# Brook Trout Outcome

## Management Strategy

2025-2035, v.4

*Brook Trout from Savage River, MD. (Photo by Matt Sell, MD DNR)*

## I. Introduction

Brook trout are the archetype indicator species for healthy waters. Brook trout occupy the coldest and least disturbed landscapes in the eastern United States. Just slight changes in forest cover or increases in impervious surfaces within a watershed can be detrimental to brook trout. Brook trout are also highly prized by recreational anglers and have been designated as the state fish in New York, Pennsylvania, Virginia, and West Virginia. They are an essential component of the headwater stream ecosystem, an important part of the watershed's natural heritage, and a valuable recreational resource. Land trusts in New York, Pennsylvania, Virginia, and West Virginia, have found that the possibility of restoring brook trout to local streams can act as a motivator for private landowners to take conservation actions, whether it is installing a fence that will exclude livestock from a waterway or putting their land under a conservation easement. Declining brook trout populations serve as a warning about the health of local waterways and the lands draining to them. While many forests have regenerated from intensive logging that occurred in the 19th and 20th centuries, human populations continue to increase putting more strain on watersheds that still harbor brook trout. Coupled with climate change, rising air temperatures, and dryer summers exacerbate land use impacts that cause brook trout declines. While many previously documented extirpations still remain (Hudy et al. 2008), the Chesapeake Bay states experienced an apparent 0.5% increase in brook trout occupied habitat from 2016 to 2023 (Rummel et al. 2023). This 0.5% increase is due to the work of many partners throughout the watershed, and reflects restoration efforts alongside prior and recent losses to habitat. Further restoration and repatriation will require considerable landscape scale improvements, funding, and coordination.

# II. Goal, Outcome and Baseline

This management strategy identifies approaches for achieving the following goal and outcome:

### *Vital Habitats Goal*

Restore, enhance and protect a network of land and water habitats to support fish and wildlife, and to afford other public benefits, including water quality, recreational uses and scenic value across the watershed.

### *Brook Trout Outcome*

Restore and sustain naturally reproducing brook trout populations in Chesapeake Bay headwater streams, with an eight percent increase in occupied habitat by 2025.

**Priority Brook Trout Conservation Strategies**

- Protect highly functional wild brook trout patches from detrimental changes in land and water use practices through land conservation.
- Connect habitats that have a high likelihood of sustaining stable wild brook trout populations.
- Restore brook trout habitats that have been impacted by poor land and water use practices. (e.g., livestock access to streams, polluted runoff, acid mine drainage).
- Enhance or restore natural hydrologic regimes (e.g. road decommissioning, increasing forest cover, and improving soil health).
- Prevent and mitigate the spread of nonnative species into allopatric brook trout patches.
- Reintroduce wild brook trout into extirpated catchments or where an increase in genetic fitness of the population is needed and supported by science.

## Baseline and Current Condition

Wild brook trout populations occupy approximately 30% of their historic range and continue to face ongoing and future threats from land use changes, climate change, invasive species, loss of genetic integrity, and a myriad of other anthropogenic impacts (Hudy et al. 2008). Within the Chesapeake Bay watershed, most wild brook trout are found in headwater streams in watersheds where human disturbance is minimal and forest cover is greater than 68-75% (Hudy et al. 2008, Wagner et al. 2013).

A 2005 assessment of brook trout status in 1,443 subwatersheds (sixth-level hydrologic unit) located in the Chesapeake Bay watershed, resulted in the following classifications: 16% Intact (brook trout are present in more than 50% of the streams); 38% Reduced (brook trout are present in 50% of the streams or fewer); 20% Extirpated (brook trout no longer exist in the streams); and 27% not classified because either the historical presence of brook trout is not known or the species was never known to occur in these subwatersheds (Hudy et al. 2008).

In 2015, a finer scale assessment of brook trout populations in the Chesapeake Bay watershed was completed by the Eastern Brook Trout Joint Venture in an effort to provide natural resource managers with better tools for detecting population changes and setting conservation priorities (EBTJV 2016). This assessment entailed determining wild brook trout occupancy at the catchment scale, which was then used to identify brook trout patches and classify them as being wild brook trout only, wild brook trout with brown trout present, wild brook trout with rainbow trout present, or wild brook trout with rainbow trout and brown trout present (Hudy et al. 2013a).

A "patch" is defined as a group of contiguous catchments occupied by wild brook trout. Patches are not connected physically (i.e., they are separated by a dam, unoccupied warm water habitat, downstream invasive species,

etc.) and are generally assumed to be genetically isolated. Patches with only brook trout present are known as allopatric and those with brown and/or rainbow trout present are known as sympatric. A GIS-based algorithm was created to extrapolate the point stream survey data to the catchment scale (Coombs and Nislow 2015). The output of the algorithm is a GIS shapefile containing polygons that are classified based on the allopatric/sympatric codes noted above. Thes 2015 assessment indicated there were 1,713 wild brook trout patches in the Chesapeake Bay watershed, with a combined area of 33,250 square kilometers (***Table 1***). There were 990 wild brook trout only (allopatric) patches and the area of these patches was 13,500 square kilometers (***Table 2***).

**Table 1. The number and area of all wild brook trout patches (allopatric and sympatric) in the Chesapeake Bay watershed (Coombs and Nislow 2015).**

| State | Number of Wild Brook Trout Patches | Wild Brook Trout Patch Area ($km^2$) |
|---|---|---|
| Maryland | 110 | 1,017 |
| New York | 359 | 5,684 |
| Pennsylvania | 925 | 18,914 |
| Virginia | 240 | 6,042 |
| West Virginia | 79 | 1,598 |
| **Totals** | **1,713** | **33,254** |

**Table 2. The number and area of patches classified as wild brook trout only (allopatric) in the Chesapeake Bay watershed (Coombs and Nislow 2015).**

| State | Number of Patches Classified as Wild Brook Trout Only | Wild Brook Trout Only Patch Area ($km^2$) |
|---|---|---|
| Maryland | 75 | 604 |
| New York | 201 | 2,498 |
| Pennsylvania | 430 | 4,754 |
| Virginia | 213 | 4,651 |
| West Virginia | 71 | 1,032 |
| **Totals** | **925** | **13,495** |

In 2024, the Brook Trout Workgroup completed a GIT funded project titled *Facilitating Brook Trout Outcome Attainability through Coordination with CBP Jurisdictions and Partners* to track BMP and habitat improvement projects implemented between 2016 - 2023 and document gains and losses of brook trout within the Chesapeake Bay watershed (Rummel et al. 2024). This occurred in conjunction with Eastern Brook Trout Joint Venture (EBTJV') 2023 catchment update to determine brook trout occupancy across the Chesapeake Bay watershed relative to the 2015 established baseline. The 2024 report documented a 0.5% net increase in brook trout occupancy, and compiled over 5,419 habitat projects completed in the Chesapeake Bay watershed between 2016 and 2022 (Figure 1). Of the 5,419 projects recorded, only 94, or 1.7%, occurred in catchments where brook trout were known to be present. The 0.5% net increase, in addition to newly discovered populations, brings the total area of allopatric brook trout occupied habitat to 15,305 square kilometers (Table 3) (Rummel et al. 2024, Coombs 2023, unpublished). Although the current area of brook trout only occupied habitat exceeds the original goal of 14,622 square

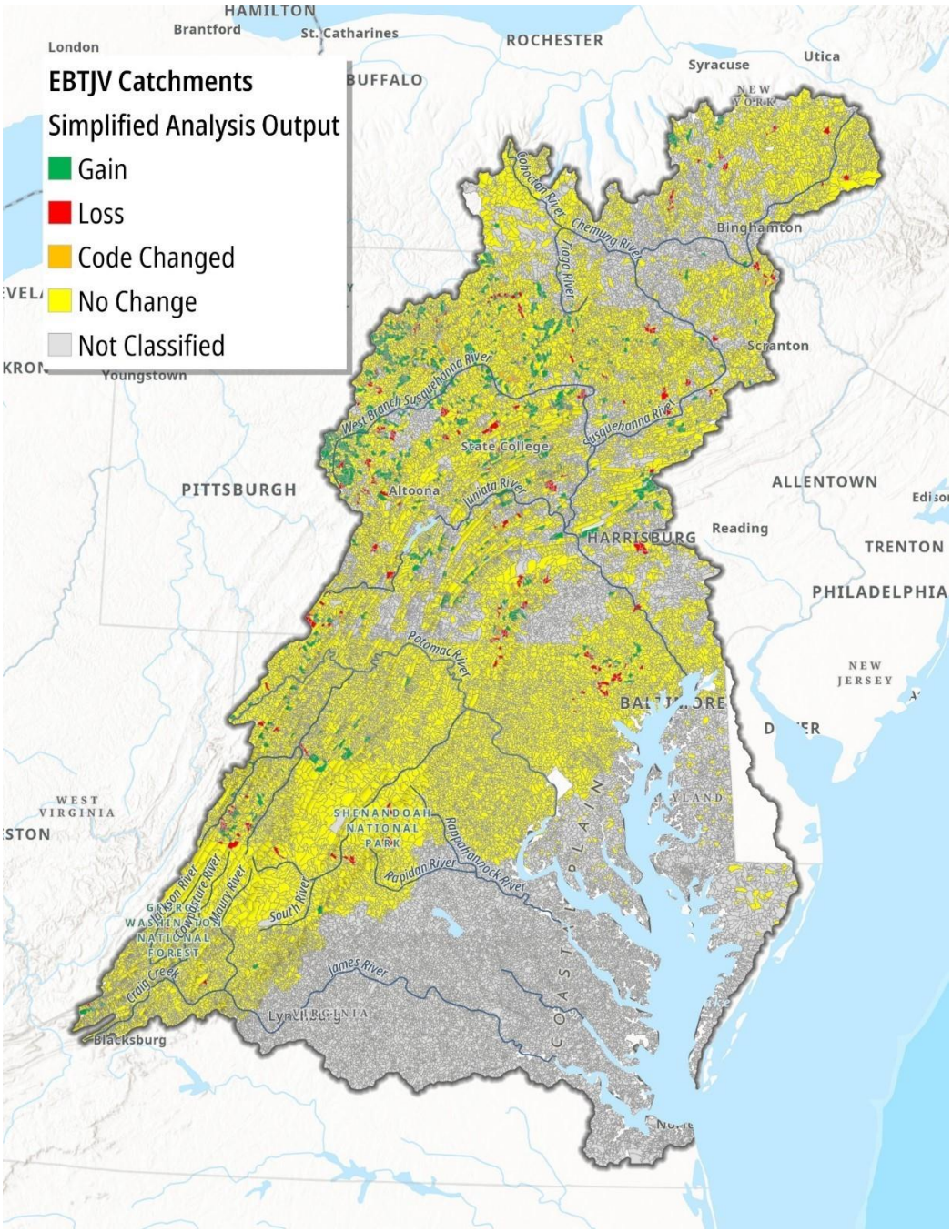


***Figure 1. Modeled Changes in Brook Trout Catchment Occupancy from 2016-2023 within Chesapeake Bay watershed from Rummel et al. (2024).***

kilometers, this is mostly attributed to new sampling and thus does not count towards our net goal of 8%. In order to meet the current goal of an 8% increase, an additional 1,012 square kilometers of occupied habitat is still needed, based on the 2015 baseline. This puts the total area of brook trout only occupied habitat needed to meet the 8% goal at 16,317 square kilometers.

**Table 3. The number and area of patches classified as wild brook trout only (allopatric) in the Chesapeake Bay watershed (Rummel et al. 20 Coombs 2023 unpublished).**

| State | Number of Patches Classified as Wild Brook Trout Only | Wild Brook Trout Only Patch Area ($km^2$) |
|---|---|---|
| Maryland | 87 | 671 |
| New York | 216 | 2,812 |
| Pennsylvania | 649 | 5,809 |
| Virginia | 229 | 4,448 |
| West Virginia | 136 | 1,565 |
| **Totals** | **1,317** | **15,305** |

## III. Participating Partners

The following partners have pledged to help implement this strategy:

**Team Lead:** Vital Habitats Goal Team

**Opportunities for Cross-Goal Team Collaboration:**

- Goal Implementation Teams:
  - Water Quality Goal Implementation Team
  - Healthy Watersheds Goal Implementation Team
- Workgroups:
  - Stream Health Workgroup
  - Fish Passage Workgroup
  - Riparian Buffers Workgroup

**Participating Signatories:**

- Maryland
- New York
- Pennsylvania
- Virginia
- West Virginia

**Other Participating Partners:**

- U.S. Fish and Wildlife Service
- U.S. Geological Survey
- National Park Service
- USDA Forest Service
- USDA Natural Resource Conservation Service
- Trout Unlimited
- Eastern Brook Trout Joint Venture

## Local Engagement

Communicating the community/watershed wide benefits of brook trout from a recreational and economic perspective is important for engaging the general public and local decision makers. As one of the many species that inhabit headwater streams, protecting brook trout also safeguards additional fish habitat and downstream waters. Adopting certain brook trout habitat protection practices, like riparian forested buffers, can provide co-benefits to other priorities like improved water quality and stream health. In 2025, the Brook Trout Workgroup will be hosting STAC workshops to build partnerships with federal, state, and local jurisdictions and develop restoration plans for select counties in PA and MD where priority brook trout strongholds are present. Workshop

outcomes will serve as a blueprint for other counties within the Chesapeake Bay watershed to implement large scale restoration projects that benefit brook trout.

## IV. Factors Influencing Success

A variety of activities, both on the land and in the water, will influence the ability to meet the Brook Trout Outcome (Figure 2). Land development, roads, undersized culverts, coal mining (past and present), and oil and gas drilling all result in four root causes of decreased brook trout occupancy in streams: increased water temperature (e.g. climate change, deforestation), changes in hydrology from increased impervious cover, changes in water chemistry (e.g. acid mine drainage, 6PPD-q, fracking water, etc.), and increased nutrient and sediment loading (e.g., livestock access, dirt and gravel roads, etc.). These activities and threats are increasing in both number and scale over time, which means that the pace of enacting conservation and restoration projects needs to increase accordingly to meet and exceed those challenges. While their relative influence has not been quantified at a watershed or landscape scale, changes in water quality, modification of hydrologic regime, altered stream flows, and fish passage barriers are other factors affecting the viability of wild brook trout populations (EBTJV 2005).

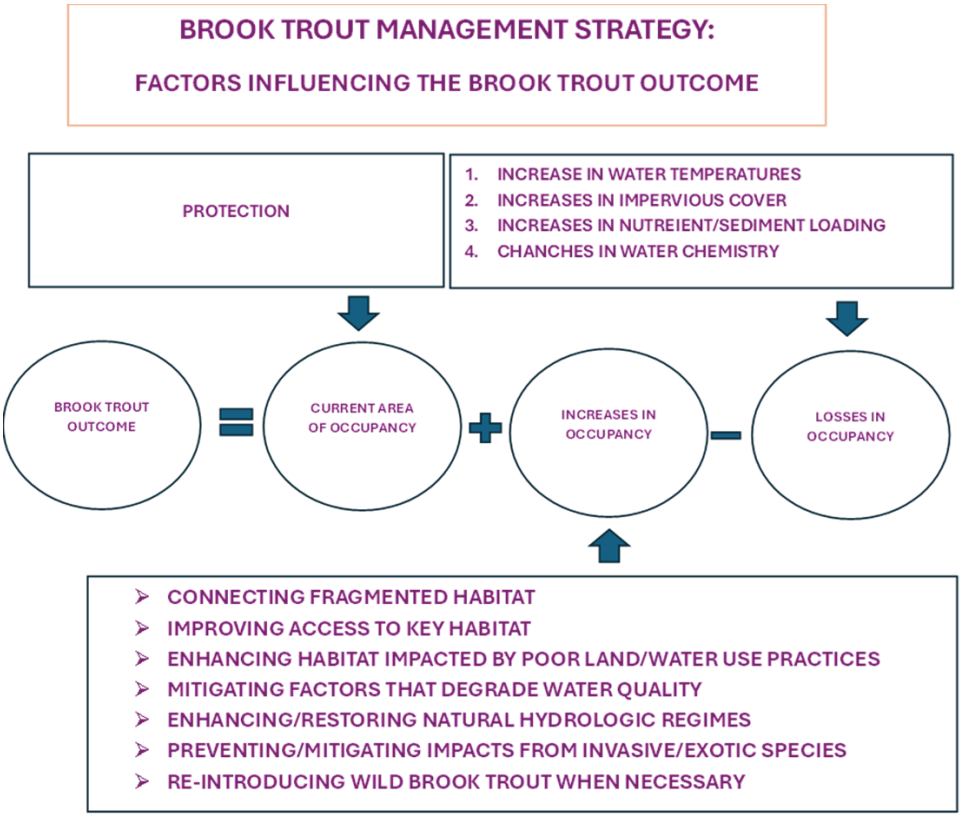


***Figure 2. Flow chart of causes to brook trout declines and corrective BMPs to increase net occupancy.***

Merriam et al. (2019) looked at land use impacts and climate change predictions to evaluate future potential losses of brook trout habitat in the Chesapeake Bay Watershed. Under their modeled climate change scenarios,

they predicted that climate change alone would only directly account for approximately 19 % loss of currently occupied stream segments, while ongoing land use practices, without mitigation, would result in a 40% loss. They noted that traditional restoration activities may recover much of the habitat previously lost to land use practices if done in the context of climate change and target more resilient watersheds.

The restoration of potential brook trout habitat and the protection of existing brook trout habitat by partners will be imperative to reaching the outcome goal. As it stands, the Chesapeake Bay Watershed must have a net gain of 1,012 square kilometers of allopatric brook trout habitat by 2025, not including any loss of existing habitat. As stream temperatures increase, areas of potential habitat will decrease. The understanding of and coordinated use of Brook Trout Habitat Decision Support Tools (see pages 14-15) by conservation managers will facilitate more targeted habitat restoration and protection efforts.

The ability of states, NGOs, and federal partners to accurately monitor brook trout occupancy and habitat will affect the Bay Program's ability to measure true outcome progress. Increased and consistent funding coupled with the advancement of enhanced methods (e.g., eDNA) will be essential to successful monitoring efforts. Having a coordinated reporting process to document restoration actions and Brook Trout occupancy is necessary to ensure that outcome progress is measured reliably and consistently through time. In 2024, the Habitat GIT developed the Habitat Tracker to enable the Brook Trout Workgroup to monitor progress towards the outcome.

## V. Current Efforts

**Maryland Department of Natural Resources**

The mission of the Fishing and Boating Services is to “develop a management framework for the conservation and equitable use of fishery resources; manage fisheries in balance with the ecosystem for present and future generations; monitor and assess the status and trends of fisheries resources; and provide high quality, diverse and accessible fishing opportunities.” The statewide Brook Trout Fisheries Management Plan was developed in 2006 by the Fishing and Boating Services' Freshwater Fisheries and Hatcheries Division, with a goal “to restore and maintain healthy brook trout populations in Maryland's freshwater streams and provide long-term social and economic benefits from a recreational fishery."

Maryland is unique among the other Bay states in that its geographic area is relatively small and thus has the ability to census all known, historic, and/or suspected brook trout populations and habitat regularly. Additionally, the geography of Maryland is such that the habitat available to brook trout is highly diverse statewide and representative of the range-wide northern and southern conditions. Maryland Freshwater Fisheries and Hatcheries Division completed a statewide census of all historic/current/suspected brook trout populations from 2014 to 2018. The census documented a statewide 27% decline in brook trout occupancy since the 1980s. Additional data collection continues in habitats that modeling or physical proximity suggest may be suitable candidates for brook trout reintroduction. High priority for restoration in Maryland is in the mountainous western portion of the state where mitigating legacy mining impacts has the greatest potential for population re-establishment. Maryland has also begun building partnerships with county DOTs to improve AOP in brook trout streams as well as increase climate resiliency of road infrastructure.

**New York State Department of Environmental Conservation**

The mission of the New York State Department of Environmental Conservation (NYSDEC) is "to conserve, improve and protect New York's natural resources and environment and to prevent, abate and control water, land and air pollution, in order to enhance the health, safety and welfare of the people of the state and their overall economic and social well-being." The NYSDEC, Division of Fish and Wildlife, Bureau of Fisheries delivers a

diverse program and annually conducts a wide array of activities to conserve and enhance New York State's abundant and diverse populations of freshwater fishes while providing the public with quality recreational angling opportunities.

Within New York State, the Chesapeake Bay drainage comprises the Chemung and Susquehanna watersheds. While brook trout are widely distributed within New York State, notably in the Catskill, Adirondack, Tug Hill, and Hudson Valley regions, the Chemung and Susquehanna watersheds include some strong populations of wild brook trout that have been the focus of fish passage and riparian habitat improvement projects for NYSDEC and partners including Trout Unlimited, NFWF, USFWS, and others. Notably, extensive habitat enhancement work has been completed on Wylie Brook since 2018. Trout Unlimited will be assessing the Cohocton River and Owego Creek watersheds to identify high priority sites for future work. Eligible partners may apply for funding to complete stream habitat projects that benefit brook trout statewide under the Clean Water, Clean Air, Green Jobs Environmental Bond Act. NYSDEC recently contributed annual sampling efforts on five streams in the Chesapeake Bay drainage for a research project examining the utility of the number of effective breeders as a metric of the health of brook trout populations. Over the last 5 years, NYSDEC completed a total of 37 trout stream surveys at stream locations within the New York portion of the Chesapeake Bay.

**Pennsylvania Fish and Boat Commission**

The mission of the Pennsylvania Fish and Boat Commission (PFBC) is to protect, conserve, and enhance the Commonwealth's aquatic resources and provide fishing and boating opportunities. Within the PFBC, the Division of Fisheries Management, Bureau of Fisheries, oversees PFBC efforts in the management of Pennsylvania fisheries. A key strategy for the PFBC is "provide high quality resource management and protection to reduce the impacts of current and increasing threats to aquatic resources." Brook Trout are a keystone species in the Commonwealth and their conservation is of high importance to the PFBC. The PFBC and partners sample hundreds of streams each year to help monitor existing Brook Trout populations and identify new populations. Brook Trout are a keystone species in the Commonwealth and their conservation is of high importance to the PFBC. The PFBC and partners sample hundreds of streams each year to help monitor existing Brook Trout populations and identify new populations.

**Virginia Department of Wildlife Resources**

The Virginia Department of Wildlife Resources' mission is to "Conserve and manage wildlife populations and habitat for the benefit of present and future generations." Connect people to Virginia's outdoors through boating, education, fishing, hunting, trapping, wildlife viewing, and other wildlife-related activities. Protect people and property by promoting safe outdoor experiences and managing human-wildlife conflicts. VDWR monitors brook trout distribution in all areas of the Virginia portion of the Chesapeake Bay watershed except sub-watersheds within the Shenandoah National Park. The National Park Service monitors those brook trout habitats. VDWR maintains a Coldwater Stream Database that classifies individual brook trout streams and documents spatial distribution of brook trout. Through VDWR monitoring program and database, changes in brook trout distribution and population health can be documented and measured. Currently, VDWR has sufficient resources to monitor Brook Trout populations in Virginia. The National Park Service has a monitoring program in place that has the same capabilities. The VDWR has added Brook Trout to the list of species of "Greatest Conservation Need" in the Virginia Wildlife Action Plan and is partnering with Trout Unlimited to restore brook trout to streams in the Shenandoah and James River Watersheds.

### West Virginia Division of Natural Resources

It is the statutory mission of the West Virginia Division of Natural Resources (WVDNR) "to provide and administer a long-range comprehensive program for the exploration, conservation, development, protection, enjoyment and use of the natural resources of the State of West Virginia". The WVDNR's Wildlife Resources Section is responsible for the management of the state's wildlife resources for the use and enjoyment of its citizens. The primary objective of the section is to maintain and perpetuate fish and wildlife at levels compatible with the available habitat, while providing maximum opportunities for recreation, research and education.

The WVDNR assesses the status and distribution in all State waters within the Chesapeake Bay watershed with NGO, Federal, and other State agency partners. The WVDNR maintains a Stream Fish Database to document all fish occurrences within the State, including brook trout. Data from within the agency and from partners' monitoring programs stored within this database allow annual assessment of change and variability of known population and the addition of new waters to elevated environmental protections. Partners such as Trout Unlimited, the U.S. Forest Service (Monongahela and George Washington/Jefferson National Forests), West Virginia University, and the WV Department of Environmental Protection extend the limited resources of the WVDNR to be able to monitor these brook trout populations at a more appropriate spatial and temporal scale.

Brook trout is a Priority 1 Species of Greatest Conservation Need in the West Virginia State Wildlife Action Plan. As such, special attention is given to habitat improvement, restoration, and conservation actions within the agency and among its partners across its West Virginia distribution range, including all waters contributing to the Chesapeake Bay. A notable agency achievement has been the establishment of a Chesapeake Bay Heritage Strain breeding and reintroduction/restoration program. A combination of captive breeding and streamside capture and spawning of brook trout to be reared in a hatchery setting for release into eligible waters has been effective at increasing the known range in West Virginia by at least five stream systems previously devoid of native Brook Trout for generations.

### U.S. Fish and Wildlife Service

The mission of U.S. Fish and Wildlife Service (FWS) is to work with others to conserve, protect, and enhance fish, wildlife and plants and their habitats for the continuing benefit of the American people. The FWS Northeast Region Fisheries Program is designed to support the conservation and management of aquatic species by maintaining, restoring, and recovering populations of species of conservation and management concern to self-sustaining levels; and, conservation and management of aquatic ecosystems by maintaining and restoring the ecological composition, structure and function of natural and modified aquatic ecosystems to ensure the long-term sustainability of populations of species of conservation and management concern.

### U.S. Geological Survey

USGS is providing decision-relevant science related to restoring and sustaining naturally reproducing brook trout populations and their habitat. USGS studies are focusing on better understanding several factors that affect brook trout populations including: (1) role of groundwater in sustaining stream temperatures, (2) effects of climate and land change on elevated stream temperature and altered hydrology, (3) competition of invasive species on brook trout populations, and (4) effects of unconventional oil and gas development on brook trout populations and habitat." USGS research provides data that contribute to brook trout management and the refinement of Brook Trout Decision Support Tools.

### National Park Service

The fundamental purpose of the National Park Service (NPS) "is to conserve the scenery and the natural and

historic objects and the wildlife therein and to provide for the enjoyment of the same in such manner and by such means as will leave them unimpaired for the enjoyment of future generations." The NPS covers more than 84 million acres and comprises 401 sites. These include 125 historical parks or sites, 78 national monuments, 59 national parks, 25 battlefields or military parks, 18 preserves, 18 recreation areas, 10 seashores, four parkways, four lakeshores and two reserves. Additionally, the National Park Service maintains active research programs that cover climate change, habitat stressors, and habitat restoration methods, providing data that contribute to brook trout management and the refinement of Brook Trout Decision Support Tools.

**USDA Forest Service**

The mission of the USDA Forest Service is to sustain the health, diversity, and productivity of the nation's forests and grasslands to meet the needs of present and future generations. The Forest Service is a multi-faceted agency that protects and manages 154 national forests and grasslands in 44 states and Puerto Rico and is the world's largest forestry research organization.

The Forest Service maintains active research programs that cover climate change, habitat stressors and habitat restoration methods, providing data that contribute to brook trout management and the refinement of Brook Trout Decision Support Tools. Forest Service experts provide technical and financial assistance to state and local government agencies, businesses, and private landowners to help protect and manage non-federal forest and associated range and watershed lands. They develop partnerships with many public and private agencies to augment their work planting trees, improving trails, providing education on conservation and fire prevention, and improving conditions in wildland/urban interfaces and rural areas. Their team also promotes sustainable forest management and biodiversity conservation internationally.

**USDA Natural Resource Conservation Service**

The mission of the USDA Natural Resource Conservation Service (NRCS) is to improve the health of our Nation's natural resources while sustaining and enhancing the productivity of American agriculture. They achieve this by providing voluntary assistance through strong partnerships with private landowners, managers, and communities to protect, restore, and enhance the lands and waters upon which people and the environment depend. NRCS is "Helping People Help the Land" by ensuring productive lands in harmony with a healthy environment is their priority. The NRSC staffs state offices in the five Chesapeake Bay states (MD, NY, PA, VA and WV).

**Trout Unlimited**

Trout Unlimited (TU) is a non-profit organization dedicated to the conservation of North America's coldwater fisheries and their watersheds-places where trout and salmon thrive. Within the Chesapeake Bay watershed, TU has over 70 local chapters and five state councils, representing over 16,000 members, and a staff of 15 that work in the watershed's headwaters protecting, reconnecting and restoring brook trout habitat.

At all levels of government, TU advocates for native trout conservation. In addition to this advocacy, TU's role in this strategy will be as an on-the-ground implementer of the priority conservation actions, specifically those related to the reconnection and restoration of Brook Trout habitat including the Home Rivers Initiative program in Virginia.

In the Gunpowder River Basin in Maryland, where 25% of the total Maryland brook trout population are found, TU and partner organizations have distributed an informational brochure to all landowners in the watershed, deployed temperature loggers, surveyed and tagged brook trout in several tributaries, and is working with the North Atlantic Aquatic Community Collaborative to identify culverts and stream crossings for restoration work. TU has also developed the Eastern Brook Trout Conservation Portfolio Analysis and Map to provide Decision Support Tools for managers and practitioners (Fesenmyer et al. 2017).

**Eastern Brook Trout Joint Venture**

EBTJV is one of the founding members of the National Fish Habitat Partnership, and works to conserve wild brook trout resources across their native range in the eastern portion of the U.S. EBTJV's vision is "healthy coldwater systems with fishable Brook Trout populations throughout their historic eastern geographic range". To achieve this, EBTJV leverages the capacity and expertise of 16 state management agencies ranging from Georgia to Maine, four federal agencies, and several NGOs including Trout Unlimited.

EBTJV provides funding annually to on-the-ground management projects designed to conserve and restore critical brook trout habitat. EBTJV has created and continues to update the most comprehensive distribution map of brook, brown, and rainbow trout occupancy across their entire eastern range. This map is foundational for scientific research and modeling as well as for directing on-the-ground management and outreach. EBTJV also brings together the leading brook trout scientists in the country to ensure their research is shared with managers and the most pressing management questions are addressed in future work.

# VI. Gaps

The main Gap to achieve success towards the brook trout outcome is interjurisdictional coordination at the local, state, and federal level to strategically prioritize, target, and implement brook trout restoration projects in watersheds most likely to succeed.

Bay states have successfully implemented monitoring programs to track brook trout occupancy. In addition, the new Habitat Tracker tool has provided the Brook Trout Workgroup the ability to track progress. Funding for brook trout conservation has generally been viewed as a limiting factor for success. However, recent increases in federal funding has made conservation efforts more attainable.

Restoration projects should target the four common causes of brook trout declines/losses and focus on improving resiliency and expanding occupancy within established stronghold watersheds to maximize the likelihood of success. Increasing riparian forest buffers, neutralizing AMD, excluding cattle from streams, and removing barriers to fish passage provide the quickest path to success for meeting the outcome goal. All of these BMPs are funded through different agencies and levels of government and are achieved in concert with NGOs.

# VII. Management Approaches

*The Partnership will work together to carry out the following actions and strategies to achieve the Brook Trout outcome. These approaches seek to address the factors affecting our ability to meet the goal and the gaps identified above.*

This management strategy is primarily focused on conserving, enhancing, and expanding "Wild Brook Trout Only" patches using the 2015 area of occupancy as the baseline for measuring progress toward achieving the Brook Trout Outcome. However, opportunities to conserve, enhance, and expand sympatric brook trout populations should also be considered.

**Prioritization**

A subwatershed restoration prioritization approach was developed that guided partners in identifying subwatersheds with the greatest potential for successful brook trout protection, enhancement or restoration actions (Hanson et al. 2014) based on watershed intactness. Hanson et al. (2014) identified 103 Intact

subwatersheds and 43 Reduced subwatersheds that are assigned high priority scores (0.79 or more) within the Chesapeake Bay watershed (***Appendix Table I***). Subwatershed priority scores provided a cross-GIT outcome focus for anti- degradation and maintenance (Healthy Watersheds Management Strategy)

A Boosted Regression Tree (BRT) model was developed that uses widely available landscape variables to predict the presence of brook trout in catchments located in the Chesapeake Bay watershed (Martin et al. 2012). The most important variables predicting brook trout abundance were mean July water temperature, impervious cover, and percent agriculture (Table 4). One of the model outputs is baseline information on the optimal potential condition of a catchment, which is presented as a natural habitat quality index (HQI). The HQI is defined as the maximum probability of brook trout presence under a zero-stress situation; essentially, the highest attainable condition in the catchment. Preliminary results from the Chesapeake Bay Brook Trout Pilot Model indicate that 54 percent of the catchments within the Chesapeake Bay watershed have an HQI greater than or equal to 0.50 (***Appendix Table II***).

**Table 4. Relative influence of all predictor variables used in the Chesapeake Bay Brook Trout BRT Model.**

| Predictor Variable Description | Predictor Variable Code | Relative Influence |
|---|---|---|
| Predicted mean July water temperature | mnjuly | 42.7 |
| Network mean imperviousness | IMP06C | 21.6 |
| Network percent agriculture | Ag_pc | 9.7 |
| Catchment slope of flowline | SLOPE_fix | 7.5 |
| Catchment mean annual precipitation | Precip | 6.6 |
| Network percent grassland (log transformed) | Log_Grass_pc | 2.6 |
| Catchment mean soil pH | SoilpH | 2.5 |
| Network percent acidic bedrock geology | Acid_geol_pc | 2.5 |
| Network percent mined, non-active (log transformed) | Log_past_minepc | 2.3 |
| Network percent wetlands (log transformed) | Log_Wet_pc | 2.1 |

### Identify and Communicate Priority Focal Areas for Brook Trout Conservation

In order to assist with strategic decision-making on where to focus Brook Trout conservation actions, the Wild Brook Trout Only patches in the Chesapeake Bay watershed have been sorted into three priority levels. Wild Brook Trout Only patches that occur in and around current brook trout strongholds, which are defined as being located in subwatersheds with a priority score ≥0.79, have been assigned priority Level 1 since these subwatersheds offer the best potential for sustaining wild Brook Trout populations and capitalizing on increased habitat connectivity (Hanson et al. 2014). Priority Level 1 Wild Brook Trout Only patches occur in 146 subwatersheds; 77 of these subwatersheds are located in Pennsylvania, 65 are in Virginia, three are in West Virginia and one is in Maryland (***Table 5*** and ***Appendix Table III***).

Wild Brook Trout Only patches that occur in subwatersheds having priority scores <0.79 but have ≥60% of their catchments with an HQI ≥0.50, have been given a Level 2 priority because they possess habitat that exhibits good potential for attaining favorable conditions when stressors are lessened. Priority Level 2 Wild Brook Trout Only patches occur in 238 subwatersheds; 152 of these subwatersheds are in Pennsylvania, 44 are in New York, 22 are in Virginia, 14 are in Maryland, and six are in West Virginia (***Table 5*** and ***Appendix Table IV***). Streams in these areas may have lost their ability to support Brook Trout due to logging, farming and loss of riparian cover. Restoration techniques exist to mitigate such land use impacts and bring Brook Trout back to these areas of

reduced habitat value.

Wild Brook Trout Only patches that occur in subwatersheds having priority scores <0.79 and have <60% of their catchments with an HQI ≥0.50 have been given a Level 3 priority. Priority Level 3 Wild Brook Trout Only patches occur in 216 subwatersheds; 82 of these subwatersheds are in Pennsylvania, 68 are in New York, 32 are in Virginia, 21 are in West Virginia, and 13 are in Maryland (***Table 5*** and ***Appendix Table V***). While prioritizing Wild Brook Trout Only patches this way is helpful in guiding strategic decision-making to achieve the outcome goal, additional potential priority focal areas can be identified using other criteria based on site-specific information.

**Table 5. The distribution of HUC 12s containing wild brook trout only (allopatric) patches sorted by priority level and state.**

| State | Number of Priority Level 1 HUC 12s | Number of Priority Level2 HUC 12s | Number of Priority Level3 HUC 12s | Totals |
|---|---|---|---|---|
| Maryland | 1 | 14 | 13 | **28** |
| New York | 0 | 44 | 68 | **112** |
| Pennsylvania | 77 | 152 | 82 | **311** |
| Virginia | 65 | 22 | 32 | **119** |
| West Virginia | 3 | 6 | 21 | **30** |
| **Totals** | **146** | **238** | **216** | **600** |

The specific locations of Wild Brook Trout Only patches can be viewed at the Spatial Hydro-Ecological Decision System (SHEDS) website, which features an interactive GIS map capable of displaying data layers {Brook Trout status and habitat patches) and tools (riparian prioritization, drainage area calculator) developed and endorsed by the EBTJV.

The communication of brook trout habitat stressors, conservation needs, and priority conservation areas with local decision makers is critical to outcome progress. The development of information fact- sheets and educational tools by Action Team partners will help relay this information.

**Consider Climate Change and Emerging Stressors in Determining Restoration Priorities** Regardless of a Wild Brook Trout Only patch's priority level, added considerations need to be given to those locations where brook trout have a lower vulnerability to the effects of climate change because their populations are less likely to disappear under various climate change scenarios (Trumbo et al. 2014). While the data layer does not cover the entire Chesapeake Bay watershed, the Brook Trout Integrated Spatial Data and Tools website has a GIS data layer {Brook Trout Patch Vulnerability) that identifies Wild Brook Trout patches with low exposure (predicted change in water temperature per unit increase in air temperature) and sensitivity (predicted frequency, magnitude and duration of water temperature averaged over a range of temperatures). Groundwater exchange may also mitigate stream thermal sensitivity to air temperature change (Snyder et al. 2016) and spatial models are needed to predict the role of groundwater for brook trout spawning, feeding and refugia across stream networks.

Impacts of stressors such as acid mine drainage (AMD) and unconventional oil and gas development, on brook trout population abundance and genetics should also be considered when identifying suitable brook trout habitat conservation and restoration areas. Considerable lengths of streams in PA, WV, and MD remain AMD impaired and present ample opportunities for restoration success via increased BIL funding.

### Refine and Apply Decision Support Tools

In addition to the SHEDS website noted above, there are several other Decision Support Tools available that will assist the conservation community in refining their efforts to conserve Chesapeake Bay brook trout resources at the local level.

Trout Unlimited Eastern Brook Trout Conservation Portfolio: The Conservation Portfolio uses the 3-R framework (Representation, Resiliency, and Redundancy) to evaluate each brook trout population patch for its resiliency to disturbances, likelihood of demographic persistence, and representation of genetic, life history, and geographic diversity. The Range-wide habitat integrity and future security assessment uses broad-scale GIS information to characterize the general habitat condition and vulnerability of EBT patches. The Chesapeake Bay focal area analysis adds regional data sources to provide additional resolution on habitat conditions and threats within Chesapeake Bay watershed.

Chesapeake Bay Fish Passage Prioritization Tool: This web-mapping platform is designed to be a screening- level tool that can be used to help investigate potential fish passage projects in the context of many ecological factors (Martin and Apse 2013). However, results do not incorporate important social, economic or feasibility factors and are not intended to be a replacement for site-specific knowledge nor a prescription for on-the-ground action. This platform includes a Brook Trout-specific scenario, though this scenario is limited to dams on small streams (those draining <100 $km^2$). Users of this tool can view results in the context of other relevant data including project data and various base maps, query results, download tabular data, search for a dam interactively or by name, annotate a map and print or save a map. (Fish Passage Management Strategy)

Riparian Restoration to Promote Climate Change Resilience Tool: This tool enables users to dynamically locate areas (within the selected region) in the riparian zone that would benefit most from increased shading produced by planting of trees. The tool operates on a 200-meter stream buffer (100 on each side), and requires the user to specify values for maximum percent canopy cover and minimum solar gain percentile. The user can additionally choose to include minimum elevation (meters) and maximum percent impervious surface values in the analysis.

Additional Decision Support Tools can be found on the EBTJV website Resources section and may be available through state and local agencies (e.g. Maryland's Statewide Brook Trout Patch Assessment and the Priority Brook Trout Restoration Watersheds layer). With the advent of multiple Decision Support Tools, it is important that conservation managers know how to use them. The Brook Trout Action team plans to hold workshops and webinars to educate partners on the use of these tools.

## Lessons Learned

**Cross-partnership Collaboration**

As resources become scarcer, we recommend adding an emphasized cross-GIT collaboration effort to our management approach. Our new Workplan will include collaboration with specific CBP outcomes (e.g., Forest Buffer, Fish Passage, Healthy Watersheds) to address specific environmental stressors identified as influencing factors in the brook trout management strategy and potentially tie their progress to progress made on some of our environmental stressor related actions and to guide conservation and restoration opportunities that would yield many cross-outcome benefits.

**Restoration Partnership Expansion**

The new workplan will emphasize expanding our partnership with on-the-ground restoration groups to keep up with the need for outcome progress.

**Partner Organization Decision Support Tool Communications**

The new workplan will include specific actions meant to communicate decision support tool use to practitioners including

**Continue and Expand Brook Trout Monitoring Efforts**

The ability of states, NGOs, and federal partners to monitor the extent and occupancy of brook trout habitat will affect the Bay Program's ability to measure true outcome progress. Consistent funding coupled with the advancement of enhanced monitoring methods (e.g., eDNA monitoring) will be important to monitoring efforts. The Brook Trout Action Team will help coordinate new information into partner monitoring programs and assist in identifying funding opportunities to sustain such programs. The creation and use of an official occupancy reporting process amongst Action Team partners will help ensure that outcome progress is measured reliably and consistently through time.

## VIII. Monitoring Progress

**Monitoring the Status of Wild Brook Trout Only Patches**

The state agency partners identified in Section V routinely conduct statewide census and monitoring efforts. Those data will be used in conjunction with other partner data to update the progress toward the outcome goal. These efforts are driven by the individual partner needs, programs, and budgets and are not all on the same timeline for data collection, review and reporting. It is anticipated the next update on progress toward the Brook Trout outcome will be in 2025.

## IX. Assessing Progress

To achieve the Brook Trout Outcome, there is a need to increase the amount of wild brook trout only occupied patch area by 1,083 $km^2$. This equates to expanding occupancy by 108 $km^2$ per year over a ten-year period. The Brook Trout Action Team will adopt the Eastern Brook Trout Joint Venture's 3-5-year range-wide assessment to measure outcome progress. To assess interim progress, pertinent jurisdictions will annually report the amount of habitat ($km^2$) occupied by wild brook trout only that was added to (through conservation actions) or removed from (due to loss in occupiable habitat) the baseline figure using a standardized occupancy reporting protocol. These annual gains will be combined with the outputs of the monitoring protocol (i.e., sentinel sampling sites) to determine overall progress. Then, after every five-year period, when all monitoring sites have been sampled at least once and assuming adequate continued funding for monitoring/evaluation, a status report will be developed that summarizes the gains and/or losses of area occupied by wild brook trout only over that time period and contains recommendations for making adjustments to maintain progress toward the outcome (i.e. managing adaptively). Such adjustments will likely take the form of interim geographic targets identified by the pilot model and articulated in biennial workplans.

## X. Adaptively Managing

The Partnership will use the following approaches to ensure adaptive management: The Brook Trout Action Team will meet at least twice annually to track progress toward the goal of an 8% increase in brook trout habitat, as well as share progress and discuss any new challenges or opportunities. The Action Team will use this time to review performance assessment information and adjust Management Strategies where appropriate. As new issues are identified, the Action Team will work with conservation partners to develop strategies to overcome barriers to restoration, as well as identify trends, priority areas, and research needs.

# XI. Biennial Work Plan

Work Plans for each management strategy will be revised every two years. It will include the following information:

- Each key action
- Timeline for the action
- Expected outcome
- Partners responsible for each action
- Estimated resources

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