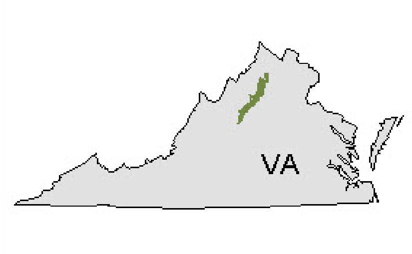
Delayed and variable recovery from acid deposition in Shenandoah National Park streams: a story of geologic history, long-term monitoring, and management of air and water resources

Ami Riscassi
Department of Environmental Sciences
University of Virginia

Jalyn Cummings
National Park Service
Shenandoah National Park

Park Purpose.



Shenandoah National Park preserves and protects nationally significant natural and cultural resources, scenic beauty, and congressionally designated wilderness within Virginia's northern Blue Ridge Mountains, and provides a broad range of opportunities for public enjoyment, recreation, inspiration, and stewardship.

Scenic Beauty: Shenandoah is a place of stunning scenic beauty, especially for those seeking escape from the pavement, brick, and steel of the eastern seaboard's bustling urban centers. Here, visitors can feast their eyes on forested mountains, lush valleys, shaded hollows, cascading streams, long sweeping ridges, and star-filled skies. The views are vast and extend well beyond the park boundaries into neighboring lands.

Clean Air: The park is one of only 49 Class I air areas under the Clean Air Act. Clean air contributes to the ecological health of the park's flora and fauna, and is also critical to maintaining a high-quality visitor experience from a human health perspective, as well as through the preservation of the extensive vistas found throughout the park.

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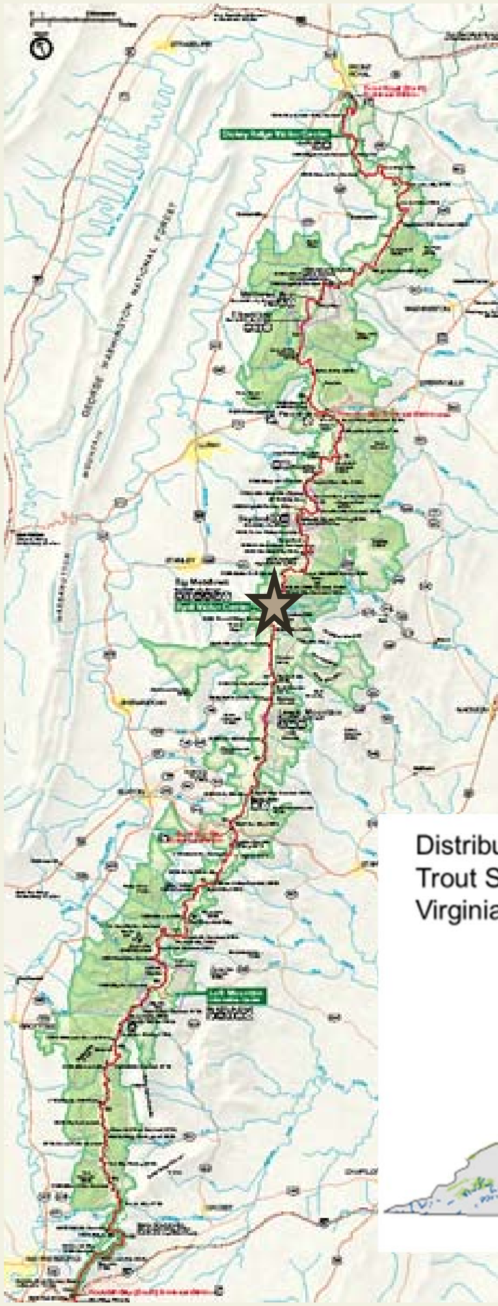
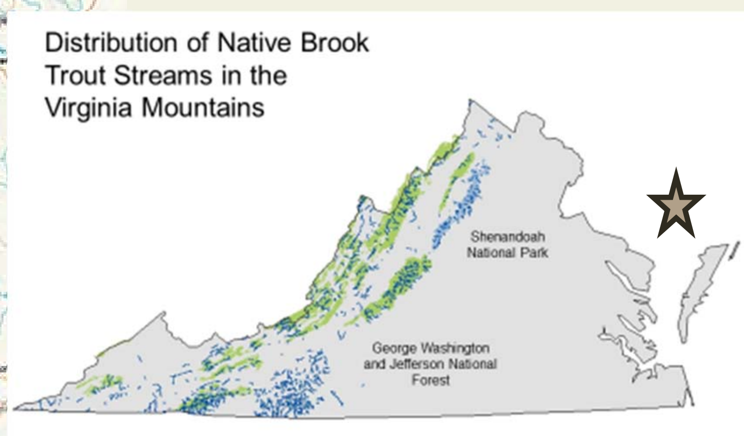
Shenandoah National Park (SHEN)



- 197,000 acres including 80,000 acres of designated wilderness
- 2,100 species of flora and fauna
- Over 500 miles of trails, including 101 miles of the Appalachian Trail
- Over 70 headwater streams
- Support diverse aquatic resources, including brook trout

★ NPS Air Quality Station



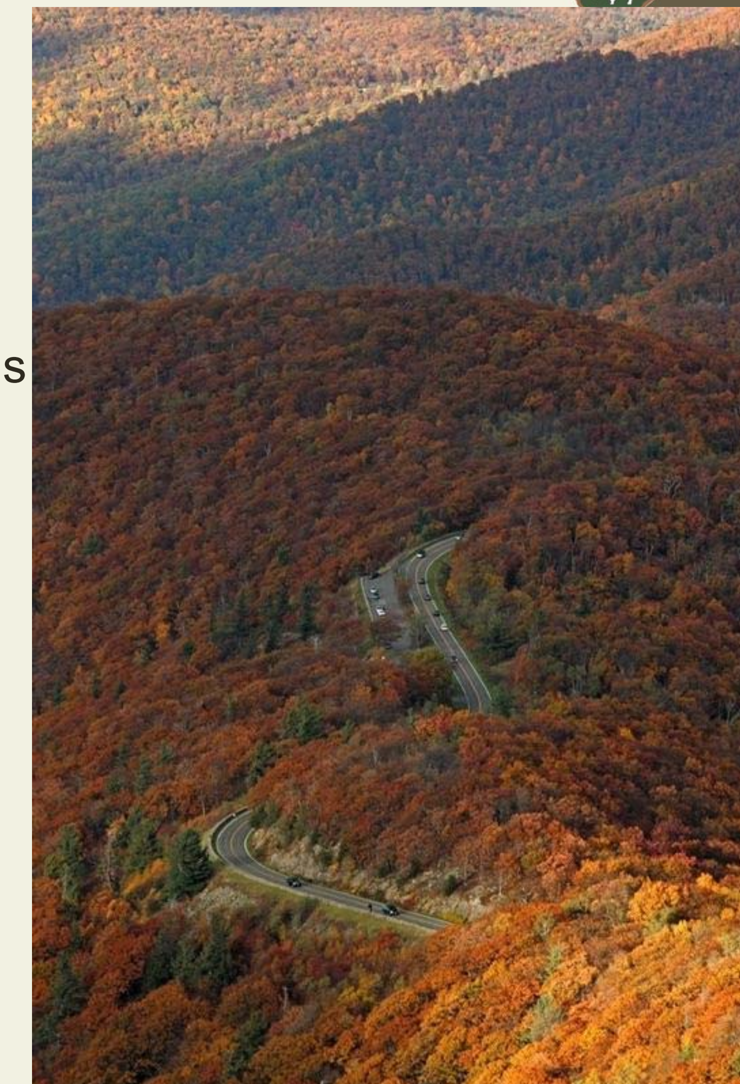
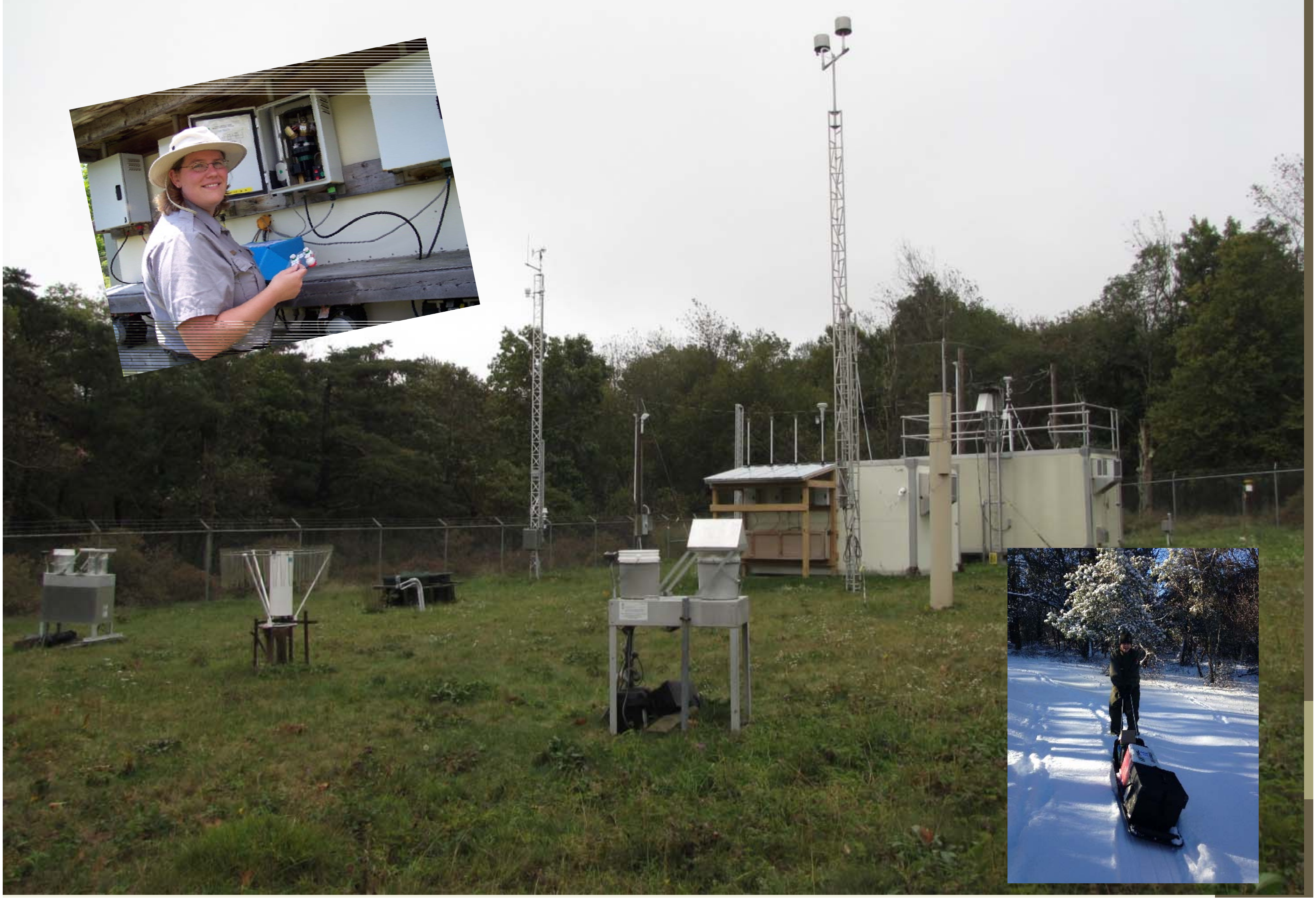


Photo credit: Visitor Shahid Durrani via SHEN Facebook 10/19/15

Big Meadows Air Quality Site
(circa 1981)



UVA Laboratory Manager: Susie Maben 1992 - current

Long-Term Water Quality Monitoring and Research Programs

- SHEN one of the first Inventory & Monitoring prototype parks in the NPS
  - Three "legacy" programs exist
    - SWAS Water Quality Monitoring
    - Fish Population Monitoring
    - Macro-invertebrate Monitoring
    - USGS—Leetown Science Center and Virginia Water Science Center

Water data coupled with SHEN's extensive record of atmospheric deposition, show a complete picture of the non-linear and site-specific relationship between atmospheric deposition and aquatic chemistry.

SHEN Physical Science Technician: Liz Garcia 2000 - current

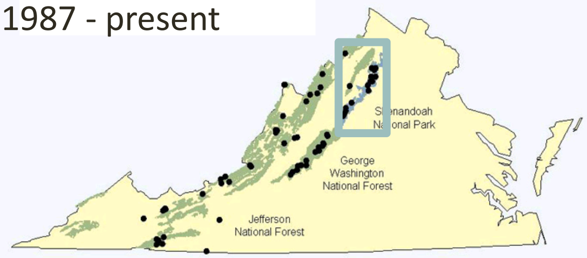
SHEN/NPS Monitoring Program

Initiated in 1979

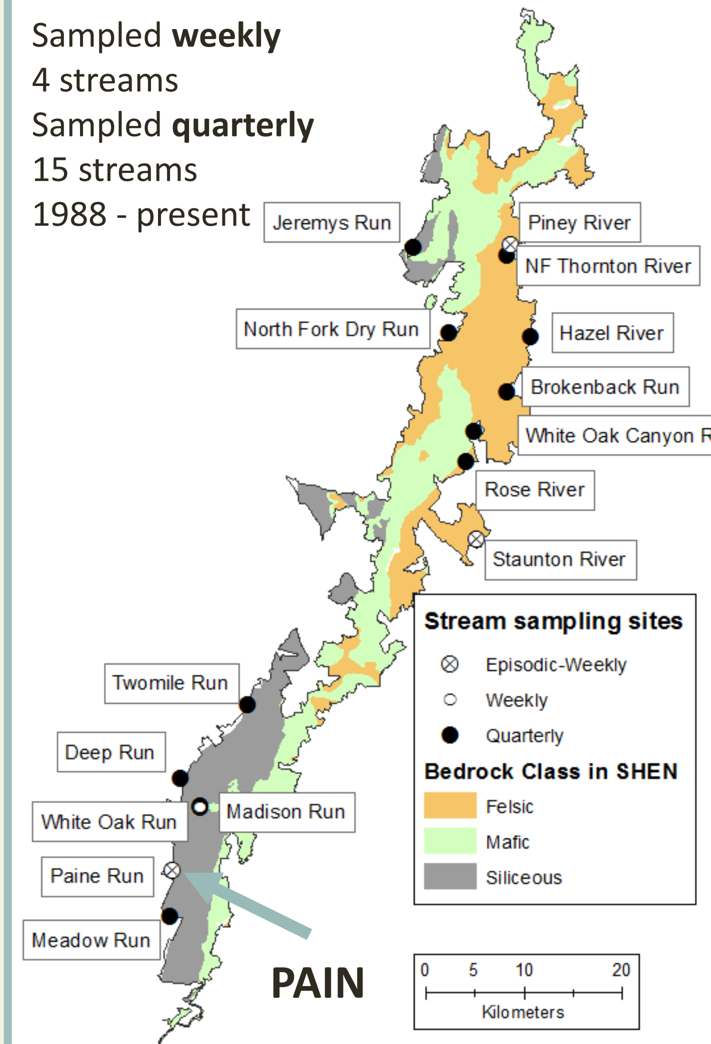
Part of a larger regional study in Western VA

Jim Galloway George Hornberger

Sampled **quarterly**
66 streams (15 within SHEN)
1987 - present



Sampled **weekly**
4 streams
Sampled **quarterly**
15 streams
1988 - present



Stream chemistry (point in time, analyzed in lab)

- pH
- Acid Neutralizing Capacity (ANC)
- Conductivity
- Base Cations: calcium, magnesium, potassium, sodium, ammonium
- Acid anions: sulfate, nitrate, chloride
- Silica
- Dissolved Organic Carbon (subset)
- Dissolved Total/Organic Monomeric Aluminum (subset)

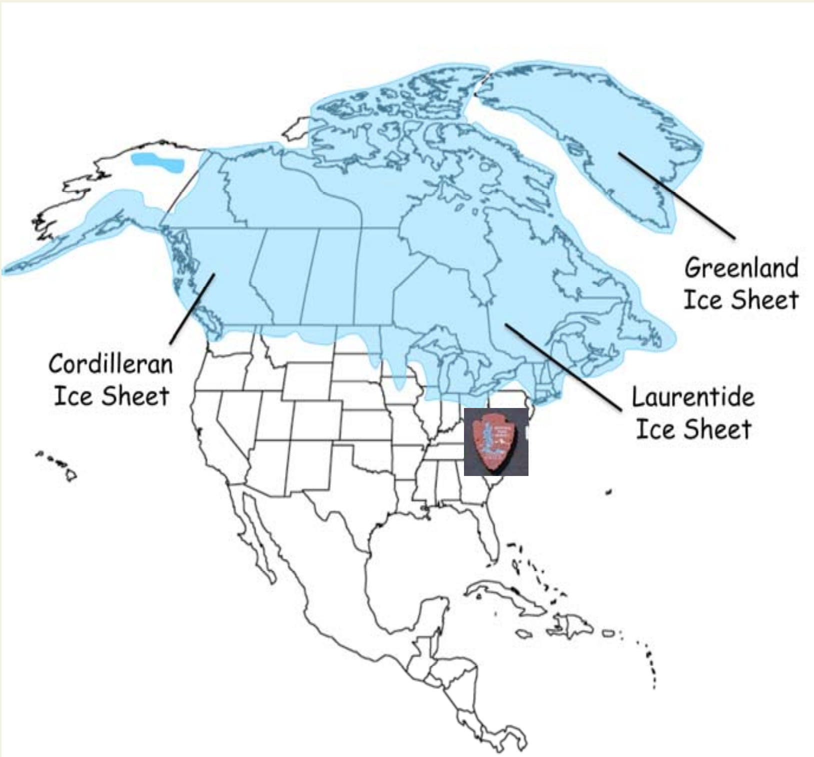
Discharge gauging (4 sites, since 1992)

Episodic sampling (3 sites, since 1992)

Longest watershed study in the NPS

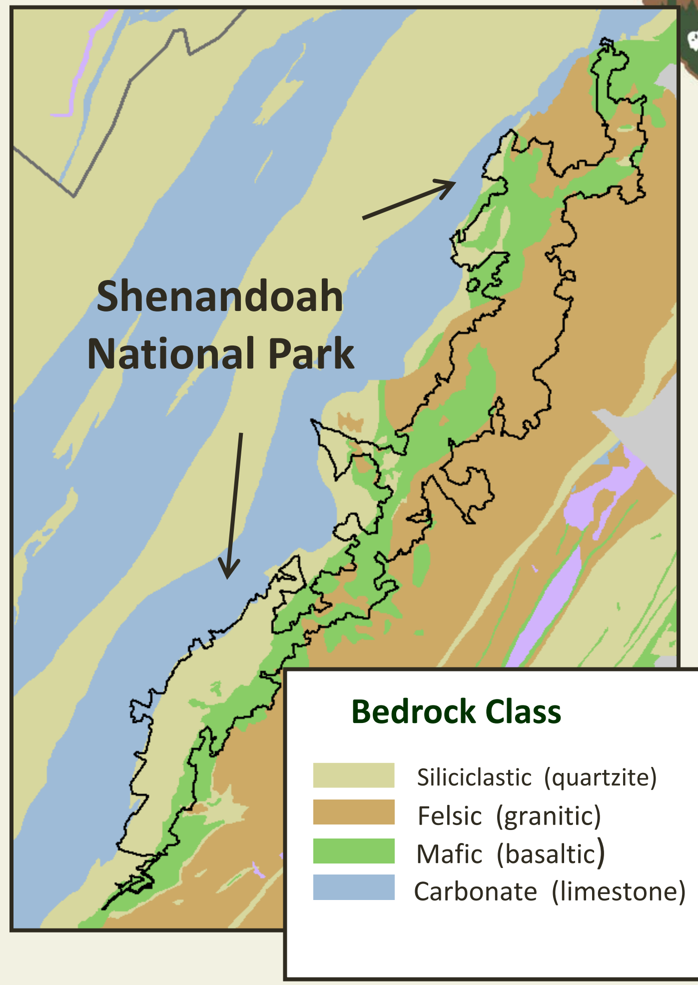
SHEN Geology

Regional distinctions



South of Wisconsinan Glaciation
- older, more weathered soils
- sulfate adsorption of soils is higher south of glaciation *(Rochelle et al., 1986)*

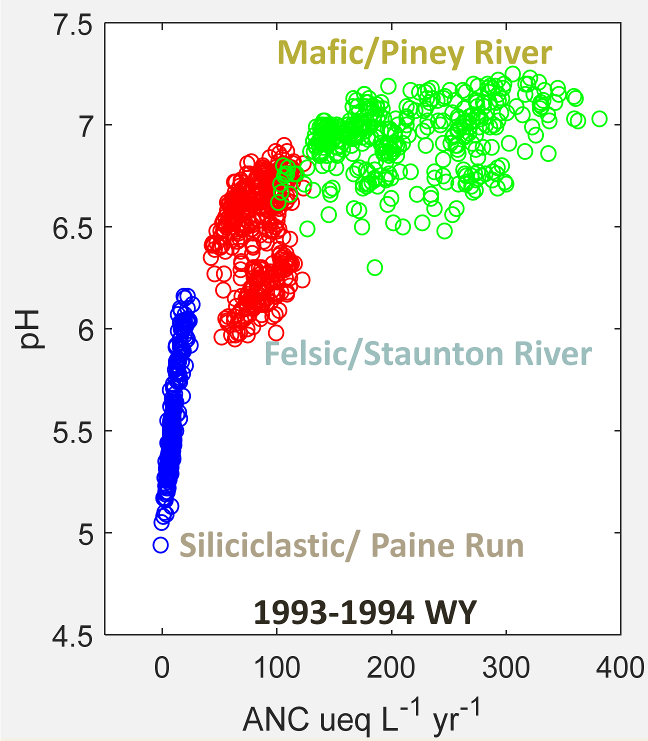
Local distinctions



Mafic- weatherable, base-rich, clay soils

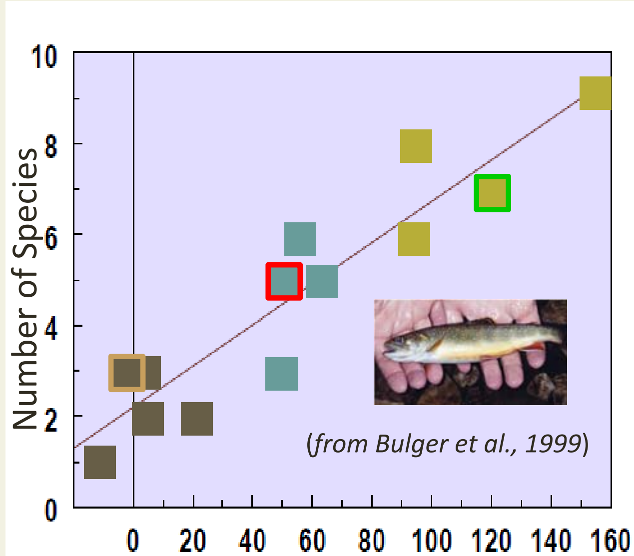
Siliclastic- weather resistant, base poor, sandy soils

Initial findings: water chemistry/fish response to acidification



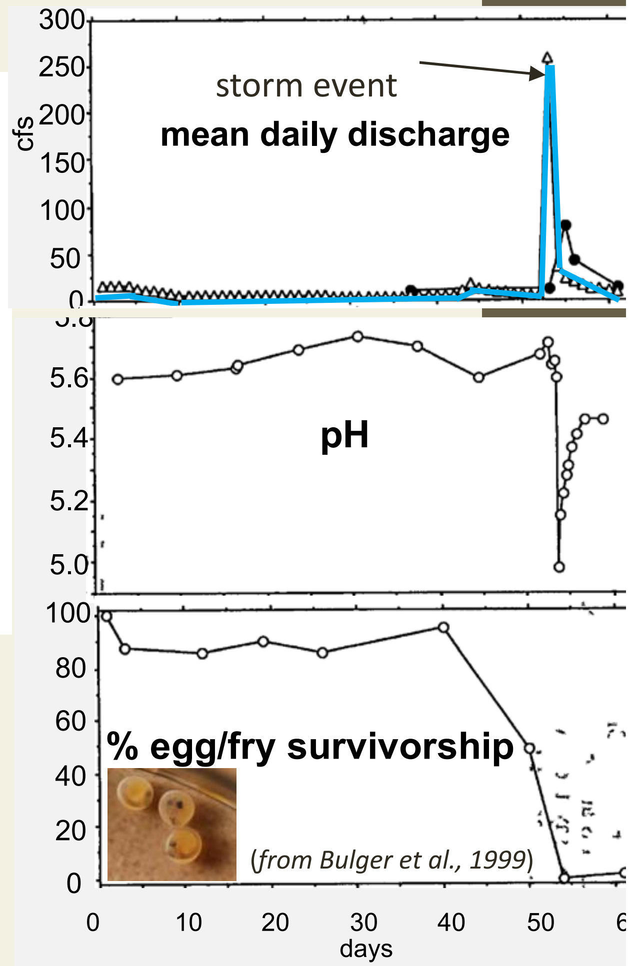
less base cations ⟷ more base cations

Chronic effects on fish abundance



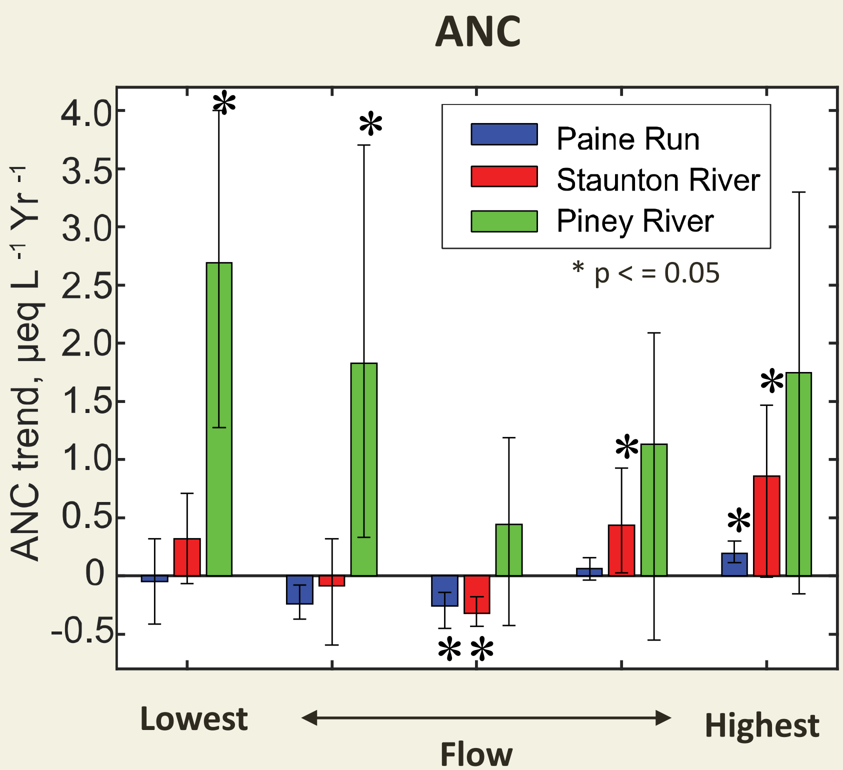
Grab sample minimum ANC (μeq/L)

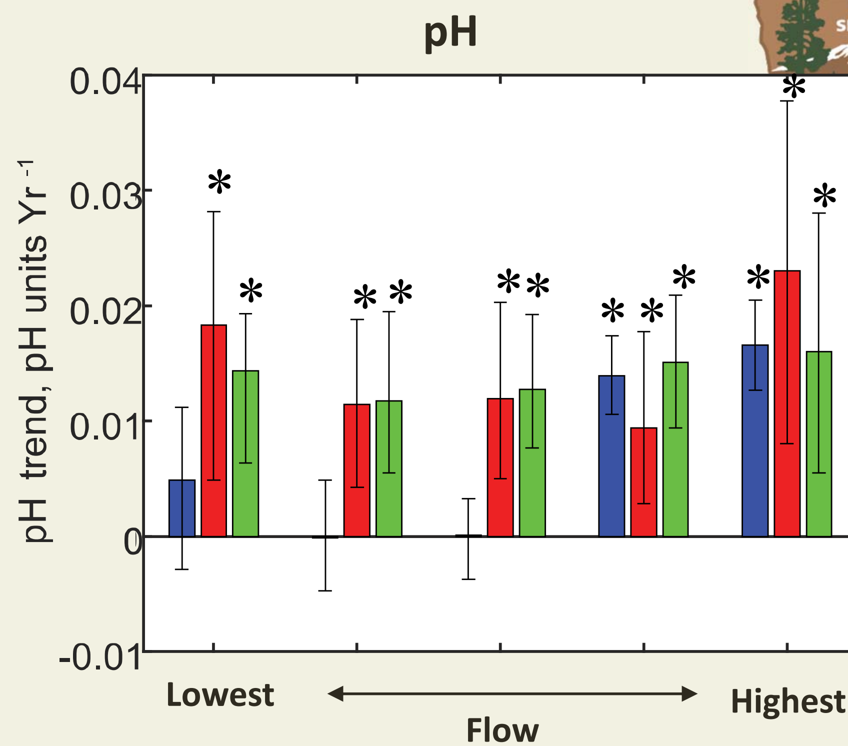
Episodic effects on egg/fry survivorship



Differences in bedrock composition and weathering result in a gradient of responses to acid inputs.

Trend in slope (WY1993/94-2014/15)





Piney River, least acid sensitive site

Recovery from acidification similar for all flow conditions. At high flow, due to sulfate declines, at low flow due to increases in base cations and sulfate declines.

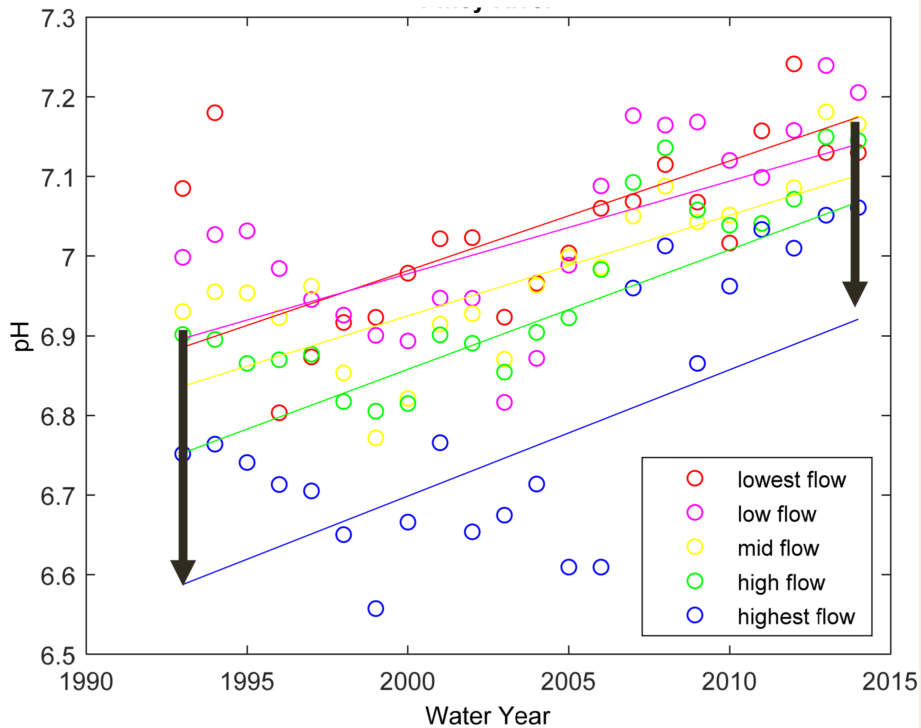
Paine Run, most acid sensitive site

Recovery from acidification only evident at higher flow due to sulfate declines.

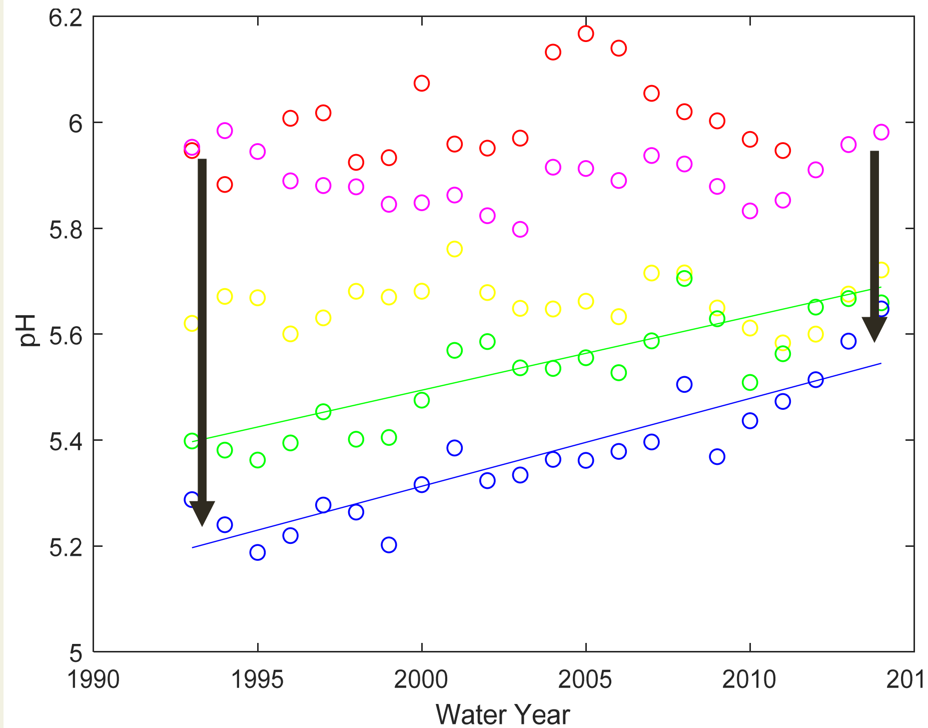
Riscassi et al., Hydrological Processes, accepted Nov. 2018

Severity of an acid 'episode'

Piney River – least acid sensitive



Paine Run– most acid sensitive



In 1992, pH decreased ~ 0.3 pH units

In 2015, pH decreased ~ 0.25 pH units

In 1992, pH decreased ~ 0.8 pH units.

In 2015, pH decreased ~ 0.4 pH units.

Riscassi et al., Hydrological Processes, accepted Dec. 2018

Summary of Key Points

- Improvements in air quality as a result of the CAA Amendments 1990, have decreased the amount of air pollutants deposited in park water and soils, and have resulted in improved conditions for water chemistry and aquatic life in some areas of the park, while others, are continuing to decline.
- Bedrock geology plays a strong role in determining which streams are damaged by acid rain. Basaltic contributes most buffering chemicals, granitic moderate, siliciclastic bedrock the worst.

- Sensitive streams (south district) are expected to get worse because pollutants such as sulfate are stored in the soil for a long time, and will continue to leach into park waters for decades.
- Park streams that are acidified were found to support fewer fish species (acid sensitive species have died off or relocated).
- Acid sensitive streams in park (those on siliciclastic bedrock) had lower fish species richness (fewer types of fish), and no increase in numbers of species were observed over the 30 year study.

SHEN Proposed project

Watershed soil amendments in Meadow Run

- Meadow Run had estimated pre-industrial ANC of 69 μeq/L
- Current ANC (2017) is 4.03 μeq/L with a 1988-2016 average of 4.58 μeq/L.
- Water chemistry is currently analyzed quarterly
- Two stream branches could allow comparison between limed and un-limed treatments
- Limestone sand ($CaCO_3$) would be applied to watershed soils by helicopter or other means (3-5 tons/acre)
- Recovery would be monitored (soil pH, water chemistry, and other components) over time.

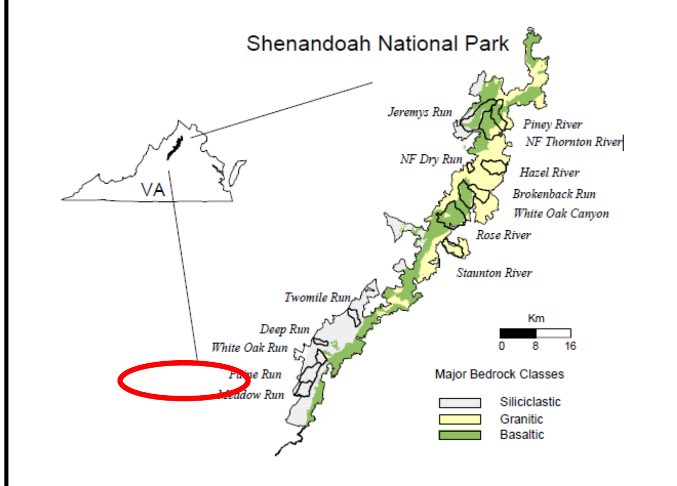


Figure 3-2: *Primary study watersheds in Shenandoah National Park shown in relation to the distribution of major bedrock. (Bedrock map based on Gathright, 1976.)*

Photo credit: USDA Forest Service, Kelly Bridges

Questions?

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