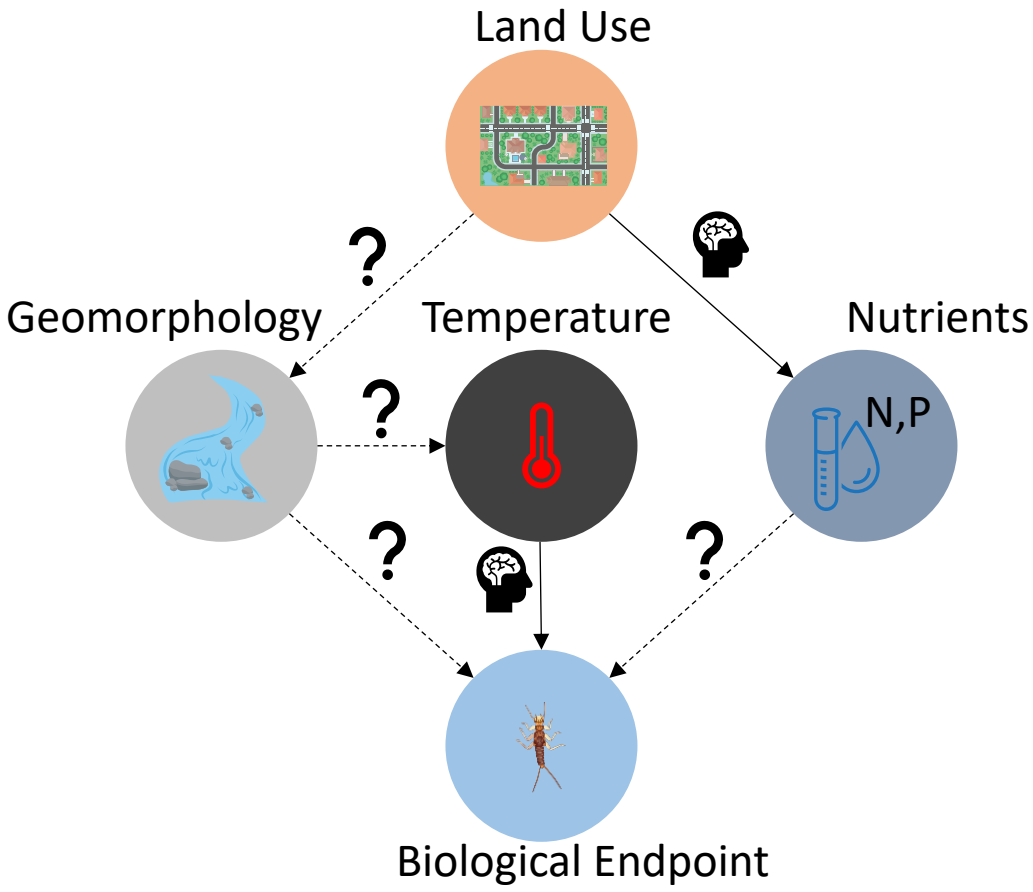
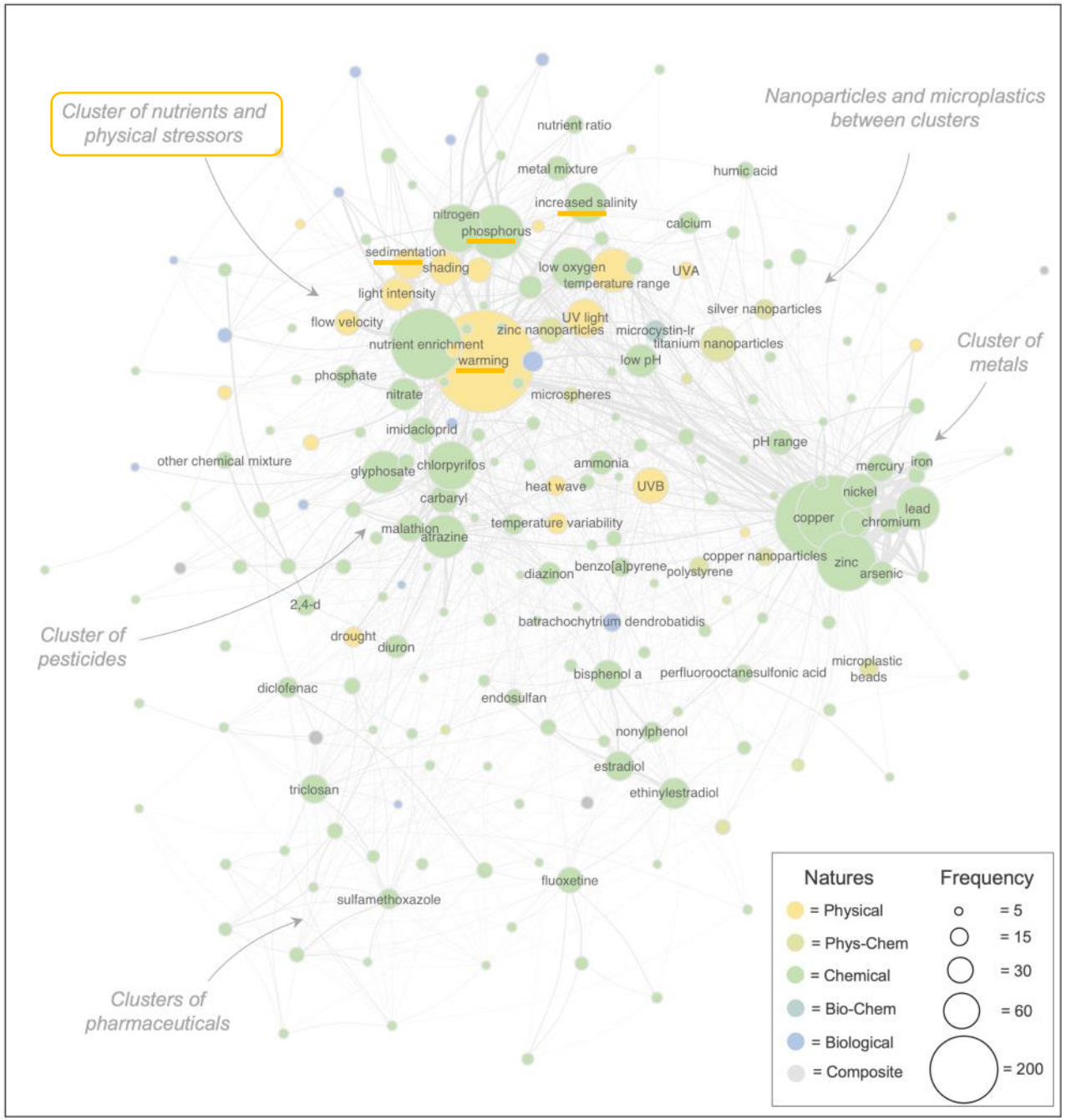
Leveraging machine learning and expert knowledge to unravel the complexities of multiple freshwater ecosystem stressors

Leveraging Artificial Intelligence and Machine Learning to Advance Chesapeake Bay Research and Management
February 24-25, 2025



Sean Emmons (USGS EESC; presenter), Matt Cashman (USGS WMA), Rosemary Fanelli (USGS SAWSC), Taylor Woods (USGS EESC), Greg Noe (USGS FBGC), Greg Pond (US EPA), Kelly Maloney (USGS EESC)

Freshwater ecosystems increasingly threatened by multiple interacting stressors



:Orr et al. 2024 – *Ecology Letters*

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Identifying stressor-response relationships meets a key Chesapeake Bay Stream Health Workgroup need

ACTION 1.2: Identify additional parameters/metrics to describe and quantify stream health and its stressors to complement, but not replace, existing biological indicators (e.g., Chessie BIBI).

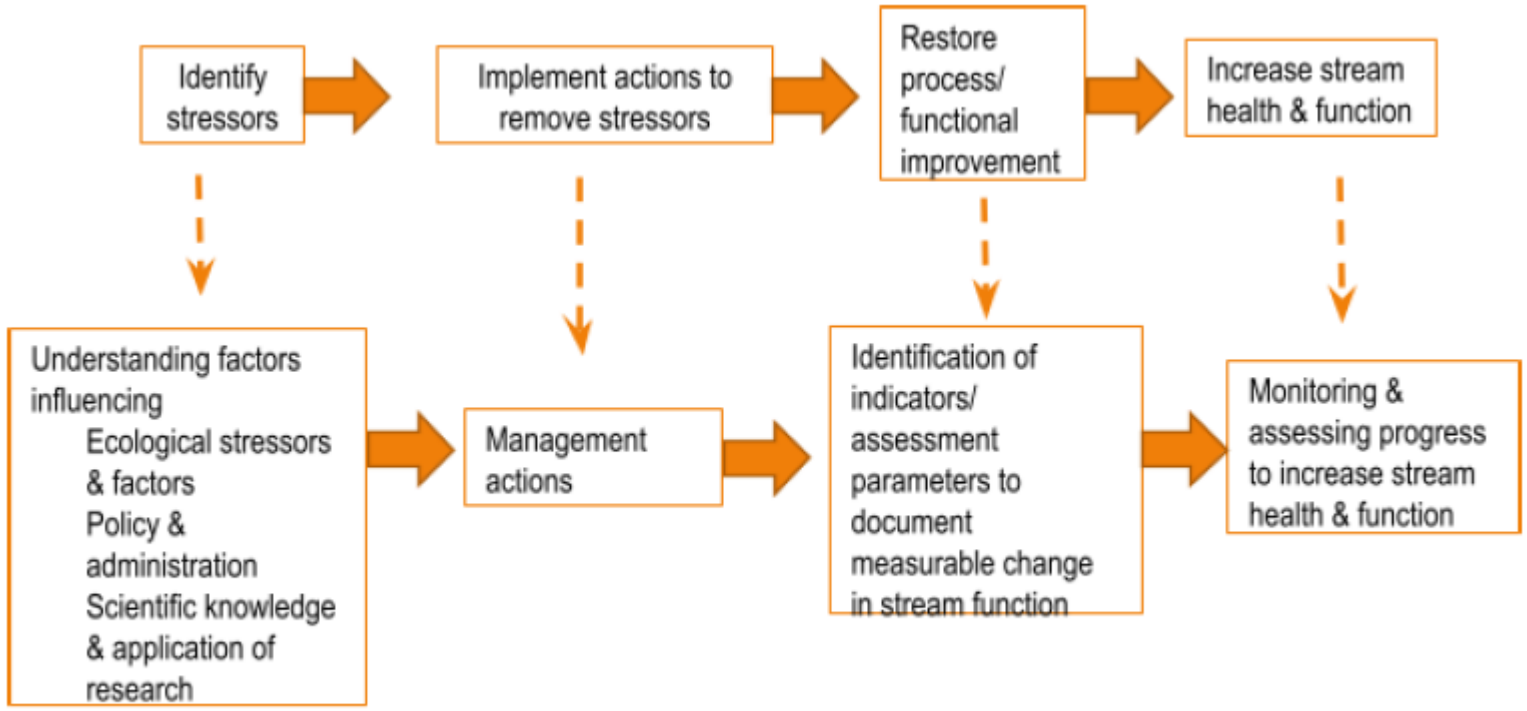

Figure 2. Schematic for Stream Health Outcome Management Strategy

:Stream Health Workgroup Management Strategy

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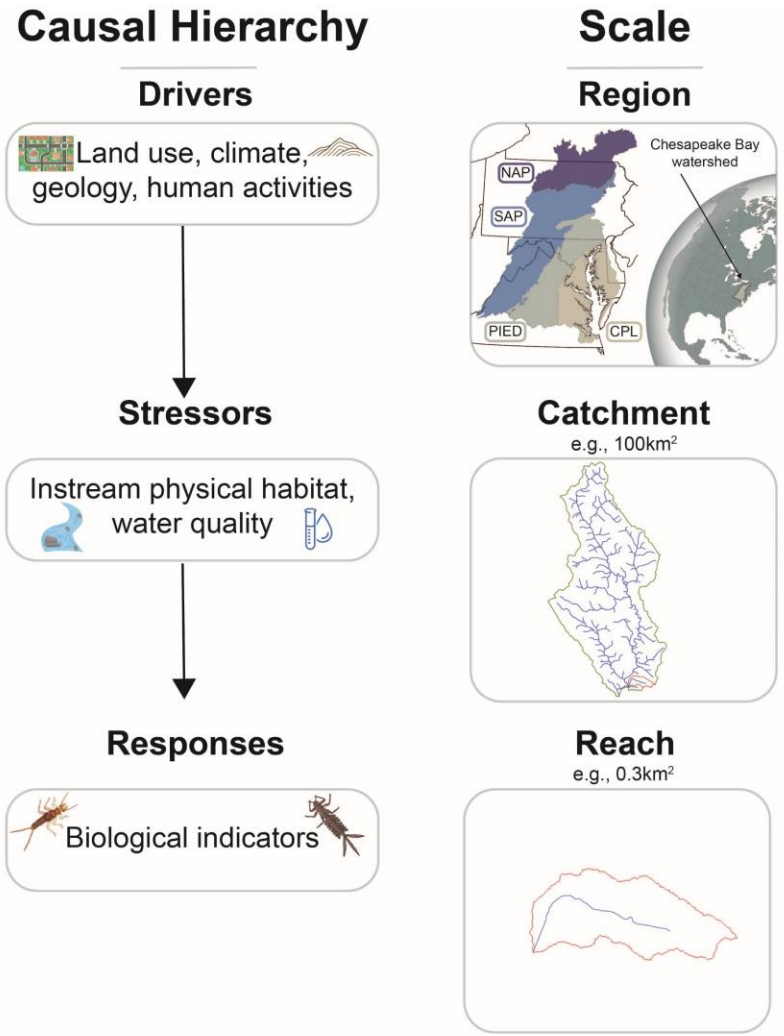
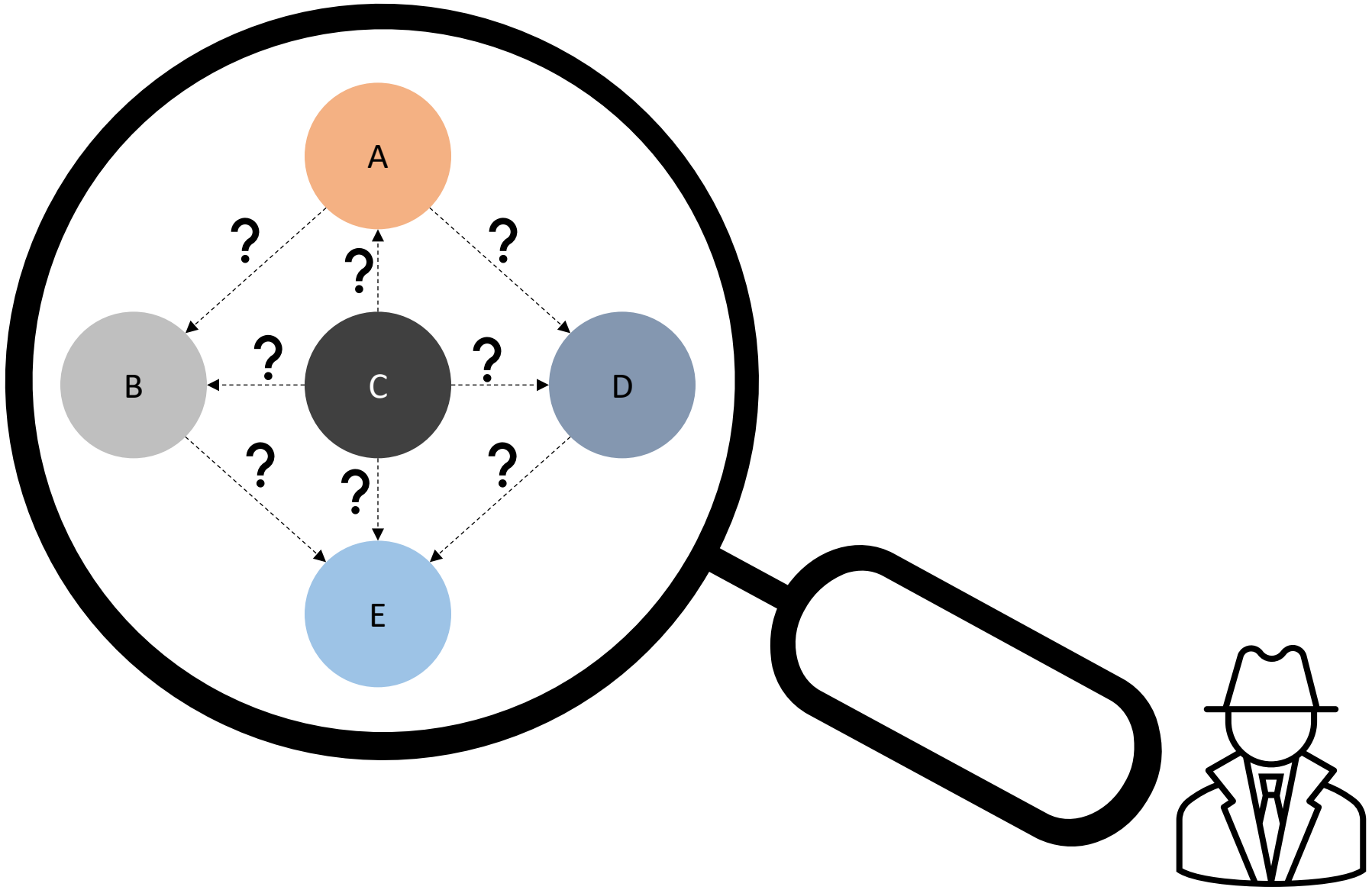
Research Question and Goals

- Overarching research question:
  - What are the key stressors impacting stream health in the Chesapeake Bay Watershed, and do these stressors vary by region?
- Goals:
  - Identify hierarchical effects of multiple stressors on benthic macroinvertebrate indicators of stream health.
  - Predict changes in benthic macroinvertebrate indicators based on stressors.
  - Provide a spatial prioritization framework to inform watershed conservation/restoration efforts.



Causal Discovery: Leveraging Bayesian Network Learning to identify complex driver-stressor-response relationships



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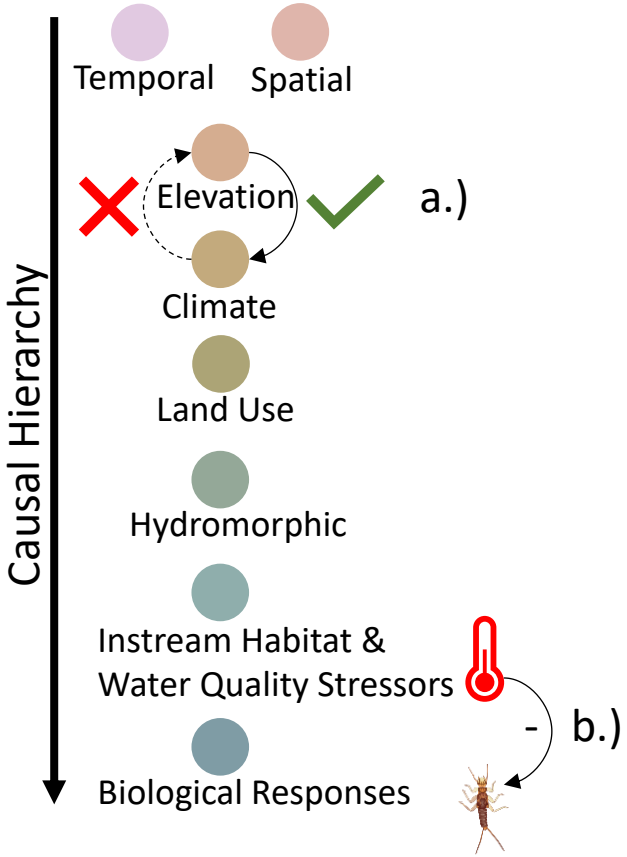
Causal Discovery: Bayesian Network Learning approach

1. Expert Knowledge Integration

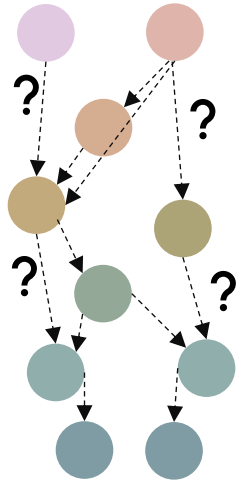
a.) Build blocklist to prevent illogical connections

b.) Incorporate stressor-response knowledge



2. Structure Learning

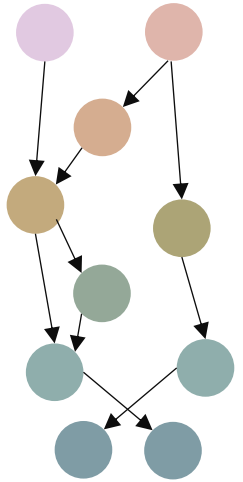
Greedy Hillclimb algorithm



x1000 bootstraps

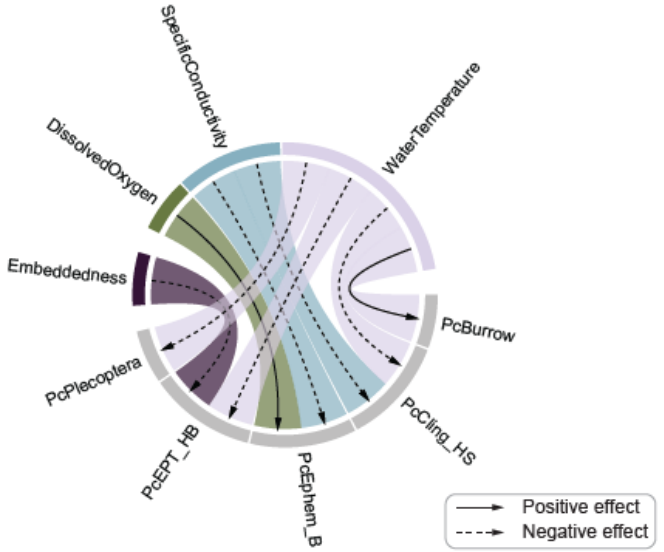
3. Model Averaging

Keep connections that occurred in > 50% of bootstrapped networks



4. Fit Data to Network Structure, Estimate Effects

e.g.) what are the major stressor effects on biological responses?



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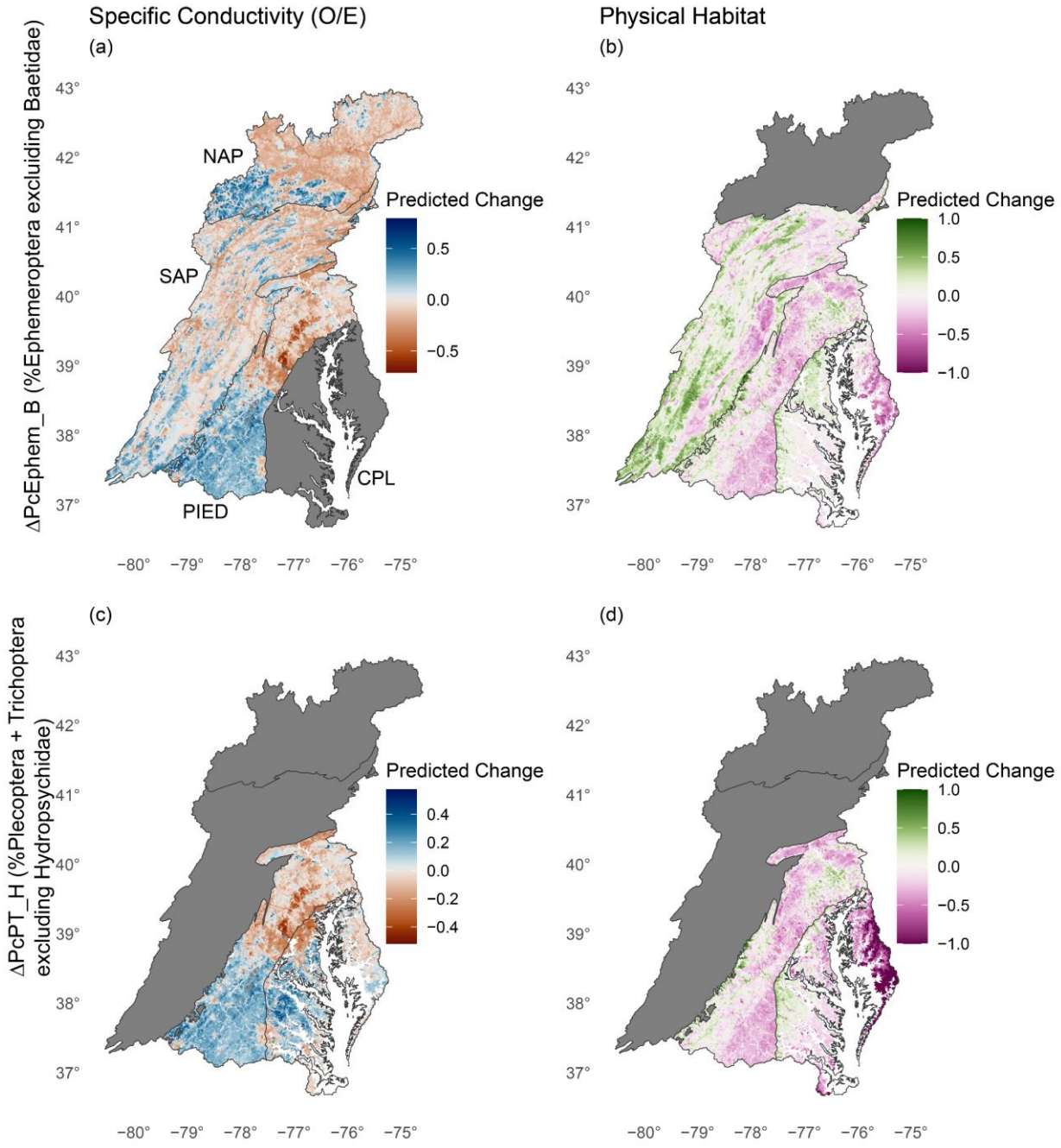
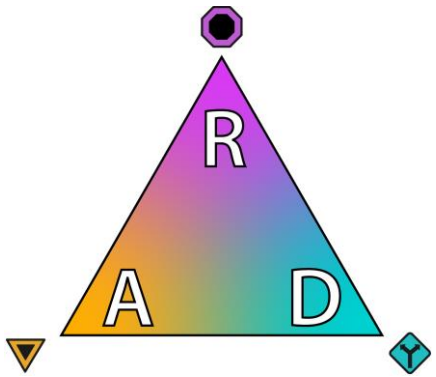
Predicted changes in key biological response metrics based on predicted stressors



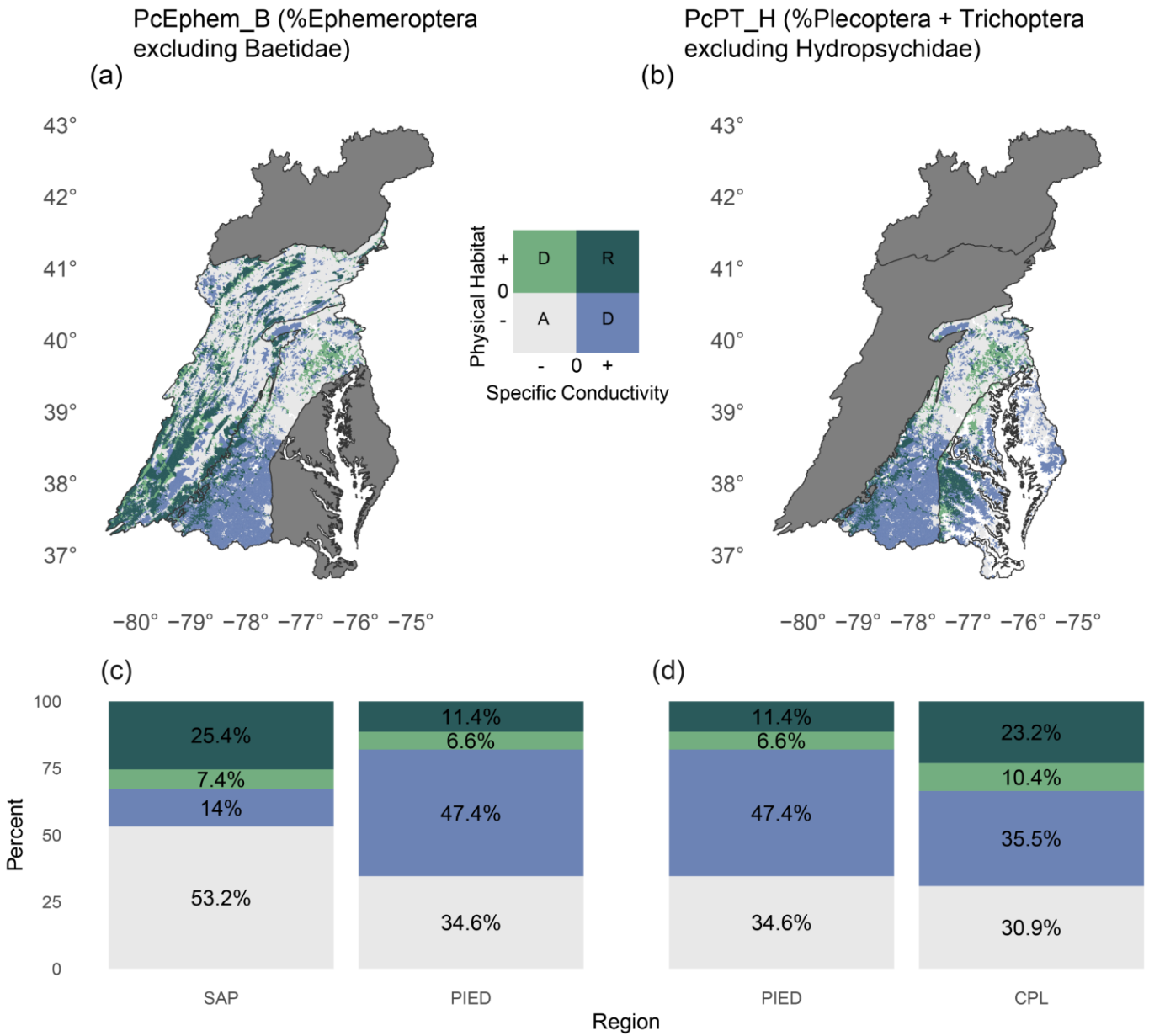
Prioritizing management options based on predicted changes



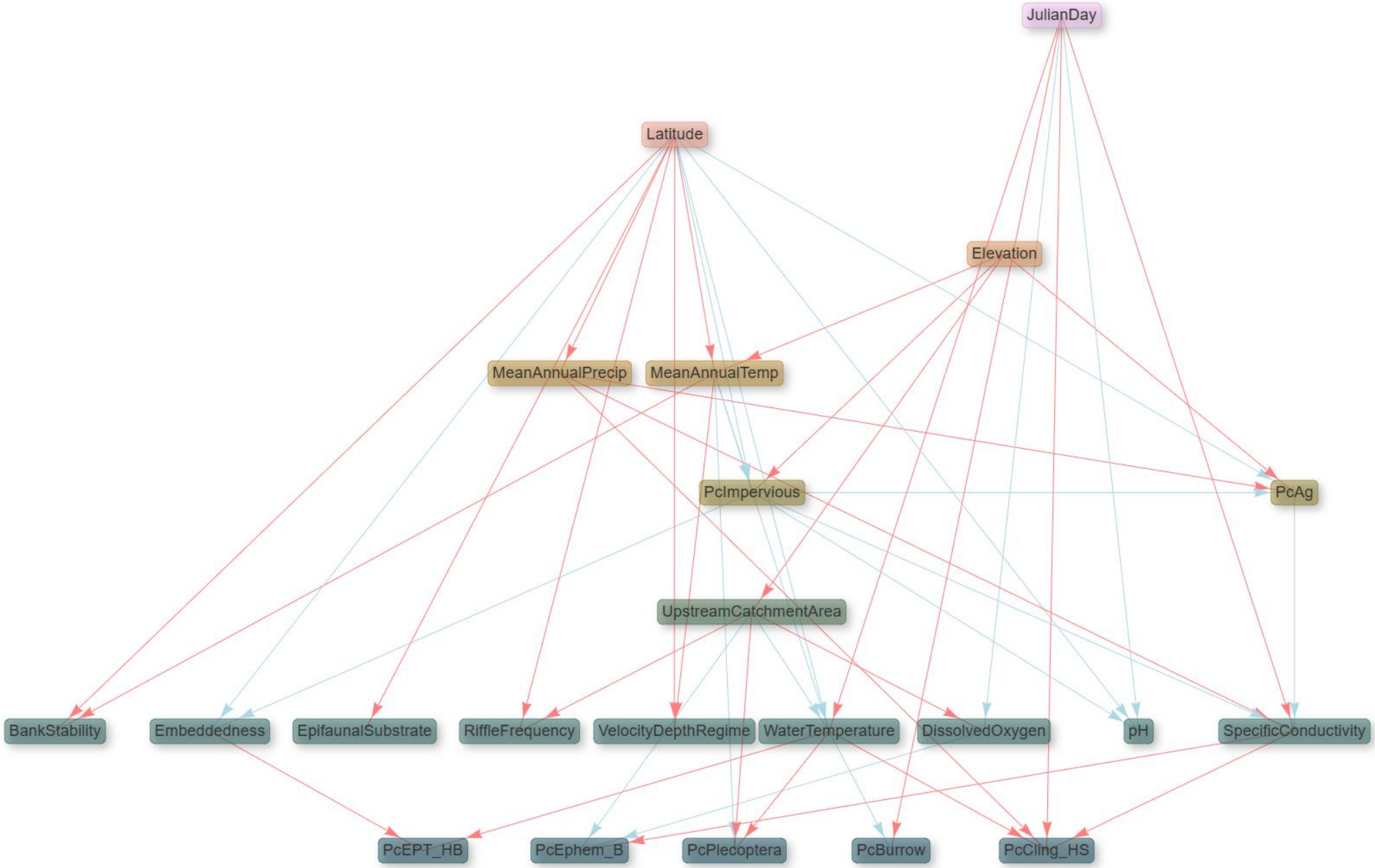
Resist
(Conservation)

Accept
(Co-occurring stressors, no action)

Direct
(Restoration or Management Practices)



Questions?


JulianDay
Latitude
Elevation
MeanAnnualPrecip
MeanAnnualTemp
PcImpervious
PcAg
UpstreamCatchmentArea
BankStability
Embeddedness
EpifaunalSubstrate
RiffleFrequency
VelocityDepthRegime
WaterTemperature
DissolvedOxygen
pH
SpecificConductivity
PcEPT_HB
PcEphem_B
PcPlecoptera
PcBurrow
PcCling_HS