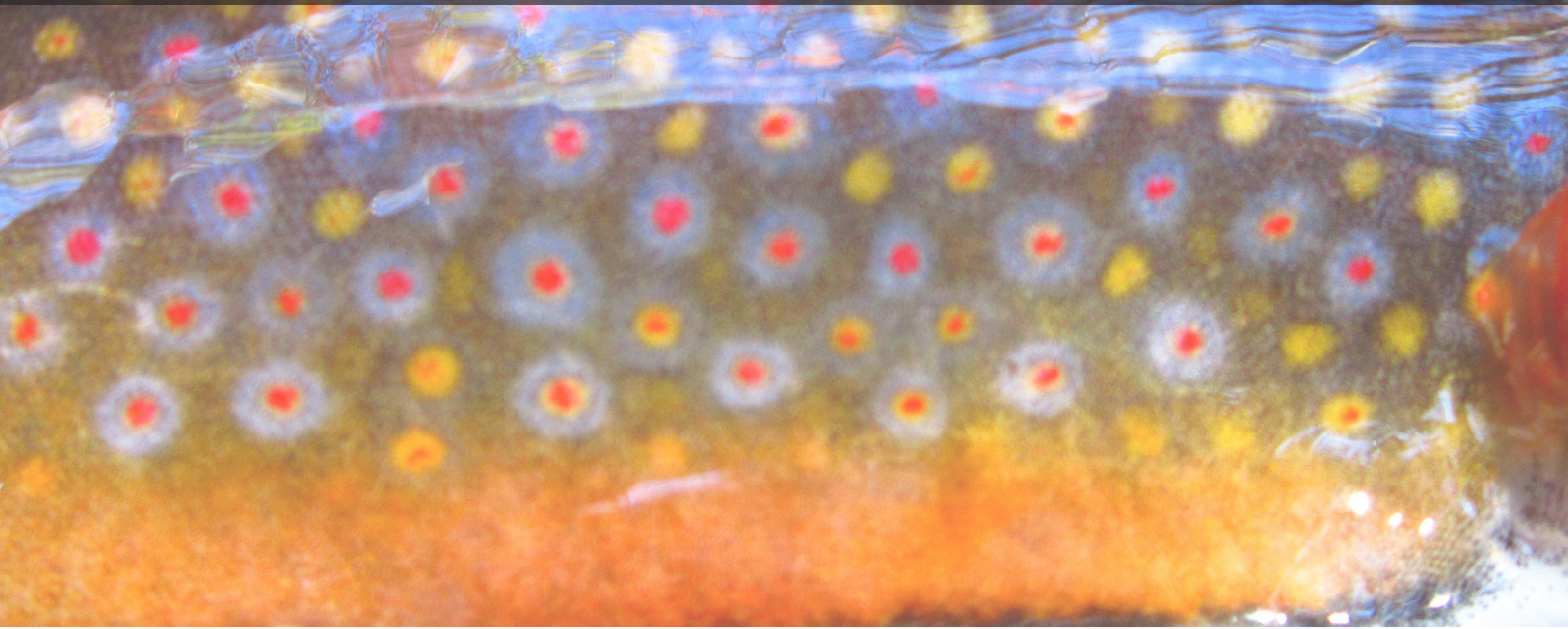
Chesapeake Bay Brook Trout Assessment 2015

Using decision support tools to develop priorities



Eastern Brook Trout JOINT VENTURE A Fish Habitat Partnership

North Atlantic LCC North Atlantic Landscape Conservation Cooperative

Downstream Strategies building capacity for sustainability

West Virginia University

PREFACE

Project Impetus

Recently, the Chesapeake Bay Watershed Agreement established a management outcome focused on restoring and sustaining naturally reproducing brook trout populations in the Chesapeake Bay's headwater streams. Partners and stakeholders desired a statistically-valid predictive model that captured underlying cause and effect relationship between habitat characteristics and brook trout within this watershed, which would ultimately assist and guide the achievement of the conservation priorities in the Chesapeake Bay's Brook Trout Management Strategy.

Downstream Strategies, funded by the North Atlantic Landscape Conservation Cooperative, created a predictive model for brook trout within the Chesapeake Bay watershed that met the needs outlined above. Some of the important outcomes from this effort are detailed on this page.

Important Outcomes

- Accurate statistical model linking present-day brook trout distributions to land use conditions throughout the Chesapeake Bay watershed.
- Independent measures of anthropogenic stress (imperviousness, agriculture, and mining) and natural habitat quality (water temperature and precipitation), which allow for priority conservation areas to be identified at multiple spatial scales.
- Predictions of likely future conditions of brook trout population status under a range of climate change scenarios.
- Web-based decision support tool that provides a user-friendly interface to examine and manipulate data and model results. www.fishhabitattool.org
- Ability to query, map and download data and model results, and an ability to integrate other relevant data and model products (e.g., EBTJV Patch Classification, TNC dispersal barriers, etc.).
- Sophisticated, interactive optimization and ranking algorithm that allows for construction of multiple, optimized conservation strategies that vary depending on user-defined preferences.
- Ability to simulate brook trout population response to spatially-explicit changes in land use within the context of current or future climate.
- Ability to download or print data or maps created within the web-based decision support tool.

INTRODUCTION

Healthy waterways and vigorous populations of fish provide clean water, vibrant economies, and numerous recreational opportunities to millions of people in the eastern United States. To more sustainably manage these resources across large geographic areas, there is a pressing need to characterize the status, habitat, and threats to fish and other aquatic species. This document provides the details of such an assessment performed for brook trout in Chesapeake Bay watershed.

WHAT IS A CATCHMENT?

A catchment, as defined by the NHD+ data utilized for this effort, is the land area draining directly to a single stream segment. Stream segments were defined by 1:100k USGS topographic maps.

Brook trout symbolize healthy water because they rely on cold, clean water and are sensitive to habitat and water quality impacts.

They are an essential part of the headwater stream ecosystem, and are an important part of the upper watershed's natural heritage and a valuable recreational resource.

This assessment provides datasets in combination with innovative tools to characterize current and future aquatic conditions, target and prescribe restoration and conservation actions, set strategic priorities, evaluate management efforts, and advocate for science-based sustainable management plans.

Assessment objectives

1. Develop models to estimate the probability of brook trout occurrence in catchments throughout the Chesapeake Bay watershed
2. Calculate measures of underlying natural habitat quality and anthropogenic stress
3. Assess future climate scenarios and the potential impact to brook trout populations
4. Provide decision support tools to facilitate visualization of data and results, prioritize conservation and restoration actions, and estimate brook trout

Assessment Components

Current Conditions

Fish surveys from 3,284 catchments (small watersheds) during 1995 to 2013 were used to predict the likelihood that brook trout were present across the Chesapeake Bay watershed. Of the total 51,474 catchments in the watershed, there were over 9,500 catchments with a predicted probability of occurence greater than 75%, and over 6,000 catchments with a probability of occurence between 50% and 75%. Refer to the map on page 6.

Natural Quality Index

The natural habitat quality index provides baseline information on the optimal potential condition of a catchment. Natural quality is defined as the maximum probability of occurence under a zero-stress situation; essentially, the highest attainable condition in the catchment. Refer to the map on page 7.

Top three most influential natural factors:

1. Mean July stream temperature
2. Slope
3. Mean annual precipitation

Anthropogenic Stress

The stress index quantifies impacts from anthropogenic process on aquatic habitat conditions at the catchment scale. Higher stress values indicate a larger change in predicted probability of occurence after removing stress, and lower stress values indicated that the catchment was relatively unaffected by removing stress.

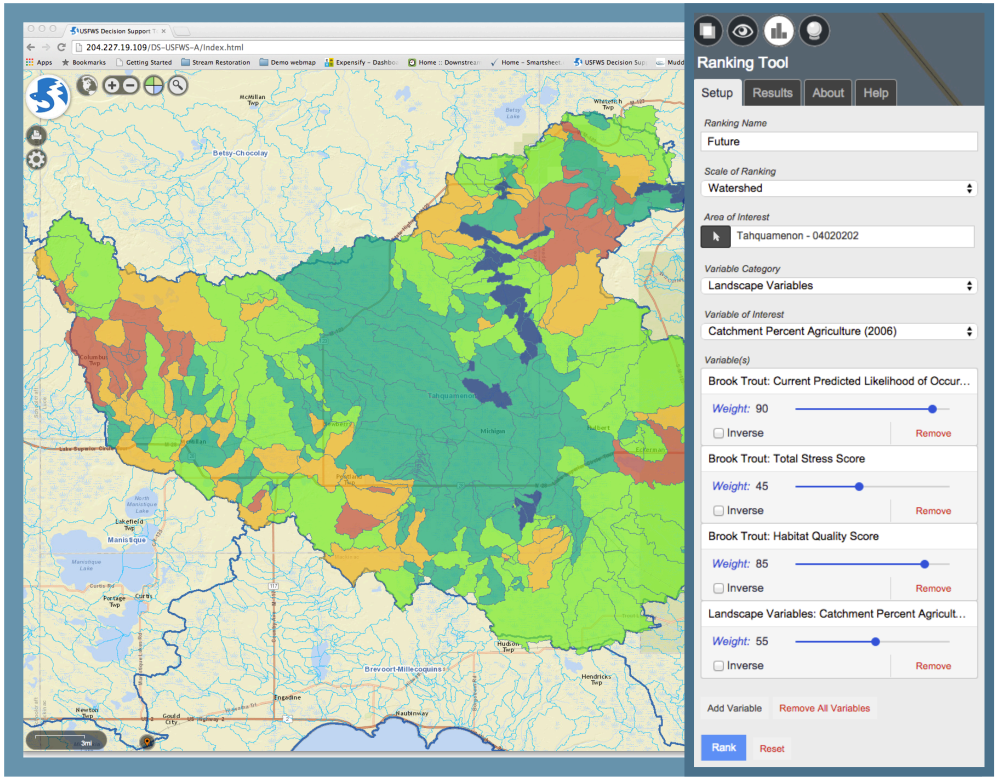
Top three most influential stress factors:

1. Cumulative impervious surface
2. Cumulative agricultural landcover
3. Cumulative percent of past mining activities

DECISION SUPPORT TOOLS

The brook trout assessment results are integrated into a web-based decision support tool. This platform provides resource managers and the general public access to data, models, and prioritization tools for use with the Chesapeake Bay Brook Trout Assessment models and similar assessment results from across the Midwest and Great Plains. The tool can be found at www.fishhabitattool.org.

Three main analytical tools (listed below) are combined with intuitive basemaps and mapping features to allow users to explore the details of the assessment and perform subsequent analyses.



Visualization tool

Datasets include landscape variables (both natural and anthropogenic), socioeconomic information, and model results. Model results include the natural quality index, stress indices, and predicted condition. Two scales of visualization are available to map and export data: regional and local. Regional results are displayed by HUC12 watershed, and local results are displayed for each catchment within a selected HUC8.

Ranking Factors

Users can rank catchments within a selected HUC8 watershed by selecting and weighting data. Variables can include modeling results and additional socio-economic factors. The tool will produce a new output that displays catchments ranked by user criteria. All data can be exported and mapped.

Futuring tool

The web-based futuring tool allows the user to examine brook trout habitat stressors for specific catchments. The user can then modify existing conditions and predict changes in overall condition, both locally and downstream for brook trout.

WHAT IS A "HUC"?

The USGS has divided the United States into successively smaller hydrologic units which are classified into six levels. The hydrologic units are nested within each other, from the largest to the smallest geographic area. Each hydrologic unit is identified by a unique hydrologic unit code (HUC) consisting of two to 12 digits. Brook trout assessment results are organized by two levels of the hierarchy, Subbasin (8 digits or "HUC8") and the smallest unit, Subwatershed ("HUC12").

ASSESSMENT PROCESS

The models, analyses, and data produced as a result of this project are intended to enable a unique, broad, and spatially explicit understanding of the links between natural habitat conditions and human influences on aquatic habitats. Specifically, the outcomes can be utilized to conduct fish habitat condition assessments based on a range of stakeholder-specified metrics and modeling endpoints to help determine natural drivers of aquatic conditions as well as primary stressors to brook trout populations. The ultimate goal is to improve understanding of how local (e.g., stream water temperature) and network (e.g., upstream agriculture) processes influence stream conditions in the region and to provide additional knowledge, data, and tools to help prioritize and inform conservation and restoration actions throughout the Chesapeake Bay watershed.

A successful assessment should be acceptable by a range of professionals, from the field biologist to a regional manager. The brook trout assessment relied on several key facets: (1) gathering data and technical input from a group of brook trout stakeholders, (2) a flexible modeling system that allows for efficient models to be developed, and (3) a post modeling process that simplifies the model results and makes them accessible by a range of users.

STAKEHOLDER INVOLEMENT

A group of Eastern Brook Trout resource experts were engaged as part of the assessment process. This technical group helped to guide the process, provide data, review assessment results, and provide feedback. The process included several modeling iterations and reviews, which provided opportunities for experts to weigh in on the results and offer feedback.

STATISTICAL METHOD

The statistical approach used for this assessment is boosted regression trees (BRT), a machine learning statistical method. This methodology was also applied in previous work across the Midwest and Great Plains (midwesthabitats.org), based on a careful review of many statistical methodologies. Stakeholders across the region decided upon BRT over competing methodologies after comparing and contrasting the strengths and weaknesses of each.

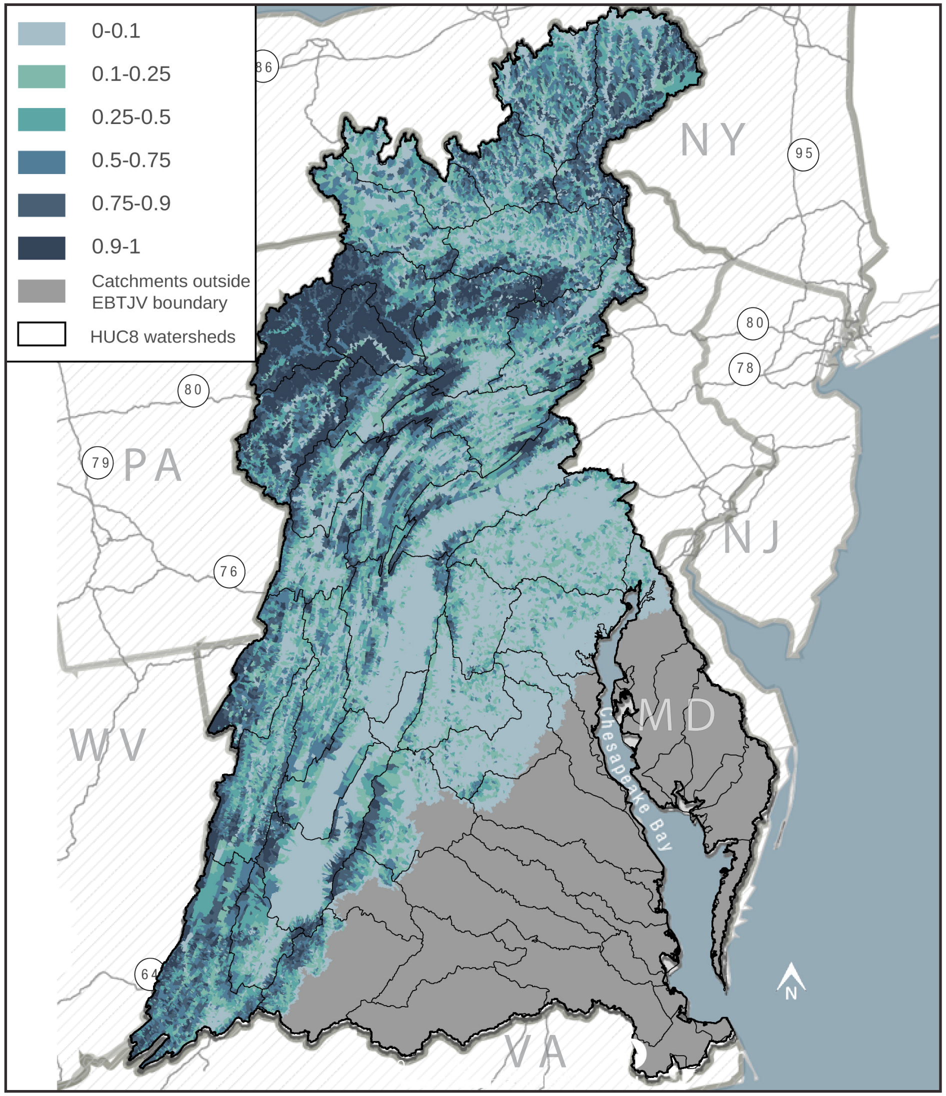
BRT models combine decision trees and boosting methodologies. Decision trees are advantageous because (1) they can incorporate any type of predictor data (binary, numeric, categorical), (2) model outcomes are unaffected by differing scales of predictors, (3) irrelevant predictors are rarely selected, (4) they are insensitive to outliers and non-normalized data, (5) they can accommodate missing predictor data, (6) they can accommodate co-varying predictor variables, and (7) they can automatically handle interactions between predictors (Elith et al., 2008). The modeling process results in a series of quantitative outcomes, including predictions of expected current conditions of all catchments in the modeling area, measurement of prediction accuracy, a measure of each predictor's relative influence on the predictions (i.e., variable importance), and a series of plots illustrating the modeled functional relationship between each predictor and the response.

The predictions of current conditions were created by extrapolating the BRT model to all catchments within the modeling area. These current conditions are useful for assessing habitats and mapping the expected range of species.

POST MODELING

Characterizing anthropogenic stress and natural habitat quality of aquatic habitats is a useful and necessary process for helping land and fisheries managers identify place-based conservation and restoration strategies. A post-modeling process was used to characterize anthropogenic stress and natural habitat quality for all catchments within the study area. Stress and natural habitat quality indices are calculated based on BRT model outputs. Once developed, these indices of stress and habitat quality can be used to generate and visualize restoration and protection priorities. For example, areas of high natural quality and low stress could represent protection priorities, whereas areas of high natural quality and high stress may represent restoration priorities. In addition, we quantified how climate change may impact natural habitat quality and brook trout distributions.

CURRENT CONDITIONS



BROOK TROUT PROBABILITY OF OCCURENCE

Current conditions are predicted by building a BRT model that predicts probability of occurrence for brook trout throughout the portion of Eastern Brook Trout Joint Venture (EBTJV) range within the Chesapeake Bay watershed. The modeling process begins by collecting and processing predictor data (landscape and environmental) and response data (brook trout location data) for the region. These datasets are then used in the model to derive the relationships between the habitat and probability of occurrence. The model is developed at the 1:100k-catchment scale, producing a map of predicted brook trout occurrence for each catchment, on a scale from 0 (no probability) to 1 (very high probability).

Of the 51,474 catchments in the Chesapeake Bay watershed and also within the historic range of eastern brook trout, there were 9,605 catchments with a predicted probability of occurence greater than 0.75 and 6,279 catchments where the probability of occurence was between 0.5 and 0.75. These results are mapped on this page.

Variable Description	Relative Influence
Mean July Stream Temperature (predicted)	42.7%
Mean network imperviousness	21.6%
Network percent agricultural landcover	9.7%
Slope of catchment flowline	7.5%
Mean annual precipitation	6.6%
Log of network percent grassland cover	2.6%
Catchment soil pH	2.5%
Network percent acidic geology	2.5%
Log of network percent past mining areas	2.3%
Log of network percent wetland cover	2.1%

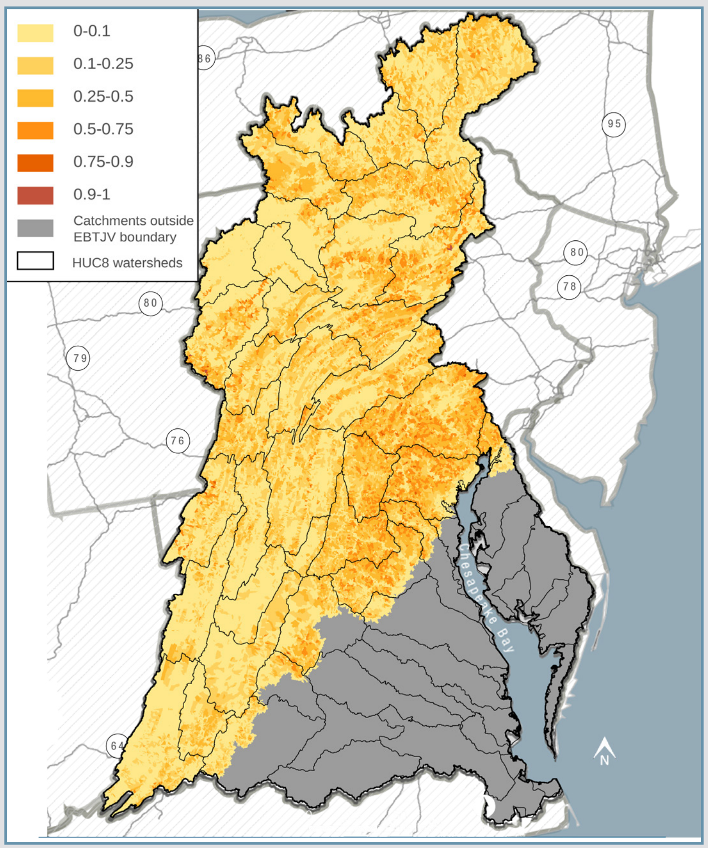
Modeled stream temperature, which represents a natural habitat quality variable, was the single most important predictor variable in the model with a relative influence of 43%. The next most important predictor was an anthropogenic stressor (mean network imperviousness) with a relative influence of 22%. The table above shows the other modeled variables and their influence on predicting brook trout occurrence.

ASSESSMENT INDICES

Independent measures of stress and underlying natural quality allow resource managers a more thorough understanding of likely conditions within each catchment, and provide a basis for intuitive priority establishment for conservation actions.

Here, we show the anthropogenic stress and natural quality indices for all catchments, even in areas where the probability of occurence is low. This is necessary and useful to consider areas outside of the current expected range where stress could have caused a historic population to be extirpated.

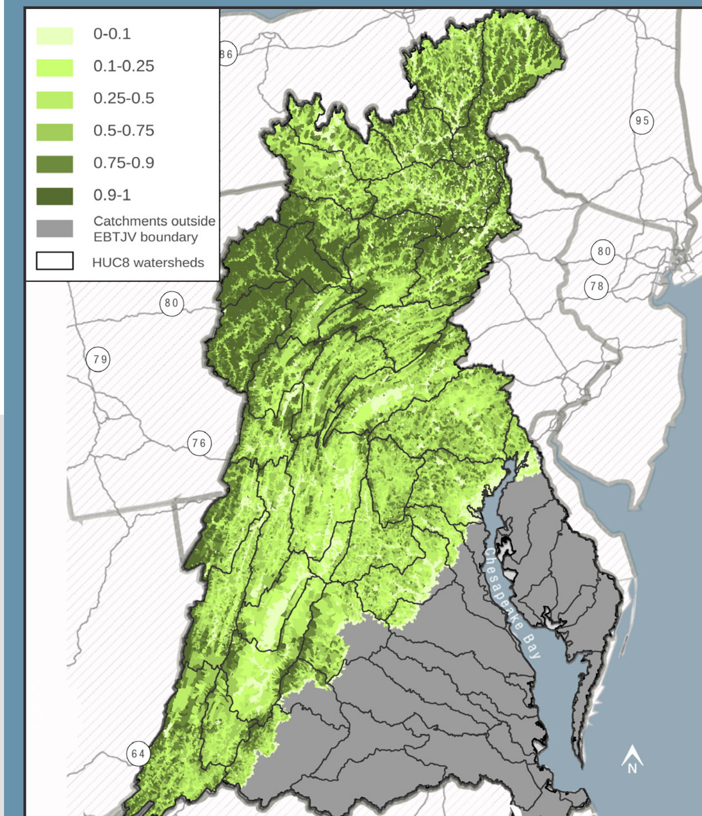
ANTHROPOGENIC STRESS INDEX



For each catchment, the individual stress metrics (e.g. agriculture stress, impervious surface stress, mining stress) were summed to produce an overall stress metric, the anthropogenic stress index (ASI). The higher the number (or darker the color) the higher the stress in that catchment.

Note that the stress values are not simply a measure of anthropogenic changes to the watershed, but also how much those changes are impacting brook trout. If an area was naturally unsuitable for brook trout (i.e. low natural quality index score), the stress index will also be low even if stressors are present in the area.

NATURAL QUALITY INDEX



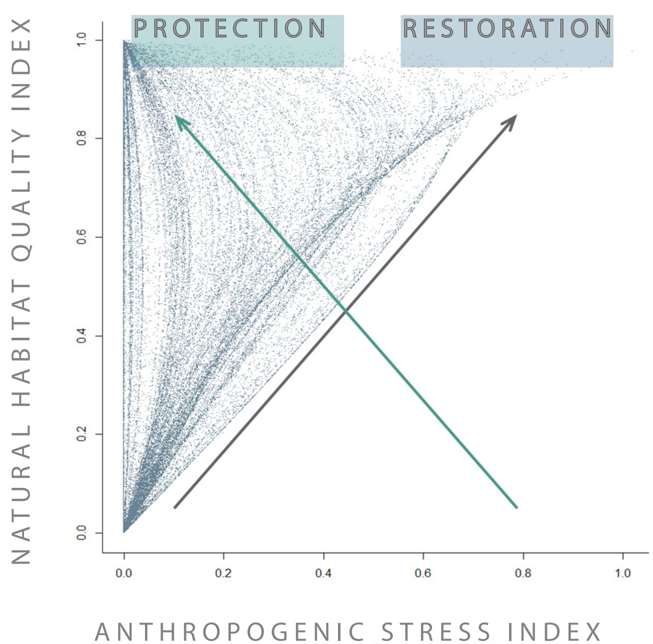
Natural habitat quality metrics provide baseline information on the optimal potential condition of a catchment. These metrics consist of environmental features that are minimally influenced by human activities, such as slope and temperature. Natural quality index can be defined as the maximum probability of occurence under a zero-stress situation; essentially, the highest attainable condition in the catchment. Stream temperature, slope, and precipitation are the three most influential natural variables. Higher habitat quality metric scores (darker colors) indicate better underlying habitat potential for brook trout.

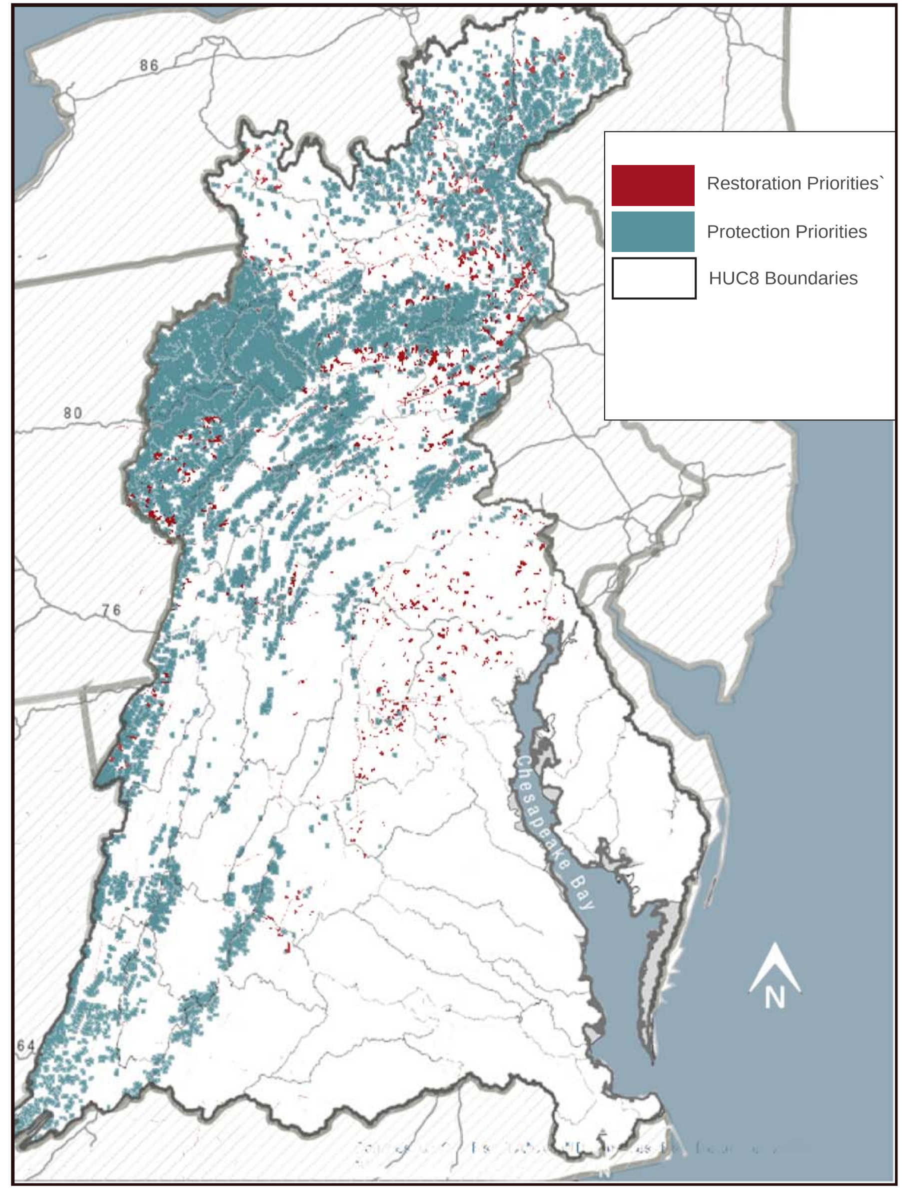
DEVELOPING PRIORITIES

Using information from the anthropogenic stress and natural habitat quality indices can be a powerful tool for developing effective restoration and protection priorities. Here we show an example of how this can be done, and while we use an informed set of criteria for identifying conservation priorities, this example is only intended to demonstrate the functionality of querying catchments for the development of priorities.

A plot of the natural habitat index values versus anthropogenic stress index values (shown below) for all catchments in the study area can be used as a reference when evaluating restoration and protection priorities. Using this plot, we set criteria for both restoration and protection priorities for this example scenario, based on relative scores represented.

Protection priorities were defined as catchments with high natural habitat quality and low anthropogenic stress; the criteria for this were HQI greater than 0.85 and ASI less than 0.2. The restoration priorities were defined as catchments with high natural habitat quality and moderate to high anthropogenic stress; the criteria for this were HQI greater than 0.85 and ASI greater than 0.4. These classifications are mapped to the right.





SCENARIOS

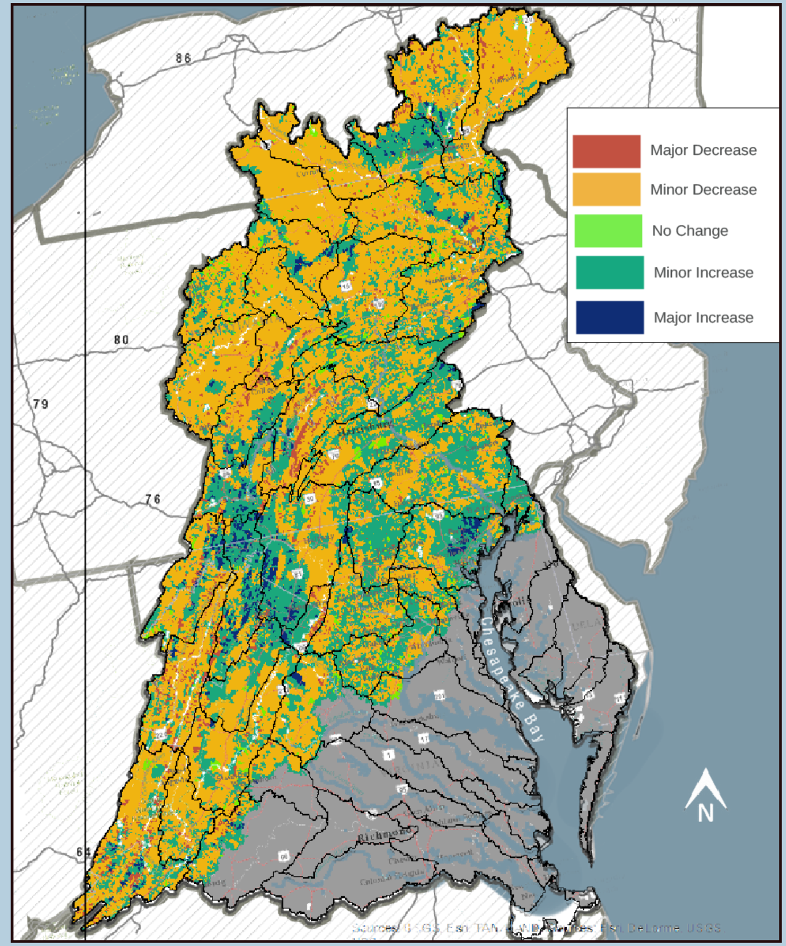
IMPACT TO BROOK TROUT HABITAT FROM CLIMATE CHANGE

For a coldwater obligate species such as brook trout, the impact of potential climate change is expected to alter their distribution across the landscape. The assessment modeled potential future conditions to understand the resiliency and vulnerability to climate change for brook trout in the Chesapeake Bay watershed. While we acknowledge that there is an amount of uncertainty with all future climate predictions, these results can be incorporated as part of the development of future restoration and protection priorities by quantifying the expected conditions of brook trout populations into the future. The assessment is based on large-scale climatic factors, which include mean annual precipitation and mean July temperature, and as such, did not consider other climatic changes, which could be a source of additional future uncertainty.

PROCESS

After examining several climate scenarios across three different decades, the stakeholders decided to focus scenarios on 2062, as that timeframe far enough in the future to see significant climate effects, but not beyond the range of implementing actionable current goals. Habitat quality and stress were calculated in a manner similar to the post modeling methodology, but in this analysis the predictor variables were manipulated to replace current climate data with projected future climate data.

The resulting difference between current and future conditions quantifies the potential effects of climate change on Brook Trout in the Chesapeake Bay Watershed. To interpret the results, both resiliency and vulnerability were determined by analyzing losses or gains in natural quality. The underlying natural quality is directly impacted by changes in climate, which indicate the anticipated impacts on brook trout occupancy. Catchments anticipated to have reduced natural quality are vulnerable to future climate change scenarios, while resilient areas show no change or an increase in natural quality under future climate scenarios."



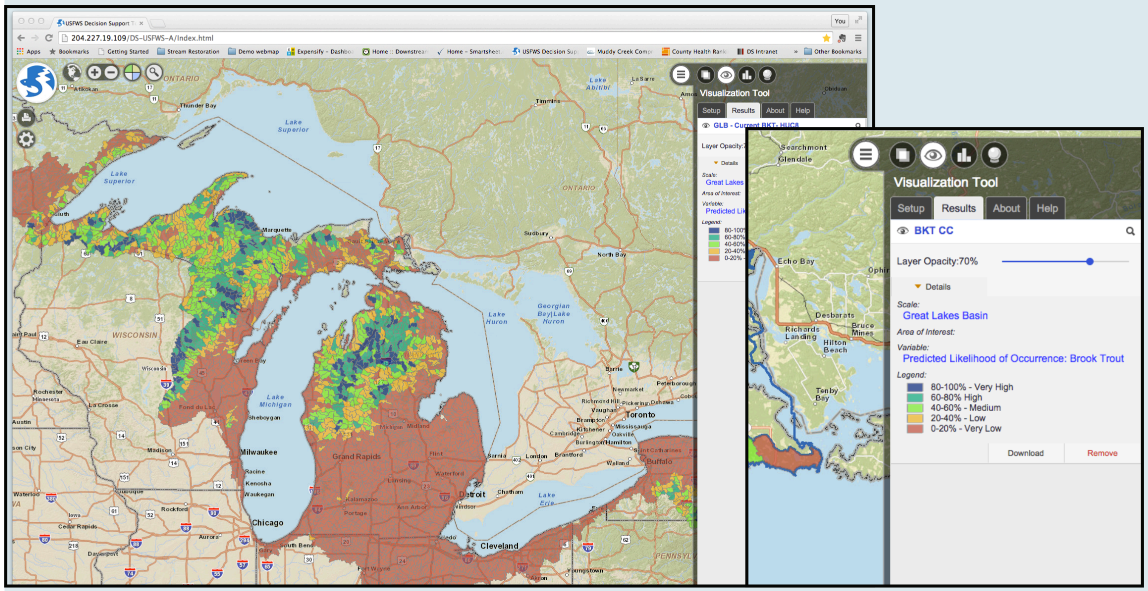
Anticipated climate effect from 2062 scenario. Climate change effect is based on the change in natural habitat quality from current condition to predicted future condition. Minor changes are between zero and +/-0.20. Major changes are greater than +/-0.20.

The map on this page illustrates the impact from climate change to natural habitat quality for every catchment within the Chesapeake Bay watershed. Climate change impact will result in nearly a 10% decrease in mean habit quality across the watershed. Over 33,000 catchments (66% of study watershed) are projected to decrease in natural quality, which indicates climate change vulnerability. These areas are red or orange on the map, and were due to increased projected water temperatures. Approximately 6,000 of those catchments (12%) show a major decrease in habitat quality (reduction in habitat quality more than 0.20). Conversely, only 17,000 catchments (34% of study watershed) are expected to be resilient to climate change in the future (i.e. habitat quality values are constant or improve under future climate scenarios). These are the dark green and blue areas on the map, and are found in areas where projected increases in precipitation are projected to ameliorate for higher projected water temperatures.

HOW THE DECISION SUPPORT TOOLS WORK

1 Visualize

This tool is used to examine all of the datasets in the assessment process. Datasets include landscape variables (both natural and anthropogenic), socioeconomic information, and model results. Model results include the natural quality index, stress indices, and predicted condition. Two scales of visualization are available to map and export data: regional and local. Regional results are displayed by HUC12, and local results are displayed for each catchment within a selected HUC8.

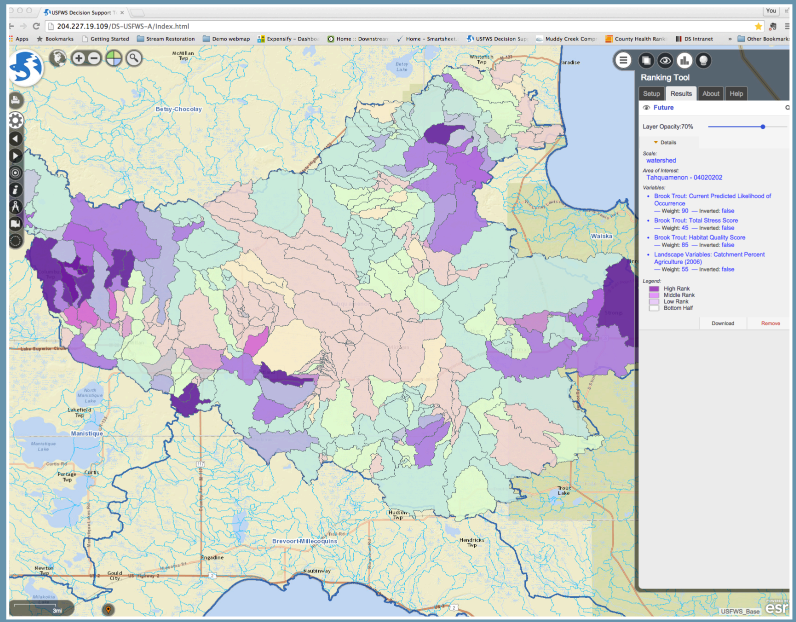


Examine current probability of occurence by watershed.

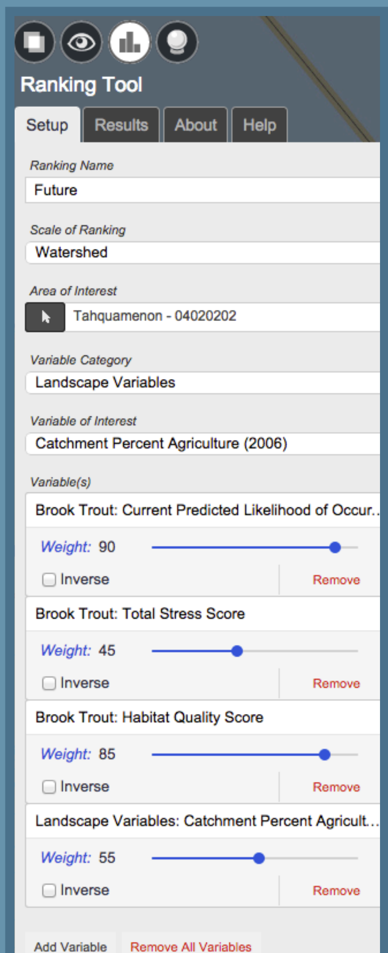
Visualize the overall current stress on brook trout populations or by specific stress variable.

2 Rank

Users can rank catchments within a selected HUC8 watershed by selecting and weighting data. Variables can include modeling results and additional socioeconomic factors. The tool will produce a new output that displays catchments ranked by user criteria. All data can be exported and mapped.



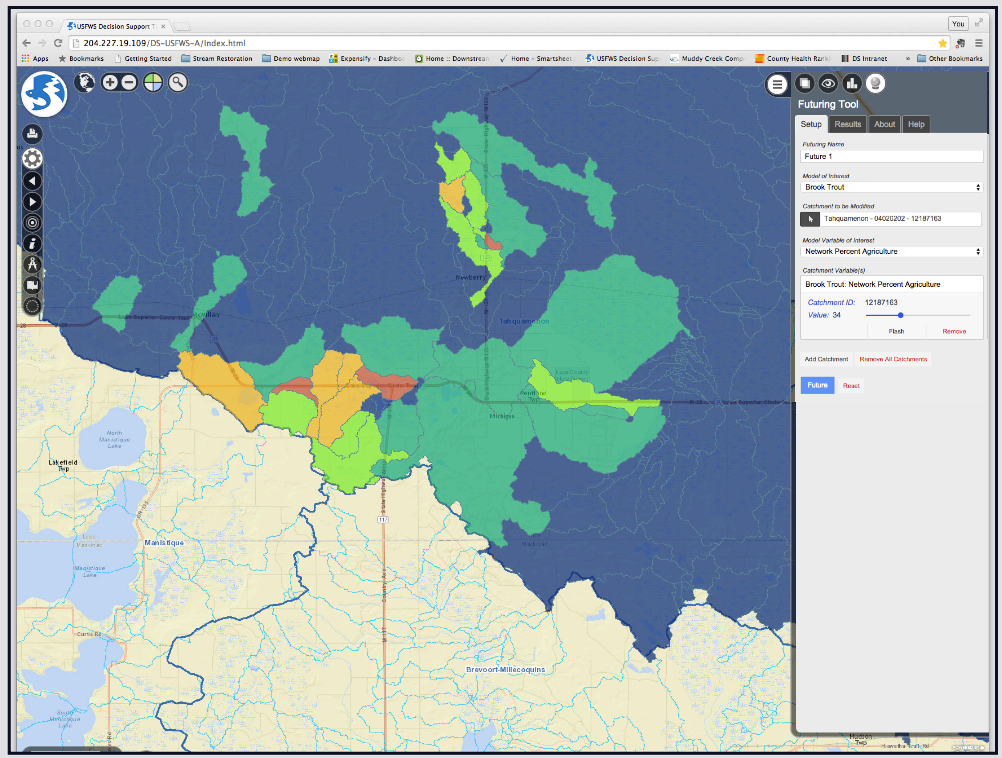
The example map above shows ranked catchments based on a user-defined weighting of probability of occurence, overall stress index, habitat quality score, and catchment percent agriculture.



Users can change weight and directionality of variables to be ranked.

3 PRIORITIZE

The web-based futuring tool allows the user to examine brook trout habitat stressors for specific catchments. The user can then modify existing conditions and predict changes in overall condition, both locally and downstream for brook trout.



Using the futuring tool, users can determine which variables are the most crucial in preserving and restoring habitat. Management decisions can be tested and guided through these predictive models. For instance, a user could lower agricultural cover from 35% to 15% and see the predicted habitat increase.

CASE STUDY: BROOK TROUT PRIORITIES IN THE CHESAPEAKE BAY

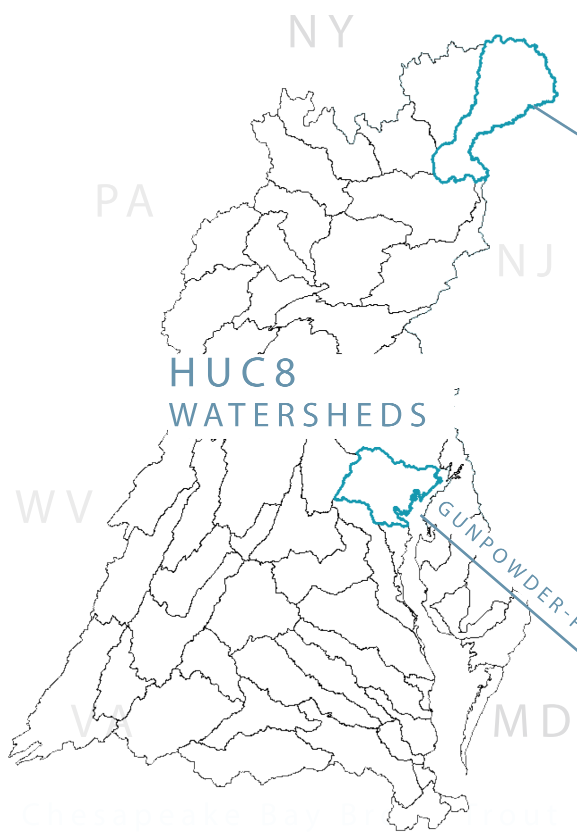
HUC8 Scale   HUC12 Scale   Catchment Scale

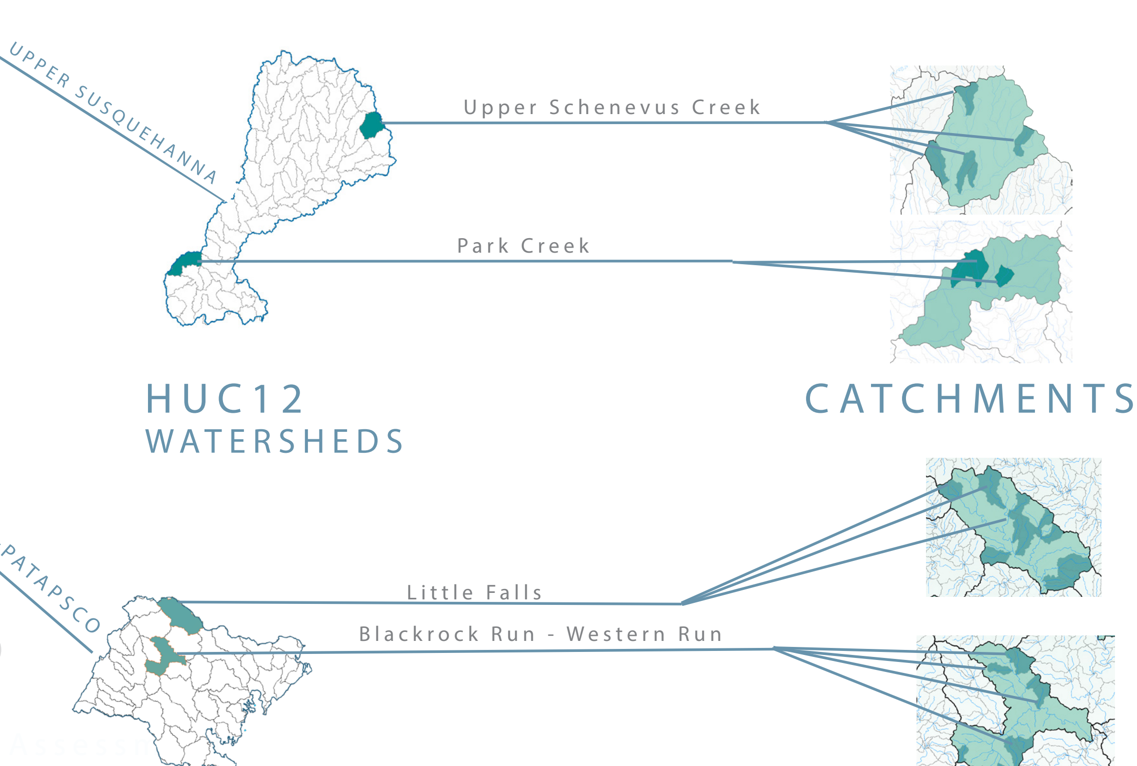
This case study shows an example of how we utilized a hierarchical process to establish restoration and protection priorities using the results from this assessment. This case study not only utilizes the information from the current model, but also uses future climate scenario predictions, which can allow natural resource managers to establish restoration priorities in areas where brook trout are expected to persist under future climate scenarios. Conversely, areas that are vulnerable to future climate scenarios could be identified and prioritized for actions that may ameliorate the impacts of warmer temperatures.

While this case study is reasonable and potentially useful at a watershed-wide scale, it is provided only as an example. Resource managers developing priorities for brook trout could incorporate data from other assessments, such as the EBTJV priority catchment information into a similar decision making process to further inform any priorities developed.

How

By estimating lost fishery value due to landscape stressors, and estimating the potential change in future fishery condition due to climate, we can begin to develop broad scale conservation priorities at the HUC8 scale. The combination of these three measures (current value, value lost due to stress, and potential value loss due to climate) provides important information for setting conservation priorities at all hierarchical scales





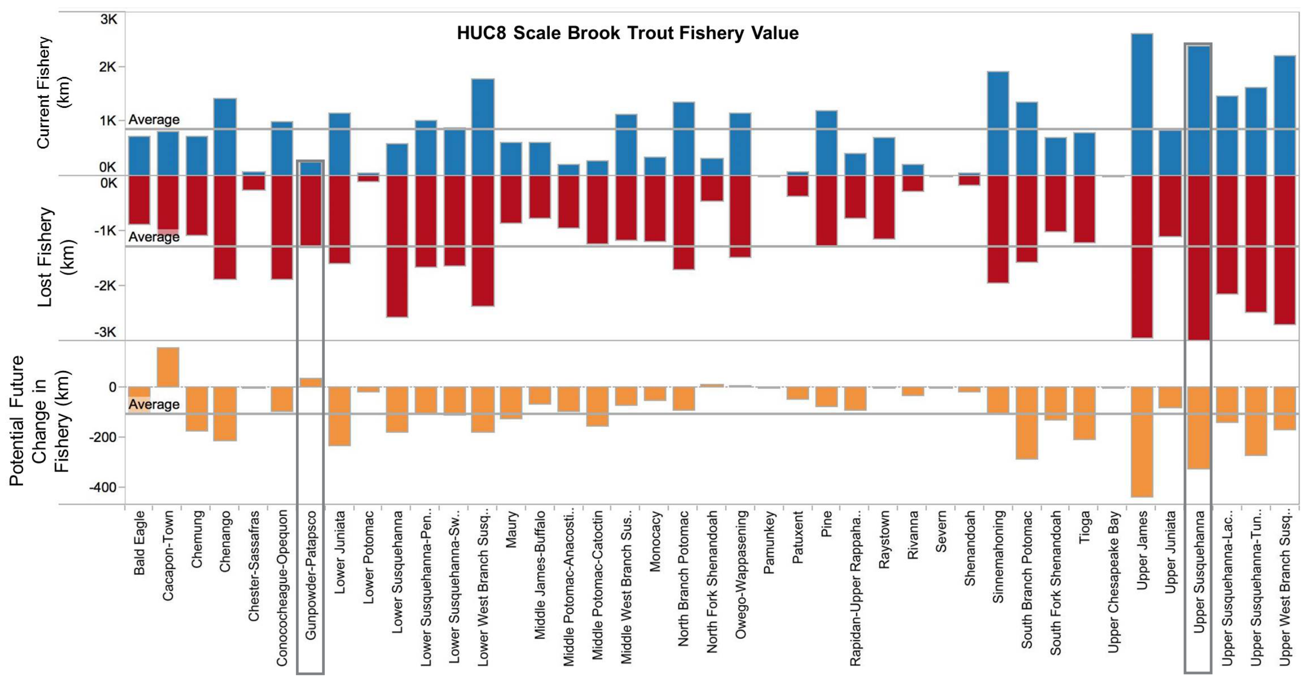
CHESAPEAKE BAY HUC8 PRIORITY WATERSHEDS

CASE STUDY: BROOK TROUT PRIORITIES IN THE CHESAPEAKE BAY

HUC8 Scale | **HUC12 Scale** | **Catchment Scale**

HUC8 Scale Priorities

Calculating Fishery Values: Here we apply a process for estimating how much of the stream length of a watershed is predicted to support brook trout now, how much has been lost due to anthropogenic stress, and how much could be lost in the future due to climate change. To calculate, we multiplied the length of the stream segment (km) by the appropriate metric (current occupancy to calculate 'current fishery', anthropogenic stress for 'lost fishery', and change in future habitat quality for 'potential future change in fishery').



PROTECTION EXAMPLE

One priority could be to protect remaining brook trout populations within highly degraded HUC8 watersheds, especially when those areas are projected to remain resilient to future climate perturbations. The two HUC8 watersheds that stand out as resilient to climate change (positive orange bar) in the figure on this page are Cacapon-Town and Gunpowder-Patapsco. Of these two watersheds, the Gunpowder-Patapsco has a very small amount of current fishery remaining (blue bar) and has lost quite a large amount of habitat due to stress (red bar). This watershed will be the focus of our first scenario, where protection of remaining populations should be a priority.

RESTORATION EXAMPLE

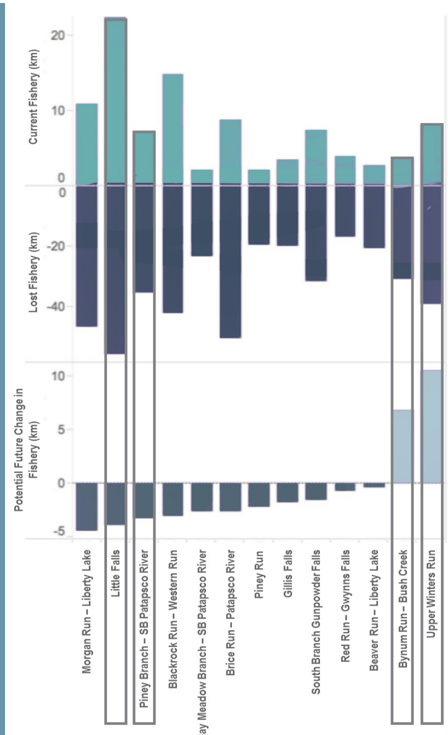
From the same graphic we can also identify those HUC8 watersheds best suited for restoration. Both the Upper James and Upper Susquehanna HUC8's possess relatively strong current fishery values (blue bar) and have also lost considerable value due to anthropogenic stress (red bar). This indicates ample opportunity to reduce stressors and build from strong remaining populations. Since the Upper Susquehanna has lower overall vulnerability to future climate change compared to the Upper James, it will be spotlighted for a priority restoration scenario.

CASE STUDY: BROOK TROUT PRIORITIES IN THE CHESAPEAKE BAY

HUC8 SCALE HUC12 SCALE CATCHMENT SCALE

PROTECTION: GUNPOWDER-PATAPSCO

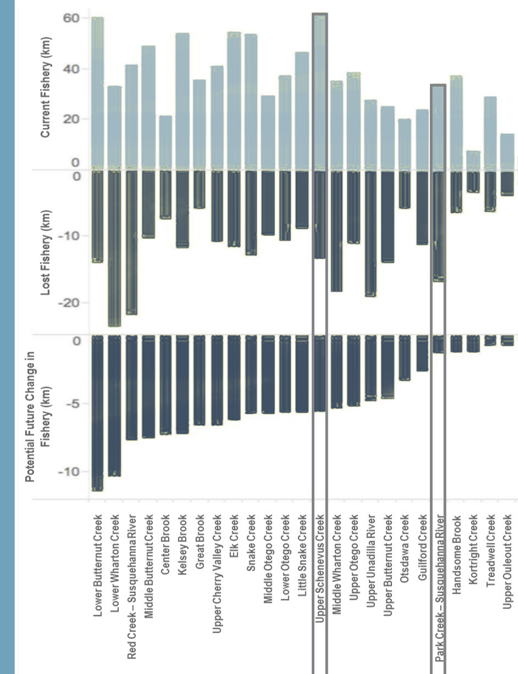
Within our first example in the Gunpowder-Patapsco, an analysis of the same factors as above (current, lost, and future brook trout habitat value) within each HUC12 can further direct the establishment of protection priorities. For directing protection of remnant populations, focusing on those areas most resilient to climate change would be beneficial to ensure protections are not undermined by future climate conditions. Given that, the two HUC12 watersheds on the far right of this chart (Bynum Run-Bush Creek and Upper Winters Run), would be watersheds to examine further for protection priorities. Areas with the highest overall remaining fishery would be other targets for this type of protection, so HUC12 watersheds Little Falls (second from left) and Blackrock Run-Western Run (fourth from the left) would also fall into this type of protection priority.



BROOK TROUT FISHERY CONDITIONS OF GUNPOWDER-PATAPSCO EVALUATION OF HUC12 CURRENT, LOST AND FUTURE BROOK TROUT HABITAT

RESTORATION: UPPER SUSQUEHANNA

Within the Upper Susquehanna HUC8, where brook trout populations are currently strong, protection may still be applicable for the HUC12s with the best conditions, but to evaluate restoration priorities, identifying HUC12s with moderate to high current condition, moderate to high lost fishery, and with the lowest detrimental impacts from future climate scenarios would be appropriate. HUC12s that match those conditions within the Upper Susquehanna HUC8 would most likely be Upper Schenevus Creek (highest current fishery and moderate lost fishery, near middle of chart) and Park Creek-Susquehanna River (sixth bar from the right, relatively high current fishery, high lost fishery, and very low climate vulnerability).



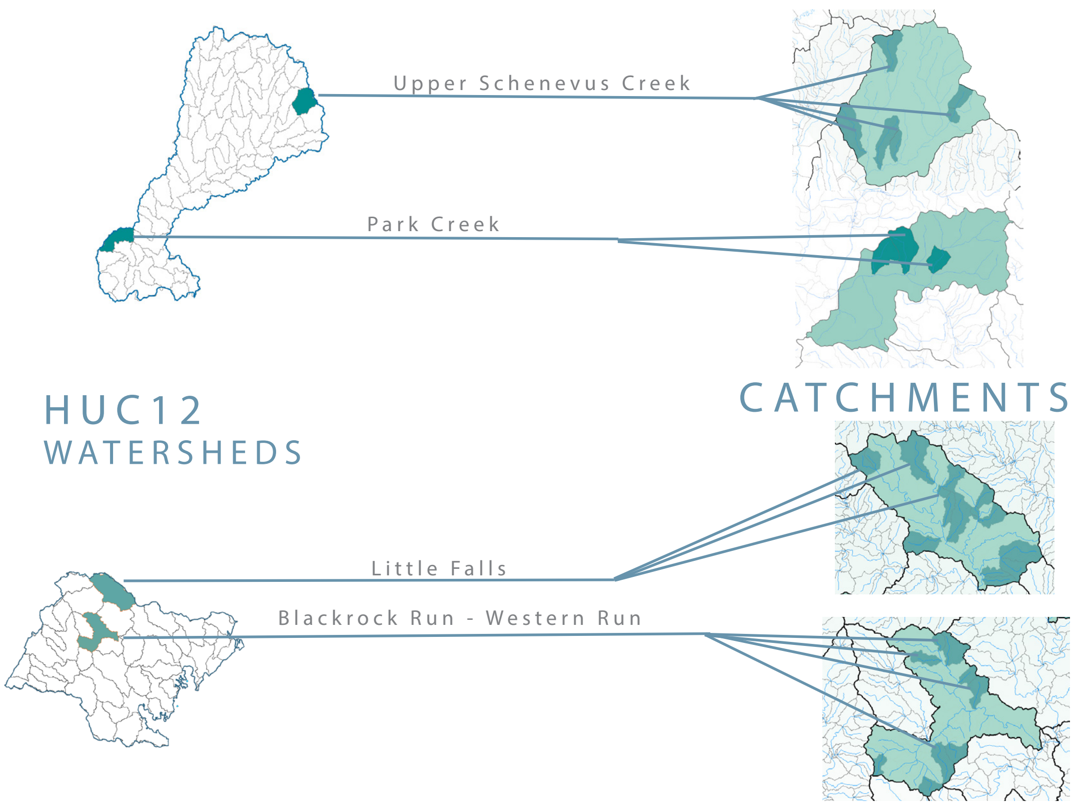
BROOK TROUT FISHERY CONDITIONS OF UPPER SUSQUEHANNA EVALUATION OF HUC12 CURRENT, LOST AND FUTURE BROOK TROUT HABITAT

CASE STUDY: BROOK TROUT PRIORITIES IN THE CHESAPEAKE BAY

HUC8 Scale | HUC12 Scale | Catchment Scale

Catchment-Scale Priority

Ultimately, all on-the-ground actions need to happen at the stream segment level. The analyses of data at the HUC8 and HUC12 can help to prioritize the best larger watershed for specific actions, but regardless of the broader priorities, catchment-level priorities are what managers will use to site specific actions. At the segment level, we can analyze several factors simultaneously to assess the most ideal stream segments for protection or restoration.



PROTECTION EXAMPLE:

For this example, we focused on the ‘Little Falls’ and ‘Blackrock Run-Western Run’ HUC12s identified on the previous page. Catchment values were queried to show only those segments with high natural quality (>0.75) and high future natural quality (>0.75). The identified catchments have high current fishery value and are anticipated be resilient to future climate scenarios. Upon further analysis, we found these catchments to be highly agricultural (approximately 35% of land area) and relatively developed (7% mean imperviousness), so protection for these areas may include ensuring proper agricultural practices continue and that runoff from impervious areas is captured before entering streams.

RESTORATION EXAMPLE:

For the two HUC12s selected as restoration priorities within the Upper Susquehanna HUC8, catchments were selected that have high natural quality (> 0.75), a current occupancy of 0.25 – 0.5, and high future natural quality score (> 0.75). This indicates segments which have high underlying potential, slightly lower occupancy rates because of stress, and high future climate resiliency. These would be streams with strong potential as brook trout habitat if restored. From further analysis, the main stressor for these 10 segments identified was agriculture, which averaged about 30% of the total land area. Likely restoration efforts for these areas may include exclusion fencing and implementation of other best agricultural practices.