Chesapeake Bay Program's
Scientific and Technical Advisory Committee Workshop

Rising Watershed and Bay Water Temperatures—
Ecological Implications and Management Responses

Findings and Emerging Storyline from the Watershed Syntheses

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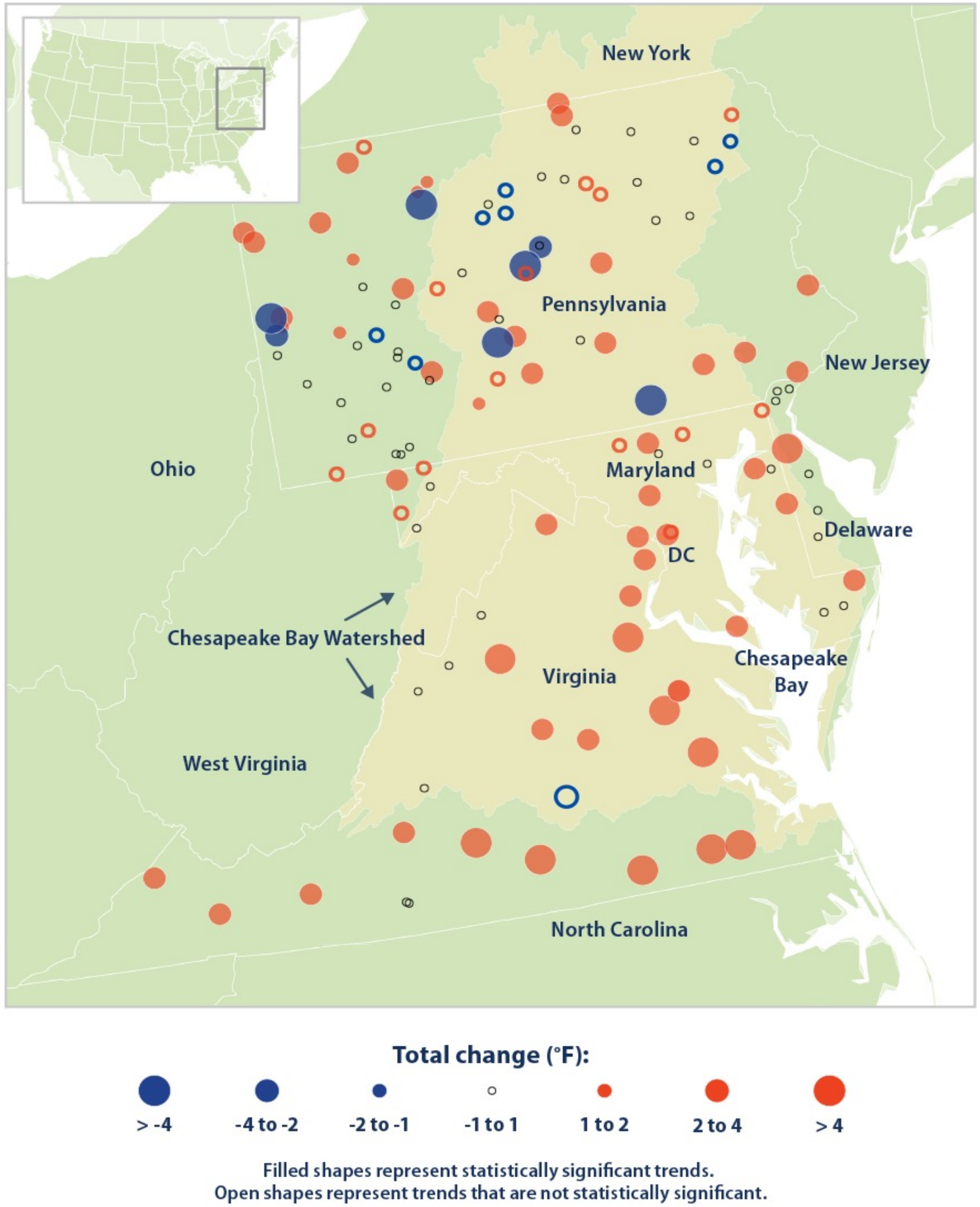
Chesapeake Bay Office

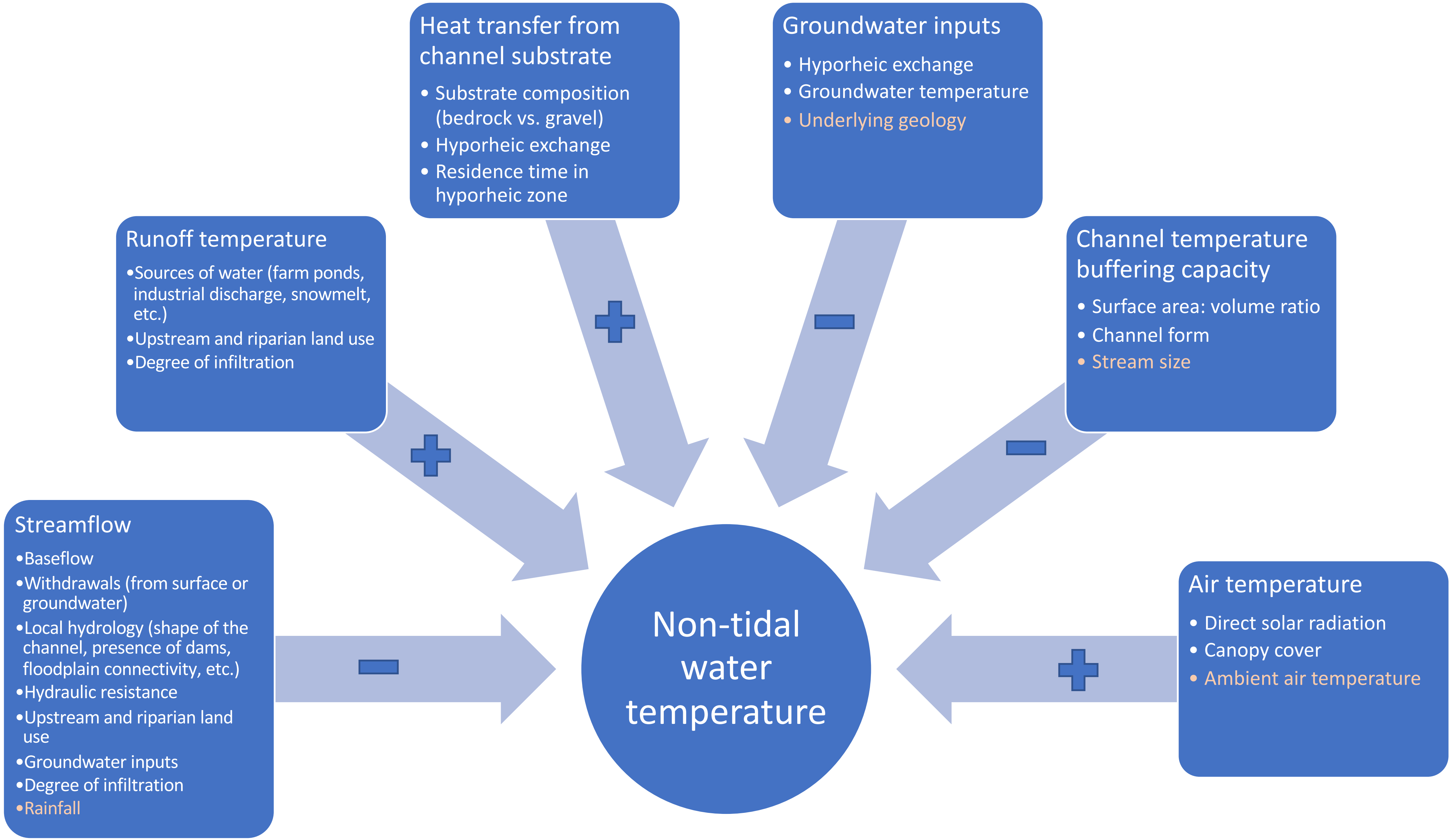
Water temperatures have been increasing in streams and rivers of the Chesapeake Bay watershed – even more than in the Bay's tidal waters



Source: Rice and Jastrow 2015

- Sites differed, but across the watershed, water temperatures increased more than air temperatures
- USGS found an average increase of 1.98° F in air temperatures and 2.52° F in nontidal freshwater stream temperatures (from 1960 to 2010)
- Air to water temperature ratios at sites showed influence of land uses

Increasing stream and river temperatures have been driven by rising air temperatures, but other drivers have a strong influence



A “healthy watershed” is more resilient to rising temperatures

Key factors influencing resiliency to rising temperatures:

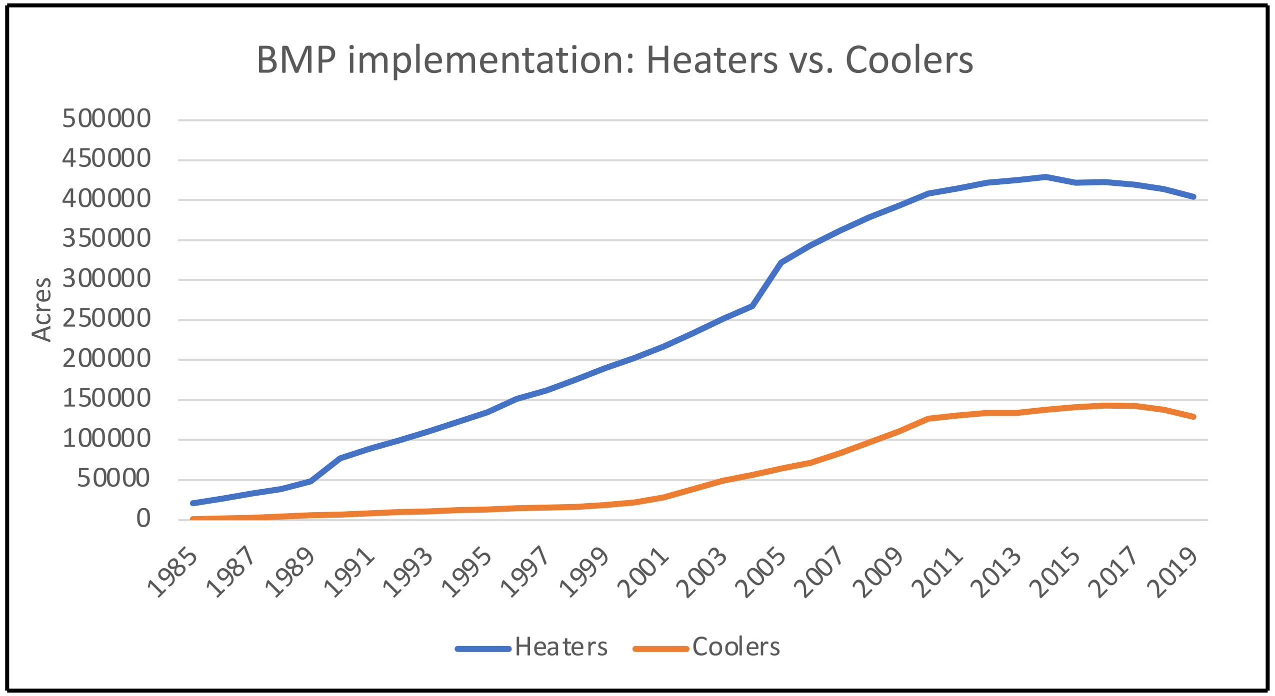
- Land use
  - % forest cover (catchment and riparian)
  - % impervious cover

- Hydrology/flow alteration

- BMP implementation

- Underlying geology/groundwater interaction

Watershed-wide, there has been substantially greater implementation of "heater" BMPs as compared with "cooler" BMPs



In many years, there has been approximately 3x as much implementation of heaters as coolers

"Heaters" include stormwater retention ponds, floating treatment wetlands and vegetated open channels.
"Coolers" include riparian forest buffers, upstream tree planting, urban stormwater infiltration, and wetlands restoration, enhancement and rehabilitation.

We know rising water temperatures negatively impact water quality – do we know enough about impacts and interactions with other pollutants in specific areas?

↑ Higher water temperature	↓ Lower oxygen solubility in water
↑ Higher water temperature	↑ Stimulates algae growth - bottom "slime" and harmful algal blooms
↑ Higher water temperature	↑ Mobilizes and increases the toxicity of other pollutants (e.g., heavy metals)

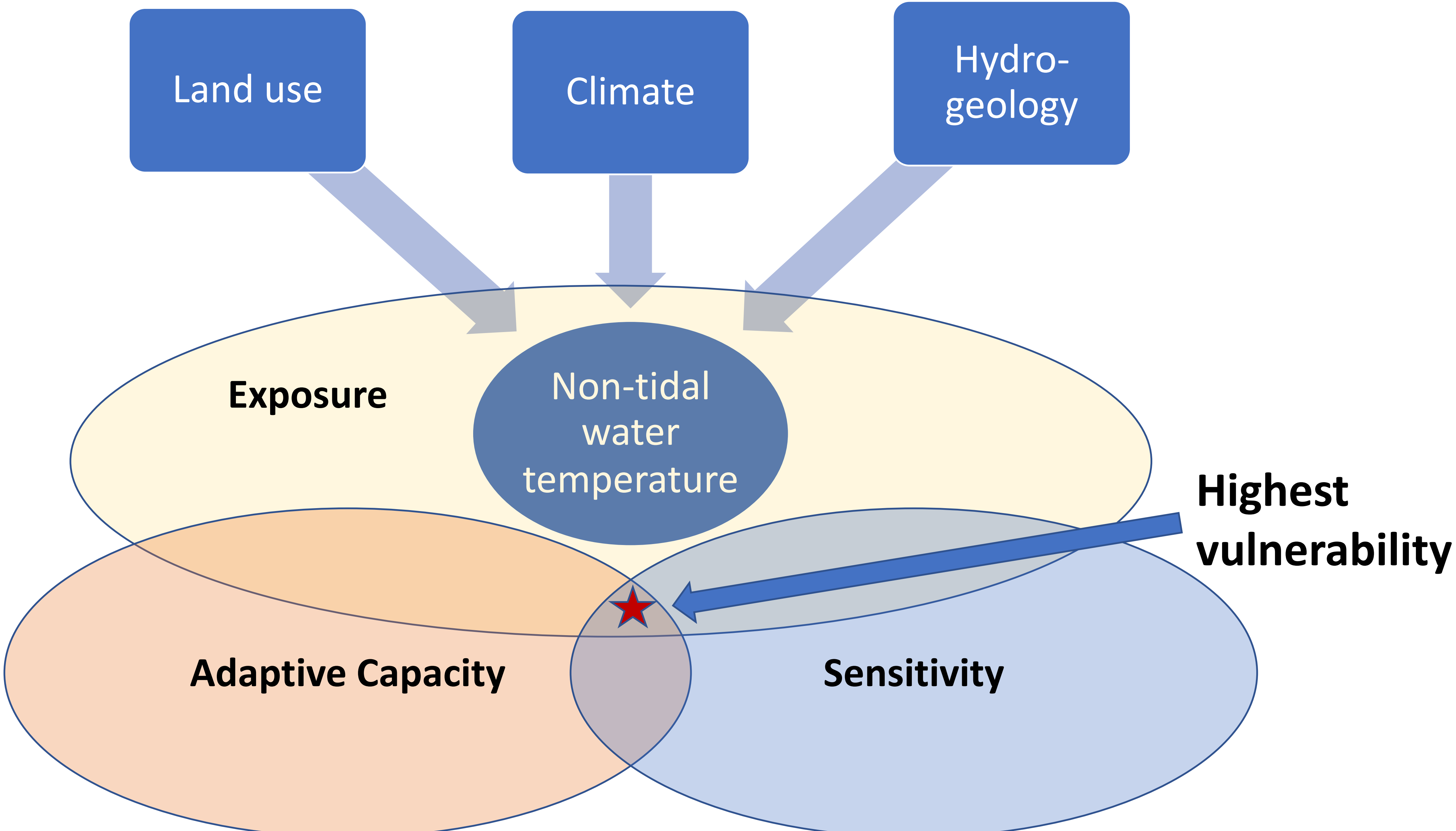
Warmer water temperatures and reduced water quality threaten many ecologically and economically important species

- **Strongest negative impacts** on coldwater species (brook trout, brown trout, rainbow trout, checkered sculpin). Protecting native brook trout habitat is urgent priority. Effects of warmer temperatures magnified by land use changes.

- **More study needed** of temperature effects on macroinvertebrates and resident mussels.

- Watershed-wide, warmwater aquatic species are most common. Although more tolerant to temperature increases, they are **sensitive to extreme temperatures** and even more to the indirect effects (e.g., invasives, pathogens) from higher temperatures.

Integration of exposure, sensitivity and adaptive capacity to identify particularly vulnerable species and habitats



What we understand

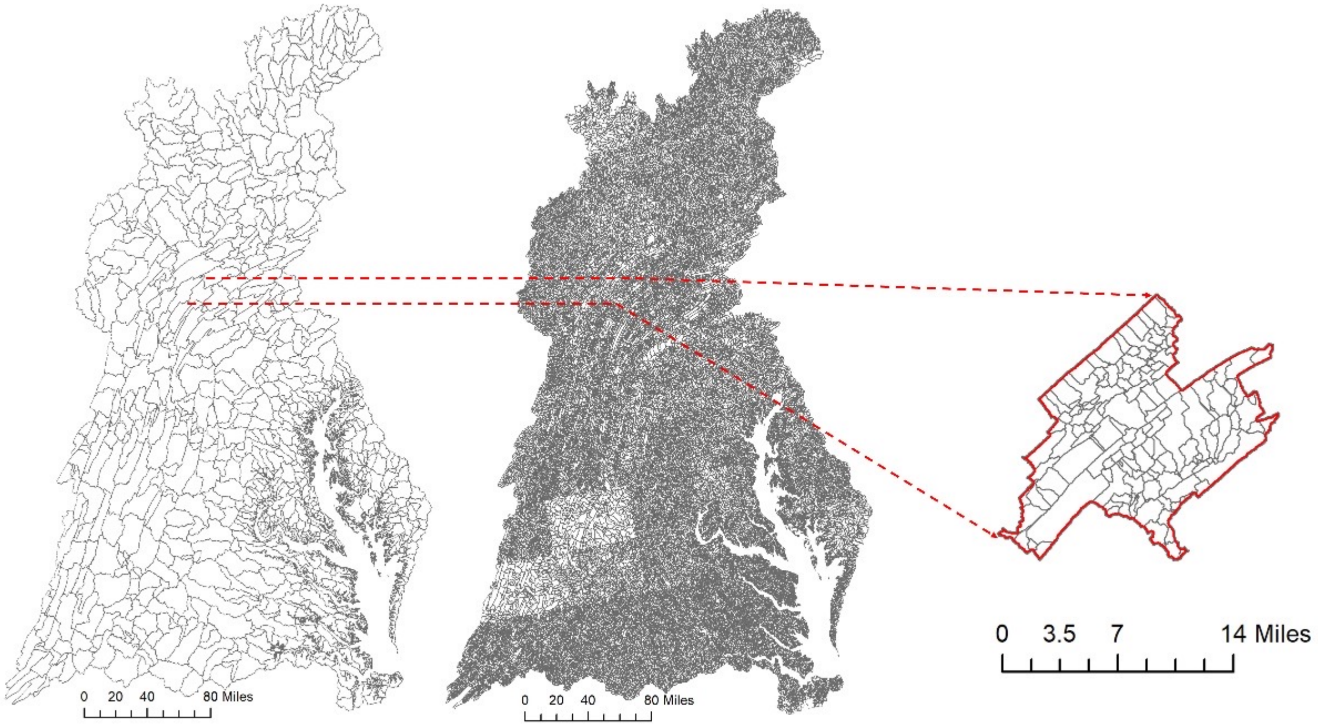
- Chesapeake Bay watershed scientists and engineers understand:
  - Effects of temperature on many aquatic species from studies and laboratory work
  - The benefits of forests and groundwater for temperature resiliency
  - The effects of urbanization on water temperatures
  - Qualitatively, the effect of urban BMPs as “warmers” or “coolers”

What we need to know

- Key knowledge gaps are:
  - Degree to which various drivers (and interactions between drivers) influence water temperatures in specific sub-watersheds
  - The influence of certain agricultural practices on water temperatures
  - Effects of temperature on aquatic species, especially the interaction of temperature and flow and the cumulative impacts of indirect effects (e.g., invasives, pathogens)
  - Temperature effects on amphibians, functional response vs. thermal max
  - How local stream temperatures will respond to resiliency measures

Better understanding influences of rising water temperatures on living resources and habitats in the Bay watershed will require enhancements to the Partnership's current modeling tools

- The current model scale is for larger streams and rivers, not streams where the most temperature-sensitive species live
- Processes controlling temperature in small streams are not necessarily the same as for larger rivers
- The temperature effects of structural BMPs are not simulated in the current model



Current Phase 6 Watershed Model

Proposed Phase 7 Watershed Model

Phase 7 Segments Nested in Phase 6 Segment

Rising Water Temperatures - Watershed Storyline

- Water temperatures in the CB watershed rising, on average, faster than air temperatures.
- Paired air and water temperature monitoring shows influence of forest cooling and warming by agriculture and open land.
- Rising water temperatures affect physical, chemical and biological processes of aquatic living resources and their habitats.
- Higher water temperature adds to biological and habitat challenges that coldwater aquatic species already face in the watershed.
- Warmwater aquatic species tolerate higher temperatures but are vulnerable to sudden or severe heating and indirect effects.

Rising Water Temperatures - Watershed Storyline

- To date, we have implemented more “warming” than “cooling” BMPs.
- Healthy Watersheds are more resilient to increasing temperatures.
- CBP Watershed Model use for temperature predictions limited; Phase 7 model with fine-scale model segments or other existing fine-scale models could really help.
- Need better tools for understanding resource effects of climate-related heating and management measures along with more/better data at management-relevant scales, taking into account state monitoring and follow-up studies for attaining temperature water quality standards.

Acknowledgements

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- **Synthesis Element #1 Addendum (Temperature Criteria in CBP Jurisdictions' Water Quality Standards and Information on Warmwater Species):** Rebecca Hanmer, EPA-retired; Jonathan Leiman, Maryland Department of the Environment; Daniel Goetz, Maryland Department of Natural Resources; Robert Breeding, Virginia Department of Environmental Quality; and Matthew Robinson, DC Department of Energy and Environment
- **Synthesis Element #4 Paper** (Watershed Characteristics and Landscape Factors Influencing Vulnerability and Resilience to Rising Stream Temperatures): Renee Thompson, USGS; Nora Jackson, CRC/CBP; Judy Okay, J&J Consulting; Nancy Roth, Tetra Tech; Sally Claggett, USFS
- **Synthesis Element #5 Paper (Trends)**: Rich Batiuk, CoastWise Partners; Nora Jackson, CRC/CBP; John Clune, USGS; Kyle Hinson, VIMS; Renee Karrh, Maryland Department of Natural Resources; Mike Lane, Old Dominion University; Rebecca Murphy, University of Maryland Center for Environmental Science/CBP; and Roger Stewart, Virginia Department of Environmental Quality
- **Synthesis Element #6 Paper (Model Projections)**: Rich Batiuk, CoastWise Partners; Gopal Bhatt, Pennsylvania State University/CBP; Lewis Linker, U.S. EPA CBP; Gary Shenk, USGS/CBP; Richard Tian, University of Maryland Center for Environmental Sciences/CBP; and Guido Yactayo, Maryland Department of the Environment
- Synthesis Element #7/8 Paper (Impacts of BMPs and Habitat Restoration on Water Temperatures): Katie Brownson and Sally Claggett, USFS; Tom Schueler, CSN; Anne Hairston-Strang and Iris Allen, Maryland Department of Natural Resources-Forestry; Frank Borsuk and Lucinda Power, EPA; Mark Dubin, UMD; Matt Ehrhart, Stroud; Stephen Faulkner, USGS; Jeremy Hanson, VT; Katie Ombalski, Woods & Waters Consulting
- **Synthesis Element #10 Paper (Monitoring)**: Peter Tango, Breck Sullivan, John Clune, and Scott Phillips, USGS

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