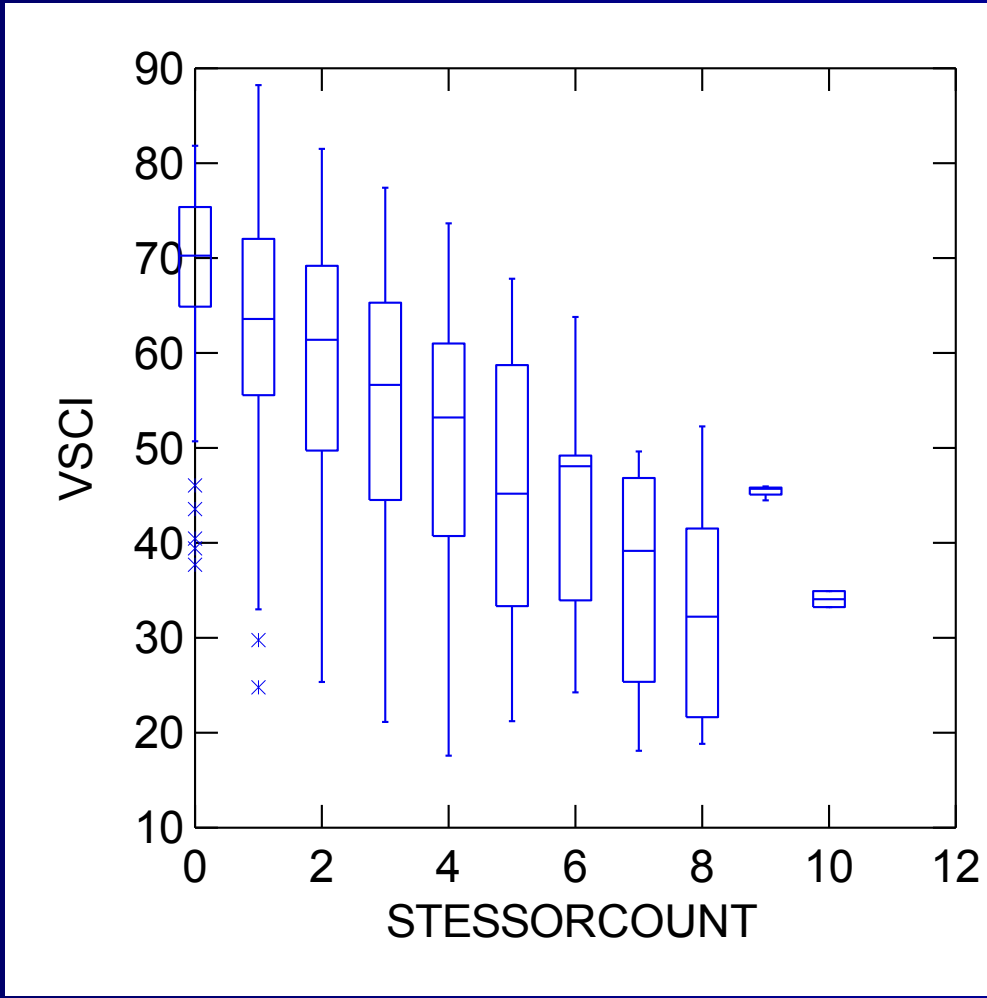


Stress Filter

DO < 5 mg/L
pH <6,>9
Sp Cond > 500 uS/cm
TN >= 2 mg/L
TP >= 0.05 mg/L
Total Habitat <= 120
LRBS <= -1
PHAB Silt Index >= 30
TSS > 30 mg/L

Embed <=7
RipVeg <=7
All Metal CCU >= 7.0
ACCLMSSZ CCU >= 3.5
% W Urban > 16%
% W Ag > 55%
Pop Dens (km) > 100
Road Dens (km) > 3.5
% W Rfor120 >= 70%

Stressor Screening Results



Acknowledgements

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Questions?

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