Improving models of biological condition to support existence valuation of freshwater ecosystems

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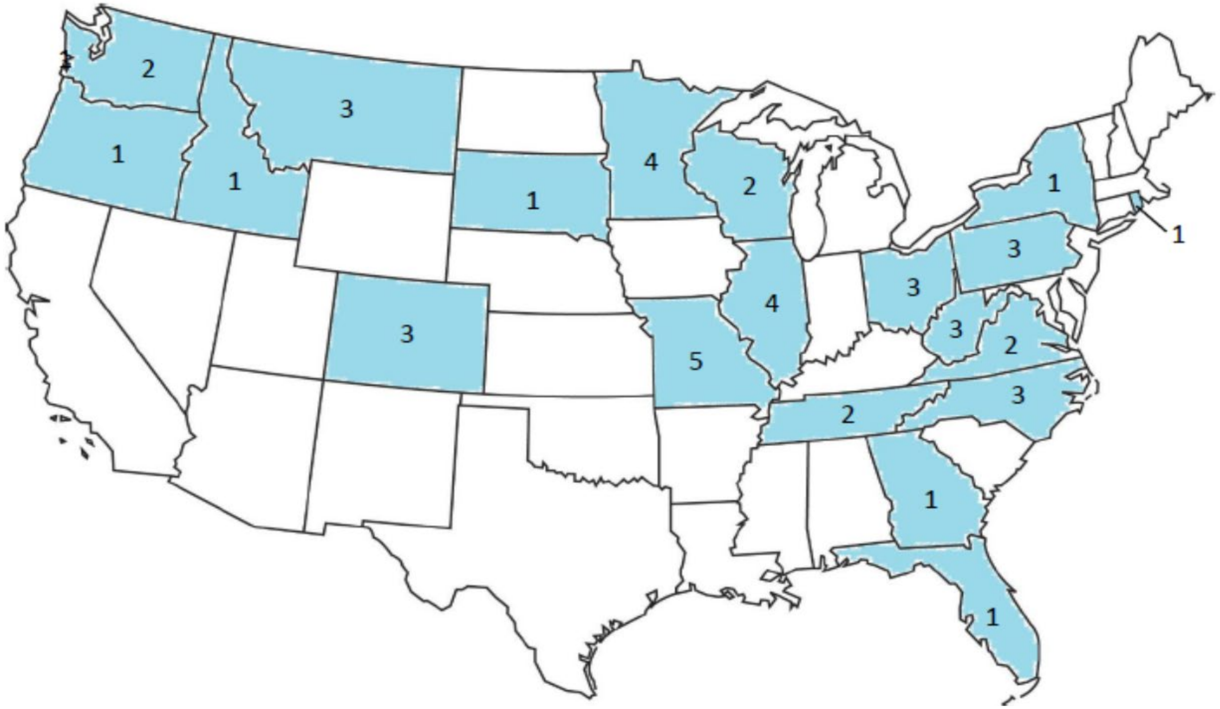
EPA Valuation of Freshwaters

- EPA is conducting a new, <u>national</u> stated preference survey for water quality
- Current valuation in EPA depends on a meta-analysis



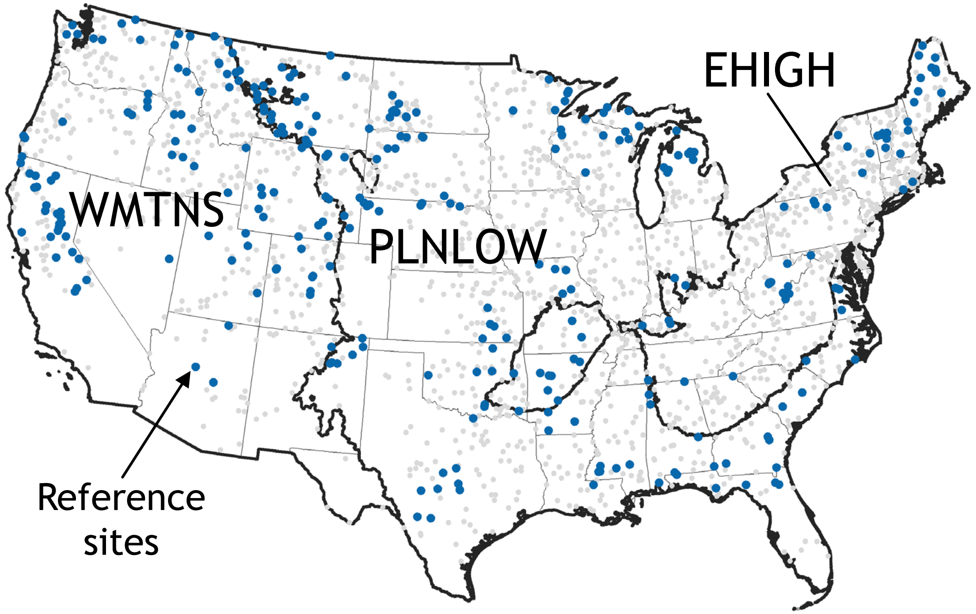
States (blue) and number of studies currently used in stated preference meta-analysis

EPA Valuation of Freshwaters

- Survey to capture use values w/ water quality ladder (WQL) and non-use (existence) values
- *Chris Moore* – Evaluated indicators of aquatic ecosystem health for valuation and policy analysis
- Identified O/E indices as meeting needs for stated preference survey of existence values
    - O/E = Loss of taxa (species) due to human-related stressors
    - E = Expected taxa at a site in the absence of (or minimal) human-related disturbance
    - O = Taxa observed of those expected

EPA Valuation of Freshwaters

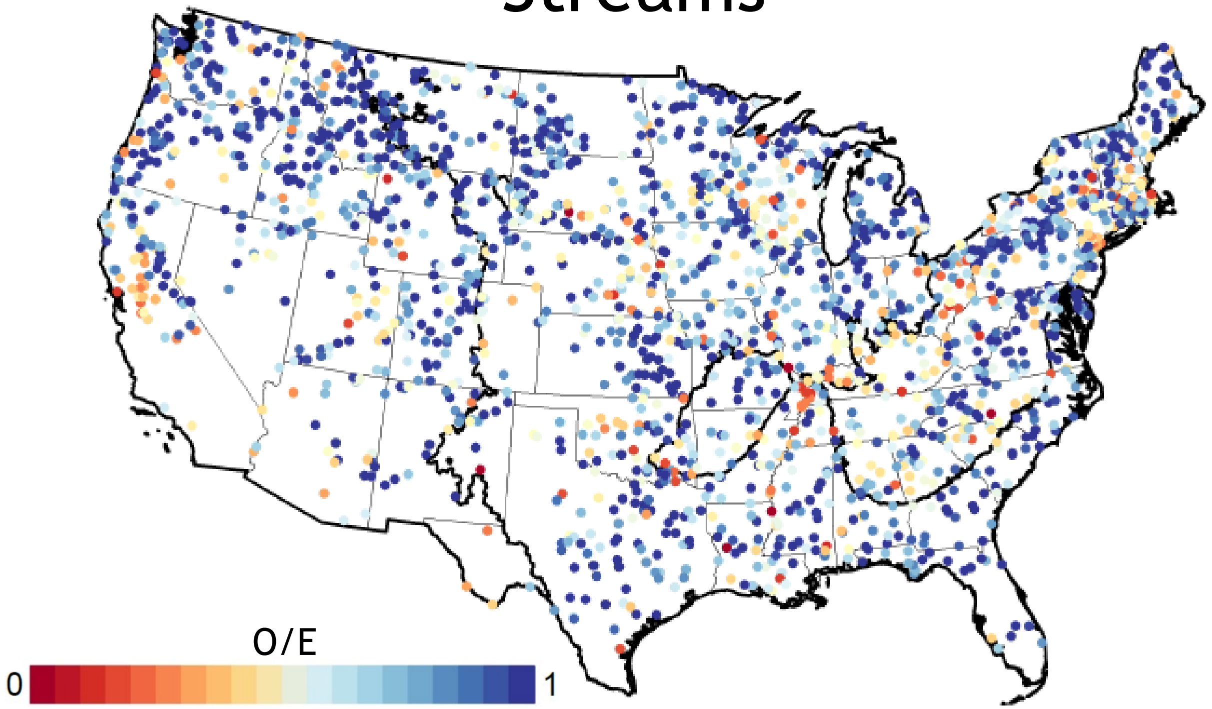
- How does EPA estimate E at assessed sites?
- Regional reference condition approach – minimal or least disturbed sites
- Model probability of occurrences based on watershed features that are insensitive to human activity – E is list of taxa predicted to occur
- Quality of reference sites varies among regions



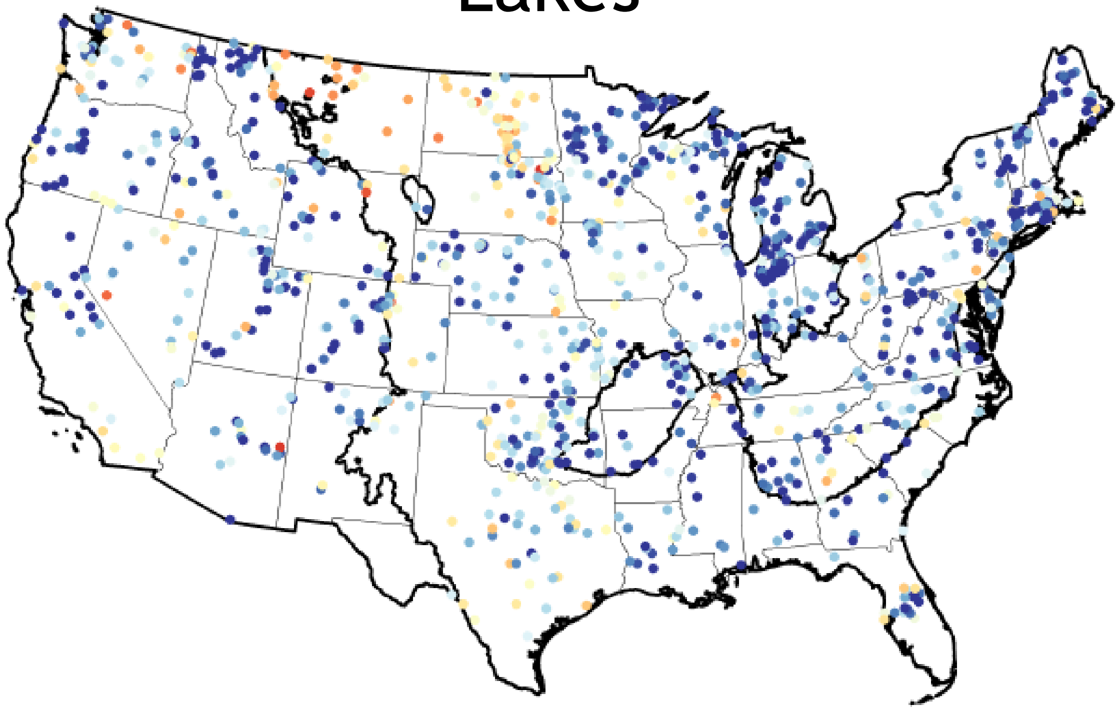
EPA Valuation of Freshwaters

- Conditions of waters near survey respondents affect their willingness to pay for water quality improvements in non-linear ways (Newbold et al. 2018)
- Need to account for these conditions in benefits analyses of state preference – **How do we estimate conditions near survey respondents nationally?**

Streams

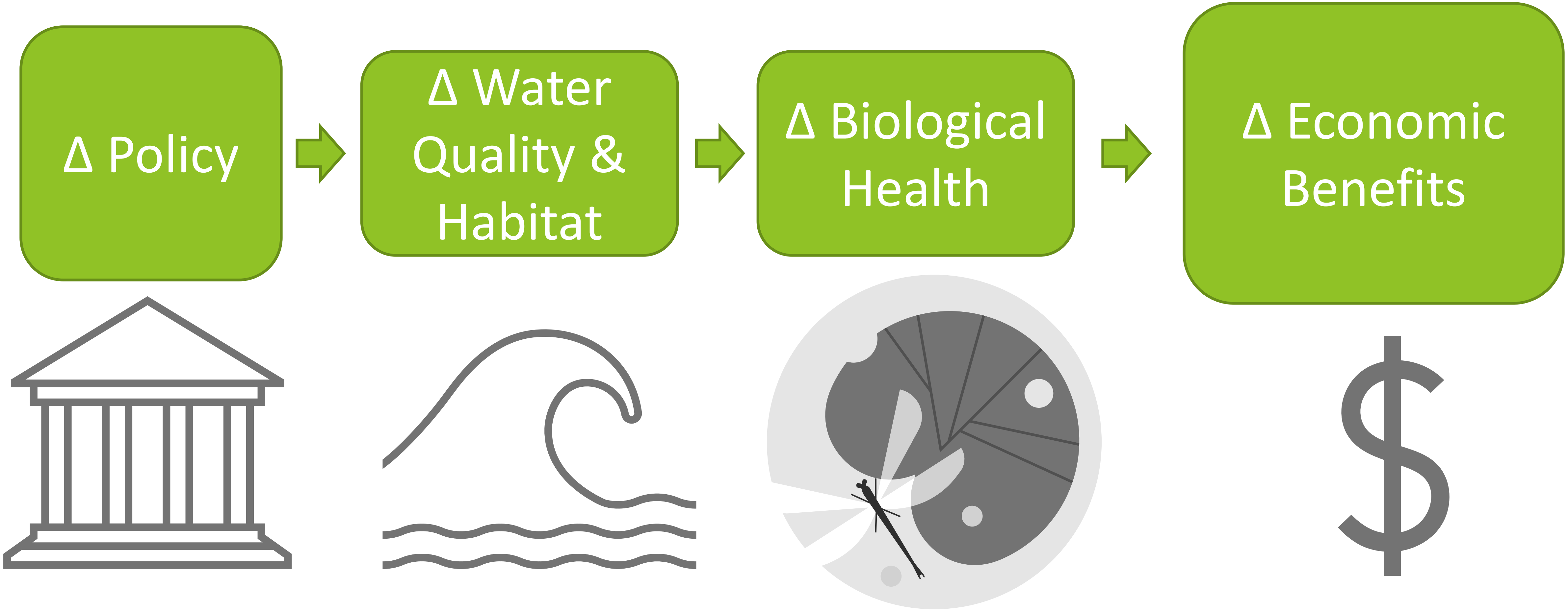


Lakes



EPA Valuation of Freshwaters

- Benefits analysis of proposed policy also **requires linked models to test management or policy scenarios**

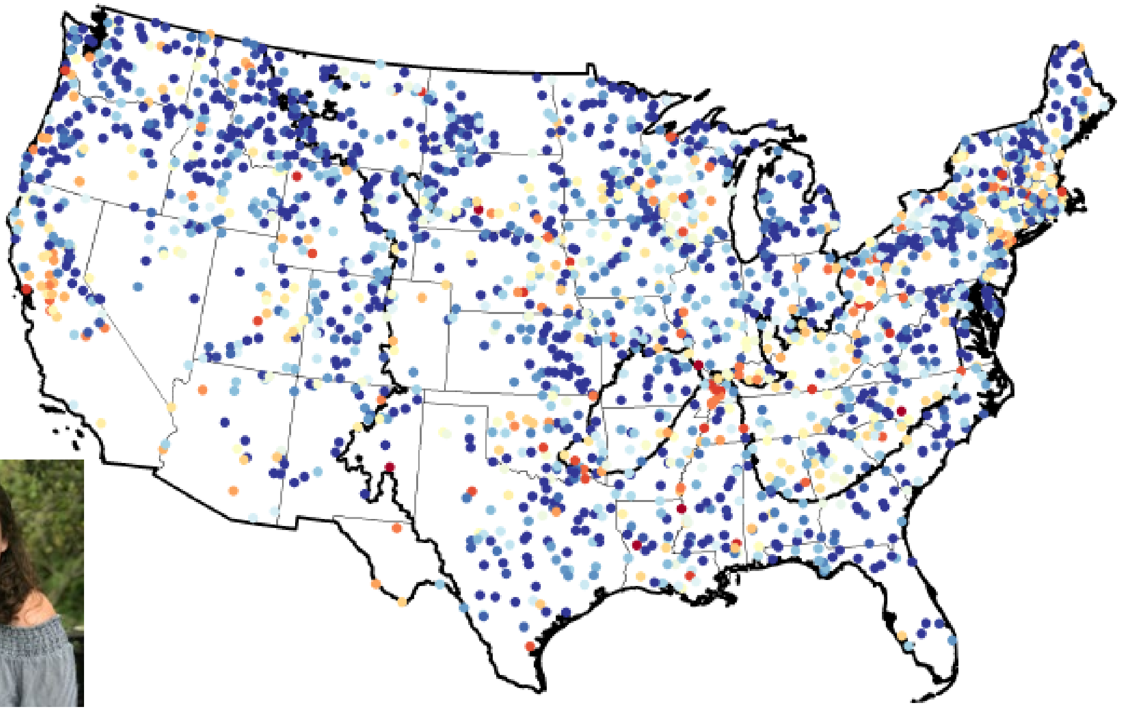


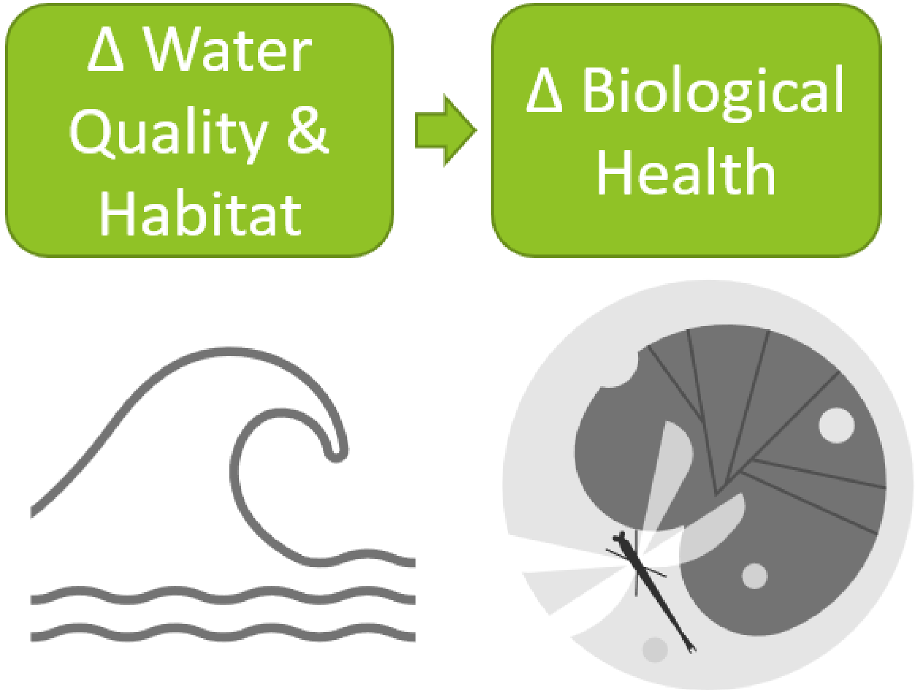
EPA Valuation of Freshwaters

Two modeling needs identified:

How do we estimate conditions near survey respondents nationally?

Can we model stream biotic condition to test policy scenarios?

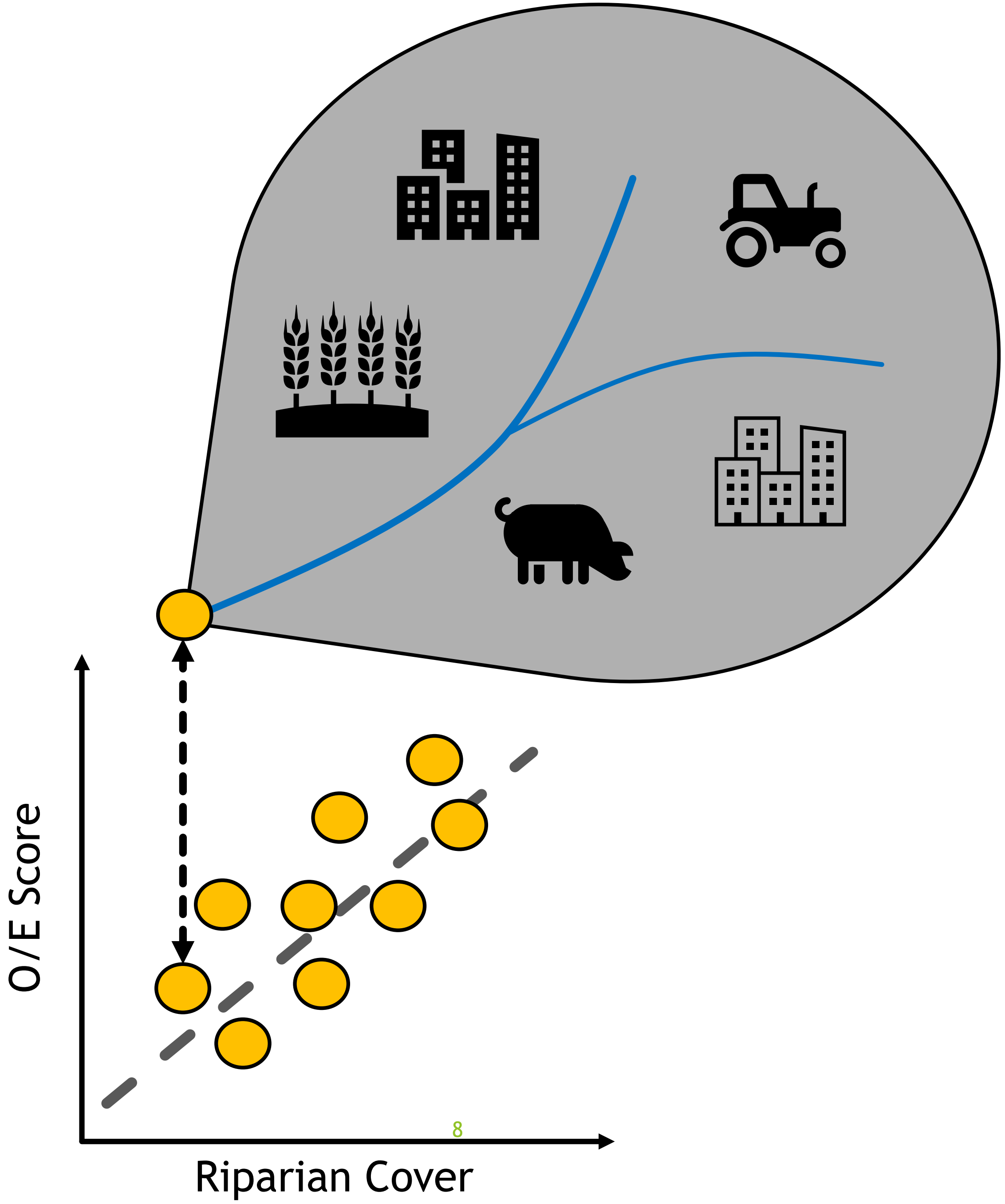




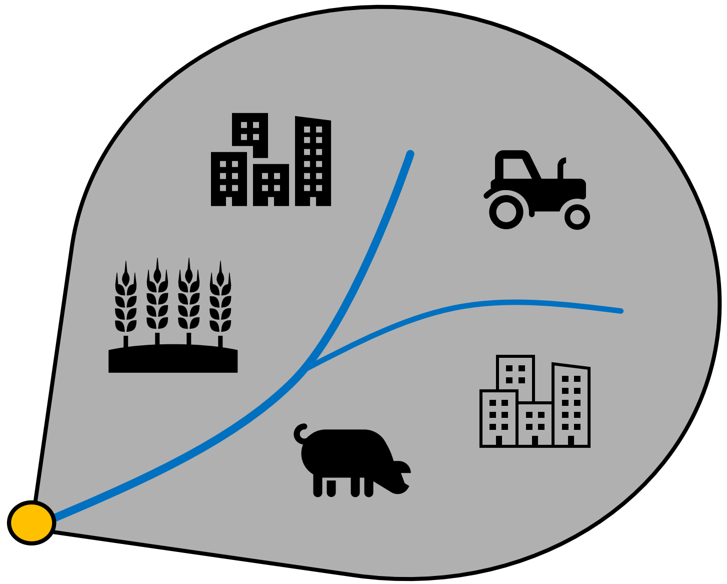
EPA Valuation of Freshwaters

How do we estimate conditions near survey respondents nationally?

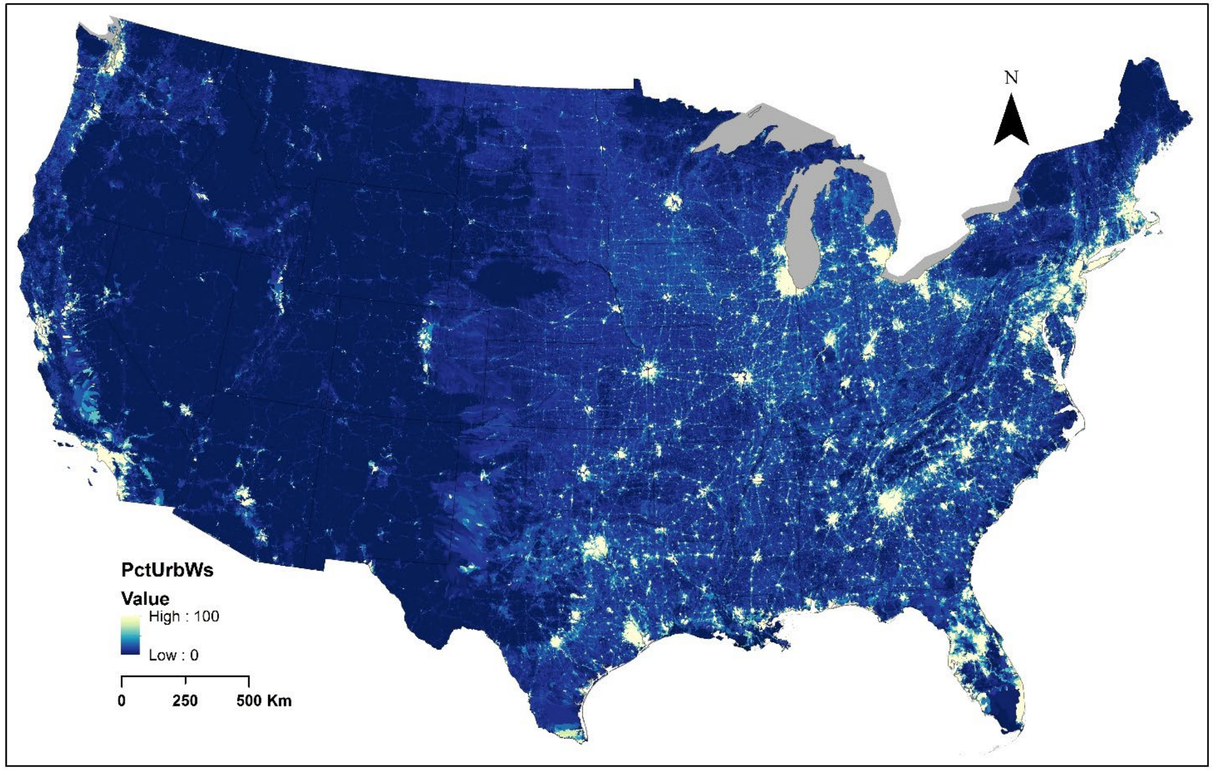
- We are using models to infill data at the appropriate scale for the forthcoming SP survey
- Models relate existing O/E scores to measures of human activity within watersheds



EPA Valuation of Freshwaters

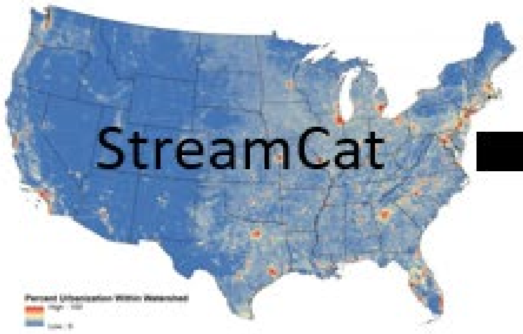


- StreamCat & LakeCat watershed data
- Anthropogenic features (e.g., urbanization, agriculture, forest loss)
- 1.1 million perennial stream segments
- 290K lakes across the US



Baseline Models

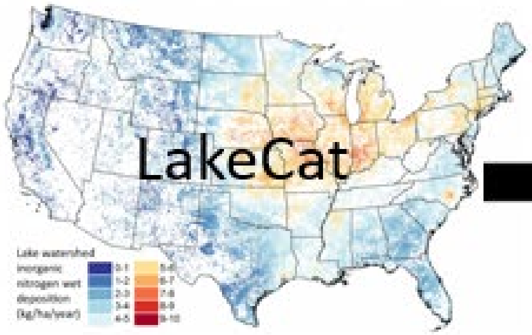
NRSA 2013-14



Random Forest Models

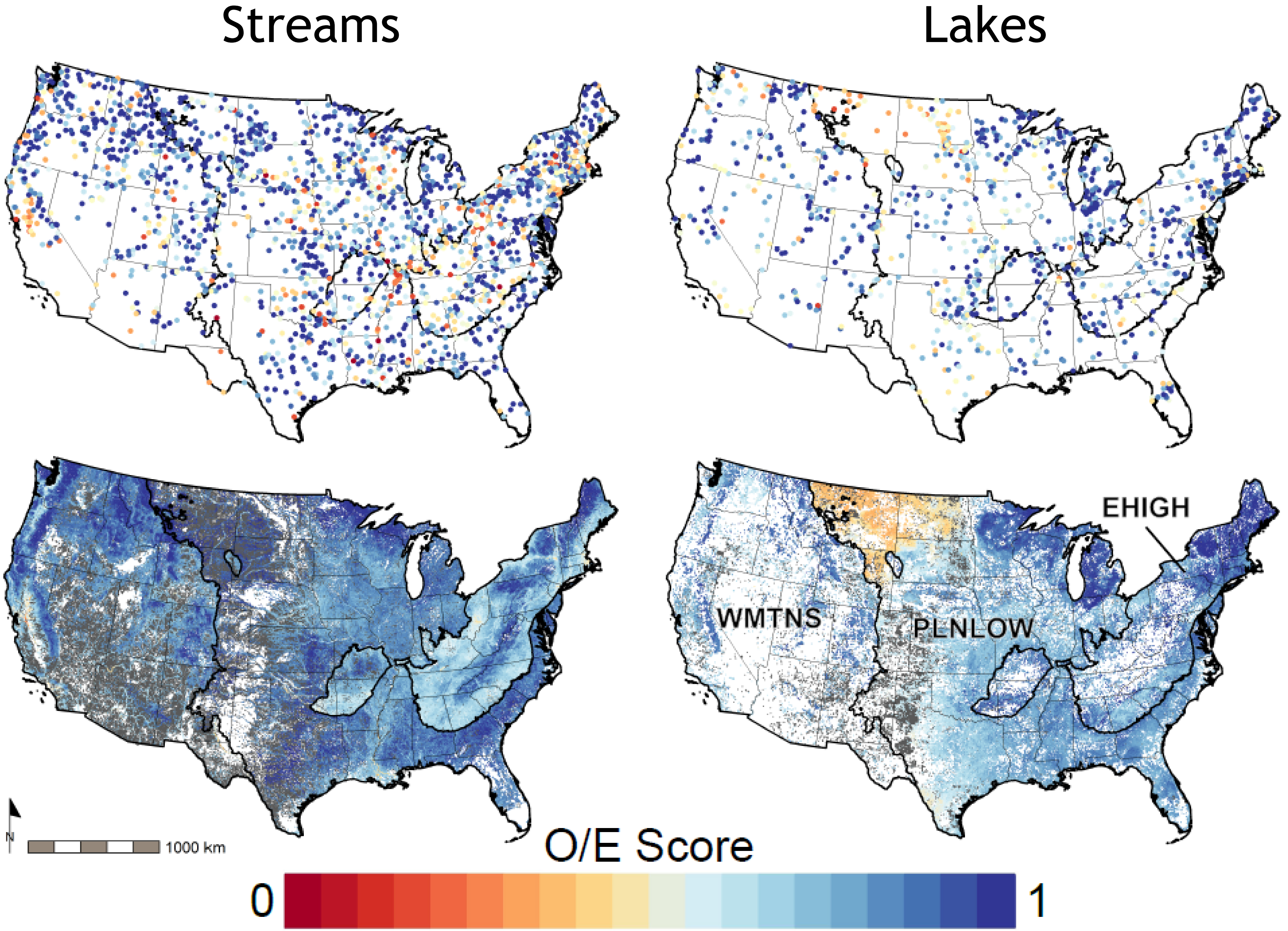
O/E Predictions

NLA 2007



Random Forest Models

O/E Predictions



- Models explained 13%-36% of variation in O/E
- Captured overall patterns in observed data
- Strong shifts in O/E values at ecoregion boundaries
- Problem of regional reference sites

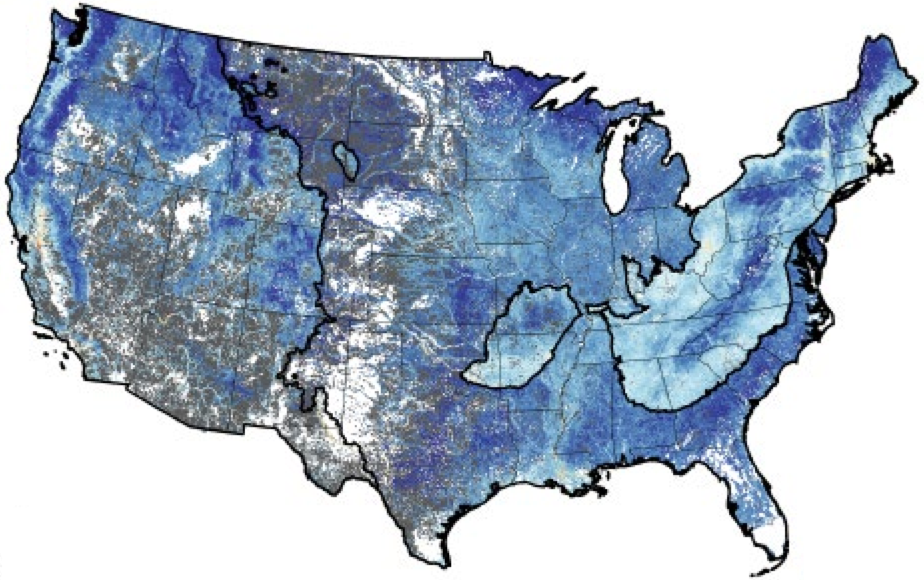
Current limitations and possible solutions

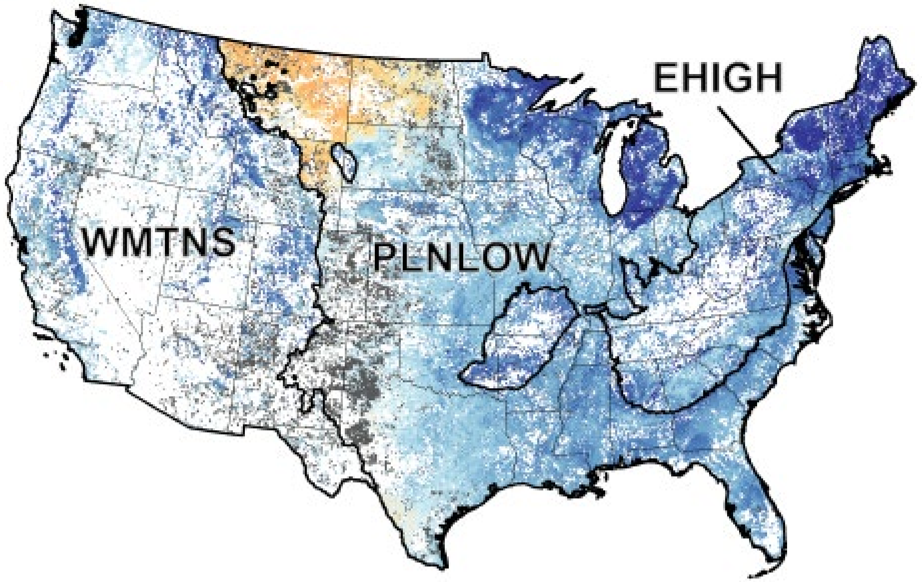
Limitations:

- Boundary Issues between ecoregions
- Models of existing NARS O/E values had low performance

Possible solution:

- Go back to the original taxa data and produce models that predict taxa directly
- Create single model(s) for CONUS to remove boundaries





How do we get there?

Need to predict reference E

Reference sites only

But also need to predict actual conditions (O) - reference to “trashed”

All possible samples sites

How do we get there?

- Start with model using full set of sites
- Allows us to experiment with adjusting land use to “reference settings” to estimate reference E
- Can return to modeling with only reference sites to estimate E

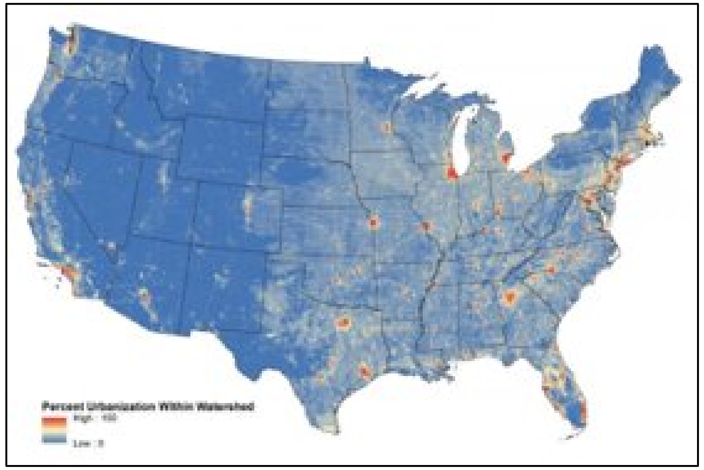
But also need to predict actual conditions (O) - reference to “trashed”

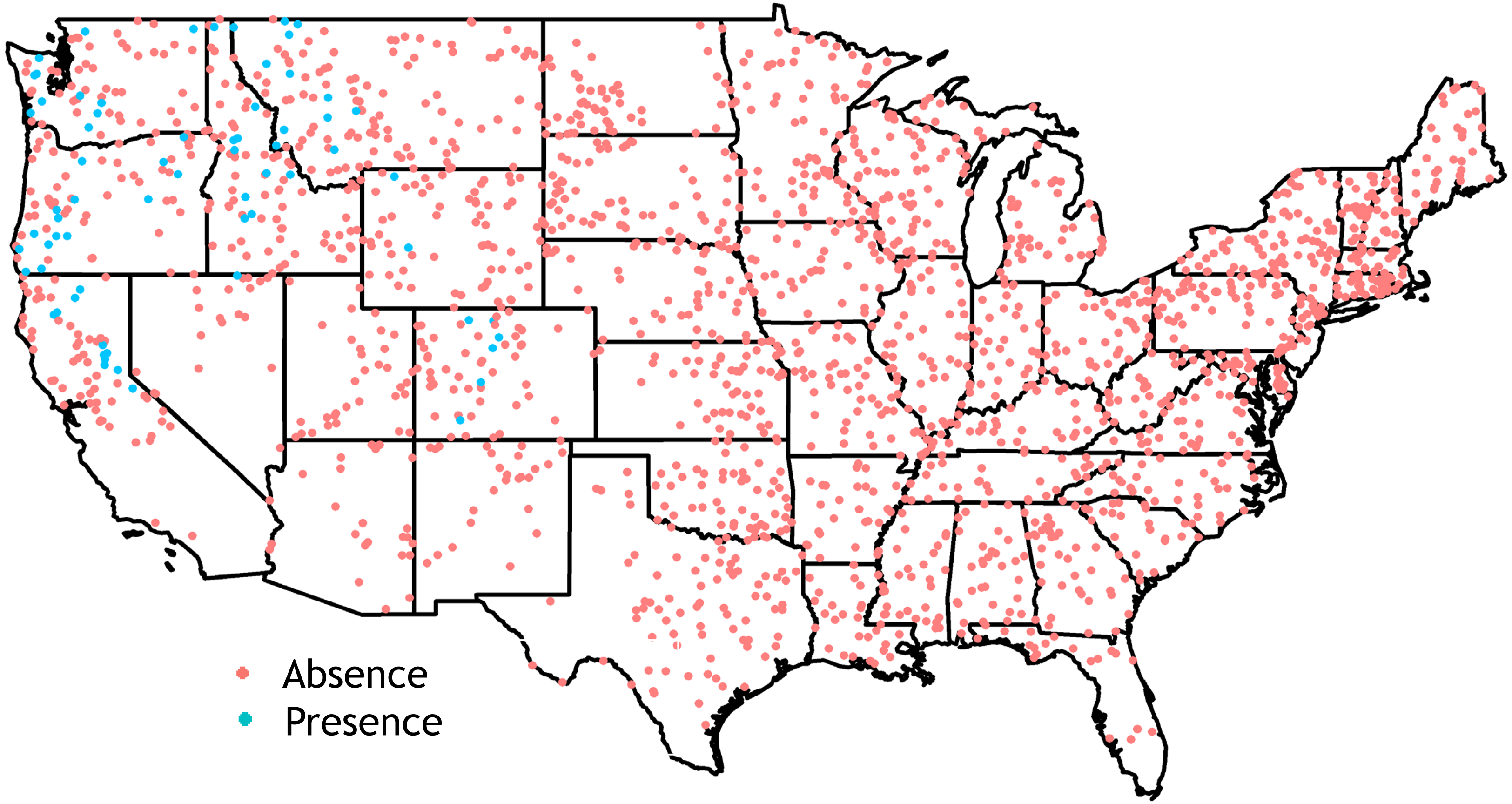
All possible samples sites

Species Distribution Modeling (SDM)

Taxon presence/absence

StreamCat Data



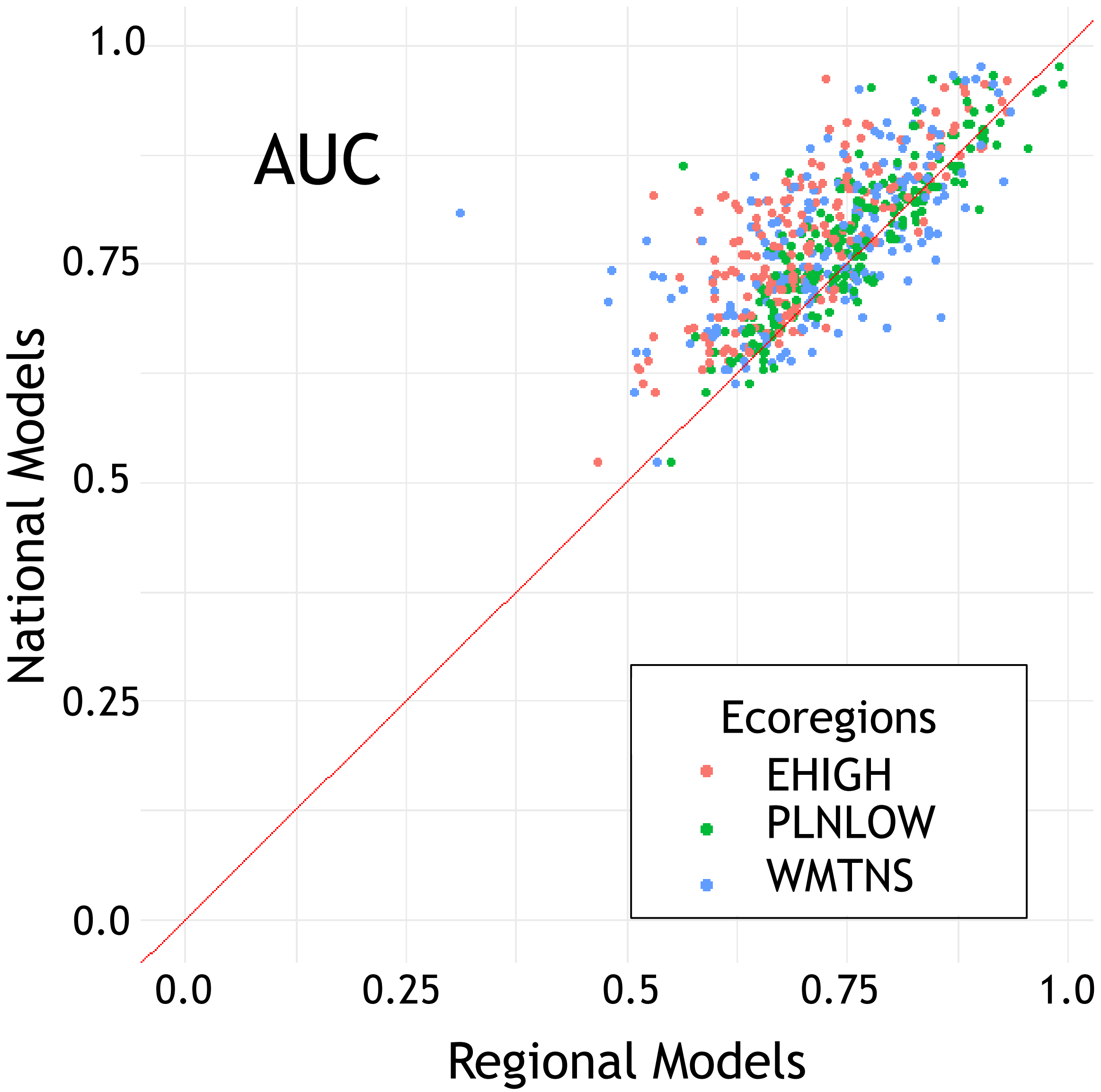


Species Distribution Modeling (SDM)

- Constructed 212 models (each taxon)
- Area under the curve (AUC) for national models > AUC for regional models
- Indicates national models can be used

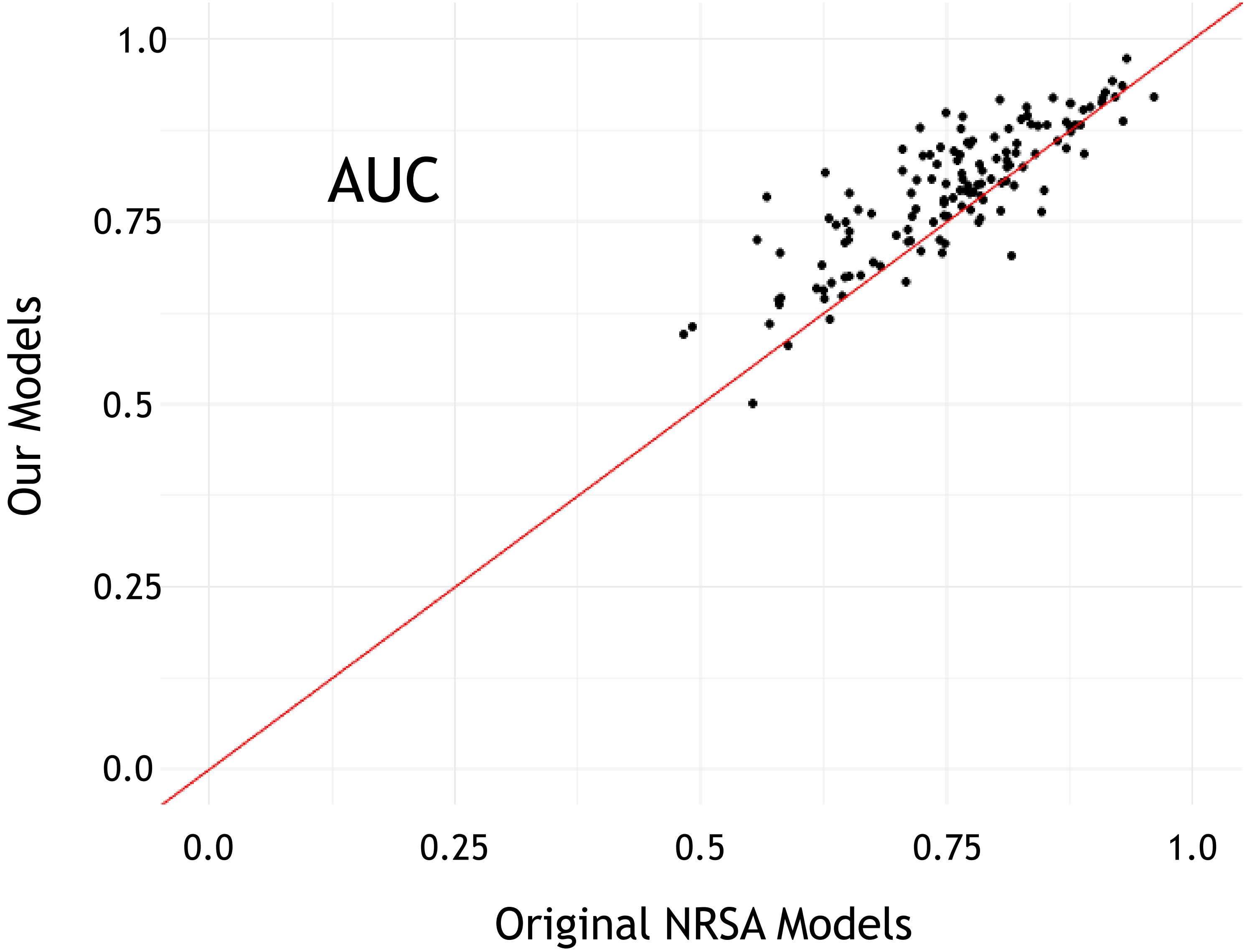
AUC **measures the ability of a classifier to distinguish between classes (true positives/ true negatives)**

- Values = 0.5: no better than coin toss
- Values = 1: perfect prediction



Species Distribution Modeling (SDM)

- AUC for our models > AUC for original NRSA models
- Indicates our models are beating the original NRSA models used to generate O/E



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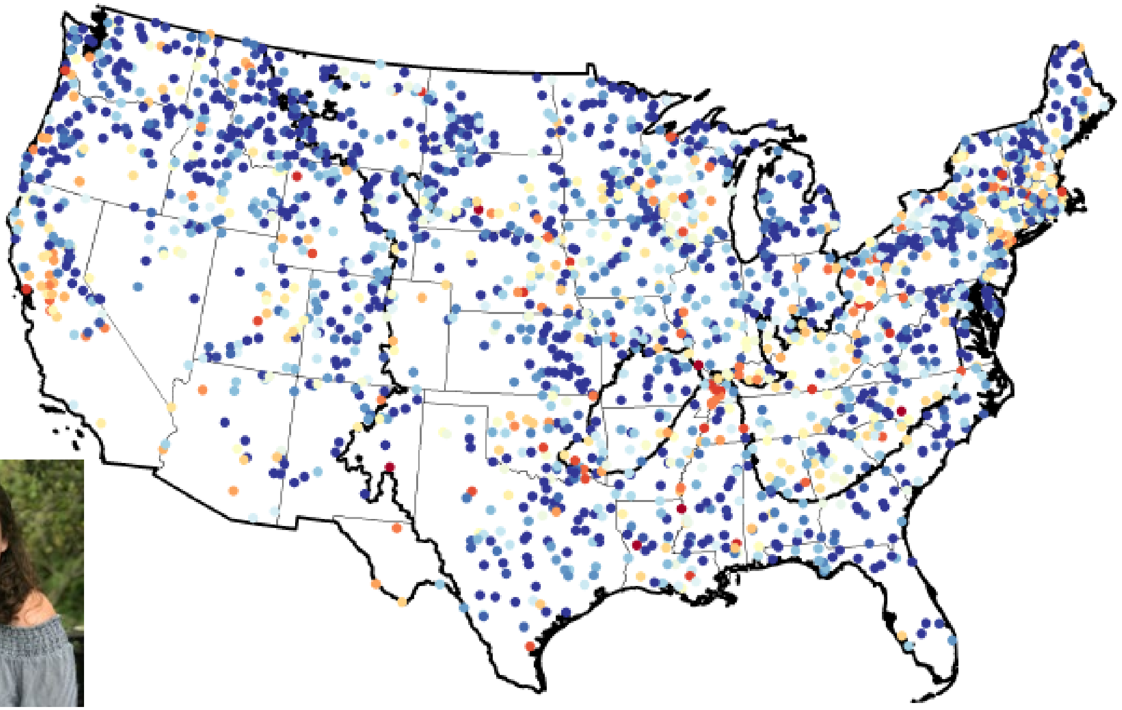
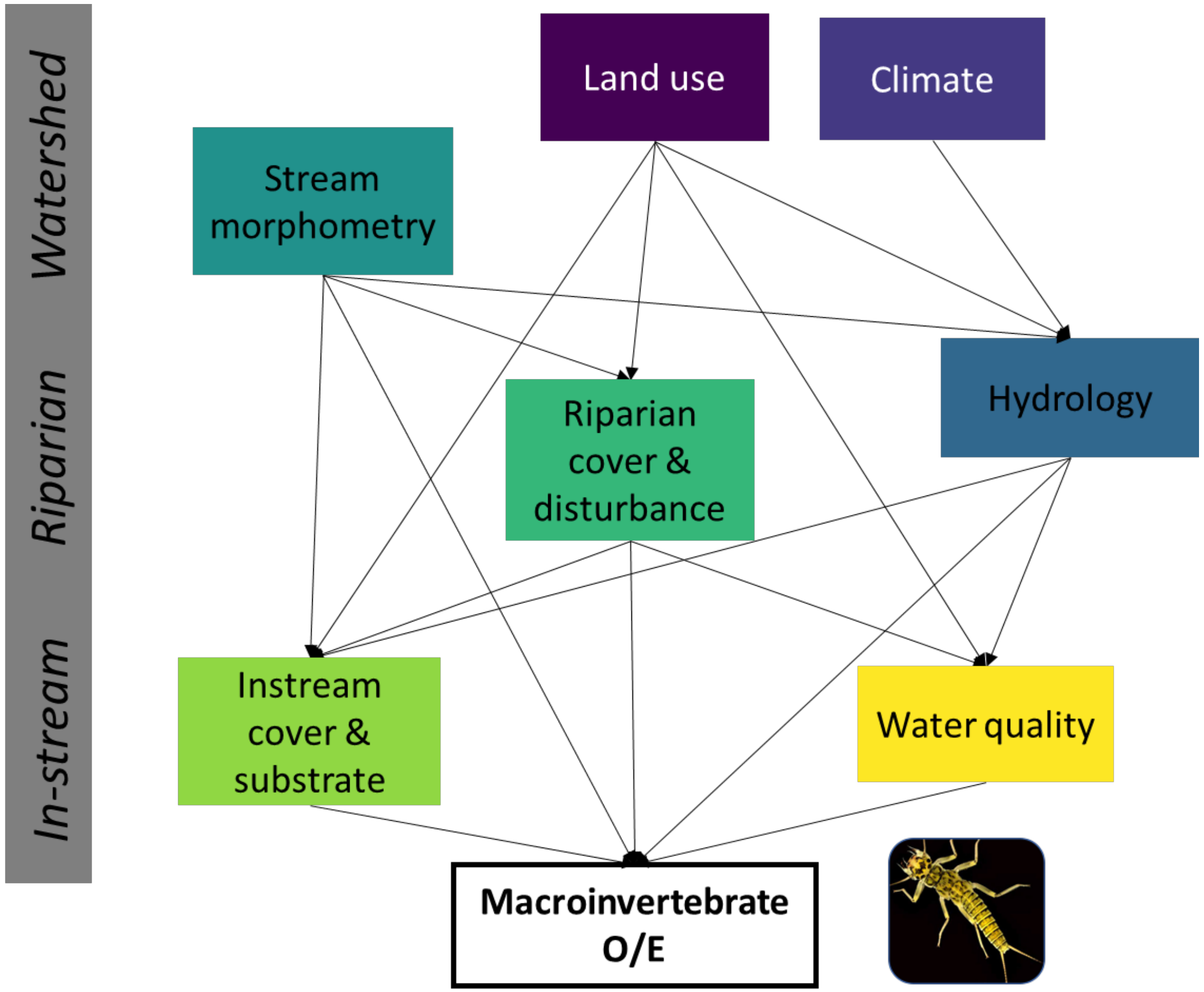


Can we model stream biotic condition to test policy scenarios?

Δ Water Quality & Habitat → Δ Biological Health

Structural equation model framework

- Scientific framework to model and test hypothesized relationships
- Gaining wider use in ecology
- Path analysis – direct, indirect, and total effects



stonefly https://www.nps.gov/articles/aquatic-macroinvertebrates-introduction.htm

Data and Spatial Extent

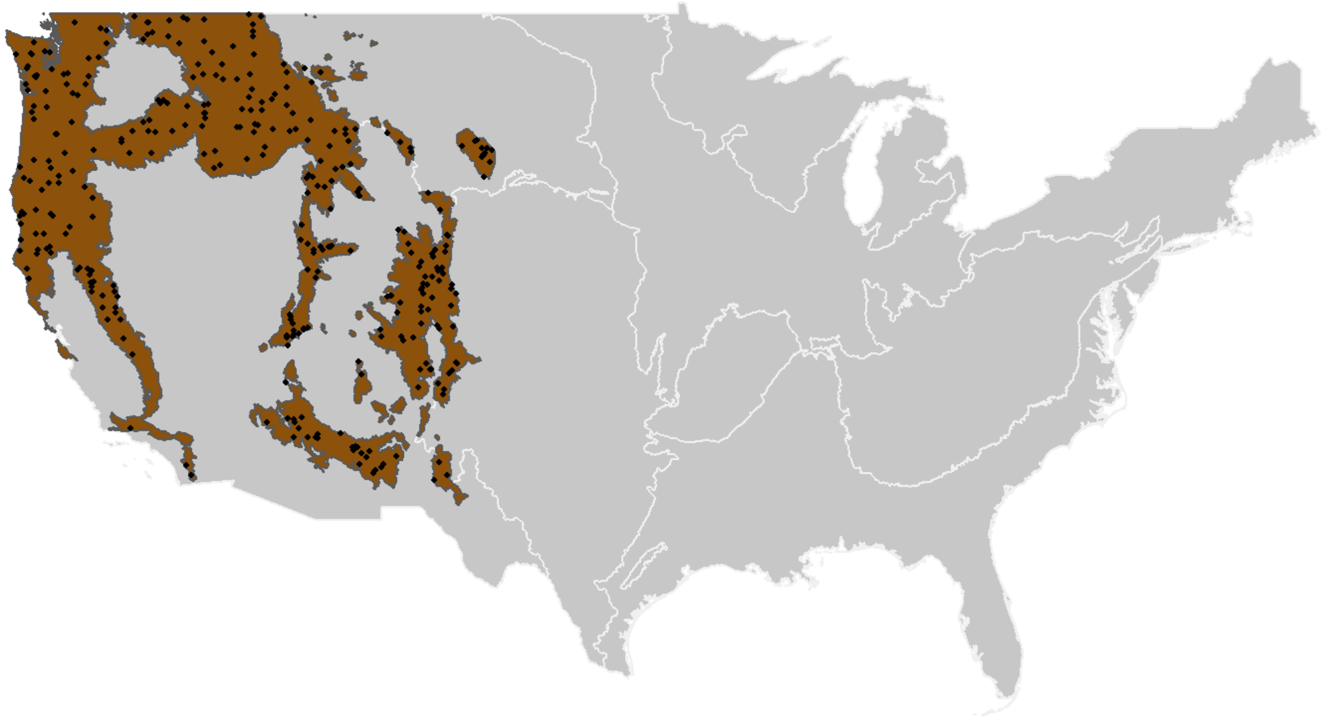
National Rivers and Streams Assessment (NRSA)

- Three surveys: 2008-09; 2013-14; 2018-19

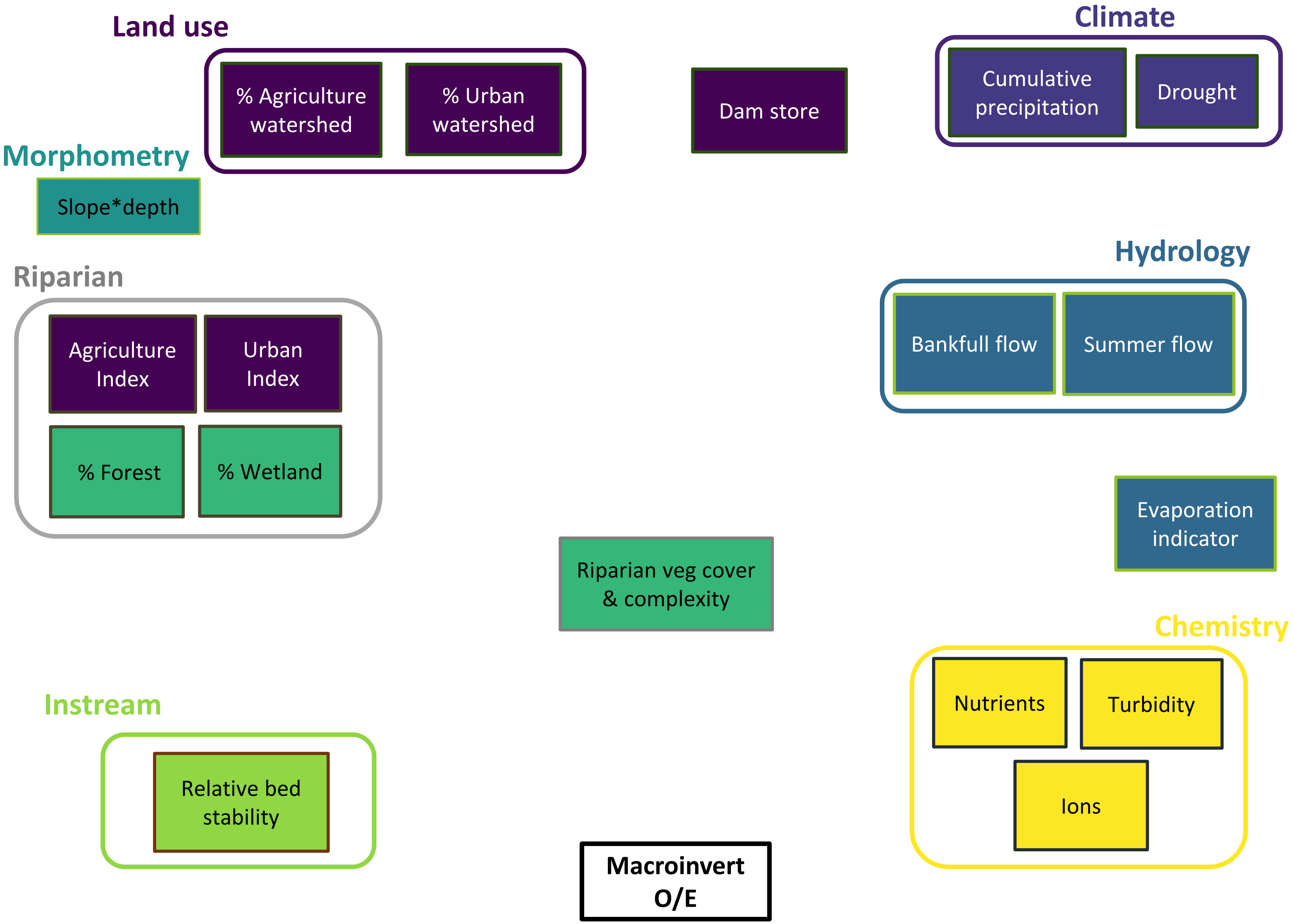
StreamCat

- Geospatial landscape database
- Climate, land cover/use, hydrology, and more

Western US wadeable streams
WMT n = 323



Conceptual model



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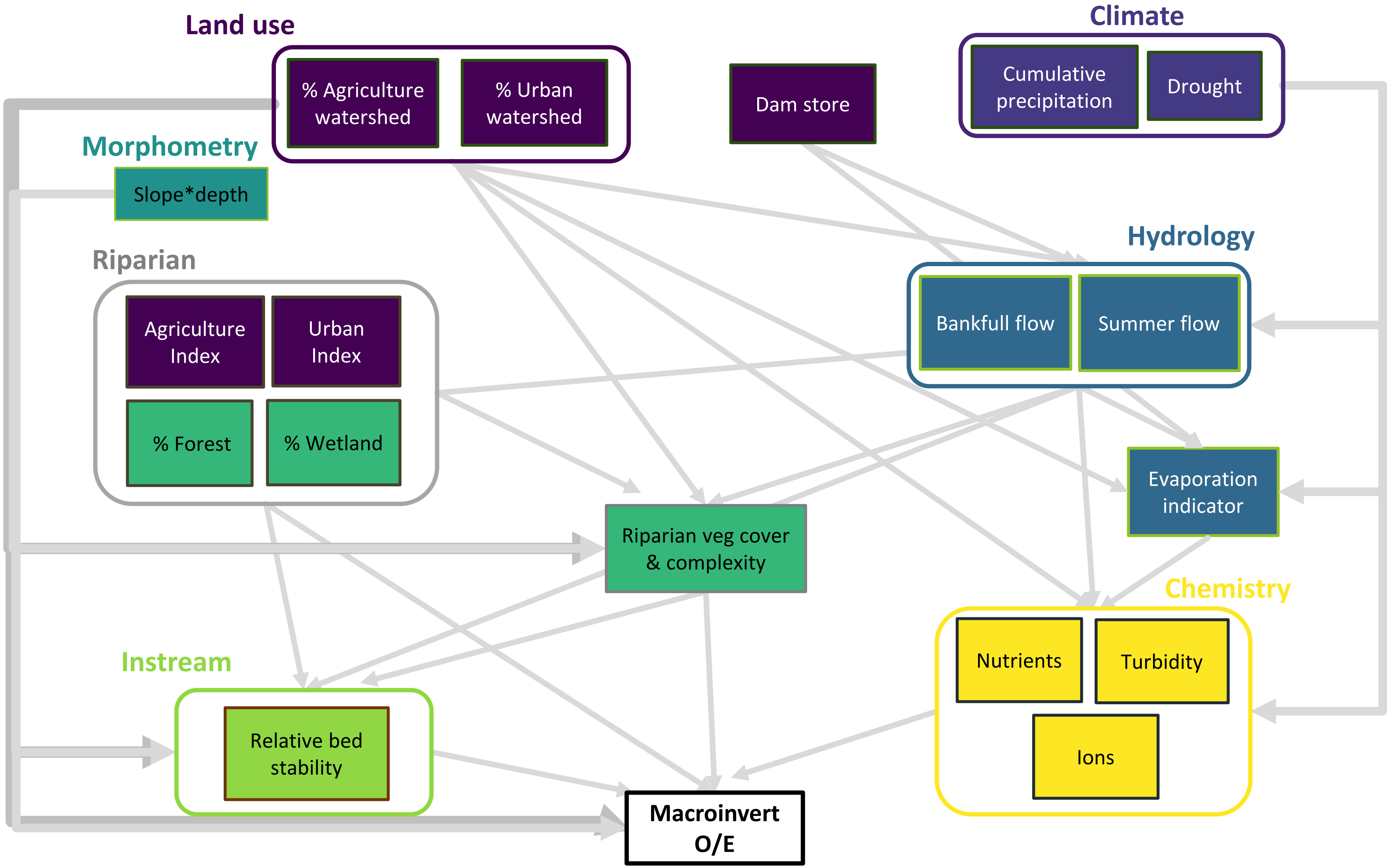
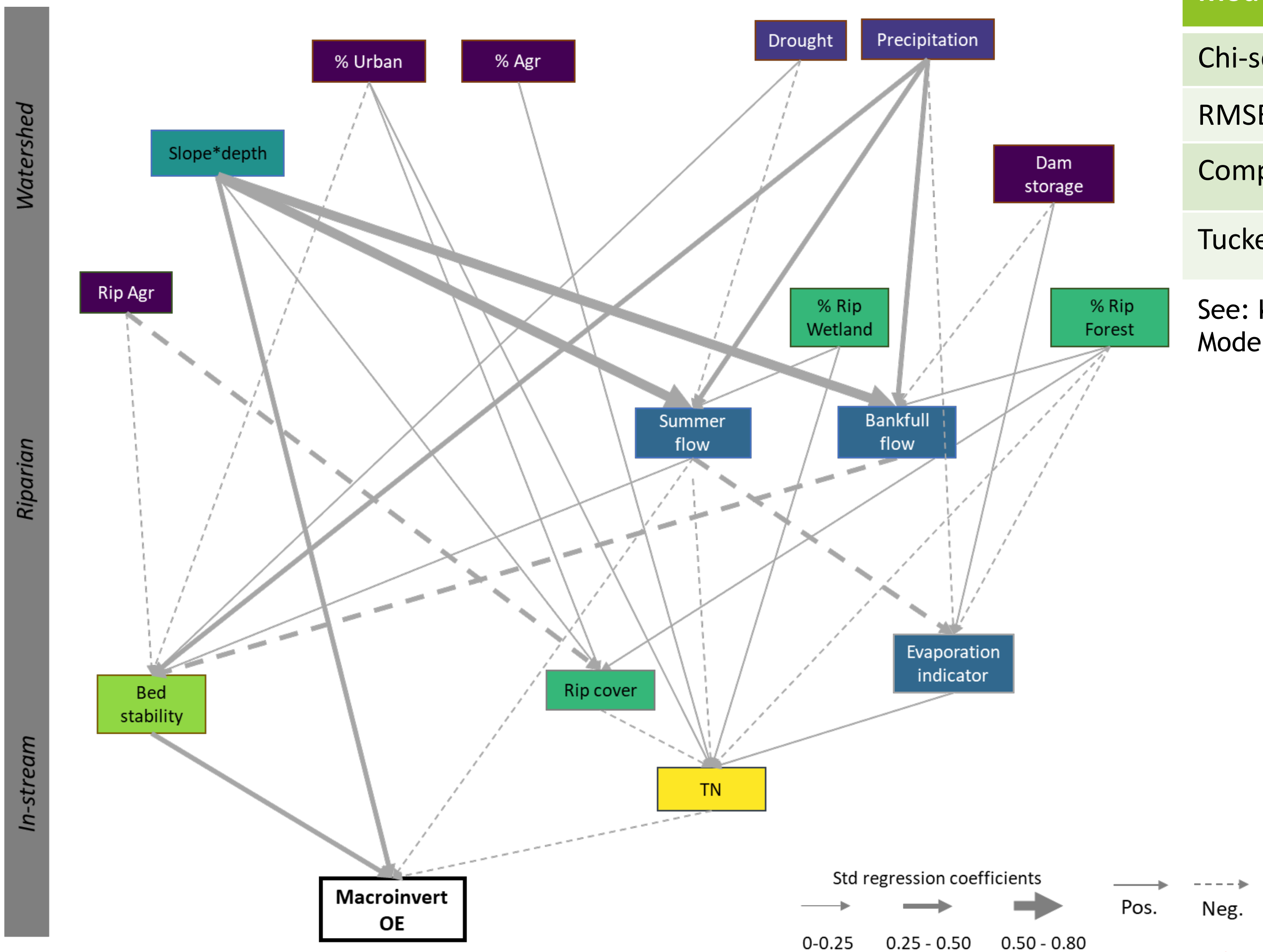


Results: Western Mountains (WMT)



Model fit parameter	Values	Evaluation
Chi-square (df)	82.4 (50)**	–
RMSEA	**0.05**	Good (<0.08)
Comparative Fit Index	**0.97**	Good (>0.90)
Tucker-Lewis Index	**0.95**	Good (>0.90)

See: Kline 2005. Principles and Practice of Structural Equation Modeling

Response	R^2
Bug O/E	**0.22**
Bed stability	0.16
Riparian cover	0.32
TN	0.25
Summer flow	0.68
Bankfull flow	0.60
Evaporation indicator	0.35

Direct effects + Indirect = Total effects

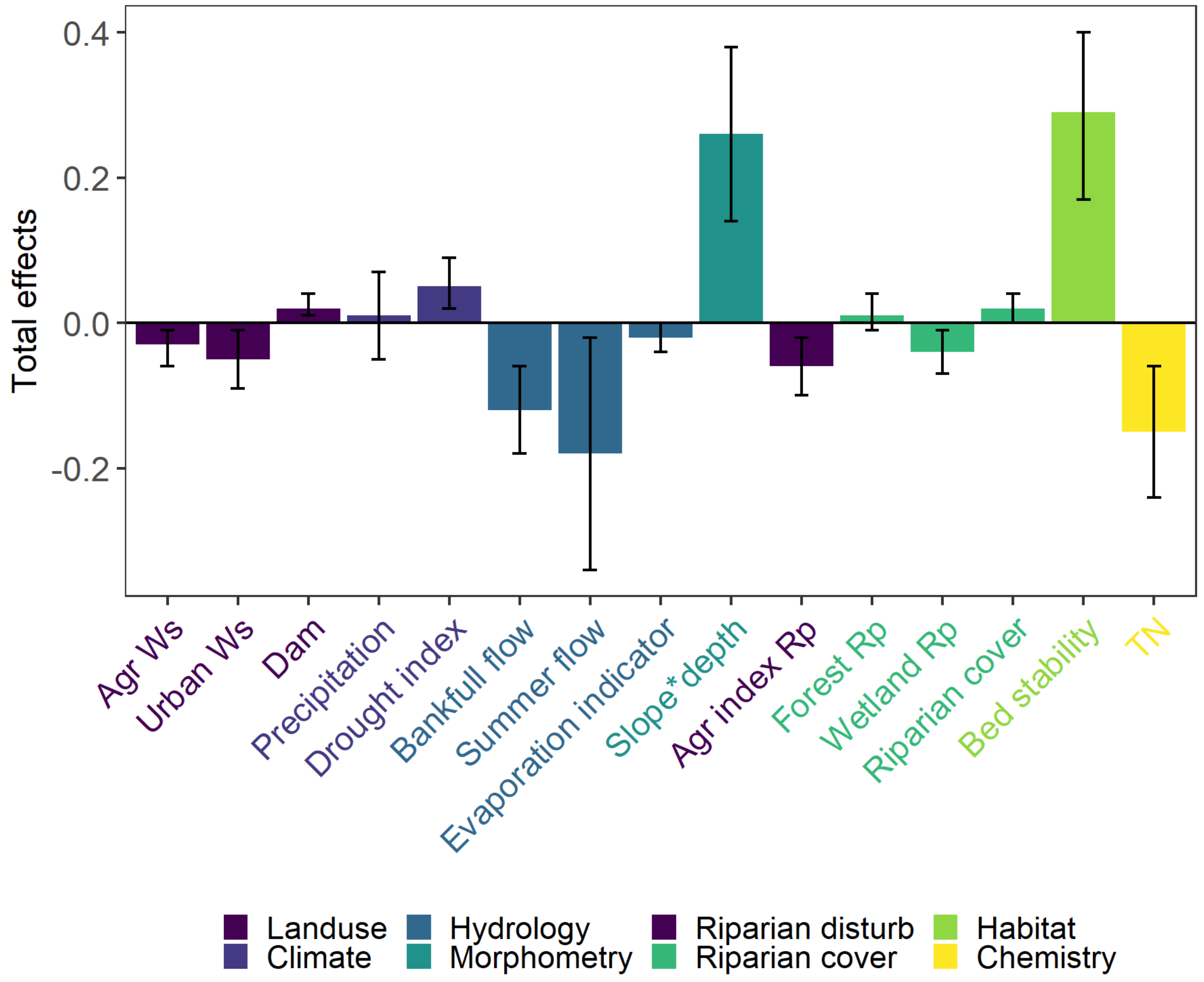
Results: WMT

Main drivers of stream bug O/E

- Relative bed stability
- Stream slope*depth = hydraulic energy
- Total nitrogen

Urban % in watershed

- Reduces bed stability (excess fines)
- Increases TN



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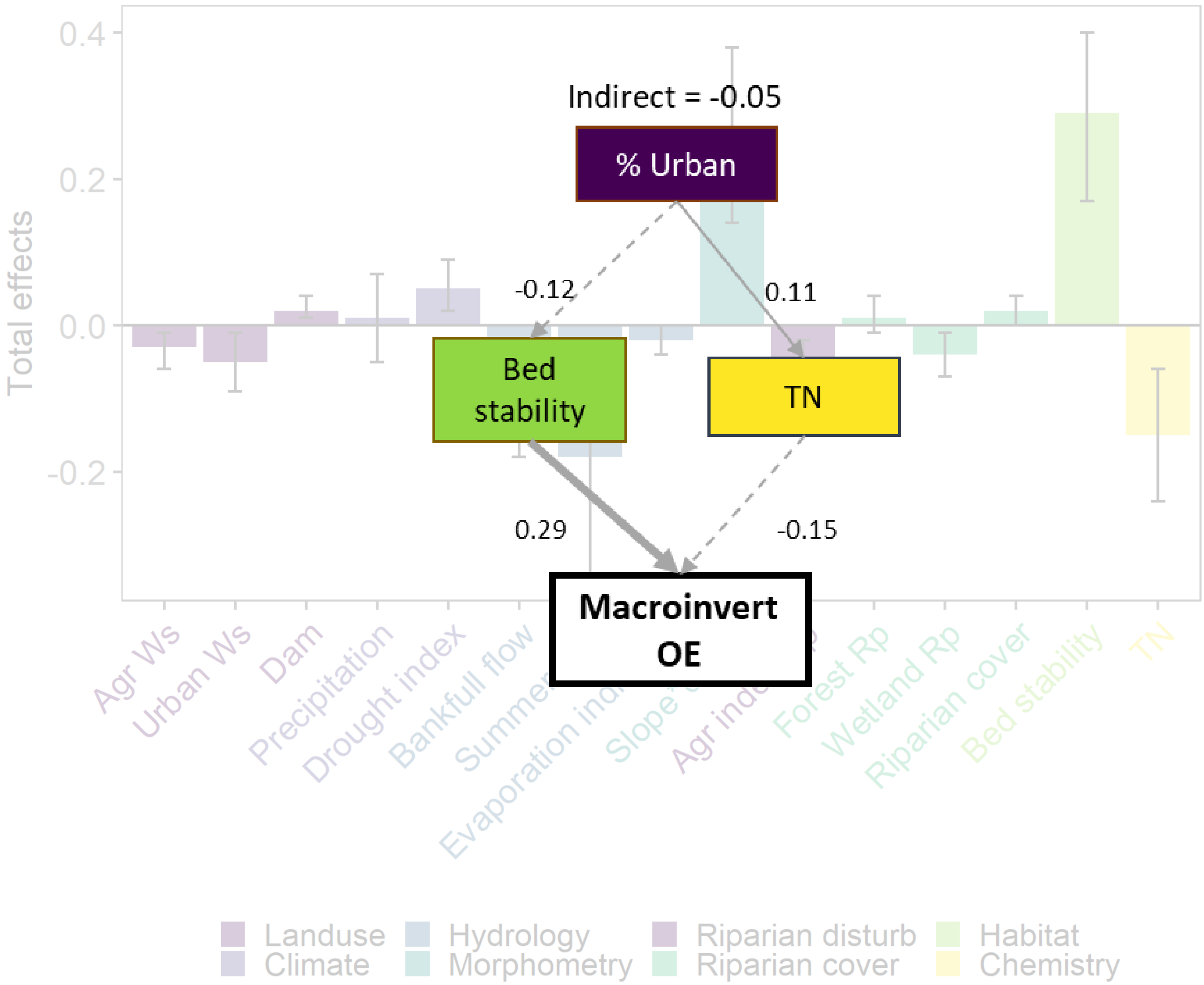

Results: WMT

Main drivers of stream bug O/E
- Relative bed stability
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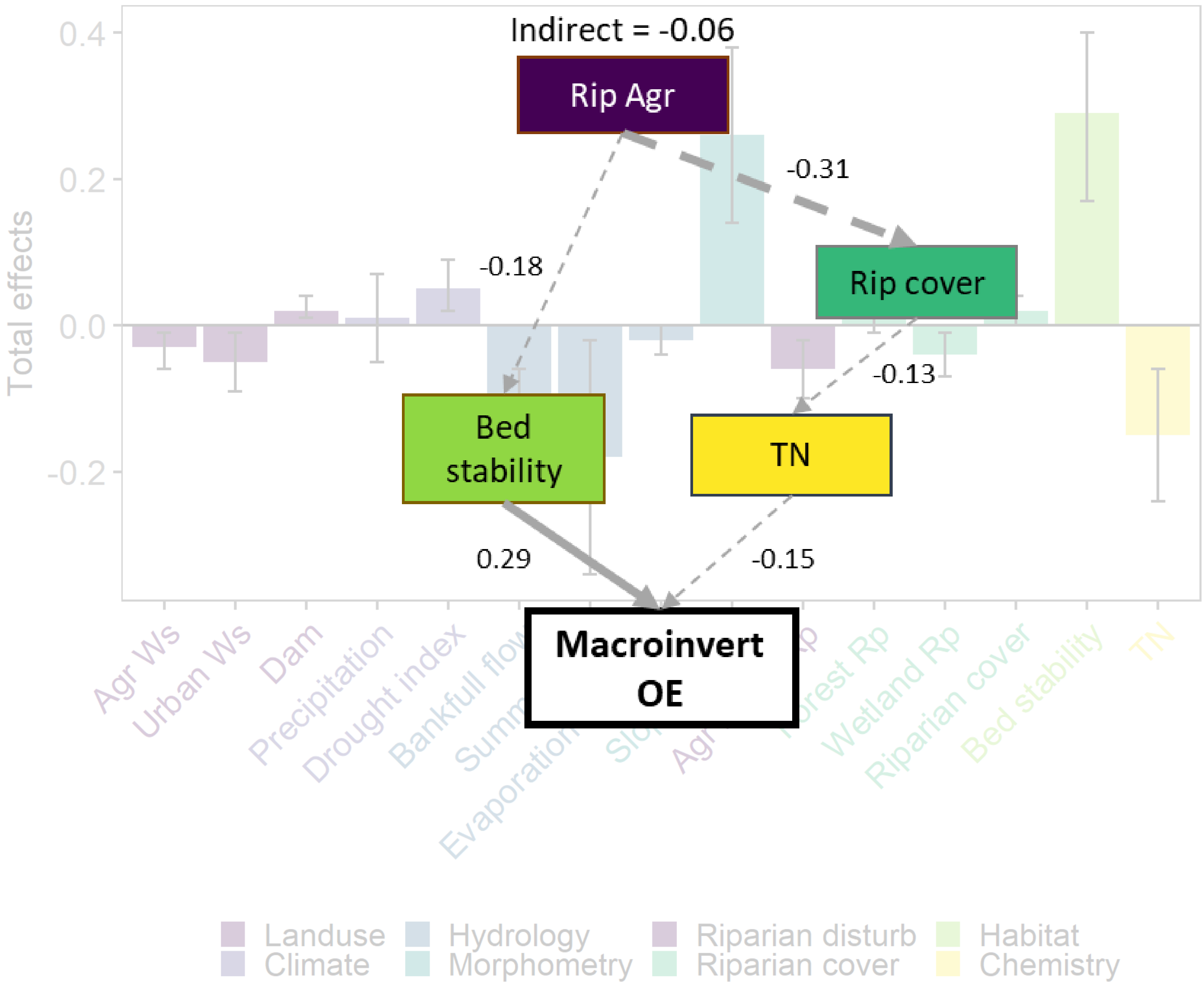
- Total nitrogen

Urban % in watershed
- Reduces bed stability (excess fines)
- Increases TN

Agricultural disturbance (riparian)
- Reduces bed stability
- Impairs riparian cover/complexity
- Increases TN

Riparian cover
- Reduces stream TN



Conclusions

Spatial Prediction Models

- SDMs look promising to fix boundary transitions in O/E
- Next steps:
  - Predict reference E at non-reference sites
  - Develop SDMs for lake benthic invertebrates

Scenario Models

- Stream bug O/E affected by multi-scaled drivers through complex pathways
- Next steps:
  - Apply model to other ecoregions
  - Application of path analysis model for scenario predictions
  - HAWQS?