Watersheds, Catchments, Riparian Buffers, and Stream Networks: Do Bugs Care About Space?

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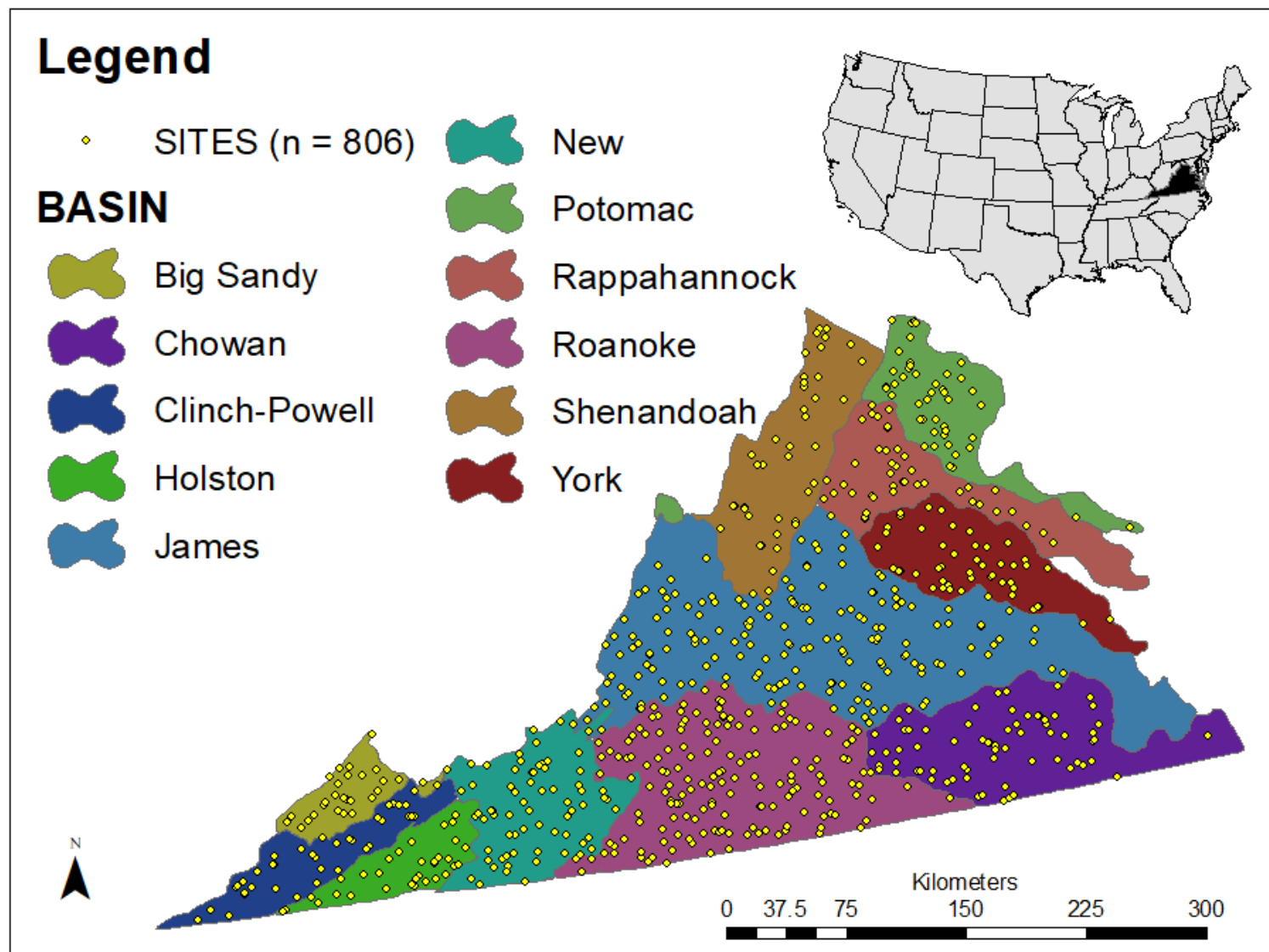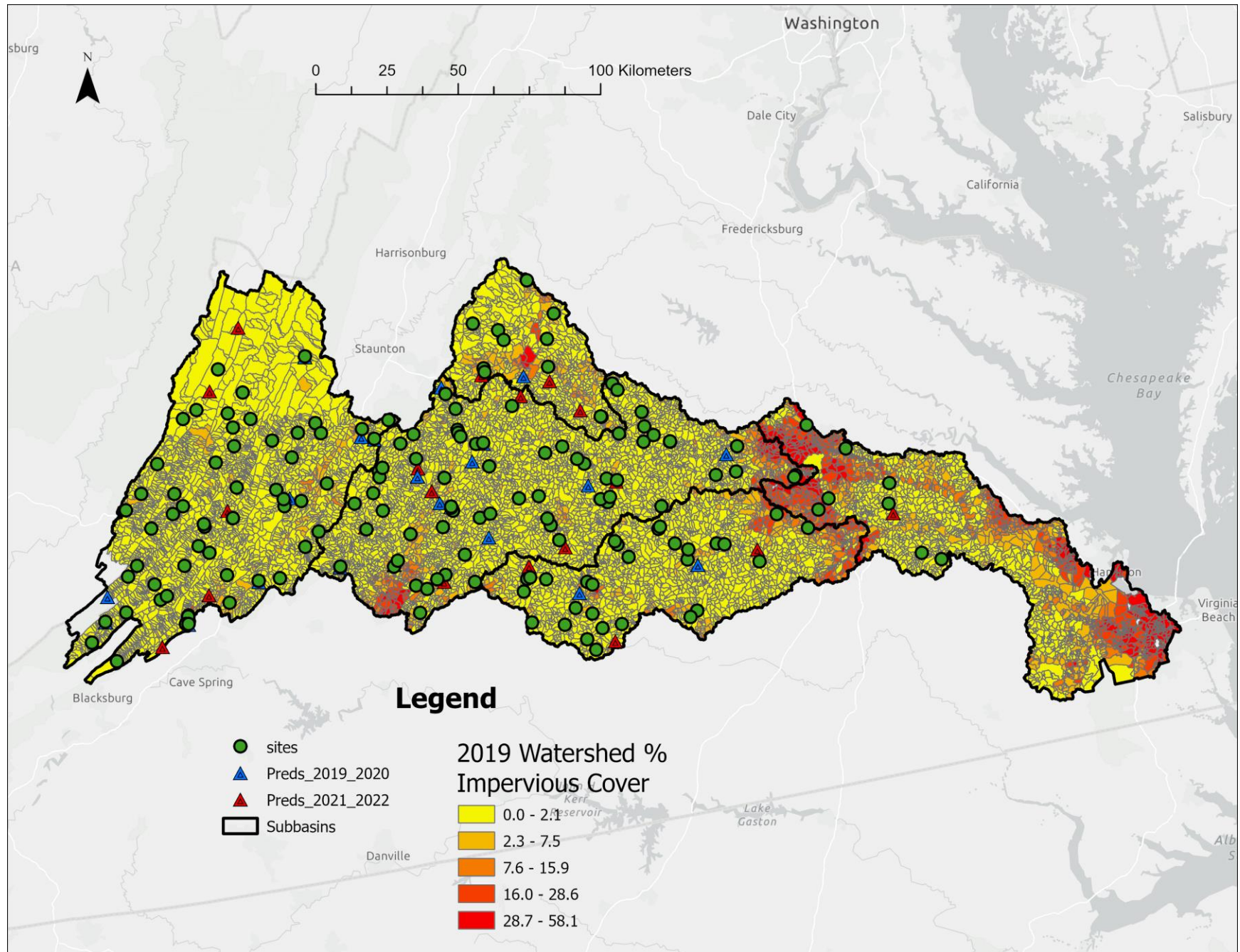
How does the geography of landscape metrics and instream stressors interact with Euclidean and stream network distances to explain variation in stream condition index of a river basin?

Virginia DEQ

Spatially balanced probabilistic monitoring sites sampled from 2001-2018

- 11 Basins
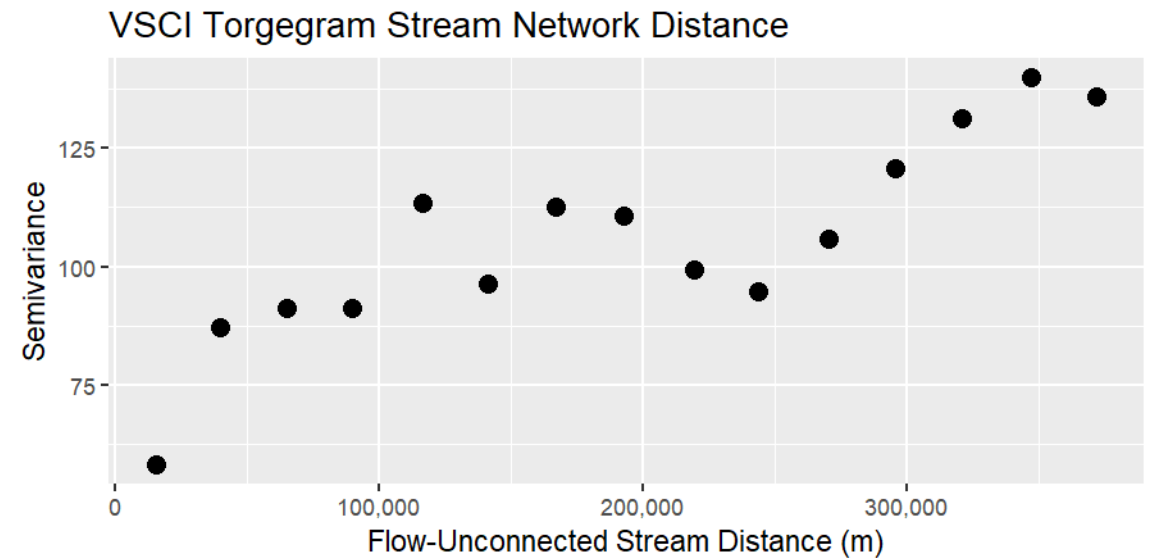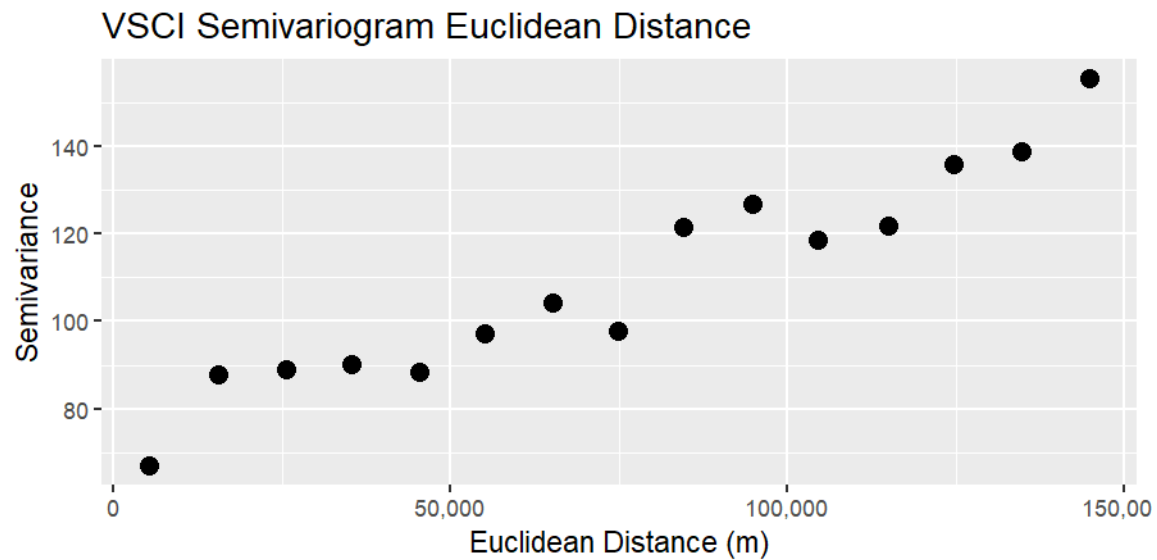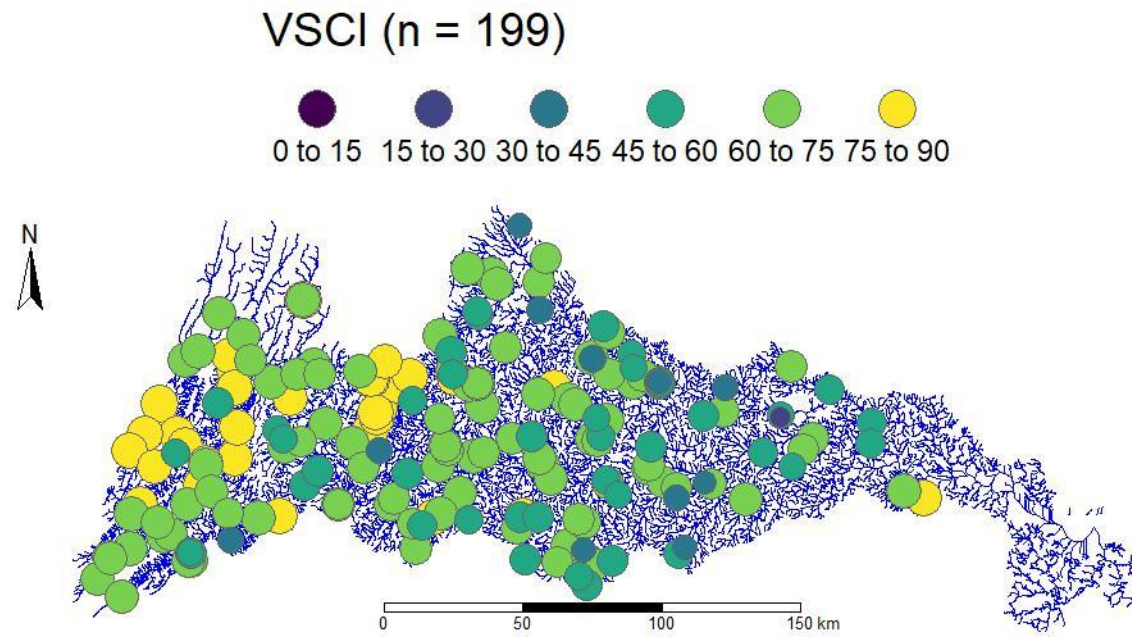
- 806 Sites

- Stratified by Strahler stream order 1-6

Legend

- ● sites
- ▲ Preds_2019_2020
- ▲ Preds_2021_2022
- ▭ Subbasins

2019 Watershed % Impervious Cover

- 0.0 - 2.1
- 2.3 - 7.5
- 7.6 - 15.9
- 16.0 - 28.6
- 28.7 - 58.1

Metrics of Virginia Stream Condition Index (VSCI)

Metric	Category	Response to Stress
Total Taxa	Taxonomic Richness	Decrease
Ephemeroptera, Plecoptera, Trichoptera (EPT) Taxa	Taxonomic Richness	Decrease
% Ephemeroptera	Composition	Decrease
% Plecoptera + Trichoptera - Hydropsychidae	Composition	Decrease
% Scrapers	Trophic Group	Decrease
% Chironomidae	Composition	Increase
% Top 2 Dominant	Diversity	Increase
Hilsenhoff Biotic Index (HBI Family Biotic Index)	Tolerance	Increase

James River Virginia Stream Condition Index 2001-2018

VSCI (n = 199)

0 to 15   15 to 30   30 to 45   45 to 60   60 to 75   75 to 90

VSCI Semivariogram Euclidean Distance

VSCI Torgegram Stream Network Distance

2001-2018 VDEQ Probabilistic Monitoring of Wadeable Stream Sites in James River Basin (n = 199)

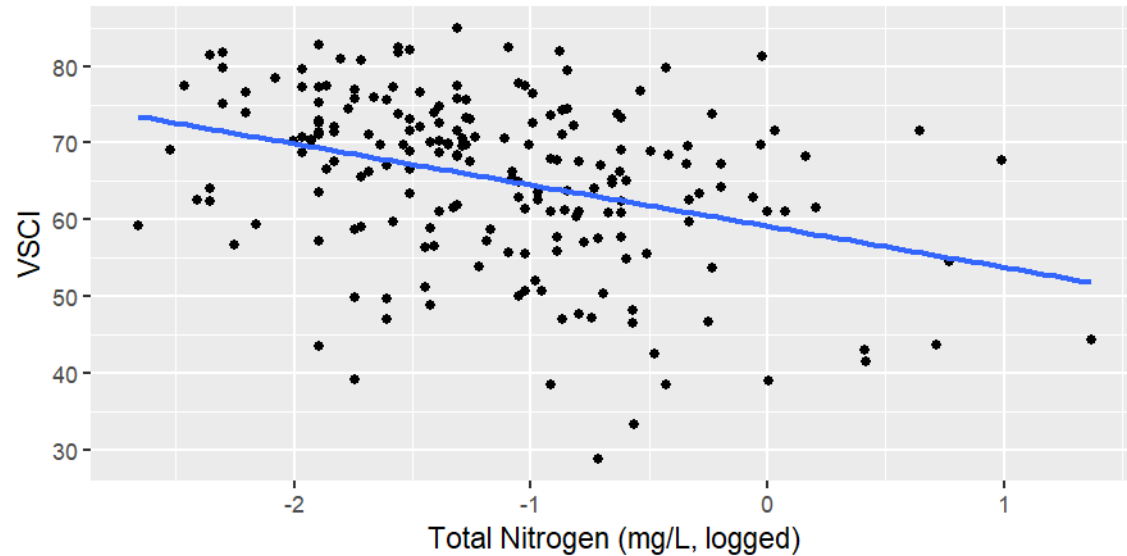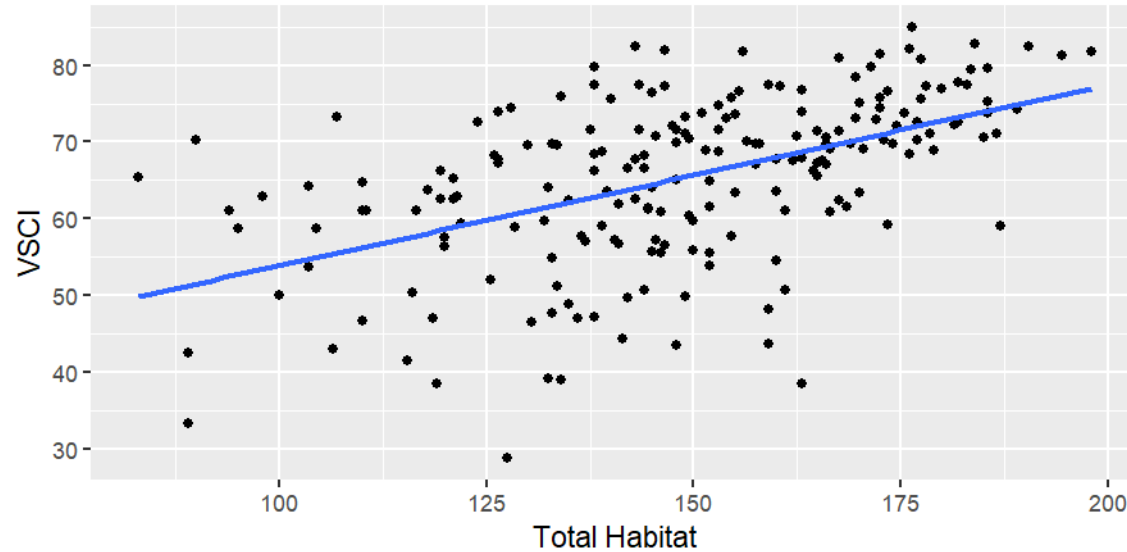| Instream Measurements |
| --- |
| Total Habitat Score (RBP) |
| Dissolved Oxygen |
| pH |
| Specific Conductivity |
| Total Dissolved Solids |
| Turbidity |
| Total Nitrogen |
| Total Phosphorous factor |
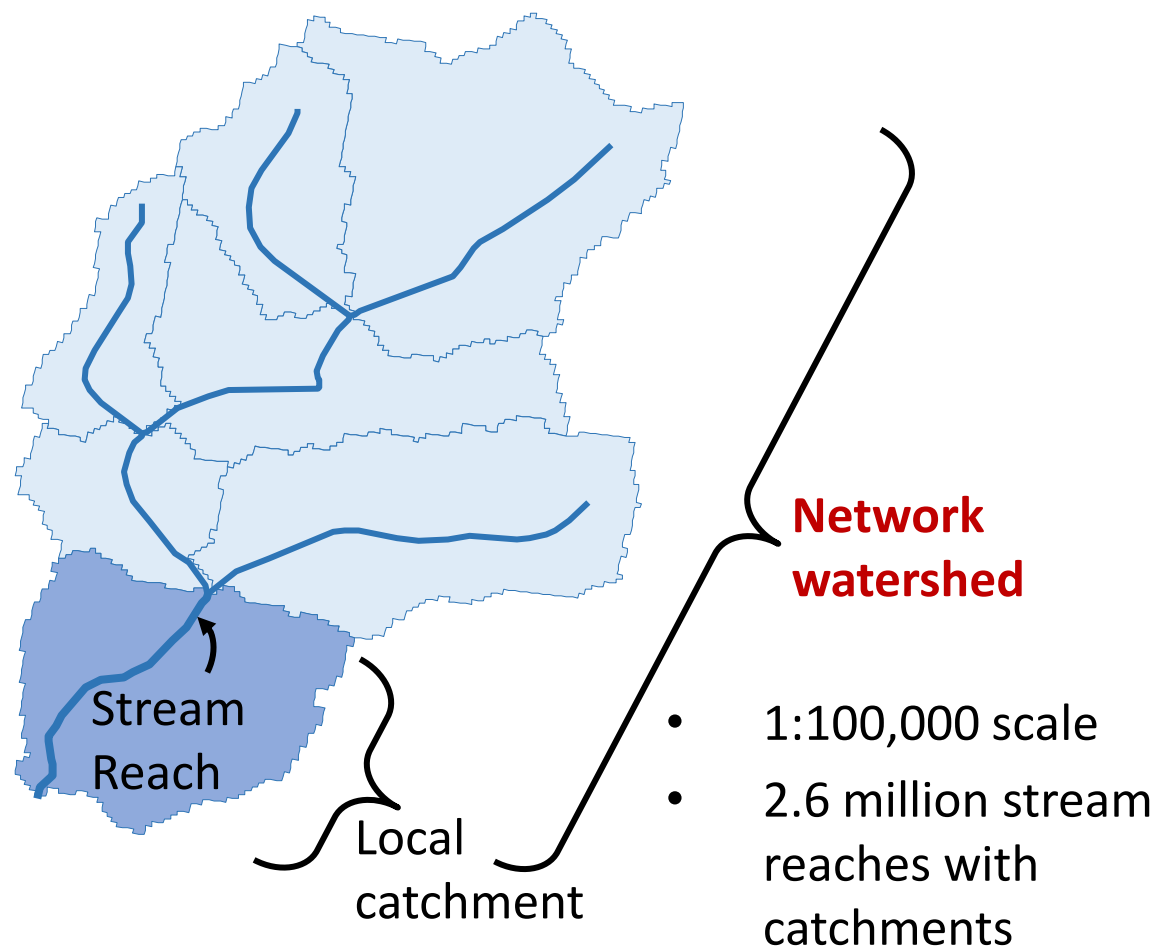
Extent & Configuration of National Land Cover Data and Impervious Surfaces are calculated at 4 geographies in StreamCat:

- Local Catchment
- Local Catchment Riparian restricted to 100 m buffers
- Watershed
- Watershed Riparian restricted to 100 m buffers

Network watershed

Stream Reach

Local catchment

- 1:100,000 scale
- 2.6 million stream reaches with catchments

Figure from Marc Weber, US EPA

Four Geographies (km²) of sites in James River Basin

| Statistic	Watershed (W)	Watershed Riparian (WR)	Catchment (C)	Catchment Riparian (CR)
Minimum	1.14	0.25	0.04	0.02
Median	35.02	4.41	2.56	0.48
Mean	223.60	39.37	4.18	0.60
Maximum	3090.81	591.93	81.89	4.08

StreamCat Metrics for the 4 Geographies

Watershed: (W) Largest Extent & Configuration	Watershed-Riparian (WR)	Catchment (C)	Catchment-Riparian: (CR) Smallest Extent & Configuration
% Impervious – W	% Impervious – WR	% Impervious – C	% Impervious – CR
% Forest – W	% Forest - WR	% Forest – C	% Forest – CR
% Hay – W	% Hay – WR	% Hay – C	% Hay – CR
% Grass – W	% Grass – WR	% Grass – C	% Grass – CR
Wetlands-presence/absence	Wetland-presence/absence	Wetland-presence/absence	Wetland-presence/absence
VA Subbasins: 5 levels	VA Subbasins: 5 levels	VA Subbasins: 5 levels	VA Subbasins: 5 levels
Averge Elevation – W	Average Elevation – W	Average Elevation – C	Average Elevation – C
Annual Precipitation (mm)	Annual Precipitation (mm)	Annual Precipitation (mm)	Annual Precipitation (mm)
Annual Temperature (° C)	Annual Temperature (° C)	Annual Temperature (° C)	Annual Temperature (° C)

VSCI and Impervious Cover: 4 Geographies
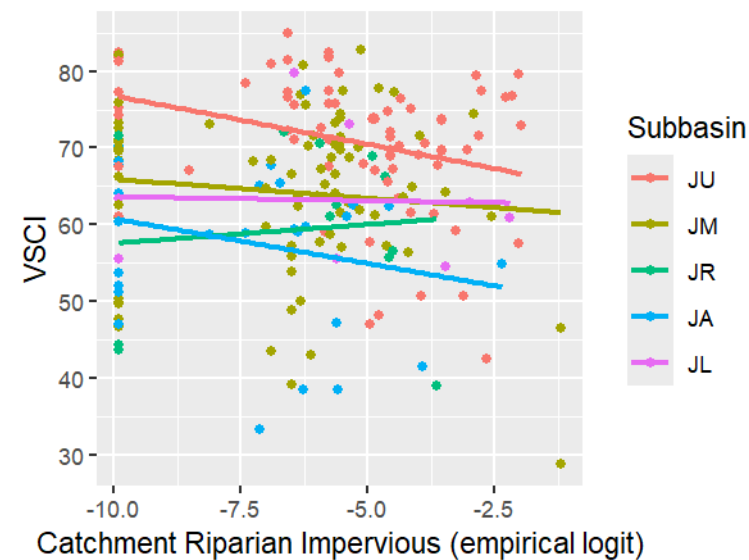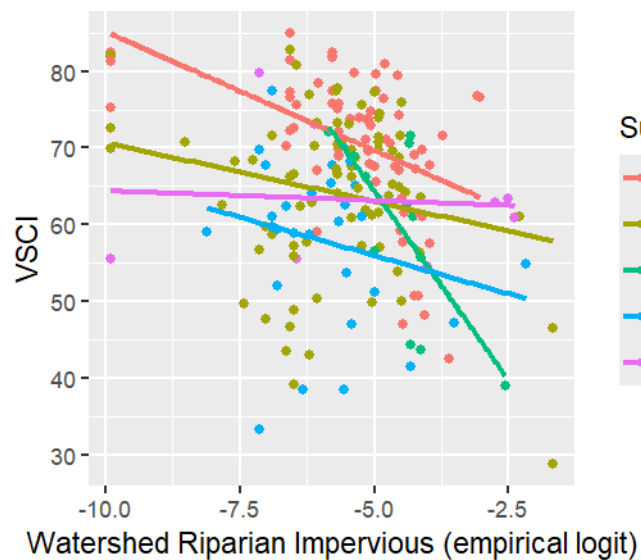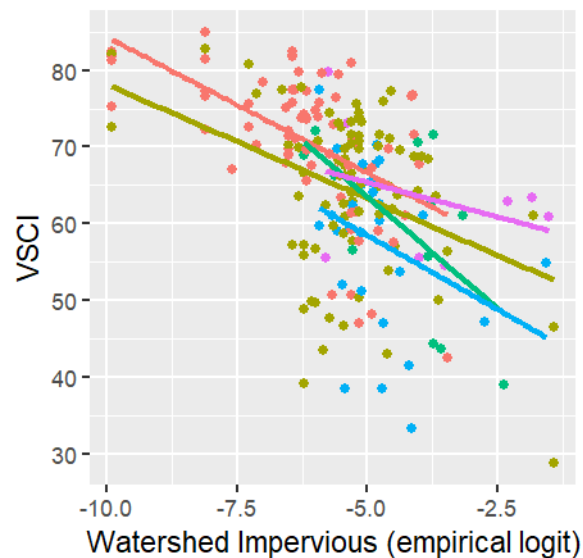
Spatial Stream Network (SSN) Autocovariance Functions for Euclidean and Stream Distances

One-Way	Two-Way	Three-Way
Tail Up (TU)	Tail Up and Tail Down (TU/TD)	Tail Up, Tail Down, and Euclidean (TU/TD/EU)
Tail Down (TD)	Tail Up and Euclidean (TU/EU)	
Euclidean (EU)	Tail Down and Euclidean (TD/EU)	

3 Types of Distances among Stations (black-dashed lines)

Euclidean   Flow-Unconnected   Flow-Connected

modified from Peterson et al. (2010), Ecology
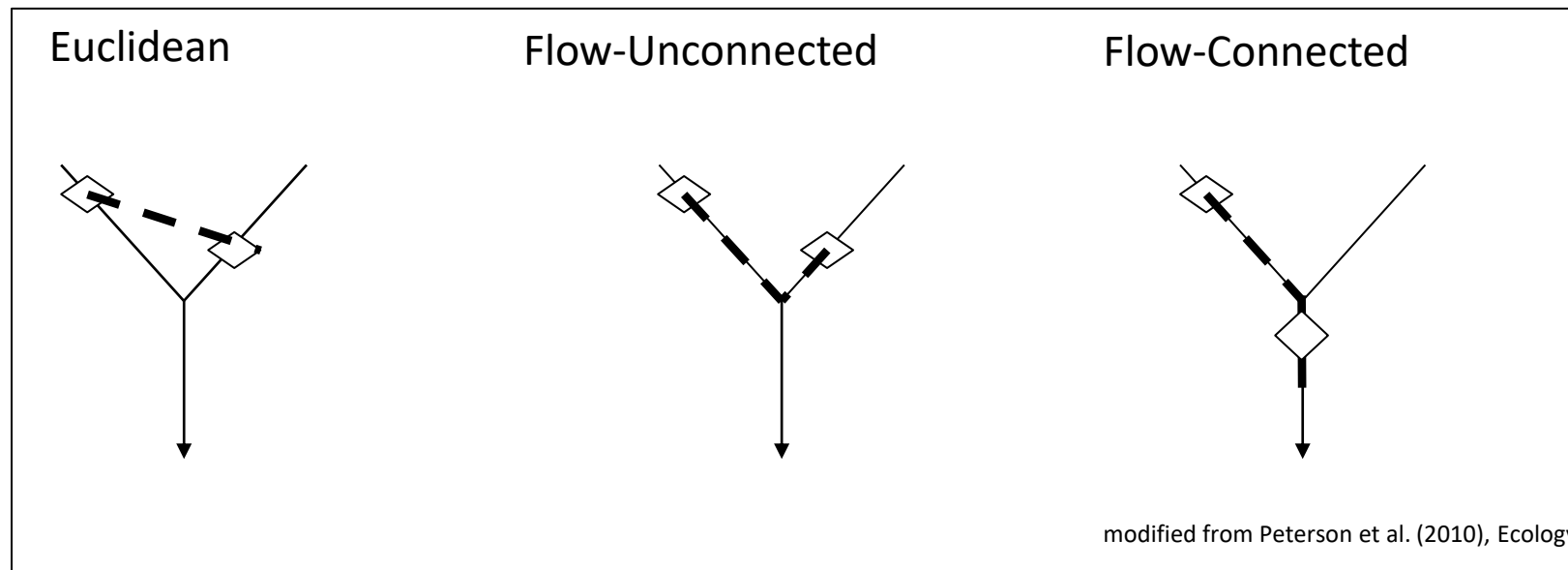
First Step of Analytical Workflow: Selection of covariate subsets (A-D) and SSN autocovariance (E)

A. Watershed/Instream – Select bestglm with 4 covariates

B. Watershed-Riparian/Instream– Select bestglm with 4 covariates

C. Catchment/Instream – Select bestglm with 4 covariates

D. Catchment-Riparian/Instream – Select bestglm 4 covariates

E. SSN Autocovariance – Select smallest AIC from y-intercept only model comparing 15 spatial autocovariances

Second Step of Analytical Workflow: Where does space give the biggest model improvement?

A. Watershed/Instream Covariates – Take bestglm 4 covariates and add selected SSN autocovariance to model

B. Watershed-Riparian/Instream Covariates – Take bestglm 4 covariates and add selected SSN autocovariance to model

C. Catchment/Instream Covariates – Take bestglm 4 covariates and add selected SSN autocovariance to model

D. Catchment-Riparian/Instream Covariates – Take bestglm 4 covariates and add selected SSN autocovariance to model

Regression Analysis for the 4 Geographies

Watershed: (W) Largest Extent & Configuration	Watershed-Riparian (WR)	Catchment (C)	Catchment-Riparian: (CR) Smallest Extent & Configuration
% Impervious – W	% Impervious - WR	% Impervious – C	% Impervious – CR
Elevation – W	Elevation – W	Elevation – C	Elevation – C
Dissolved Oxygen	Dissolved Oxygen	Total Nitrogen	Total Nitrogen
VA Subbasins: James Low	Total Habitat Score	Total Habitat Score	Total Habitat Score
% MLR Covariates: 41	% MLR Covariates: 41	% MLR Covariates: 40	% MLR Covariates: 39

Spatial Stream Network Analysis for the 4 Geographies

Watershed: (W) Largest Extent & Configuration	Watershed-Riparian (WR)	Catchment (C)	Catchment-Riparian: (CR) Smallest Extent & Configuration
% Impervious – W	% Impervious - WR	% Impervious – C	% Impervious – CR
Elevation – W	Elevation – W	Elevation – C	Elevation – C
Dissolved Oxygen	Dissolved Oxygen	Total Nitrogen	Total Nitrogen
VA Subbasins: James Low	Total Habitat Score	Total Habitat Score	Total Habitat Score
% SSN Covariates: 29	% SSN Covariates: 35	% SSN Covariates: 33	% SSN Covariates: 30
% Euclidean: 17	% Euclidean: 51	% Euclidean: 4	% Euclidean: 5
% Tail Down: 43	% Tail Down: 2	% Tail Down: 63	% Tail Down: 59
$SSN_{AICc} < MLR_{AICc}$	$SSN_{AICc} < MLR_{AICc}$	$SSN_{AICc} < MLR_{AICc}$	$SSN_{AICc} < MLR_{AICc}$
LOOCV: $SSN\text{-}R^2 > MLR\text{-}R^2$	LOOCV: $SSN\text{-}R^2 > MLR\text{-}R^2$	LOOCV: $SSN\text{-}R^2 > MLR\text{-}R^2$	LOOCV: $SSN\text{-}R^2 > MLR\text{-}R^2$

SSN Model Comparison

Model	AICc	Cor2	RMSPE
Watershed	1414	0.42	8.36
Watershed-Riparian	1419	0.41	8.43
Catchment	1419	0.40	8.46
Catchment-Riparian	1423	0.39	8.55
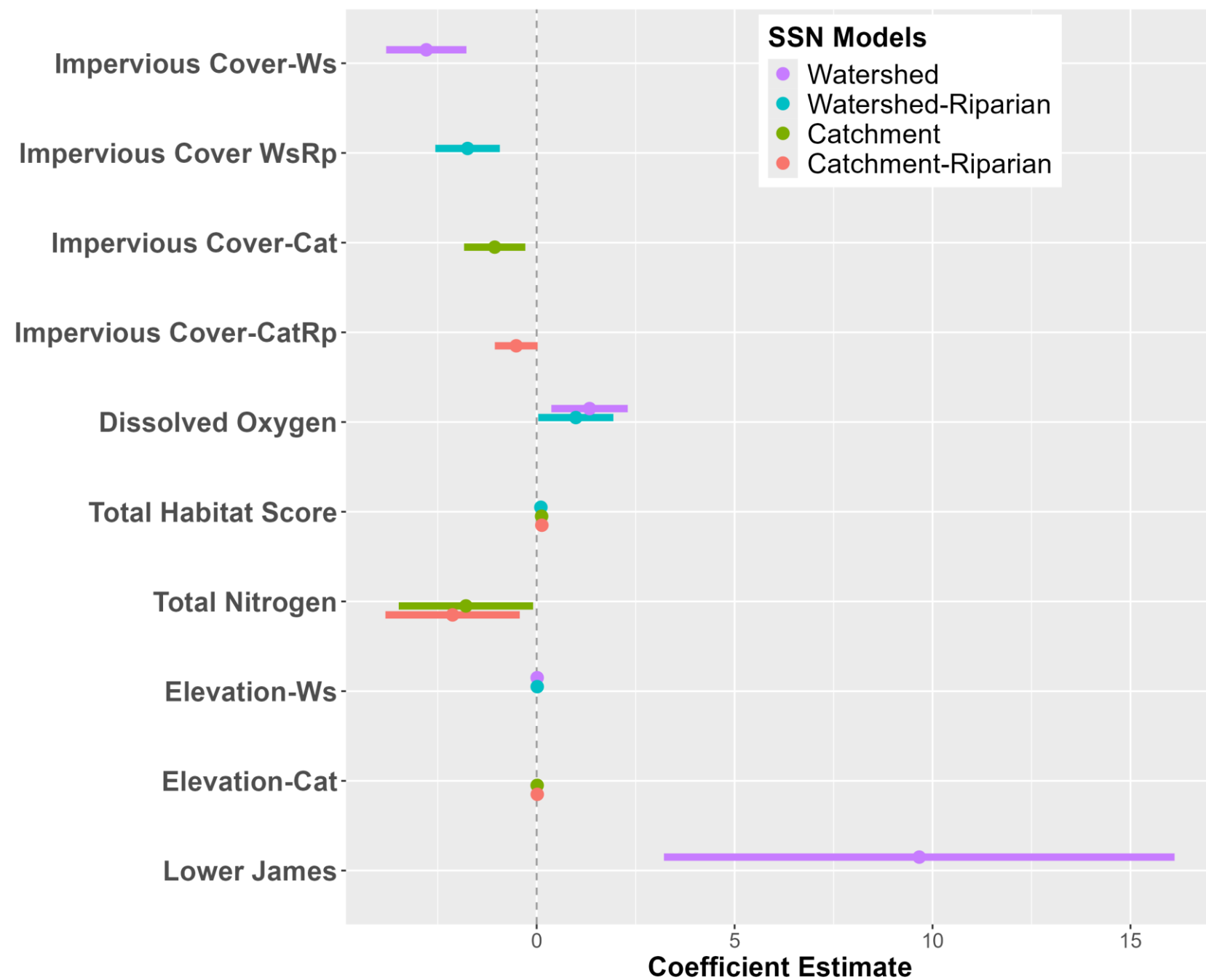
How does the geography of landscape metrics and instream stressors interact with Euclidean and stream network distances to explain variation in stream condition index of a river basin?

- Space Matters: A large amount of the variation in stream condition index was accounted for by random, spatially dependent error.

- Geography Matters: Stream condition index decreased with increased impervious cover, but that relationship was diminished as the size and configuration of that land cover became smaller.

Biologists at <u>Virginia Department of Environment Quality</u>, especially Jason Hill and Emma Jones.

Ellen D'Amico, GIS Analyst, at Pegasus Technical Services Inc.

Marc Weber, Geographer, for <u>StreamCat database and Tools</u>, and Michael Dumelle, Spatial Statistician, for R package <u>SSN2</u>, both at U.S. EPA ORD.