Improved Biological Assessment Methods for Virginia's Non-Coastal Streams

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Virginia Department of Environmental Quality
U.S. Environmental Protection Agency

What's Bioassessment, and Why Do We Do It???

VA Admin. Code 9VAC25-260-10: Adapted From the U.S. Clean Water Act:

All state waters…are designated for……:

1) **Recreation** (e.g., swimming, boating)
2) **Aquatic Life**
3) **Wildlife**
4) **Fish and Shellfish (Edible and marketable).**

SOME state waters designated for: 5) **Drinking water** use

"Fishable and Swimmable" uses apply to all waters

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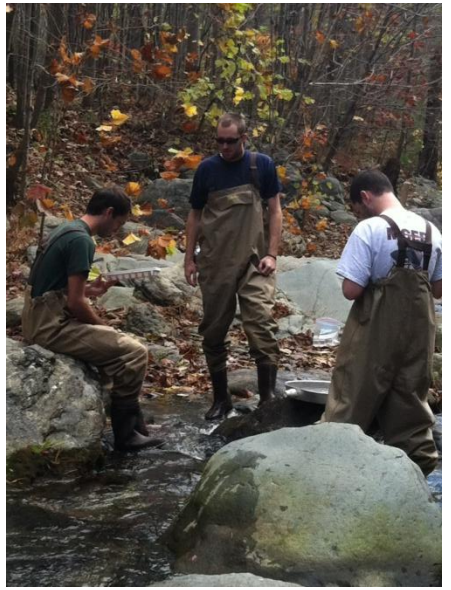
Bioassessment, Biomonitoring, Biological Assessment…….A Short Quiz……..

- What is bioassessment (a.k.a biomonitoring, etc….)?
- Drew's working definition: Using data on biological communities or assemblages to evaluate the magnitude, specific effects, or sources of anthropogenic disturbance in an ecosystem.
- The VA designated use for which bioassessment is most applicable is:
  a) Wildlife
  b) Recreation
  c) Fish/shellfish
  d) Aquatic life
  e) Drinking water
  f) Catfish Noodling



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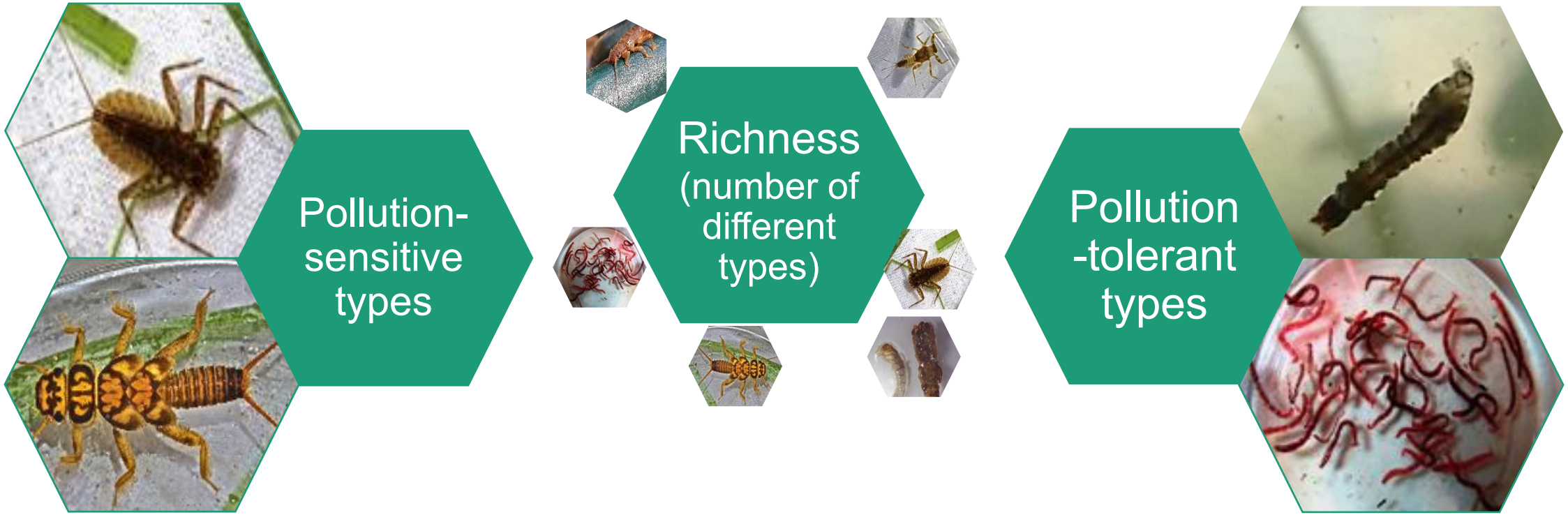
Biological Monitoring

- **Living Recorders*:** Animals, plants, other organisms affected by environmental conditions over longer time scales and at larger spatial scales than water quality measurements (e.g., pH, dissolved oxygen).
- **Metrics**: aspects of the biological community expected to be responsive to human impacts.
- **Multimetric Index** (MMI; also Index of Biotic Integrity; IBI): Bioassessment method that combines multiple metrics into a single score, used as a rating of ecological condition.



*** W. Smigo, DEQ Biologist**

Photos: Bob Henricks: https://aquaticinsectsofcentralvirginia.blogspot.com/2013/08/pteronarcys-dorsata-our-summer-warm.html

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Biological Monitoring

- Current indices: 110-specimen samples identified (mostly) to Family
- **Breaking news- our biologists are SMART!**
  - DEQ biologists now trained to make genus-level identifications
  - 12-year Dataset, with 220-specimen samples identified (mostly) to genus
- **More Breaking news- Bugs are SMART!**
  - Wide variation in ecology, pollution tolerance within families (more info.at genus level)
  - 220 > 110 (larger samples are more representative of the community)
  - New indices expected to produce more accurate and precise results

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Study Approach

1. Classify sites based on degree of human disturbance
   - Reference Condition Approach (Stoddard et al. 2008)
   - **Reference Sites** (least disturbed) and **Stressed Sites** (more disturbed)
2. Classify samples based on natural variability
   - How do communities (macroinvertebrates) vary naturally among sites/samples?
3. Create multi-metric indexes/indices (MMIs)
   - Not affected by natural changes, highly responsive to human disturbance
4. Choose the best MMI(s), also set criteria for determining impairment
5. **Communication**
   - Guidelines for use and interpretation
   - For technical AND non-technical audiences

Step 1: Classify human disturbance: **reference** and **stressed** sites

- Measurements NOT used in your MMI
  - That is: We can't use macroinvertebrates to classify disturbance.

Parameter	Reference Criteria	Stressed Criteria
Dissolved Oxygen	>8 mg/L	<7 mg/L
pH	6-9	<6 or >9
Specific Conductance	<250 µS/cm	>500 µS/cm
Total Nitrogen	≤1 mg/L	≥2 mg/L
Total Phosphorus	≤0.02 mg/L	≥0.05 mg/L
Habitat Score*	>150	≤ 120

Reference Site: At least 5/6 reference criteria met AND no stress criteria met*

* Criteria relaxed slightly in southern Piedmont

Stressor Document:
https://www.deq.virginia.gov/home/showpublisheddocument/4313/637461491358800000

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Step 1: Classify human disturbance

Parameter	Reference Criteria	Stressed Criteria
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Total Nitrogen	≤1 mg/L	≥2 mg/L
Total Phosphorus	≤0.02 mg/L	≥0.05 mg/L
Habitat Score*	>150	≤ 120

Multiple stress criteria met

DISTURBED

Stressor Document:
https://www.deq.virginia.gov/home/showpublisheddocument/4313/637461491358800000
Joke: Kelly Hazelgrove, DEQ Biologist

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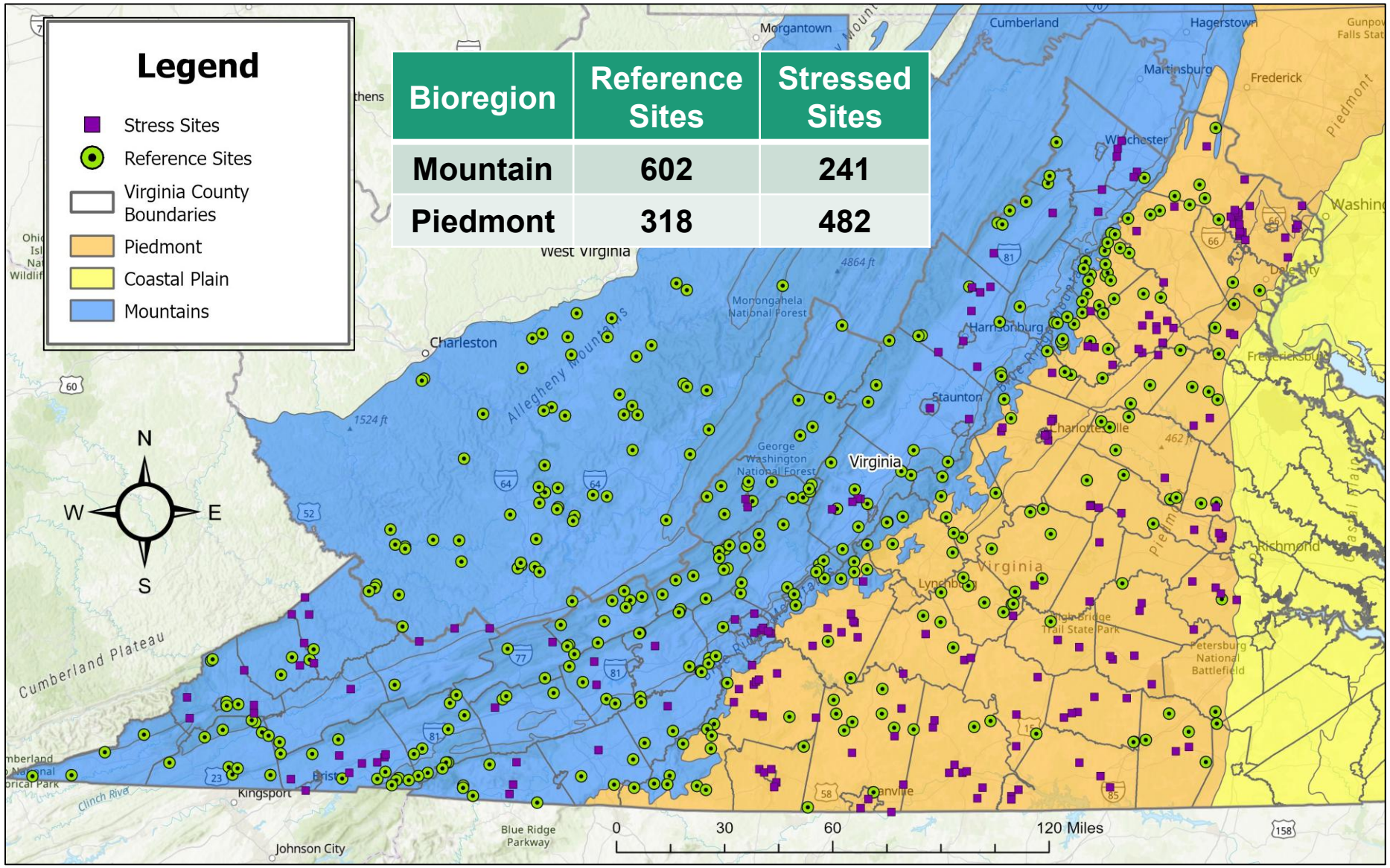
Study Sites



Bioregion	Reference Sites	Stressed Sites
Mountain	602	241
Piedmont	318	482

Step 2: Evaluate Natural Variability Among Macroinvetebrate Communities

Analyzed data for differences in communities at reference sites based on:

- Season (Spring, Fall)
- Bioregion (Piedmont, Mountains)
- Ecoregion (**Mountains:** Blue Ridge, Central Appalachians, Ridge/Valley, **Piedmont:** Northern Piedmont, Piedmont)
- DEQ Admin Region (is there collector bias?)
- Sampling Method (is there methodology bias?)
- Stream order (measure of stream size)
- Water Quality Standards Classes (9VAC25-260-50)- upland streams: Class 3 - 7

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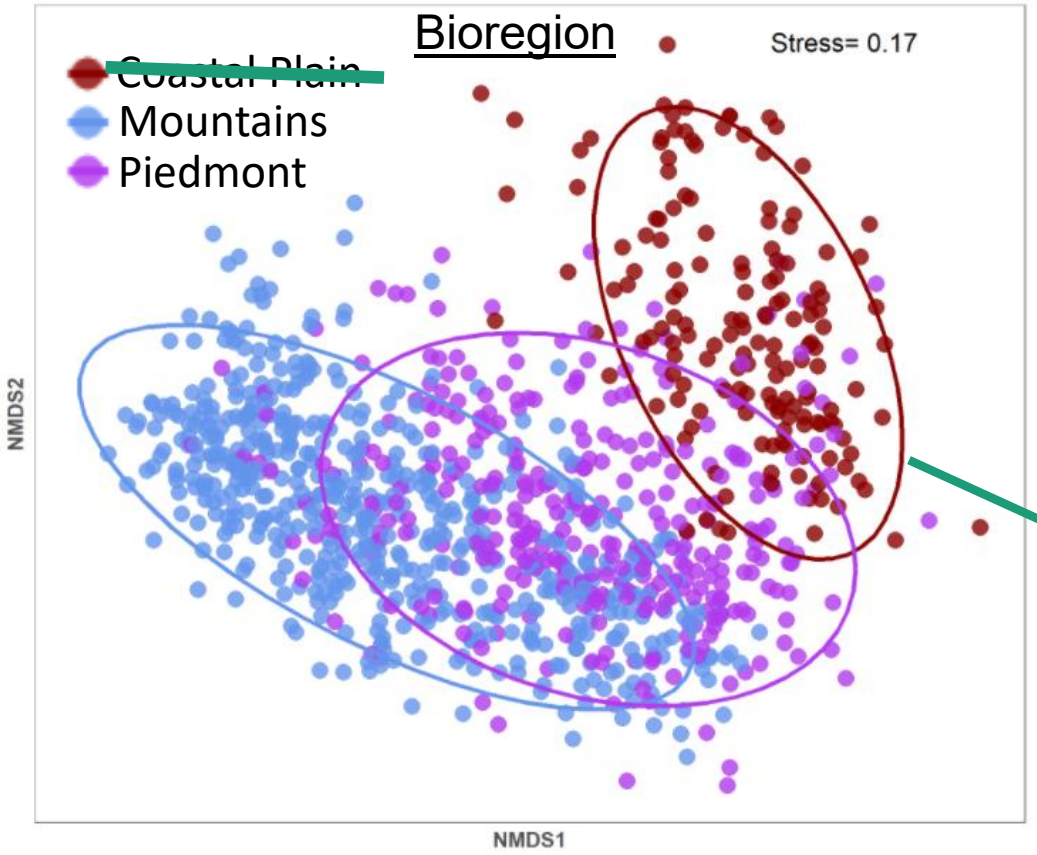
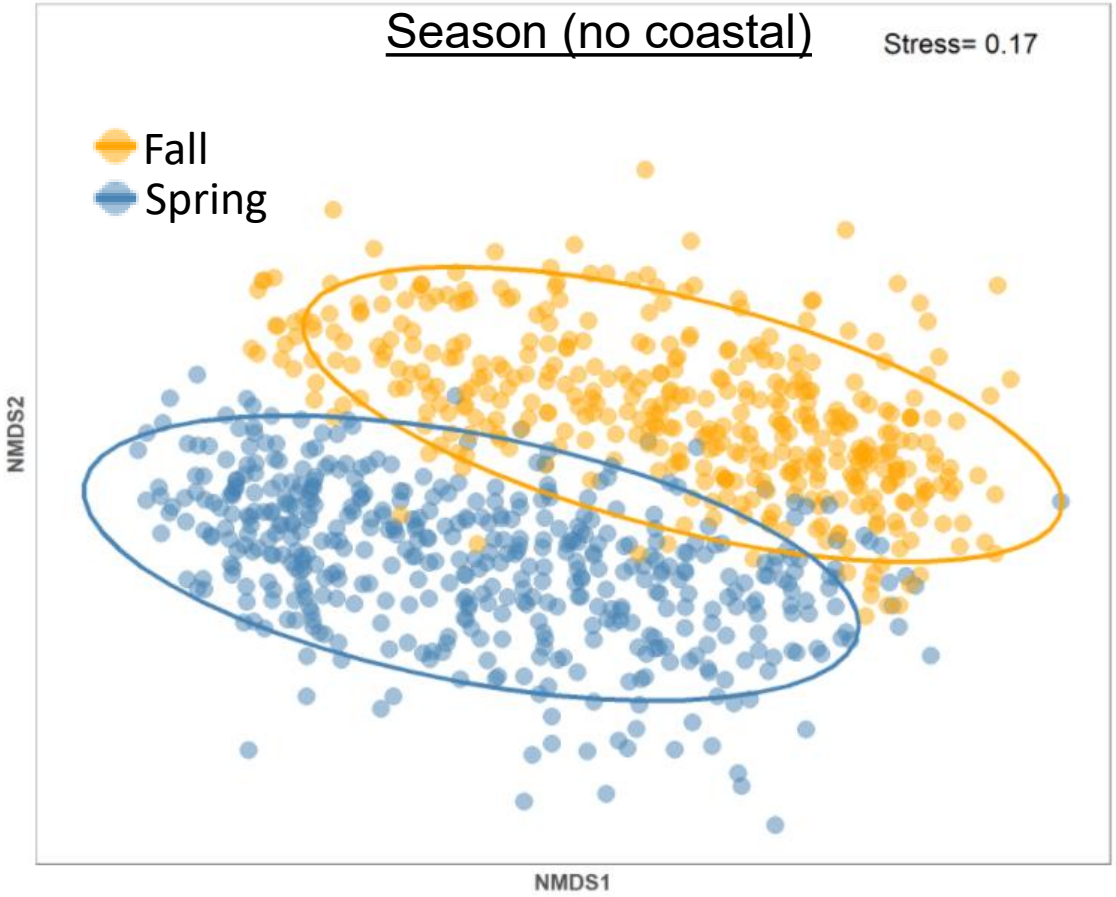
Macroinvertebrate community variation based on…





Coastal sites excluded from this study (but stay tuned…)

Plots: Non-metric Multiple Dimensional Scaling Ordinations. Significant differences between groups ($p<0.05$), according to Multi-response Permutation Procedures (see Data Analysis Slide for Details)

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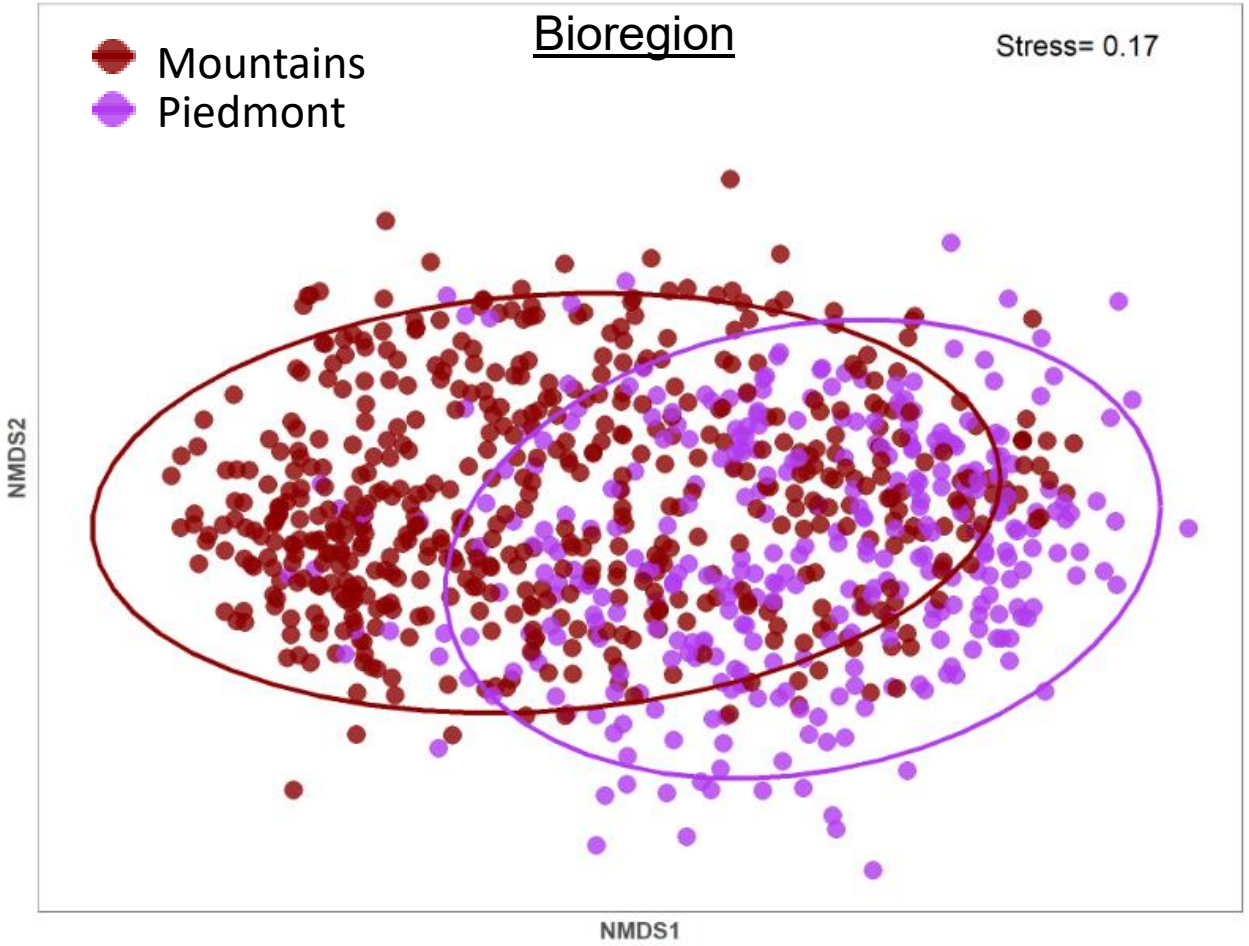
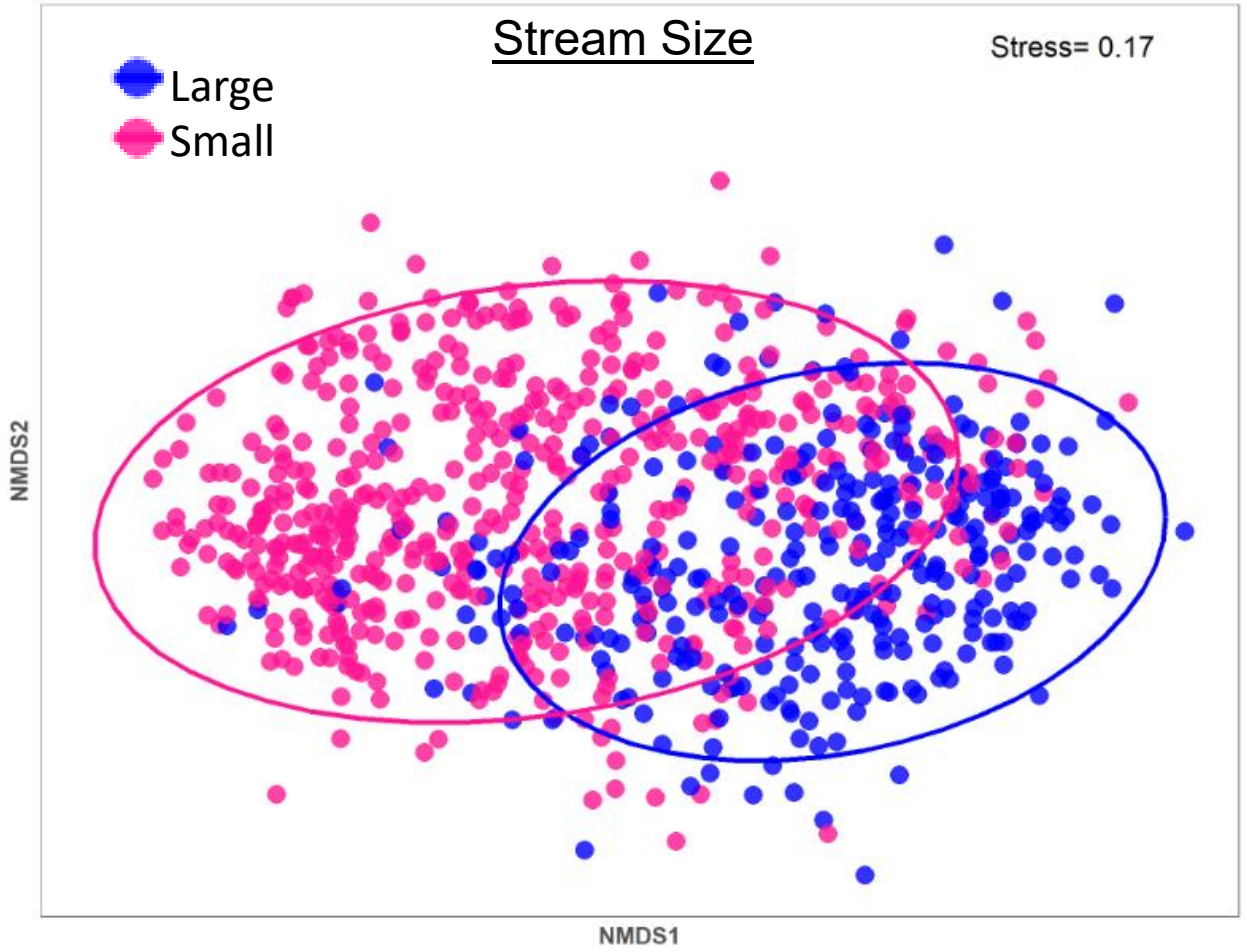
Macroinvertebrate community variation based on…





Conclusion: build MMI

Plots: Non-metric Multiple Dimensional Scaling Ordinations. Significant differences between groups ($p<0.05$), according to Multi-response Permutation Procedures (see Data Analysis Slide for Details)

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Step 3: Create multi-metric indices

- Calculated metric over 200 metrics calculated based on ecological data:
  - aquametBio R Package (Karen Blocksom EPA)
  - Feeding strategy, diversity, ecological habits, pollution tolerance, etc…
  - e.g. Percentage of predators in this sample……..

Dragonfly larva: **PREDATOR**

Giant Stonefly: **LEAF SHREDDER**

= 50 %

Photos: Dragonfly: Kelly Hazlegrove, VADEQ, Giant Stonefly: Bob Henricks: https://aquaticinsectsofcentralvirginia.blogspot.com/2013/08/pteronarcys-dorsata-our-summer-warm.html

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Step 3: Create multi-metric indices

- Metric Reduction
  - Many provide little information (little response to stress)
  - 64 candidate metrics
- Convert metric values to scores based on comparison to reference conditions
  - e.g. 50% predators in sample = score of 40 out of 100 points (hypothetical)
- Aggregate metrics into final index score (sum, **average**, other method)
  - Metric Score A + Metric Score B, Metric Score C + …… = Final Index Score

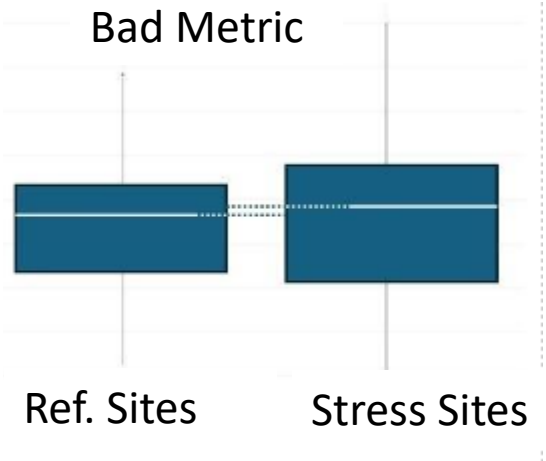


Photo: Kelly Hazlegrove, VADEQ

Step 4: Choose best MMI(s)

- EPA All Subsets Analysis
  - There are **1.84*10^{19}** possible combinations of 64 metrics (My Computer Hurts ☹)
  - All *practical* Subsets- limited how metrics can be combined: **~ 2 million different indices calculated**
  - All Subsets Analysis: extensive diagnostics on index performance:
    - Automated selection: Millions of MMIs → 100's of MMIs
    - Staff review and consensus building: 100's of MMIs to **Final MMI(s)**
    - **Reviewers aided by interactive diagnostic applications**

S:N	SD	CI90	%CV	%RPD	RMSE
3.41	3.59	4.61	5.65	8.48	4.7

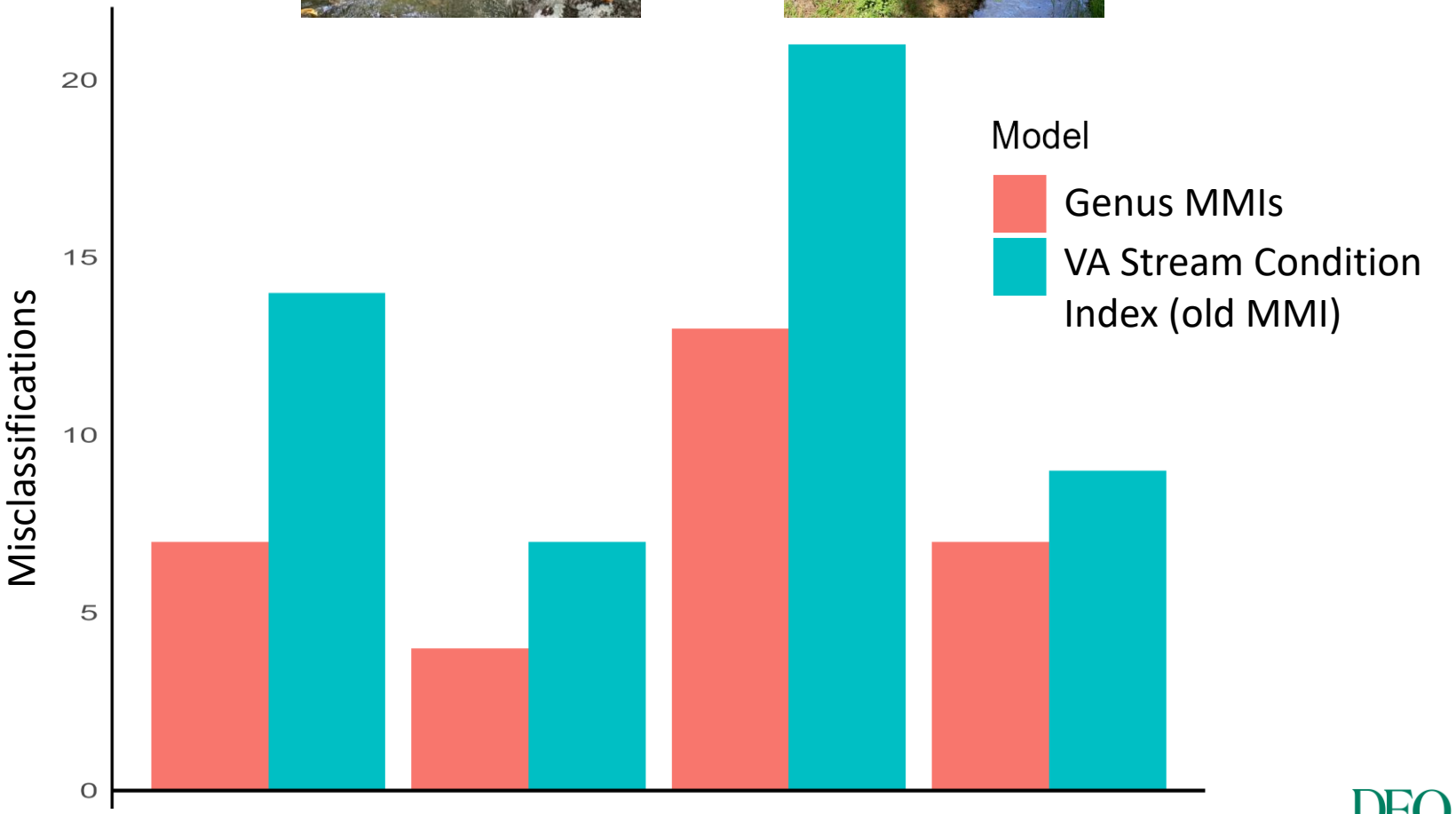
Thank You Kansas Keeton!

Four MMIs recommended

Changes???

- 220-count samples (prev. 110)
- Genus taxonomy (prev. Family)
- Four Models for Upland Streams (prev. 1 model)
- Coastal streams??? (TBD)

Mountain Fall | **Mountain Spring** | **Piedmont Fall** | **Piedmont Spring**



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Step 5: Communication (or: THE SPRINT TO THE FINISH LINE!)

- Technical report (draft complete)
- Short communications for:
  - DEQ leadership
  - EPA
  - Non-technical audiences
- Procedural documents for DEQ staff
  - Job aid on score interpretation
  - Water Quality Assessment Guidance
- Timeline:

NOW → **July 2026** → **Early 2027** → **2027-2028**

- **Academic Expert Review**
- **DEQ Staff Review**
- **DEQ Leadership Review**
- **EPA Review**
- **Publication**
- **First Genus-Level Assessments: Integrated Report 2028**

Photo: Man with Flag: Paul Baker: https://www.flickr.com/photos/38134532@N02/4745908442, Stream: Kelly Hazlegrove, VADEQ

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Questions?

Extra Info on following slides (Contact Drew with Questions)……

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Some References

- **Reference Condition Concept**
  - Stoddard, J., D.P. Larsen, C.P Hawkins, R.K. Johnson, and R.H. Norris. 2006. Setting expectations for the ecological condition of streams: the concept of reference condition. Ecological Applications 16:1267-1276.
- **Range Test, Redundancy, Box Score, Basic MMI Development:**
  - Blocksom, K.A., J.P Kurtenbach, D.J. Klemm, F.A. Fulk, and S.M. Cormier SM. 2001. Development and evaluation of the lake Macroinvertebrate Integrity Index (LMII) for New Jersey lakes and reservoirs. Environmental Monitoring and Assessment 77 (3):311-333.
  - Blocksom, K.A. and B.R. Johnson. 2009. Development of a Regional Macroinvertebrate Index for Large River Bioassessment. Ecological Indicators. Elsevier Science Ltd, New York, NY, 9(2):313-328.
  - Klemm, Donald & Blocksom, Karen & Fulk, Florence & Herlihy, Alan & Hughes, Robert & Kaufmann, Philip & Peck, David & Stoddard, John & Thoeny, William & Griffith, Michael & Davis, Wayne. (2003). Development and Evaluation of a Macroinvertebrate Biotic Integrity Index (MBII) for Regionally Assessing Mid-Atlantic Highland Streams. Environmental management. 31. 656-69.
- **All Subsets Approach:**
  - (PDF) A web-based tool for assessing the condition of benthic diatom assemblages in streams and rivers of the conterminous United States (researchgate.net)
  - Carlisle, Daren & Spaulding, Sarah & Polaskey, Meredith & Schulte, Nicholas & Lee, Sylvia & Mitchell, Richard & Pollard, Amina. (2022). A web-based tool for assessing the condition of benthic diatom assemblages in streams and rivers of the conterminous United States. Ecological Indicators. 135. 108513. 10.1016/j.ecolind.2021.108513.
- **R Packages**
  - Blocksom, K (2024). aquametBio: Calculate NRSA and NLA Biological Metrics & Indicators. R package version 2.2.3
  - Oksanen, J., Blanchet, F.G., Friendly, M., Kindt, R., Legendre, P., McGlinn, D., et al. (2023). vegan: Community Ecology Package. R package version 2.6-4. https://cran.r-project.org/package=vegan
  - R Core Team (2024). _R: A Language and Environment for Statistical Computing_. R Foundation for Statistical Computing, Vienna, Austria. <https://www.R-project.org>

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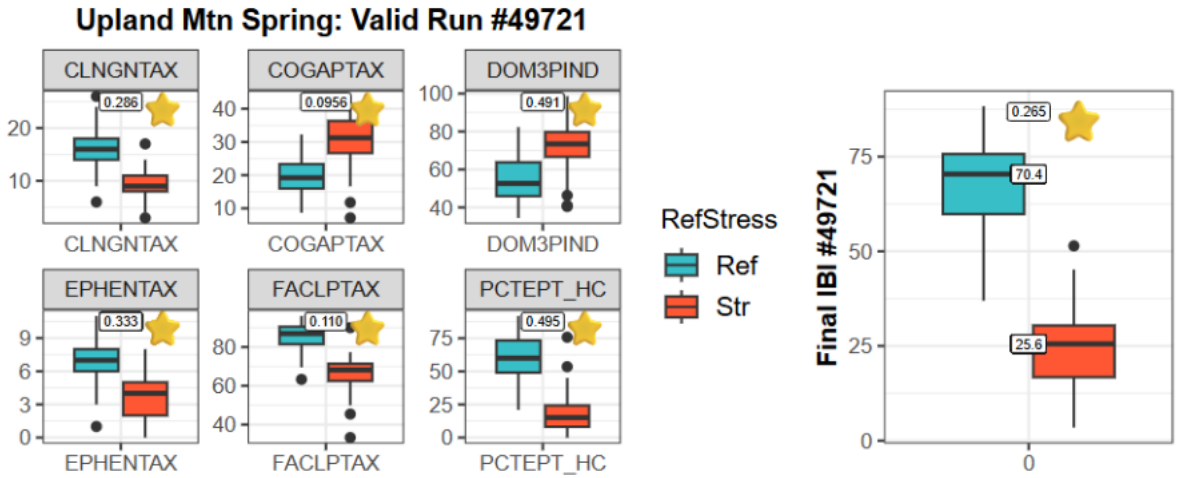
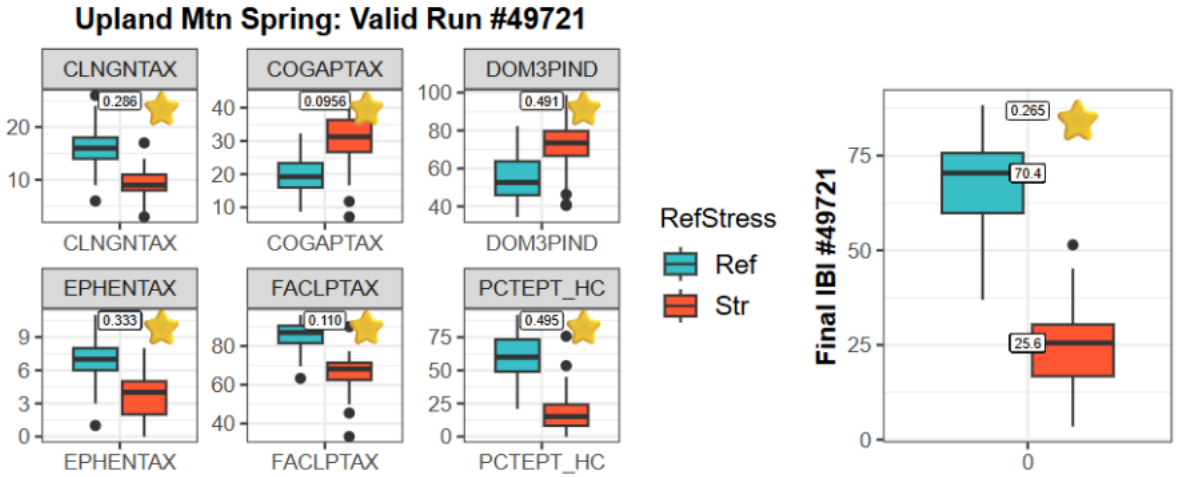
Data Analysis Notes

- Reference benthic community data analyzed in R using the VEGAN package
  - Non-metric Multiple Dimensional Scaling (NMS) using Bray-Curtis dissimilarity
    Visualizes dissimilarities between samples based on multi-variate data
    - Evaluated in 3D – reduced to 2D
    - Stress < 0.20 = non-random patterns
  - Multiple Response Permutation Procedure (MRPP)
    - Measure of significance between 2+ groups based on multiple variables
    - “A” statistic ≥ 0.03 = groups with considerable separation
  - Excluded rare taxa and log(10)+1 transform
    - Remove Chironomidae
    - 1% exclusion, 3.5% and 10%
    - Saw same patterns

Upland Mountain Spring

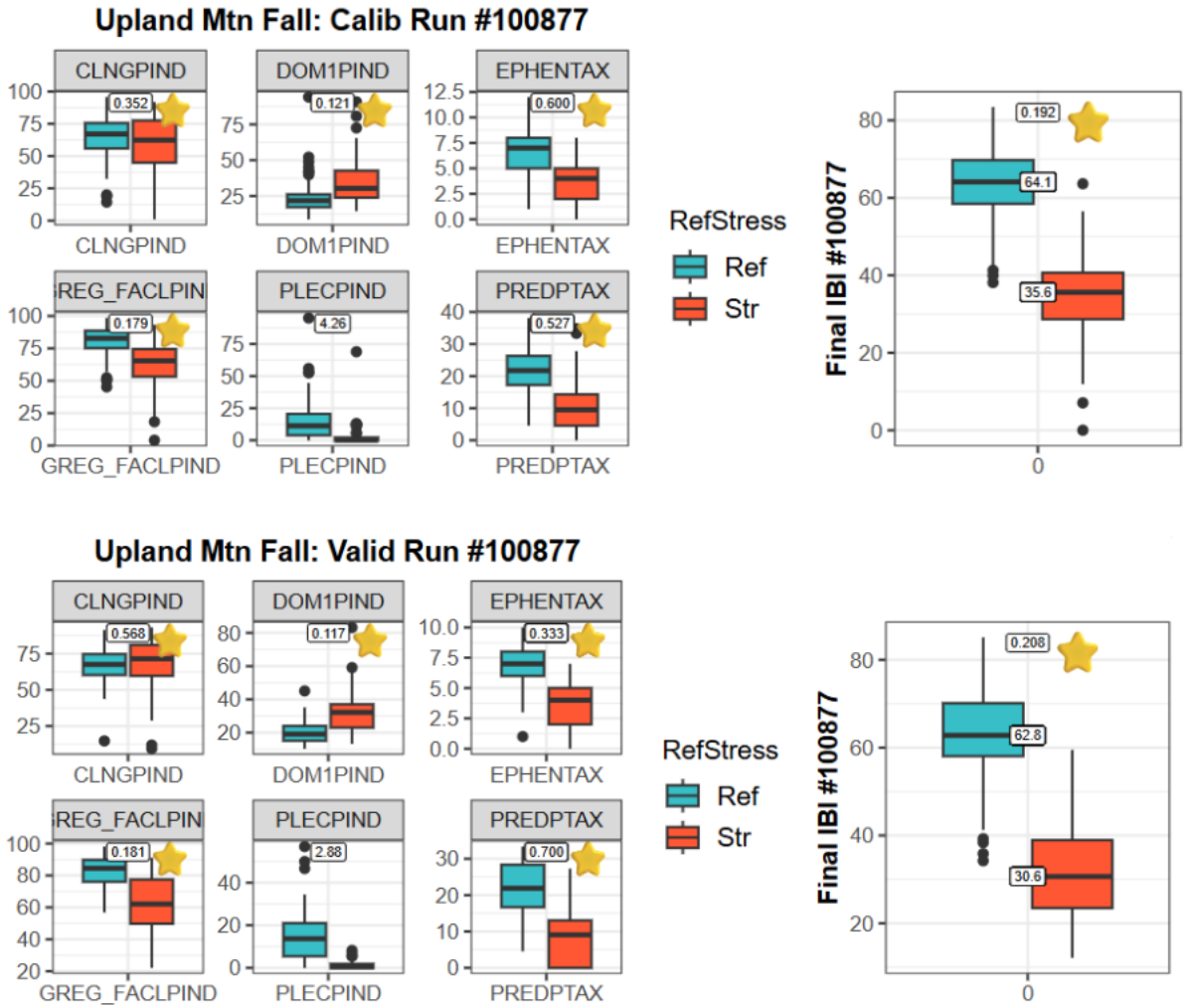
Metric Abbreviation	Metric Description	Metric Category
PCTEPT_HC	% EPT - Hydropsyche and Cheumatospsyche	Composition
DOM3PIND	% individuals in dominant 3 distinct taxa	Dominance
COGAPTAX	% Collector-gatherer taxa	FFG
CLNGNTAX	Number of Clinger taxa	Habit
EPHENTAX	Number of Ephemeroptera taxa	Richness
FACLPTAX	% Facultative (3< PTV <7) taxa	Tolerance





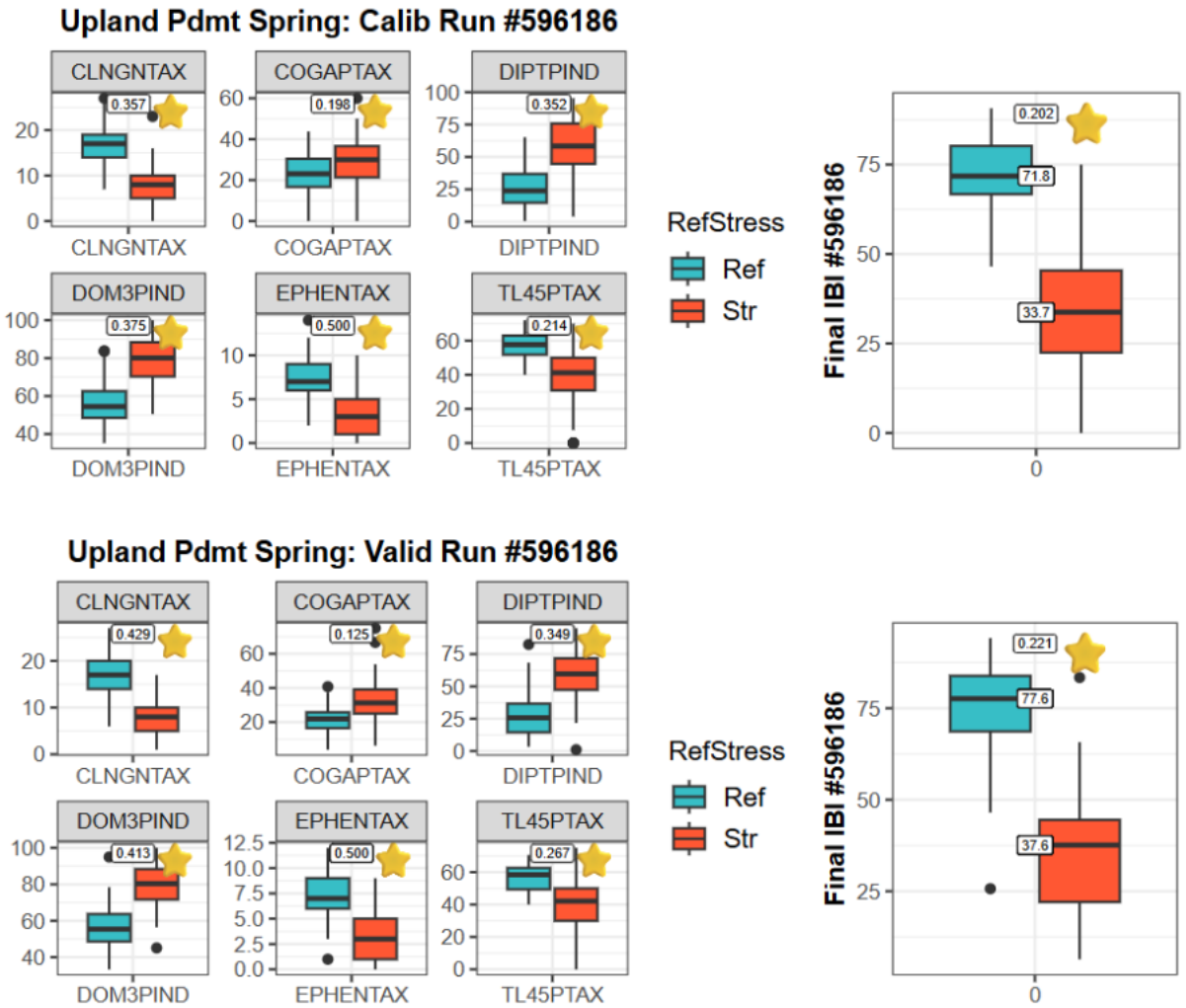
Upland Mountain Fall

Metric Abbreviation		Metric Category
PLECPIND	% Plecoptera individuals	Composition
DOM1PIND	% individuals in dominant distinct taxon	Dominance
PREDPTAX	% Predator taxa	FFG
CLNGPIND	% Clinger Individuals	Habit
EPHENTAX	Number of Ephemeroptera taxa	Richness
FACLPTAX	% Facultative (3< PTV <7) taxa	Tolerance



Upland Piedmont Spring

Metric Abbreviation	Metric Description	Metric Category
DIPTPIND	% Diptera individuals	Composition
DOM3PIND	% individuals in dominant 3 distinct taxa	Dominance
COGAPTAX	% Collector-gatherer taxa	FFG
CLNGNTAX	Number of Clinger taxa	Habit
EPHENTAX	Number of Ephemeroptera taxa	Richness
TL45PTAX	% taxa with PTV >= 4 & 6	Tolerance



Upland Piedmont Fall

Metric Abbreviation	Metric Description	Metric Category
CHIRPTAX	% Chironomidae taxa	Composition
GENUS_PCT2_DOM	% top two dominant genus-level taxa	Dominance
COGAPTAX	% Collector-gatherer taxa	FFG
CLNGPIND	Percent Clinger individuals	Habit
EPHENTAX	Number of Ephemeroptera taxa	Richness
FACLPTAX	% Facultative (3< PTV <7) taxa	Tolerance