# Adjusting Fairfax BIBI scores to account for natural variability

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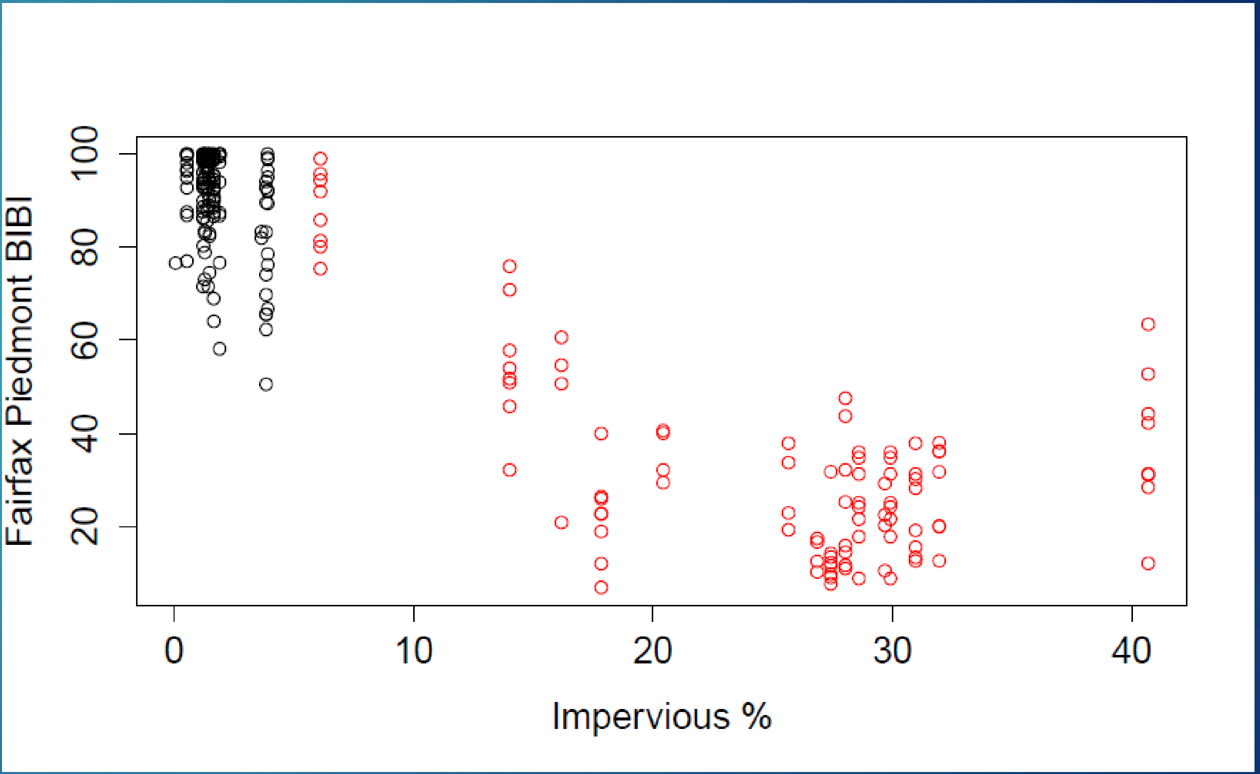
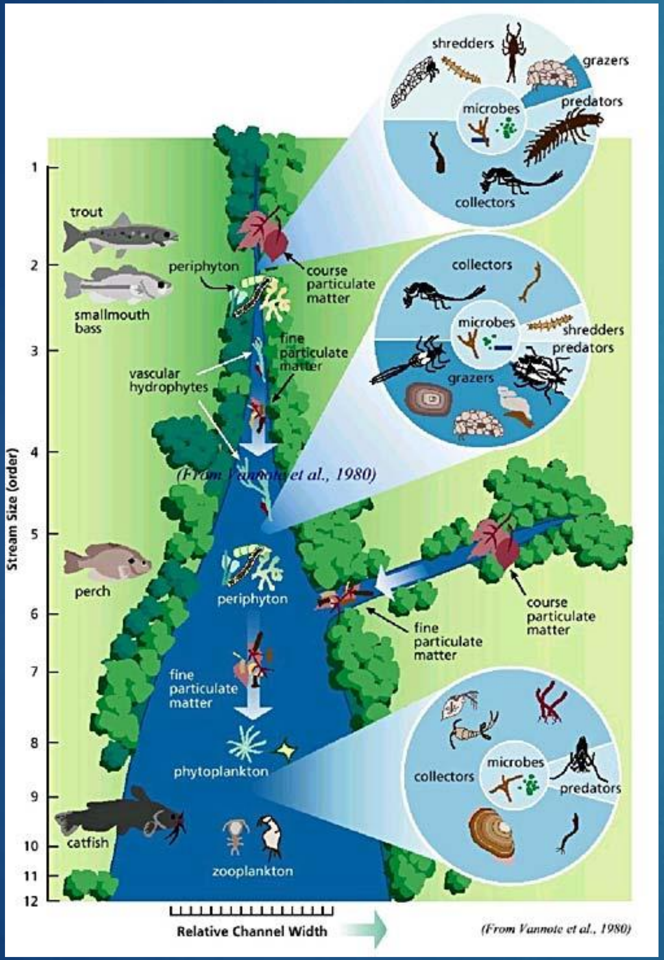
# Goals: Thinking about natural variability

- It's worth attempting to quantify sources of inter–annual, and inter–site variability, and measure their effects on metrics
- Natural variability can confound our understanding of anthropogenic impacts
- Present an approach for normalizing some of that unaccounted for variability



# Natural variability: Habitat



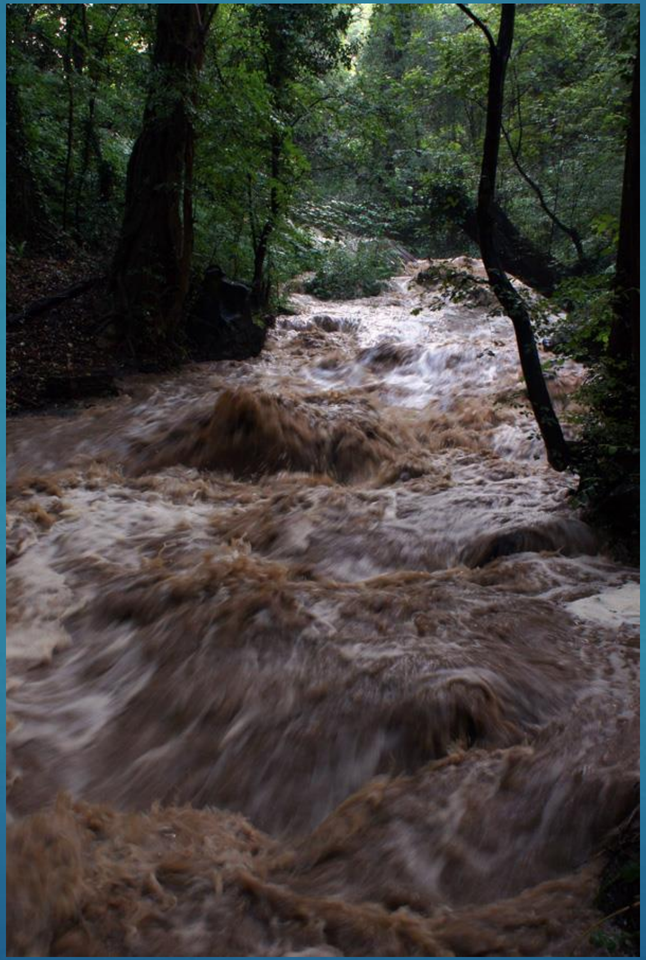

- Stream slope and drainage area:
  - Stream velocity
  - Discharge
  - Frequency of riffles
- Ecoregions / Provinces
- Soils and Nutrients, e.g., Triassic Basin
- Substrate
- Vegetation

Many are confounded with urbanization (e.g., substrate)

Drainage area and ecoregion are frequently classifiers in BCG and multimetric indices.

Many variables are built into O/E models.

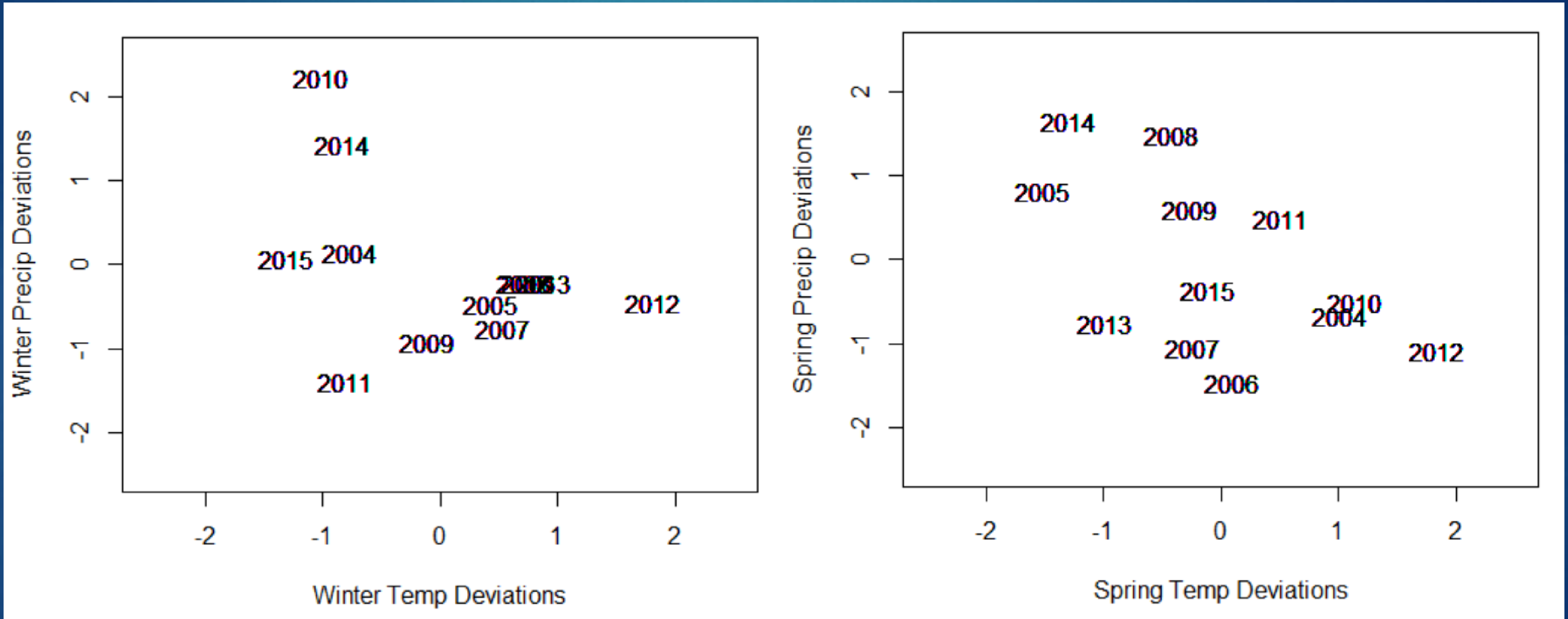
# Natural variability: Hydroclimate



- Precipitation
- Baseflow
- Air Temp
- Water Temp

- Annual and Seasonal Variability

# Climate Variability in Fairfax County

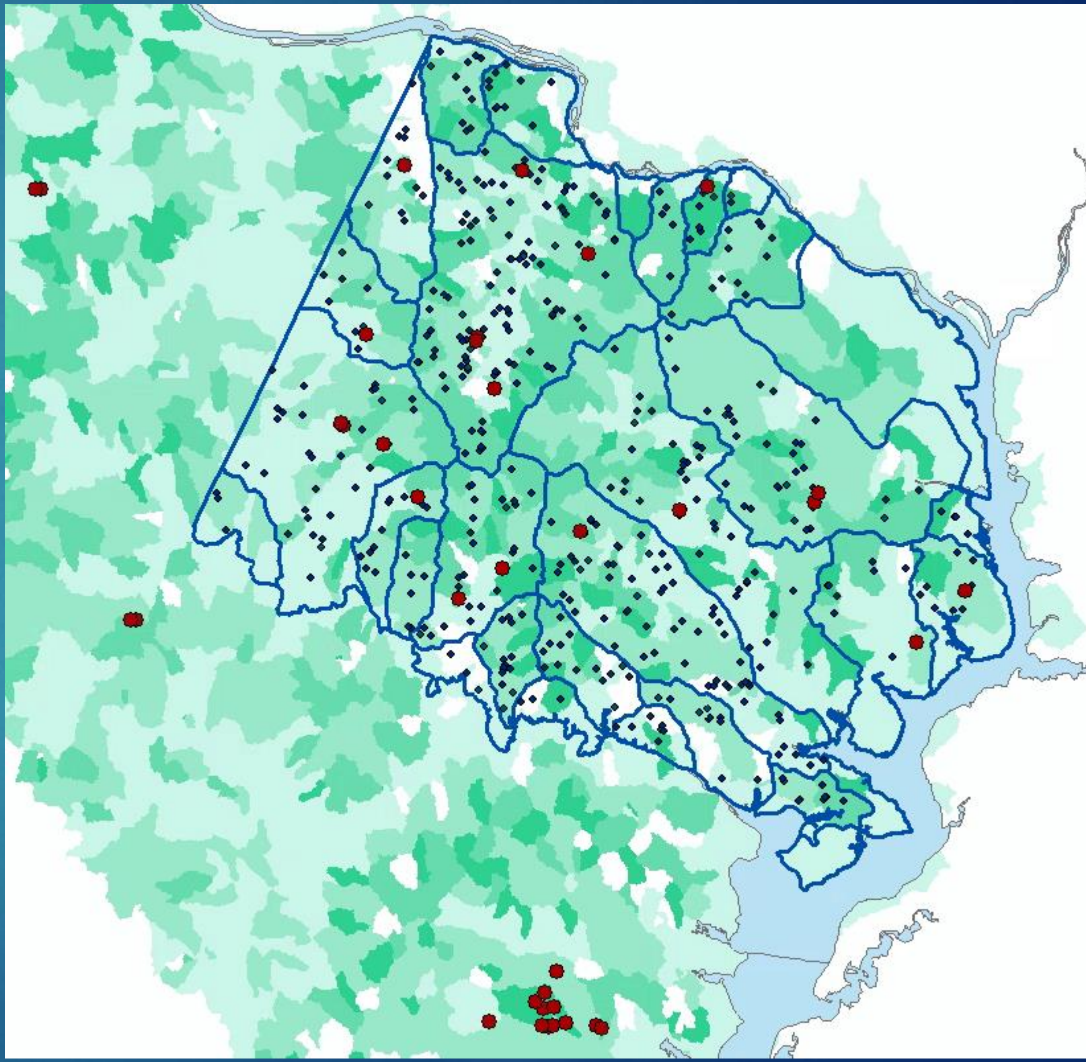


# Objectives

1. Perform a regression of the Fairfax County reference and trend sites against physical and climate variables not considered in the BIBI.
2. Adjust BIBI scores to account these sources of natural variability.
   - E.g., if larger drainage area trend sites tend to have better BIBI scores, boost scores for smaller drainage area sites
   - E.g., if hot dry summers depress the BIBI, boost scores for years those condition occur
   - Goal is to provide better resolution when considering the urban gradient and comparing between sites
   - **Think "bowling handicap"**
3. Test model performance on probabilistic, non-trend, monitoring sites.

# Data Sources:

- Fairfax County Macroinvertebrate Piedmont BIBI
- 18 Reference Trend Sites
  - 12 Piedmont
  - 2 Coastal Plain
  - 4 Triassic Basin
- 20 USGS Trend Sites
  - Piedmont, Coastal Plain, and Triassic Basin
- 241 trend sites from 2004 – 2015
- 471 probabilistic sites from 2004 – 2015



# Physical Variables

- Log Drainage Area ($ft^2$)
- Sqrt Slope (%): Associated with NHDPlus V2.1 catchments

# Dummy Variables

Because we opted to include more trend sites from outside Piedmont reference condition we included some additional variables to correct for urban trends and physiographic effects.

- Sqrt Impervious (%) in the drainage area
- USGS Trend Site (yes: 1, no: 0)
- Piedmont (yes: 1, no: 0)
- Year (2004 – 2015)

# Climate Variables: PRISM 4 $km^2$ Rasters

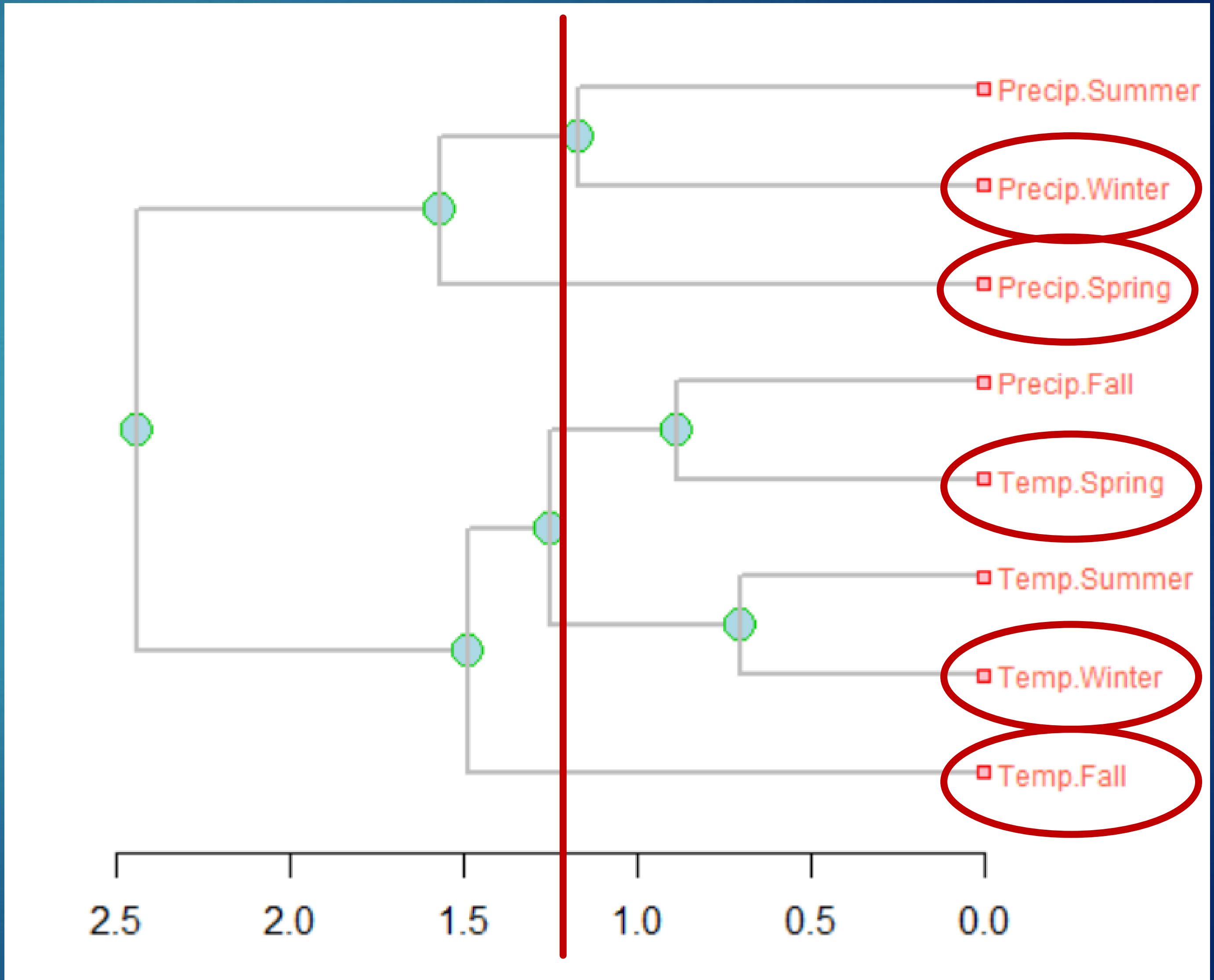
Macroinvertebrates are collected in the spring, so seasonable variables extend a year back

| | | |
|---|---|---|
| Spring | precip (mm) and air temp (C) | e.g. MAM 2006 |
| Winter | precip (mm) and air temp (C) | e.g. D 2005 & JF 2006 |
| Fall | precip (mm) and air temp (C) | e.g. SON 2005 |
| Summer | precip (mm) and air temp (C) | e.g. JJA 2005 |

- Values are averaged across county.

# Climate Variables

- Many climate variables correlated
- Selected climate variables based on hierarchal clusters
- Prioritized variables closer to the sampling period



# Data Analysis

- All possible regression models for the above variables; models were selected using a combination of following selection criteria:
  - AICc
  - Adjusted $R^2$
  - PRESS Statistic (leave one out validation)
  - Mallow's Cp
  - All Important BPJ
- BIBI scores were Logit transformed prior to use to fit assumptions.  I.e. a BIBI score from 0-100 functions like lot like a percent.
- All variables were standardized prior to use in the regression.
  - Parameter changes are "deviations" from average conditions

# Selected Model Output

| Parameter | Estimate | SE | t | P |
|---|---|---|---|---|
| Intercept | 0.000 | 0.034 | 0.00 | 1.0000 |
| Slope | 0.118 | 0.055 | 2.13 | 0.0341 |
| Drainage Area | 0.189 | 0.056 | 3.38 | 0.0009 |
| Winter Precip | 0.077 | 0.035 | 2.19 | 0.0293 |
| Spring Temp | -0.120 | 0.034 | -3.50 | 0.0006 |
| Impervious % | -0.649 | 0.095 | -6.85 | < 0.0001 |
| USGS Gage | -0.251 | 0.097 | -2.60 | 0.0100 |
| Year | 0.107 | 0.038 | 2.84 | 0.0049 |

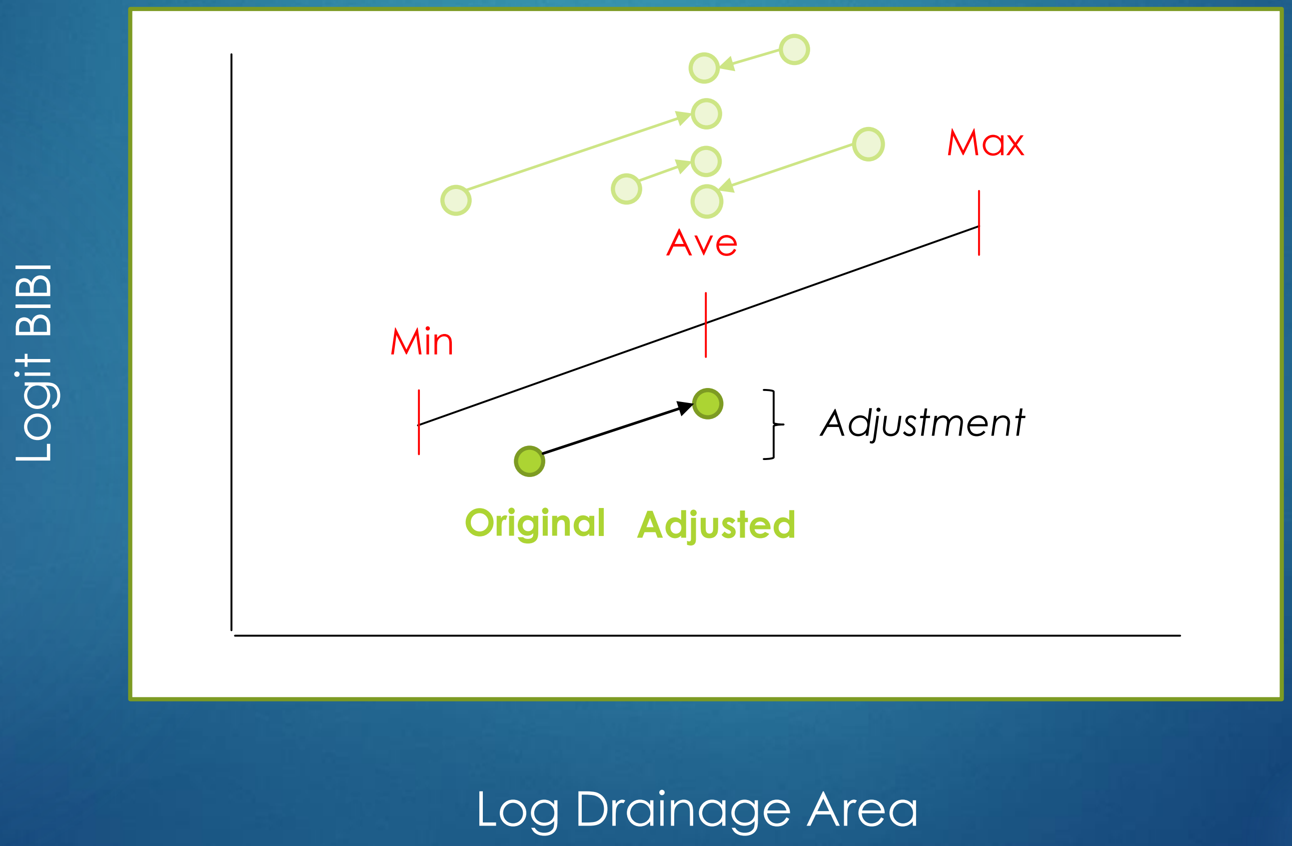
Residual standard error: 0.528 on 233 degrees of freedom
Multiple R-squared: 0.729, Adjusted R-squared: 0.721
F-statistic: 89.67 on 7 and 233 DF, P < 0.0001

- Selection came down to adding a marginally significant fall temperature variable. For simplicity we left it out. Fit statistics were similar in both models.

# Adjusting BIBI Scores

BIBI values are normalized to the average.

In this case the data point is adjusted up.  A value originally above the average would be adjusted down



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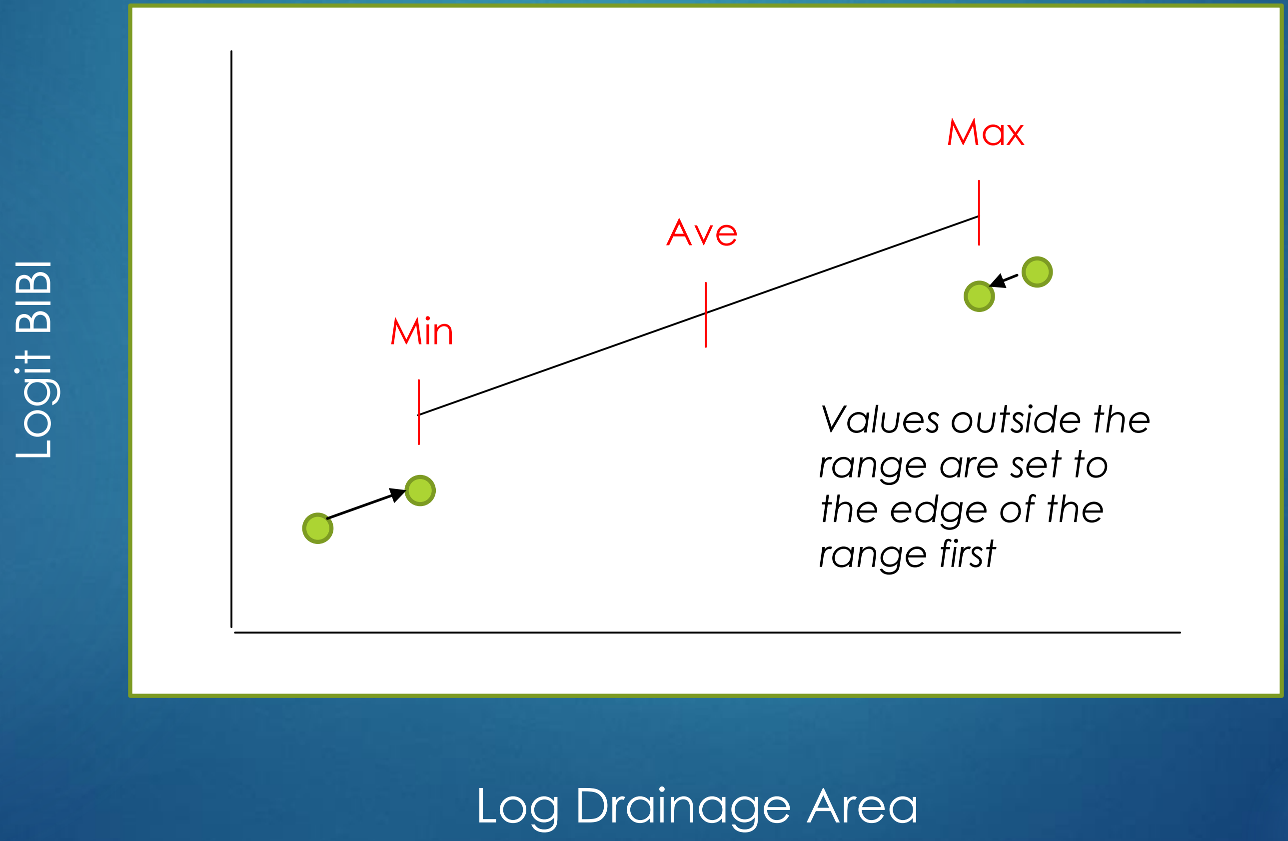

# Adjusting BIBI Scores

| | Trend Sites | | | Probabilistic | | |
|---|---|---|---|---|---|---|
| Province | BIBI Shift | Slope | Dr Area | BIBI Shift | Slope | Dr Area |
| Coastal Plain | 6 | 0.095 | -0.499 | 9 | -0.615 | -0.739 |
| Piedmont | 5 | -0.009 | 0.058 | 8 | -0.394 | -0.768 |
| Triassic Basin | 3 | -0.062 | 0.247 | 5 | -0.624 | -0.107 |

Normalizing all points to their average

- Coastal Plain sites received a larger shift due to their smaller drainage areas and flatter slopes
- Triassic basin sites tend to have larger drainage areas, so receive less of an adjustment
- If a BIBI score of 40 or less is failing, these adjustments shift 62 sites above that threshold and 14 sites below

# Adjusting BIBI Scores

| | Probabilistic Sites | | | |
|---|---|---|---|---|
| Province | Average | Winter Precip +1 | Spring Temp -1 | Both |
| Coastal Plain | 9 | 15 | 17 | 20 |
| Piedmont | 8 | 11 | 13 | 17 |
| Triassic Basin | 5 | 8 | 10 | 14 |

Good and bad climate years:

- Consider a wetter than average winter and cooler than average spring
- The additional climate forcing moves many sites into a different category: Fair -> Good, etc.
- If a BIBI score of 40 or less is failing, both adjustments shift 154  sites above that threshold and 4 sites below.

# Relationship to Stressors and Trends over Time

- How does adjusting BIBI scores affect your ability to detect patterns in the data?
- Regressed original BIBI scores and adjusted scores against impervious (%), median specific conductance, and sample year for both the trend and probabilistic data sets.
  - $R^2$ values are shown.

# Relationship to Stressors and Trends over Time

| Parameter | Trend Sites ($R^2$) Original | Trend Sites ($R^2$) Adjusted | Trend Sites ($R^2$) Difference | Probabilistic Sites ($R^2$) Original | Probabilistic Sites ($R^2$) Adjusted | Probabilistic Sites ($R^2$) Difference |
|---|---|---|---|---|---|---|
| IMP % | 0.678 | **0.699** | **+** | 0.366 | **0.400** | **+** |
| SC | 0.534 | **0.566** | **+** | 0.051 | **0.056** | **+** |
| Year | 0.029 | 0.029 | **0** | **0.025** | 0.014 | **-** |

- The adjusted BIBI values performed better for impervious and specific conductance parameters, and worse for the yearly trend
- Year has a 0.22 correlation with winter precipitation.
  - Part of the temporal trend can be accounted for by shifting climate over the 12 years

# Closing Thoughts

- Variability unrelated to urbanization can hinder and confound our ability to assess impairment.
  - Small flat site on really hot year.  Bad year or bad site?
  - Can it be compared fairly with a higher gradient site on a cool wet year?
  - This is especially true without trend data.
- Adjusting BIBI scores along those gradients can lead to better comparisons and inference
- Regardless of the tools you have, it's worthwhile investigating natural variability and effects on metric performance
- Consider adding these variables as artificial stressors into the BIBI itself

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