Rising Temperatures STAC workshop

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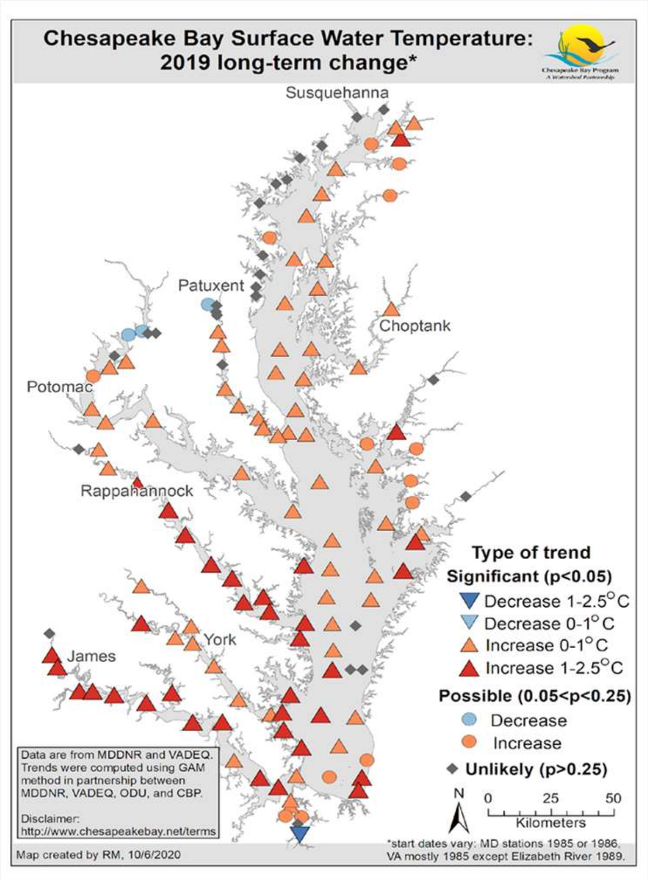
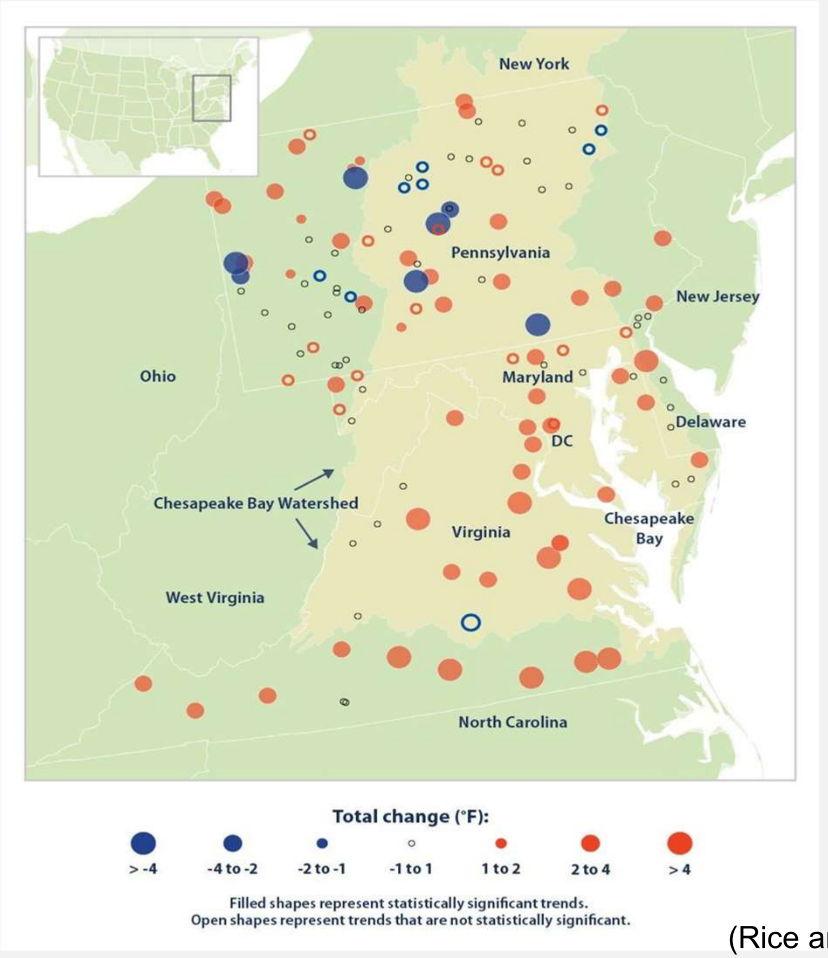
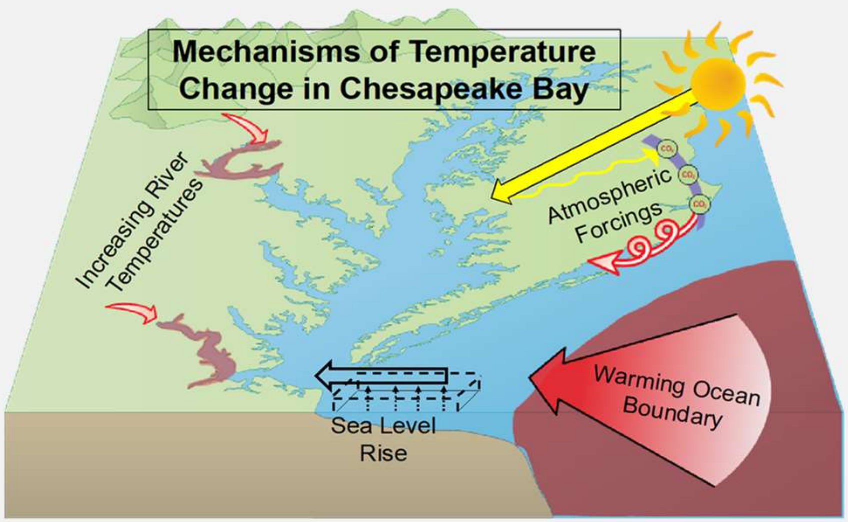
Increasing temperatures in Chesapeake Bay tidal and non-tidal waters

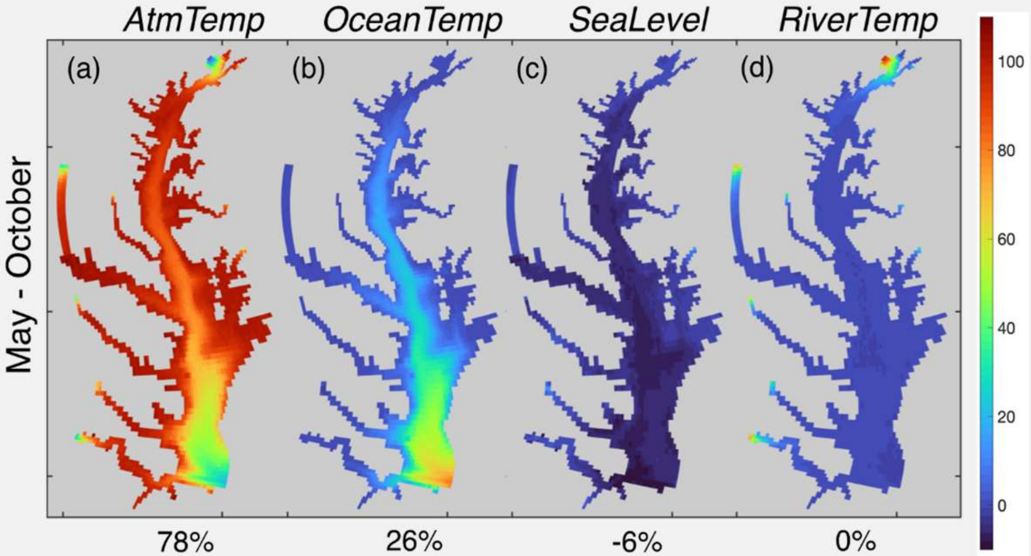




(Rice and Jastram, 2015)

Increasing Bay temperatures driven largely by air temperatures and coastal ocean temperatures

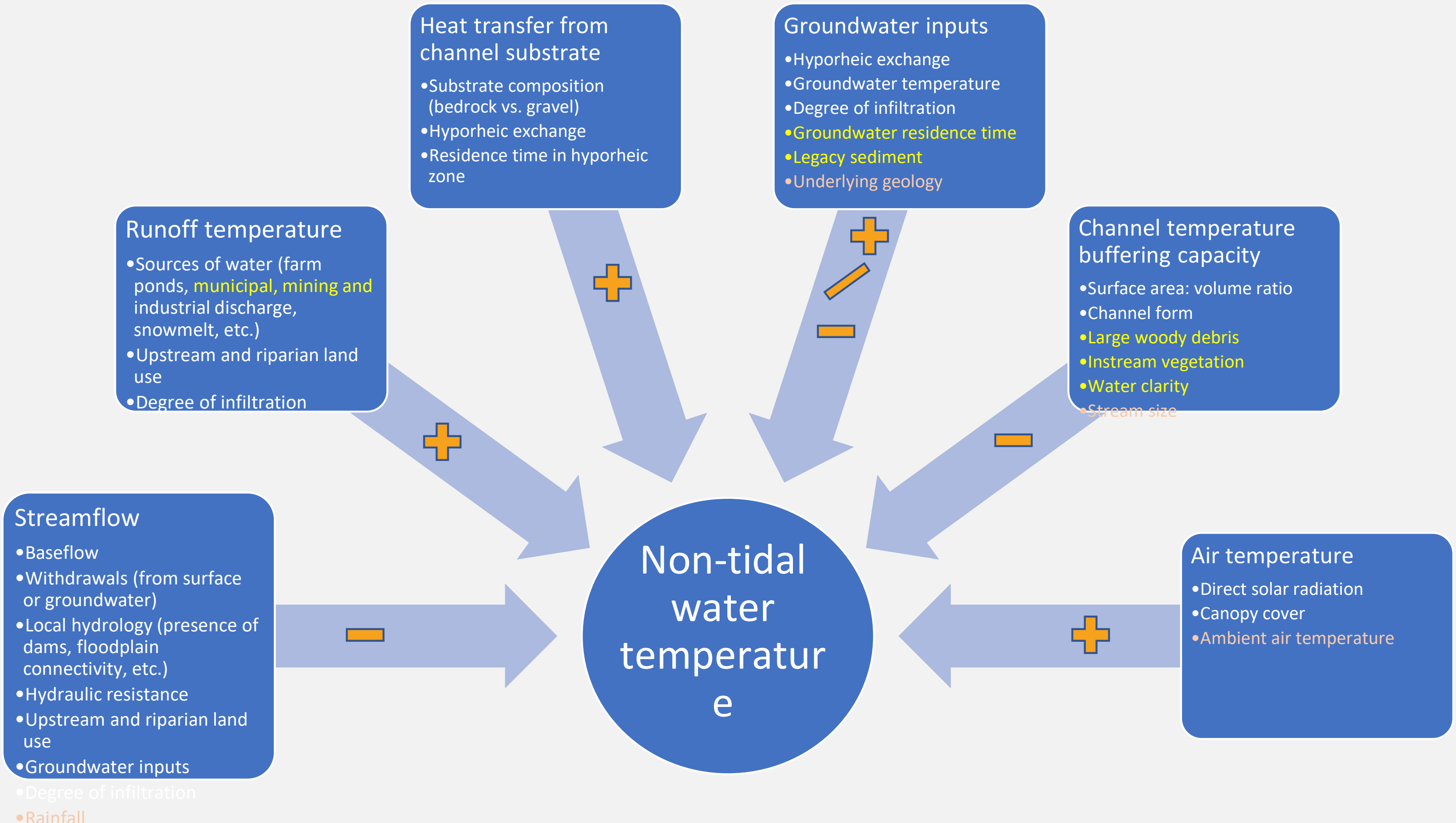




1) Air temperatures
2) Ocean temperatures
3) Sea level rise
4) River temperatures

Source: Hinson at el. 2021

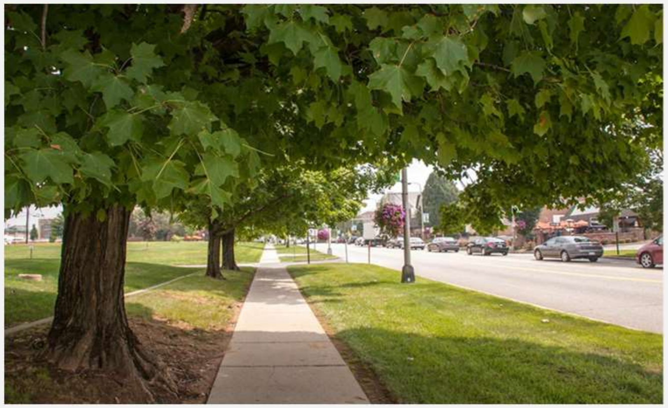
Increasing stream temperatures driven by rising air temperatures and other drivers



Counter water temperatures in the watershed through cooling strategies

BMPs

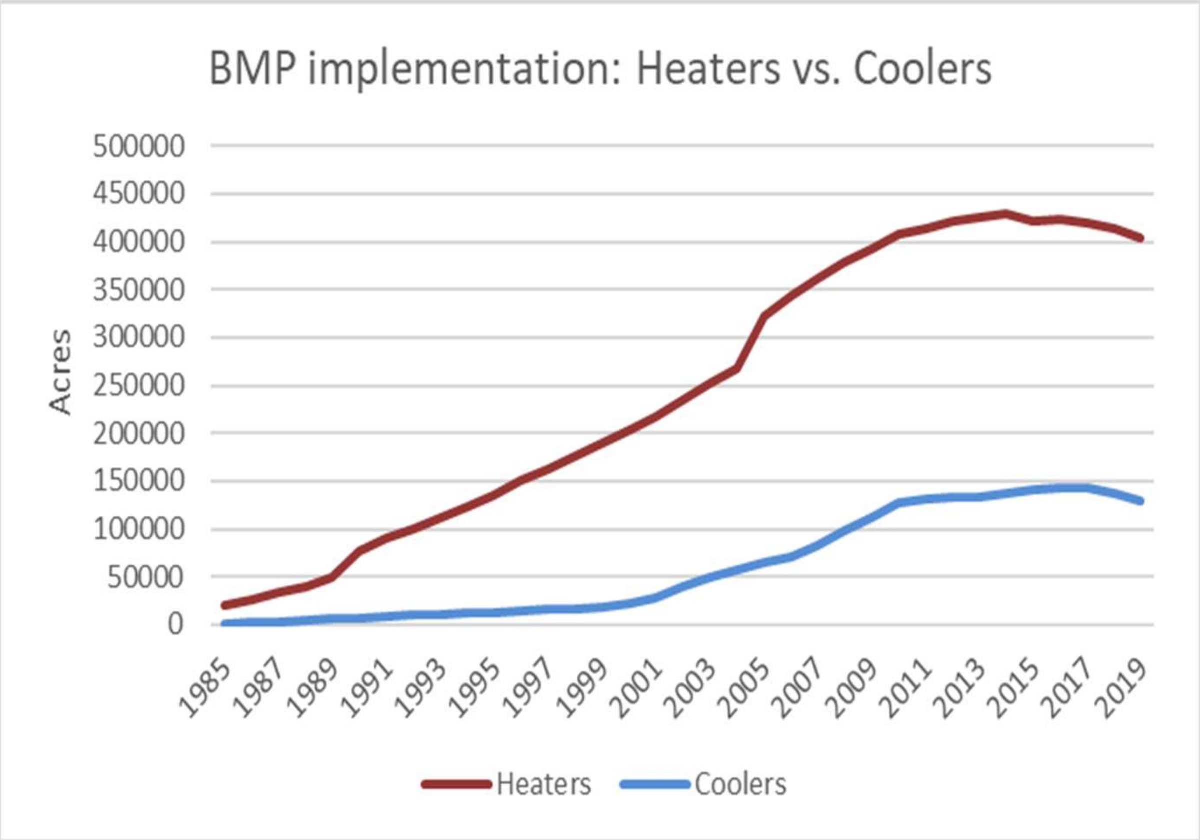
Conservation



Land Use

Common theme = More trees

Counter water temperatures in the watershed through cooling strategies



Farm pond

Riparian buffer

Minimize impacts to Chesapeake Bay and adapt management


SAV


Oysters


Crabs


Forage fish


Striped bass

- **Strongest negative impacts** on coldwater species (e.g., trout, sculpin) and their habitats (esp. where streams aren't driven by groundwater)

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

- **More study needed** of temperature effects on lower foodweb
  - Algae, biofilms, zooplankton
  - Macroinvertebrates
  - Freshwater mussels & host species

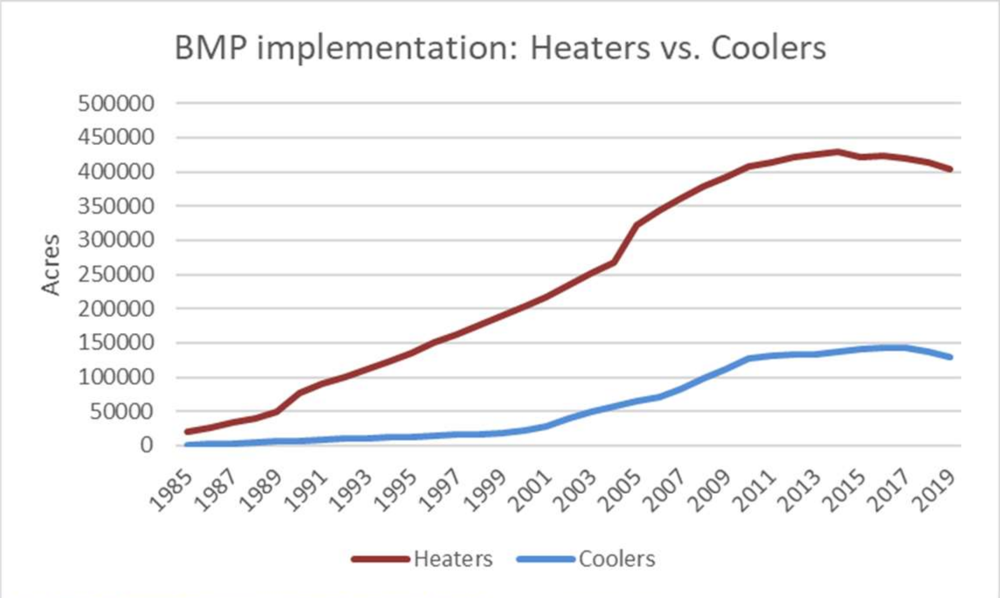
Watershed

Ecological Impacts and Recommendations

Leads: Katie Brownson, U.S. Forest Service & Rebecca Hanmer, Forestry Workgroup Chair

What can the Bay Program do to help moderate rising water temperatures?

- **Incentivize forest conservation** to protect the coldwater streams now supporting healthy aquatic life
- **Prioritize best management practices that cool or moderate water temperatures**, including riparian forest buffers and upstream tree planting, paying particular attention to vulnerable ecosystems and communities
- **Work with local governments to promote good land use planning** to increase infiltration and minimize impervious surfaces
- **Review and modernize the current Water Quality Standards** systems to better address climate-related heating in streams and rivers



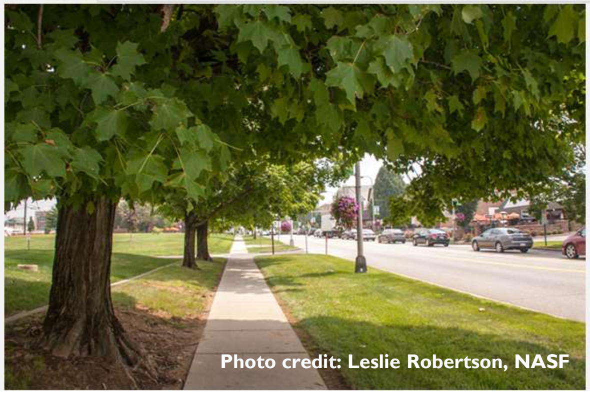
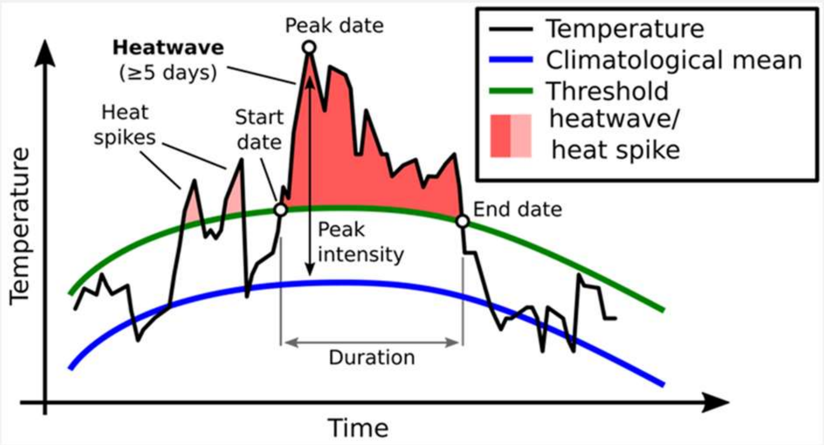


Photo credit: Leslie Robertson, NASF

What can the Bay Program do to help adapt to rising water temperatures?

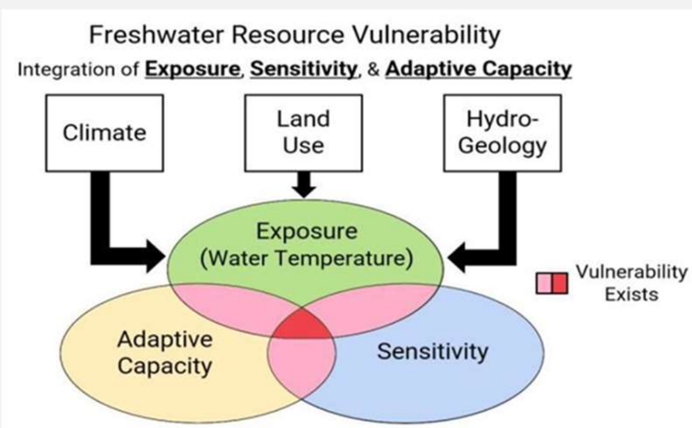
- Develop BMP design recommendations to create or maintain thermal refugia, especially during summer heatwaves
- Improve connectivity by restoring habitats and/or removing barriers to suitable cold and coolwater habitats

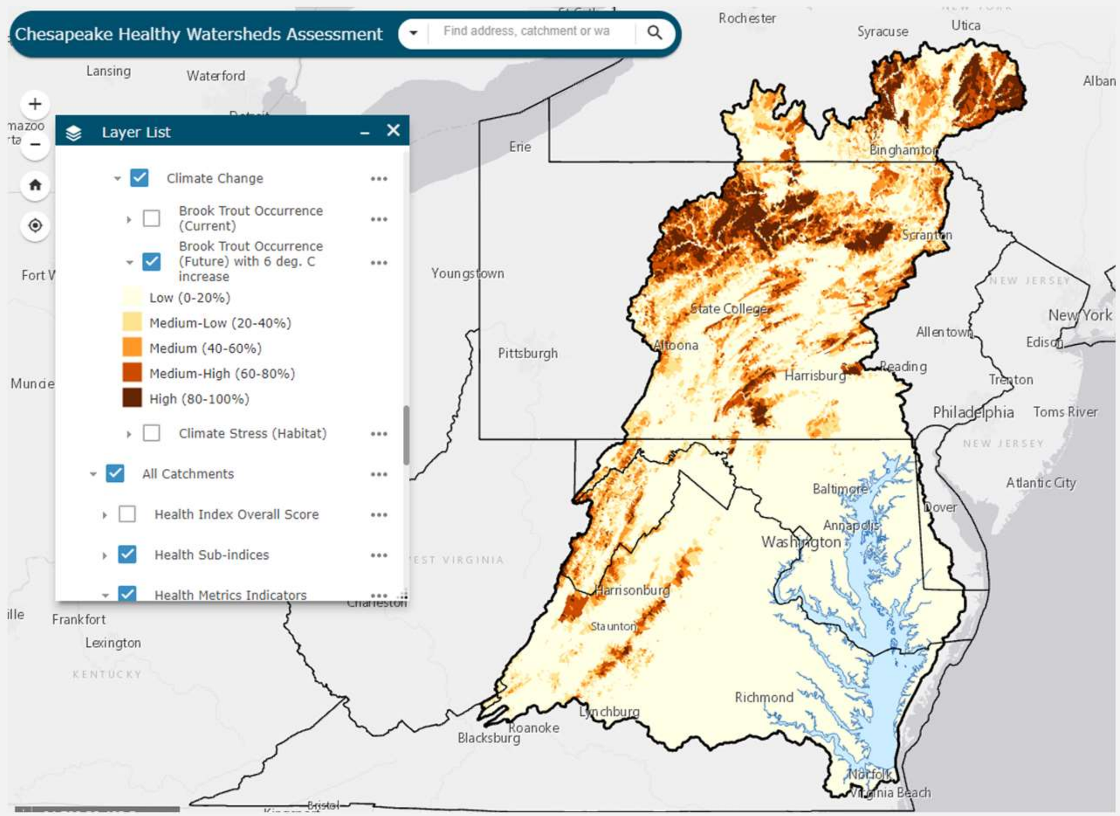


marineheatwaves.org

What can the Bay Program do to advance science around rising water temperatures?

- Advance understanding of how BMPs influence water temperature
- Continue resiliency analyses and mapping to focus coldwater habitat restoration efforts.
- Improve water temperature monitoring and modeling to better inform management





TIDAL

Ecological Impacts & Recommendations

Leads: Julie Reichert-Nguyen (NOAA), Bruce Vogt (NOAA), Brooke Landry (MD DNR), Rich Batiuk (Coastwise Partners) & Jamileh Soueidan (CRC/NOAA)

Rising Tidal Water Temperatures:
Chesapeake Bay of the Future will not be the Chesapeake Bay of the Past

- Bay water temperatures are increasing and will continue to increase – affects all water quality, living resources, and habitat outcomes in the Chesapeake Bay Watershed Agreement.
- Managing greenhouse gas emissions to reverse the rising water temperature trend is outside the purview of the Chesapeake Bay Program
- Focus on building resilience and adapting with strategic restoration and management strategies to minimize negative impacts and promote positive outcomes.

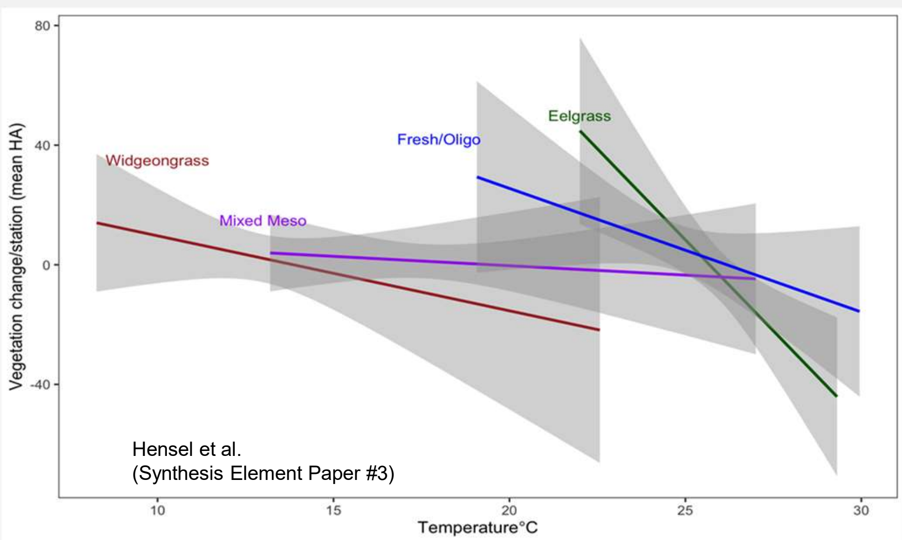
Photo: Dave Harp, *Bay Journal*

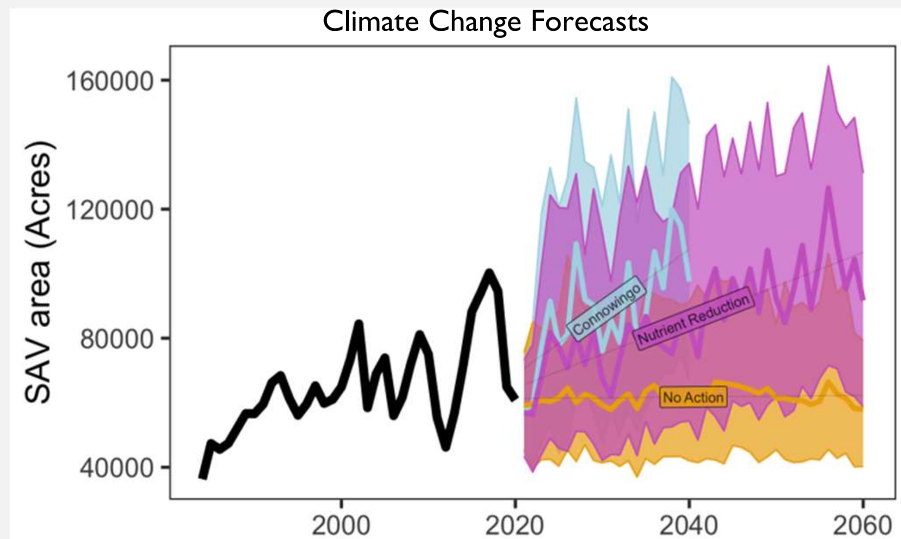

Photo: Peter McGowan, USFWS

Submerged Aquatic Vegetation

- Eelgrass is negatively affected by rising water temperature, while other species (e.g., widgeongrass, freshwater species) are more heat tolerant.
- Unknown how SAV community shifts will affect habitat use of fish and blue crabs – research needed.
- Continuing water quality management goals to maximize water clarity is key for SAV; SAV more resilient to temperature stress in clear water.

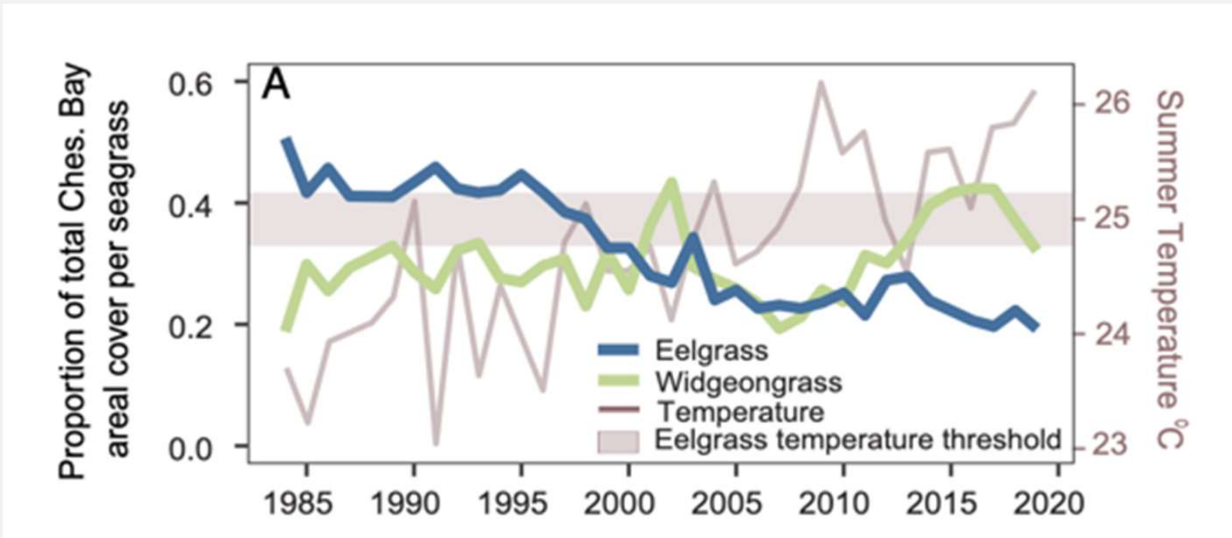
Photo: Jay Fleming





Hensel et al. SAV Climate Model Data Synthesis GIT-Funded Project

SAV: Eelgrass declining & widgeongrass increasing



PNAS

RESEARCH ARTICLE | ECOLOGY SUSTAINABILITY SCIENCE

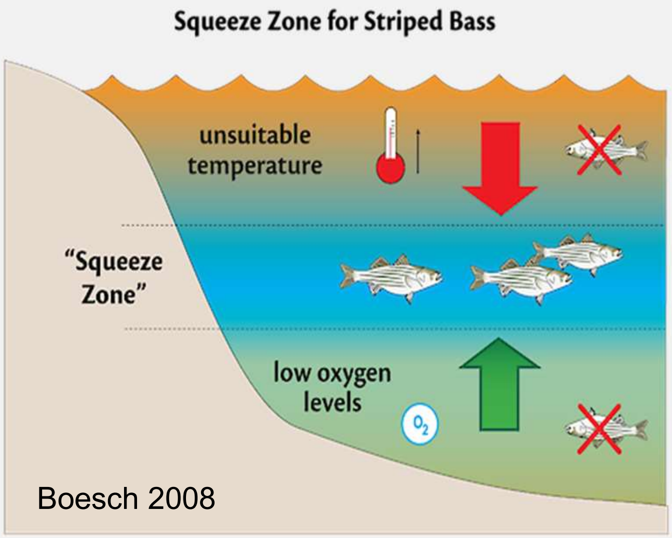
OPEN ACCESS

Rise of *Ruppia* in Chesapeake Bay: Climate change–driven turnover of foundation species creates new threats and management opportunities

Marc J. S. Hensel[a,1], Christopher J. Patrick[a], Robert J. Orth[a], David J. Wilcox[a], William C. Dennison[b], Cassie Gurbisz[c], Michael P. Hannam[d], J. Brooke Landry[e], Kenneth A. Moore[a], Rebecca R. Murphy[f], Jeremy M. Testa[g], Donald E. Weller[h], and Jonathan S. Lefcheck[i]

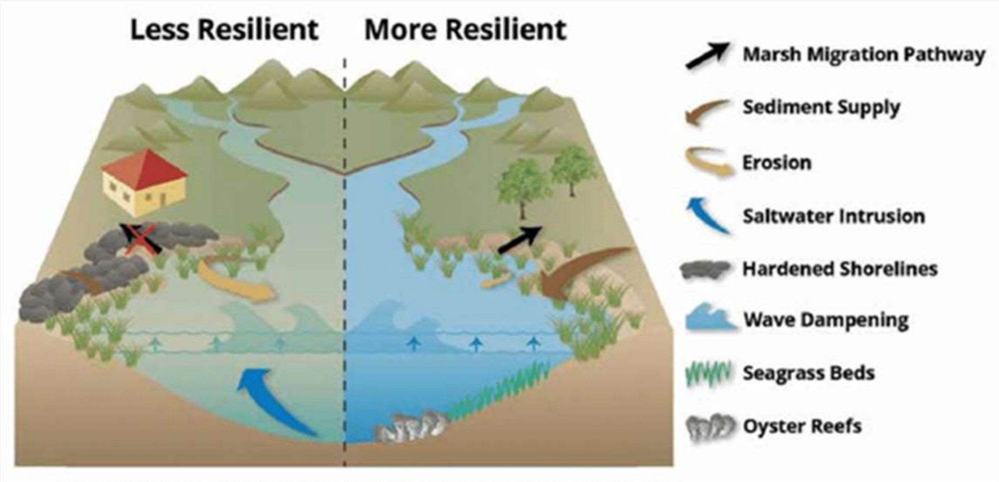
Rising Tidal Water Temperatures:
Ecological Impacts to Fisheries and Recommended Actions

- Decreases in water quality and habitat suitability for vulnerable species (e.g., striped bass, summer flounder) due to multiple stressors (e.g., climate change, excess nutrients, fishing pressure) and extreme events (e.g., marine heat waves).
  - Identify environmental thresholds and fishing guidance to minimize stress on vulnerable species.
- Impacts to fisheries from rising water temperature may be positive or negative
  - Maximize habitat restoration to promote positive outcomes.
- Northward shifts in species range. Species from the south are becoming more prevalent.
  - Support social science research and develop and implement communication strategy for existing and future scenarios.
  - Take proactive approach to prepare for change in species using the Bay.



Rising Tidal Water Temperatures:
Nearshore Habitat Recommended Actions

- Develop common criteria to help target, site, and design natural infrastructure projects, such as living shorelines, that benefit both communities and ecosystems.
  - Investigate restoration designs that incorporate multiple habitat types (e.g., seagrass, marshes, oyster reefs) to maximize resilience.
- Support efforts to increase understanding on the design, placement, and extent of water quality BMPs to minimize nearshore warming in tidal tributaries (e.g., coolers versus heaters).
  - Research on how best to create thermal refugia for vulnerable SAV and fish species.



Kister 2016 (Reprinted with permission from the Integration & Application Network, 2013)

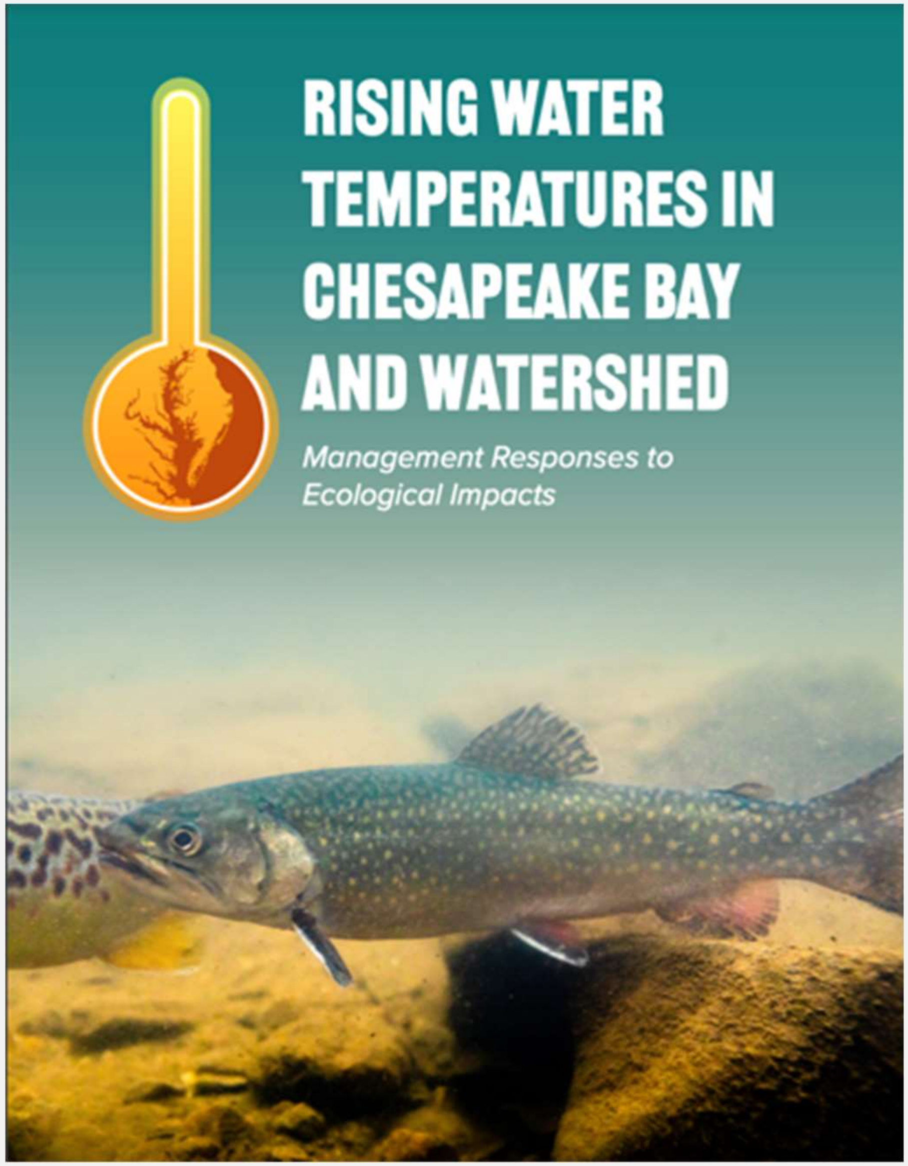
Common Themes Across the Workshop: Science & Research

- Improve Monitoring
  - Increase and develop strategic monitoring systems to collect environmental and biological data necessary to track water temperature, other stressors, and ecological change.
    - Include more frequent monitoring in smaller streams and critical fish habitat areas.
  - Improve the ability to pair air temperature trends with water temperature trends.
- Modeling tool improvements
  - Finer-scale modeling that incorporates temperature change to determine the response of living resources to inform management.
- Thresholds
  - Support research to better understand environmental condition and habitat thresholds and communicate the implications of rising water temperatures for living resources.

What are some implications of this report for 2025 and Beyond?

- Warming water temperatures will make it more difficult to reach our 2025 TMDL water quality goals and multiple Watershed Agreement goals (Brook trout, Stream Health, Healthy Watersheds, Fish Habitat, Blue Crab Abundance, SAV, etc.)
- For non-tidal waters, need to put even more emphasis on Riparian Forest Buffers and Forest Conservation to help mitigate and adapt to rising water temperatures
- For tidal waters, we need strategic habitat restoration to minimize stress on vulnerable fisheries and SAV species and continued improvements in long-term monitoring to better assess environmental and ecological change.
- Moving beyond 2025, water temperature should be incorporated more explicitly into the goals, outcomes and management strategies of the Partnership to better achieve both water quality and living resources goals

8 pp
Executive
Summary
produced



Causes and Effects of Rising Temperature

Counter water temperatures in the Chesapeake Bay watershed through cooling strategies

Water temperatures are rising in the Chesapeake Bay watershed

Water temperatures have been increasing in streams and rivers of the Chesapeake Bay watershed over the past several decades—even more than in the Bay's tidal waters. In many areas, water temperatures increased more than air temperatures, demonstrating that air temperature is not always the primary driver of water temperature in non-tidal waters.

Rising air temperatures and other drivers have a strong influence

Land use has a significant impact on temperatures of stream flow and precipitation-induced runoff from land surfaces. Trees and riparian forests play a central role in stream temperature moderation, through shading, evapotranspiration and facilitating infiltration. Conversely, exposed agricultural lands and developed areas with impervious surfaces contribute heated runoff to streams. Other landscape factors, like groundwater inputs, may help identify places that are more resilient to climate change to target for conservation, including healthy watersheds.

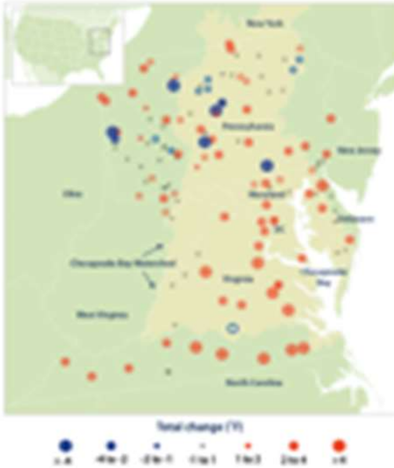


Figure 3. Changes in stream water temperatures in the Chesapeake Bay region, 1960-2014. Filled shapes and open shapes represent statistically significant and not statistically significant trends, respectively. Source: EPA, based on data from Jastram and Rice, 2015.

Figure 4. Major drivers of non-tidal water temperature and the direction of their influence. Source: Synthesis Element Paper 7B, Appendix K.

Water temperatures can affect sensitive species

Warmer water temperatures, including shorter-term extreme heat events, will negatively impact aquatic habitats and threaten many ecologically and economically important aquatic species. Stream temperature has direct and indirect effects on many biological, physical and chemical processes in the freshwater environment. Rising water temperatures may increase the occurrence or co-occurrence of known stressors (such as harmful algal blooms) that negatively impact aquatic species and habitats.

Eastern brook trout (Salvelinus fontinalis) swim at the Virginia Living Museum in Newport News, VA. Photo by Will Parson/CBP.

Algae covers the surface of a pond in Warrenton, VA. Photo by Will Parson/CBP with aerial support by Southwings.

Stream temperature monitoring data is critical

In the past 70 years, stream temperature data has been collected at 31,342 sites by multiple agencies across the Chesapeake Bay watershed. The U.S. Geological Survey has begun compiling data from multiple agencies for assessing status and trends of stream temperature across the Chesapeake Bay watershed. Monitoring and analysis strategies need updating in the light of climate and land use change—for example, higher-frequency monitoring during critical periods to understand places and aquatic organisms most exposed and sensitive to pulsed heating events.

Figure 5. Available stream temperature data has increased over time (left), showing how average monthly temperatures change over time (right). Source: U.S. Geological Survey.

Causes and Effects of Rising Temperature

Minimize impacts to the Chesapeake Bay and adapt management

Water temperatures are rising in the Bay

Over the past three decades, the tidal water temperatures in the Chesapeake Bay have been increasing. These changes in tidal water temperatures are primarily driven by global atmospheric forcing (e.g., increasing surface air temperatures) and the influence of warming ocean waters entering the Bay. Warming ocean boundary effects are important in summer, but small otherwise during the rest of the seasons. Sea level rise slightly cools the Bay's main stem from April to September and warms bottom waters in winter. River temperatures produce little to no warming in the Bay's main stem. Other environmental factors are influenced by rising water temperatures, such as dissolved oxygen. Increasing Bay water temperatures will result in increased volumes of low dissolved oxygen due to direct effects on oxygen solubility, biological process rates, and stratification.

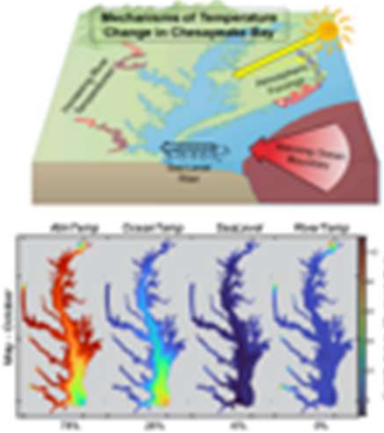


Figure 7. The four major mechanisms driving changes in water temperature throughout the Chesapeake Bay's main stem, tidal tributaries and embayments (top). Percent contribution to the total change in main stem bottom temperatures from each sensitivity experiment for May through October based on a 30-year timeframe (late 1980s-late 2010s, bottom). Source: Hinson et al. 2021.

Figure 6. Long term trends in surface water temperatures at the Chesapeake Bay Mainstem and Tidal Tributary Water Quality Monitoring Program stations from a start date of 1985 or 1986 to an end date of 2019 (left). Temperature change over time in the Chesapeake Bay (right). Sources: CBP 2020; Hinson et al. 2021.

Ecological implications predicted at a Bay scale

Rising water temperature in the Chesapeake Bay is already affecting many key species, such as striped bass, eastern oyster, eelgrass, and blue crab, contributing to future ecosystem changes. Research focused on assessing climate vulnerability shows both positive and negative responses of living resources to temperature and other climate change related factors depending on species, life stage, and location within the estuary.

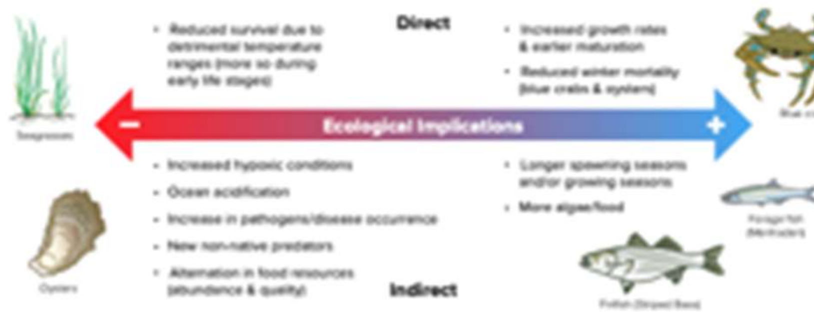


Figure 8. There are a range of positive and negative responses of living resources and habitats (e.g., forage fish, finfish, benthic organisms, and submerged aquatic vegetation) to rising water temperature and other climate change related factors.

Ecological shifts expected at an ecosystem-level

Rising water temperatures have resulted in northward shifts in several Bay species' ranges, while new species from the south are becoming more prevalent in the Bay. These shifts can impact species abundance and distributions, food web dynamics, fishing behavior and the potential for new fisheries. Likewise, habitats required by fish and shellfish species, such as underwater grasses, are also shifting in range and experiencing temperature-driven impacts on area and composition that can affect fish abundance, distribution and reproduction success.

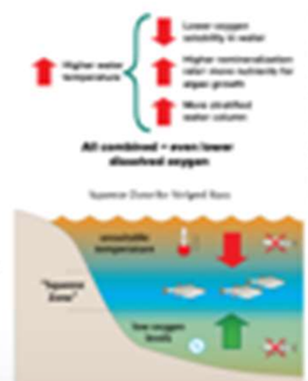


Figure 9. Conceptual diagram illustrating the compressed habitat of the striped bass from the low oxygen levels from the bottom, and the unsuitable temperatures from the surface. Diagram courtesy of the Integration and Application Network (ian.umces.edu), University of Maryland Center for Environmental Science. Source: Boesch 2008.

Management and Research Recommendations

Rethink Chesapeake restoration

The Chesapeake Bay Program's (CBP) management strategies and action plans to meet goals set by the 2014 Watershed Agreement need to take account of a critical, basic condition—water temperature—that has been changing and will continue to do so. The Scientific and Technical Advisory Committee (STAC) workshop was structured to initiate full consideration of rising water temperatures in nearly every restoration, conservation, education and public communication decision—made individually as well as collectively—by the CBP partners. The recommendations include many actions which can be initiated now, as well as actions in science, monitoring, modeling and program implementation which will help guide the Program in setting future goals.

Brook trout fishing in a tributary of Seneca Creek in Pendleton County, WV. Photo by Steve Droter/CBP.

Fishing Creek is protected by a riparian buffer as it flows past Schrock Farms in Loganton, PA. Photo by Will Parson/CBP.

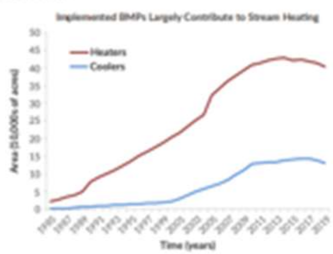


Figure 1. Trends in implementation of BMPs that may have an adverse impact on stream water temperature. Source: Synthesis Element Paper 7/8, Appendix K.

Protect coldwater fisheries

CBP partners need to accelerate conservation actions like maintaining and increasing intact forested watersheds to protect the coldwater streams now supporting healthy aquatic life, especially native brook trout, which are extremely sensitive to rising water temperatures, and continue analyses and mapping/modeling to identify stream reaches with thermally resilient groundwater inputs to focus habitat restoration efforts.

Restore aquatic habitats

CBP partners should work to strategically conserve and restore aquatic habitats, improving connectivity between healthy forested habitats and providing access to thermal refugia, both in sensitive rural watersheds and in urban streams.

Enhance "coolers" and reduce "heaters"

CBP partners should work to minimize the extent to which some water quality best management practices (BMPs) are further heating waterways and use forest buffers, good agricultural stewardship practices, stormwater infiltration, and other cooling BMPs to reduce the amount of heated runoff. Pay particular attention to expanding tree canopy coverage in historically under-served urban areas.

Modernize water quality standards

Given the vital role of Clean Water Act water quality standards (WQS) in protecting water quality and aquatic life, the states and EPA should review and update the components of current WQS systems that would strengthen their capability to address climate-related rising water temperatures and drive targeted protection and restoration strategies.

Apply Bay environmental thresholds to inform fisheries management

Establish fishing guidance based on temperature and dissolved oxygen thresholds to reduce vulnerability on key recreational fish species, such as striped bass and summer flounder, during periods of poor environmental conditions. Take actions to engage with fisheries stakeholders to explore strategic, long-term ways to advance ecosystem approaches to fishery management in the Bay that incorporate environmental thresholds influenced by climate change.

Communicate temperature risk

Better communicate the impacts of rising water temperatures and expected scenarios for existing Bay fisheries and fisheries moving into the Bay from the south between living resources managers, scientists, and stakeholders.

Create heat wave alert system

Convene an interdisciplinary team of scientists, resource managers, meteorologists, and communicators to design and create a publicly available marine heat wave alert system in connection with habitat preferences of key fisheries and underwater seagrasses.

Target nearshore projects

Develop common criteria and metrics to help target, site, and design natural infrastructure projects and implement in the nearshore, where ecological and climate resilience benefits are maximized across multiple habitat types, such as oyster reefs, underwater seagrass beds, and marshes.

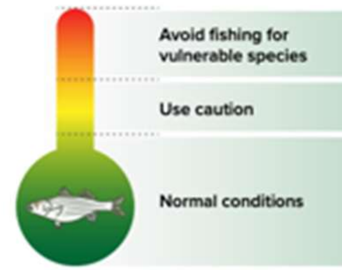


Figure 2. Defining temperature and dissolved oxygen thresholds for striped bass and other key species can minimize stress from fishing practices.

Striped bass fishing on the Chesapeake Bay. Photo by Steve Droter/CBP.

A yellow-crowned night heron hunts along a shoreline oyster reef on the Lafayette River in Norfolk, VA. Photo by Will Parson/CBP.


Moving Forward
Stay focused
Focus on the Chesapeake Bay TMDL and consider stream temperatures in the context of existing goals.
Keep positive
Despite changes to the watershed and Bay, we must push forward and tell our story as changes unfold.
Prioritize BMPs
Implement cooling BMPs/natural infrastructure that reduce heated runoff from developed areas, farms, & forests.
Integrate monitoring
Link smaller streams, groundwater, living resources and air temperature with water temperature monitoring.
Communicate
Help people to understand why water temperatures are rising and what they can do about it.
Increase trees
Better communicate the benefits of conserving mature trees and don't just rely on new tree planting.
Update standards
State water quality standards need to address climate-related changes to water temperature.
Adapt fisheries
Future management and monitoring of fisheries must adapt as fisheries change with rising water temperatures.
Target restoration
Factor rising water temperatures into our tools for targeting the lands to conserve and where to apply BMPs.
Land-sea opportunities
Consider shorelines/nearshore environments for restoration and habitat protection of at-risk species.

Two workshop songs produced

Temperature on the Rise

Bill Dennison & Scott Phillips

21 June 2021

University of Maryland
CENTER FOR ENVIRONMENTAL SCIENCE

Marine Heatwaves in the Chesapeake Bay

Piero L. F. Mazzini and Cassia Pianca*

Virginia Institute of Marine Science, William & Mary, Gloucester Point, VA, United States

Heat Waves

Lyrics by Bruce Vogt & Bill Dennison
Vocals & guitar by Jack Shenk

Watershed Acknowledgements

- **Synthesis Element #1 Paper (Water Temperature Effects on Fisheries and Stream Health in Nontidal Waters):** Stephen Faulkner, Kevin Krause, Rosemary Fanelli, Matthew Cashman, Than Hitt and Benjamin Letcher, USGS; Frank Borsuk and Greg Pond, EPA
- **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

Thank you to all the contributors and workshop participants!

Tidal Acknowledgements

- **Synthesis Element #2 Paper (Tidal Fisheries and Habitat Impacts)**: Bruce Vogt, Jay Lazar, and Emily Farr, NOAA; Mandy Bromilow, NOAA Affiliate; Justin Shapiro, CRC
- **Synthesis Element #3 Paper (SAV Impacts)**: Brooke Landry and Becky Golden, Maryland DNR; Marc Hensel and Chris Patrick, VIMS; Dick Zimmerman and Rhianne Cofer, Old Dominion University; Bob Murphy, TetraTech
- **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 #9 Paper (Indicators)**: Julie Reichert-Nguyen and Bruce Vogt, NOAA; Mandy Bromilow, NOAA Affiliate; Ron Vogel, UMD for NOAA Satellite Service; Breck Sullivan, USGS; Anissa Foster, NOAA-CRC Internship Program
- **Synthesis Element #10 Paper (Monitoring)**: Peter Tango, Breck Sullivan, John Clune, and Scott Phillips, USGS

Thank you to all the contributors and workshop participants!

Role for Chesapeake Bay Program

- What role do you see the Bay Program can do to help build in temperature considerations in our management strategies?
- What can the Bay Program do to support jurisdictions in the implementation of these recommendations?

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- Julie Reichert-Nguyen
  - julie.reichert-nguyen@noaa.gov

Find the report here:

- www.chesapeake.org/stac/document-library/rising-watershed-and-bay-water-temperatures-ecological-implications-and-management-responses/