# Relationship Between Land Use and Benthic Macroinvertebrate Indices of Biological Integrity: A Study of Historical Water Quality Data in the Delaware River Basin

Kathryn Christopher, Stefanie Kroll, Kevin Biallas, Dung Luong, Roland Wall
The Academy of Natural Sciences of Drexel University, Patrick Center for Environmental Research, Philadelphia, PA 19103

## Introduction

State and federal agencies, such as Pennsylvania's and New Jersey's departments of environmental protection and the USGS National Water Quality Assessment Program, have been monitoring macroinvertebrates in Delaware River basin streams for over 20 years. In a first step toward developing a uniform index for the basin, we compared PADEP's Index of Biological Integrity (PA-IBI) (Chalfant, 2007) and the Macroinvertebrate Aggregated Index for Streams (MAIS) (Smith and Voshell, 1997). Both are multimetric assessment protocols that utilize ecological information from macroinvertebrate counts to score sites, giving a measure of stream integrity.

Research shows that land use affects stream integrity, which can be illustrated using biotic indices. Percent impervious surface (artificial structures) and forested and agricultural land uses were examined to determine the sensitivity the indices to land use.

## Methods: The Indices

Historical macroinvertebrate data was gathered from PADEP, NJDEP and USGS-NAWQA (1250 sites in the Delaware River Basin), and the PA-IBI and MAIS scores were calculated for each stream sampling point.

**PA-IBI Metrics:**
- Total Taxa Richness
- EPT Richness
- Beck's Index
- Shannon Diversity Index
- Hilsenhoff Biotic Index
- % Sensitive Indiv. (PTV 0 -3)

**Score range:** 0-100
- 0 – 45 = "Poor"
- 45.1 – 74 = "Fair"
- 74.1 – 100 = "Good"

**MAIS Metrics:**
- Ephemeroptera Richness
- EPT Richness
- Intolerant Taxa Richness
- % Ephemeroptera
- % EPT
- % 5 Dominant Taxa
- Simpson Diversity
- HBI (Hilsenhoff Biotic Index)
- % Scrapers
- % Haptobenthos

**Score range:** 0-20
- 0 - 6 = "Poor"
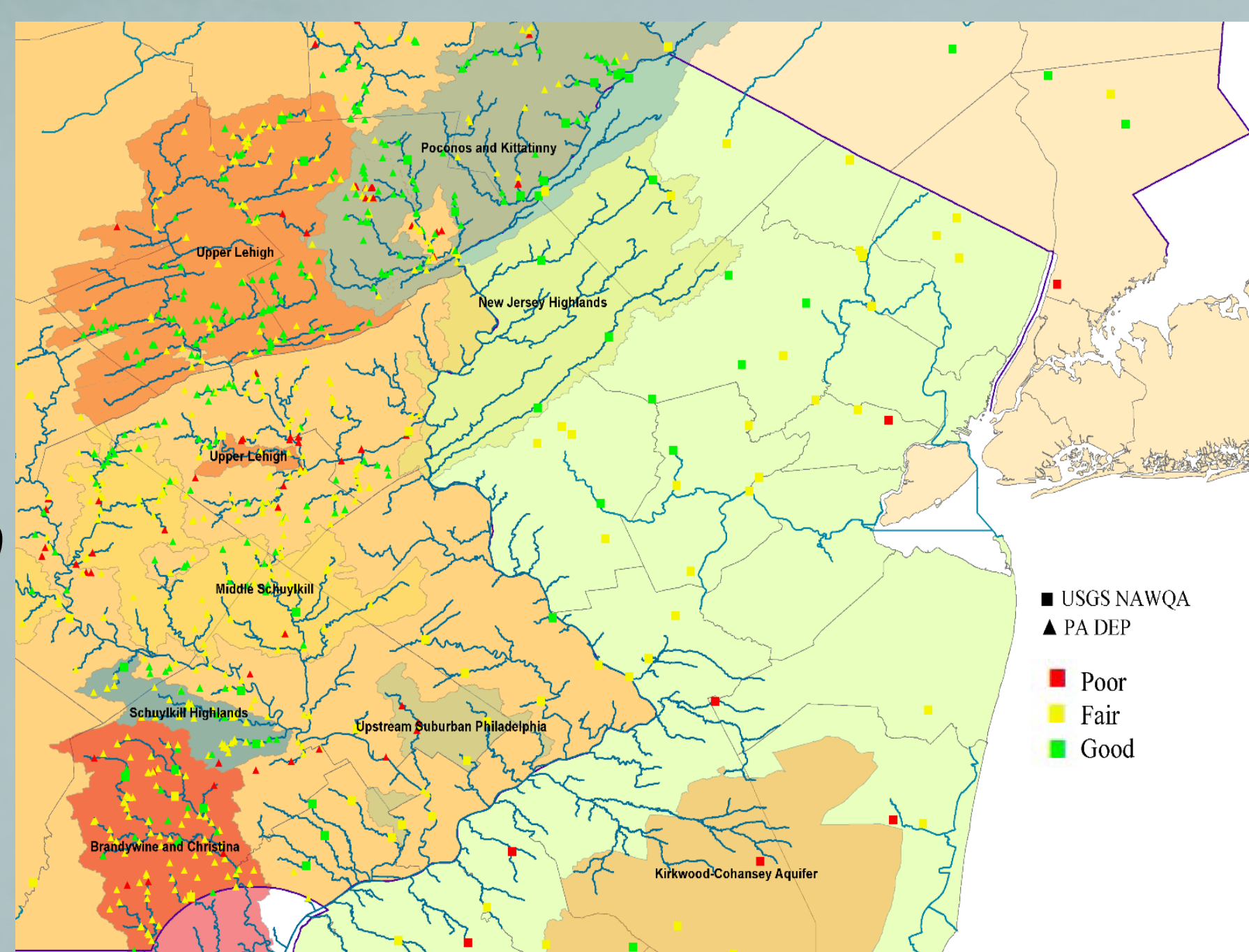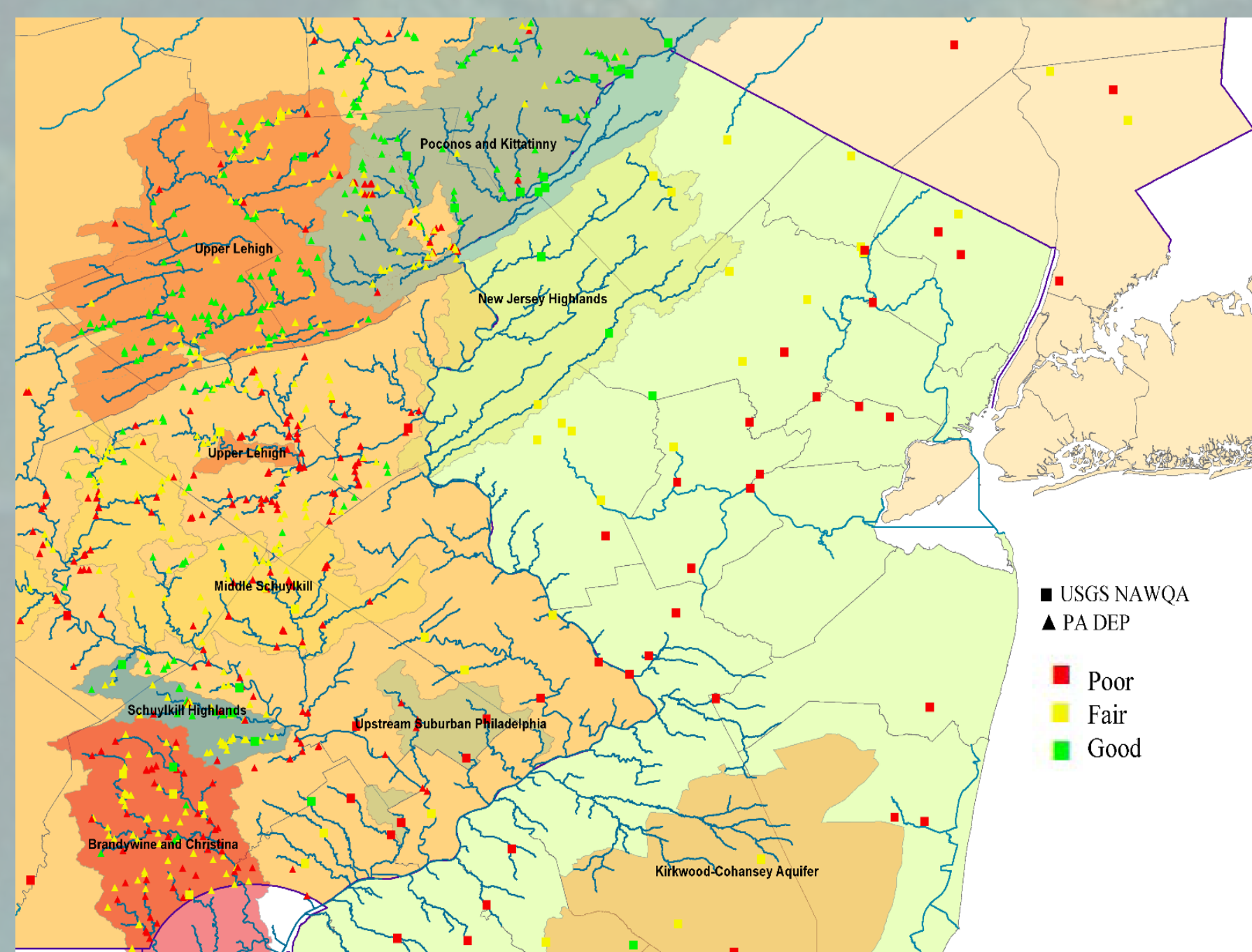- 6.1 - 13 = "Fair"
- 13.1 - 20 = "Good"



**Figure 1**. MAIS (top) and PA-IBI (bottom) scores. The average PA-IBI score is 56.25; the average MAIS score is 11.86 -- both considered "fair."

## Methods: The Analysis

Using Streamhiker software (developed by J.V. Mead) and land use data from 2001, land use in the streams' drainage basins and along the sampling reaches (100m from each bank) was calculated. Stepwise multiple linear regressions models were used (via SPSS v.22) to relate PA-IBI and MAIS scores to the different types of land use. Redundancy analysis (RDA) was performed (via CANOCO v.5) to further examine relationships between the indices and land use types and scales.

$R^2$ values for reach-scale regressions were much lower than the basin-wide regressions (Figure 2), suggesting that basin-wide land use data provides better information for assessing stream integrity.

| R² Values | REACH | | BASIN | |
|---|---|---|---|---|
| | PA-IBI | MAIS | PA-IBI | MAIS |
| **IMPERVIOUS** | 0.0092 | 0.0017 | 0.1771 | 0.1267 |
| **FORESTED** | 0.0881 | 0.0255 | 0.2143 | 0.1107 |
| **AGRICULTURE** | 0.0131 | 0.0021 | 0.1252 | 0.0525 |

**Figure 2.** R2 values for both metrics as they relate to land cover at both the reach and basin scale.
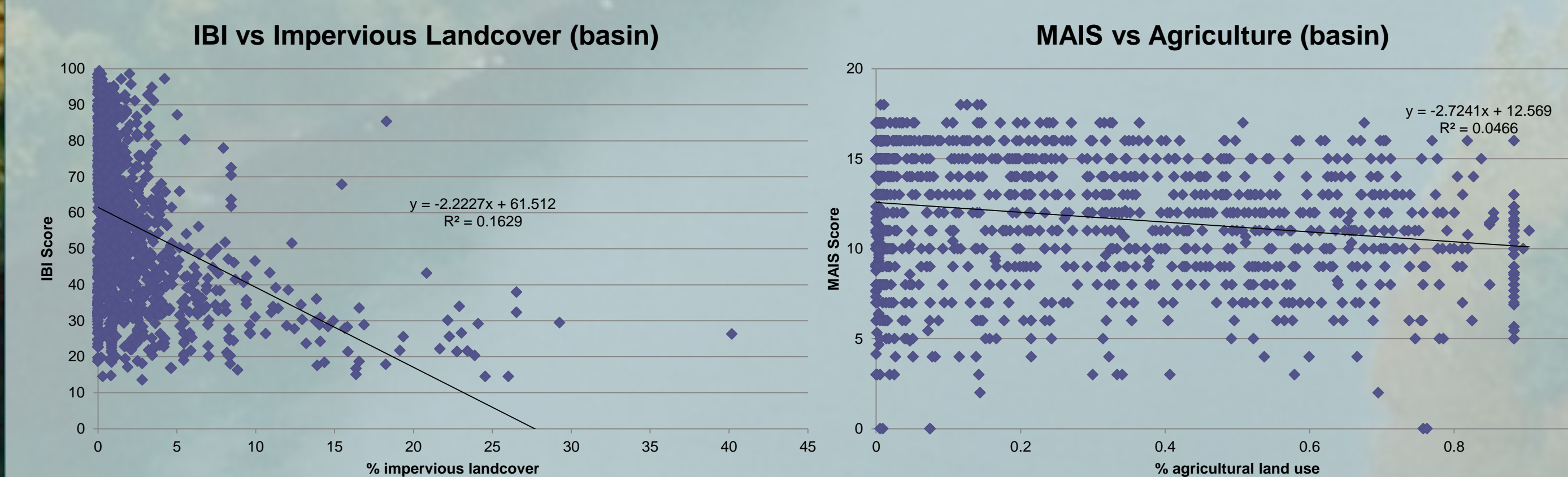


**Figure 3.** Examples of linear regressions. PA-IBI vs impervious land cover (left) and MAIS vs agriculture (right).

The use of just "% impervious" and "% forested" explained greater than 99% of the variation. Agricultural land use was therefore omitted from the RDA ordination.
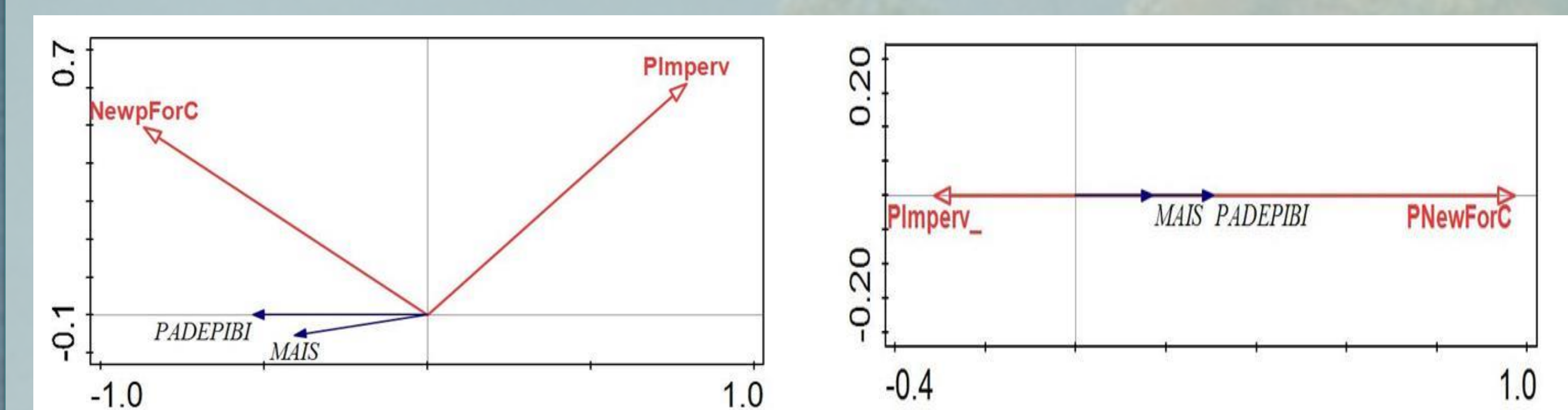


**Figure 4.** RDA ordination comparing forested land use (newpForC) and impervious landcover (Pimperv) with the two indices. P=0.002.

RDA ordination (Figure 4) implies that forested cover has a positive relationship with both indices.



Capniidae



Perlidae

## Results and Discussion

Multimetric indices are useful because they incorporate biotic responses to stressors, and can provide a more clear idea of stream integrity than basic taxa counts. MAIS metrics focus on EPT and Ephemeroptera, whereas the PA-IBI has a focus on intolerant taxa and pollution sensitive metrics.



Rhyacophilidae

Basin-wide (whole catchment) land use showed a better fit to both index scores than reach-scale (local) land use (Figure 2). In all regression cases, the $R^2$ values are higher with PA-IBI, suggesting that index is more sensitive to various land usages. However, the $R^2$ values only range from 0.1 to 0.2. Low $R^2$ values may indicate that other stressors are in play or that indices like these are not the best single assessment tools, although they give a general idea of stream integrity.

RDA ordination (Figure 4) suggests that forested cover has a better relationship with indices than impervious cover, with stronger significance with PA-IBI than MAIS. Forested cover retains rain water efficiently and provides filtering for runoff, thereby protecting streams from the same degree of nutrients and contaminants that are present in runoff from impervious and agricultural lands, and which are known to impact aquatic macroinvertebrate communities. This helps explain why both indices have a positive relationship with forested cover.

## Conclusions and Next Steps

Neither index correlated very strongly with land use type at either the reach or basin scale, illustrating the need to investigate the relationship between other stressors and the indices, and to examine how to use different assessment tools in conjunction with multi-metric indices to more accurately categorize stream integrity.

**Next steps:**
- Inclusion of other multimetric indices, such as HGMI, PMI and CPMI
- Further analyses to determine IBI performance according to stressors
- Regression and ordination analysis using low/high intensity residential activity, natural wetlands, pastures, crops, velocity and substrate type
- Use of more recent land use data
- Include fish and algae assessments: algae are indicators of nutrients, fish are indicators of small-and large-scale habitat .

## Acknowledgements and Credits