Virginia Trout Stream Sensitivity Study

VTSSS 2021

Rodney Minor

Pink Trillium
Photo by Rob Cain

Stan Ikonen

Brynna Strand

Susie Maben

Results Summary

Presentation Outline

Review of how acid deposition impacts fish

Review of VTSSS program

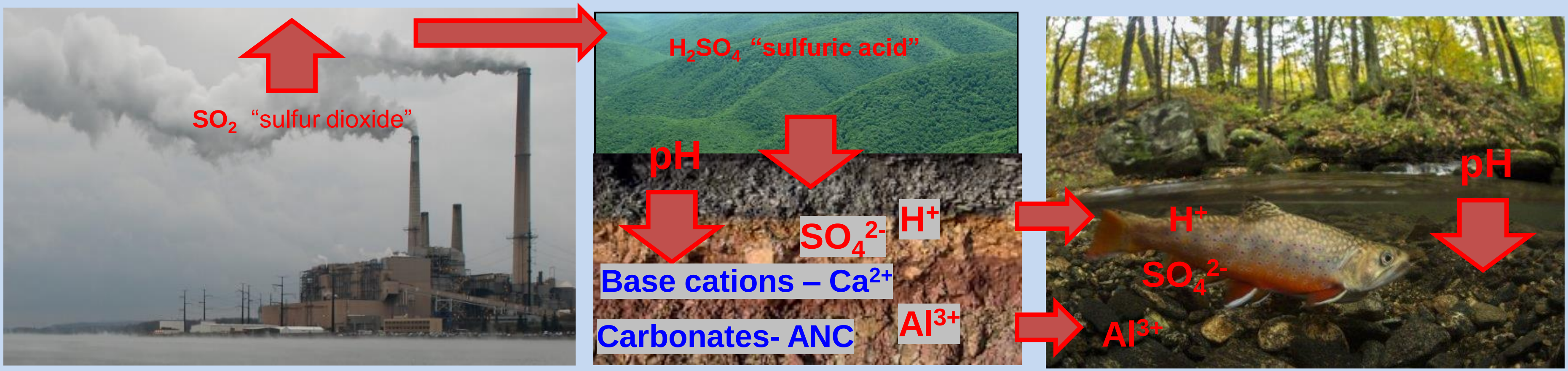
2021 VTSSS – Sampling summary, names and photos

Stream chemistry data/findings

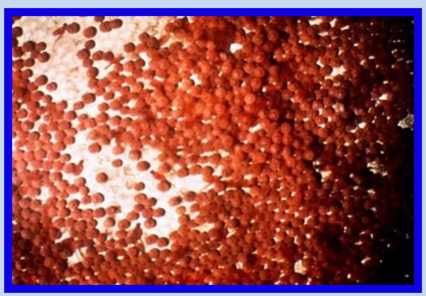
Summary

Emerging threats and future climate

Acid deposition and relationship to native trout stream



Impacts developing fish

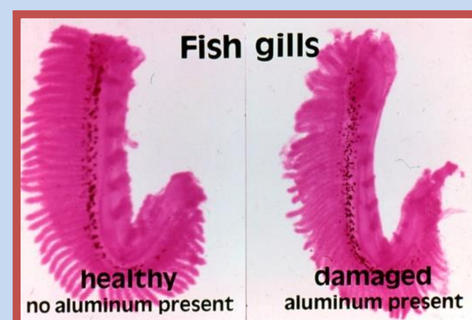


pH 6.0

pH 5.0

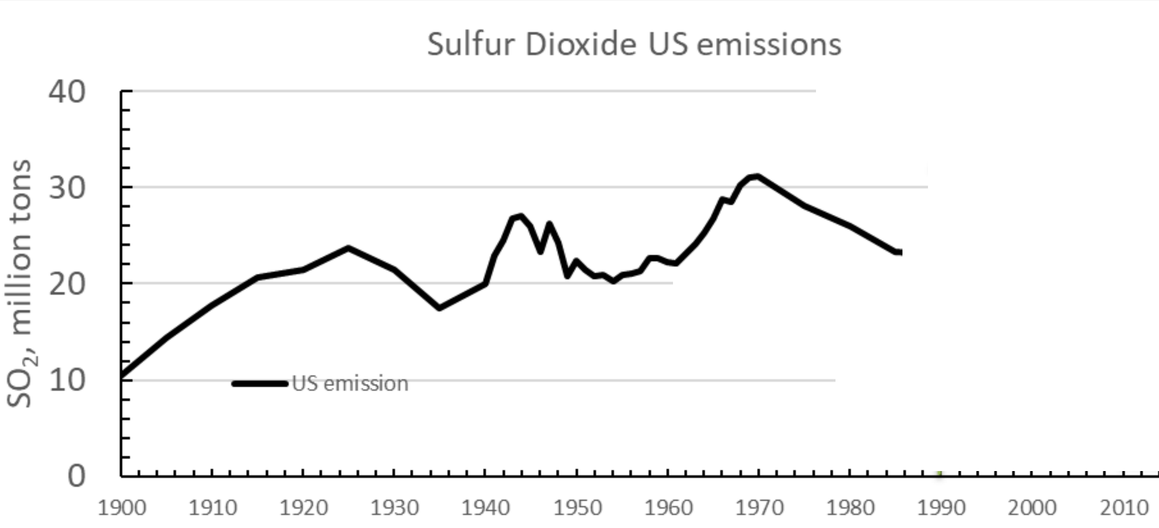
Impacts adult fish

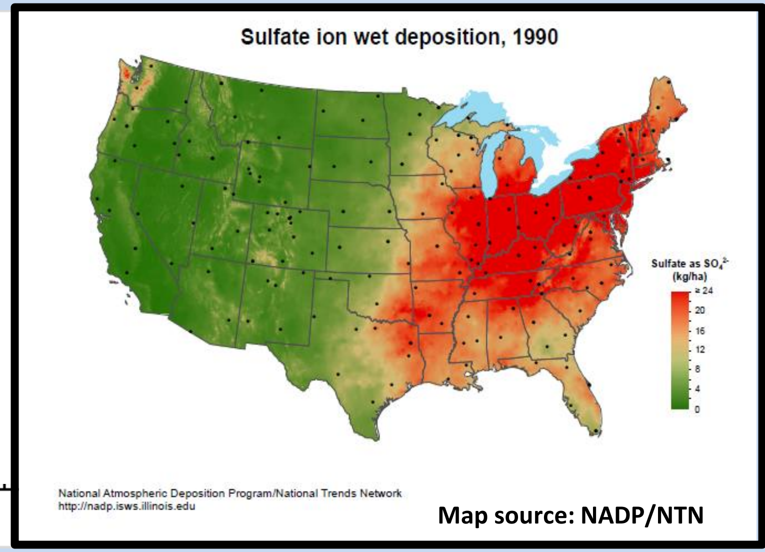
- H^+ and Al^{3+} bind to iono-regulation sites on gills
- Disrupt salt and water balance in blood



Decadal VTSSS, purpose & history

Acid emission and subsequent deposition has resulted in acidification of many streams in the Eastern US.

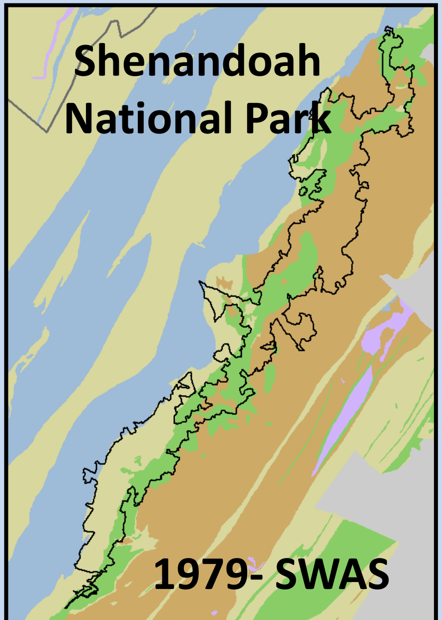


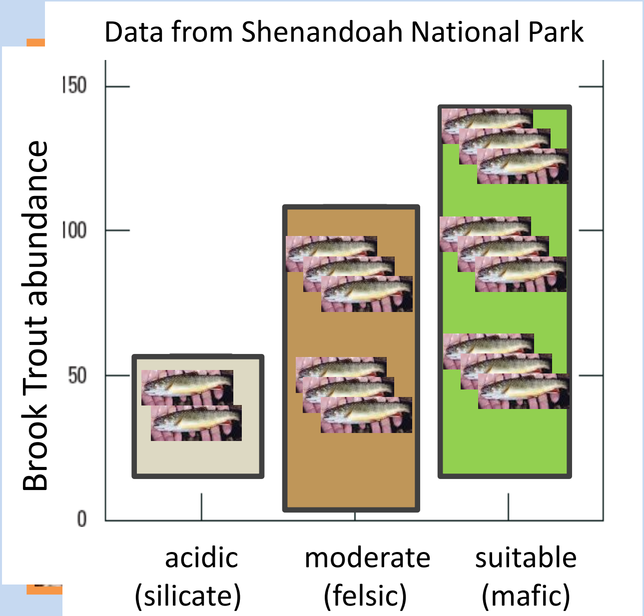


Variability in <u>bedrock composition </u>was found to be a key control on stream response to acid deposition in Shenandoah National Park.

Mafic bedrock: well buffered, moderate pH, diverse fish species present, abundant brook trout.

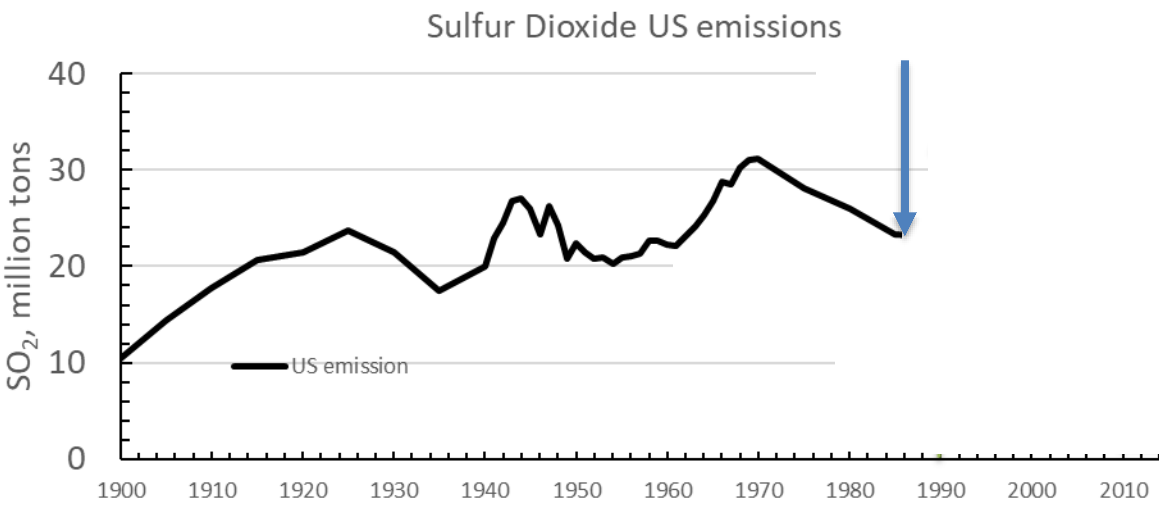
Silicate bedrock: not buffered, low pH, few fish species present, less abundant brook trout.

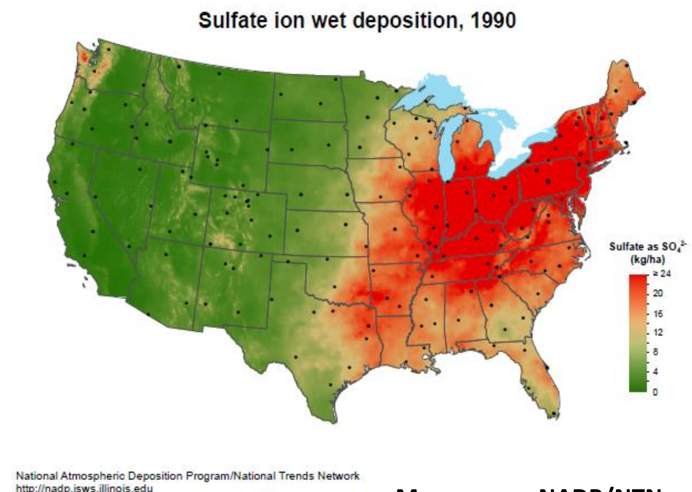




Decadal VTSSS, purpose & history

Acid emission and subsequent deposition has resulted in acidification of many streams in the Eastern US.



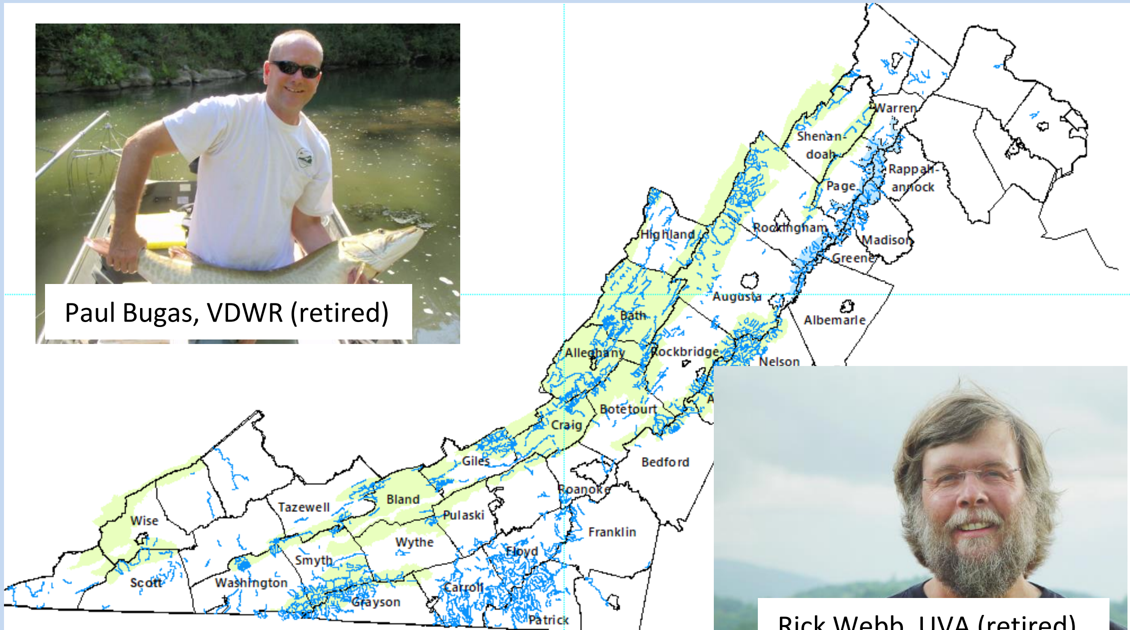


Map source: NADP/NTN

What is the acid/base status of native trout streams throughout Virginia?

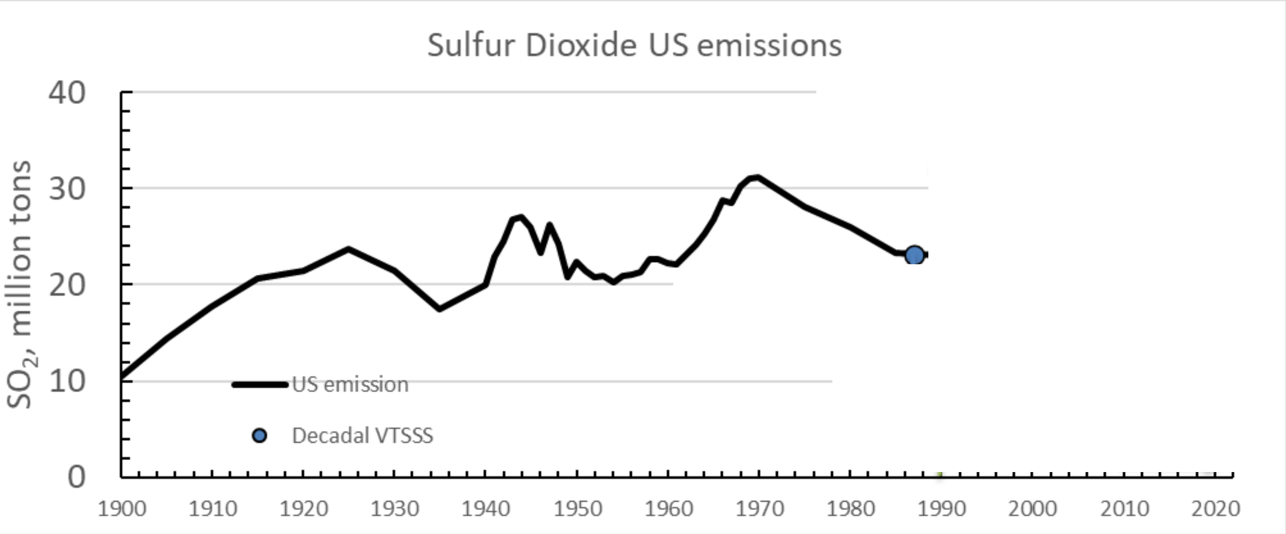
1987 VTSSS – 367 native trout streams assessed for acid/base chemistry in VA mountains by TU, UVA and collaborators

Paul Bugas, VDWR (retired)



Rick Webb, UVA (retired)

Decadal VTSSS, purpose & history



Since passing of the Clean Air Act Amendments of 1990, SO_2 emissions (and deposition) have decreased by ~90%.

VTSSS Surveys were repeated every ~10 years to assess the regional response of streams to emission/deposition reductions.

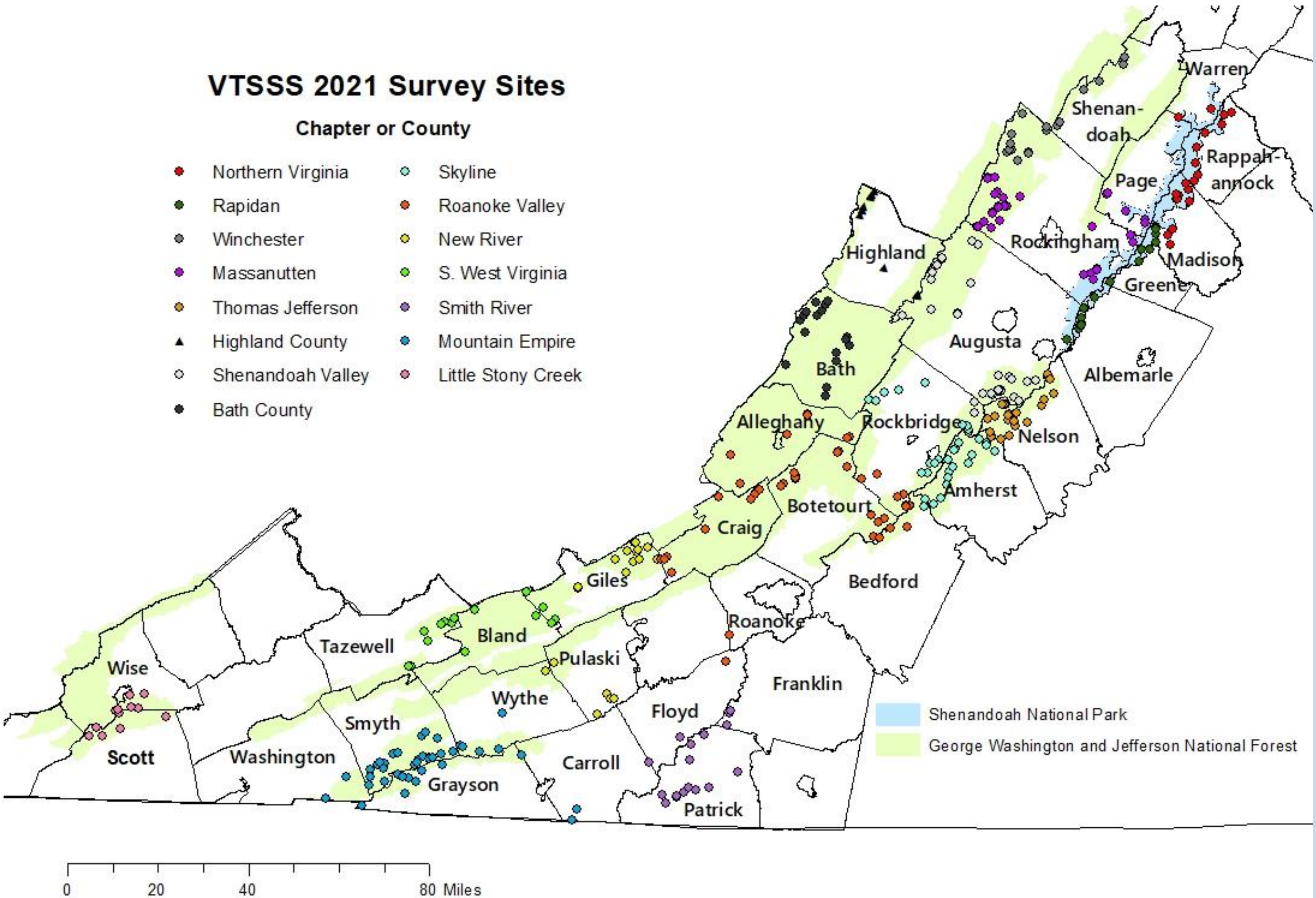
1987 - 367 sites sampled

2000 - 445 sites sampled

2010 - 455 sites sampled

2021 – 454 sites sampled

Volunteer Sample Site Map



Sample Window: Last week of April 2021

VTSSS 2021 sample collection summary

- 1 state TU coordinator: **Tom Benzing**
- Northern VA regional coordinator: Marcia Woolman
- 13 TU Chapters and Coordinators (+ Bath and Highland County)

  - Northern VA – Rob Cain/Chris Rich
  - Rapidan- Amy Orr
  - Winchester- Stan Ikonen
  - Massanutten – Rodney Miner
  - Shenandoah Valley – Tom Benzing
  - Roanoke – Mark Taylor
  - Thomas Jefferson – Chubby Damron
  - Skyline – Steve Romine
  - Smith River – Wayne Kirkpatrick /Eric Tichay
  - Little Stony – Justin Bently
  - Mountain Empire – Heather Davidson
  - New River – Arnold Graboyes
  - Southern WVA – Chris Mullins/Steve Pugh

  Highland/Bath County – Rick Webb/ Ryan Hodges

- **Each Chapter sampled 12-45 sites**
- **155 volunteers, 383 sites** (+ 71 additional quarterly) = 454 sites sampled
- **Volunteer hours reported: 1150 hrs**

Notable Repeat Volunteer Samplers (based on field forms)

2021 TU Chapter	Name	Years sampled (1987, 2000, 2010, 2021)
Rapidan	Andy Holmaas	1987, 2000, 2010, 2021
Roanoke Valley	Jeff Cutright	1987, 2000, 2021
Shenandoah Valley	Doug Stegura	2000, 2010, 2021
Rapidan	Marcia Woolman	2000, 2010, 2021
Smith River	Rusty Lacy	1987, 2021

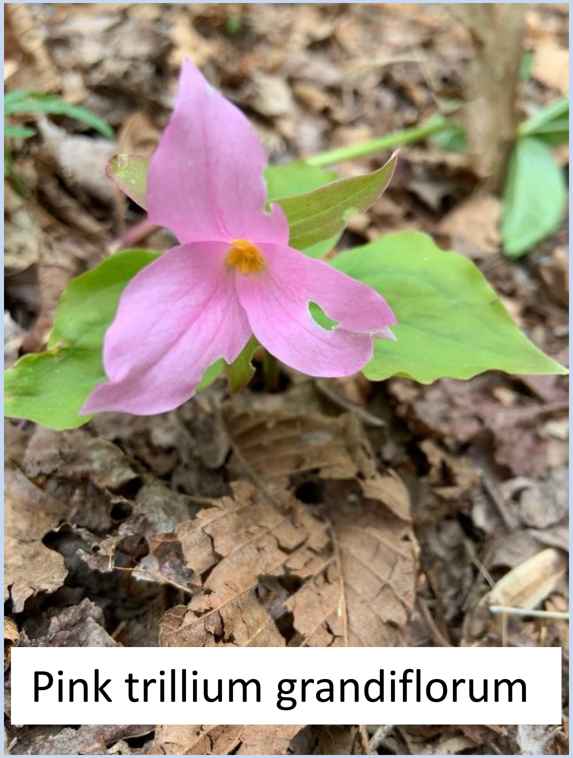
Most Sites Sampled by an individual/family in 2021

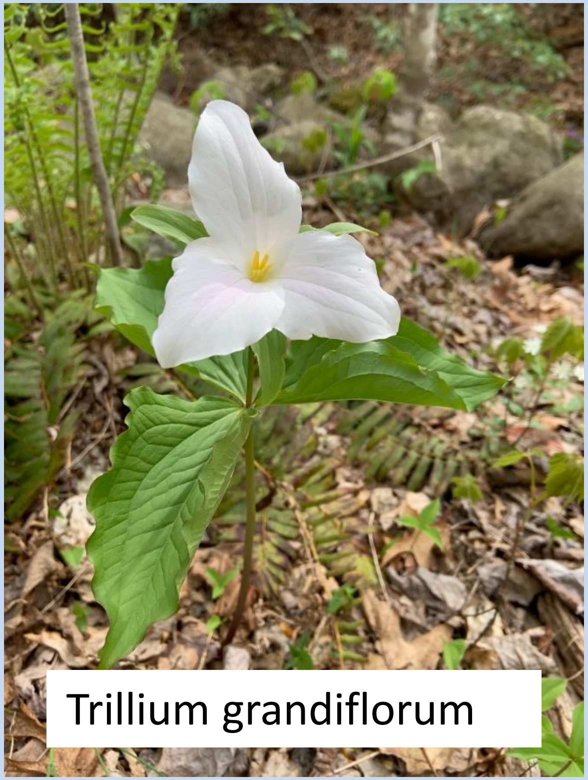
Mountain Empire	Lisa Benish	15 sites!
Thomas Jefferson	Chubby Damron & Jaydon Damron	12 & 2 sites
Mountain Empire	Heather, Kevin, Kaydee Davidson	10 & 9 & 8 sites

VTSSS 2021

Thanks to all those who sampled!

Rob Cain photograph/flower ID





VTSSS 2021

Thanks to all those who coordinated and delivered samples!


Arnold Graboyes, New River

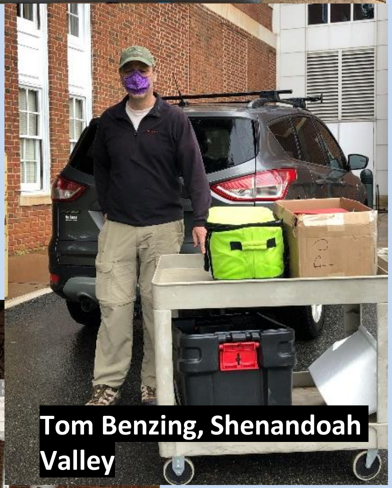

Eric Tichay, Smith River


Mark Taylor, Roanoke Valley


Rodney Minor, Massanutten

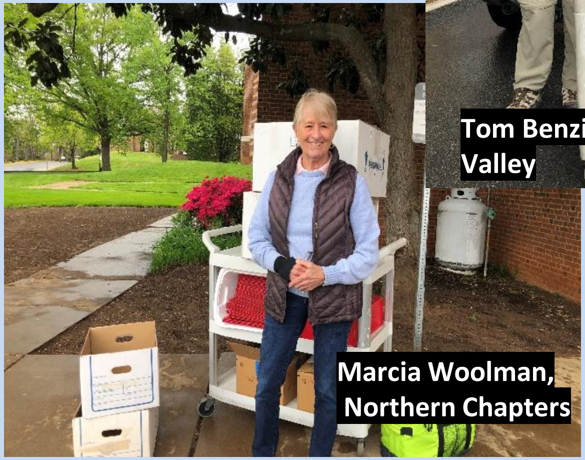

Chubby Damron, TJ


Heather Davidson, Mountain Empire & Little Stony, S. West Va

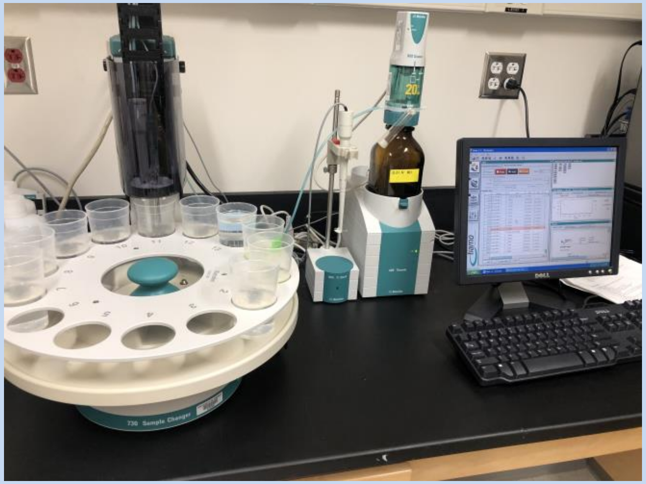

Tom Benzing, Shenandoah Valley


Rick Webb, Highland & Bath County

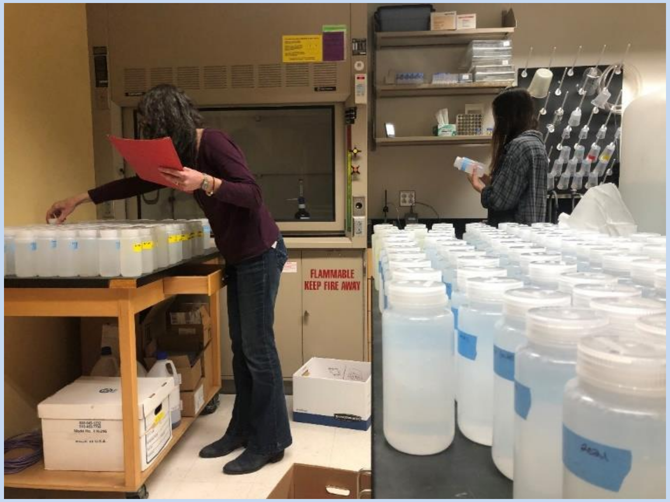

Steve Romine, Skyline


Marcia Woolman, Northern Chapters

Stream chemistry data in this presentation include:



UVa VTSSS Laboratory



Acid-neutralizing capacity (ANC)

- ANC is a general measure of stream sensitivity to acid and is used to classify streams as suitable or unsuitable for Brook Trout

pH

- pH is a more direct measure of current stream conditions and has biological implications

SO_4^{2-}

- Sulfate is the main acidifier from acid deposition

NO_3^-

- Nitrate, also acidifies but typically very low in VA mountain forest streams

Sum of Base Cations (SBC)

- SBC (Calcium + Magnesium+ Sodium+ Potassium)
- Weathering products from bedrock that neutralize acid inputs.

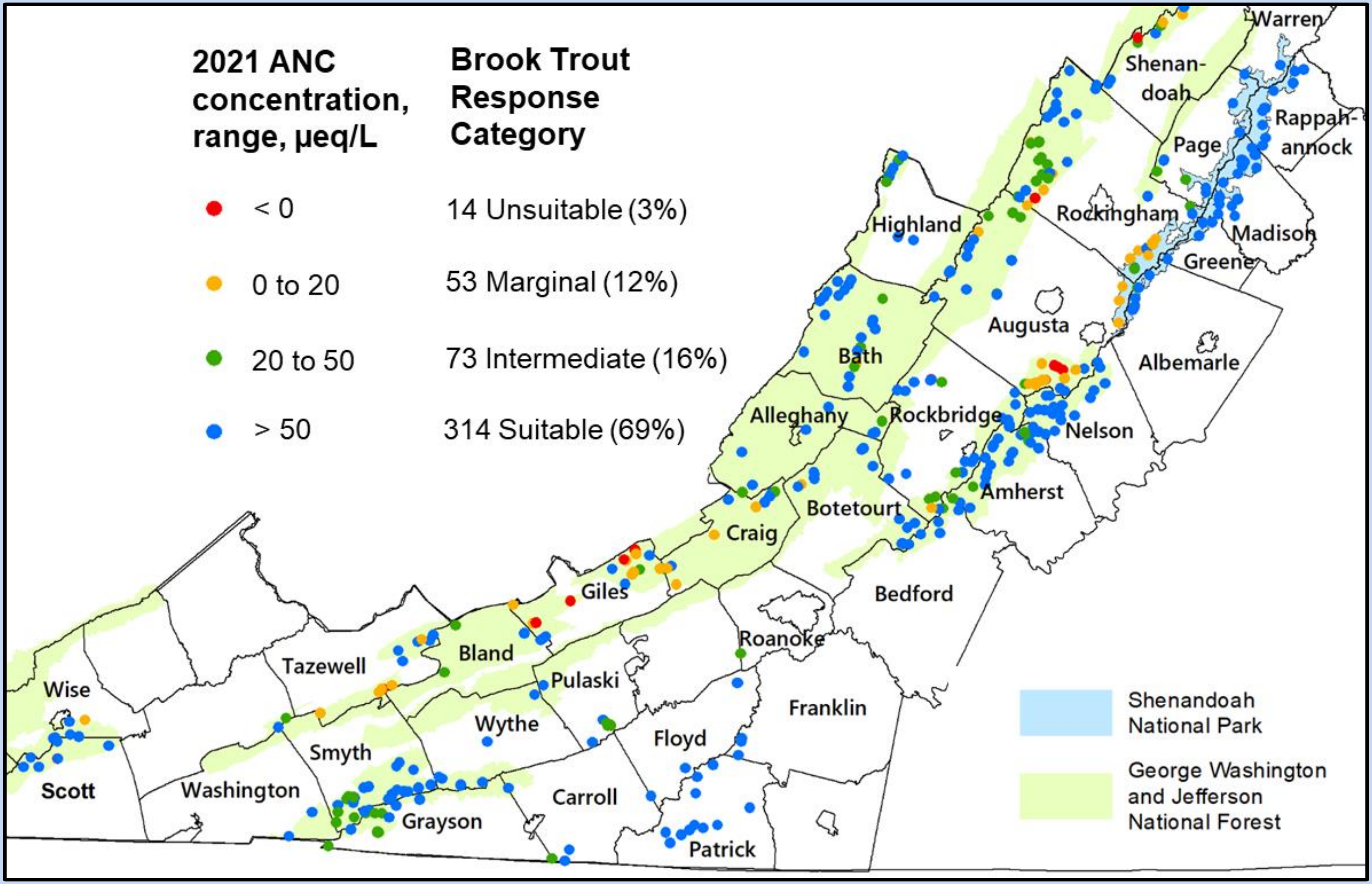
ANC thresholds and Brook Trout response

Response Category	ANC Class	ANC Range µeq/L	Brook Trout Response
Suitable	Not acidic	>50	Reproducing brook trout populations expected where habitat suitable
Indeterminate	Indeterminate	20-50	Extremely sensitive to acidification; brook trout response variable
Marginal	Episodically acidic	0-20	Sub-lethal and/or lethal effects on brook trout possible
Unsuitable	Chronically acidic	<0	Lethal effects on brook trout probable

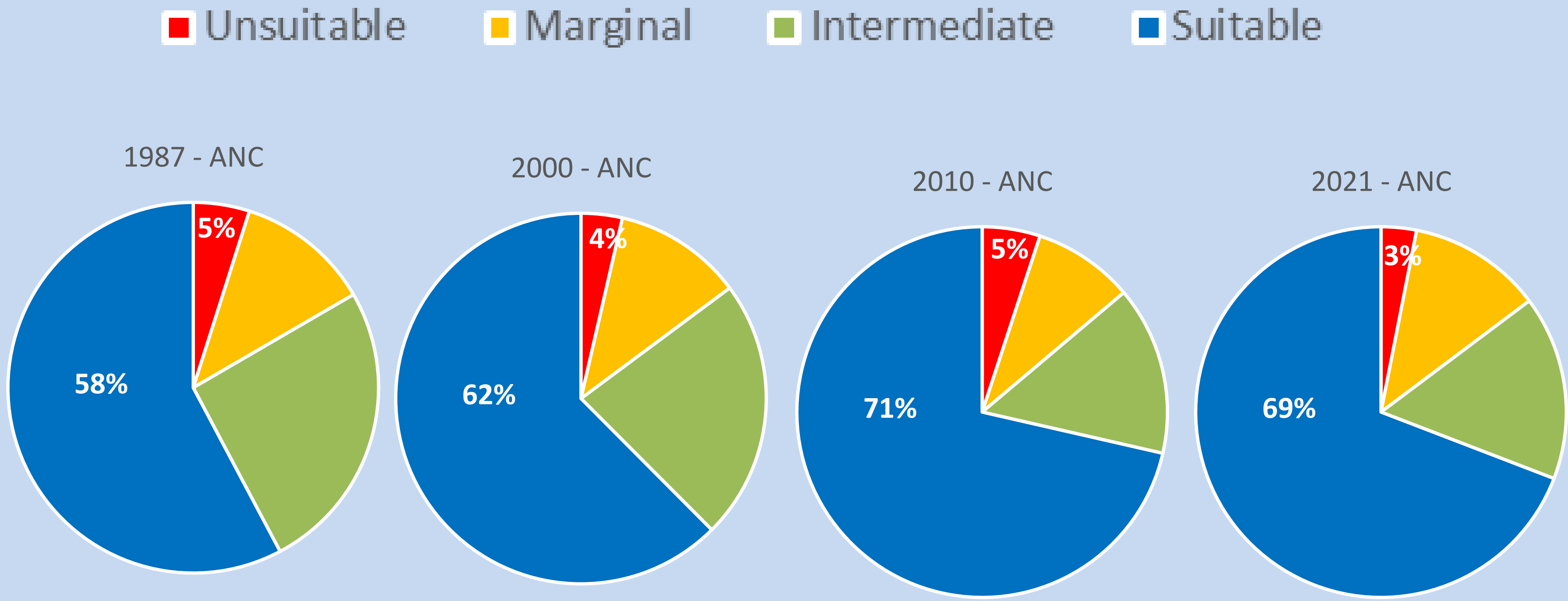
Note: ANC range based on volume-weighted annual mean.

ANC concentrations will be presented by their associated brook trout response category, as listed in the table

2021 Acid Neutralizing Capacity (ANC) by 'response category'



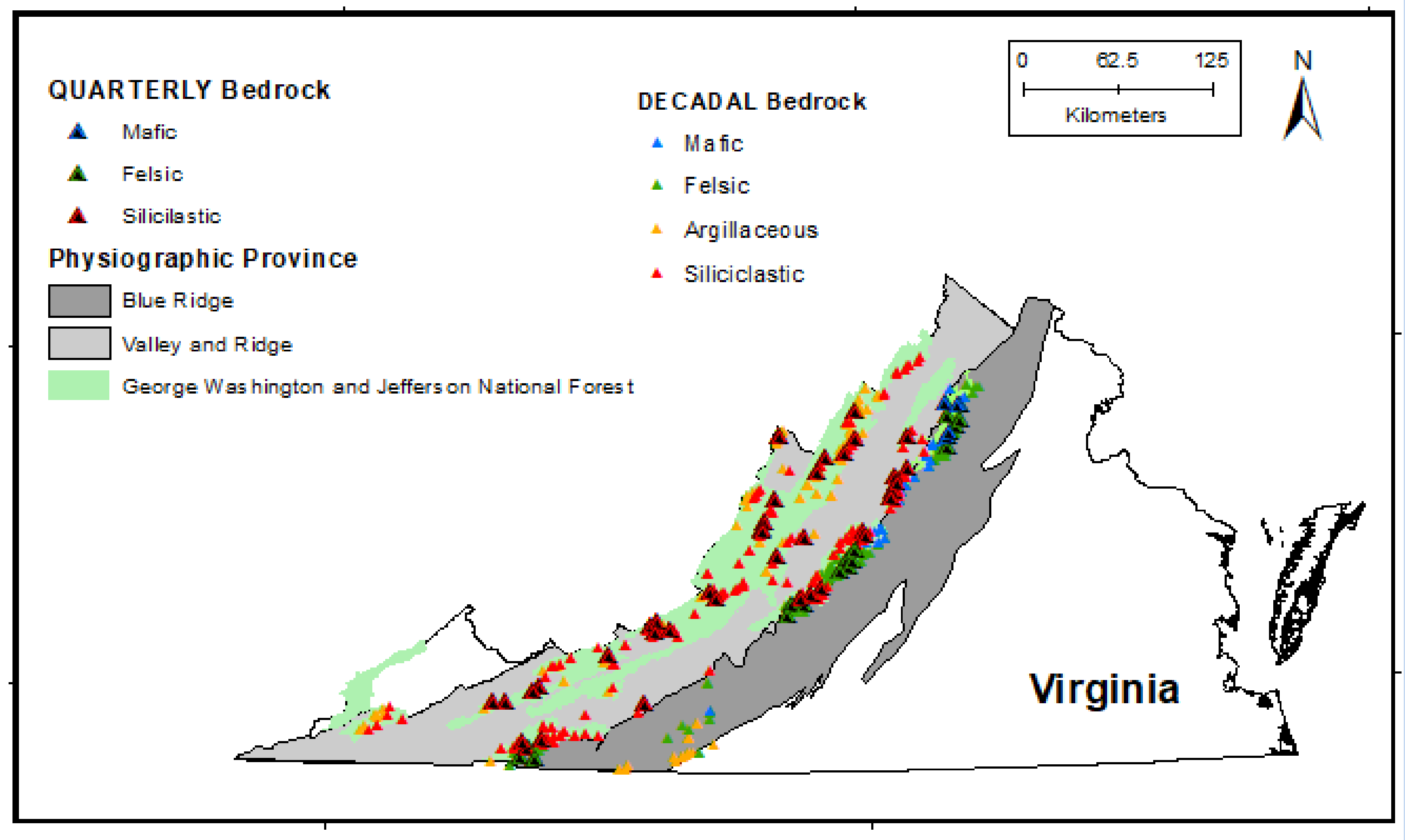
Brook Trout Response Category for each of the VTSSS decadal surveys



	1987	2000	2010	2021
Median ANC	**62**	**69**	**94**	**85**

- We have observed increases in the percentage of sites with suitable habitat, between 1987 and 2021.
- The percent of sites with unsuitable habitat has decreased between 1987 and 2021.

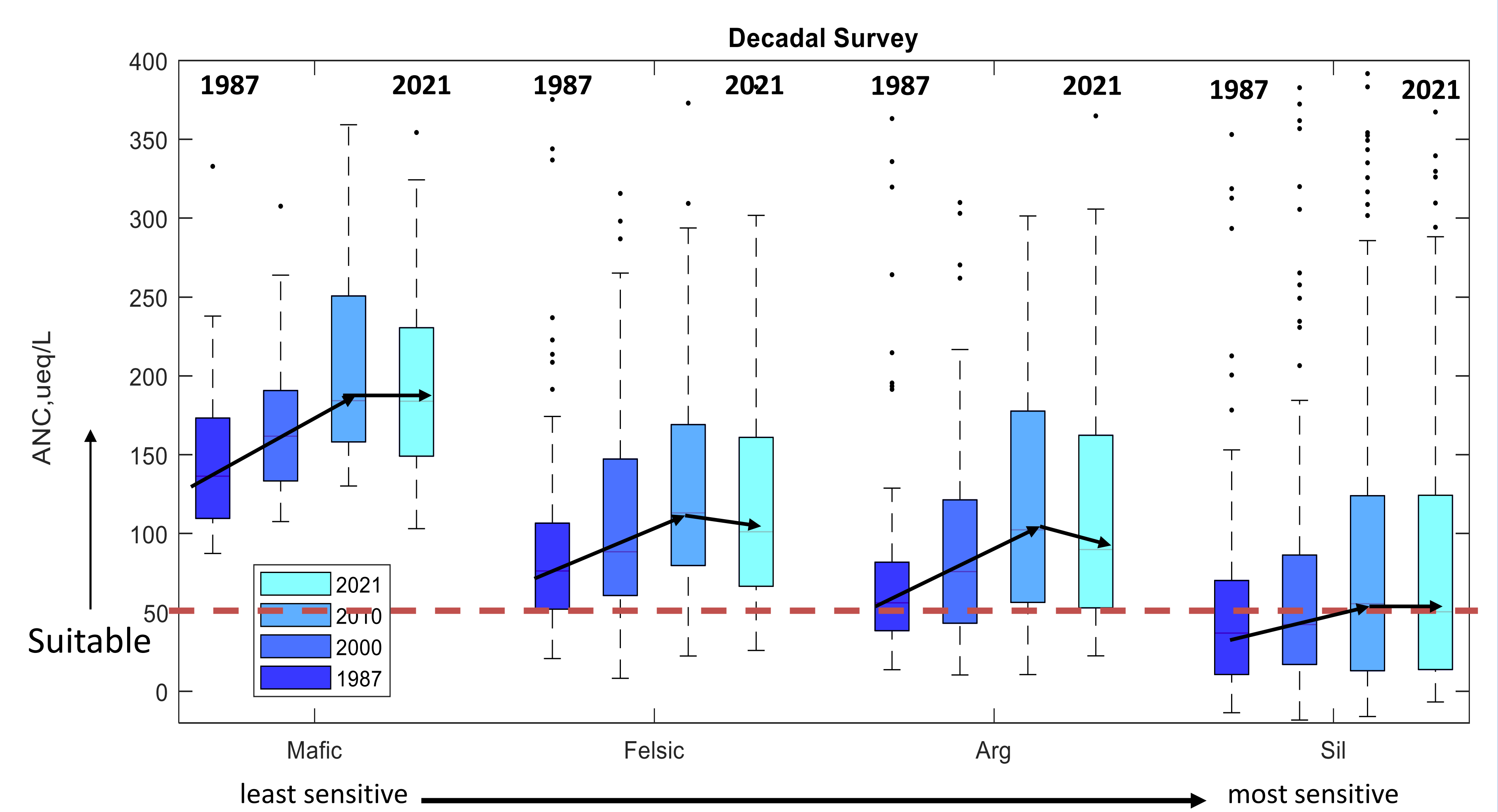
Bedrock class for VTSSS 2021 sites



Some bedrock types can more easily neutralize acids

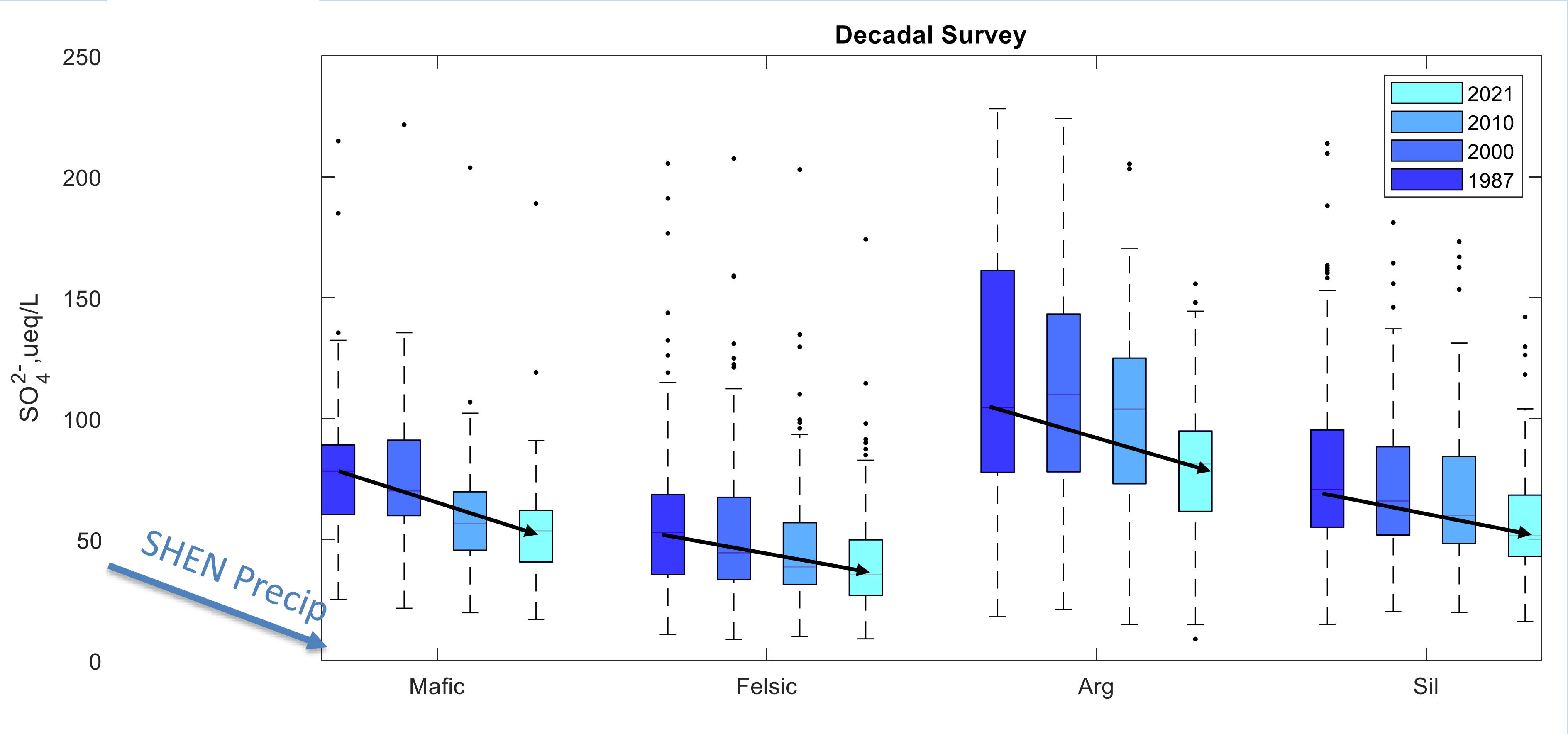
least sensitive	**Mafic** high ANC, not sensitive to acidification	**(29 sites)**
	Felsic	**(104 sites)**
	Argillaceous	**(105 sites)**
most sensitive	**Siliciclastic** low ANC, very sensitive to acidification	**(215 sites)**

ANC, for each survey year, grouped by bedrock



For sites on each bedrock class, we observe improvements in median ANC from 1987-2010, but not between 2010 and 2021.

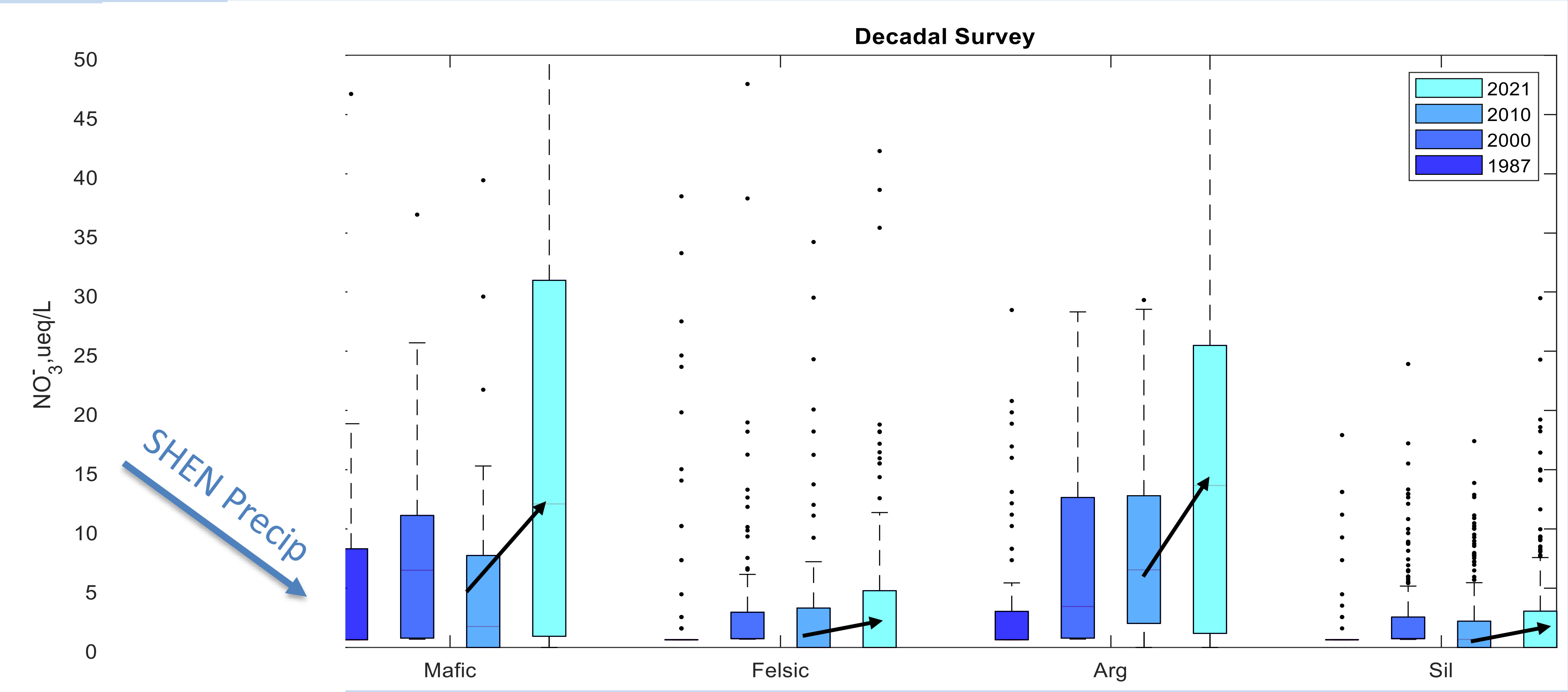
Sulfate, for each survey year, grouped by bedrock



For sites on each bedrock class, we observe improvements (decreases) in median sulfate from 1987 to 2021.

Sulfate decreases in streamwater are more moderate than rainwater (~38 to 3 μeq/L), due to **years of accumulation in soils.**

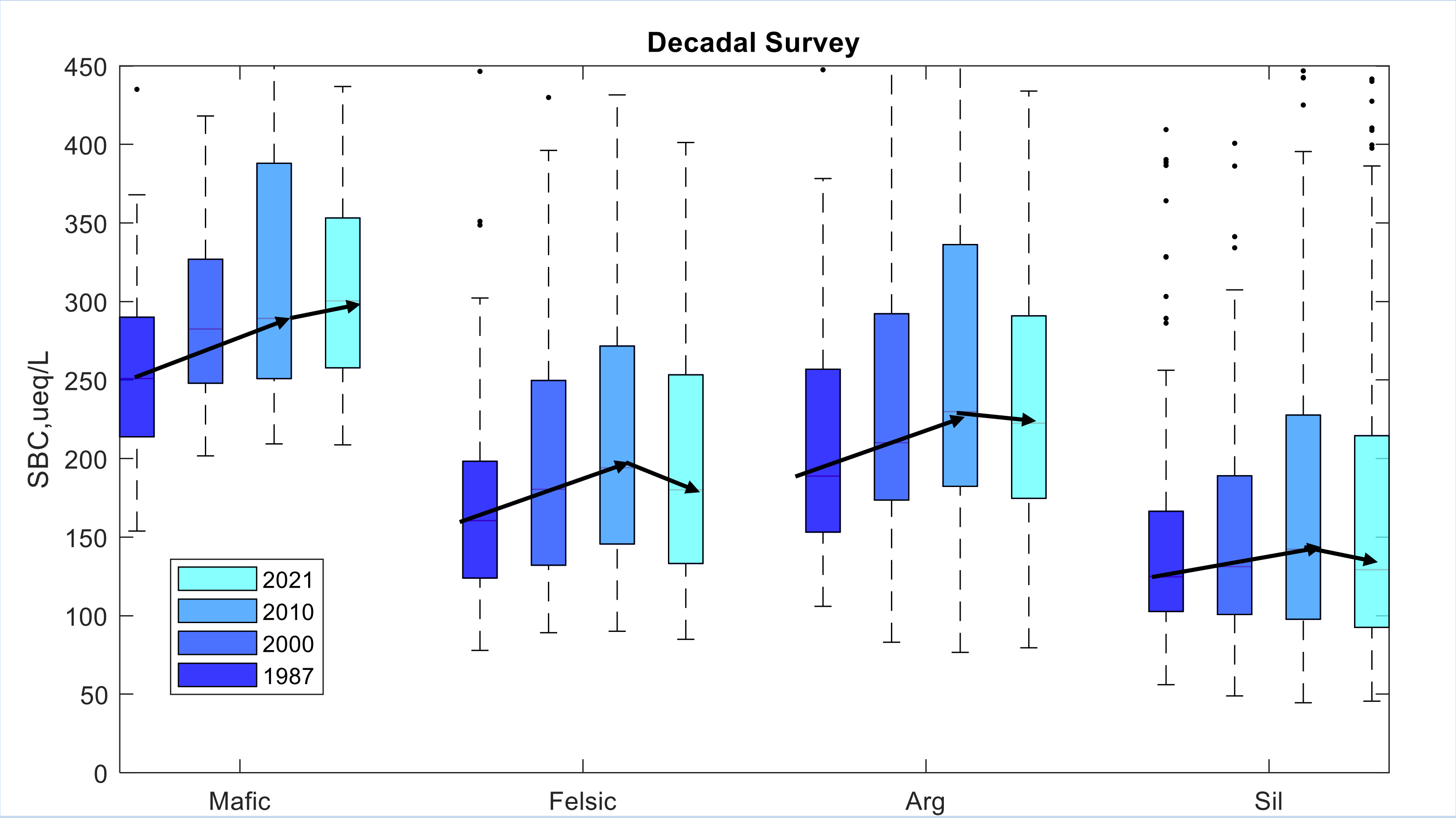
Nitrate, for each survey year, grouped by bedrock



In 2021, increases in nitrate in 2021 (~15 µeq/L) observed. Potential reasons for increase in nitrate include watershed disturbance (e.g., defoliations/pests).

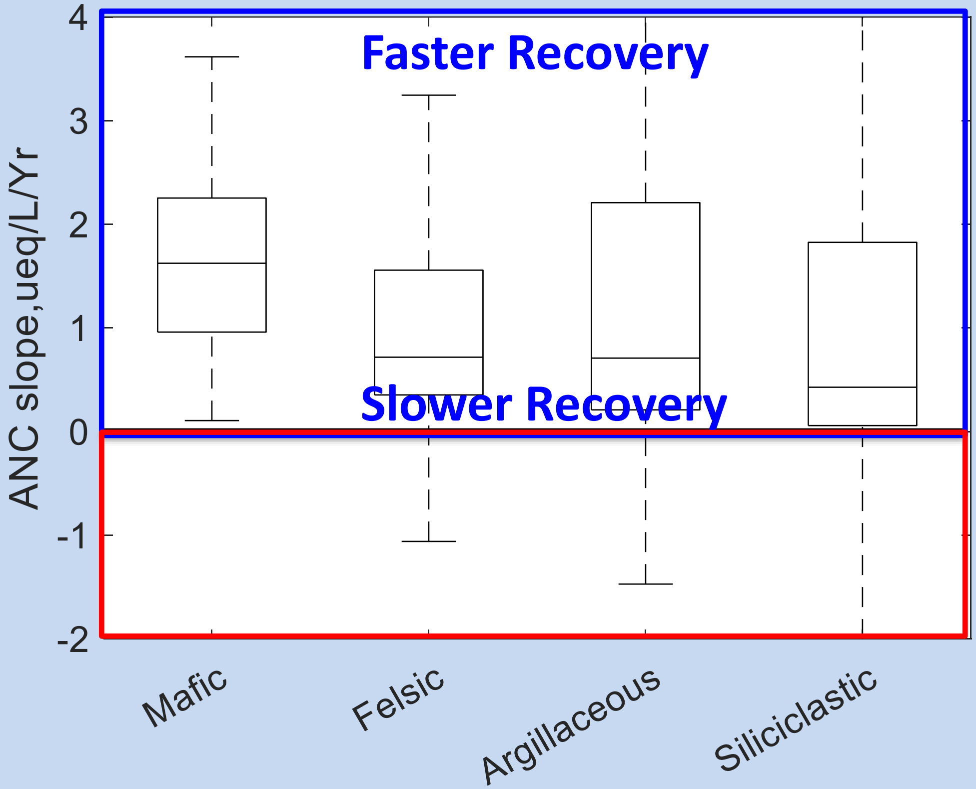
Nitrate concentrations in precipitation in SHEN have decreased between 1987 and 2020, from 16 to 5 µeq/L.

Sum of Base Cations, for each survey year, grouped by bedrock



For sites on each bedrock class, we observe increases in median SBC from 1987-2010, but not from 2010 to 2021 (except Mafic), like ANC trends.

ANC trends, 1987-2021



Median ANC, μeq/L/yr

1.6 0.7 0.7 0.4

The trend in ANC from 1987-2021 indicates a range in recovery rates for individual sites within a bedrock class.

Mafic sites have a greater median increasing rate of ANC.

Do stream chemical trends relate to watershed characteristics?

There is variability in chemical trends over time.

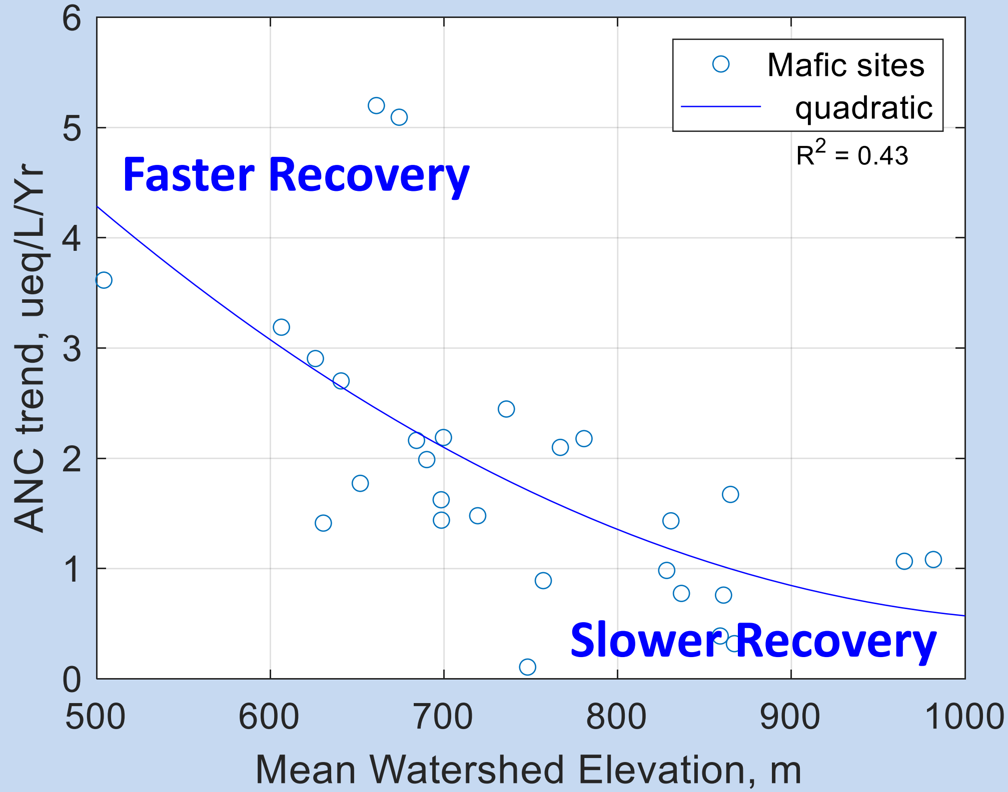
Is there a relationship to watershed characteristics?

<u>Watershed Characteristics</u>

Latitude
Longitude
Area
Mean Leaf Area Index
Mean Annual Precipitation
Min elevation
Max elevation
Mean elevation
Mean Slope
Mean Aspect (east/west and north/south)
% Forest Cover

Lower elevation sites are recovering faster

Mean/Max watershed elevation is the most consistent predictor variable for trends for all sites and individual bedrock groupings.

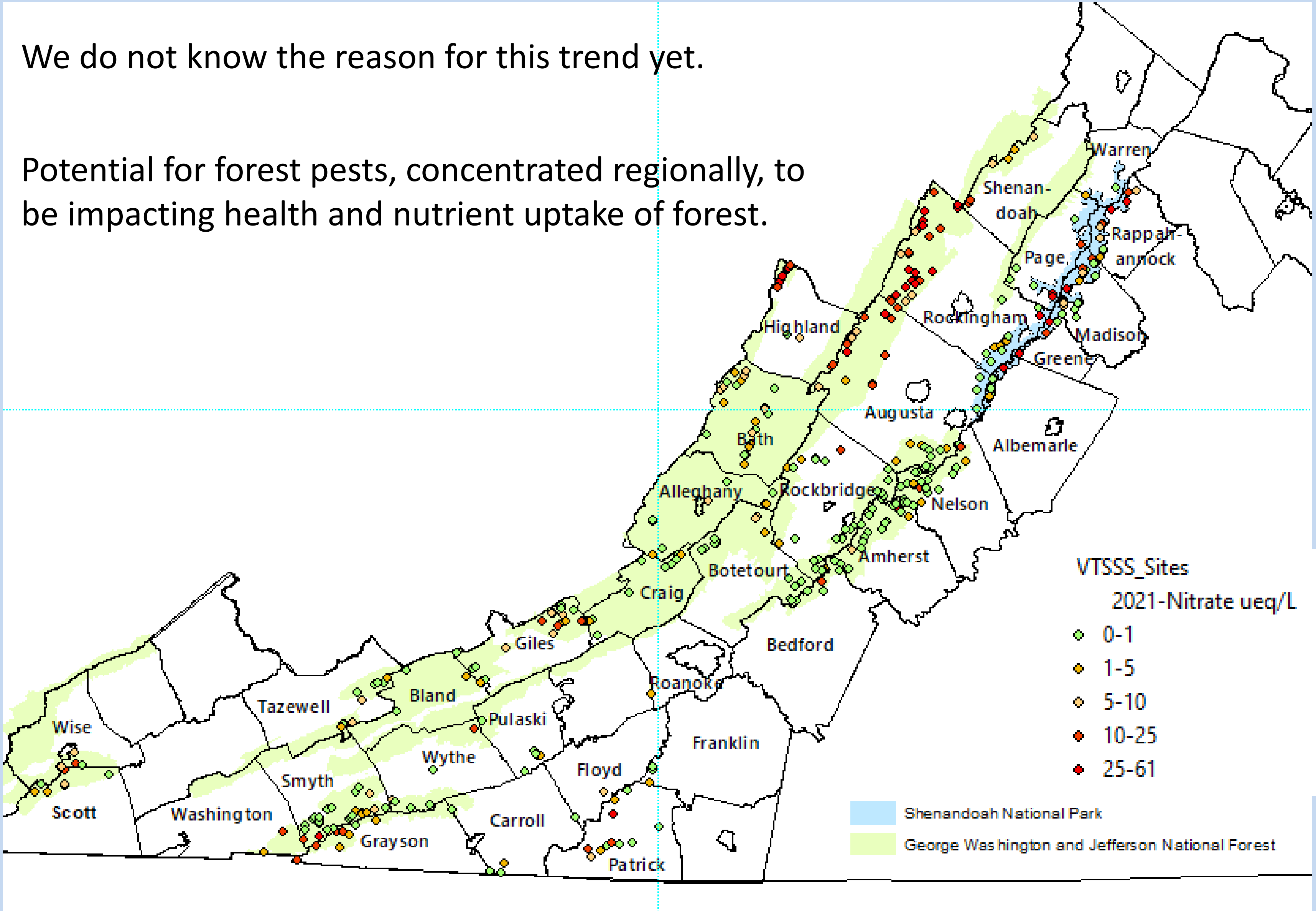


Nitrate trends – relationship to watershed characteristics

There is a strong significant relationship between nitrate trends and watershed Latitude. Northern sites had greater increases in nitrate.

We do not know the reason for this trend yet.

Potential for forest pests, concentrated regionally, to be impacting health and nutrient uptake of forest.



Summary

Chemical conditions (ANC) in Appalachian mountain streams that support native brook trout have improved for the majority of sites (~86%) between 1987 and 2021.

Declines in stream water sulfate concentrations, driven by emission regulations initiated with the 1990 Clean Air Act Amendments, contribute to improvements in stream chemistry.

Sites with mafic bedrock and those at lower elevations are recovering at a faster rate.

Despite improvements, only 69% of streams have ANC levels that are consistently ‘suitable’ for brook trout.

Data dissemination

Environmental Protection Agency – Clean Air Markets Division, assesses response to acid rain in US
Virginia Department of Environmental Quality

National Park Service –Evan Childress, supervisory fisheries biologist
U.S. Forest Service – Dawn Kirk, fisheries biologist for GW and Jefferson NF
Virginia Department of Wildlife Resources – Steve Reeser, fisheries biologist

Public, via the SWAS-VTSSS website and federal database (Water Quality Portal)

Regulators

United States Environmental Protection Agency

Virginia Department of Environmental Quality

Resource Managers and Scientists

Public

- Teachers
- Students
- Citizen scientists
- Fisherman
- …

SWAS-VTSSS Mountain Stream Database

https://swas.evsc.virginia.edu/POST/scripts/overview.php

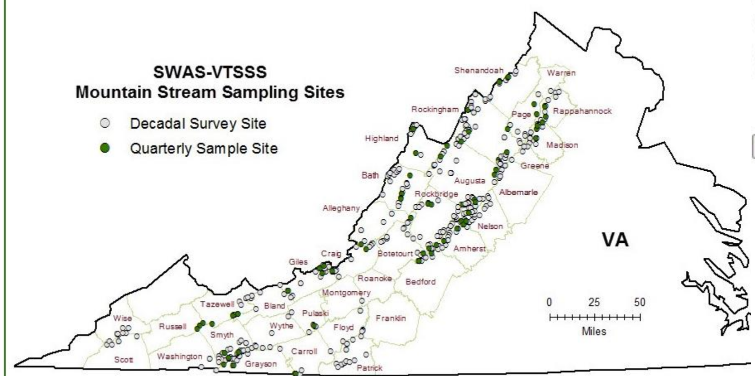
Shenandoah Watershed Study & Virginia Trout Stream Sensitivity Study

Overview | Mountain Stream Database | Documents | Program Team | Cooperators | VTSSS 2021

VA counties with sampling sites
Select county below and press submit.

- Albemarle
- Alleghany
- Amherst
- Augusta
- Bath
- Bedford
- Bland
- Botetourt
- Carroll
- Craig
- Floyd
- Franklin
- Giles
- Grayson
- Greene
- Highland
- Madison
- Nelson
- Page
- Patrick
- Pulaski
- Rappahannock
- Roanoke
- Rockbridge
- Rockingham

Submit

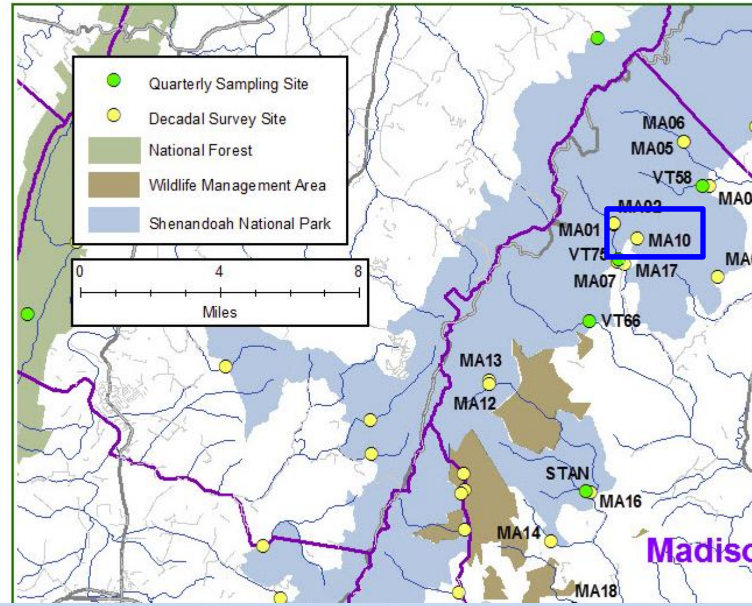


Madison County
Select option below and press submit.

- Survey sample data
- Quarterly sample data
- Graphical data display
- Sample site information
- Stream names and detailed site-location maps

Submit

List and map of counties



Shenandoah Watershed Study & Virginia Trout Stream Sensitivity Study

Overview | Mountain Stream Database | Documents | Program Team | Cooperators | VTSSS 2021

Madison County
Select site(s) below for survey data and press submit.

- [ ] MA01: White Oak Canyon
- [ ] MA02: Tims River
- [ ] MA03: Ragged Run
- [ ] MA04: Brokenback Run
- [ ] MA05: Hannah Run
- [ ] MA06: Hughes River
- [ ] MA07: Cedar Run
- [x] MA10: Berry Hollow

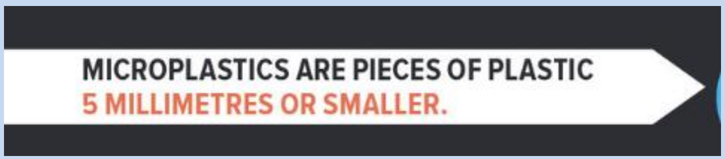
List and map of counties | List of available info and site map for Madison County
Excel file | Descriptions of methods and water quality measurements

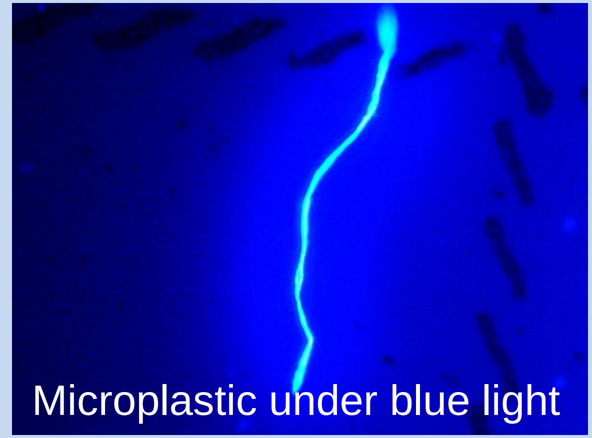
Headings	Measurements	Units
ANC	acid neutralizing capacity	µeq/L
pH	hydrogen ion	pH
Cond	specific conductance	µS/cm
Temp	water temperature	°C
SO_4^{2-}	sulfate	µeq/L
NO_3^-	nitrate	µeq/L
Cl^-	chloride	µeq/L
Ca^{2+}	calcium ion	µeq/L

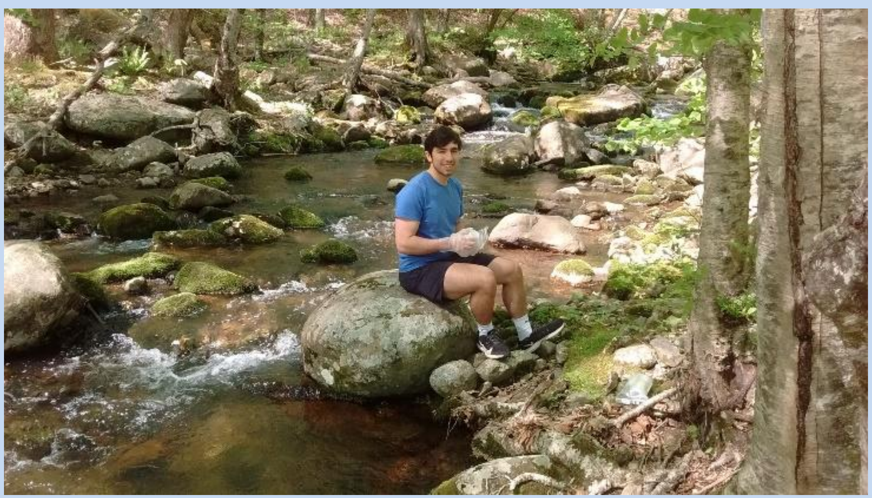
Site	Stream	Date	ANC	pH	Cond	SO_4^{2-}	NO_3^-	Cl^-	Ca^{2+}	Mg^{2+}	K^+	Na^+	SiO_2
MA10	Berry Hollow	1987-04-25	41.98	6.4	19.3	91.23	0.65	25.85	64	36	10.43	63.6	
MA10	Berry Hollow	2000-04-24	52.08	6.1	21.93	92.41	0.73	25.36	59.63	38.52	10.28	71.72	162.4
MA10	Berry Hollow	2010-04-24	111.37	6.7	20.5	45.04	0	26.43	56.37	31.72	16.5	78.19	180.0
MA10	Berry Hollow	2021-04-24	100.62	6.8	19.6	44.38	0	21.7	52	30.07	15.17	74.32	174.4

Looking towards the future environment…

Emerging threat: Microplastics




Microplastic under blue light

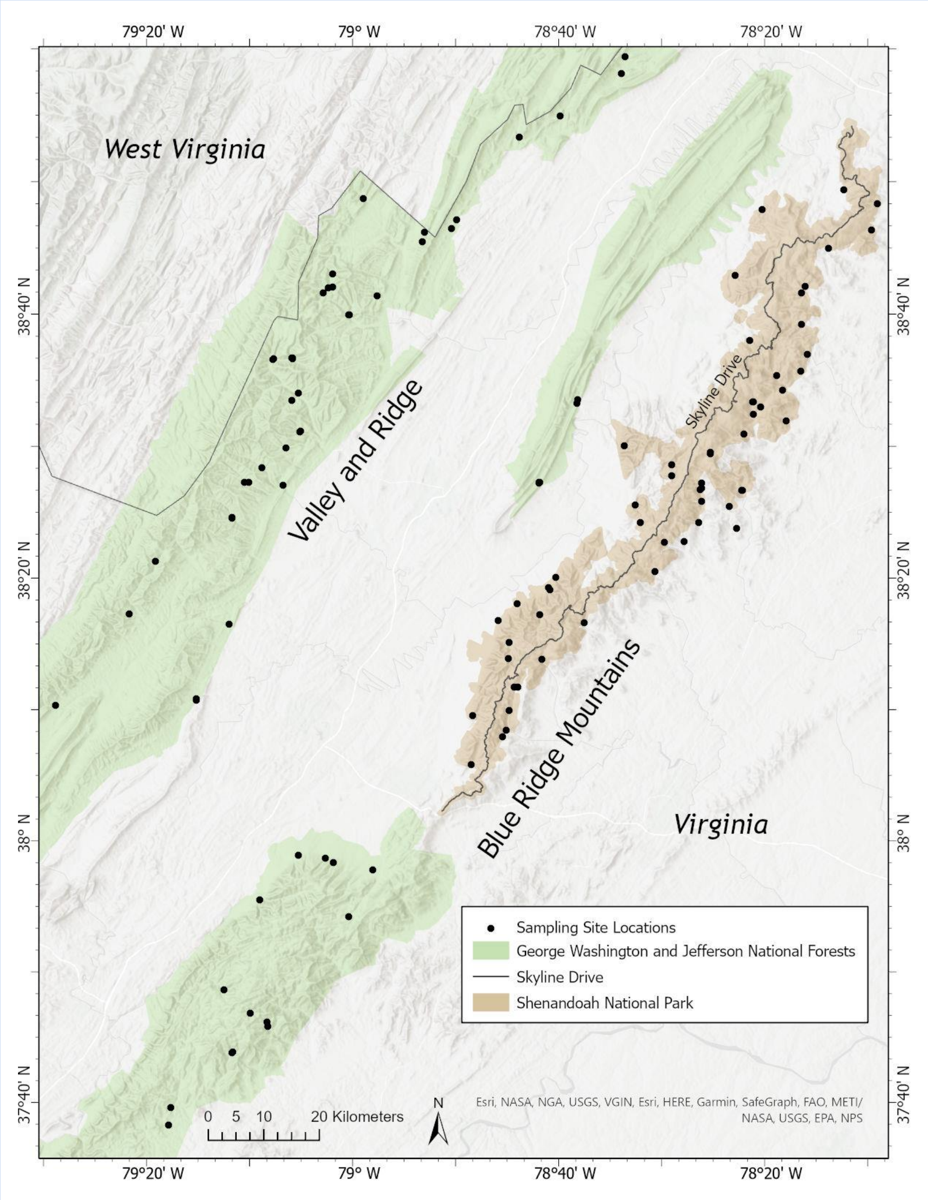


Matthew Zaragoza, 4th-year UVA student

<u>Biological effects on fish:</u>

- Accumulates in digestive track and liver
- Obstructs gills
- Increase mercury bioaccumulation
- Prevent nutrient assimilation
- Carriers for organic pollutants, heavy metals, pesticides, and harmful pathogens

Emerging threat: Microplastics



Sampling added to VTSSS in 2021.

<u>Results</u>

194 samples collected

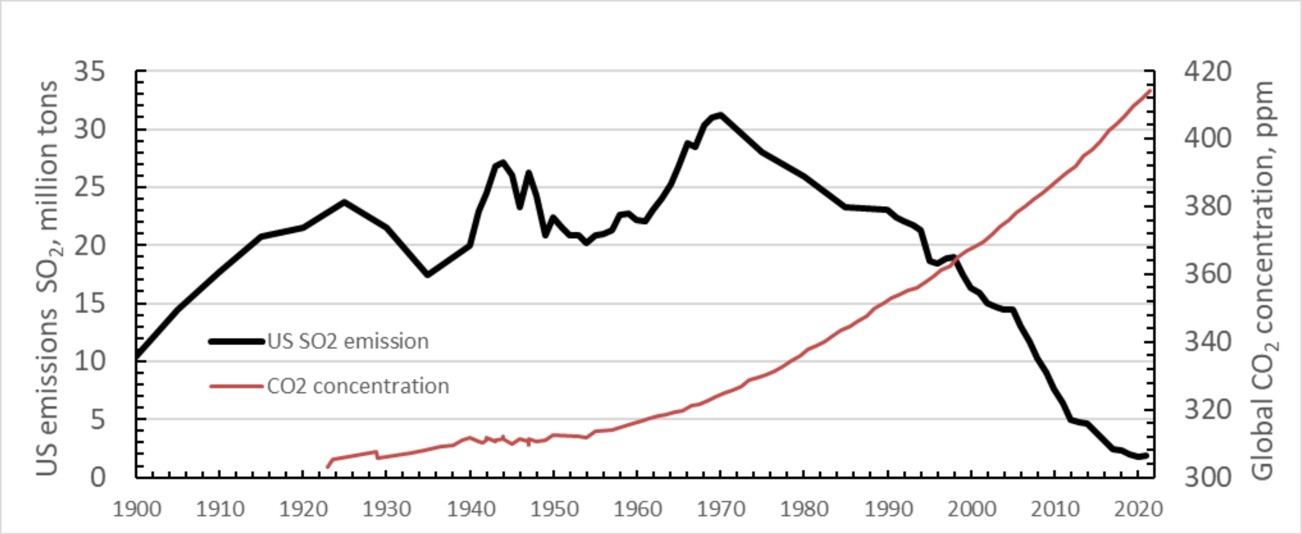
122 stream samples analyzed

23% have microplastics in a 1L sample

~0.26 microplastic pieces per L in VA mountain streams

BASELINE DATA important to understanding future changes

Multiple Environmental Stressors: a changing climate combined with slow recovery from acid emission/deposition



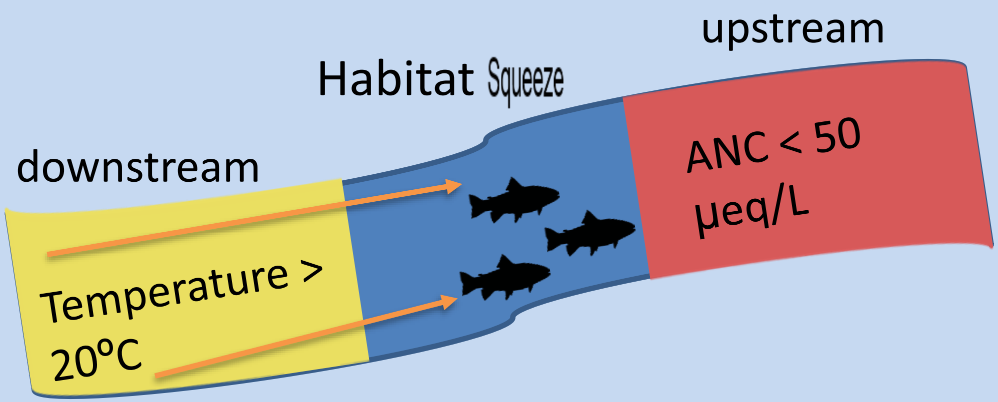
The brook trout's very name reflects its vulnerability. "Fontinalis" means "of the springs," revealing the species' reliance on cool, clear water to survive.

Increasing stream temperature

- caused by increasing air temperature
- caused by a decrease in stream shading

Projections for a changing climate

- Downstream warming and headwater acidity may diminish cold water habitat (McDonnell *et al.* 2015)
  - 2 -4°C air temperature increase = 6%- 10% reduction in cold water habitat in SE US forests



- Changes in streamflow may have mixed effects (*Blum et al.* 2019)
  - Increased fall and summer baseflows are beneficial
  - Higher intensity storms may harm eggs and juveniles in winter and spring

Thank you for participating and listening!

And thank you to our funders (47.1K raised)

Appalachian Stewardship foundation

DEQ Virginia Department of Environmental Quality

Virginia DWR

Individual donations!

EPA United States Environmental Protection Agency

UVA ARTS & SCIENCES

DEPARTMENT OF ENVIRONMENTAL SCIENCES