Regional Vulnerability Assessments to Detect Climate Change Effects in Streams

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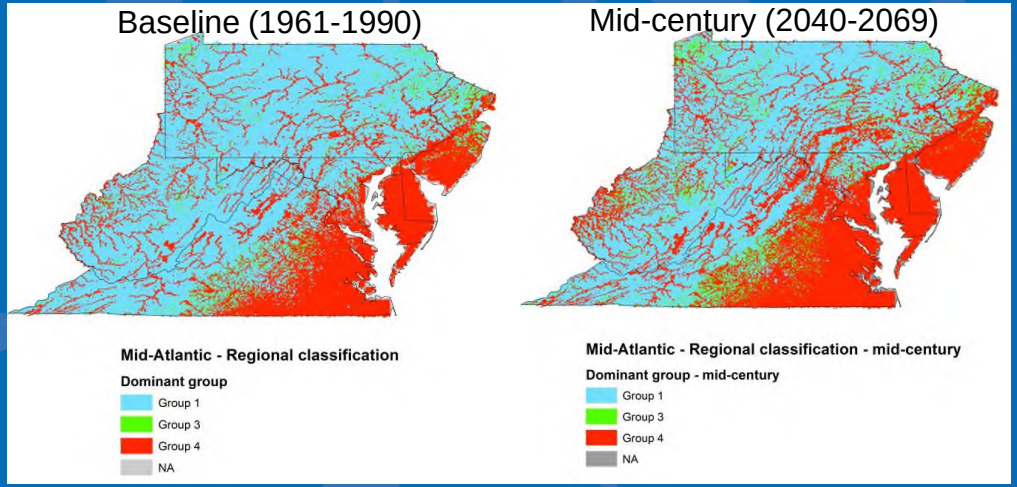

Office of Research and Development
Air, Climate and Energy Program, National Center for Environmental Assessment

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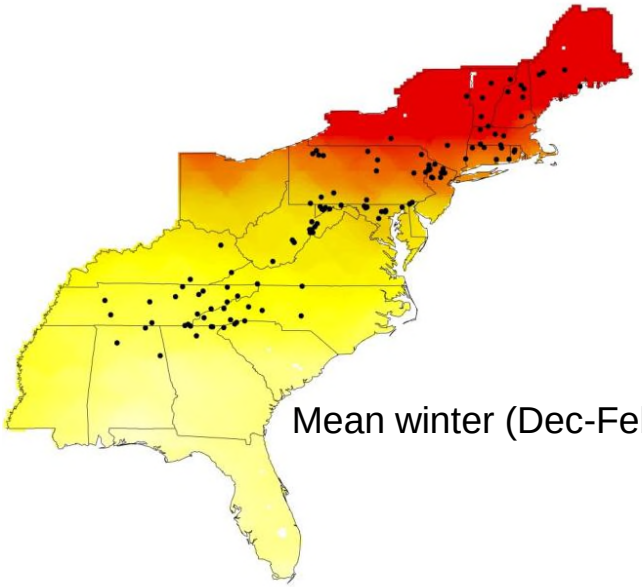
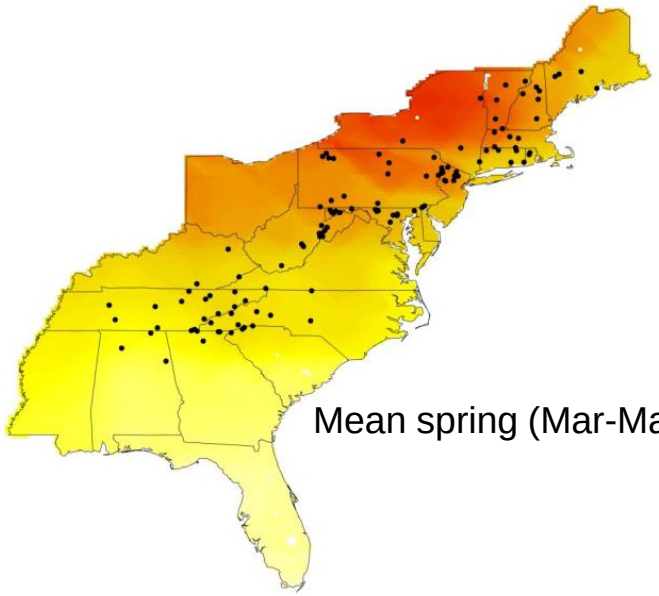
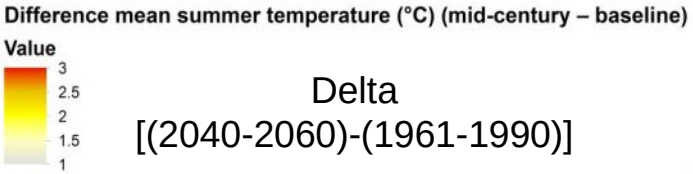
Air temperature



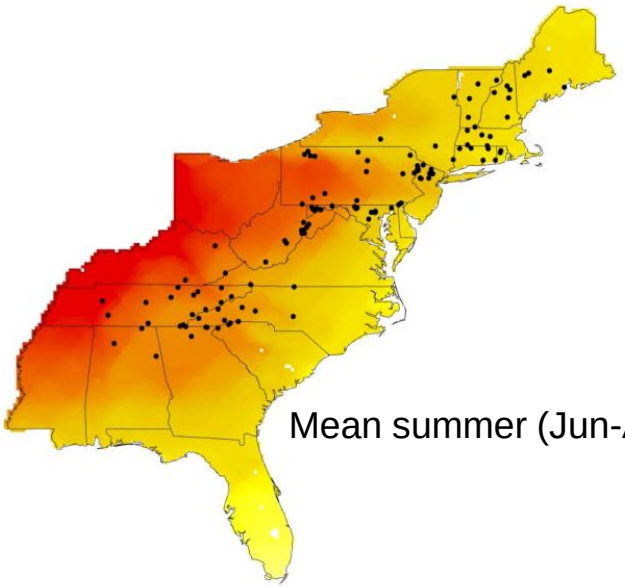
Mean winter (Dec-Feb)



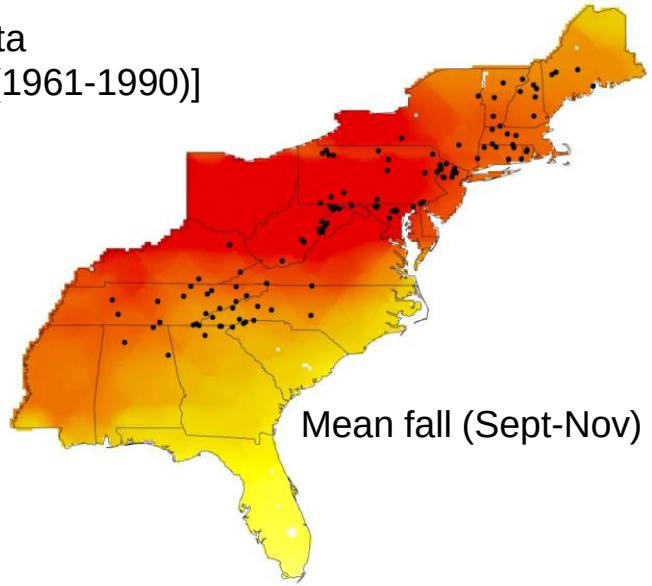
Mean spring (Mar-May)



Delta
[(2040-2060)-(1961-1990)]

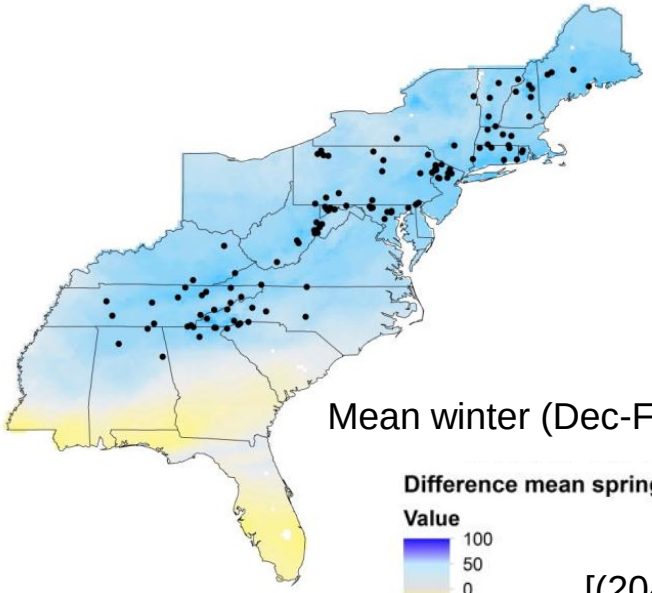


Mean summer (Jun-Aug)

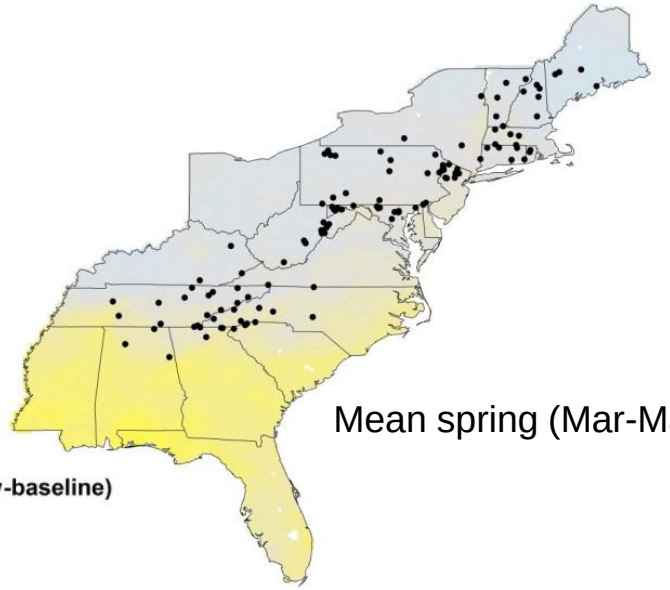


Mean fall (Sept-Nov)

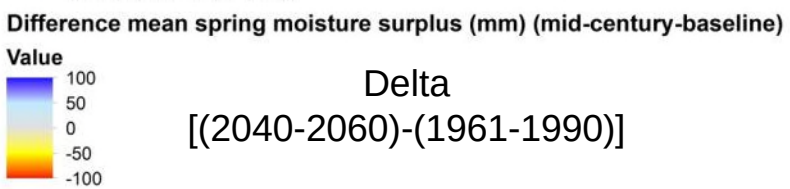
Moisture surplus (mm)



Mean winter (Dec-Feb)



Mean spring (Mar-May)



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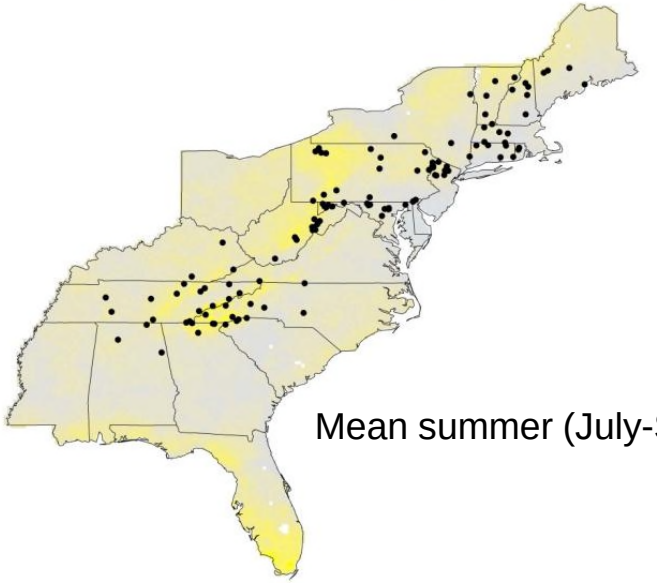
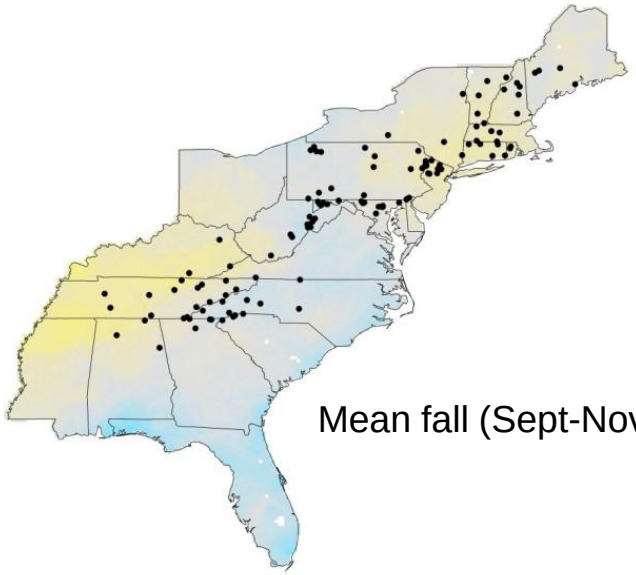


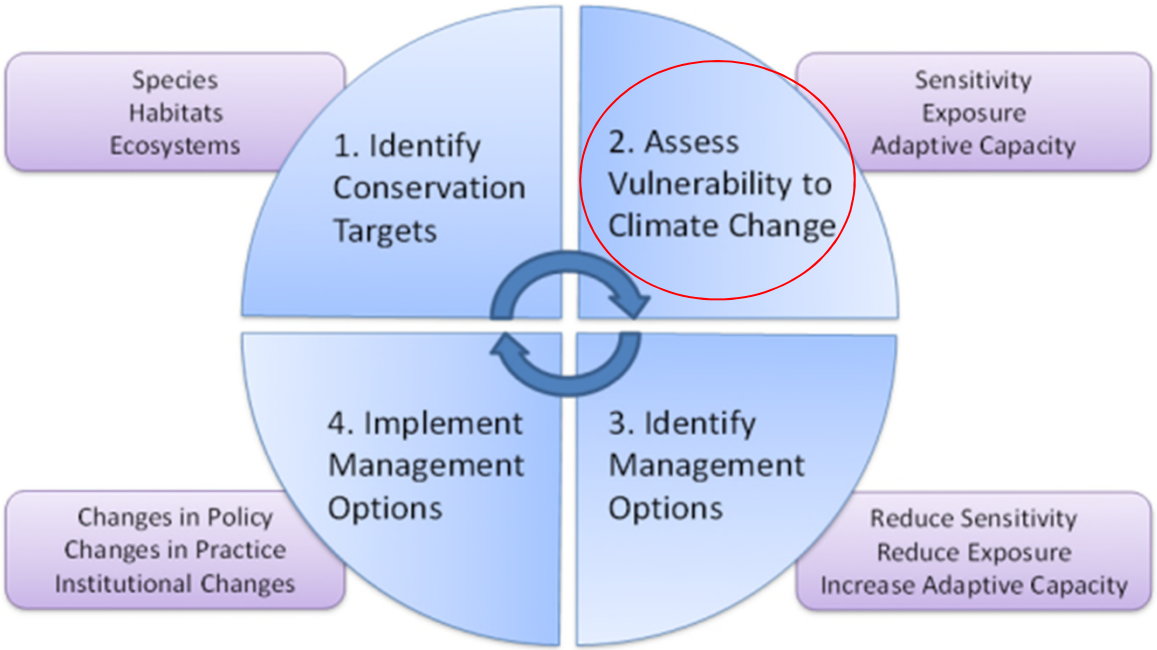
Mean summer (July-Sep)



Mean fall (Sept-Nov)

GOAL

Provide aquatic biologists and resource managers with a broad regional assessment of the **vulnerability of catchments** and **stream reference sites** to effects of **climate change**



Glick et al. 2011 (www.nwf.org/vulnerabilityguide)

FRAMEWORK & TERMINOLOGY

from Glick et al. 2011

Vulnerability is a function of the *sensitivity* of a particular system to climate changes, its *exposure* to those changes, and its *capacity to adapt* to those changes (IPCC 2007).

Exposure – measure of how much of a change in climate and associated problems a species or system is likely to experience

Sensitivity –measure of whether and how much a species or system is likely to be affected by a given change in climate

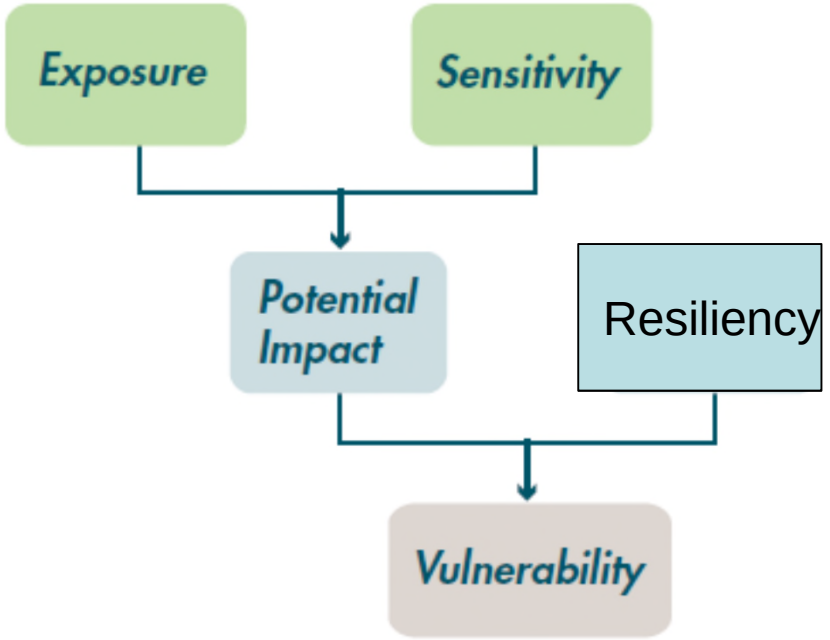


Figure 2.1. Key components of vulnerability, illustrating the relationship among exposure, sensitivity, and adaptive capacity.

Adaptive capacity refers to the opportunities that may exist to ameliorate the sensitivity or exposure of that species or system.

Ecosystem **resilience** is the ability of an ecosystem to retain essential processes and support native diversity in the face of disturbances or expected shifts in ambient conditions (definition modified from Gunderson 2000 - TNC 2013).

Stream Condition Assessments

- Variety of chemical, physical, and biological components assessed
  - Frequently one sample in time per site
  - Generally no information on variability

- Data assessed with common measures (e.g., biological condition gradient)
- Current condition assessed across multiple indicators

Projecting Future Condition

- Requires understanding of changes in conditions
  - Trends, rates
- Requires understanding environmental and biological variability
  - Variances, responses

Vulnerability assessment tries to prioritize sites with greatest changes

Uncertainties in Vulnerability Assessments

- Datasets used to inform vulnerability assessments have many uncertainties
  - Climate change projections, especially precipitation
  - Derivative datasets using these projections in other models, e.g., streamflow
  - Proxies for variables of interest (air vs. water temperature)
- Uncertainties in biological responses
  - Species interactions, species adaptations, degree of sensitivity to climate exposures
- Uncertainty in human responses
  - Actual management interventions

Context of Regional Vulnerability Assessment

Current context of biomonitoring

- Where do we expect biological assemblages (and biological conditions) to change the most by mid-century in response to changing temperature and hydrologic conditions

Coarse, broad-scale assessment

- Other more sophisticated assessments and models available, but often cover only specific sites or watersheds, not large regional

Catchment-level assessment

- Vulnerability ratings (least, moderate, most) assigned to each **NHDPlus v1 catchment** in the study area

Given many uncertainties and unknowns, results should be regarded as **hypotheses**, which can be tested through data-gathering efforts at RMN sites

“FIRST GENERATION” ASSESSMENT

Should be refined as better data become available.

Strategies for dealing with limitations and uncertainties

- Do the best we can with available data
- Acknowledge limitations and uncertainties
- Place more weight on data with most confidence
- Leave a trail of ‘bread crumbs’
  - Carefully document what we do
  - Retain original data (may want to go back and change thresholds; someone else may want to try a different approach with the same data, etc.)

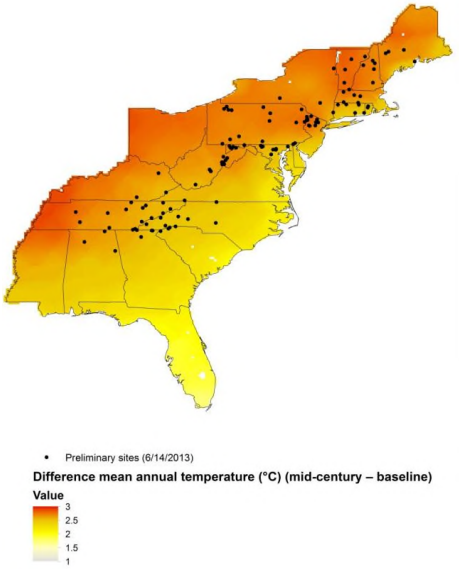
STEPS

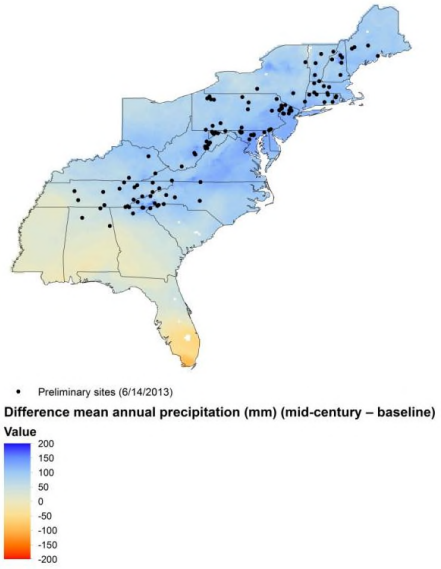
1. Define **objectives, geographic range/scale** and **target population**
2. Develop list of potential **climate scenarios**
3. **Brainstorm** list of variables to assess **exposure, sensitivity** and **resiliency** for the scenarios being considered
4. Conduct **data inventory**
5. **Assess** data (quality, availability over the study area)
6. **Delineate regions/classification schemes**
7. Conduct **analyses** for each scenario
   - Combine exposure, sensitivity and resiliency variables to assess vulnerability of streams
8. Solicit **feedback**
9. **Finalize** results

Climate Exposure Scenarios

During an earlier phase of this project, we selected three exposure scenarios:

1. Increasing **temperatures**
2. Increase in frequency and severity of **peak flows**
3. Summer **low flows**





SCENARIO 1 – Increasing Temperatures

Focused on **summer** –

- Captures a **critical time** period for most aquatic species' **survival**
- Hawkins et al. (2013) found that mean summer stream temperature was a **better predictor** of stream macroinvertebrate distributions than mean winter and mean annual stream temperatures
- **Highly correlated** with other seasonal temperature variables

- Ideally use stream temperatures if appropriate datasets are available

SCENARIO 1 – increasing summer temperature

Within each class, we scored exposure, sensitivity and resiliency based on these variables:

Exposure

- ***Projected change*** in summer air temperature (mid-century minus baseline)
- ***Rate of change*** (climate velocity)
- ***Shading***
  - Riparian
  - Local catchment
  - Total watershed
- ***Baseflow***
- ***Urban*** land use (medium and high intensity)

Sensitivity

- ***Macroinvertebrate*** assemblage
  - Probability of occurrence in small, cold, fast-flowing catchments

Resiliency/Adaptive Capacity

- ***Connectivity*** with ***cold water*** habitat (TNC 2013)

Flags (wildcards)

- Dams
- Lakes
- Land use (e.g., row crops)

SCALING/NORMALIZING

- We had to normalize the variables before going through the scoring process (note: all the original values were retained)
- Ratings are based on relative scales
- We used a scale from 0 (least) to 100 (most vulnerable)

End result – each NHD local catchment is assigned to 3 categories of vulnerability (by tertiles):

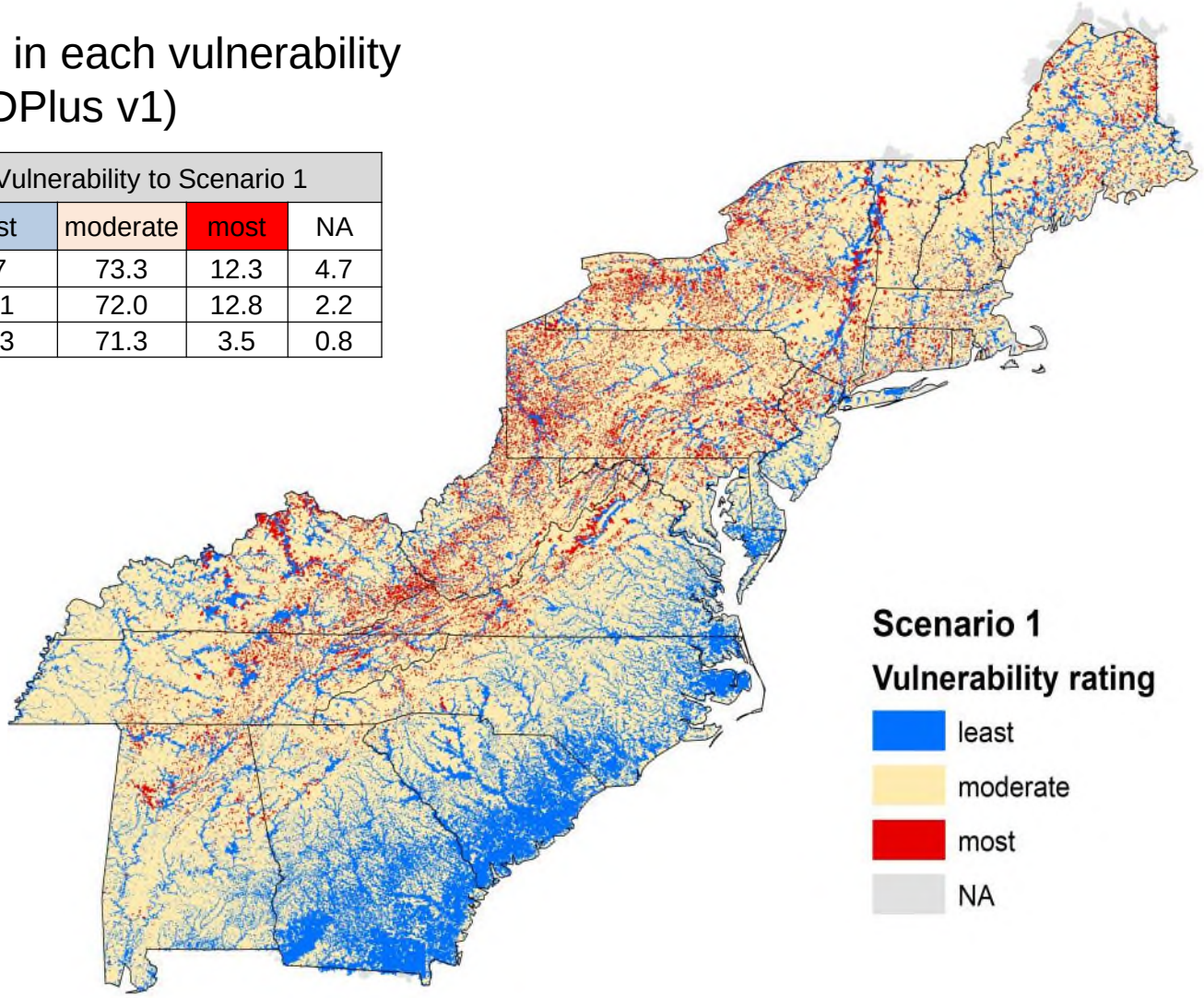
- Least
- Moderate
- Most

SCENARIO 1 – increasing summer temperature

Percent stream length in each vulnerability category (source: NHDPlus v1)

Region	Total stream length (km)	Vulnerability to Scenario 1			
		least	moderate	most	NA
Northeast	195607.6	9.7	73.3	12.3	4.7
MidAtlantic	264856.4	13.1	72.0	12.8	2.2
Southeast	571371.2	24.3	71.3	3.5	0.8

Results are preliminary!



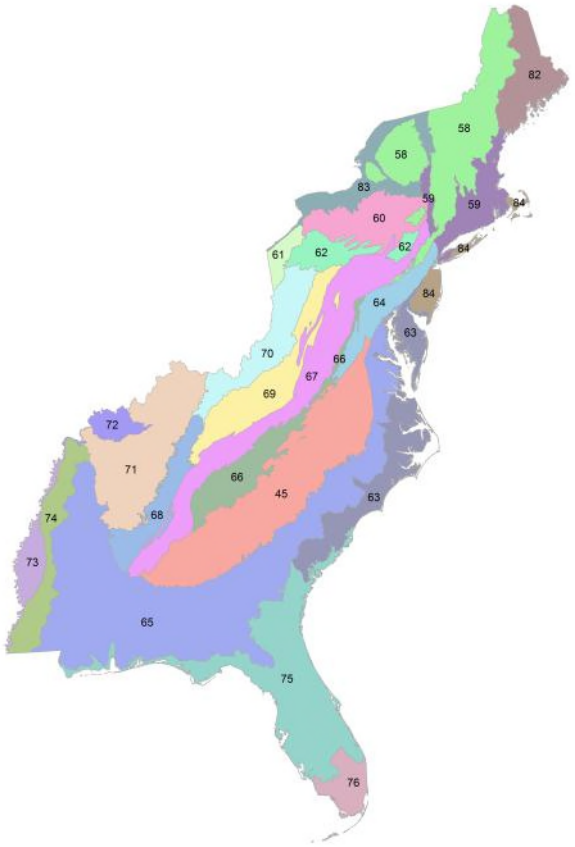
SCENARIO 1 – increasing summer temperature

United States Environmental Protection Agency

EPA Level 3 ecoregions

Percent stream length in each vulnerability category (source: NHDPlus v1)

L3 CODE	L3 NAME	Total stream length (km)	Vulnerability to Scenario 1			
			least	moderate	most	NA
45	Piedmont	137133.6	21.4	77.3	1.3	0.0
58	Northeastern Highlands	73142.7	8.0	83.3	8.5	0.2
59	Northeastern Coastal Zone	31085.8	12.9	67.8	11.2	8.2
60	Northern Allegheny Plateau	33996.8	6.1	74.0	20.0	0.0
61	Erie Drift Plain	8317.8	8.6	65.2	26.1	0.2
62	North Central Appalachians	19305.4	7.1	81.2	11.7	0.0
63	Middle Atlantic Coastal Plain	48930.0	44.9	44.6	0.0	10.4
64	Northern Piedmont	23624.9	10.5	75.9	13.1	0.5
65	Southeastern Plains	195332.0	31.0	68.1	0.4	0.5
66	Blue Ridge	43009.6	6.2	85.9	7.9	0.0
67	Ridge and Valley	92079.3	12.8	73.4	13.8	0.0
68	Southwestern Appalachians	32671.1	10.6	77.4	12.0	0.0
69	Central Appalachians	50279.7	9.6	71.6	18.8	0.0
70	Western Allegheny Plateau	43545.5	12.9	69.4	17.2	0.4
71	Interior Plateau	76874.5	13.4	79.5	7.0	0.1
72	Interior River Valleys and Hills	11040.1	19.5	78.6	0.9	1.0
73	Mississippi Alluvial Plain	1426.2	34.1	60.8	0.1	5.0
74	Mississippi Valley Loess Plains	17562.5	7.9	91.9	0.2	0.0
75	Southern Coastal Plain	18962.2	62.3	32.1	0.0	5.6
82	Acadian Plains and Hills	29841.7	11.3	69.5	10.6	8.6
83	Eastern Great Lakes Lowlands	28690.1	10.4	64.5	20.2	5.0
84	Atlantic Coastal Pine Barrens	9282.3	13.8	57.8	0.4	27.9



Results are preliminary!

SCENARIO 2 – high flows

We scored exposure and resiliency in each catchment based on these variables:

Exposure

- Extreme precipitation
- Flowline slope
- Catchment slope
- Stream size
- % Impervious
- % Open water and wetlands
- % Forest (local, watershed)
- Soil permeability

Resiliency/Adaptive Capacity ?

Sensitivity

- No a priori classification based on biology

Flags (wildcards)

- Dams

SCENARIO 3 – Low flow events

We scored exposure, sensitivity and resiliency in each catchment based on these variables:

Exposure

- Summer moisture surplus
  - Baseline
  - Change (mid-century minus baseline)
- Watershed size
  - Headwaters (<10 km2)
- Baseflow

Sensitivity

- No a priori classification based on biology

Flags (wildcards)

- Dams
- Moisture deficit, water withdrawals

SCENARIO 3 – summer low flows

Percent stream length in each vulnerability category (source: NHDPlus v1)

Region	Total stream length (km)	Vulnerability to Scenario 3			
		least	moderate	most	NA
Northeast	195607.6	3.1	71.0	21.5	4.4
MidAtlantic	264856.4	0.5	58.3	39.1	2.0
Southeast	571371.2	2.0	52.0	40.7	5.3

Results are preliminary!

Future of Vulnerability Assessments

- Currently calculate relative vulnerability
  - Ideally, identify meaningful ecological thresholds to calculate vulnerability
- Use fewer proxy datasets
  - E.g., need modeled data across large spatial scales on future stream temperatures
- Need information on the magnitude of biological responses to climate change exposures
- Need more information on species traits, especially related to hydrology

EPA United States Environmental Protection Agency

QUESTIONS? COMMENTS?

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