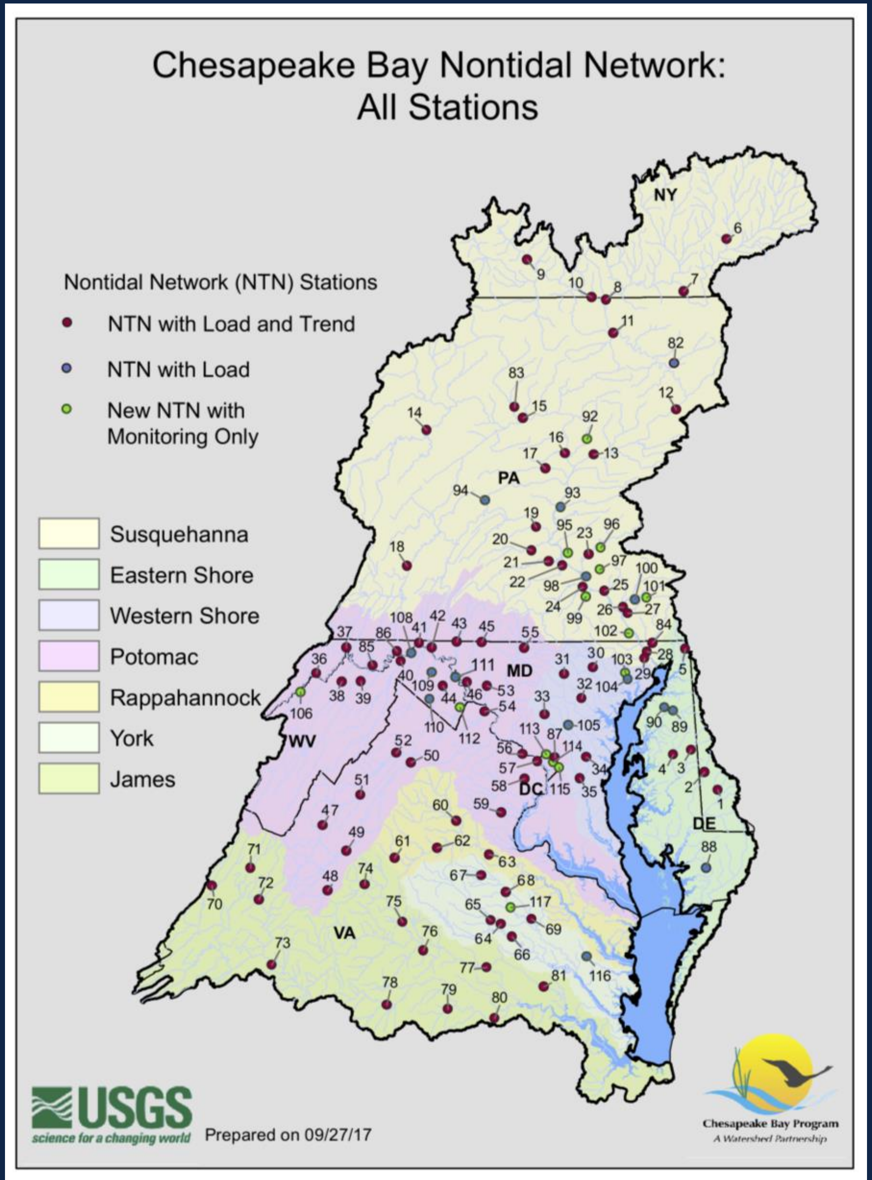
Tracking Status and Trends in Seven Key Indicators of River and Stream Condition in the Chesapeake Bay Watershed

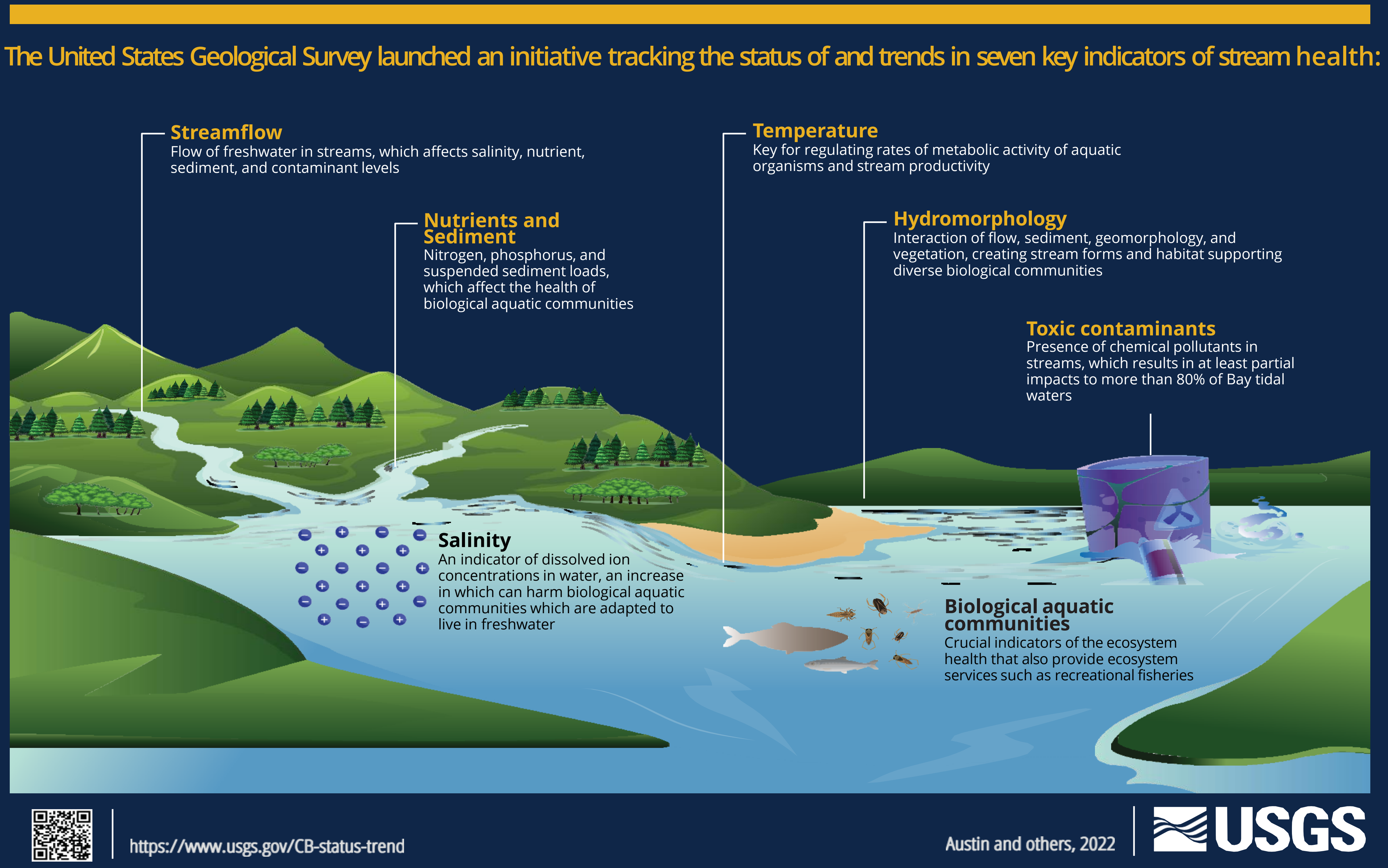
Presenters: Rosemary M. Fanelli and Lindsey J. Boyle

USGS



Chesapeake Bay Nontidal Network:

- Collaborative effort between the USGS, EPA, bay States, District of Columbia, and the Susquehanna River Basin Commission
- At 123 stations across the watershed, water quality data is assembled to estimate nutrient and sediment loads (mass passing a gaged nontidal location per unit time) and trends in loads over time
- Consistent standardized methods for data collection and trend analysis

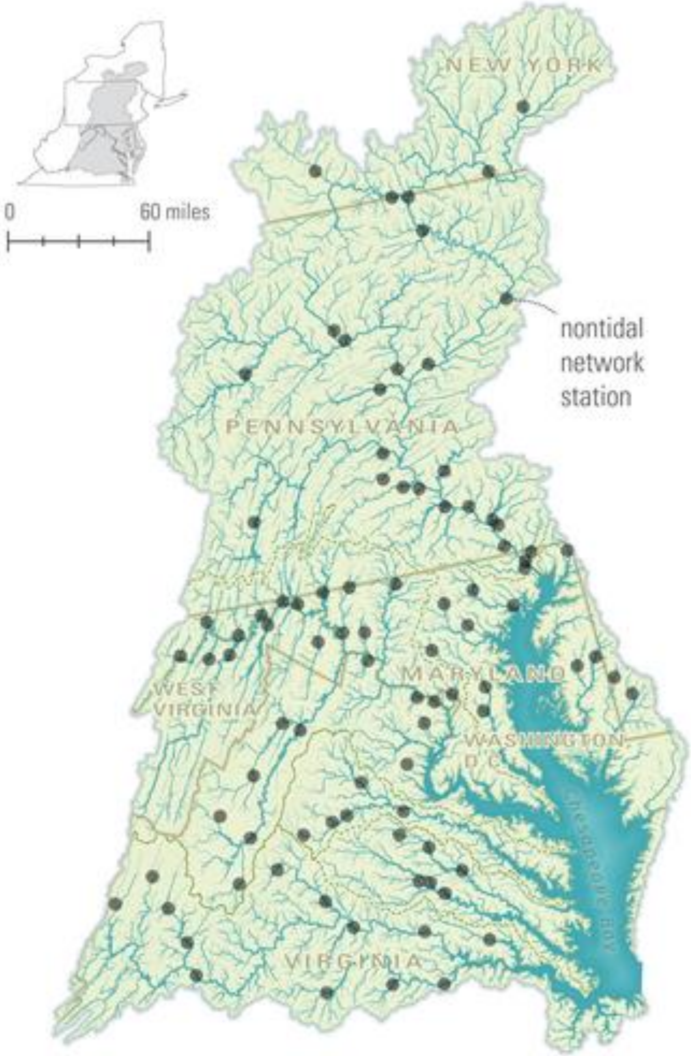


The United States Geological Survey launched an initiative tracking the status of and trends in seven key indicators of stream health:
Streamflow
Flow of freshwater in streams, which affects salinity, nutrient, sediment, and contaminant levels
Nutrients and Sediment
Nitrogen, phosphorus, and suspended sediment loads, which affect the health of biological aquatic communities
Temperature
Key for regulating rates of metabolic activity of aquatic organisms and stream productivity
Hydromorphology
Interaction of flow, sediment, geomorphology, and vegetation, creating stream forms and habitat supporting diverse biological communities
Toxic contaminants
Presence of chemical pollutants in streams, which results in at least partial impacts to more than 80% of Bay tidal waters
Salinity
An indicator of dissolved ion concentrations in water, an increase in which can harm biological aquatic communities which are adapted to live in freshwater
Biological aquatic communities
Crucial indicators of the ecosystem health that also provide ecosystem services such as recreational fisheries
https://www.usgs.gov/CB-status-trend
Austin and others, 2022
USGS

Nutrients and Sediment

Purpose

Christopher A. Mason and Douglas L. Moyer



- **Observe:**
  - Monitor nutrient and sediment conditions at 123 monitoring stations throughout the Chesapeake Bay Watershed Nontidal Network (NTN).
- **Compute:**
  - Compute loads, and trends in flow-normalized loads, every year at the nine River Input Monitoring locations and every two years at the 123-site NTN.

Mason, C.A., Colgin, J.E., and Moyer, D.L., 2023, Nitrogen, phosphorus, and suspended-sediment loads and trends measured at the Chesapeake Bay Nontidal Network stations: Water years 1985-2020 (ver. 2.0, January 2023): U.S. Geological Survey data release, https://doi.org/10.5066/P96H2BDO.

USGS

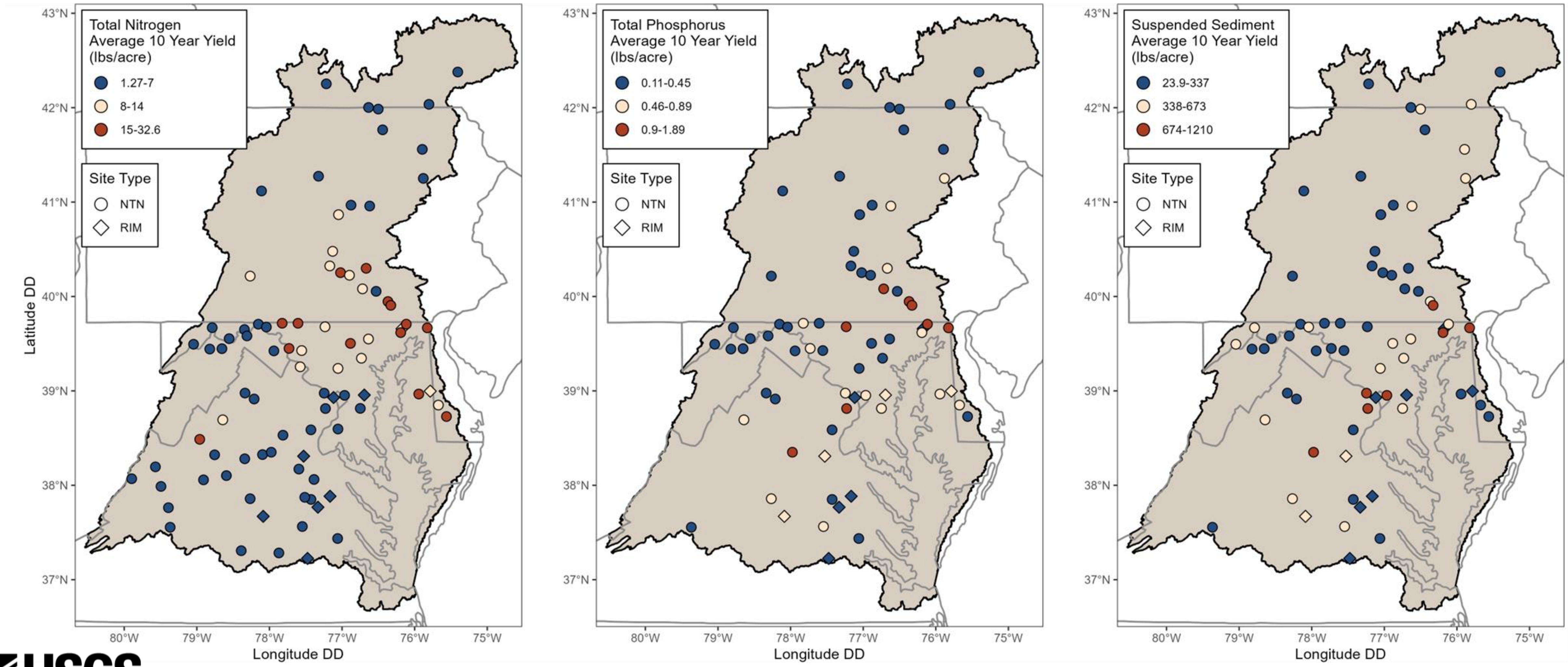
Nutrients and Sediment — Data/Site Criteria

- **Streamflow:**
  - USGS National Water Information System (NWIS) daily-value (DV) data from 70-89 gaged sites with complete years of continuous streamflow record from October 1, 1984 to September 30, 2020.
- **Total Nitrogen:**
  - Discrete field sampling from 89 sites. At least 20 samples per year, with at least 8 high-flow targeted samples. All results are lab-derived.
- **Total Phosphorus:**
  - Discrete field sampling from 70 sites. At least 20 samples per year, with at least 8 high-flow targeted samples. All results are lab-derived.
- **Suspended Sediment:**
  - Discrete field sampling from 70 sites. At least 20 samples per year, with at least 8 high-flow targeted samples. All results are lab-derived.

Nutrients and Sediment

Status

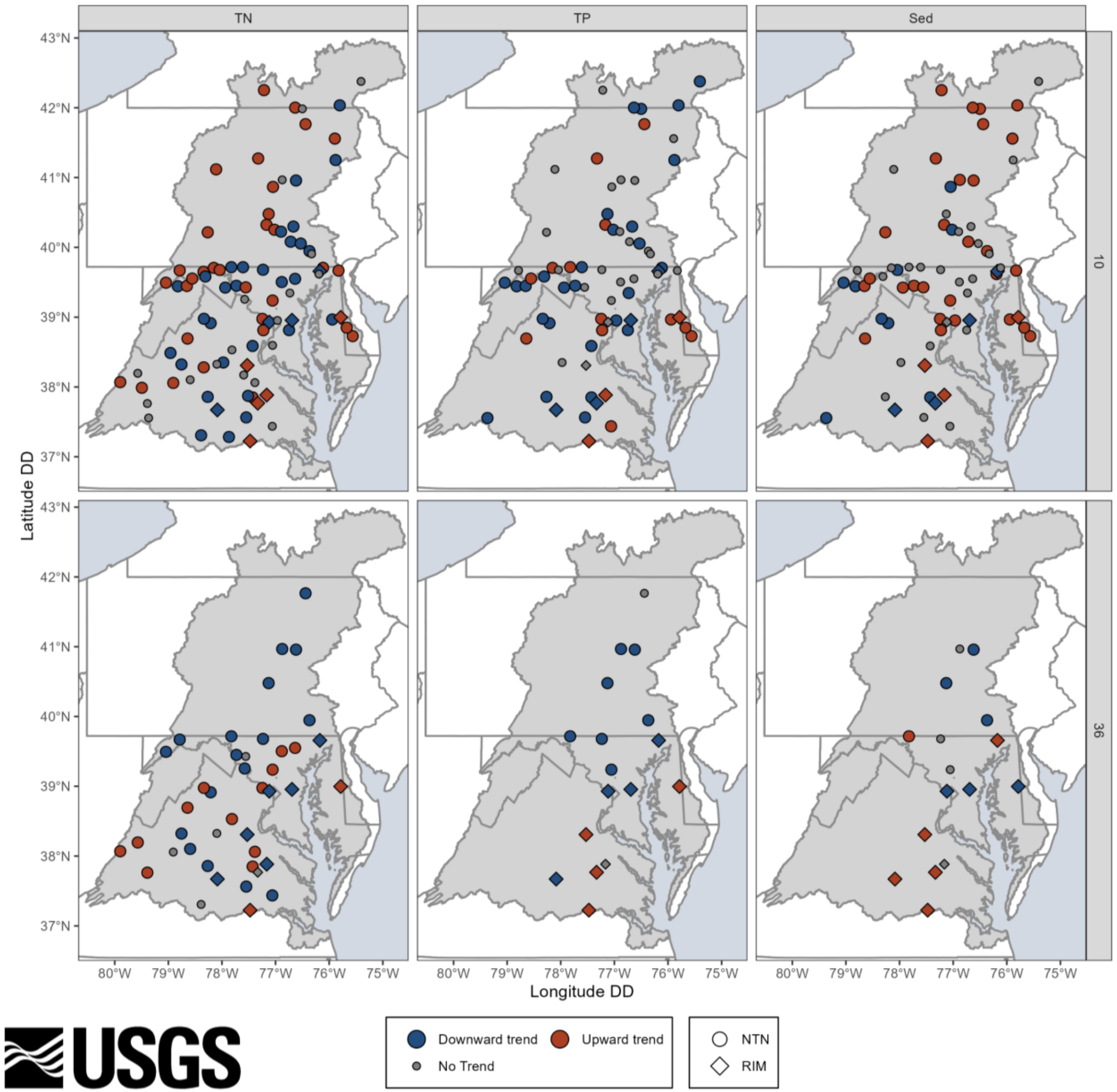
10 Year Average Yield 2011-2020



USGS

Preliminary data, not for citation or distribution

Nutrients and Sediment — Trends



Trends in flow normalized loads using Weighted Regression on Time, Discharge and Season (WRTDS)

	Metric	Percent Improving	Percent Degrading	Percent No Trend
10 Year (2011-2020)	Total Nitrogen	38	42	20
	Total Phosphorus	44	23	33
	Suspended Sediment	19	46	35
36 Year (1985-2020)	Total Nitrogen	55	34	11
	Total Phosphorus	67	22	11
	Suspended Sediment	39	39	22

USGS

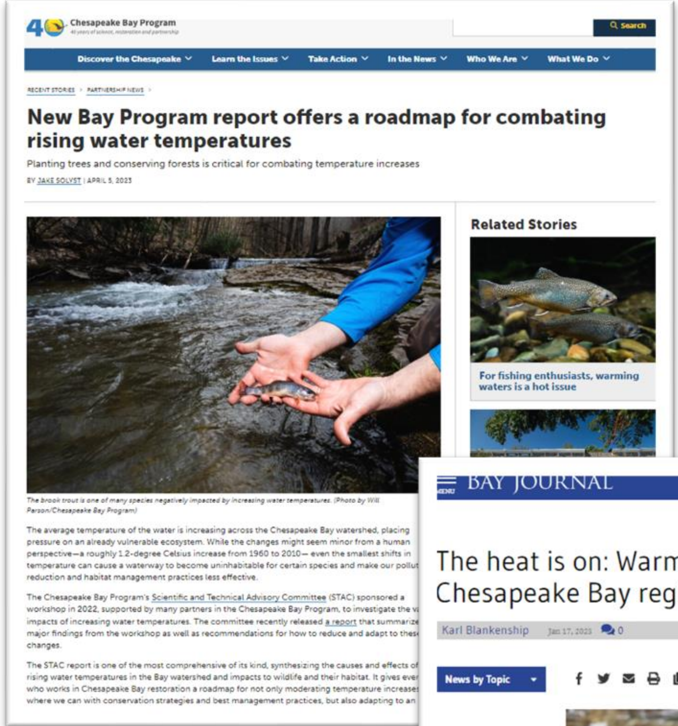
Preliminary data, not for citation or distribution

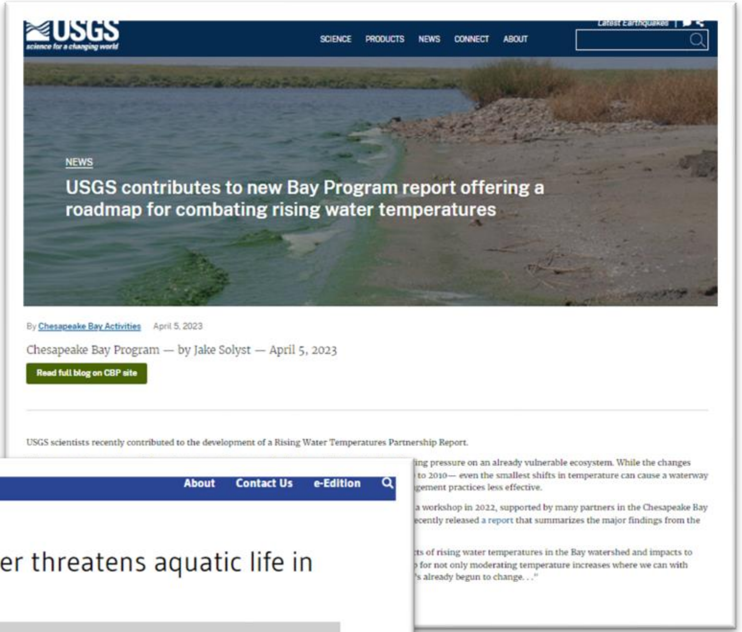
Stream Temperature

Purpose

John W. Clune, Guoxiang Yang, Nathaniel P. Hitt, Karli M. Rogers, James E. Colgin, Elizabeth A. Hittle, and Tammy M. Zimmerman

Batiuk et al., 2023

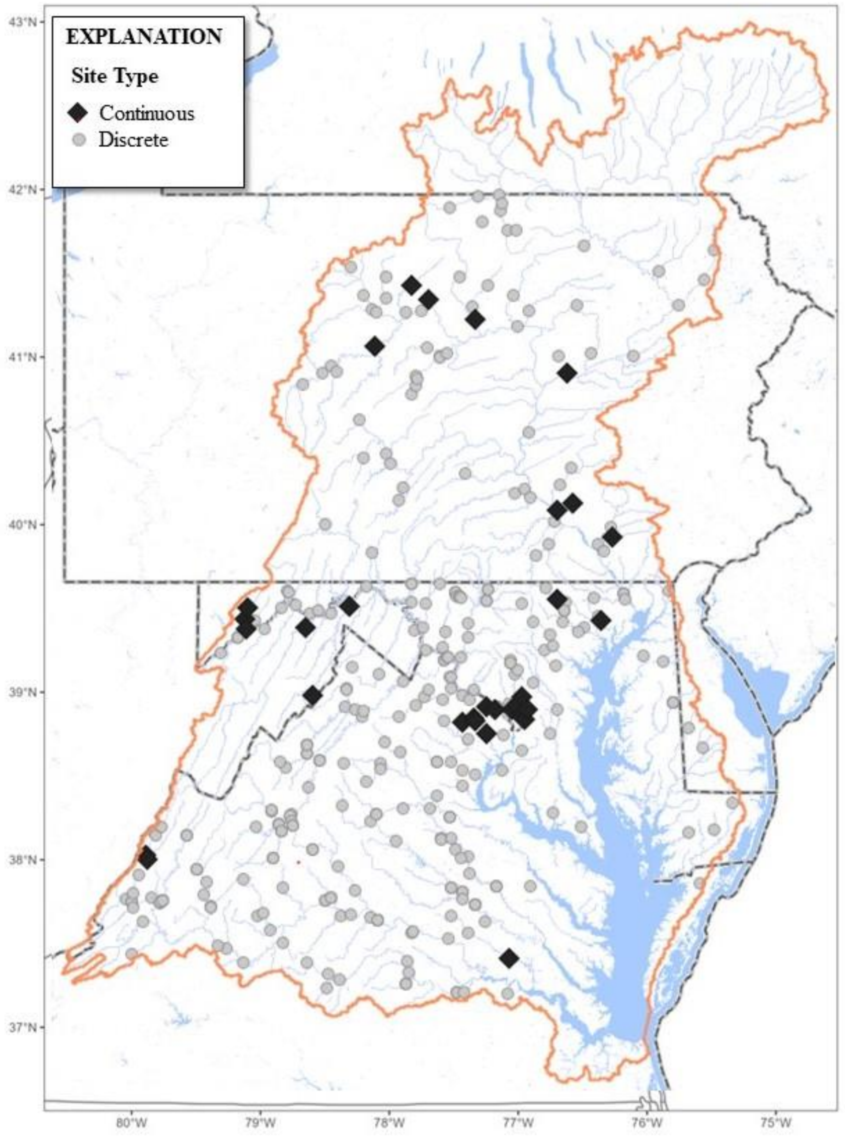




USGS

Stream Temperature Data/Site Criteria

	Continuous Data		Discrete Data	
Data Compilation	**NWIS Daily Values** ~1.2 million records 191 sites	**NWIS Unit Values** ~43 million records 141 sites	**Water Quality Portal** ~442,000 records 14,148 sites	**Aquarius** ~102,000 records 1,589 sites
Data Harmon-ization	• Spurious/Missing/Duplicates • Metadata Issues • Multiple Time Series • QC Flags		• Spurious/Missing/Duplicates • Metadata Issues (e.g., time) • QC Flags	
Site Selection Criteria	• 2013/14-2020/22 • > 300 days of data per year • **31 sites**		• 1985 to 2022 • No more than 5 gap years • **320 sites**	
Status & Trends	**Trends -** GAMs (Decadal Trends) **Status -** Difference between 2022 mean temperature and 2013-2022 mean temperature		**Trends -** Linear Mixed Effects (35 Year Trend)	



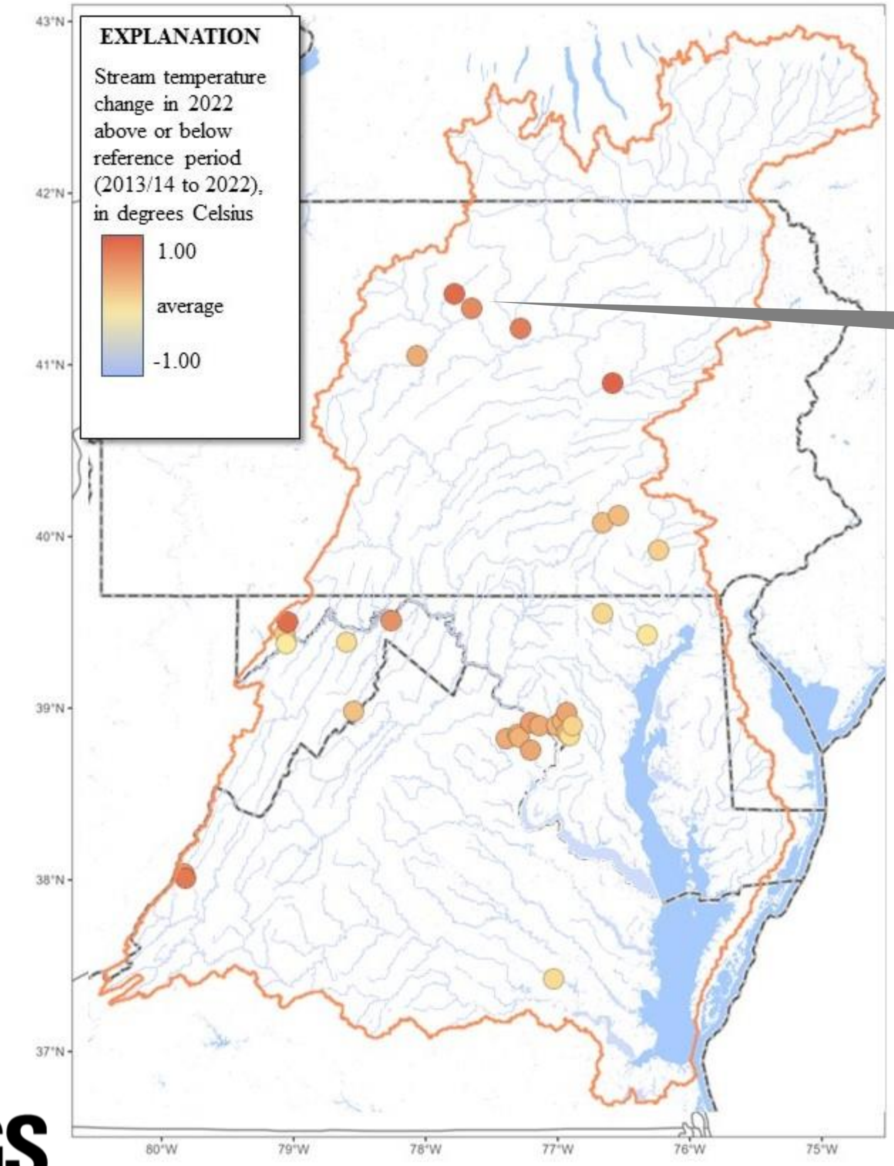
Preliminary data, not for citation or distribution

Clune, J.W., Colgin, J.E., and Zimmerman, T.M., 2023, Compilation of multi-agency water temperature observations for streams within the Chesapeake Bay watershed: U.S. Geological Survey Data Release, https://doi.org/10.5066/P92SHG66.

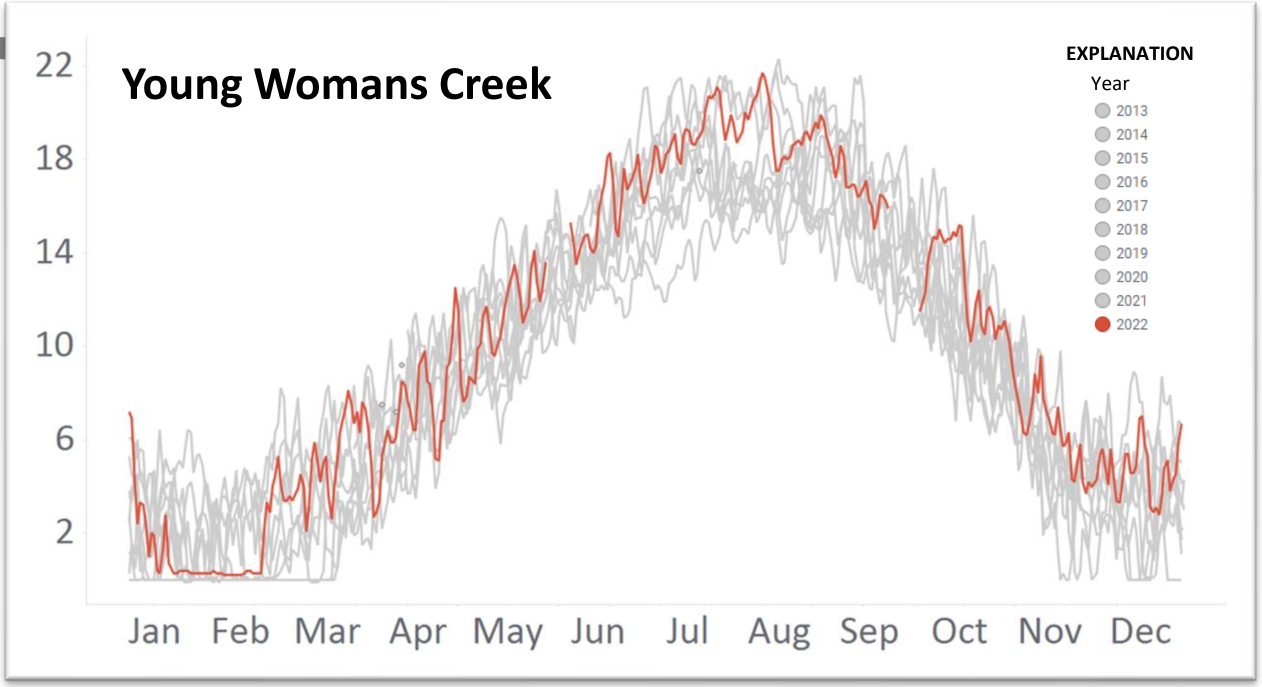
USGS

Stream Temperature

Status



The 2022 water year was the second warmest year for stream temperature on average for **continuous** sites with a 9- or 10-year period of record (2013/2014 to 2022).

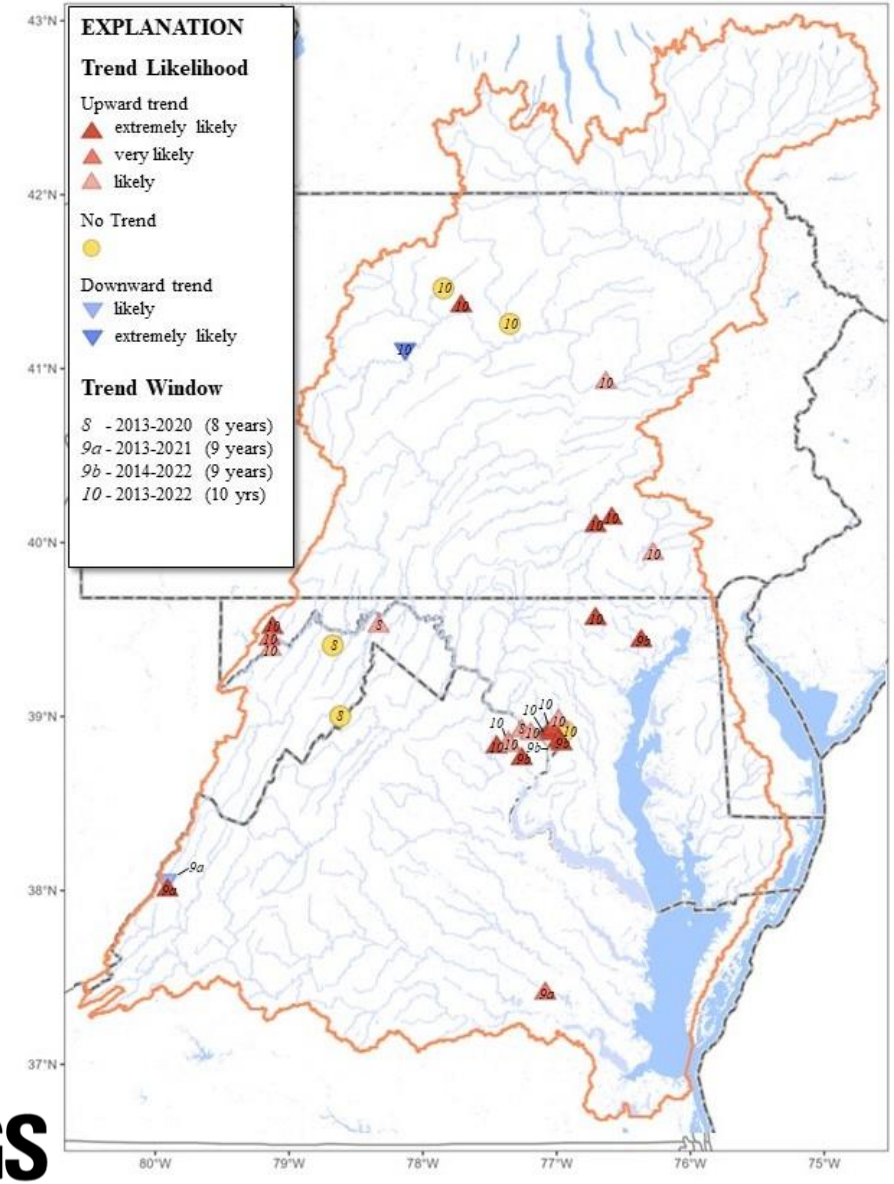


Preliminary data, not for citation or distribution

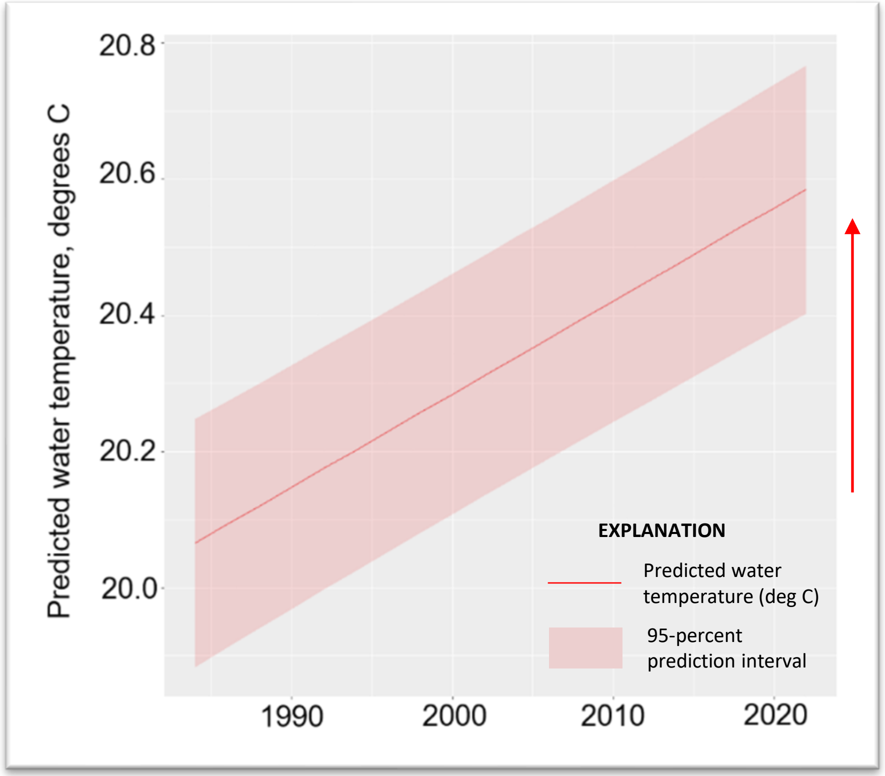
USGS 01545600

The seasonal fluctuation in stream temperature represents a substantial fraction of the annual variability

Stream Temperature Trends



Increasing trends (0.19 to 1.09 degrees Celsius over period of record) in stream temperature were likely to extremely likely for 79% of the individual **continuous** sites across the Chesapeake Bay watershed, with only two sites indicating downward trends.



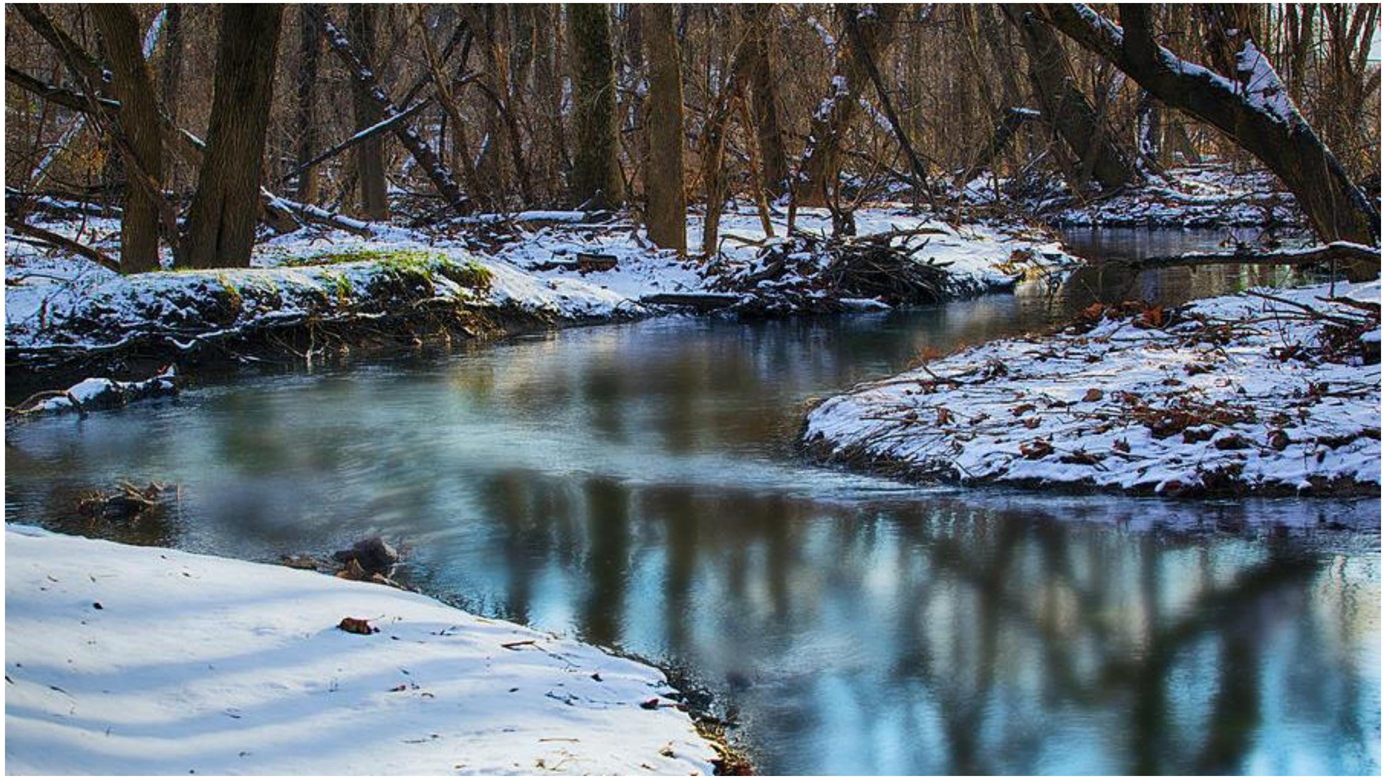
Additionally, significant warming trends were apparent across the Chesapeake Bay watershed when grouping **discrete** sites

USGS

Stream Salinity

Purpose

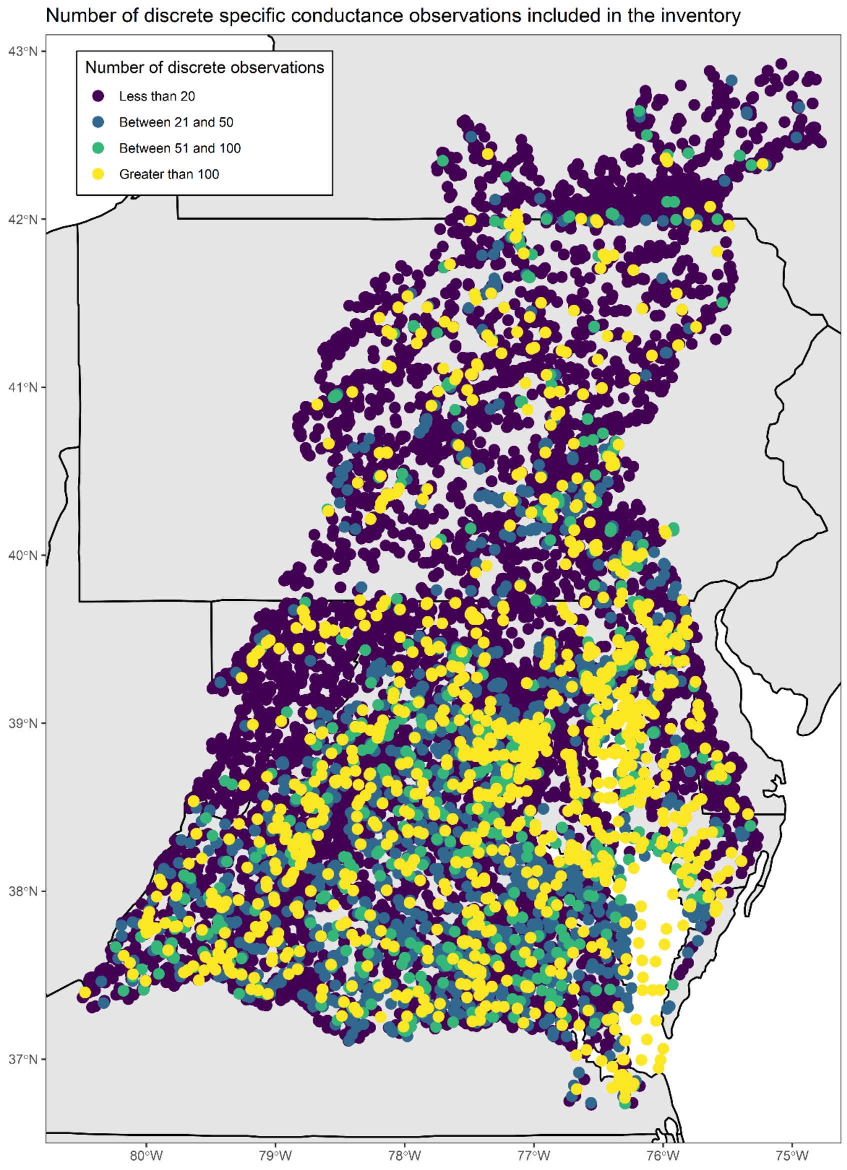
Rosemary M. Fanelli and Kaitlyn E. M. Elliott



USGS

Stream Salinity Data/Site Criteria

- Retrieved SC data from National Water Quality Portal and USGS NWIS
- 1.2+ million discrete obs at 16,900+ sites
- Date range: 1980-2022
- Dataset clean up and unit harmonization
  - QA/QC samples removed
  - Surface water samples retained
  - Units harmonized to µS/cm
  - Database screened for duplicate entries
- Retained sites that had at least 1 sample per season per year and computed median annual SC as status metric
  - Removed sites with tidal influence



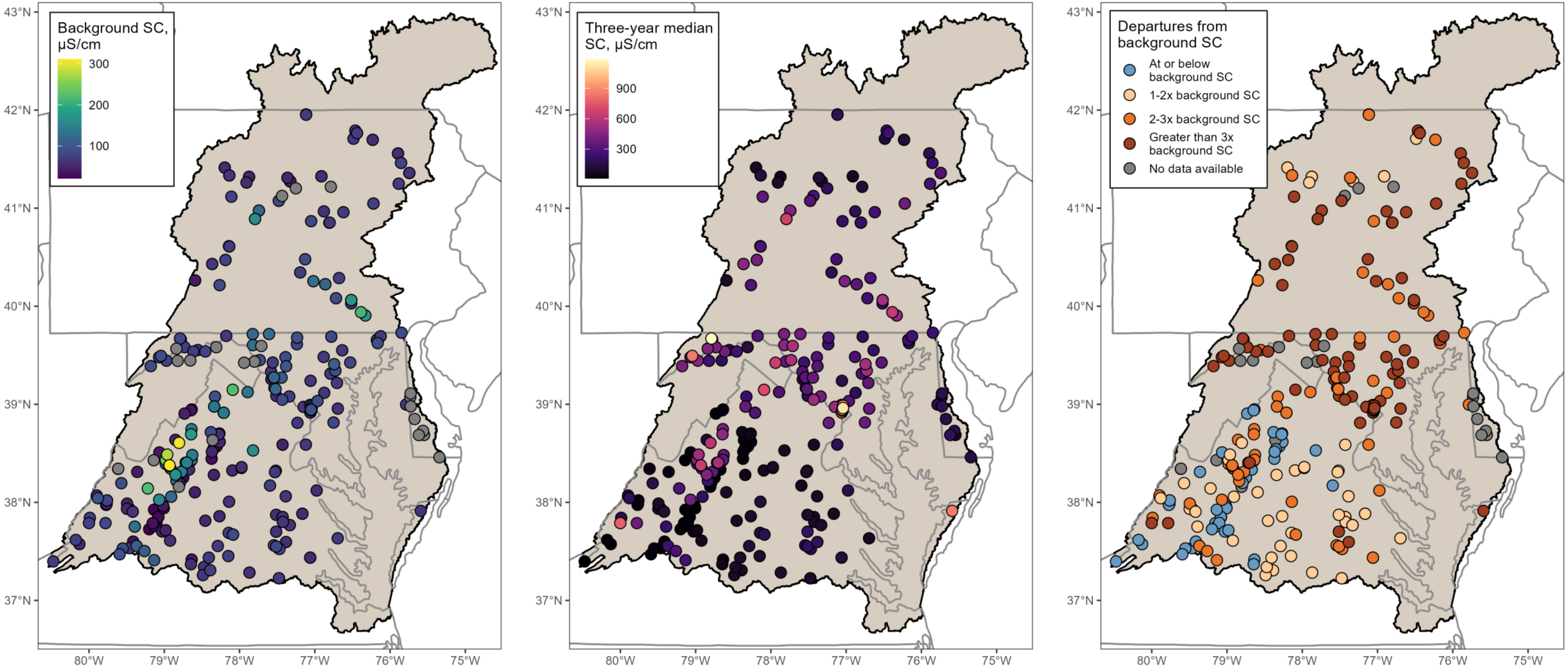
Fanelli, R.M., Sekellick, A.J., and Hamilton, W.B., 2023, Compilation of multi-agency specific conductance observations for streams within the Chesapeake Bay watershed, U.S. Geological Survey data release, https://doi.org/10.5066/P98O2HQJ.

USGS

Stream Salinity

Status

3-year median SC for years 2015-2017 compared to SC background dataset



USGS

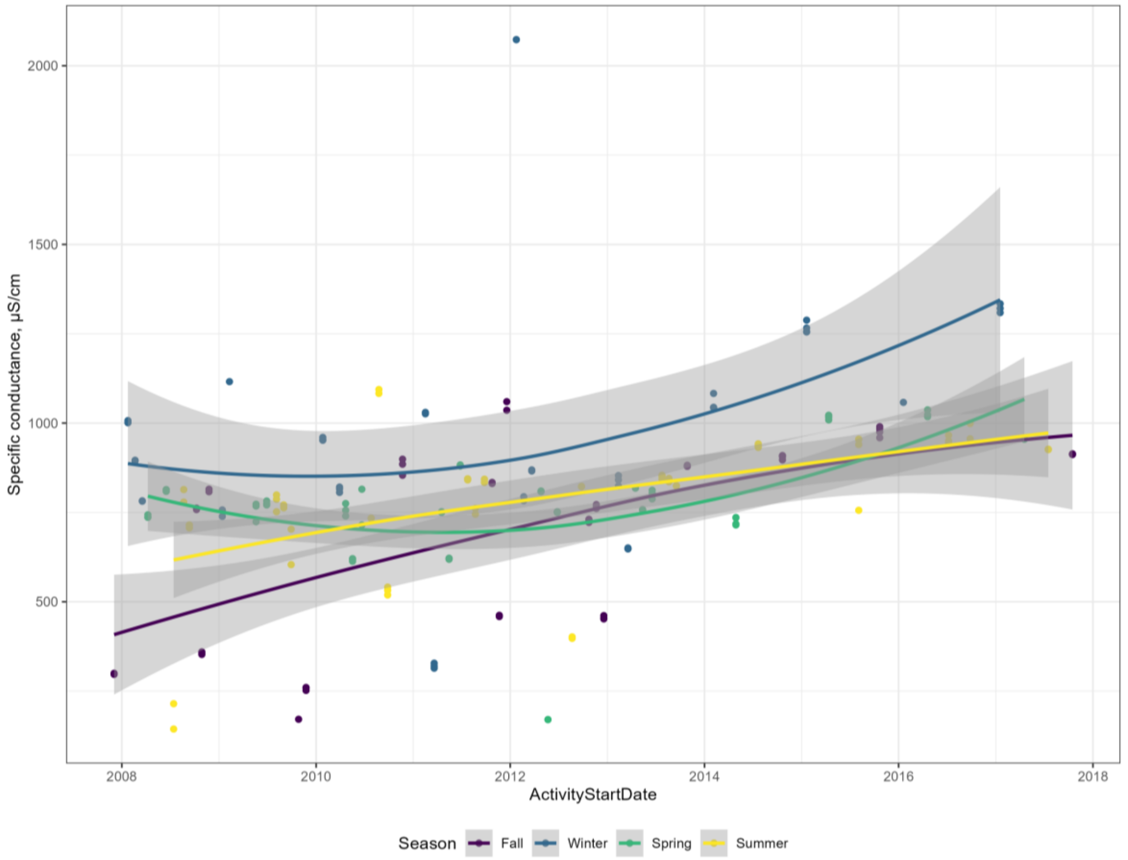
Olson, J. and S. Cormier. 2019. Modeling Spatial and Temporal Variation in Natural Background Specific Conductivity. *Environ. Science and Technology.* 53, 4316–4325. https://pubs.acs.org/doi/10.1021/acs.est.8b06777

Preliminary data, not for citation or distribution

Stream Salinity — Trends

- SC trend time period: 2008-2017
- Approach 1: WRTDS
  - Accounts for interannual flow variability
  - Requires discharge record
  - SC data criteria: three samples per season for each of the 10 years in trend period
  - 35 sites qualified for WRTDS
- Approach 2: Seasonal Mann-Kendall
  - Does not require streamflow records
  - SC data criteria: one sample per season for each of the 10 years in trend period
  - 278 sites qualified for SMK
  - Defined criteria for characterizing trend significance and uncertainty

Example SC trends by season at a single site



USGS

Preliminary data, not for citation or distribution

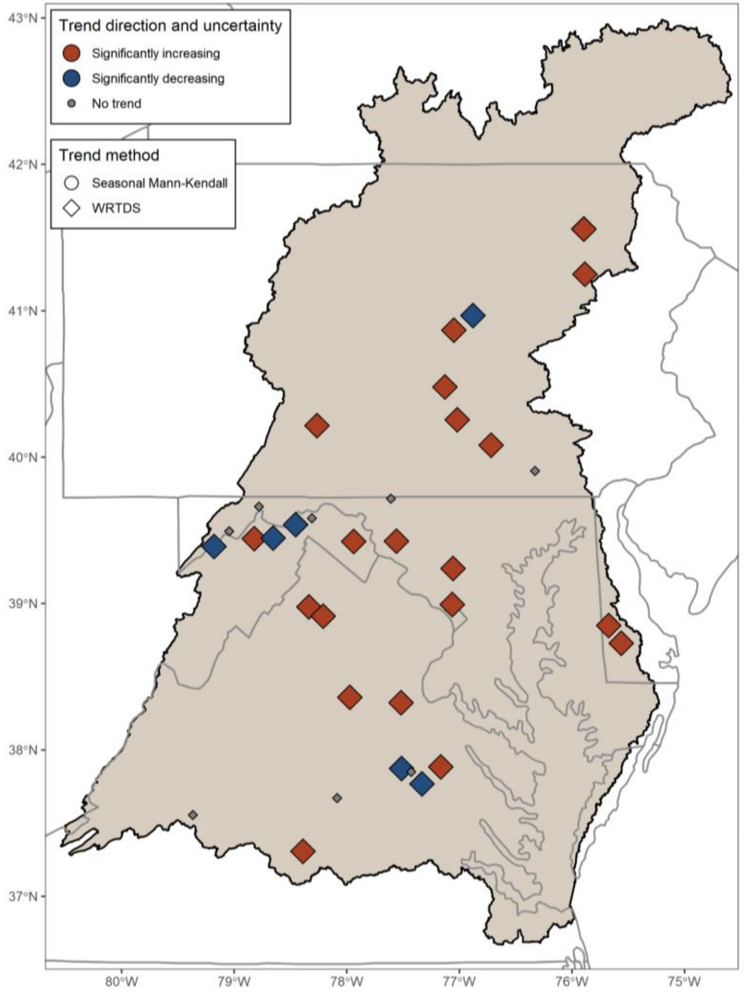
Stream Salinity Trends

WRTDS - Accounts for interannual flow variability, requires 3 samples per season per year, has fewer qualifying sites

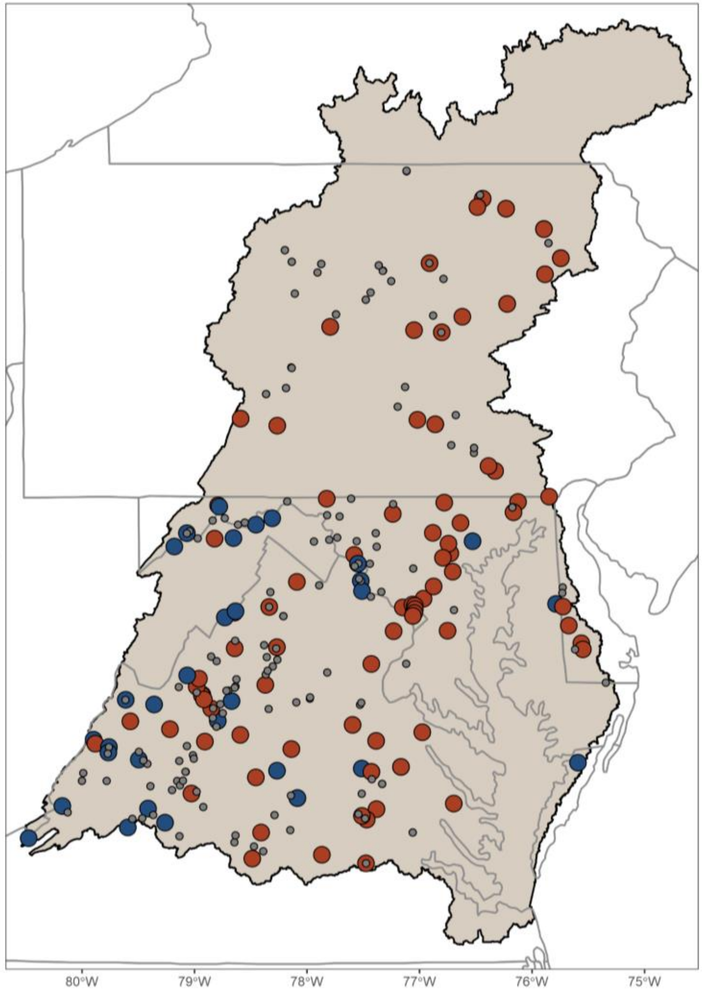
Seasonal Mann-Kendall – Does not account for flow, requires 1 sample per season per year, more qualifying sites

Trend Metric	Percent Increasing Trend	Percent Decreasing Trend	Percent No Trend
WRTDS (n = 35)	60	18	23
SMK (n = 278)	33	12	55

WRTDS Trends



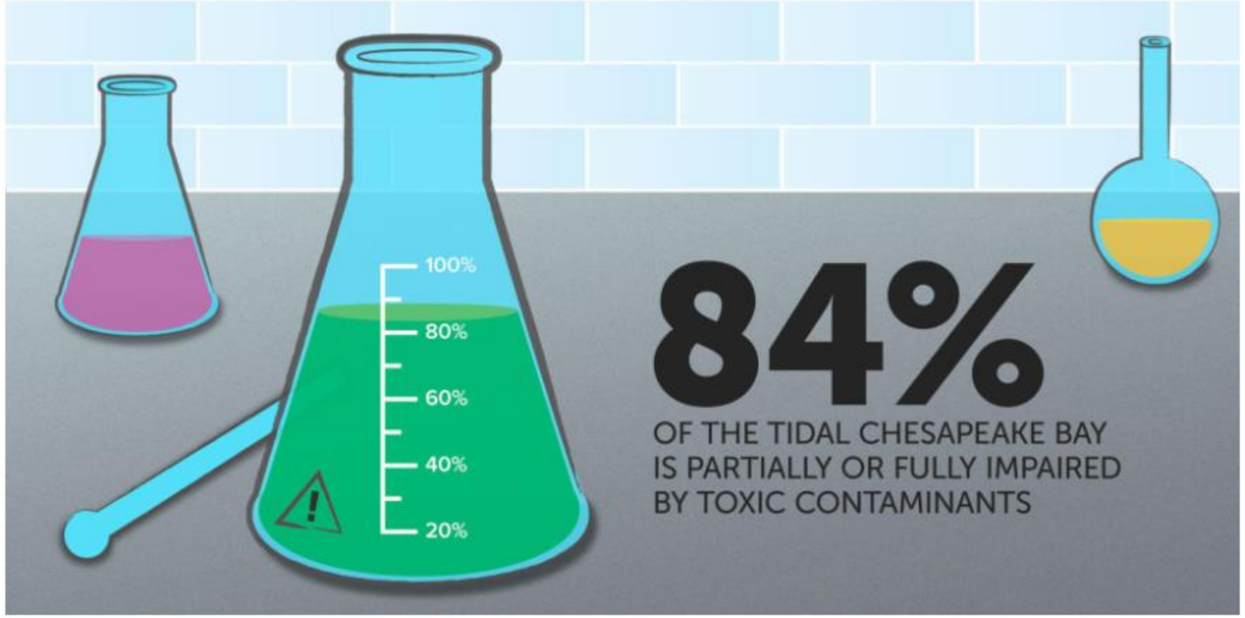
SMK Trends



Toxic Contaminants

Trevor P. Needham, Ellie P. Foss, Emily H. Majcher

How much of the Chesapeake Bay is impacted by chemical contaminants?



Data from the U.S. Environmental Protection Agency

According to data submitted to the U.S. Environmental Protection Agency in 2018, 84 percent of the Chesapeake Bay's tidal segments are partially or fully impaired by toxic contaminants.

While chemical contamination is often seen as a localized problem occurring in "hot spots" or "regions of concern," metals, polychlorinated biphenyls (PCBs) and priority organics exceed water quality criteria in at least part of all of the tidal tributaries that deliver water to the main stem of the Bay. A technical report shows PCBs and mercury are particularly problematic in the region, and are considered widespread in severity and extent

Pesticides

PCBs

Mercury

USGS

https://www.chesapeakebay.net/issues/threats-to-the-bay/chemical-contaminants

Toxic Contaminants

Data

Summary of toxics database developed by media and contaminant:

	Water	Biological	Sediment	Solids	Soil
Pesticide	200,804	5,552	6,465	2,514	0
PCB	1,614	9,001	2,827	55	25
Hg	2,484	7,767	1,942	13	45

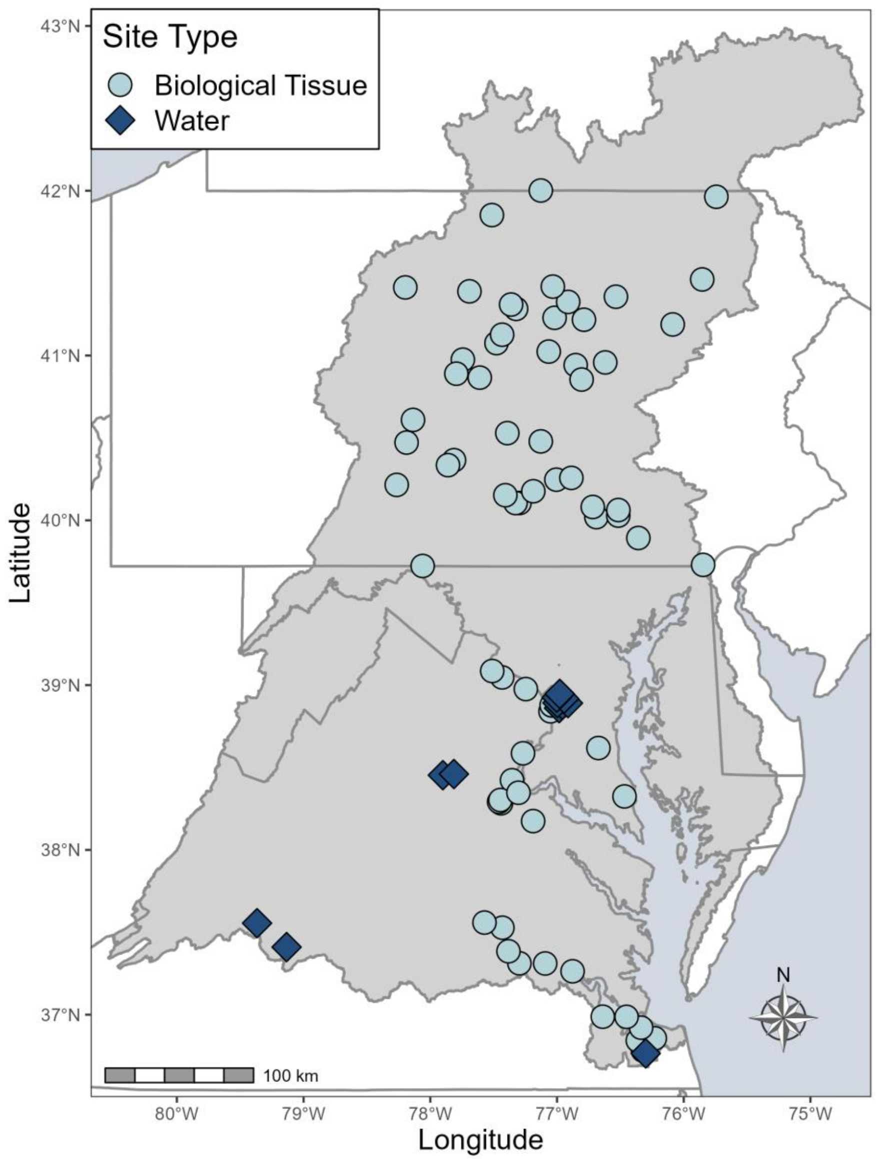
- Toxic contaminant database developed for polychlorinated biphenyls (PCB), mercury (Hg), and pesticides published in Science Base (Banks and others, 2022)
- Records compiled from DE, PA, MD, NY, VA, WV, DC, NWIS, and WQP from 1938 to 2019.
- Data availability by contaminant and media was driven by total maximum daily load enforcement and exposure pathways (for example PCBs in fish)

Banks, B.D., Needham, T.P., Dugan, C.M., Foss, E.P., and Majcher, E.H., 2022, Priority Toxic Contaminant Metadata Inventory and Associated Total Polychlorinated Biphenyls Concentration Data: U.S. Geological Survey data release, https://doi.org/10.5066/P9R78SQ6.

Toxic Contaminants

Site Criteria

- **No sites with enough consistent, repeat samples in the same sampling medium. Trend analysis currently not possible.**
- **Identified 89 PCB sites where trend analysis might be possible if monitoring continues. Site criteria:**
  - Temporal Duration: Sites with 3 or more sampling points for the same media over a 5-year span or greater.
  - Recency: Sites need to have been sampled between 2014 and 2020 (end of data record).
  - Method Compatibility: PCB analysis must be by a method that reports total PCB concentration or individual PCB congeners; Aroclor methods were excluded.
  - Media Compatibility: Only similar media can be compared for trend analysis. The selection was limited to solids, water samples, fish of the same species, or different fish species with a reported lipid content as these media types contained enough data for within-media trend comparisons.



Preliminary data, not for citation or distribution

Streamflow

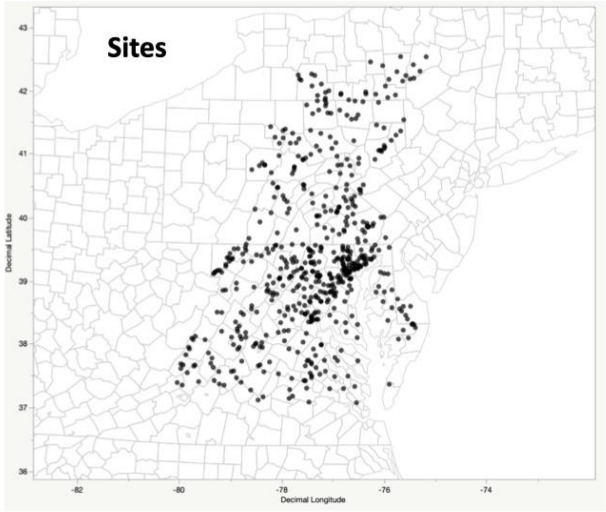
Purpose

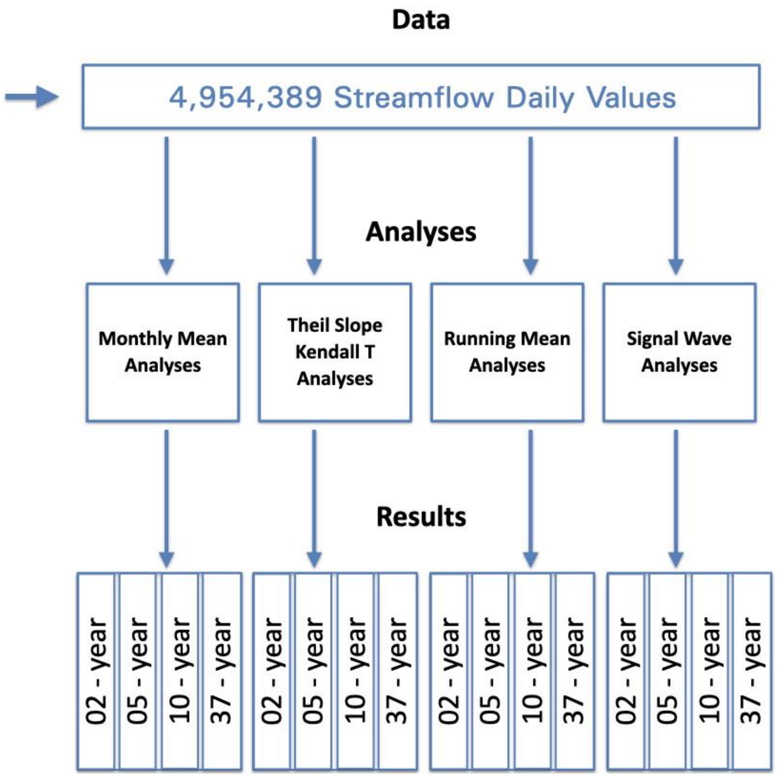
Samuel H. Austin

USGS

Streamflow — Data/Site Criteria

- USGS National Water Information System (NWIS) daily-value (DV) data from 417 gaged sites with at least 10 complete years of continuous streamflow record within the October 1, 1984 to September 30, 2022 interval



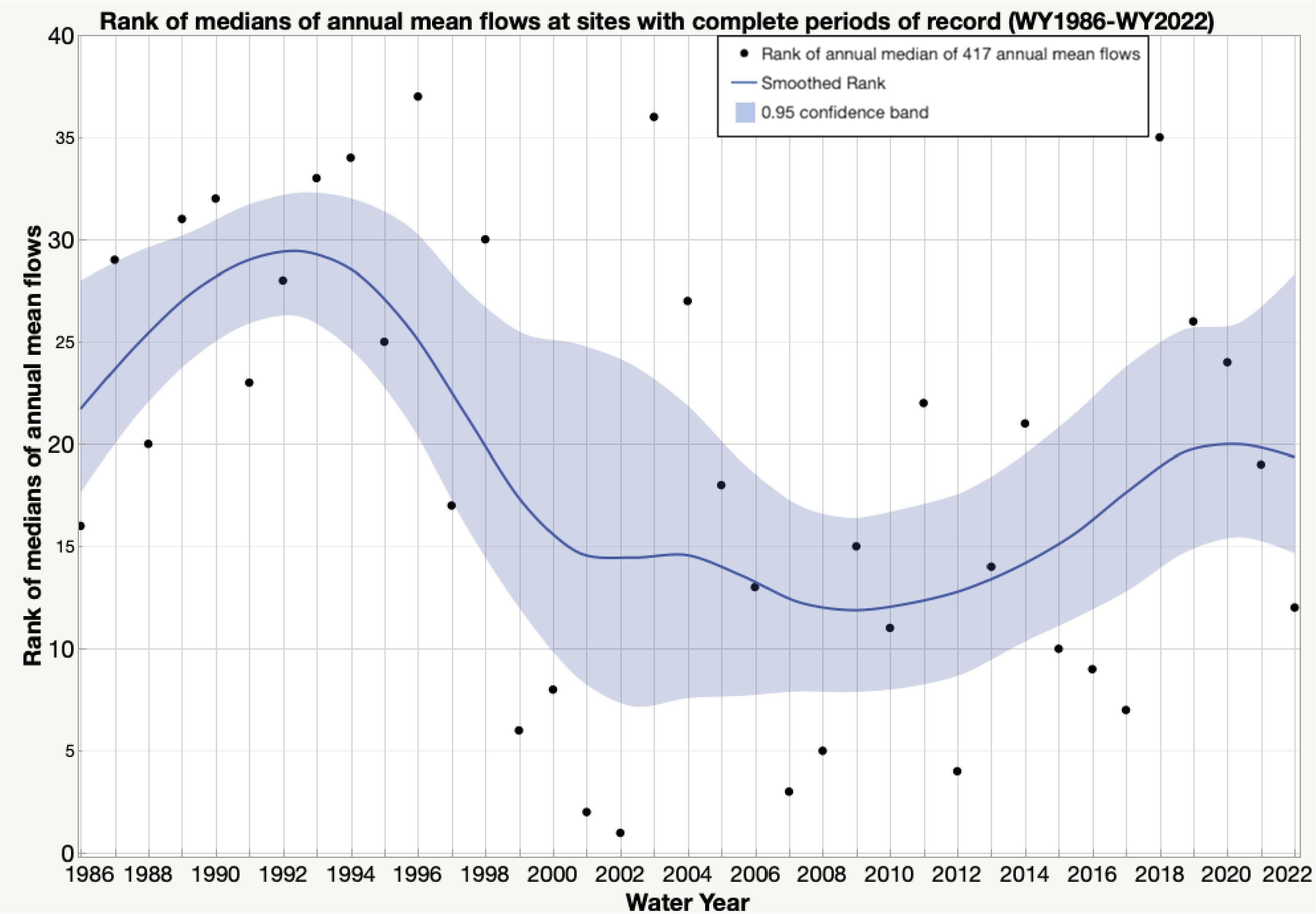


- Four methods of evaluating streamflow were calculated to provide maximum relevance and flexibility when addressing policy needs and questions specified within shorter-term and longer-term time intervals-of-interest
- Status = mean yearly flow of all sites relative to all water years in period of record (1986-2022)
- Trends = Theil-Sen regression at 2, 5, 10 and 36 year intervals

Streamflow

Status

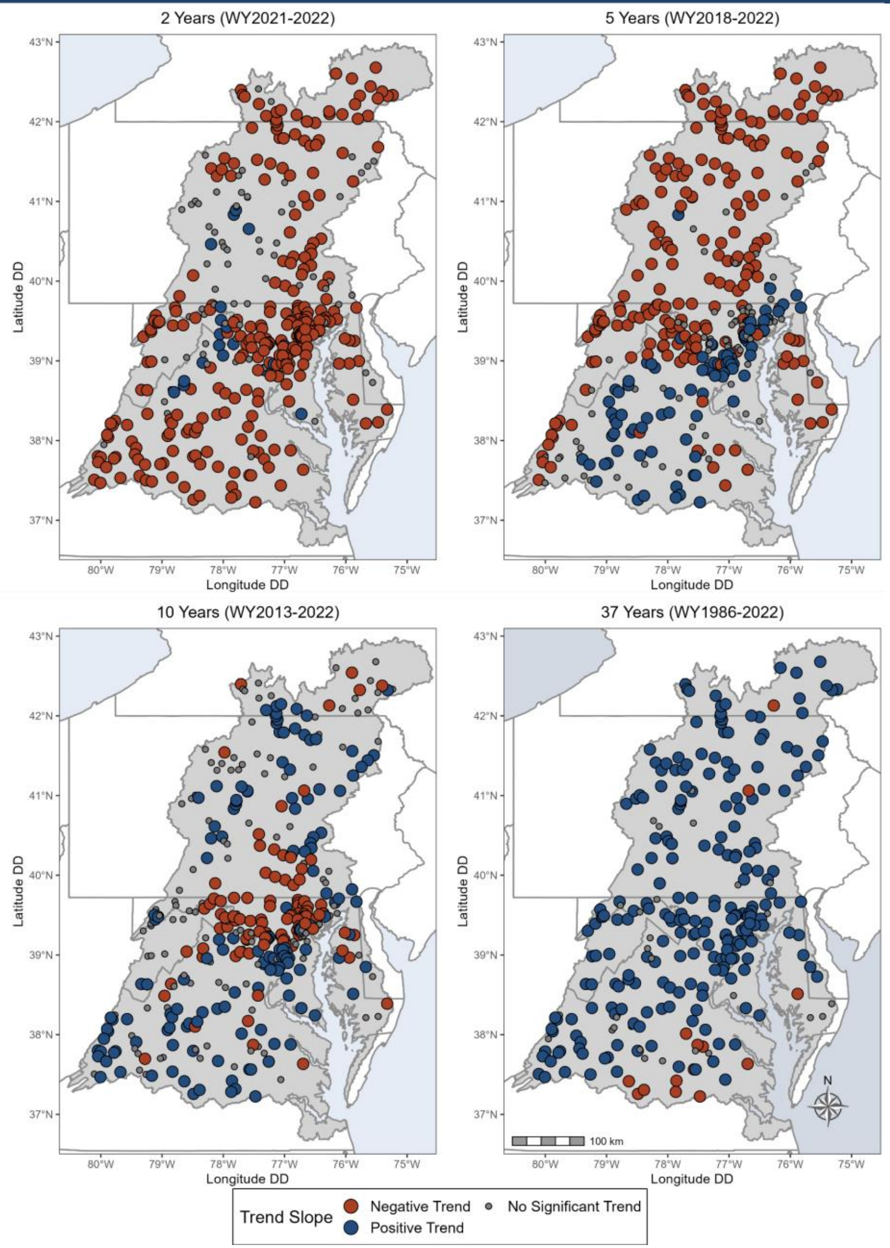
- Status = mean yearly streamflow of all sites
- 2022 ranked 12th lowest mean annual flow out of the past 37 water years
- 2002 was the lowest water year and 1996 was the highest water year



Streamflow Trends

Trends in short-term (2-5 years) and long-term (10-37 years) streamflow

Trend Intervals	Percent Negative Trend	Percent Positive Trend	Percent No Trend
2 Years (n=378)	73	6	21
5 Years (n=377)	54	23	23
10 Years (n=372)	27	39	34
37 Years (n=273)	5	83	12



Hydromorphology Purpose

Matthew J. Cashman, Coral M. Howe, Joshua J. Thompson, Marina Metes, Zachary Clifton

- Sediment & physical habitat degradation have been identified as a leading cause of local ecological impairment across the Chesapeake Bay watershed (CBW)(Fanelli & others, 2022)
- Degraded bed conditions often regulatorily linked to sediment, but sediment is only one of several possible factors of degraded bed conditions
- Two approaches to evaluating these trends in these factors within the CBW:
    1. **Rapid Habitat Assessments across multiple jurisdictions**
    2. **Specific Gage Analysis, i.e. trends in channel dimensions and hydraulics at USGS streamgages**

Image credit: Marina Metes

USGS

Hydromorphology (Rapid Habitat) Data/Site Criteria

Rapid Habitat Assessment:

- Field methods for measuring hydromorphic & physical habitat conditions at a site
- Intended to be a **quick, visually-qualitative ranking** (0=poor, 20=optimal) of conditions at a **meso- and microhabitat spatial scale**

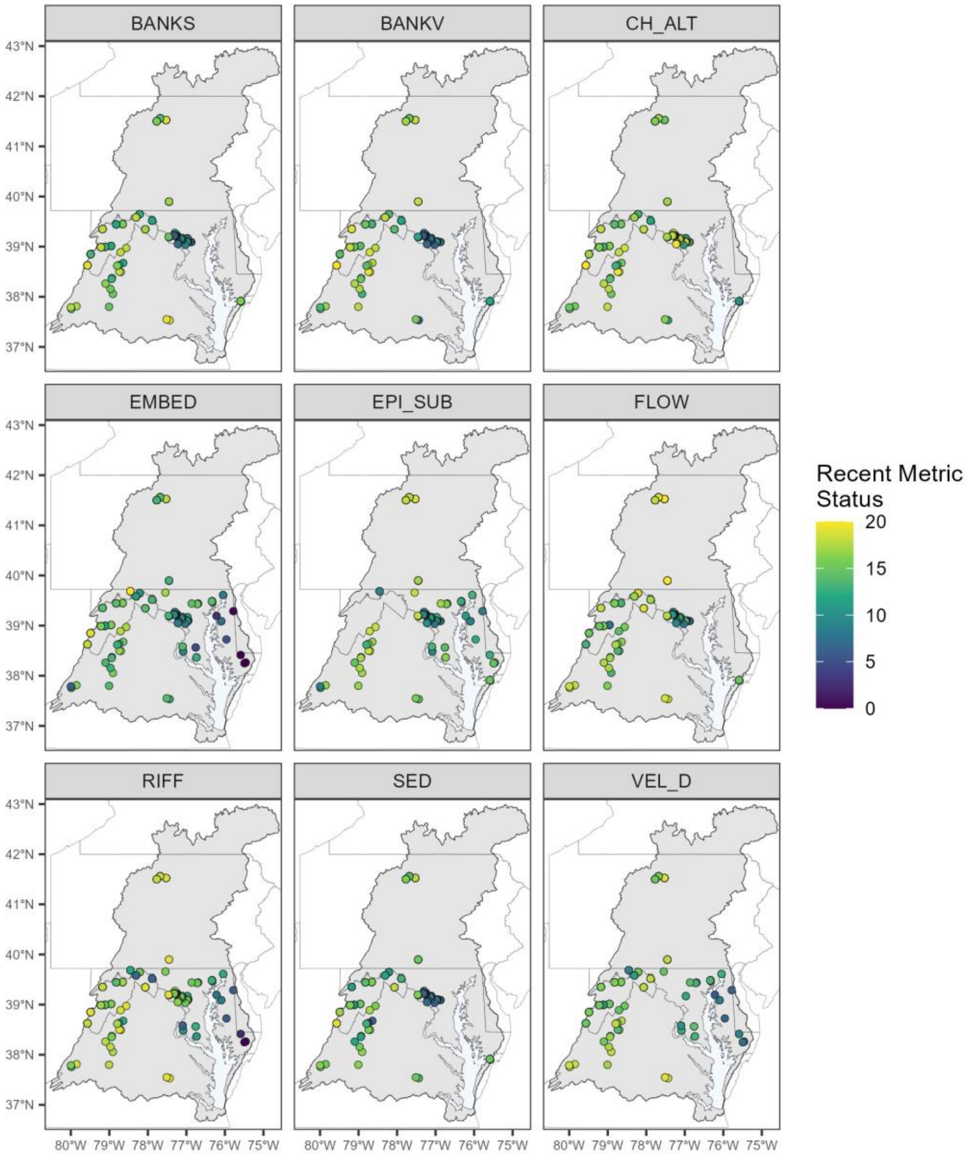
Data from 19 different federal, state, and local agencies/jurisdictions pulled from the Chesapeake Bay Program's DataHub database → 2008-2017 → 7 years of data →

METRIC SHORT NAME	METRIC LONG NAME	RANGE	QUALIFYING SITES (N)
BANKS	Bank Stability	0-20	83
BANKV	Bank Vegetative Protection	0-20	83
CH_ALT	Channel Alteration	0-20	84
EMBED	Embeddedness	0-20	101
EPI_SUB	Epifaunal Substrate/Available Cover	0-20	93
FLOW	Channel Streamflow Status	0-20	84
RIFF	Frequency of Riffles (or Bends)	0-20	51
SED	Sediment Deposition	0-20	84
VEL_D	Velocity/Depth Combinations	0-20	55

USGS

Hydromorphology (Rapid Habitat) Status

- Average metric value for the most recent three years of data per site
- Metrics averaged from 12.0 to 16.4
  - Lowest average = Channel Embeddedness
  - Highest average = Channel Alteration
- Lower scores generally clustered near urban centers and on the Delmarva Peninsula

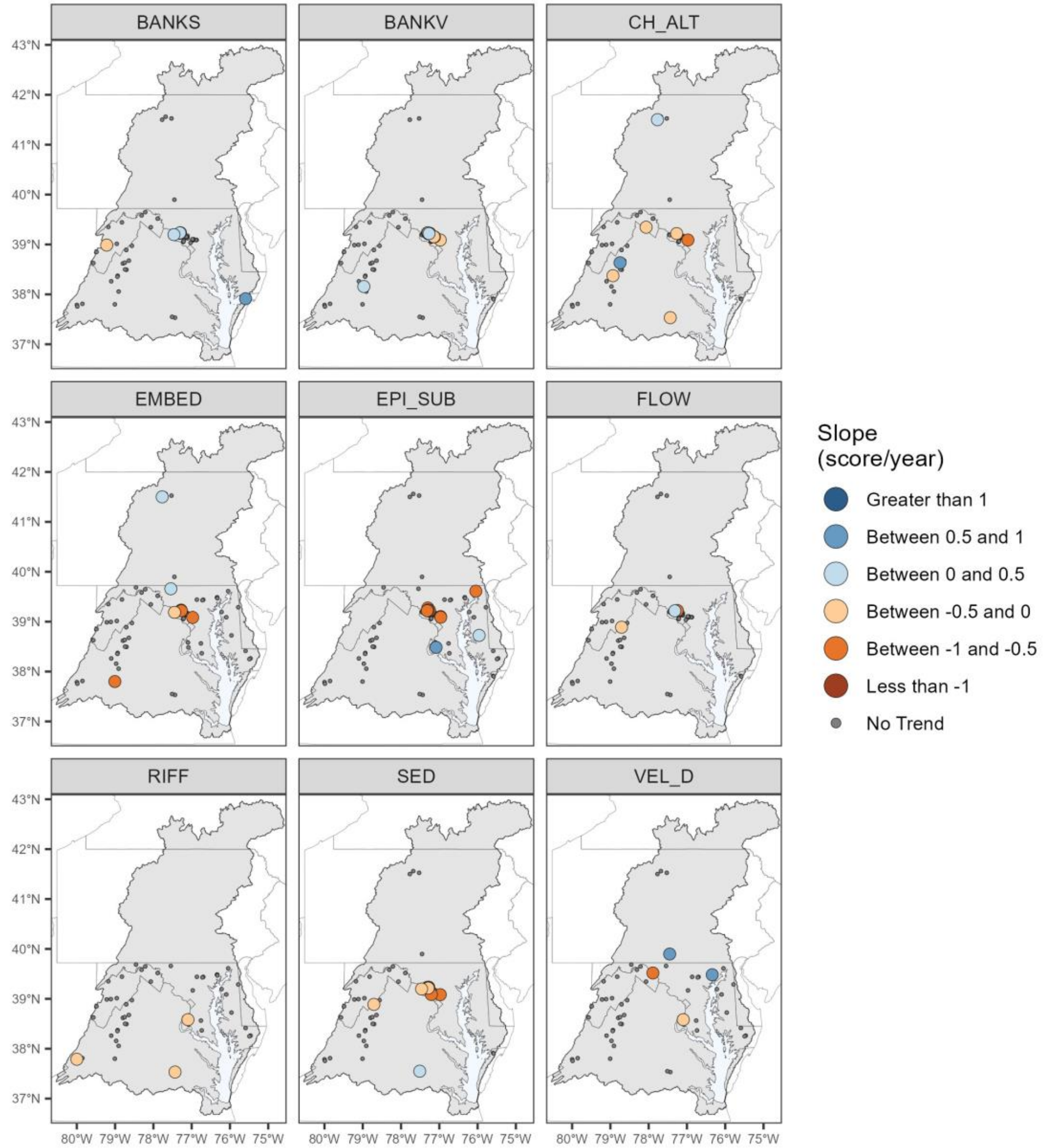


0=Poor Condition 20=Optimal Condition

USGS

Hydromorphology (Rapid Habitat) Trends

- Generalize additive model results 2008-2017
- Among all sites and metrics, 9% had strong significant trends
- Of these trends, 77% indicated **degrading conditions**
- Overall **trend** for all metrics was an avg of **-0.37pts/year**
- Significant changes scattered throughout watershed, but the most notable changes were clustered near urban centers



Negative Slope= Degrading **Positive Slope = Improving**

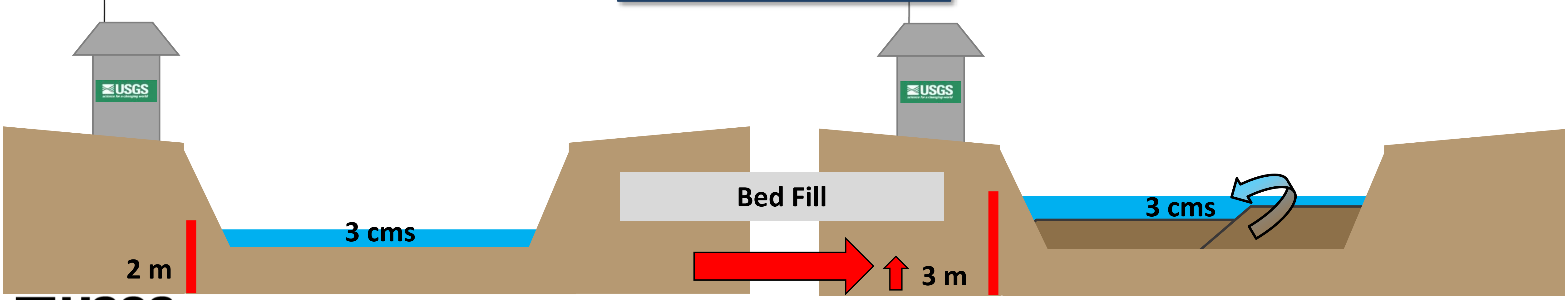
USGS

Hydromorphology (Specific Gage) Data/Site Criteria

Specific Gage Analysis:

- Uses routine streamflow measurements collected at USGS streamgages to document changes to channel dimensions and hydraulics, i.e., channel evolution
- Three metrics; Bed Elevation, Channel Area and Channel Velocity, selected for analysis

Streamgage data for all watershed gages queried from the National Water Information System → at least 10 years of continuous streamflow and stage data → 342 USGS gages qualified for at least a 10-yr trend analysis



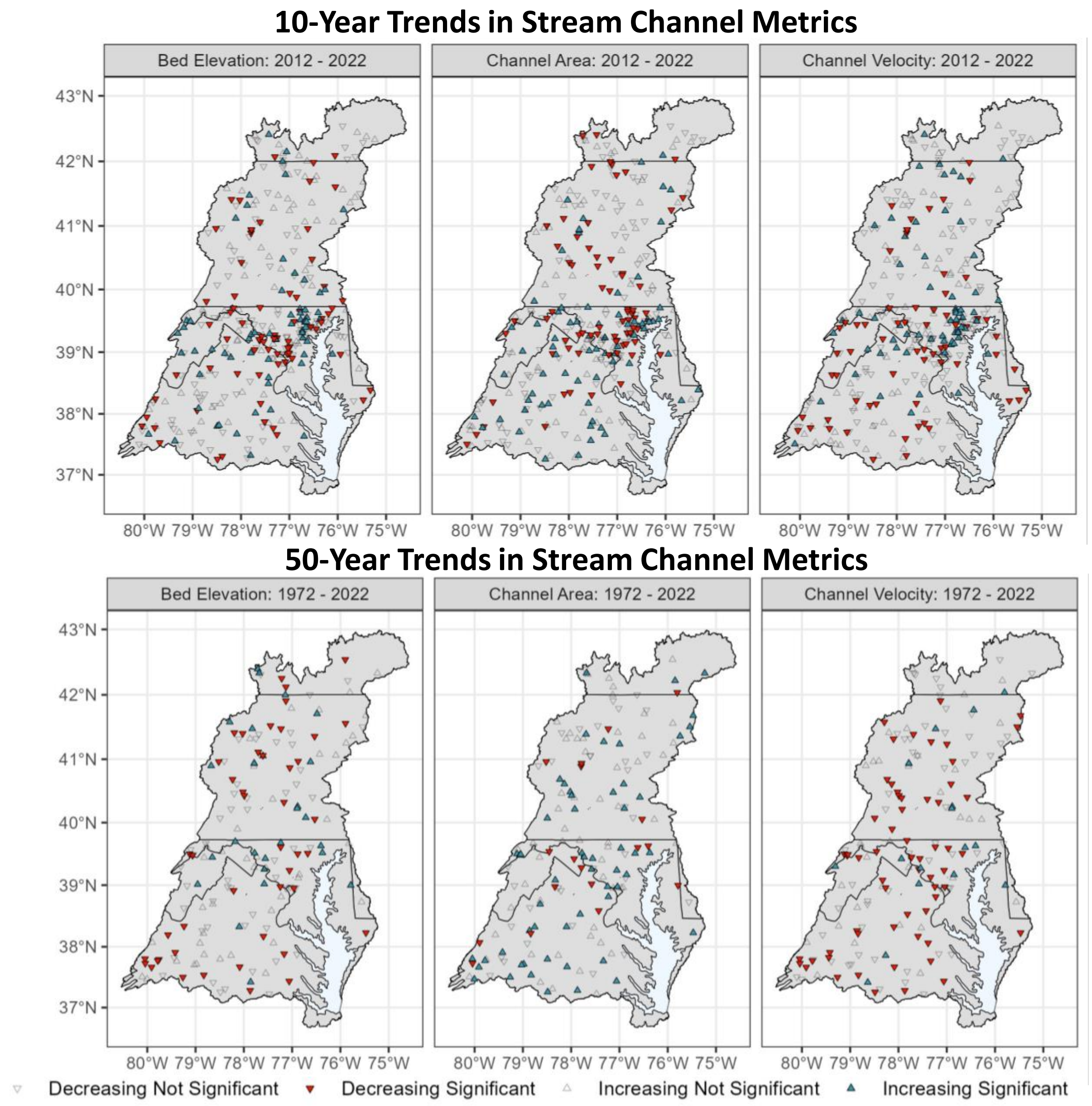
USGS

Hydromorphology (Specific Gage) Trends

- Between 36%-51% of trends analyzed for each time interval (10-, 25-, 50-, 75-yrs) were significant (p-value ≤ 0.05). 75-yr intervals had the most significant trends.

- Channel Velocity and Channel Area had fewest significant trends (41%), Bed Elevation the most (47%)

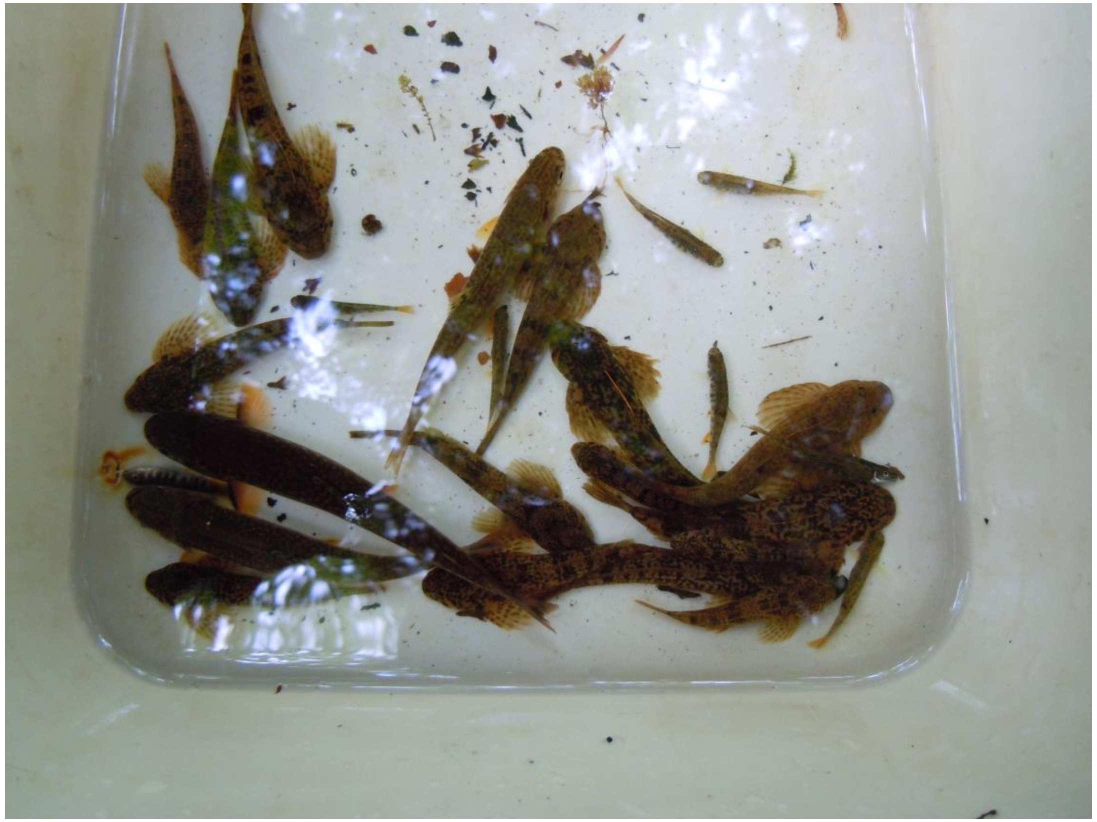
- Bed Elevation and Channel Velocity more likely to be decreasing through time, Channel Area more likely to be increasing through time



USGS

Biological Assemblages

Purpose



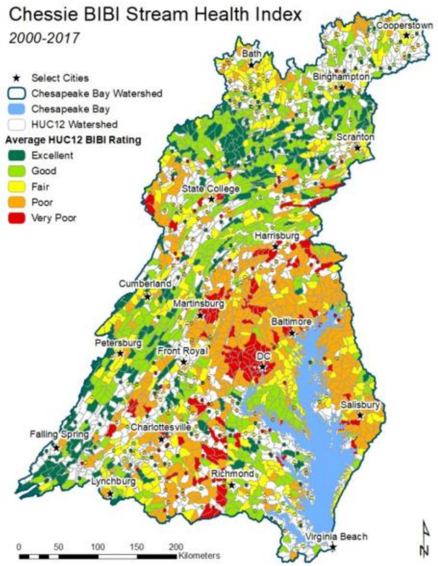
USGS

Biological Assemblages

Data/Site Criteria

<ins>Multi-Metric Index</ins> – aggregates multiple biological assemblages metrics into a single value indicating overall biological condition

- Macroinvertebrates = Chessie BIBI (Interstate Commission on the Potomac River Basin)
- Fish = EPA MMI



Interstate Commission on the Potomac River Basin

<ins>Assemblage Sensitivity</ins> – metric quantifying the proportion of species or individuals within a population that are highly sensitive to disturbance

- Macroinvertebrates = % Ephemeroptera, Plecoptera & Trichoptera Taxa excluding the tolerant family Hydropsychidae (EPT-H)
- Fish = Percent of non-tolerant individuals

USGS

Biological Assemblages

Data/Site Criteria

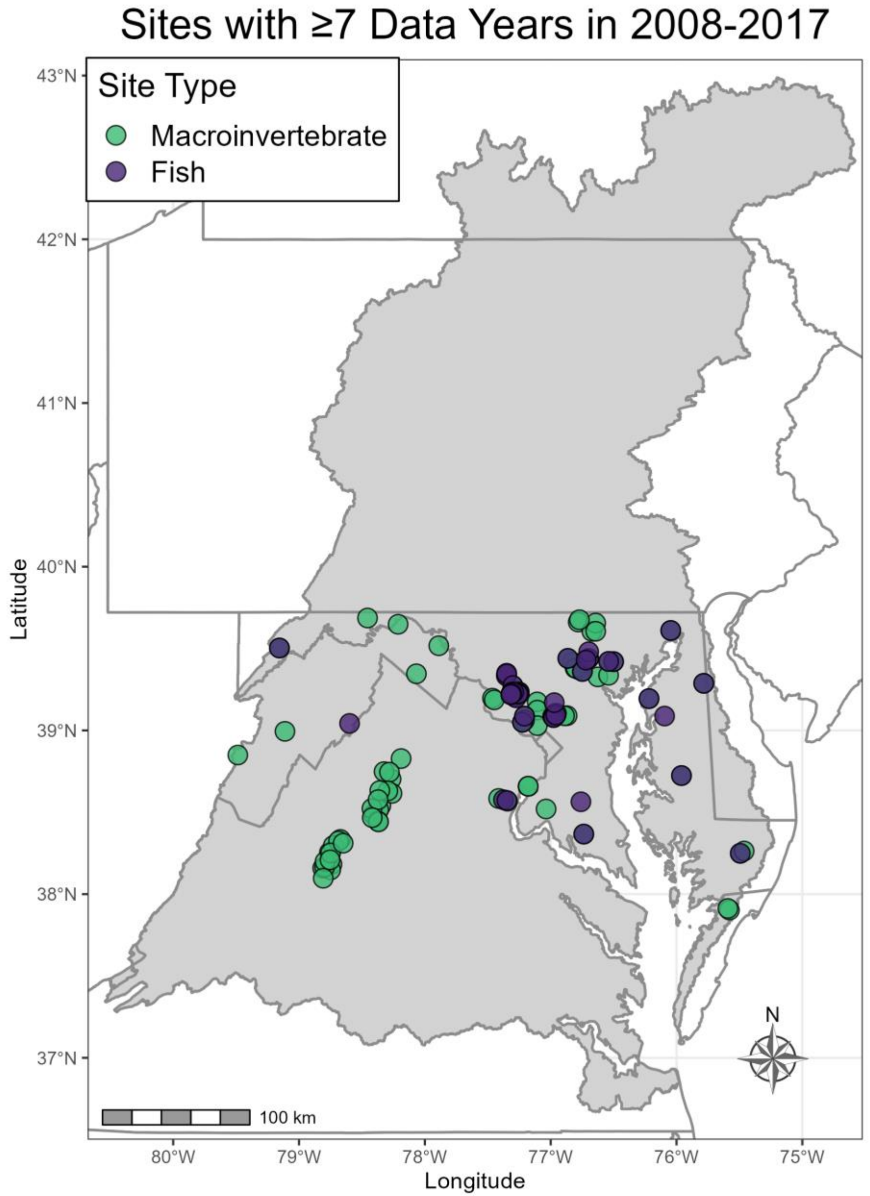
29,009 Macroinvertebrate samples (ICPRB)

12,418 Fish samples (USGS)

2008-2017

7 years of data collected in the same season

	Spring	Summer	Autumn	Total
Macroinvertebrate Sites	93	4	2	**99**
Fish Sites	0	36	8	**44**



Preliminary data, not for citation or distribution

USGS

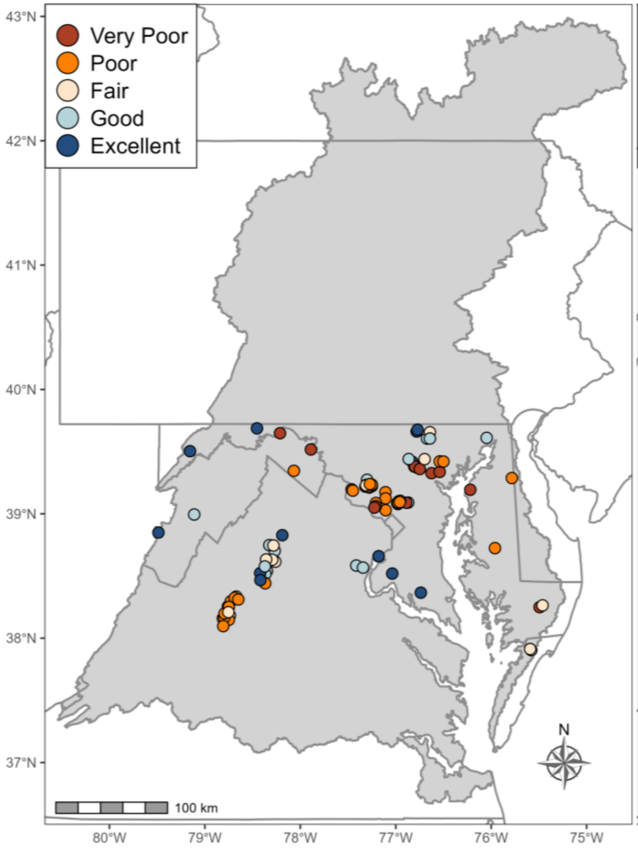
Biological Assemblages

Status

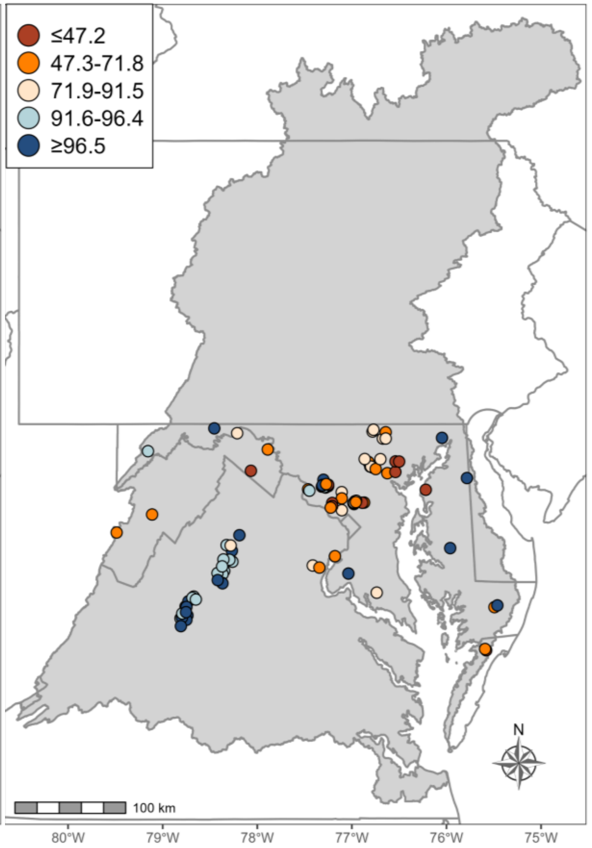
Average metric value for the most recent three years of data per site

Macroinvertebrates

BIBI Condition Category

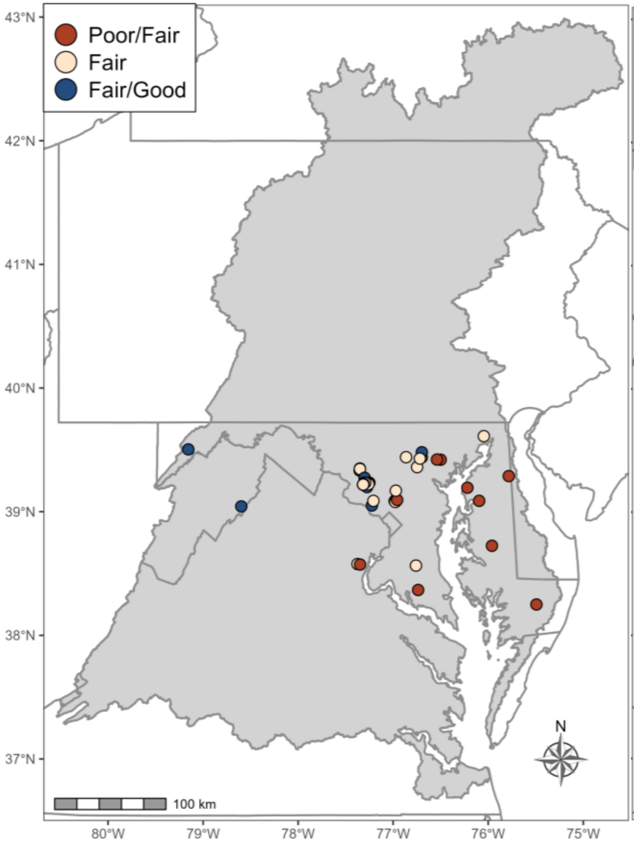


Percent EPT-H Taxa

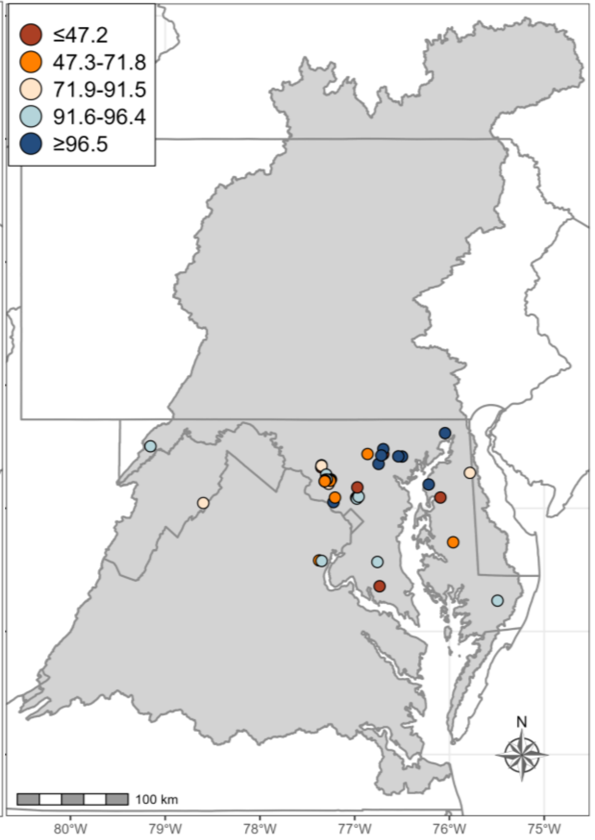


Fish

EPA MMI Condition Category



Percent Non-Tolerant Individuals



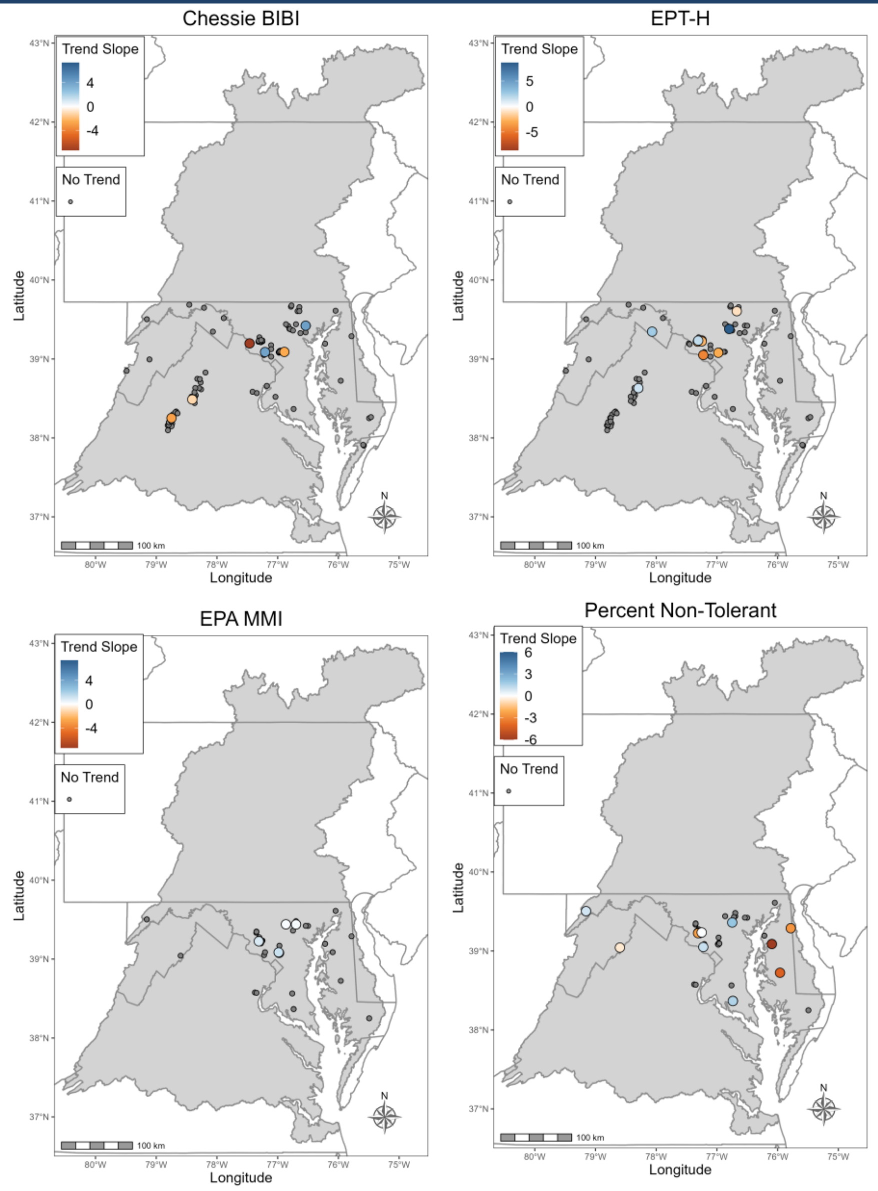
USGS

Biological Assemblages

Trends

Generalize additive model results 2008-2017

	Metric	Percent Increasing Trend	Percent Decreasing Trend	Percent No Trend
Macroinverte-brates	BIBI Score	2	4	94
	Percent EPT-H Taxa	4	8	88
Fish	MMI Score	11	0	89
	Percent Non-Tolerant Individuals	11	14	75



USGS

Preliminary data, not for citation or distribution

Key Takeaways

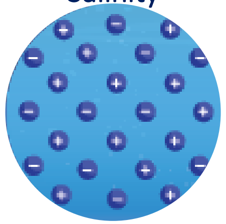
Nutrients and Sediment

Largest TN yields near the mouth of the Susquehanna and on the Eastern Shore, TP yields near the mouth of the Susquehanna and suspended sediment yields near mouth of the Potomac. Majority of sites showed **either improving or degrading trends for TN, improving trends for TP and either degrading or no trend for suspended sediment**.

Stream Temperature

The 2022 water year was the **second warmest year** and increasing trends (0.19 to 1.09 C) were likely for 79% of the available continuous sites (2013/2014 to 2022) and **warming trends** were apparent across the Chesapeake Bay watershed when grouping discrete sites.

Salinity



85% of sites had 3-year median SC values **above predicted background** SC. SC was **increasing at 60% of WRTDS trend sites**.

Toxic Contaminants

Differences in sampling medium, sampling frequency and monitoring protocols make trend analysis of toxic contaminants (PCBs, Hg, pesticides) difficult. **Not enough data exists** in the toxic contaminant dataset for trend analysis, but **89 sites** have repeat samples that **may be suitable for future analysis** if monitoring continues.

Streamflow

Annual streamflows into the Chesapeake Bay Watershed during the 2022 water-year were **below average**, ranking 12th of 37 years. Trends show decreasing flows at short (2 or 5 year) timescales but **little change over the full period of record** (37 years).

Hydromorphology

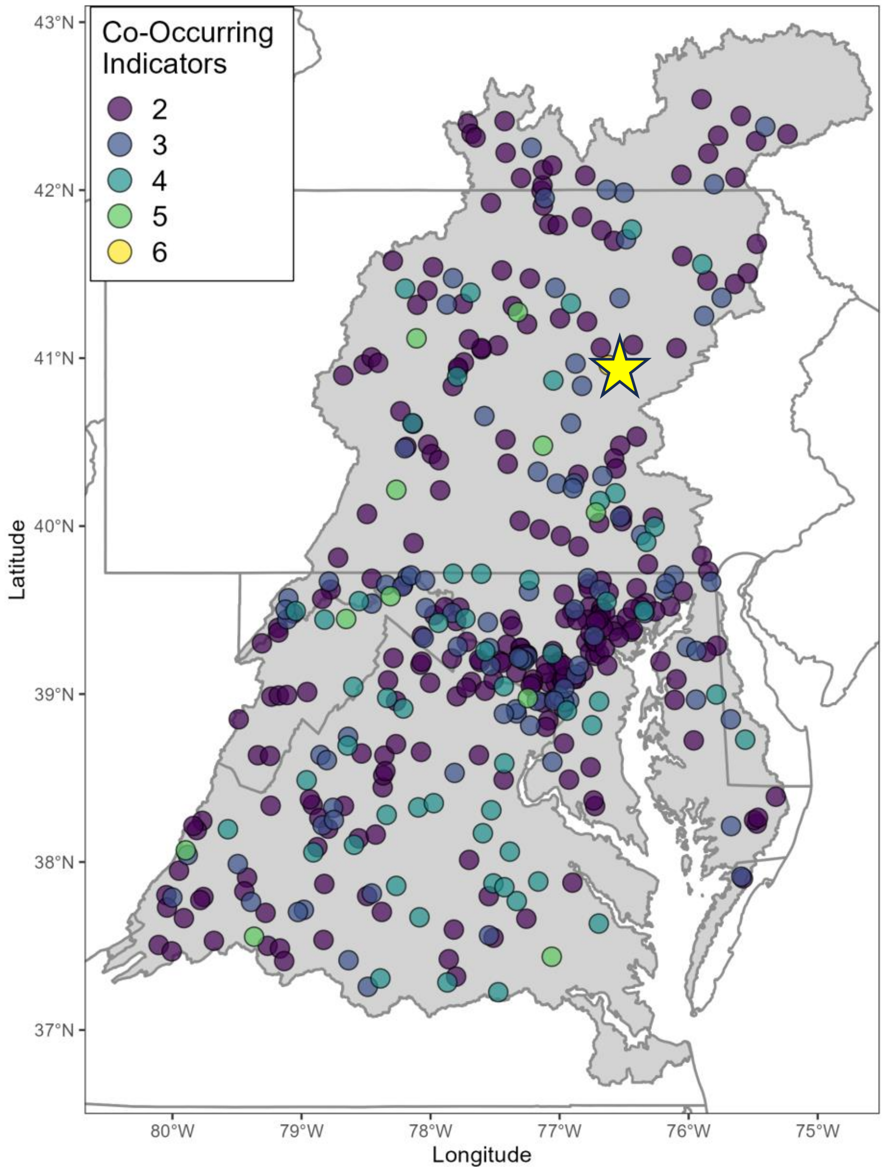
Analysis of field-based Rapid Habitat Assessment data showed **the majority of habitat metrics with significant trends indicate degrading condition**. Specific Gage Analysis captured a pattern of **streams becoming more shallow, and wide with lower channel velocity** over time.

Biological Assemblages

Very few sites had strong directional change in trend window (2008-2017) but significant **trends show more declines than increases in macroinvertebrate and fish sensitive taxa, increases in fish multi metric index scores, and decreases in macroinvertebrate multi metric index scores**. Additional data (currently compiling 2018-2023) may greatly increase spatial and temporal coverage of biological trend sites.

Challenges

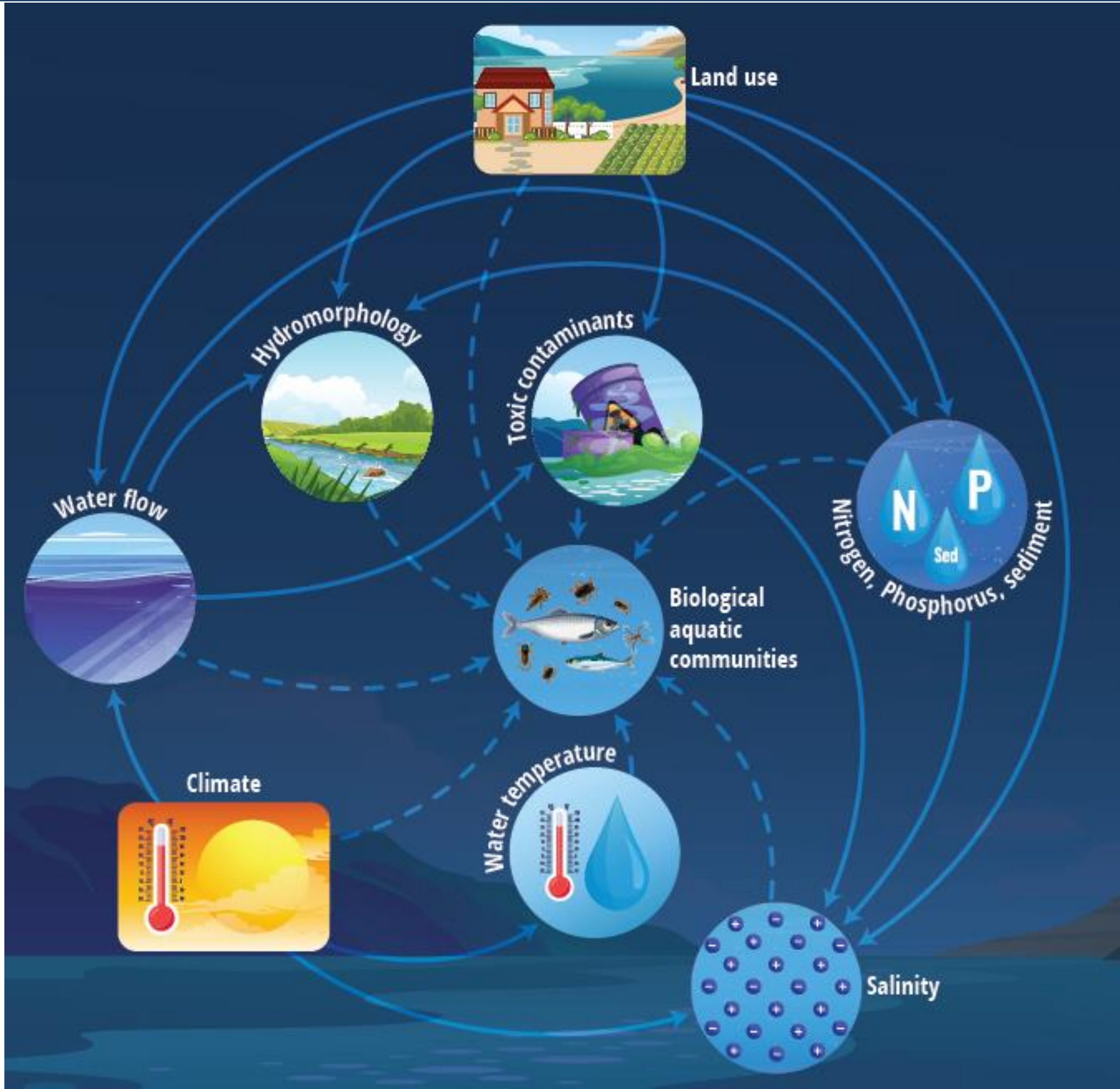
	Stream flow	Specific Gage	Nutrients Sediment	Salinity	Temp.	Toxics	Habitat	Macroinv erts.	Fish
Streamflow	417	342	115	88	28	13	9	7	0
Specific Gage		342	107	80	26	13	9	2	4
Nutrients Sediment			123	60	15	6	4	0	0
Salinity				278	10	21	7	9	0
Temp.					31	3	1	0	1
Toxics						89	0	0	0
Habitat							105	45	28
Macroinverts.								99	26
Fish									44



Preliminary data, not for citation or distribution

Next Steps

- Stakeholder Feedback and Partners
- Network Gap Analysis- Spatial, Temporal
- Incorporate Additional Data
- Routine Status and Trends Analysis
- Explore Factors Driving Status and Trends



USGS

Mentimeter Feedback

Link: https://www.menti.com/blku1fwzprfo
Access Code: **9140 0374**

Status and Trends of Stream Temperature in the Chesapeake Bay Watershed

Samuel H. Austin, Lindsey J. Boyle, Matthew J. Cashman, John W. Clune, James E. Colgin, Kaitlyn E. M. Elliott, Rosemary M. Fanelli, Ellie P. Foss, Nathaniel P. Hitt, Elizabeth A. Hittle, Coral M. Howe, Emily H. Majcher, Kelly O. Maloney, Christopher A. Mason, Douglas L. Moyer, Trevor P. Needham, Karli M. Rogers, Joshua J. Thompson, Guoxiang Yang, Tammy M. Zimmerman

Questions?

Indicator Contacts:

- Nutrients and Sediment- Christopher Mason (camason@usgs.gov)
- Temperature – John Clune (jclune@usgs.gov)
- Salinity – Rosemary Fanelli (rfanelli@usgs.gov)
- Toxic Contaminants – Trevor Needham (tneedham@usgs.gov)
- Streamflow – Samuel Austin (saustin@usgs.gov)
- Hydromorphology – Zachary Clifton (zclifton@usgs.gov) & Marina Metes (mmetes@usgs.gov)
- Biological Assemblages – Lindsey Boyle (lboyle@usgs.gov)

References:

- Austin, S.H., Cashman, M.J., Clune, J., Colgin, J.E., Fanelli, R.M., Krause, K.P., Majcher, E.H., Maloney, K.O., Mason, C.A., Moyer, D.L., and Zimmerman, T.M., 2023, Tracking status and trends in seven key indicators of stream health in the Chesapeake Bay watershed: U.S. Geological Survey Fact Sheet 2023–3003, 6 p., https://doi.org/10.3133/fs20233003.
- Banks, B.D., Needham, T.P., Dugan, C.M., Foss, E.P., and Majcher, E.H., 2022, Priority Toxic Contaminant Metadata Inventory and Associated Total Polychlorinated Biphenyls Concentration Data: U.S. Geological Survey data release, https://doi.org/10.5066/P9R78SQ6.
- Batiuk, R., Brownson, K., Dennison, W., Ehrhart, M., Hanson, J., Hanmer, R., Landry, B., Reichert-Nguyen, J., Tassone, S., and Vogt, B., 2023, Rising Watershed and Bay Water Temperatures: Ecological Implications and Management Responses – A STAC Workshop: STAC Publication Number 23-001, 505 p.
- Fanelli, R.M., Sekellick, A.J., and Hamilton, W.B., 2023, Compilation of multi-agency specific conductance observations for streams within the Chesapeake Bay watershed, U.S. Geological Survey data release, https://doi.org/10.5066/P98O2HQJ.
- Mason, C.A., Colgin, J.E., and Moyer, D.L., 2023, Nitrogen, phosphorus, and suspended-sediment loads and trends measured at the Chesapeake Bay Nontidal Network stations: Water years 1985-2020 (ver. 2.0, January 2023): U.S. Geological Survey data release, https://doi.org/10.5066/P96H2BDO.
- Olson, J. and S. Cormier. 2019. Modeling Spatial and Temporal Variation in Natural Background Specific Conductivity. *Environ. Science and Technology.* 53, 4316–4325. https://pubs.acs.org/doi/10.1021/acs.est.8b06777