Watershed Briefing Paper

For March 15, 2022 Rising Water Temperature STAC Workshop

Watershed Discussions for March 15th: Potential Management Actions and Science Needs

1) Coldwater Fisheries and Habitat

Potential Management Actions

- CF-1. Prioritize protecting forested watersheds with high quality brook trout habitat by maintaining and enhancing current forest cover.
- CF-2. Minimize the amount of impervious surface and agricultural land use in watersheds with high quality brook trout habitat.
- CF-3. Avoid placing "heater" BMPs (e.g., headwater ponds) near brook trout streams. Relevant regulatory and stormwater permitting agencies should collaborate to review existing design criteria for new stormwater and restoration practices installed in cold and cool-water watersheds avoid further stream warming.
- CF-4. Develop stronger private landowner engagement and conservation easement programs and incentives.

Priority Science Needs

- CF-5. Develop geospatial modeling/mapping tools to identify stream reaches with thermally resilient groundwater inputs.
- CF-6. Determine how interactions between climate change and land use will affect brook trout and mussel populations including cumulative impacts.
- CF-7. Identify genetic metrics necessary to determine brook trout and mussel population resiliency to rising temperatures including adaptive variation to higher temperatures.
- CF-8. Evaluate genetic metrics as a management tool to boost climate resiliency.

2) Rural Waters and Habitat

Potential Management Actions

- R-1. Install and enhance riparian forest buffers to ensure rivers and streams are well buffered and avoid heater BMPs in rural watersheds.
- R-2. Use the improved Bay watershed mapping capability to prioritize specific headwater stream reaches that are the most suited for riparian buffer plantings to exert the greatest cooling impact in rural watersheds.
- R-3. Use aquatic habitat restoration to improve connectivity between suitable habitat patches and improve access to thermal refugia.

Priority Science Needs

- R-4. Conduct targeted research in small agricultural watersheds to measure temperature impacts of agricultural land and water management practices. Align priorities for getting reliable BMP field monitoring data to include cropping, tillage and field drainage practices.
- R-5. Perform demonstration research projects that measure the cooling impact of scaled-up riparian buffer plantings on stream and groundwater temperatures in rural watersheds.

- R-6. Perform research to define how wetlands and other stream corridor habitats influence hydrologic processes that can enhance cooling in streams and rivers.
- R-7. Use new CBP data to calculate the maximum rural stream mileage available for forestation and develop models to determine whether the installation of future stream "cooler" and "shader" practices will mitigate watershed warming factors.
- R-8. Investigate the potential for dam/pond removal and floodplain restoration projects as a cooling mitigation strategy for sensitive rural watersheds.
- R-9. Determine how interactions between climate change and rural land use will affect mussel populations, including cumulative impacts.

3) Urban Waters and Habitat

Potential Management Actions

- U-1. Encourage use of stormwater "cooler" BMPs over "heater" BMPs in the Bay watershed for pollutant reduction going forward.
- U-2. Update urban and forestry BMP plant lists to make sure the species we are planting are appropriate for the future hardiness zones in our warming watershed. Encourage diversity in plant selection to hedge against potential losses to invasive pests and plants.
- U-3. Encourage the retention and expansion of urban tree cover (both in the riparian zone and upstream), especially in under-served urban areas which historically suffer the worst heating and human health outcomes.
- U-4. Use aquatic habitat restoration to improve connectivity between suitable habitat patches and improve access to thermal refugia.

Priority Science Needs

- U-5. Update the CBP watershed model to simulate expected trends in future stream warming in urban watersheds and determine whether it is possible to mitigate warming with BMPs.
- U-6. Investigate the benefits of retrofitting older legacy ponds to reduce downstream warming and pollutant reduction performance
- U-7. Conduct BMP field monitoring to determine the temperature impact of widely used stormwater LID practices, such as bioretention, permeable pavement, infiltration and green roofs.
- U-8. Institute Temperature Screening analysis for urban CBP BMPs—this entails a rapid effort to synthesize existing research on BMP temperature impacts for the most common BMPs applied to urban and suburban watersheds. A structured expert elicitation process could be used to establish Bay-wide delta-Ts for each class of urban BMPs and to develop recommendations for stormwater BMP design and construction criteria to mitigate stream warming.
- U-9. Utilize higher-frequency continuous monitoring of urban streams and floodplains to better understand the ecological implications of stream warming for urban waters.
- U-10. Explore the use of a proffer system for development that incorporates cooler BMPs.

4) State temperature water quality standards (WQS), monitoring and implementation

Potential management actions

- WQS-1. CBP jurisdictions have water temperature policy in place through their temperature water quality standards (WQS). Explore what needs to be done to make them more effective to combat rising water temperatures.
- WQS-2. These Clean Water Act tools can protect indigenous populations of coldwater, coolwater and warmwater aquatic life from climate-related water temperature increases using WQS designated use zones, temperature and biological health criteria, monitoring, and management instruments like TMDLs. Do they need to be modernized?
- WQS-3. Interstate cooperation through CBP could increase effectiveness through information-sharing, problem solving and monitoring-modeling support.
- WQS-4. Stronger anti-degradation measures could improve protection of temperature-threatened high-quality waters, e.g. native trout streams.

Priority science needs

- WQS-5. Evaluate whether WQS temperature monitoring networks designed for point source control are adequate for detecting and evaluating climate-related thermal increases, including land use influences.
- WQS-6. As a follow-up to the PSC report to improve monitoring, have the CBP work with appropriate federal and state agencies to review monitoring to support temperature standards in streams, and develop recommendations for improvements needed to assess rising water temperatures.
- WQS-7. Use fine-scale CBP mapping to identify priority monitoring areas (and help target studies and restoration priorities) and evaluate if infrared imagery could aid water temperature monitoring?

5) Monitoring and Modeling Recommendations for Addressing Rising Temperatures in the Chesapeake Watershed

These are items that cut across all three of the landscape types but there are additional science needs listed above for coldwater, urban, and rural waters and habitat.

Primary Recommendations for Monitoring

- MON-1. Use existing monitoring data to assess temperatures in rivers and streams. An inventory of data collected by multiple agencies is available from the USGS. Status, trends, and correlations with land use types and other factors should be investigated.
- MON-2. Monitoring data is insufficient and needs to be improved for assessing temperatures in streams draining all landscape areas. Smaller streams generally lack consistent monitoring for temperature and new temperature monitoring is needed in smaller streams important for cold-water fisheries.
- MON-3. Integrated monitoring programs should be established that can differentiate the influences of air and groundwater on stream temperatures in places important for coldwater fisheries and detect responses to management actions.

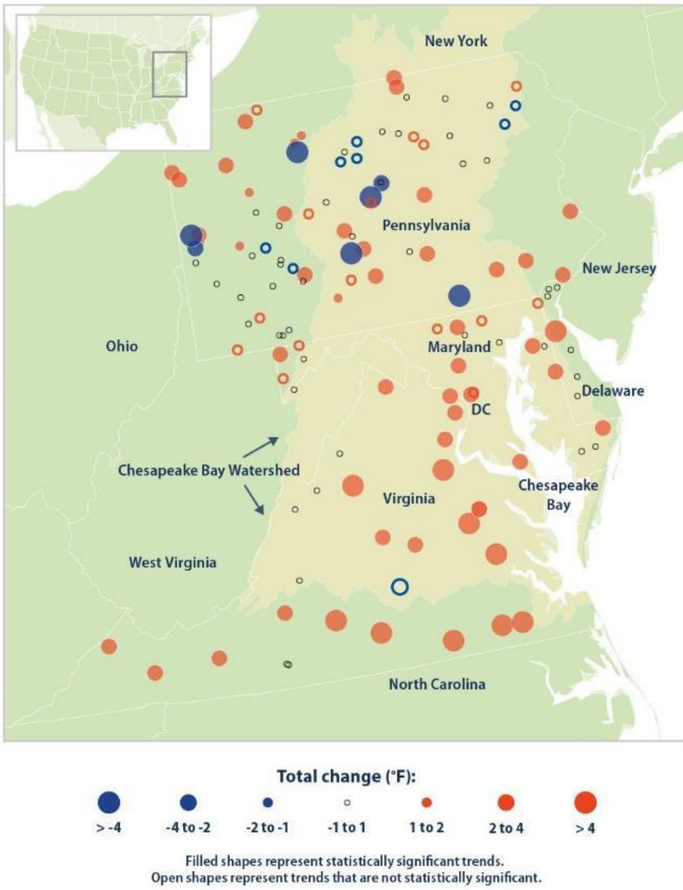
- MON-4. Paired air and water relationships should be evaluated throughout to help identify thermally resistant watersheds and those where land uses are exacerbating water temperature rises above air temperature rises.

Primary Recommendations for Modeling

- MOD-1. Develop locally focused models that better simulate the influence of land use and groundwater on local steam temperatures. The model results should be useful by fishery managers to identify areas in danger of exceeding temperature thresholds important for coldwater species.
- MOD-2. Conduct a vulnerability assessment of how climate and land change may affect stream temperatures. The assessment could link climate, land change, and watershed models to forecast changes in stream temperatures linked to different climate and land-use scenarios.
- MOD-3. The Chesapeake Healthy Watersheds Assessment (CHWA) should be used to enhance local and regional models. The CHWA includes data and metrics related to key landscape factors and watershed characteristics that may influence stream temperature. There are additional opportunities to incorporate stream temperature, and vulnerability thresholds for key habitat and species into the CHWA.
- MOD-4. Temperature impacts on watershed biota and fisheries should be better represented in the CBP's existing management tools to influence land use and BMP implementation decisions. Information on management practice effects on water temperatures should be considered for the Chesapeake Assessment Scenario Tool (CAST). Adapt and improve stream and fish habitat models to model the connection between temperature changes estimated in CAST and estimated effects on stream biota and fisheries in the watershed.

Watershed Storyline and Day 1 Summary

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



● Sites differed, but generally, water temperatures increased more than air temperatures from 1960 to 2010 (Rice and Jastram, 2015).

● In non-tidal waters, air temperature is not always the primary driver of water temperature change.

● The air to water temperature ratios at sites shows where land use or other factors are driving or buffering changes in water temperature.

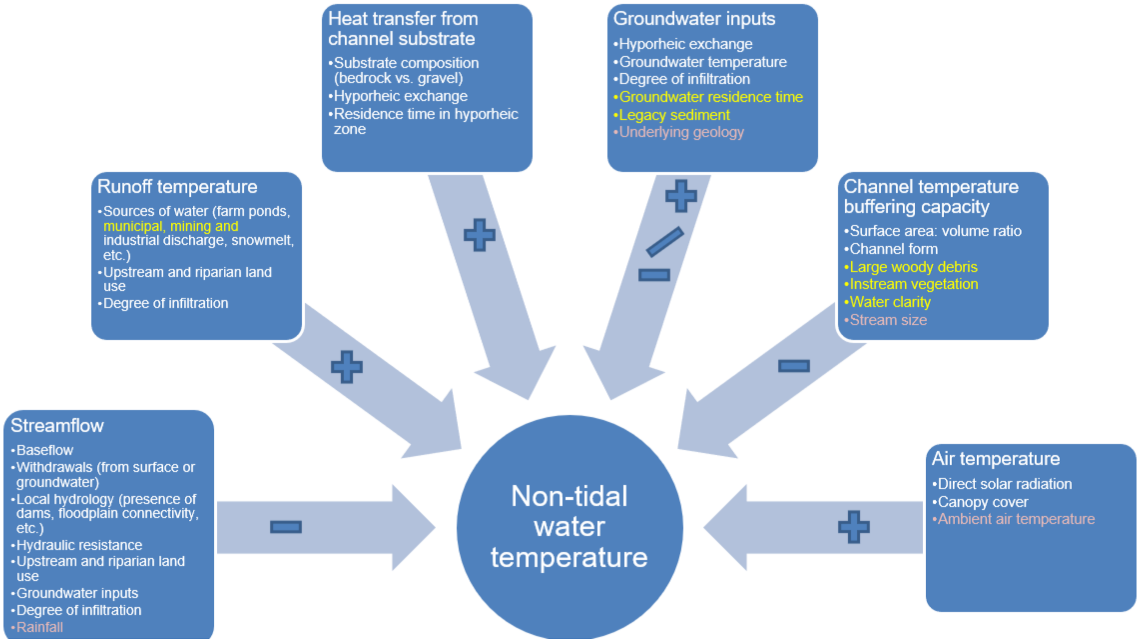
● Rising water temperatures have major implications for stream ecosystems, local communities, as well as land and water management.

● Workshop 1 participants were particularly concerned about the impacts of rising water temperatures on stream ecosystems, including impacts on particularly vulnerable species like brook trout, as well as broader water quality implications.

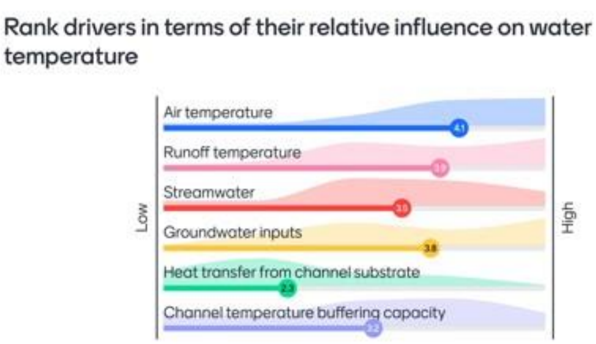
<u>**Drivers of Increasing Water Temperature**</u>

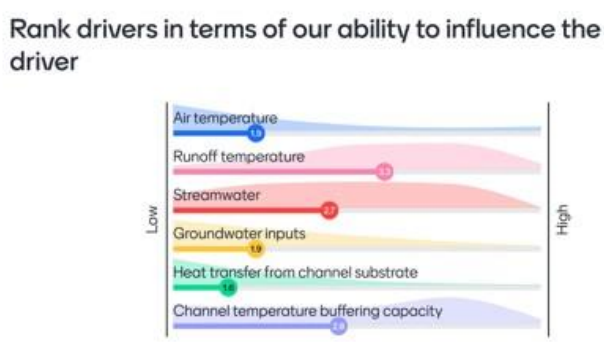
Increasing stream and river temperatures have been driven by rising air temperatures, but other drivers have a strong influence.

- The workshop team developed a conceptual model (below) summarizing the mechanistic drivers of non-tidal water temperature and their direction of influence. Negative arrows indicate drivers that can reduce water temperatures or provide a buffer against warming water temperatures. Positive arrows indicate drivers that can further exacerbate rising water temperatures.
- The factors listed in each box influence the broader drivers. Workshop participants identified a few additional factors to add to the model (in yellow). The factors highlighted in peach are unlikely to be influenced through management.
- This model is an oversimplification. Many factors interact with one another, and the relative importance of each driver will vary depending on the focal landscape.



- The model also doesn't address issues of spatial or temporal scale. Certain drivers will have a stronger influence either in the short or the long term, and certain drivers will have a more localized influence on water temperatures (i.e., channel buffering capacity), while others may have a broader influence on water temperature across the landscape (i.e., upstream land use).
- Additional work is needed to connect these mechanistic drivers with specific management activities and land use decisions to better inform management.
- Workshop participants were asked to rank the primary drivers in terms of their relative influence on water temperature and our ability to influence the driver:



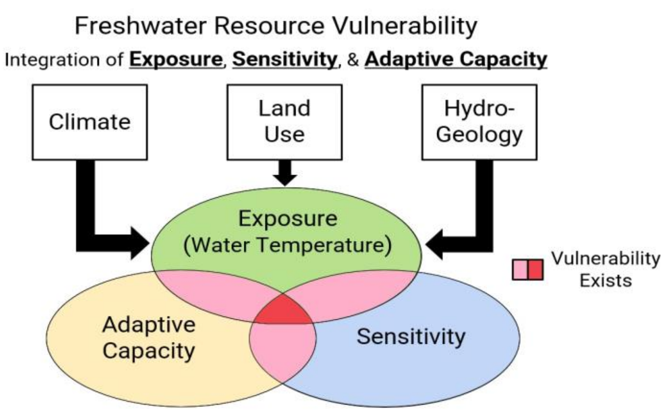


  - Most of the drivers ranked highly in terms of their influence on water temperature. Runoff temperature, stream flow and channel buffering capacity were also identified as drivers that we can influence through management.
  - Other drivers, like groundwater inputs, may be important to consider when identifying places that may be more resilient to climate change to targeting for conservation.

Drivers of rising water temperatures: Priority information needs

- A key uncertainty is the degree to which various drivers and interactions between drivers influence water temperature in specific sub-watersheds. More localized information is needed to inform management.
- Higher-frequency or continuous water temperature monitoring is needed to better understand the relative local influence of various drivers as well as water temperature trends (including seasonal effects). State water quality standards monitoring that focus on point source impacts may not be as useful for monitoring broader spatial and temporal trends.
- Additional monitoring is needed at the air/water interface to identify hotspots where drivers are having a particularly large impact on water temperature as a way to target management.
- Improved understanding of groundwater inputs is needed. Specific needs include better regional/subwatershed models, more localized information about groundwater inputs, and a better understanding of how climate change could impact groundwater inputs.

Ecological Implications of Rising Water Temperatures



The workshop team developed a high-level conceptual model of freshwater resource vulnerability. This biophysical model does not include resource management considerations, such as the costs associated with protecting species or habitats. The model integrates a species or habitat's vulnerability based on its **exposure** to rising water temperature, its **sensitivity**, as well as its **adaptive capacity**.

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

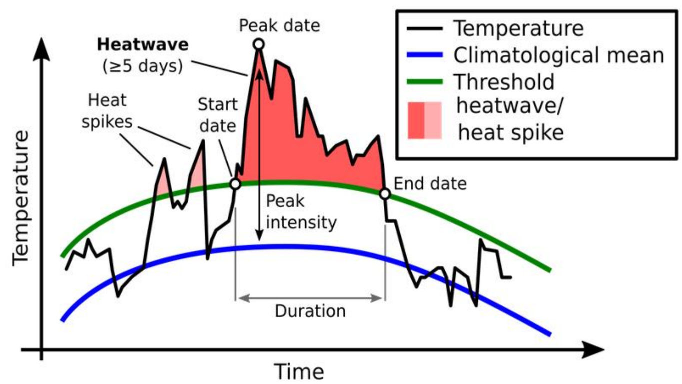
- It is expected that the strongest negative species level impacts will be on coldwater species (e.g., trout, sculpin) due to their perceived exposure and sensitivity to rising water temperature.
- Watershed-wide, warmwater aquatic species are most common. Although more tolerant to temperature increases, they are sensitive to extreme temperatures and to indirect effects of higher temperatures, such as physiological stress that lowers the ability to fight off pathogens.
- Workshop participants were asked to rank eight species in terms of their relative exposure and sensitivity to rising water temperature. Participants perceived a positive relationship between a species' perceived exposure to rising temperature and a species' sensitivity to rising temperature. Brook trout and checkered sculpin (coldwater species) were ranked the most exposed and sensitive to rising water temperature (*Note: most of the respondents to this poll with fish expertise work in coldwater systems*).

Warmer water temperatures will negatively impact aquatic habitats

- The strongest negative impacts will likely be on relatively small, coldwater streams not driven by groundwater. These vulnerable systems are also where we find our most sensitive species and is why protecting native brook trout habitat, including watershed, is an urgent priority.
- Larger waterways with low forested watershed cover, riparian cover, and heated urban runoff are likely vulnerable as well.

The ecological impacts of rising water temperature are influenced by the specific ways in which temperature is warming

- Shifts in seasonality (e.g., warmer winters, shift in season length) may impact spawning timing or migration which could influence exposure to rising water temperature.
- Spatial characteristics, including cross-sectional features of the stream channel, aquatic connectivity, and landscape features can influence exposure to rising water temperatures and whether there are accessible thermal refugia during extreme heat events.
- Pulsed extreme warm water events (i.e., heatwaves) have a disproportionate impact on the environment relative to long-term changes in mean water temperature. Aspects of aquatic heatwaves that are likely to affect vulnerable species include heatwave frequency, duration, intensity, and onset rate.



Rising water temperatures may increase the occurrence or co-occurrence of known stressors that negatively impact aquatic species and habitats

- Water temperature is a catalyst for biochemical reactions that negatively impact habitat quality at high water temperatures. Some known stressors that occur as temperature increases include:
  - Low dissolved oxygen: gas solubility decreases with increasing water temperature (warm water holds less oxygen than cooler water).
  - Invasive species: warmwater species have a longer invasion window open.
  - Algal blooms: cyanobacteria known to perform well with elevated water temperatures.
  - Bacterial/viral outbreaks: warmwater increases physiological stress making it harder for species to fight off infection.
  - Distribution & toxicity of other pollutants (e.g., heavy metals, pesticides, ammonia, etc): Rising water temperature mobilizes and increases the toxicity of other pollutants.
- Increasing water temperatures will likely alter ecosystem structure and function: Ecosystems may move from diatom dominated to green-algae or cyanobacteria dominated. This alteration would represent a shift towards less nutritious food sources.

- Increasing water temperature will further isolate coldwater populations while expanding the range of warmwater and non-native species.
- As novel communities interact there will be shifts in predator/prey interactions that are likely to alter energy and nutrient flow.

Ecological implications of rising water temperatures: Priority information needs

- More research is needed on the impacts of elevated temperature to non-trout species, including lower parts of the food web such as algae, biofilms, zooplankton, macroinvertebrates.
- More research is needed on the impacts of elevated temperature on species life stages, predator prey interactions, and how these interact with multiple stressors.
- Additional high-frequency (sub-daily) monitoring is needed to understand which places are most exposed and sensitive to pulsed heating events such as heatwaves.
- There is a need to integrate water temperature datasets across federal, state, and academic institutions as well as those required to monitor as part of permitting.

Management Implications

Multiple policies and practices could be considered to address the drivers of rising water temperature and ecological implications:

- Policies that promote the protection and maintenance of natural lands that provide cooling benefits, including forests, wetlands and healthy watersheds.
- Best Management Practices (BMPs) included in Watershed Implementation Plans (WIPs) or in habitat restoration strategies.

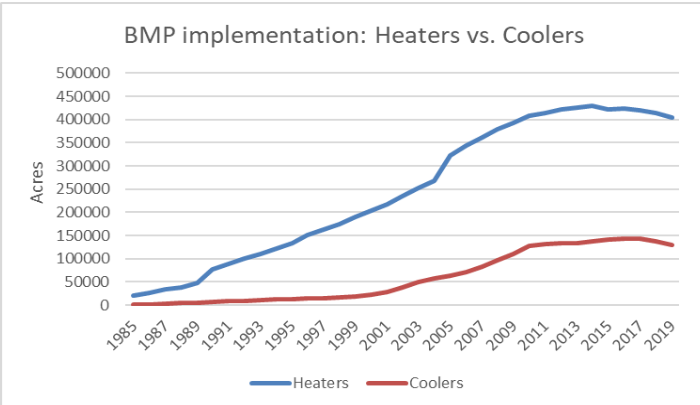
Conserving existing healthy watersheds can help promote resiliency to rising water temperatures.

- Key factors of healthy watersheds that may moderate rising temperatures:
    - Land use/land cover: % forest cover (catchment and riparian), % natural land cover
    - Hydrology/flow alteration, including infiltration rates of land use/land cover types
    - Underlying geology/groundwater interaction
- Promoting practices that maintain or increase forest and natural land cover types, reduce flow alteration of streams, and utilize our understanding of underlying geology and groundwater recharge can increase resiliency to rising water temperatures.
- Percent forest in the riparian area and percent forest in the watershed were identified by workshop participants as potential management targets.

Some BMPs have the potential to mitigate rising water temperatures, but watershed-wide, there has been substantially greater implementation of "heater" BMPs as compared with "cooler" BMPs

- BMPs can influence water temperature by impacting multiple drivers of water temperature identified in the conceptual model. The workshop team conducted a synthesis effort evaluating the temperature impacts of Bay Program BMPs and grouped BMPs based on the strength and direction of their impact on water temperature.

- **"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.



- Many BMPs were classified as either "uncertain" or "thermally neutral".
- In many years, there has been approximately 3x as much implementation of heaters as coolers, suggesting that some of the practices we are implementing to improve water quality may be having adverse, unintended consequences for water temperature.

Management Implications: Priority Information Needs

- More information is needed on the relative influence of BMPs on water temperature, including identifying which BMPs are most cost-effective for cooling water temperatures. More research and guidance is also needed on the temperature of impacts of certain BMPs:
    - Agricultural infiltration and soil health practices: These practices are implemented on a very large scale, but temperature effects have not been explicitly studied.
    - Stream restoration: Stream restoration may influence water temperature via multiple drivers, but the ultimate influence on water temperature is likely influenced by project design. Additional guidance on minimizing unintended warming effects could be helpful.
    - Wetlands: The influence of wetlands on water temperature is also influenced by project design, so design guidance to minimize unintended warming effects could be helpful.

- Incorporating stream temperature into the Chesapeake Healthy Watersheds Assessment and other mapping tools could help support decision-making.

- Additional data and modeling capacity could help predict future changes in stream temperatures and how temperature will respond to BMPs (for example, to derive temperature response curves for BMPs). The CBP watershed model and land-change models could better support this need.

- Additional research is needed to better understand how stream temperature and living resources will respond to management actions.

For additional information and references please refer to Synthesis Papers # 1 (including the Addendum), #4, #5, #6, #7/8, and #10.

Many thanks to the workshop steering committee and project team members who contributed to this paper and to the Day 1 STAC workshop participants for sharing their knowledge and ideas.