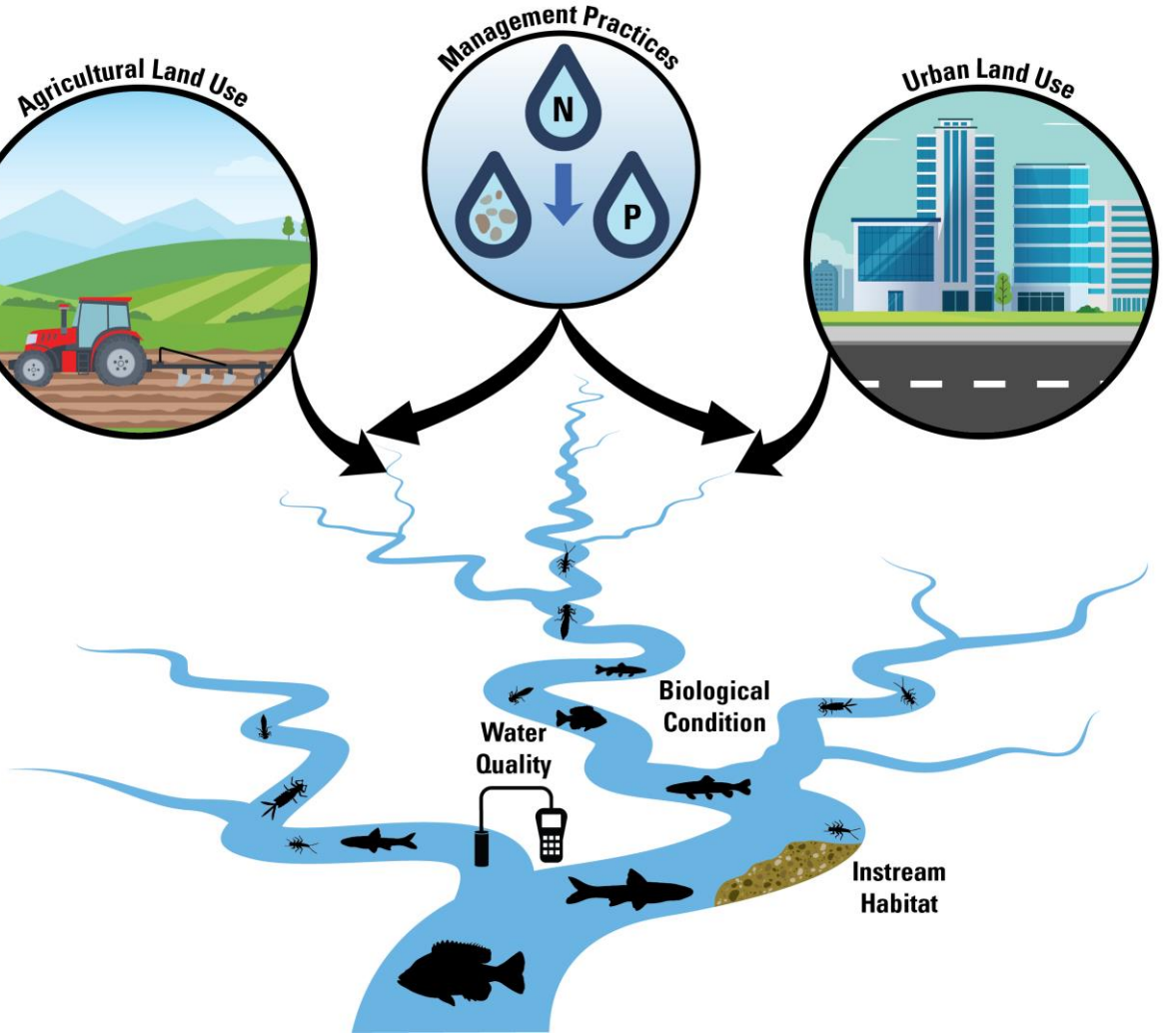
Causal Inference Approaches Reveal Both Positive and Negative Effects of Management Practices on Instream Biological Condition



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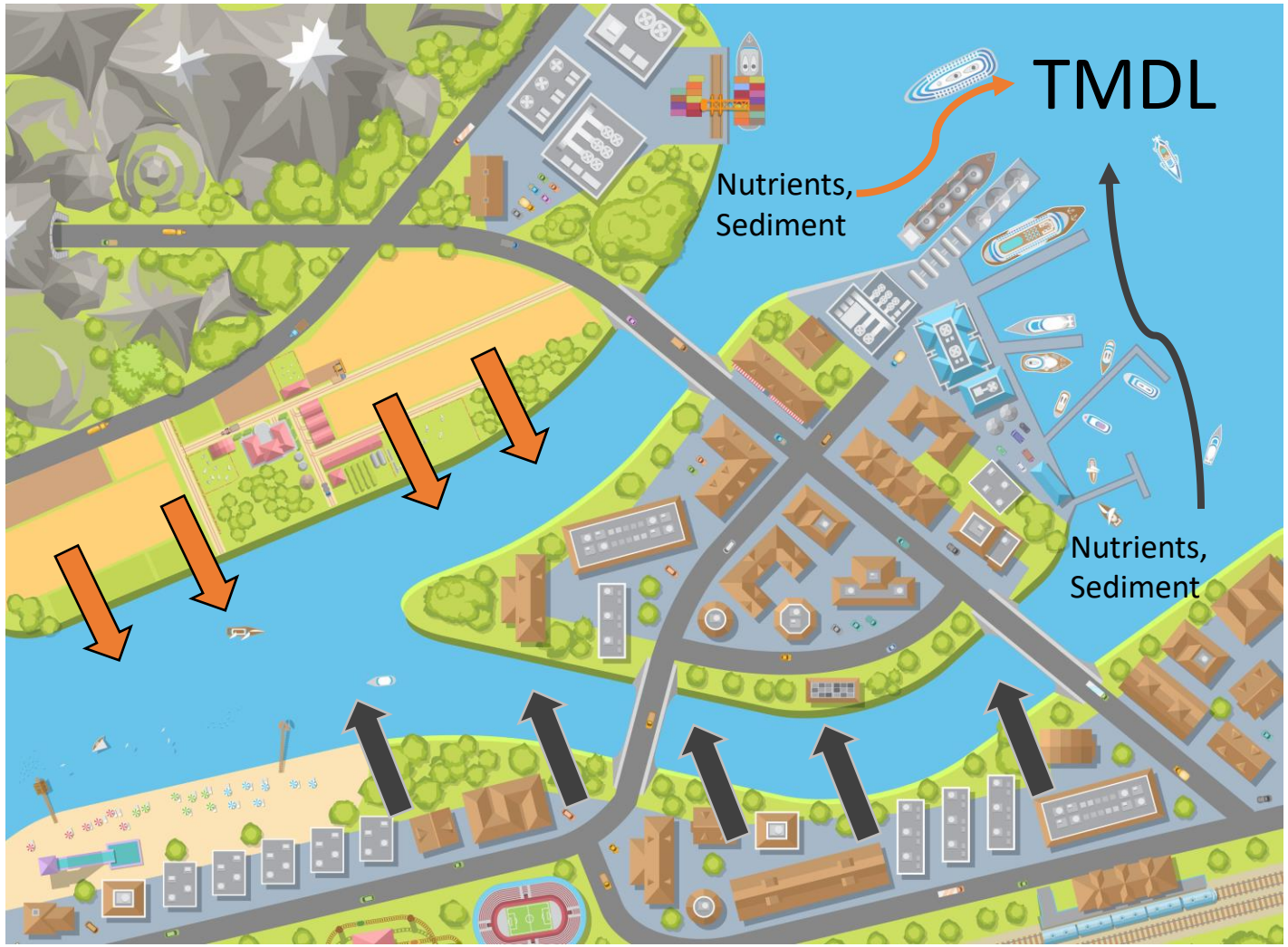
Sean Emmons, Taylor Woods, Matthew Cashman, John Young, Greg Noe, Olivia Devereux, Scott Stranko, Jay Kilian, Katherine Hanna, Kelly Maloney

Management Practices (MPs) - Targeting Non-Point Source Pollutants

Agricultural MPs

Reduce Amounts of

Nitrogen, Phosphorus, Sediment, Pesticides, Herbicides, Estrogenic Compounds, and other Pollutants



Urban MPs

Reduce Amounts of

Sediment, Water Quantity, Septic Pollutants, Urban Pesticides and Fertilizers, and other Pollutants

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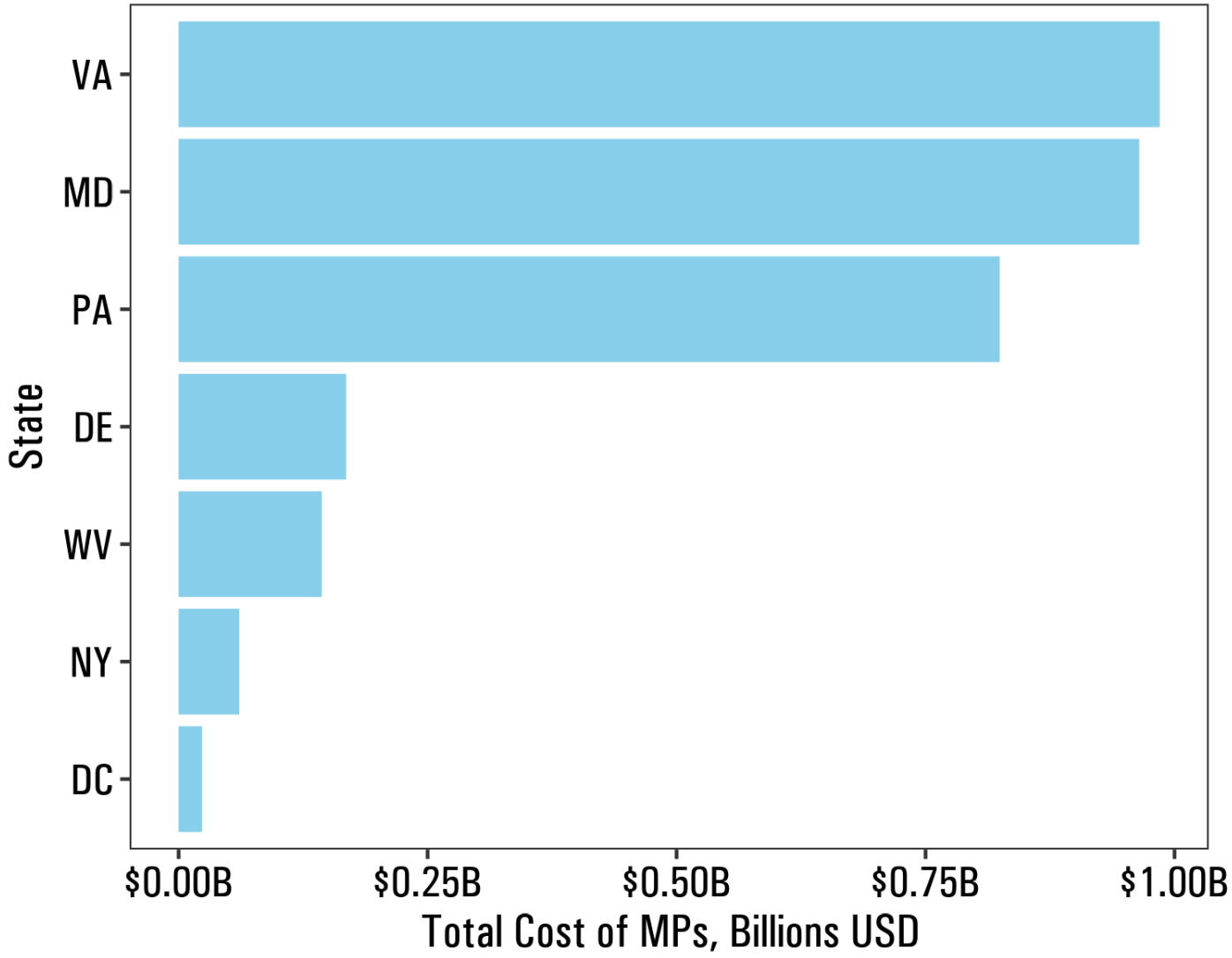
Management Practices (MPs) – Costs and Co-Benefits

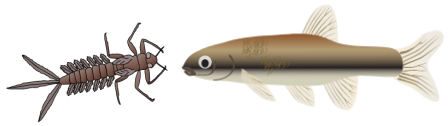


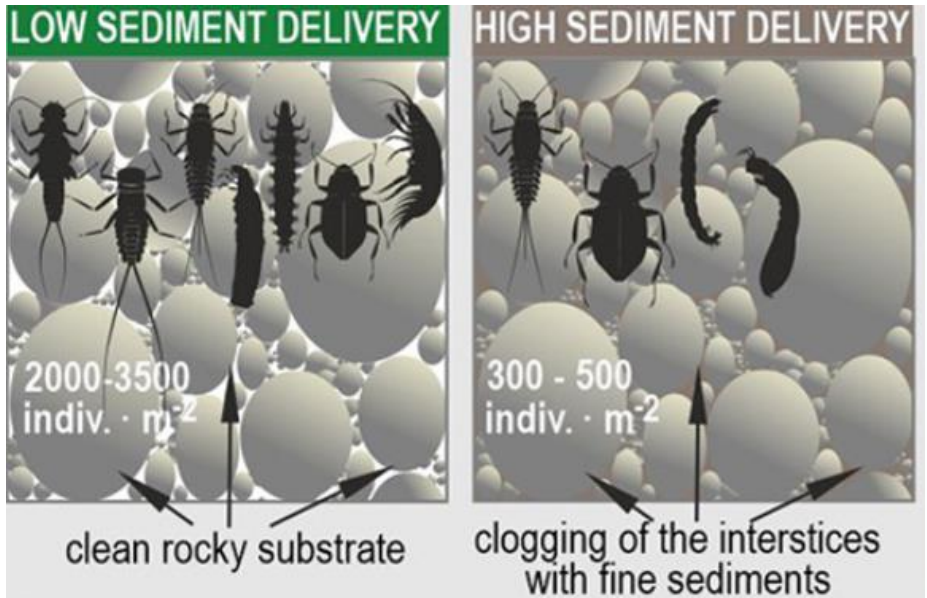
Source: Chesapeake Assessment Scenario Tool (CAST)
Cost estimated as annualized average costs per unit of BMP (e.g.: $/acre treated/year) in 2022 progress scenario for BMPs currently implemented and those planned.

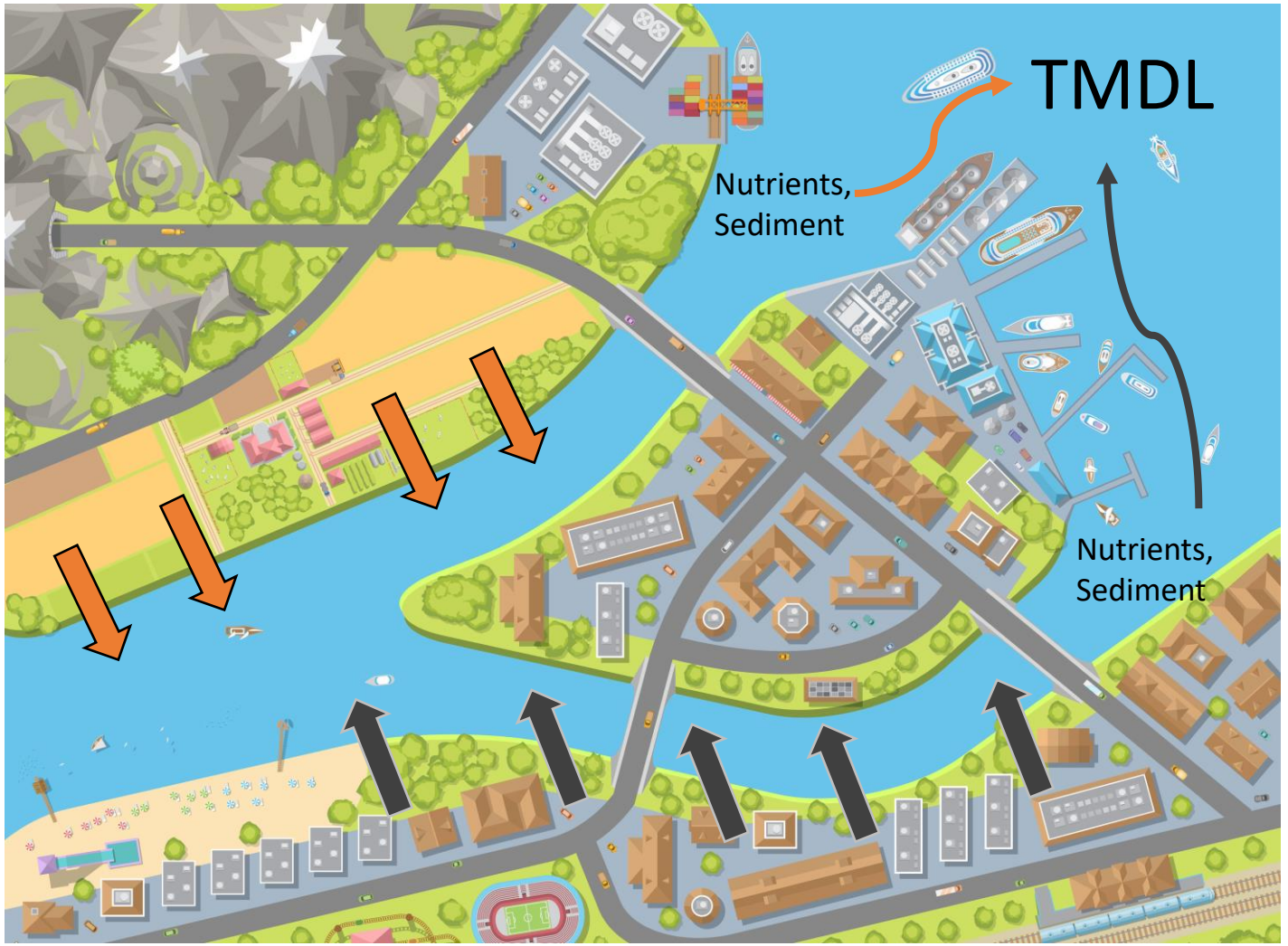
Management Practices (MPs) - Co-Benefits

Co-Benefit: Additional, unintended benefit to the primary objective of nutrient and sediment reduction

MPs designed to reduce sediment delivery could improve instream habitat, boosting macroinvertebrate and fish populations.

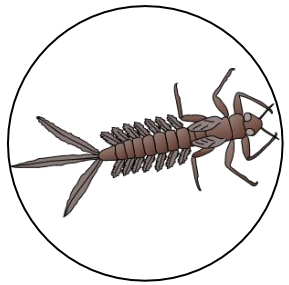




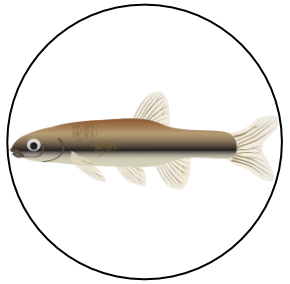


Bylak & Kukula (2022)

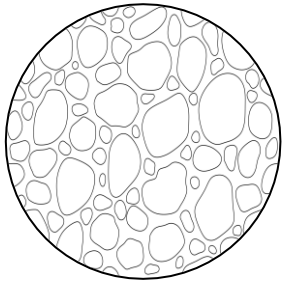
Testing For Co-Benefits – Maryland Biological Stream Survey



Benthic Macro - invertebrates

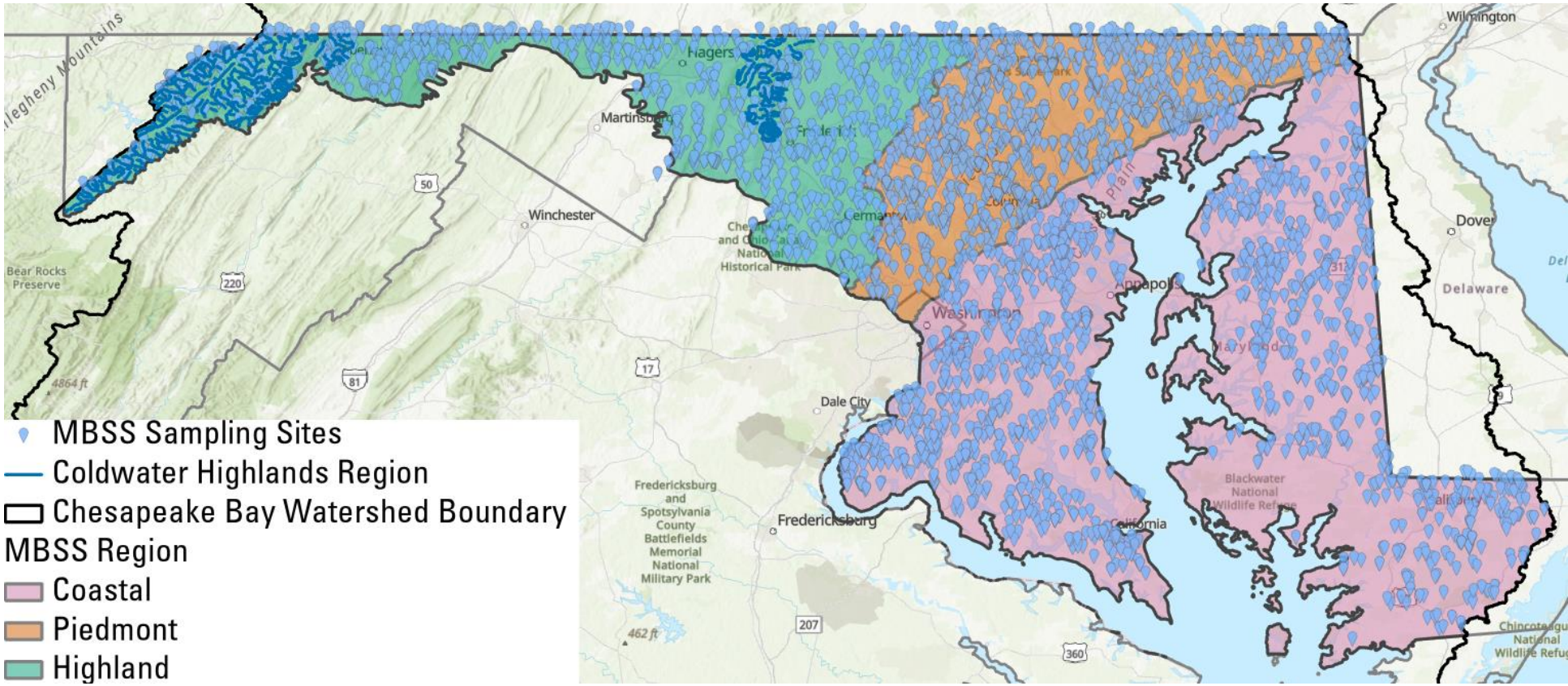


Fish

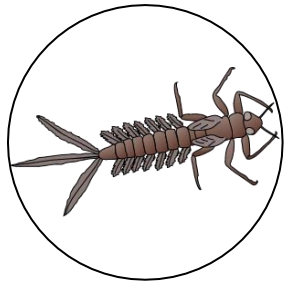


Instream Habitat

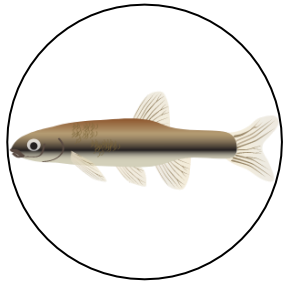
Water Quality



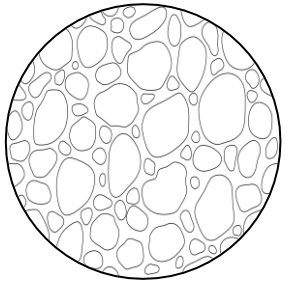
Testing For Co-Benefits – Maryland Biological Stream Survey



Benthic Macro - invertebrates



Fish

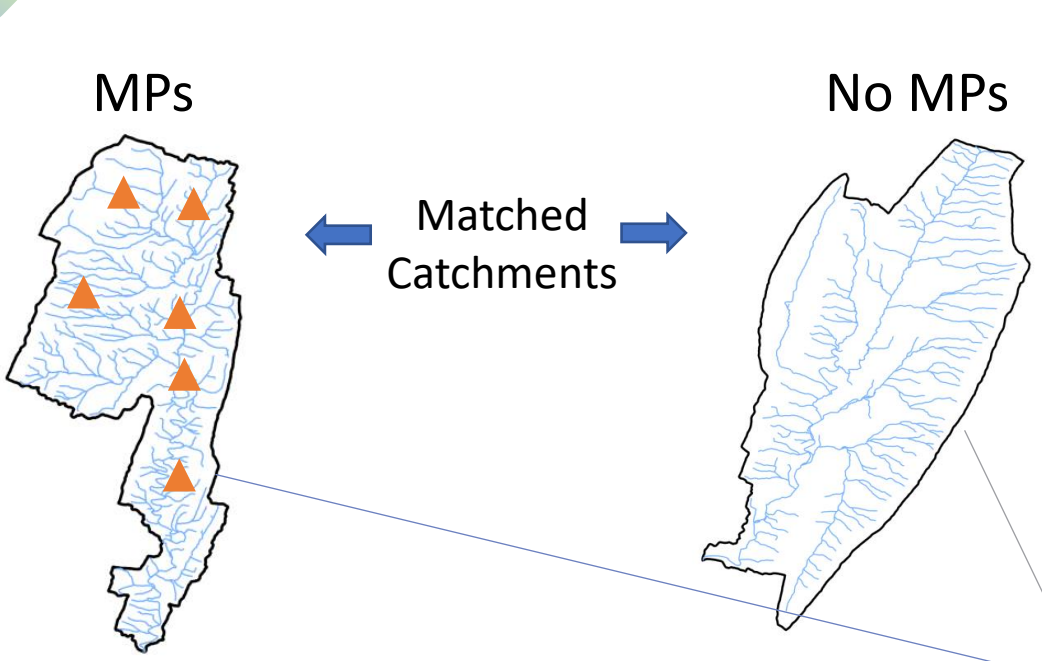


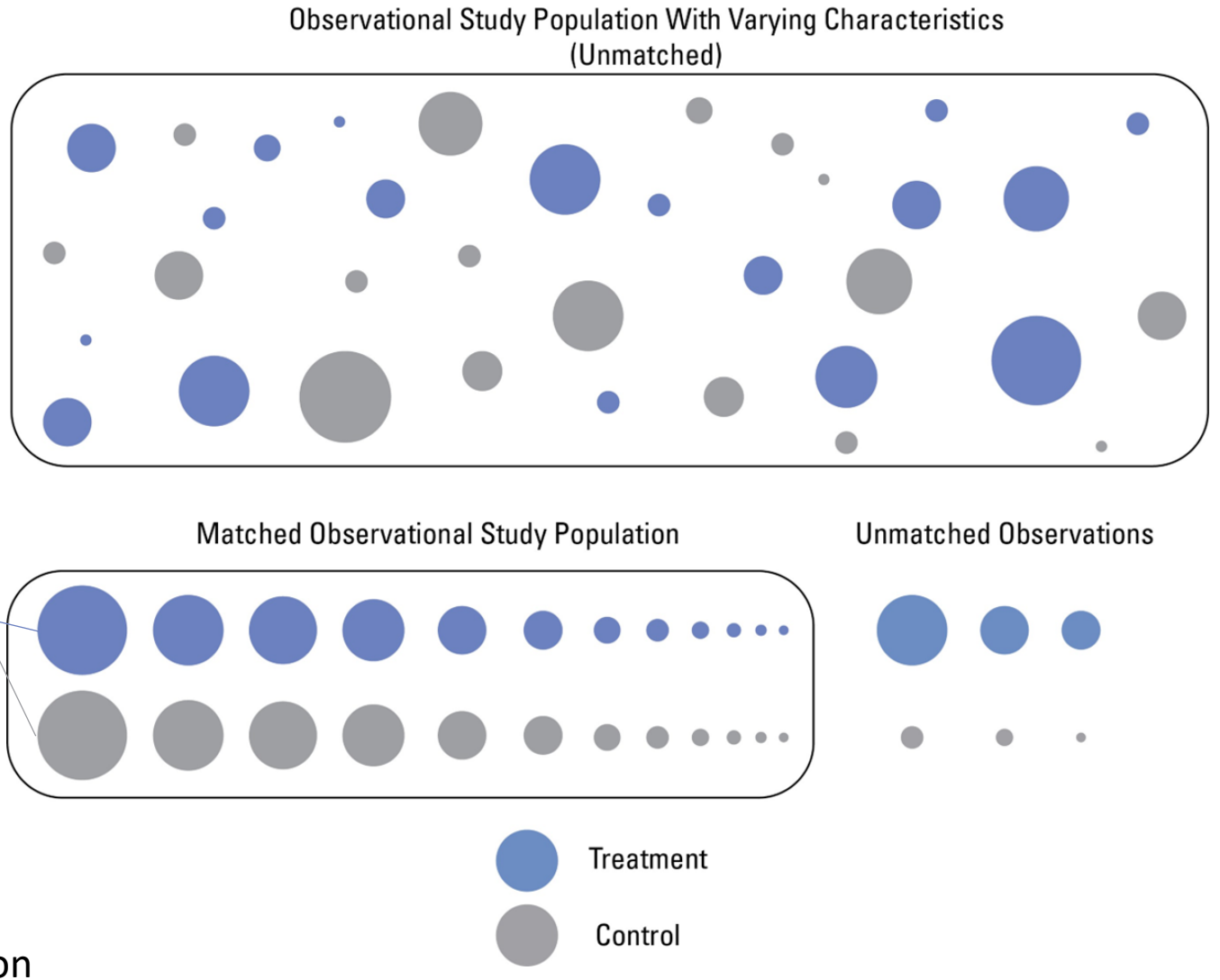
Instream Habitat

Water Quality

Metric	Description	Predicted Response to Anthropogenic Stress	Hypothesized Response to Management Practices
BIBI	Benthic Macroinvertebrate Index of Biotic Integrity	Decrease	Increase
Number of EPT Taxa	Number of taxa in the orders Ephemeroptera, Plecoptera, and Trichoptera in the sub-sample	Decrease	Increase
Percent lithophilic spawners	Number of fish collected in the sample that use rock substrates to spawn divided by the total number of fish collected in the sample, multiplied by 100	Decrease	Increase
Embeddedness	The percent of coarse riffle substrates surrounded by fine substrates, such as sand and silt.	Increase	Decrease
Nitrates	Nitrate-nitrogen (N03, mg/L) measured in a laboratory setting from water grab samples taken at biological sampling sites.	Increase	Decrease

Causal Inference Approach #1 - Propensity Score Matching

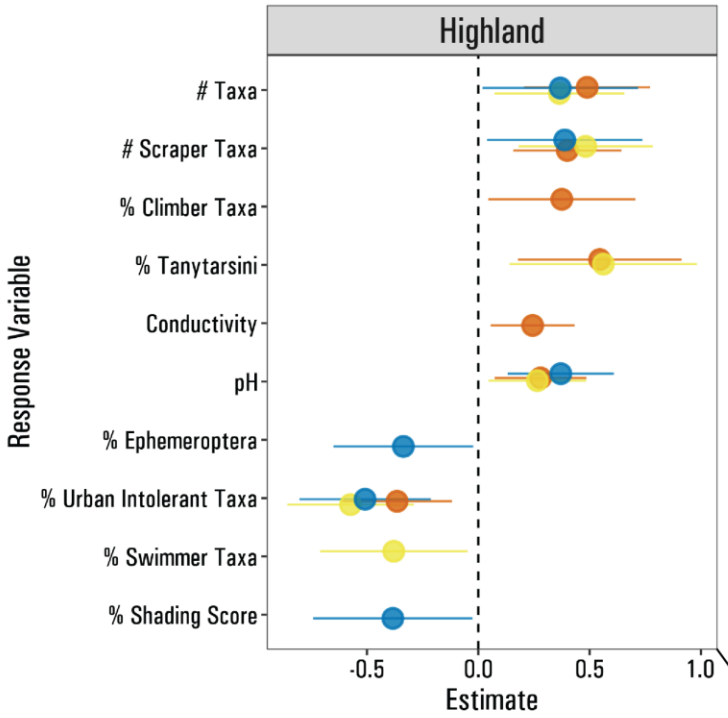


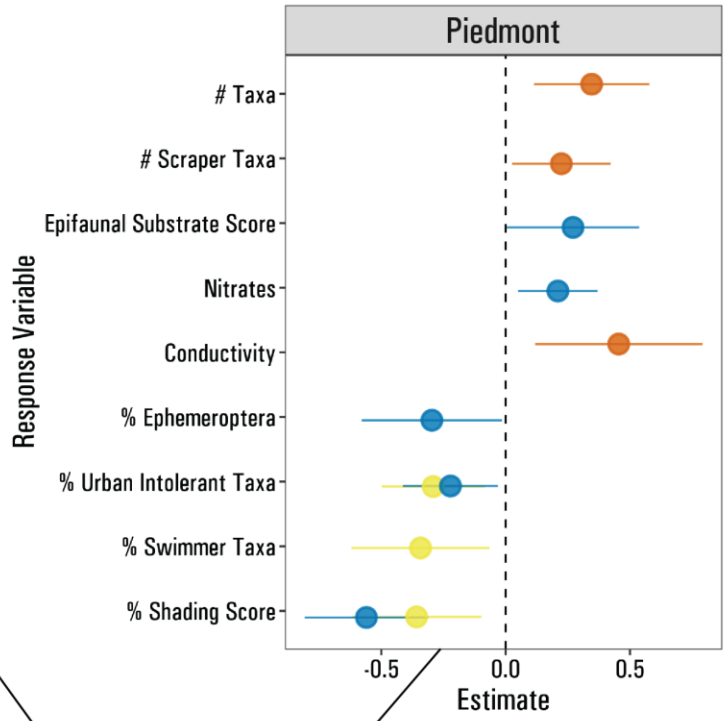


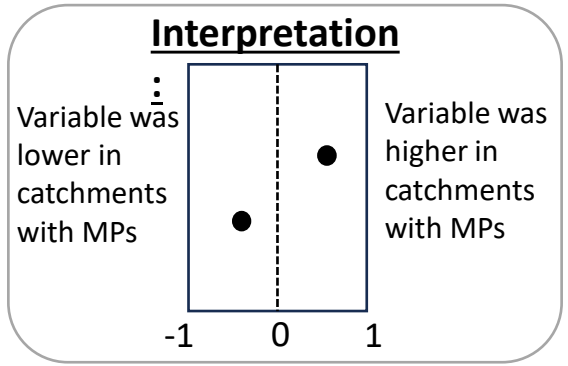
- Eastern Piedmont Region
- Fair IBI Condition
- 567m Elevation
- 12% Developed Land
- 19% Agricultural Land
- 149 km^2 Catchment Area
- 1129 mm/year Precipitation
- 13.2 °C Average Annual Temperature

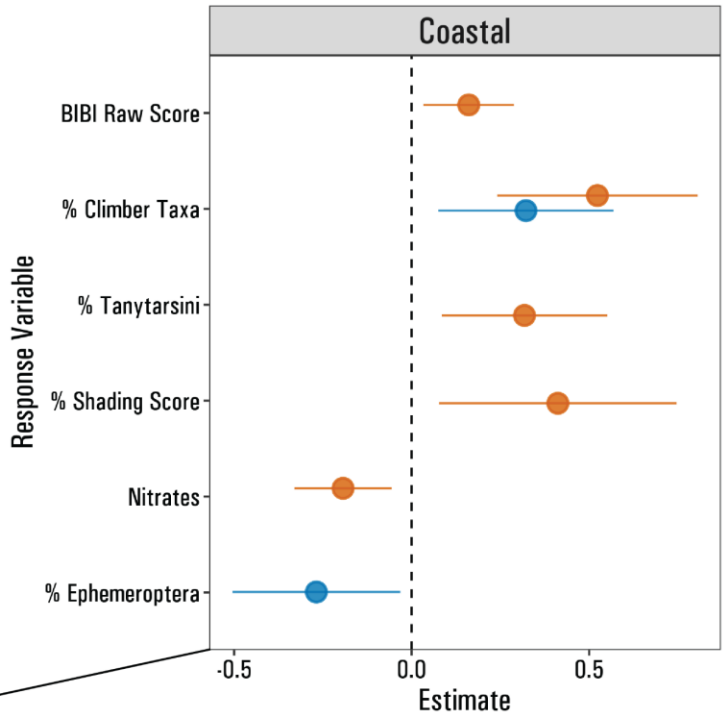
- Eastern Piedmont Region
- Fair IBI Condition
- 572m Elevation
- 14% Developed Land
- 17% Agricultural Land
- 158 km^2 Catchment Area
- 1137 mm/year Precipitation
- 13.5 °C Average Annual Temperature

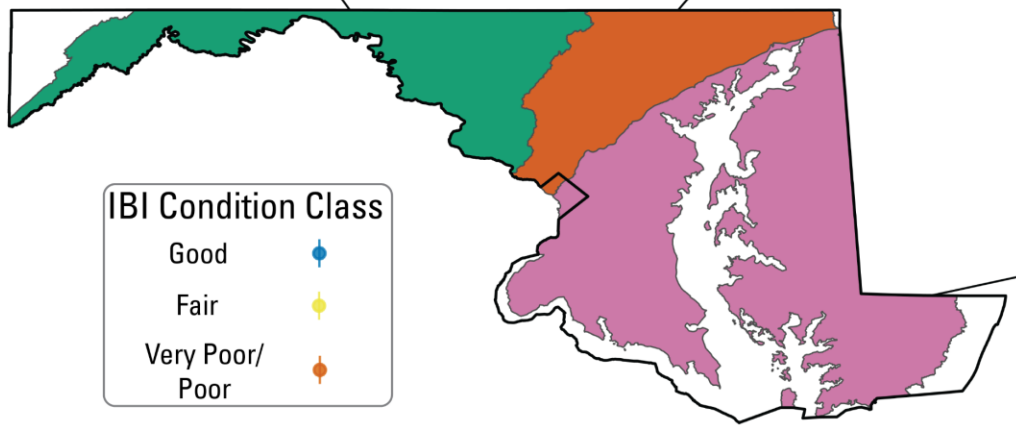
Propensity Score Matching – Benthic Macroinvertebrate Results



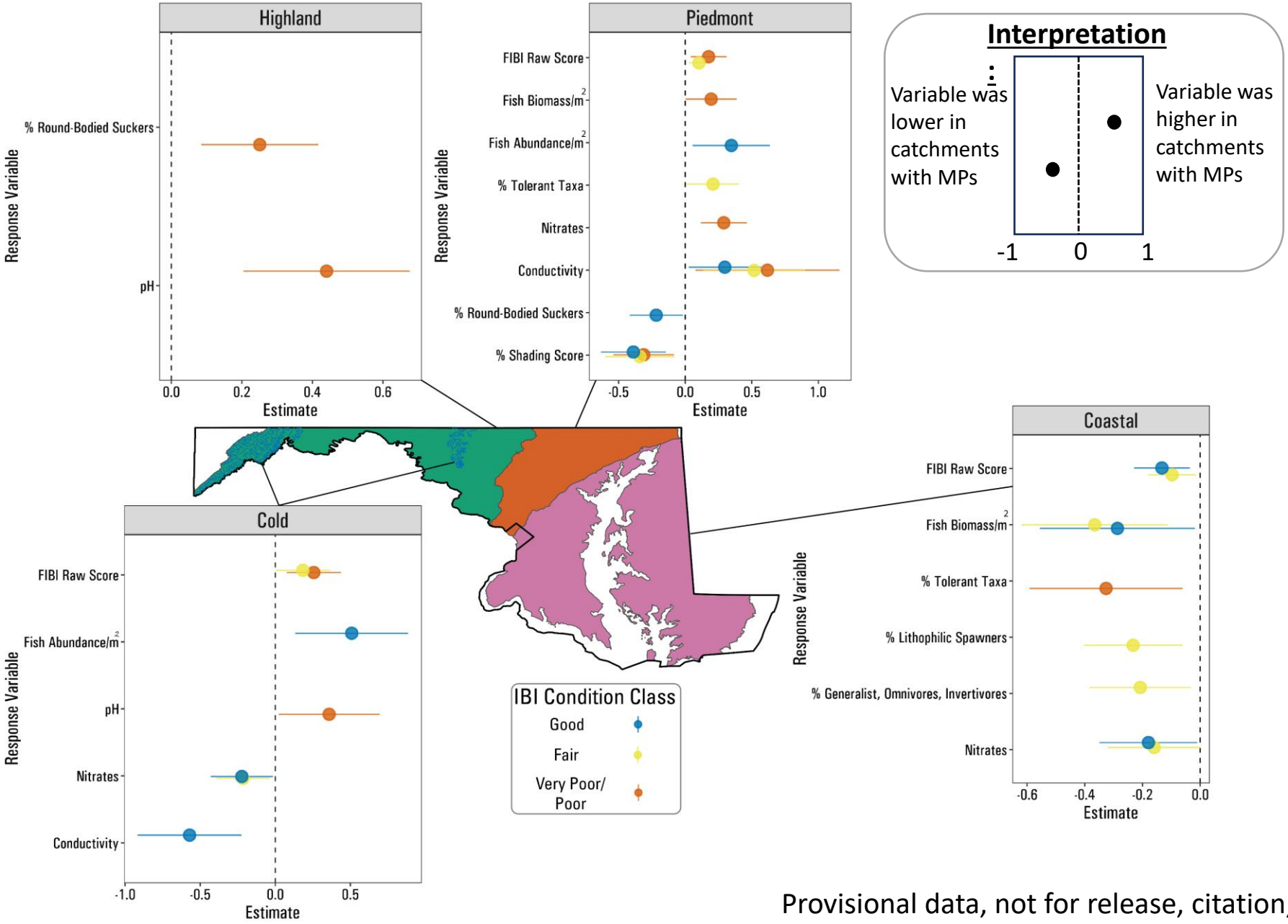




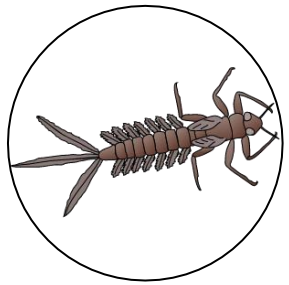




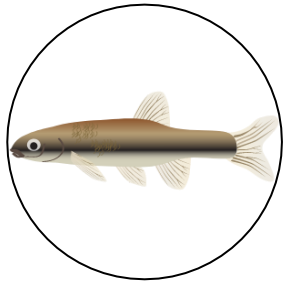
Propensity Score Matching –Fish Results



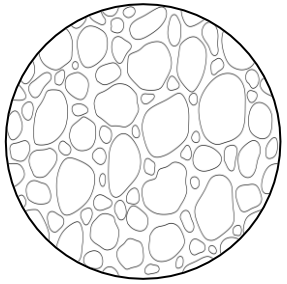
Propensity Score Matching – Takeaways



Benthic Macro - invertebrates



Fish

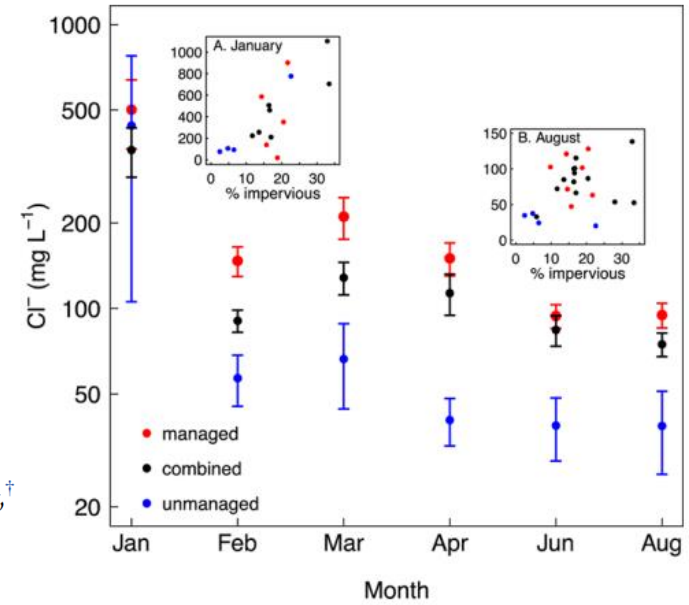


Instream Habitat

Water Quality

- MPs co-benefit in degraded catchments in all three IBI regions
  - MPs co-benefit certain groups as well as biological condition (IBI)
    - Climbing habit & Scraping feeding group, Tanytarsini taxa
  - MPs have negative effects on sensitive groups in catchments with good biological condition
    - Ephemeroptera, Urban Intolerant Taxa
- MPs co-benefit fish biological condition in Coldwater Highlands & Piedmont regions in degraded catchments
- MPs had negative effects and no effects on fish in Coastal & Highlands region, respectively
- MPs had both positive and negative effects on r substrate scores depending on region
- **Influence of Modern Stormwater Management Practices on Transport of Road Salt to Surface Waters**

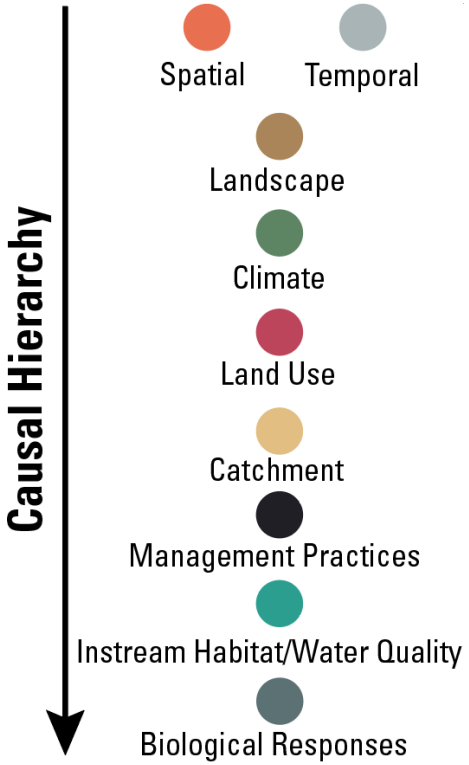
  Joel W. Snodgrass,*,†,‡ Joel Moore,† Steven M. Lev,† Ryan E. Casey,† David R. Ownby,† Robert F. Flora,† and Grant Izzo†



Causal Inference Approach #2 -Bayesian Networks

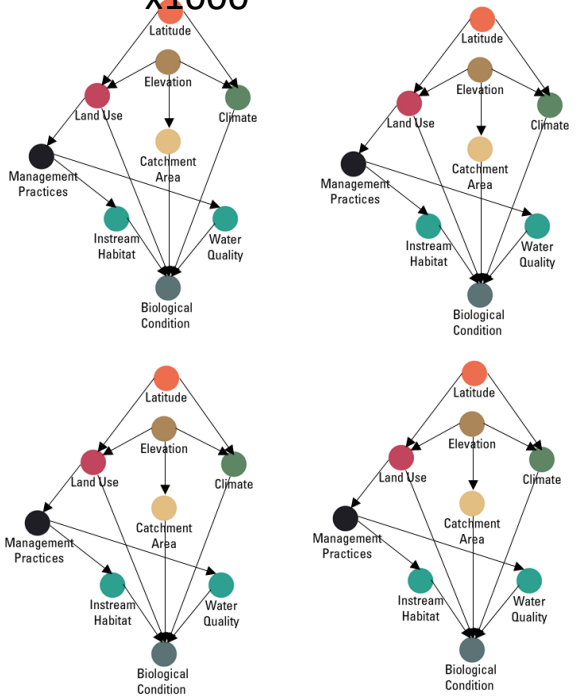
1. Data Organization

Build blocklist to prevent illogical connections



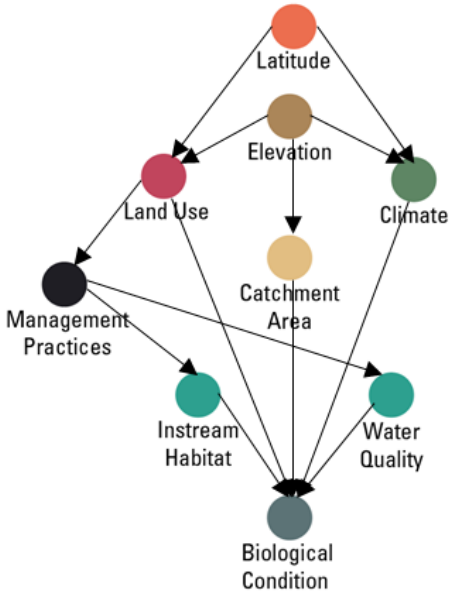
2. Algorithmic Search

Learn networks x1000



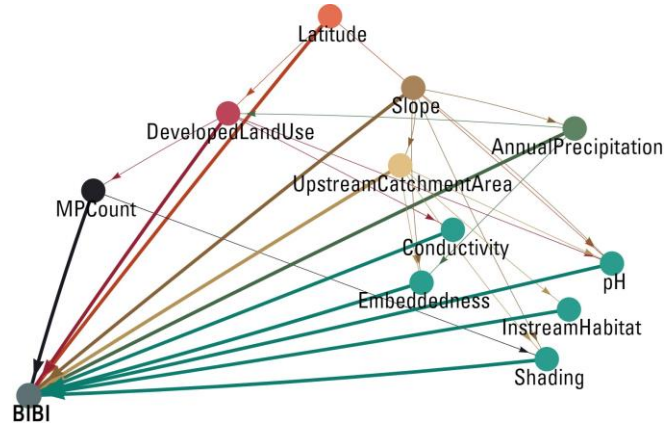
3. Model Averaging

Keep connections that occurred in > 50% of bootstrapped networks

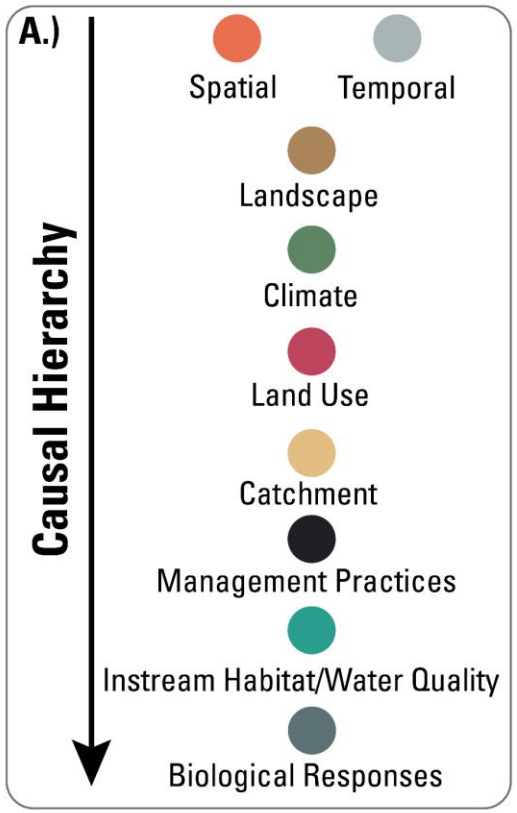


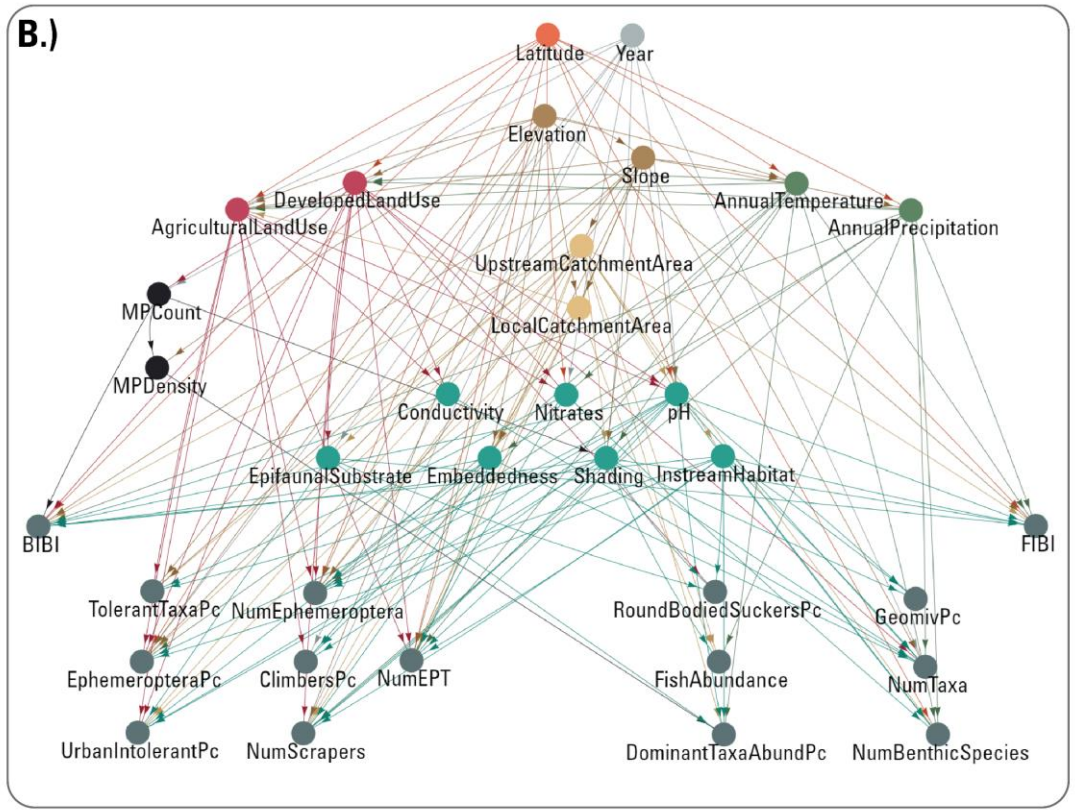
4. Model Effects

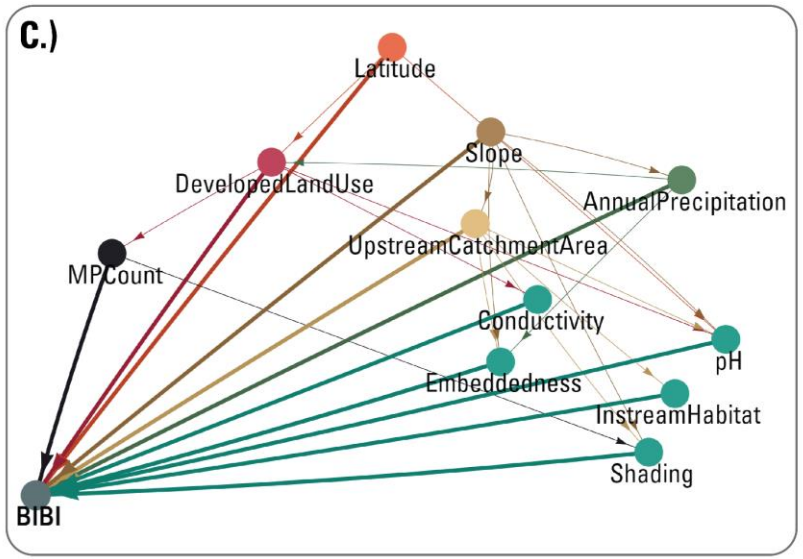
Identify effects on nodes of interest

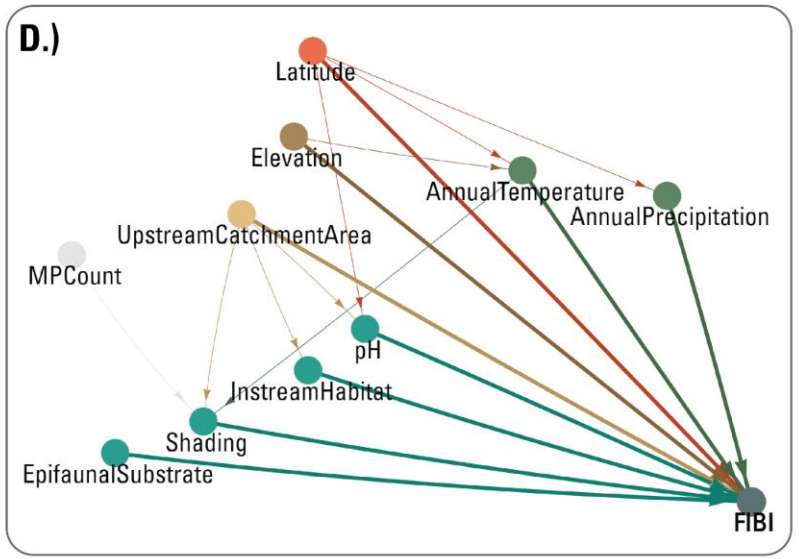


Coastal Region









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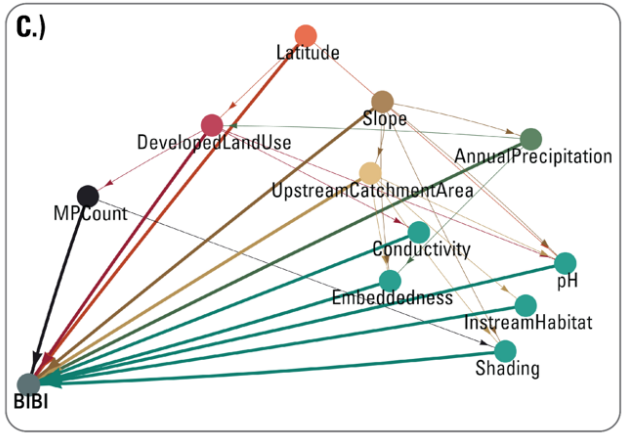
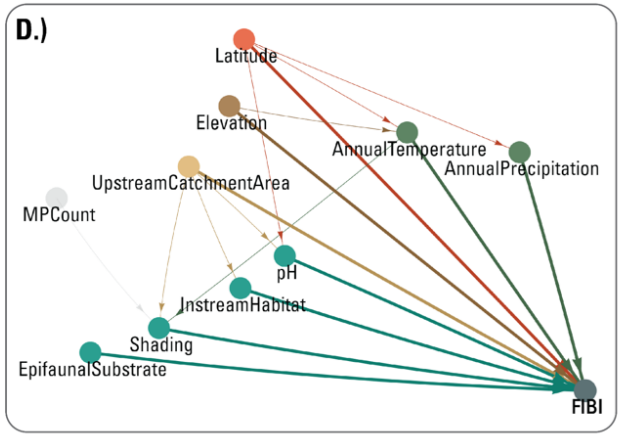
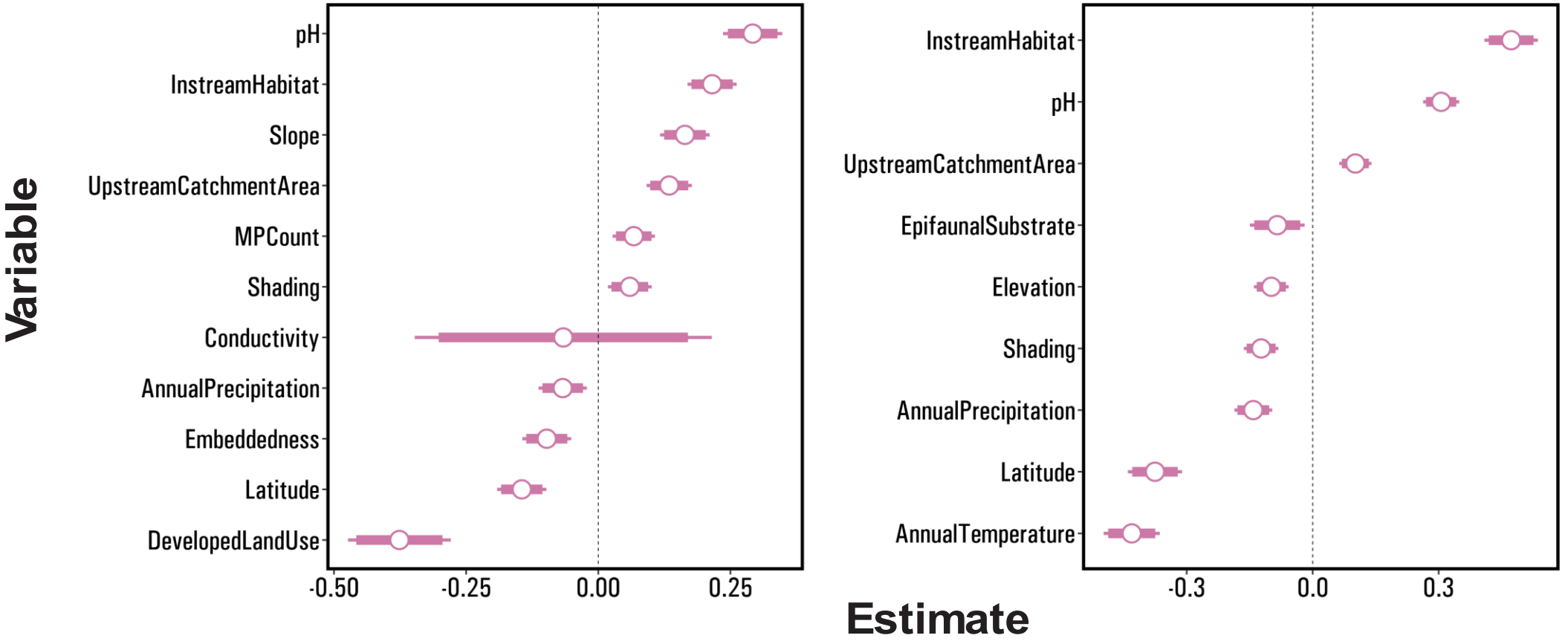
Coastal Region







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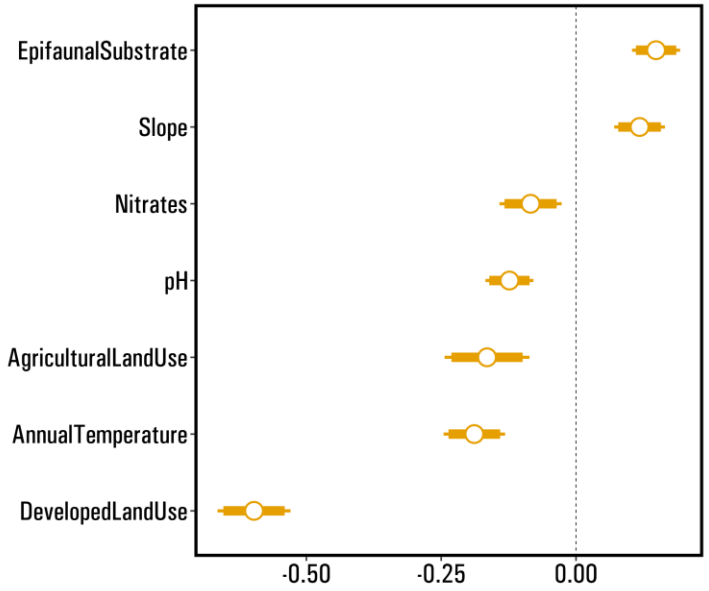
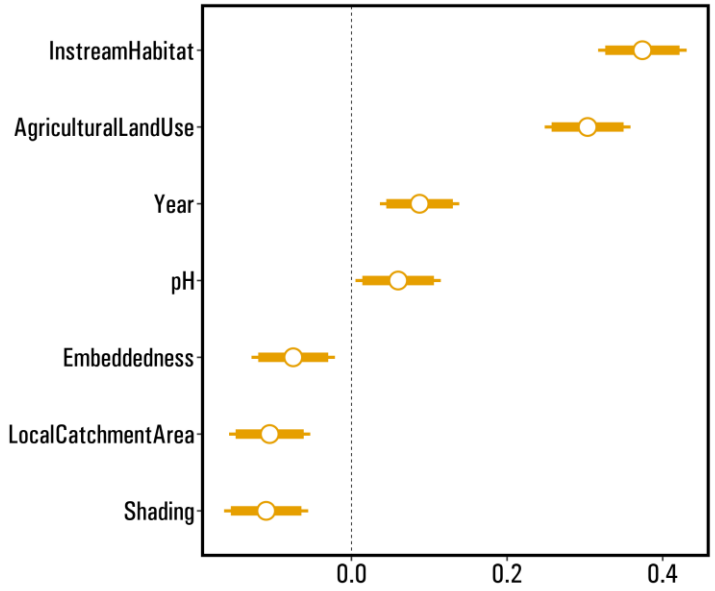
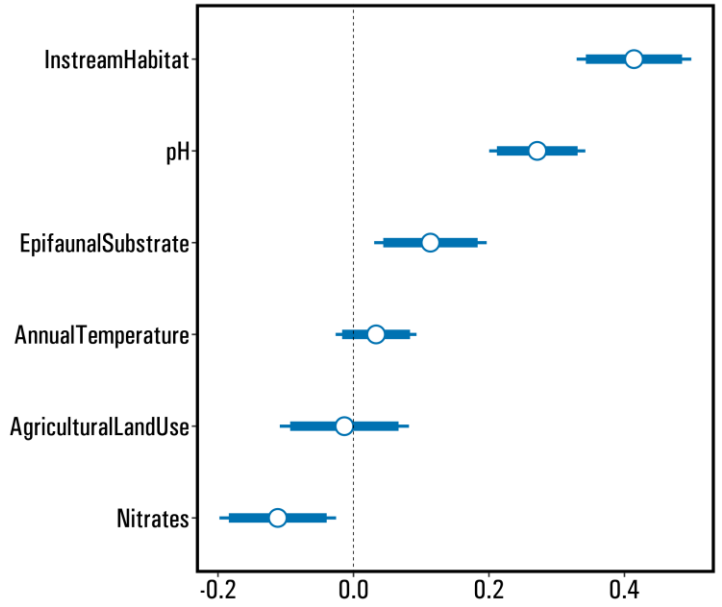
Eastern Piedmont Region



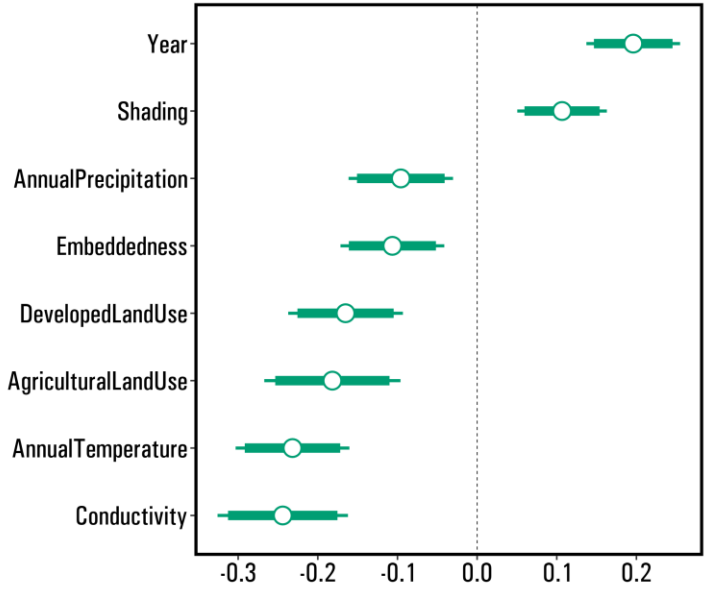


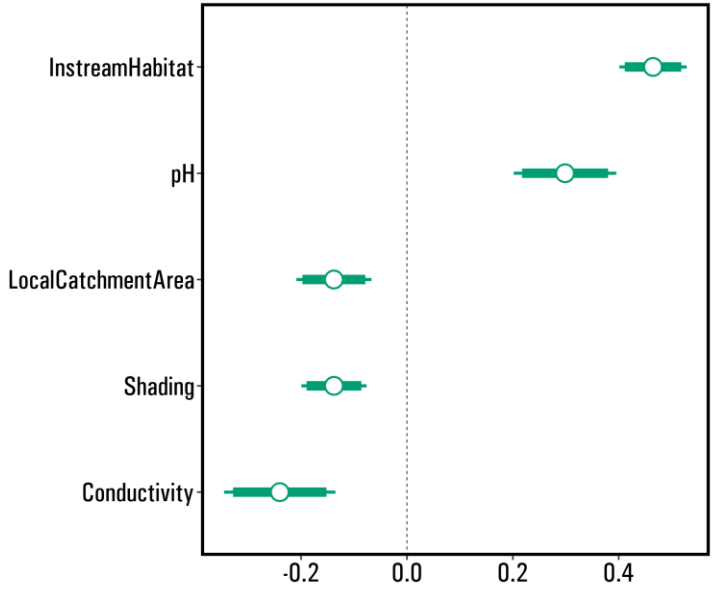
Coldwater Highland Region (Fish Only)



Variable

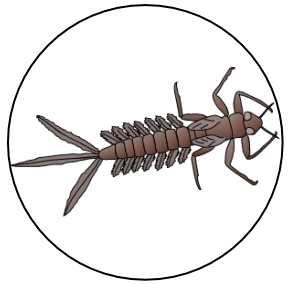
Highland Region





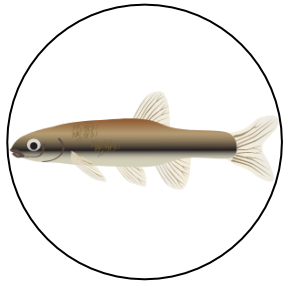
Estimate

Bayesian Networks – Takeaways



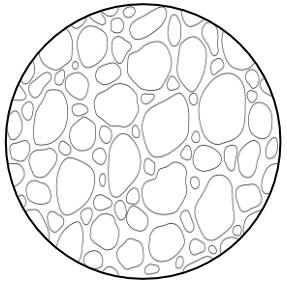
Benthic Macro - invertebrates

- MPs co-benefit in coastal IBI region – direct effect of MP count on BIBI score
  - Variables known to structure assemblages (climate, land use, instream habitat, water quality, etc.) largely dominated causal pathways for explaining BIBI scores



Fish

- No co-benefits observed
  - Variables known to structure assemblages (climate, land use, instream habitat, water quality, etc.) largely dominated causal pathways for explaining FIBI scores



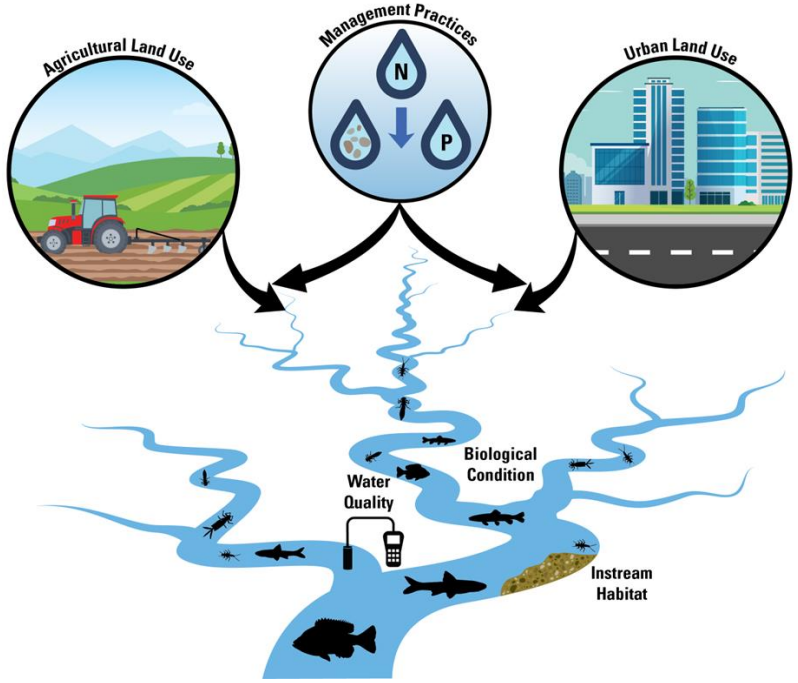
Instream Habitat

- Positive effect of MP Count -> Riparian shading score observed in Coldwater highlands region
- Negative effect of MP Count -> Riparian shading score observed in Coastal region

Water Quality

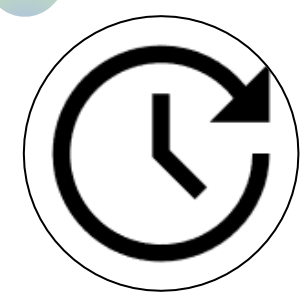
- No co-benefits observed

Overall Takeaways

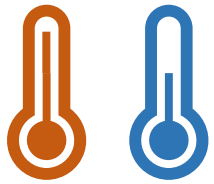


- Observed both positive and negative MP effects on instream conditions
  - These effects varied across region, taxa, and stream conditions
- Identification of MP co-benefits may be more prevalent in catchments with degraded conditions
  - Some carefully designed, catchment scale MP implementation could produce co-benefits
- Identified negative MP effects on instream conditions in catchments with good conditions
  - Underscores need to carefully examine MP types at catchment scale
- Identified MP effects on both biological condition (IBI) and specific endpoints (scrapers, lithophilic spawners)
  - Highlights need to understand MP effects across different groups in addition to overall biological condition

Future Work

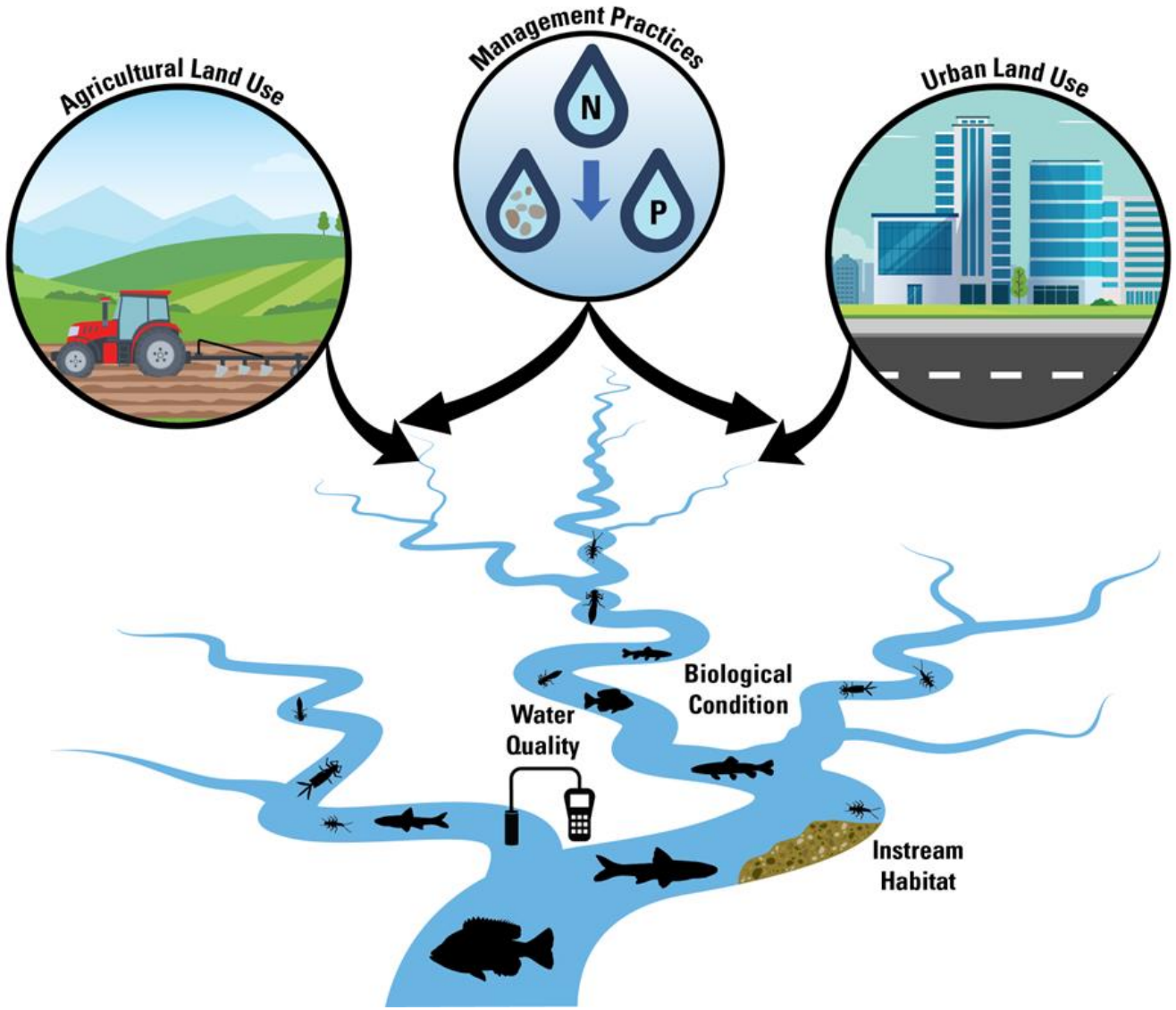


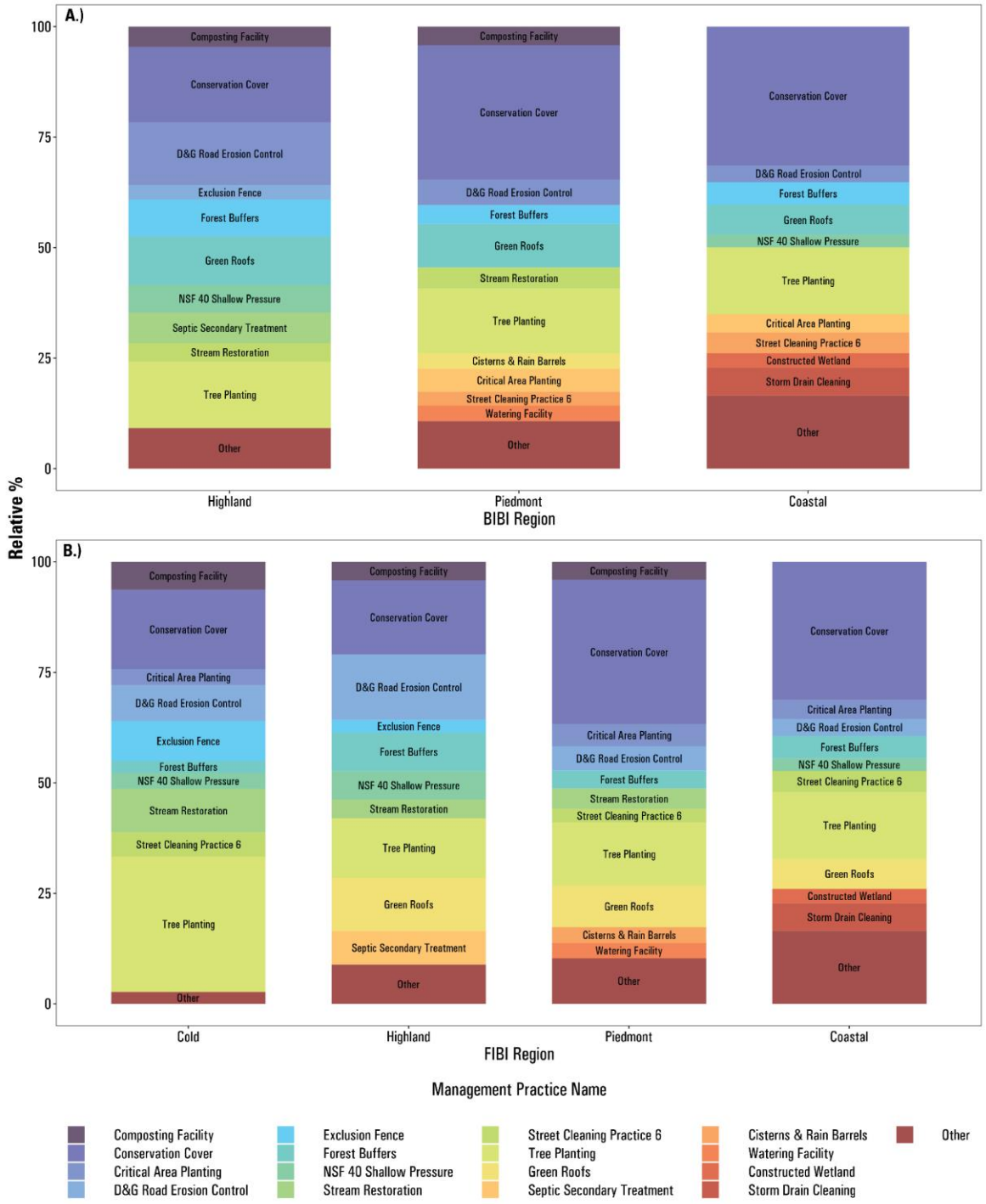
- Scale up analyses to entire non-tidal bay to assess cumulative MP effects
  - Attempt to identify specific MPs with potential co-benefits at regional scales
  - Attempt causal inference analyses that consider continuous (how many MPs/MP intensity) rather than binary treatment (MPs or no MPs)



- Attempt to identify “heater” vs. “cooler” MPs with additional dataset from Maryland Biological Stream Survey
  - Links with recent STAC Report on Rising Temperatures

Questions?


Agricultural Land Use
Management Practices
N
P
Urban Land Use
Water Quality
Biological Condition
Instream Habitat



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