New York State Riparian Opportunity Assessment

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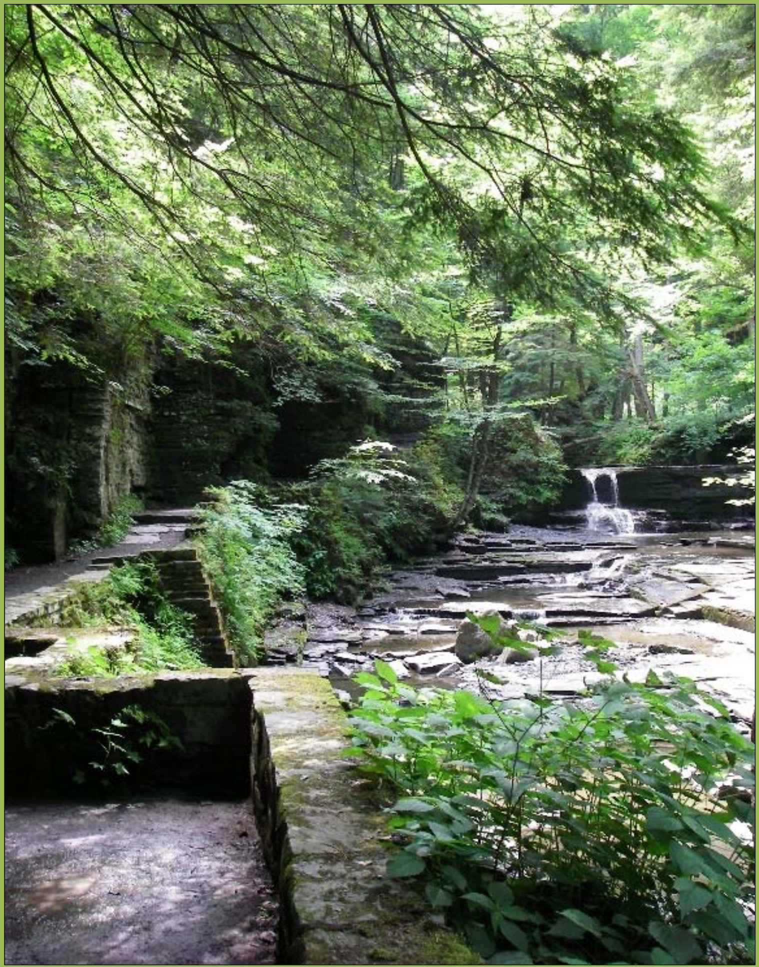

New York Natural Heritage Program

Cover photos: Top: Stewart Creek, by Erin White 2016; Bottom Left: Fillmore Glen State Park, by Erin White 2016; Bottom Right: Coxing Kill, Hudson Estuary Trees for Tribs Restoration site, by Beth Roessler 2013

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The New York Natural Heritage Program

The New York Natural Heritage Program (www.nynhp.org) is a program of the State University of New York College of Environmental Science and Forestry that is administered through a partnership between SUNY ESF and the NYS Department of Environmental Conservation. We are a sponsored program within the Research Foundation for State University of New York.

The mission of the New York Natural Heritage Program is to facilitate conservation of rare animals, rare plants, and significant New York ecosystems. We accomplish this mission by combining thorough field inventories, scientific analyses, expert interpretation, and a comprehensive database on New York's distinctive biodiversity to deliver high-quality information for natural resource planning, protection, and management.

Established in 1985, our program is staffed by 27 scientists and specialists with expertise in ecology, zoology, botany, information technology, and geographic information systems. Collectively, the scientists in our program have over 300 years of experience finding, documenting, monitoring, and providing recommendations for the protection of some of the most critical components of biodiversity in New York State. With funding from a number of state and federal agencies and private organizations, we work collaboratively with partners inside and outside New York to support stewardship of New York's rare animals, rare plants, and significant natural communities, and to reduce the threat of invasive species to native ecosystems.

In addition to tracking recorded locations, NY Natural Heritage has developed models of the areas around these locations important for conserving biodiversity, and models of the distribution of suitable habitat for rare species across New York State.

NY Natural Heritage has developed two notable online resources: Conservation Guides include the biology, identification, habitat, and management of many of New York's rare species and natural community types; and NY Nature Explorer lists species and communities in a specified area of interest.

NY Natural Heritage also houses *i*MapInvasives, an online tool for invasive species reporting and data management.

In 1990, NY Natural Heritage published *Ecological Communities of New York State*, an all-inclusive classification of natural and human-influenced communities. From 40,000-acre beech-maple mesic forests to 40-acre maritime beech forests, sea-level salt marshes to alpine meadows, our classification quickly became the primary source for natural community classification in New York and a fundamental reference for natural community classifications in the northeastern United States and southeastern Canada. This classification, which is continually updated as we gather new field data, has also been incorporated into the National Vegetation Classification.

NY Natural Heritage is an active participant in NatureServe (www.natureserve.org), the international network of biodiversity data centers. NatureServe's network of independent data centers collects and analyzes data about the plants, animals, and ecological communities of the Western Hemisphere. The programs in the NatureServe Network, known as natural heritage programs or conservation data centers, operate throughout all of the United States and Canada, and in many countries and territories of Latin America. Network programs work with NatureServe to develop biodiversity data, maintain compatible standards for data management, and provide information about rare species and natural communities that is consistent across many geographic scales.

New York Natural Heritage Program
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SUNY College of Environmental Science and Forestry
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Introduction

Project Background and Overview

The New York State Riparian Opportunity Assessment began April 1, 2016 and was completed in January of 2018. It followed a project with similar methodology within the Great Lakes watersheds of NY (the Great Lakes Basin Riparian Opportunity Assessment, April 2015-March 2016) and was designed as an expansion to include the whole state. The New York Natural Heritage Program (NYNHP) of the State University of New York College of Environmental Science and Forestry (SUNY ESF) completed this project for the New York State Department of Environmental Conservation's (NYS DEC) Division of Lands and Forests. The goal of the project was to strategically identify and prioritize sites for implementation of DEC's Trees for Tribs program (http://www.dec.ny.gov/animals/77710.html), which enlists the help of volunteers to plant native trees and shrubs in riparian buffers to improve wildlife habitat, water quality, climate resiliency, and to provide flood protection during storm events. We designed the assessment to meet this target goal as well as be flexible enough for use in the prioritization of other restoration and protection efforts. The Great Lakes assessment directly supported multiple goals and actions contained in New York's Interim Great Lakes Action Agenda (http://www.dec.ny.gov/docs/regions_pdf/glaai.pdf) including conserving and restoring native fish and wildlife biodiversity and habitats, and enhancing community resiliency and ecosystem integrity through restoration and protection. The statewide assessment provides the same capabilities throughout New York. The results also facilitate an ecosystem-based management approach to riparian restoration and protection work by promoting strategic, science-based decision-making to achieve multiple benefits. The expansion applies an adaptive management approach, identifying lessons learned from the Great Lakes assessment to develop more user-friendly tools that would better advance riparian buffer restoration efforts in New York State.

Given the variety of potential end-users, we designed the products of the assessment to offer a suite of tools, rather than a static prioritization of sites, that conservation practitioners, watershed stakeholders, local community decision makers, and others can use to inform their decisions about where to perform riparian restoration and protection work in their region. Finally, it must be stressed that site-specific knowledge is imperative and field validation is a necessary step before actual implementation of conservation actions. The statewide assessment seeks to allow users to plan for field analysis by providing online mapping tools where local roads, aerial images, and other basemaps can be viewed along with sub-watershed and catchment data.

Study Area

The project study area consisted of watersheds within the borders of New York State. We included all sub-watersheds and catchments falling within these political boundaries (Figure 1). New York State has over 70,000 miles of lotic freshwater systems (rivers and streams). By analyzing the riparian areas statewide, we created robust conservation and restoration tools to help prioritize riparian plantings to improve water quality and protect water resources for New York.

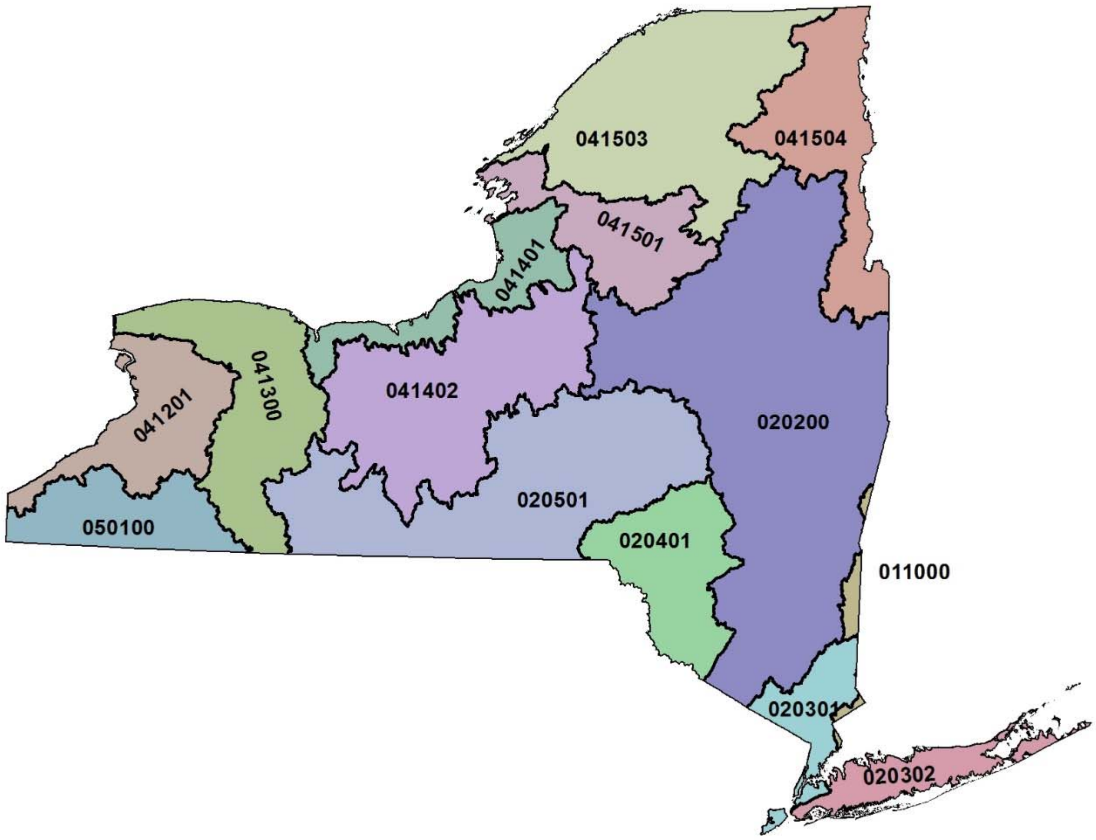

Figure 1. Project study area, using HUC 6 sub-basin boundaries. The sub-basins are labeled and indicated in different colors.

Project Steering Committee

We assembled a project steering committee to review and provide feedback on the methodology and interim results of this project. The committee was made up of NYS DEC staff as well as partner agencies and organizations with expertise in restoration and protection. All project steering committee members provided critical input at each stage of the development process. We met three times during the course of the project to review our methods and results from our sub-watershed and catchment analyses. Committee members included Sarah Walsh (formerly of NYS DEC), Jeffrey Mapes (NYS DEC Division of Lands and Forests), Shannon Dougherty, Emily Sheridan, Jennifer Dunn (NYS DEC Great Lakes Watershed Program), Beth Roessler (NYS DEC Hudson River Estuary Program and Cornell University), Tracey Tomajer, Fred Henson (NYS DEC Division of Fish and Wildlife), Lauren Townley, Karen Stainbrook, Brian Duffy (NYS DEC Division of Water), Stevie Adams, Cathy Gibson (The Nature Conservancy), Carolyn LaBarbiera, Rebecca Newell (Department of State), Scott Fickbolm, Victor DiGiacomo (NYS Department of Agriculture and Markets), Gabriella Spitzer (formerly of NYS Dept. of Ag. and Markets), Lydia Brinkley (Upper Susquehanna Coalition [USC]) and Patrick Raney (formerly of USC).

Project Details

In a landscape, the riparian zone has a large influence on water quality within, and downstream from, its adjacent streams, lakes, wetlands, and other water bodies (Brinson *et al.* 2002). Thus, maintaining or improving riparian areas to filter sediment, accumulate excess nutrients, and perform other important hydrologic, geomorphic, and biological functions is important for maintaining and improving the health of our inland water bodies. Identifying locations most important for riparian area improvements, maintenance, or protection, however, requires an understanding of the relative condition of sub-basin and riparian zones throughout an area of interest.

We completed a literature review and developed a methodology to assess the condition of areas with the input of a Steering Committee during the previous project for the Great Lakes Basin. We began working with this methodology to assemble appropriate habitat condition indicators for our analysis. We modified our analysis as needed based on Committee feedback, sometimes including new indicators or components in our analysis or reworking existing pieces.

For this assessment, we decided to work at two scales (levels), to assess both patterns of statewide variation in ecological health and stress as well as variation at the local level, suitable for prioritization within a smaller region. The first level of analysis was at the sub-watershed, or HUC 12 unit. At both scales, we include a suite of habitat indicators for relative ecological health and ecological stress within the sub-watershed (Table 1). Ecological Health indicators included brook trout locations, native fish richness, a stream invertebrate health metric called Biological Assessment Profile, rare species locations (Ecological Significance), floodplain complex locations, presence within large forested areas (Matrix Forest Blocks), presence within a functional river network, the amount of canopy cover, and the amount of natural land cover. Indicators for ecological stress included the DEC priority waterbody list for known water impairments, high runoff areas, high erosion areas, dam storage ratio, impervious surface, and the Landscape Condition Assessment metric (a synthesis layer of many other stressors, Feldmann and Howard 2013).

Table 1. Ecological Health and Ecological Stress indicators used in our assessment.

Ecological Health Indicators	Ecological Stress Indicators
Canopy Cover	Landscape Condition Assessment
Natural Cover	Impervious Surface
Matrix Forest Blocks	Erosion Index
Floodplain Complexes	Topographic Wetness Index
Functional River Networks	Known Water Impairments
Ecological Significance	Dam Storage Ratio
Presence of Brook trout	
Native Fish Richness	
Predicted Biological Assessment Profile	

We also included indicators under the categories “Resiliency to Climate Change” and “Social”. Resiliency data were obtained from the work of the Eastern North American Division of The Nature Conservancy (Anderson *et al.* 2012, 2013b). These include terrestrial resilience and three freshwater resiliency indicators (stream temperature, size, and gradient classes) designed to highlight areas with greater resilience to climate change. Social indicators are designed to highlight areas with previous community involvement in restoration, conservation, or biological science efforts. We include data from NYS DEC’s CSLAP (Citizens Statewide Lake Assessment Program), the WAVE (Water Assessments by Volunteer Evaluators) Program where citizens have collected water quality data, and the Trees for Tribs Program where citizens have restored riparian habitat in the past.

We describe all indicators in more detail in the methods section below and Appendix A. Health and Stress Indicator Scores are summaries of all individual heath indicator scores and stress indicator scores, respectively, so that practitioners can quickly grasp the sub-watersheds currently predicted as having higher or lower overall stream condition. Such a ranking does not necessarily determine the amount of action needed; however, it helps practitioners understand the likely type of action most applicable within each basin (such as restoration or protection).

The second level of the assessment was intended to help prioritize locations *within* a sub-watershed to improve or maintain the riparian zone. At this level, we used catchments – very small drainage areas feeding into each stream segment. We prioritized catchments based on the condition of indicators (Table 1) within each catchment and within its riparian zones. Again, this type of stream condition ranking will improve our understanding of the types of actions most appropriate for specific riparian areas, but does not necessarily exclude certain areas for potential future actions.

The assessment products may be launched from our project website (http://www.nynhp.org/treesfortribsny) and include two ArcGIS Online Maps (AGOL, Sub-watershed and Catchment) and our Data Explorer, an online visualization tool. Users can approach these products with a specific conservation goal in mind and utilize certain aspects of the data (e.g., one or both scales of analysis, individual indicator scores or overall summary scores, etc.), depending on their goal, to help arrive at a prioritization scheme for their work. To assist you, case studies, or scenarios, have been presented in the discussion section below to offer examples of how this dataset may be used to answer specific questions. We further suggest all users read and understand the methods below to assist you in determining how best to use our tools.

Methods

Units of Analysis

Sub-Watershed

Sub-watershed boundaries were defined according to the National Hydrography Dataset (NHD) Watershed Boundary Dataset’s HUC 12 units; each HUC 12 represented one sub-watershed. It is available, along with the high resolution (1:24,000 scale) NHDFlowline data that we used in our analysis, here: http://nhd.usgs.gov/data.html.There are 1663 sub-watersheds within New York State, averaging 60 square kilometers in size. Sub-watersheds that extended into other states were clipped to the New York state line before analysis.

Catchments

The catchment level analysis describes habitat quality at a much smaller scale than the sub-watershed features. Each sub-watershed was divided into smaller units (catchments), which were scored similarly to the sub-watersheds. These scores reflect the quality of habitat within each catchment, to aid in prioritizing work at a smaller scale. In the Great Lakes Basin Assessment (Conley *et al.* 2016), we created catchment polygons ourselves using the Arc Hydro toolset. For this statewide analysis, we used a catchment delineation prepared by SHEDS (Spatial Hydro-Ecological Decision System), the NHD high resolution delineation, version 2 (Conte-Ecology, U.S. Geological Survey 2015). SHEDS catchments are based on the National Hydrography Dataset high resolution dataset flowlines, adjusted such that streams are only initiated if they meet the minimum 0.75 square kilometer drainage area threshold. Catchments represent the drainage area contributing to an individual stream segment, the reach in between confluences, in this adjusted stream network.
(Source: http://conte-ecology.github.io/shedsGisData).

Riparian Buffer Delineation

To specifically assess the quality of habitat within the riparian zone, the boundaries of the riparian zone needed to be defined. We chose to use a variable width riparian buffer. Variable width buffers take into account surrounding hydrology and can provide a more accurate delineation of riparian habitat than the more commonly used fixed width buffers (Lee *et al.* 2004, Polyakov *et al.* 2005), although they take longer to create.

We created a riparian buffer for qualifying streams in the National Hydrography Dataset (high-resolution NHD, Figure 2). This riparian boundary was defined using the Riparian Buffer Delineation Model (Abood *et al.* 2012), an ArcGIS compatible tool that calculates the riparian boundary based on digital elevation data, a streams layer, a wetland layer, and an estimate of the 50-year flood height in the area. The 50-year flood height for each sub-watershed was estimated based on annual flow data and field measurements from gages statewide, acquired from the US Geological Survey's Surface-Water data points for the Nation, as well as additional data from the USGS Stream Stats service. For all scores and indicators described as "riparian," source data were first clipped to just those areas within the boundaries of the riparian layer. For full descriptions of methods and parameters involved in creating the riparian buffers, see Appendix B of this report and Appendix E, available on our project webpage in the left menu under "Downloads".

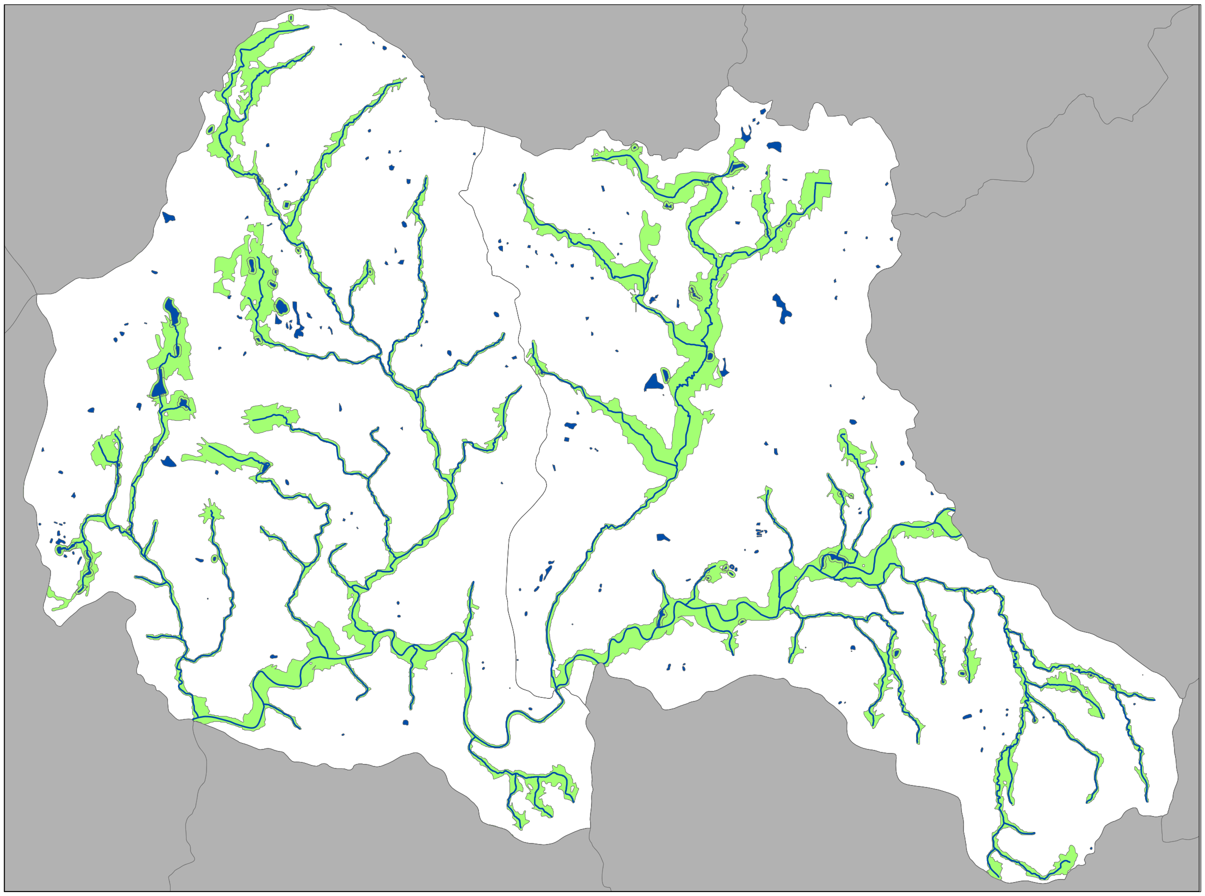

Figure 2. Example of two sub-watersheds with streams in blue and the variable width riparian buffer delineated in green.

Habitat Indicators/Ecological Health and Stress Indicators

When designing the assessment, the selection of indicator variables was focused on those aspects of habitat quality which could most directly inform the optimal placement of vegetative riparian buffers (Figure 3). We chose to present a suite of indicators in our results, to accommodate a range of conservation priorities, instead of a single score tuned for a specific purpose. Restoring riparian buffer habitat can be used to improve several aspects of stream health. For instance, a partner interested in using buffers to shade streams for trout habitat may need to focus on a different set of riparian areas than a partner interested in ameliorating the impact of upland agriculture. By creating a suite of indicators, we are able to meet the needs of multiple stakeholders who are interested in using this assessment to maintain and restore riparian areas.

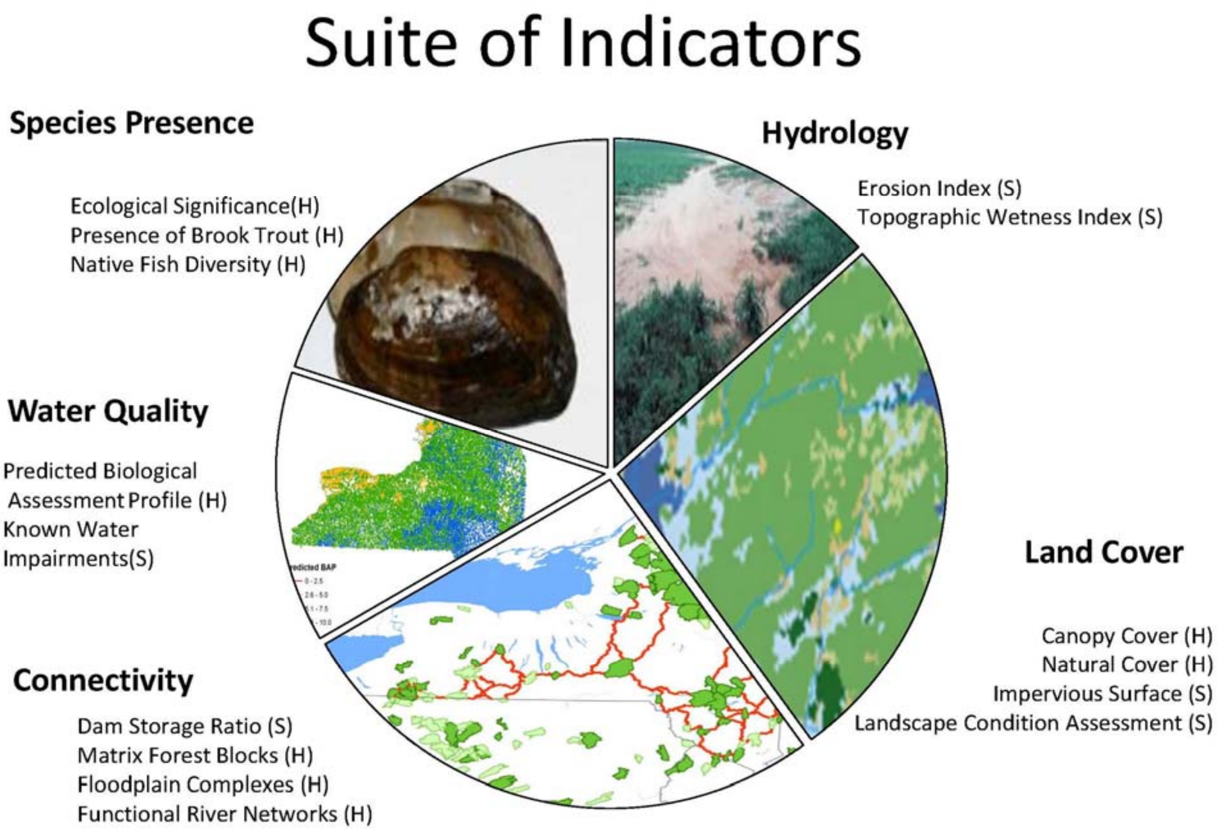

Figure 3. Set of ecological habitat indicators used in assessment. “H” indicates an ecological health indicator, “S” indicates an ecological stress indicator.

Habitat indicator scores were aggregated at the level of the sub-watershed and the catchment to create the raw score. Aggregation methods for each indicator varied slightly depending on the source data (Table 2) and complete methods are presented in Appendix A. All raw scores can also be found in the ArcGIS feature class.

Table 2. Habitat Indicators and Aggregation Methods. For each indicator (Indicator Name), the following are listed: Indicator Quality group (ES = Ecological Stress, EH = Ecological Health), where the indicator was Applied (R = at the Riparian Zone only, W= at the Watershed/Catchment wide only, B = both Watershed/Catchment wide and Riparian Zone), the Data Type of the indicator (CR = continuous raster, BR = Binary raster, PT = point values, PY = polygon, LI = line), and the Aggregation Method. For more detailed information about the development and sources for each indicator, see Appendix A.

Indicator Name	Quality	Applied	Data Type	Aggregation Method
Biological Assessment Profile	EH	R	LI	Avg. value for cells in unit
Canopy Cover	EH	B	CR	Avg. value for cells in unit
Dam Storage Ratio	ES	R	PT	Sum of values falling in unit
Eastern Brook Trout	EH	W	PY	Proportion of unit in a Brook Trout patch

Indicator Name	Quality	Applied	Data Type	Aggregation Method
Ecological Significance	EH	B	PT	Avg. value for cells in unit
Erosion Index	ES	R	CR	Avg. value for cells in unit
Floodplain Complexes	EH	B	PY	Proportion of unit area composed of Floodplain Complex
Functional River Networks	EH	R	LI	Sum of total length of functional river network in unit
Impervious Surface	ES	B	CR	Avg. value for cells in unit
Landscape Condition Assessment	ES	B	CR	Avg. value for cells in unit
Matrix Forest Blocks	EH	B	PY	Proportion of unit area composed of Forest Blocks
Native Fish Richness	EH	R	LI	Weighted average by stream length
Natural Cover	EH	B	BR	% Natural cover *
Wetness Index	ES	R	CR	Avg. value for cells in unit
WI/PWL Status	ES	R	LI	Weighted average by stream length**

* The NLCD classes included in this group are listed in Appendix A.
**Calculated as the proportion of the total stream length in the unit (sub-watershed or catchment) classified as Impaired, Threatened, or with Minor Impacts.

Scoring

The results of this analysis are presented as a set of scores for each area, which vary in specificity and focus.

Raw and Normalized Scores

Raw scores were calculated for all habitat indicators in the same manner at the sub-watershed and catchment scales. Habitat indicator scores were normalized before calculating composite values like the Ecological Health, Stress, and Comprehensive scores to account for the different scales of the individual indicator raw scores. We normalized scores using the formula:

$$Normalized\ (x) = a + \frac{(x - A)(b - a)}{B - A}$$

Where: A is the minimum raw score value, and B is the maximum raw score value.

We normalized all scores so they ranged in value from 0-1, so a=0 and b=1.

So for all raw scores, x, the new value = $Normalized(x) = \frac{x - minimum\ Raw\ Score}{Raw\ score\ range}$

This method does not change the distribution of scores, only scales them so that they have the same maximum and minimum. All normalized scores ranged from 0-1. Normalized scores are principally used in the calculation of other scores that require combining multiple indicators, like the Comprehensive Score or the Ecological Stress score.

At the sub-watershed scale, raw score values were normalized relative to the scores of all other sub-watersheds in New York State. Sub-watersheds with similar scores represent similar conditions. Two sub-watersheds that both have a Comprehensive score of 0.9, for example, both represent high quality habitat.

Catchments were scored using the same methodology as the sub-watershed analysis. However, because the goal of this level is to rank locations within each sub-watershed, the final scoring step for catchments was slightly different than for sub-watersheds. Whereas sub-watersheds were ranked across the entire state, with a Comprehensive Score of "1" representing the highest quality to be found in New York, **catchments were ranked relative *only to the scores of other catchments in the same sub-watershed***. A catchment with the lowest Comprehensive score in a very healthy sub-watershed may, in fact, represent overall better quality habitat than the catchment with the highest Comprehensive score in a sub-watershed with high ecological stress.

Displaying/Accessing Scores:

Sub-watersheds are visualized per their raw scores for all indicators in the online map. Clicking on a sub-watershed reveals a pop-up window that displays the raw score, along with the statewide minimum and maximum values for the score. The range of a score can also be viewed by looking at the map legend. In the case of Composite Scores, (see below) the normalized values for all indicators used in calculating the composite score can be quickly reviewed by scrolling down to see the pie chart inside the pop-up window. Catchments are visualized per their percentile scores in the online map. Clicking on a catchment reveals a pop-up menu that displays the raw score, the statewide minimum and maximum values of that indicator, and in which percentile of the sub-watershed the catchment score falls. The pie charts displaying normalized scores for any components in a composite score (see below) are also available on the catchment map. The online Data Explorer displays scores at the sub-watershed and catchment level in both plots and maps. Normalized scores are used in the plots at both scales, and the sub-watershed map also displays normalized scores, while the catchment map displays percentile scores. (Raw, normalized, and percentile scores for all indicators are available in the ArcGIS geodatabase, where a user could recalculate metrics based on a different methodology, if desired).

Composite Scores: Ecological Health, Ecological Stress, and Comprehensive Score

To calculate the Ecological Health score, we added together the normalized scores for all Ecological Health indicators. Likewise, to calculate the Ecological Stress score, we added together the normalized scores for all Ecological Stress indicators. The Comprehensive score was calculated as the difference between the Ecological Health and Ecological Stress scores. It had a potential minimum of -1 and a potential maximum value of 1. This was normalized to also range from 0-1 for easier plotting on the online Data Explorer.

The Comprehensive score describes the results at the most general level; it considers the contributions of every habitat indicator (remember, it does not include resiliency or social indicators) and allows for fast and simple identification of the best and worst habitats. Sub-watersheds and catchments with high comprehensive scores (closer to 1) represent habitats with low levels of ecological stress and several positive indicators of ecological health. Areas with low comprehensive scores (closer to -1) represent habitat with poor health and high stress. When opening the AGOL sub-watershed or catchment maps, the map will automatically default to displaying the comprehensive scores, showing lower comprehensive scores in red and higher comprehensive scores in blue.

Indicator Scores

The most specific scores provided are the indicator scores, one for each habitat and resilience indicator (described in the section above). Looking at an individual indicator score by selecting the desired indicator in the content section of the AGOL maps, can help answer very specific questions, i.e. “Where is there low canopy cover in the riparian zone?”. For details on how raw scores were aggregated, see Table 2.

Resiliency to Climate Change Indicators

We also included indicators in our analysis designed to highlight areas with greater resilience to climate change, using data obtained from the Eastern North American Division of The Nature Conservancy (Anderson *et al.* 2012, 2013b). These include terrestrial resilience and three freshwater resiliency indicators (stream temperature, size, and gradient classes). Full details on these indicators can be found in Appendix A. The resilience to climate change indicators were **not included** in the calculation of Ecological Health, Ecological Stress, or Comprehensive Score.

Resilience Score

The resiliency indicators were combined into an overall Resilience Score using the same procedure described under the “Scoring” section for habitat indicators above. All individual resiliency scores were normalized on the same 0-1 scale. Terrestrial indicators (terrestrial resilience and terrestrial resilience in the riparian zone) were summed and divided by two and freshwater indicators (stream temperature classes, stream size classes, and gradient classes) were summed and divided by three. The means for Freshwater and Terrestrial resilience were then summed and normalized. Again, sub-watersheds were ranked across the entire state, with a “1” representing the highest quality to be found in the state, while catchments scores were ranked relative *only to the scores of other catchments in the same sub-watershed.*

Social Involvement Indicators

Social indicators are designed to highlight areas with previous community involvement in restoration, conservation, or biological science efforts, which may have higher potential for successful collaborations in the future with local citizens. We include data from CSLAP (Citizens Statewide Lake Assessment Program), the WAVE (Water Assessments by Volunteer Evaluators) Program where citizens have collected water quality data for the NYS DEC, and the Trees for Tribs Program where citizens have restored riparian habitat in the past. Because the level of social involvement in an area may reflect a number of factors, some of which are unrelated to habitat condition, the social involvement indicators were **not included** in the calculation of the Ecological Health, Ecological Stress, or Comprehensive Score, but provided separately.

Community Involvement Score

Individual social involvement indicators were aggregated into an overall Community Involvement Score by summing all individual social scores. This is a quick way to see if an area (sub-watershed or catchment) has had community involvement in the past through one or more of the aforementioned groups. Due to the sparse nature of the data set, Community Involvement Scores are presented in all online maps in their raw scores.

Filters

At the catchment scale, we also wanted to provide a simple screening method to allow users to quickly identify areas which meet specific criteria. These filters aren't like other scores in that they are not stress or health indicators nor do they reflect habitat quality. They are simply used to identify if a catchment qualifies as urban, agricultural, or public land, information which can be fundamental to assess qualification for some conservation projects.

Urban Areas Filter: We classified catchments as "in Urban Areas" if they intersected with Urbanized Area Polygons or Urban Clusters as defined by the 2010 Census (available from https://www.census.gov/geo/maps-data/. Any catchment which intersected an urban area or urban cluster polygon will still appear when this filter is selected. In the attribute table they are given a value of "1". All other catchments appear in grey in the AGOL map and have an attribute table value of "0".

Agricultural Areas Filter: Catchments were classified in Agricultural Areas if their riparian zone was composed of more than 25% agricultural land use (Pasture/Hay [NLCD type 81] or Cultivated Crops [type 82]) according to the National Land Cover Dataset (NLCD, U.S. Geological Survey 2011).

Public Lands Filter: We classified catchments as Public Land if they intersected areas designated as such in the NYPAD (New York Protected Areas Database) layer (March 2017 version).

Themes – Catchment Scale Only

At the catchment scale of analysis, several scores were developed that addressed specific questions of conservation interest. Some of these "theme" scores were combinations of sub-sets of our existing indicators, while a few required the input of additional data. The purpose of the theme scores is to provide information that is more comprehensive than that available from any single habitat indicator and more specific than the Comprehensive score. Details on the formulas and precise weighting schemes involved in all score calculations can be found in Appendix A.

Water Quality

The focus of the Water Quality Theme was to highlight locations where riparian protection or restoration activities could support water quality by using metrics both within the stream buffer and the stream catchment. Indicators used include impervious surface, Landscape Condition Assessment (LCA), natural cover (see Appendix A for classes included), wetness index, erosion index, predicted Biodiversity Assessment Profile (BAP), known water impairments (PWL), canopy cover, and matrix forest blocks. All were weighted heavily except for canopy cover and matrix forest blocks, which were weighted lightly.

Connectivity

The purpose of the connectivity theme is to identify gaps in forest cover along streams where planting trees could increase connectivity. We provide this theme with the caveat that any restoration efforts with the primary goal of improving connectivity or identifying critical gaps would benefit highly from further analyses of forest fragmentation and this type of analysis was outside the scope of this project. What we provide here is an indirect indicator of low scoring riparian areas within sub-watersheds with existing good riparian connectivity; possibly locations where restoring the riparian zone of low scoring catchments may eliminate gaps hindering connectivity.

Stream Temperature

The purpose of the Stream Temperature theme is to help identify areas where stream temperature might be decreased by planting trees in the riparian zone. Increasing the canopy cover along streams would make the habitat more suitable for cold-water fish and improve connectivity among already forested, cold-water segments. We used all ecological health and stress indicators within the riparian buffers of streams, and weighted brook trout, BAP, functional river networks, floodplain complexes, matrix forest blocks, natural area, and canopy cover more heavily than all other indicators.

Runoff Risk

The purpose of the Runoff Risk theme is to identify areas with potential erosion hotspots that occur on land-use classes with soils likely to contribute to excessive runoff that may be addressed by riparian buffers. We used the erosion index indicator and overlaid this with specific land cover classes from both the 2011 NLCD and the CropScape dataset (USDA National Agricultural Statistics Service 2014) to determine areas with non-natural or agricultural cover with high erosion potential that could benefit from planting. For more details on the specific categories used from these datasets, see Table 3 below and Appendix A.

Table 3. CropScape cover types used in the Runoff Risk Theme.

Alfalfa	Millet	Speltz	Dbl Crop Barley/Corn
Asparagus	Mustard	Spring Wheat	Dbl Crop Barley/Soybeans
Barley	Oats	Squash	Dbl Crop Corn/Soybeans
Broccoli	Onions	Strawberries	Dbl Crop Oats/Corn
Buckwheat	Other Crops	Sugarbeets	Dbl Crop Soybeans/Oats
Cabbage	Peas	Sunflower	Dbl Crop WinWht/Corn
Carrots	Peppers	Sweet Corn	Dbl Crop WinWht/Soybeans
Cauliflower	Potatoes	Tomatoes	Fallow/Idle Cropland
Corn	Pumpkins	Triticale	Misc Vegs & Fruits
Cucumbers	Radishes	Turnips	Other Hay/Non Alfalfa
Dry Beans	Rye	Vetch	Pop or Orn Corn
Flaxseed	Sorghum	Watermelons	
Herbs	Soybeans	Winter Wheat	

Wetland Resiliency

The purpose of the Wetland Resiliency theme is to identify those areas along streams with greater flood capacity due to the presence of intact wetland habitat. We compared the riparian buffers to the National Wetlands Inventory (NWI) dataset and estimated the relative contribution of wetlands to the area of buffer. The least resilient basins would be those with fewer wetlands in the riparian zone. Conversely, the most resilient basins would be those with the highest proportion of wetlands in the stream corridor.

Prioritization

The products of the assessment allow for several approaches to prioritizing restoration and preservation activities.

Prioritizing by a single score

Locations can be ranked according to their Comprehensive score, or the score of any indicator of interest. Those locations with the lowest comprehensive score, or high score for an ecological stress indicator, represent areas that may benefit the most from restoration activities. Locations with the highest comprehensive score, or the highest scores for ecological health indicators, will represent locations that may benefit from protection to conserve existing habitat of high quality.

Prioritizing by multiple scores

Using plots is one method for prioritization based on multiple criteria (Norton *et al.* 2009), which provides more information than comparing the ranks of a single indicator of interest (Figure 4). This method provides a different kind of assessment from prioritizing using the composite index, which incorporates all indicators. Plotting two indices against each other, like Ecological Health and Ecological Stress, allows for the distinction between watersheds with good health and low stress (pristine), poor health and high stress (high need for restoration, although potentially low chance of success); and the intermediate classes of good health and high stress (good habitat at high risk) and poor health and low risk (moderately valuable habitat). This is especially useful for prioritizing areas of overall moderate habitat quality that can be overlooked in single factor ranking schemes. To enable this type of prioritization, a Data Explorer was developed.

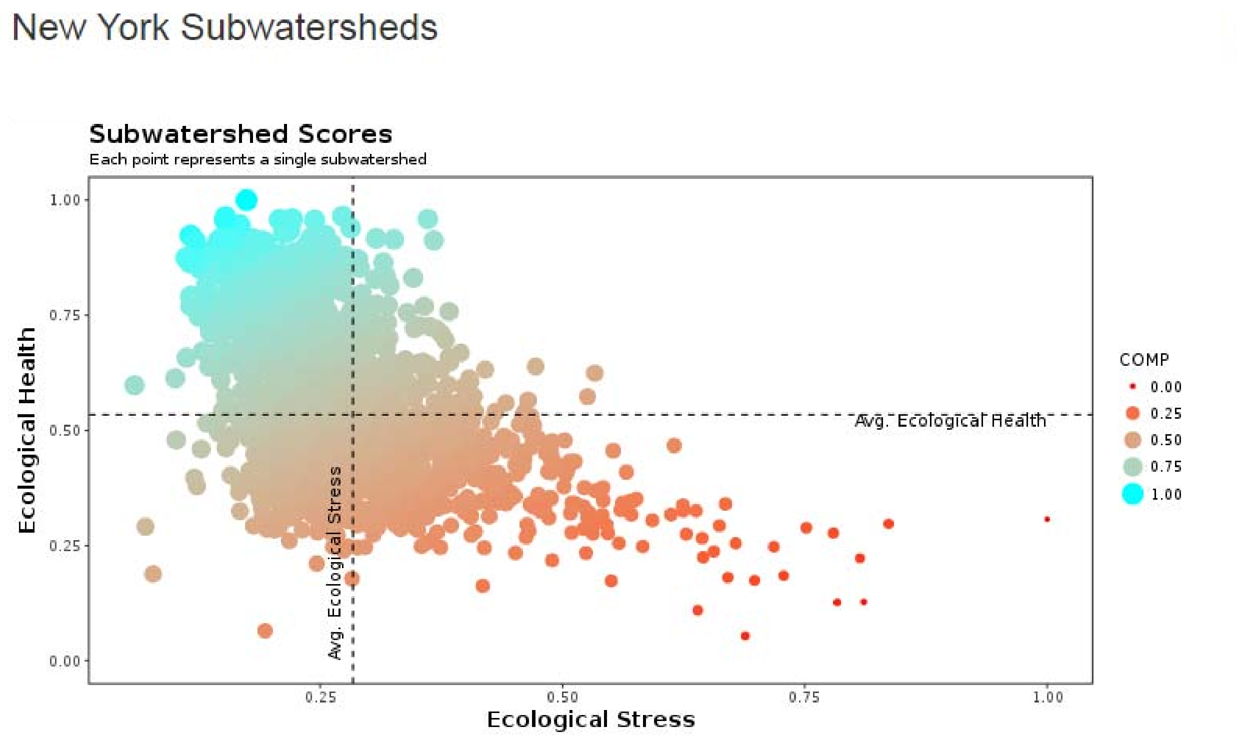

Figure 4. An example of comparing multiple criteria through visualization in a plot. The Ecological Stress and Ecological Health scores are compared on the X and Y axes, while the Comprehensive score is displayed via dot color and size.

Results

Our products are all available on the project website (http://www.nynhp.org/treesfortribsny), where there are links to the AGOL maps and our online Data Explorer.

ArcGIS Online (AGOL) Maps

We provide our results as two interactive AGOL maps, one providing results at the sub-watershed or HUC 12 scale, and one at the catchment scale. A description of these two maps is below.

Sub-watersheds

Our analysis completed at the sub-watershed scale is available by following the ArcGIS Online Sub-watershed Map link in the "Products" section of the left menu on our website. The overall ranking of each sub-watershed within New York is provided in the Comprehensive Score, which is the default upon opening the map. This map includes 12 different optional base layers such as aerial imagery, topography, and street names, to allow users compare the scores with aerial displays, and use features like roads to aid in ground-truthing the data. We have also included a reference layer from the US Geological Survey displaying the boundaries of HUC units from HUC2 (Regions) through HUC10 (Watersheds) that will be displayed as the user zooms in on the map. This can aid in comparing these results with NYS watershed assessment information or for use in watershed management planning. Each individual indicator, composite score, or filter used in the analysis is included in the map as a layer that can be turned on and off. The Composite Score layers (Comprehensive Score, Health Score, Stress Score, Resilience Score, and Community Involvement Score) are listed below the Filters in the "Contents" tab to the left of the map view. Each Ecological Health indicator is preceded by an "H" in the layer name, then a number, so they can be displayed together in the "Contents". Likewise, Ecological Stress indicators are preceded by an "S" and a number, resiliency layers are preceded by an "R". Details on ranking descriptions, calculations for our metrics, and justifications for each metric's inclusion are found in Appendix A. A user orientation guide for the AGOL maps can be found in Appendix C.

Catchments

The catchment-level analysis is available by following the ArcGIS Online Catchment Map link in the "Products" section of the left menu on our website. Again, base layers are available in the Catchment Map along with the Sub-watershed (HUC 12) boundaries. Filter layers for urban and agricultural areas as well as public lands are available for the fine-scale analysis, to identify and prioritize opportunities for collaboration and overlap with other restoration or protection efforts. When a filter layer is selected, all catchments that do not qualify will be turned gray. You can then turn on any score layer, and you will only see the values of catchments which meet the criteria described for that filter.

As in the Catchment Map, the Composite Score layers (Comprehensive Score, Health Score, Stress Score, Resilience Score, and Community Involvement Score) are listed below the Filters in the "Contents" tab to the left of the map view. Themes (water quality, connectivity, stream temperature, wetland resiliency, and runoff risk) are also available as separate layers in this fine scale analysis map and are found beneath the composite scores in the "Contents". Each Ecological Health indicator is preceded by an "H" in the layer name, then a number, so they can be displayed together in the "Contents". Likewise, Ecological Stress indicators are preceded by an "S" and a number, resiliency layers are preceded by an "R". **Remember that catchments are ranked only relative to other catchments *within the same sub-watershed*. Therefore, catchments that appear the same color but fall in different sub-watersheds may have very different raw scores**. The color of a catchment on the map represents its percentile score, its rank relative to the scores of the other catchments in the sub-watershed. Clicking on a catchment (with layers of interest turned on) will reveal a pop-up window that displays both the raw scores and the percentile score for a given indicator. It is important to remember that all sub-watersheds will have high quality (blue) catchments and lower quality (red) catchments, regardless of how pristine the habitat may be overall. The scores are meant to allow users to compare catchment scores relative to others *within the same area* and do not represent absolute values. Details on ranking descriptions, calculations for our metrics, and justifications for each metric's inclusion are found in the indicator table in Appendix A of this document. A user orientation guide for the AGOL maps can be found in Appendix C.

ArcGIS Geodatabase

For users with access to GIS software, the results of our analysis are also available as ArcGIS feature classes. A file geodatabase containing two feature classes, one for the sub-watershed level results, and one for the catchment level results, is available on our website in the "Downloads" section of the left menu.

Sub-Watersheds

The sub-watershed feature class ("Subwatershed_Scores") contains polygons for all sub-watersheds in New York State. The attribute table contains scores for all indicators used in the analysis, both raw scores (field name is the indicator code, see Appendix A for codes) and normalized scores (an "N" in front of the indicator code in the field name), as well as the Ecological Health, Ecological Stress, Comprehensive, Resiliency, and Community Involvement Scores.

Catchments

The catchment feature class ("Catchment_Scores") contains the catchment polygons and their associated scores. It contains the raw scores, normalized scores, and percentile scores (a "P" before the indicator code in the field name) for each catchment. Percentile scores were used for display purposes and should not be used in further calculations.

Data Explorer

It is very important that users have the opportunity to explore patterns in the wide array of data developed through this project. To maximize the effectiveness of data exploration and make it as accessible as possible, we combined plot prioritization and mapping into a tool which gives users the ability to interact with and visualize the assessment results using only a web browser. In our experience, it works best using the Firefox browser and Internet Explorer should be avoided. The Data Explorer, available from our website and left "Products" menu, is also found online at http://lab.nynhp.org/trees_tribs_ny/data_explorer, allows users to prioritize sub-watersheds and catchments using multiple indicators, visualize those locations, and interact with a sortable data table to explore the full set of scores from the analysis (Figure 5). The application is based on the same data that is available in the attribute table attached to the ArcGIS feature class, but allows for visualization and prioritization to take place in a way that isn't possible using ArcGIS alone. A general orientation to the tool is below, but we urge you to review the detailed user guide to the Data Explorer, available in Appendix D.

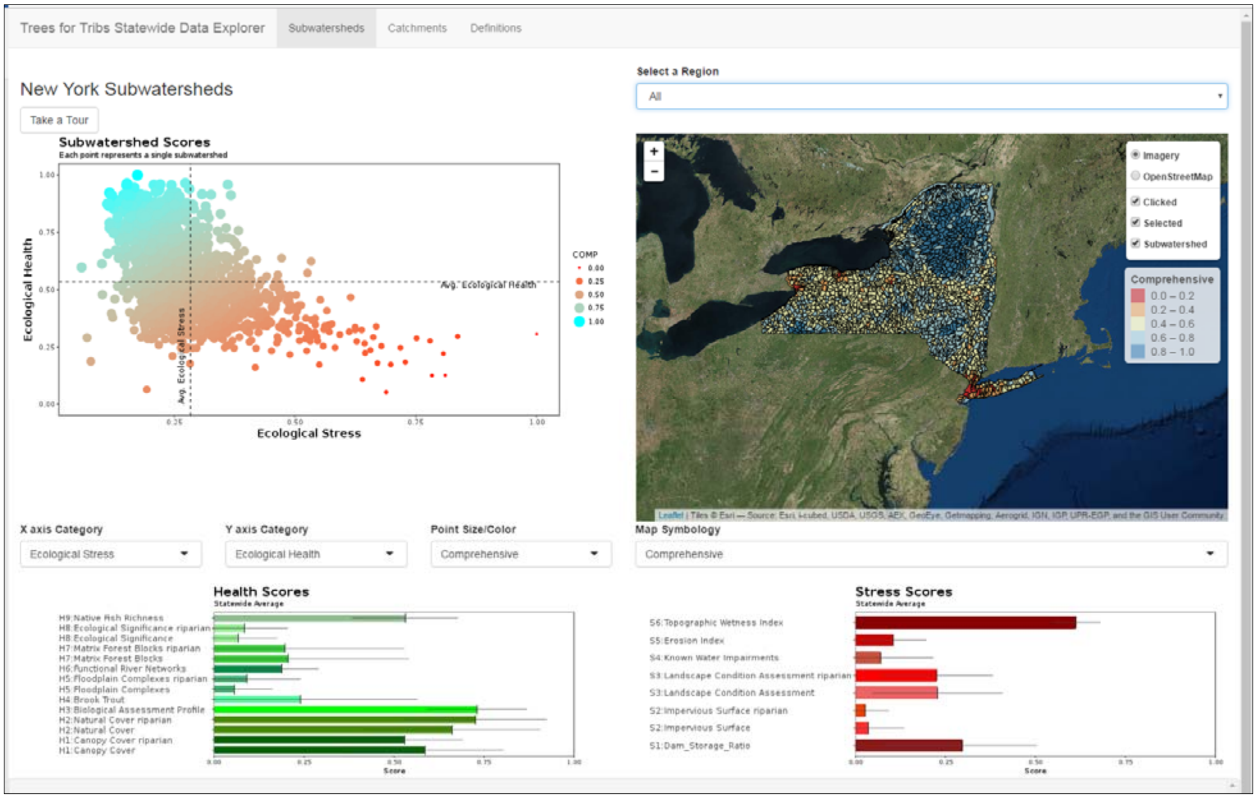

Figure 5. Trees for Tribs Statewide Data Explorer. Initial view upon opening. Vertical lines in the graph on the left represent the mean value for the Ecological Stress score among all 1663 sub-watersheds. The horizontal line represents the mean Ecological Health score. An online map is pictured top right above. A dashboard is displayed at the bottom of the sub-watershed map showing bar plots of the health and stress indicator scores.

Prioritizing with Two Indicators:

The Data Explorer allows users to plot the scores for all sub-watersheds, using any indicator for the X and Y axis. The choice of indicators is available in drop down menus. The default setting upon start-up will allow the user to compare the overall Ecological Health and Ecological Stress scores (Figure 5). Users can also select a region of the state from the drop down menu and see plotted scores in watersheds for a region of interest. The vertical and horizontal lines in the plot indicate the mean value for the X and Y axis variables, respectively. They divide the plot into quadrants, which allows you to focus on different sets of points based on your conservation goals. If your project is more targeted towards preserving habitat that is currently in great shape, you might examine the watersheds represented by the points in the upper left of the graph: these are areas that have high scores for health and low scores for stress. Points that fall in the lower right of the graph are the most stressed watersheds with the lowest scores for ecological health. These points represent habitats in dire need of restoration work. However, because they are likely experiencing multiple stressors, restoring them could be a significant challenge; one that riparian buffers alone may not address. Points in the lower left quadrant represent sub-watersheds experiencing less stress, but scoring poorly for ecological health. Riparian restoration projects focused on sub-watersheds in this portion of the chart could be aimed at improving the below-average Ecological Health scores by planting native trees and plants in the riparian zone.

In any quadrant, sub-watersheds represented by points falling towards the middle of the graph, where the axes cross, score about average. While restoration may not be as urgent as in the extremes of the chart, these may be sounder investments because they face relatively fewer challenges. The ability to distinguish between the different classes of the vast numbers of watersheds “in the middle” is one advantage of using the Data Explorer over a single indicator prioritization method, like the AGOL maps, or sorting through the attribute table in the geodatabase.

Figure 6. Data Explorer with default X and Y axis, with point size (Z axis) proportional to the presence of Brook Trout.

Prioritization Using Three Indicators:

The user can also select a third indicator, the Z axis, which will change the size of the points. Using the default X and Y axis and selecting an indicator from the Z axis allows you to quickly prioritize locations based on their overall health, as described above, while allowing you to quickly see locations that may be closely related to your area of interest (in this example, improving habitat for Brook Trout, Figure 6). In addition, one may focus on a single region (HUC6) of the state on the map by using the “Select a Region” drop down above the map. Selecting a Region from the menu generally makes the Data Explorer run more quickly.

Discussion

We designed our project to provide an objective, science-based site selection procedure for protection and restoration activities. Using our products for strategic planning for programs, such as the Trees for Tribs (Goal 5.10 in the Agenda below), will help ensure the success of such programs by targeting activities where they are most needed or have the best chance of success.

In addition, we envision our products furthering several goals of New York's Interim Great Lakes Basin Action Agenda and Hudson River Estuary Action Agenda. More specifically, these products could be used to help identify priority areas for riparian buffer restoration and protection in the Great Lakes Basin (goals 2.8, 5.8, 8.2), areas for improving stream corridor connectivity (if improving canopy cover is a goal for targets identified, goal 5.6), and places to expand green infrastructure in flood-prone areas (goal 7.11). These products could also be used to further Benefit 2, Target 2 in the Hudson River Basin, calling for the prioritization of streamside areas in greatest need of protection and restoration.

We envision that in pairing this information with the field reconnaissance of priority sites, and utilizing state and federal restoration guidance and best management practices (such as those found here: http://www.dec.ny.gov/chemical/106345.html) to develop and implement projects will help advance efficient and effective riparian restoration and protection projects in areas of greatest need throughout the state. We believe the tool can also be used in applying to funding programs such as DEC's Water Quality Improvement Project, Natural Resource Conservation Service, and NYS Department of Agriculture and Markets non-point source grants to provide science-based criteria for project site selections. The information can also be used in the development of watershed management plans to complement and possibly corroborate watershed modeling and/or monitoring data.

Undoubtedly, users will approach our dataset with specific goals in mind and may only utilize certain aspects of the data, depending on their goal, to help arrive at a prioritization scheme for their work. It is important to keep in mind that depending on a user's goal or question, other datasets and spatial data layers may be necessary to identify priority areas. Therefore, we do not intend our dataset as a stand-alone product, but rather another suite of tools that can be helpful when making conservation decisions. To assist users, below we present specific examples or case studies, to demonstrate how our dataset can be used to answer specific questions and to support site prioritization in riparian zones.

Data Uses

While all the products from this project are available in GIS format, these examples are targeted towards non-GIS users and thus utilize the AGOL maps and Data Explorer. All of these examples could also be applied using the GIS data in a GIS environment.

It is important to emphasize that in all scenarios and all uses of these products that any areas targeted must be checked with field visits to verify their condition and suitability for management actions.

Scenario 1. Improve riparian zone condition to promote higher stream water quality in the Eastern Lake Erie Basin.

You have the goal of improving the water quality of a stream in the Eastern Lake Erie Basin of New York State. Your funding would allow you to complete restoration work on both public lands as well as agricultural lands (with owner permission).

Step 1.1. Assess condition of sub-watersheds

Since you already have a region of interest, rather than seeking a statewide perspective, you begin by navigating to the Data Explorer (https://lab.nynhp.org/trees_tribs_ny/data_explorer/) and select "Eastern Lake Erie" from the drop down on the right of the screen within the Sub-watershed tab. You refer to Appendix D for help with using this website. You keep the default settings on the bubble plot to display Ecological Stress on the x axis, Ecological Health on the y axis and the Comprehensive Scores on the plot itself (selected in the point size/color and map symbology drop downs). Remember, the Comprehensive Score is a composite score that incorporates both the health and stressor habitat indicators calculated for each sub-watershed, and is described in more detail in the methods and results sections of this report above, as well as Appendix A (Figure 7).

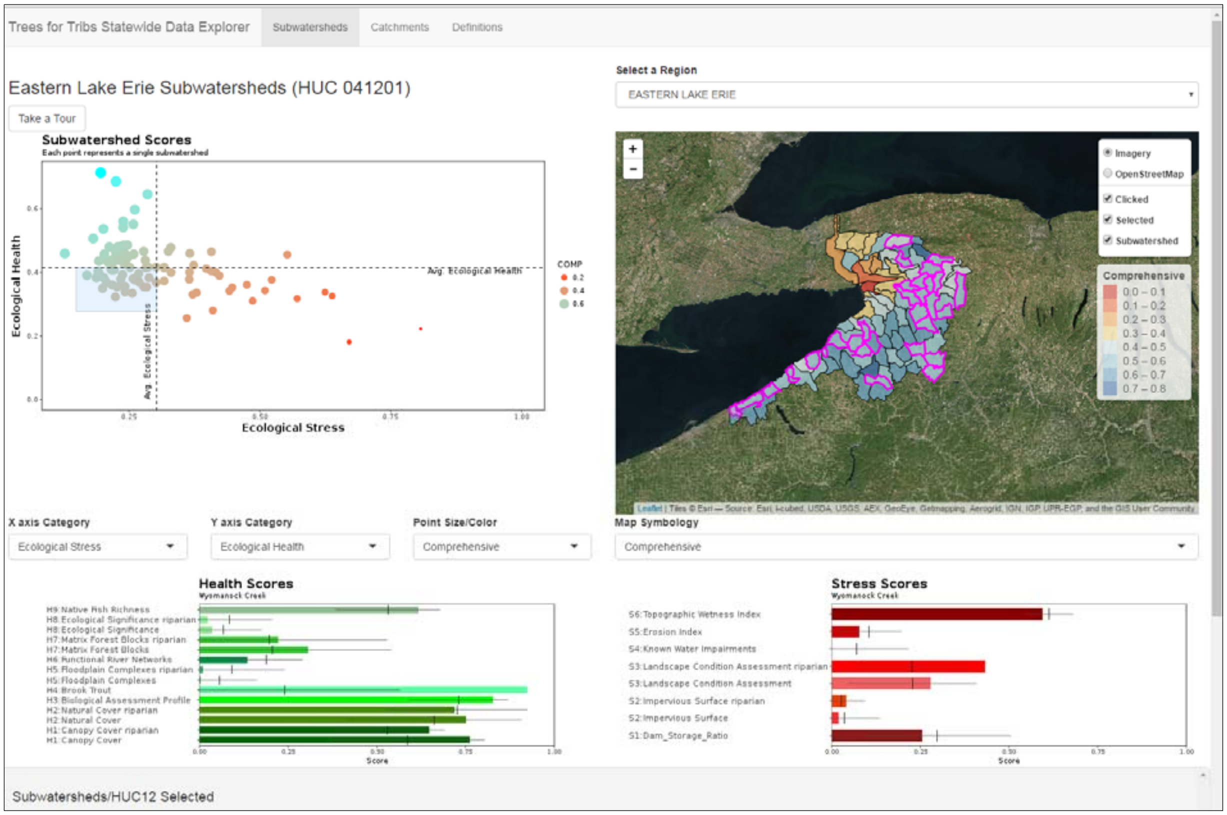

Figure 7. Data Explorer with Eastern Lake Erie region selected and the default X, Y, and Z axes. The points in the lower left quadrant are selected and reflect those sub-watersheds with lower than average Ecological Health scores as well as lower than average Ecological Stress scores.

Step 1.2. Select sub-watersheds with health and stress scores that are lower than average

You select the sub-watersheds in the lower left quadrant of the bubble plot by clicking on the plot and dragging our mouse. These dots will now have a light blue box around them in the bubble plot and will be selected in pink on the map (Figure 7). These sub-watersheds may have lower than average health scores (based on habitat indicators used in our analysis) and therefore could use conservation attention to improve condition, but they also have lower than average stress scores (less stressors than the lower right quadrant) and could therefore be good targets for riparian restoration work. For example, a site receiving a relatively low stress score, and a relatively low health score, may be easier to restore and maintain than a site with a low health score, but with a higher stress score (although such a site may arguably be in greater need of restoration work). Streams with higher stress scores might need larger scale restoration to address those stressors and riparian buffer restoration alone might not be as effective or achieve the desired results.

Step 1.3. Change map symbology to assess riparian canopy cover

You can select riparian canopy cover in the Map Symbology drop-down to quickly glean which of the selected sub-watersheds may also have streams with less forested riparian buffers (Figure 8). The map now displays the proportion of canopy cover in the riparian zone with lighter green having less forested streams in the riparian zone, and darker green with greater cover. To see the selected sub-watersheds, turn the "selected" display off and on again in the map legend and this will return the pink highlighted areas to view.

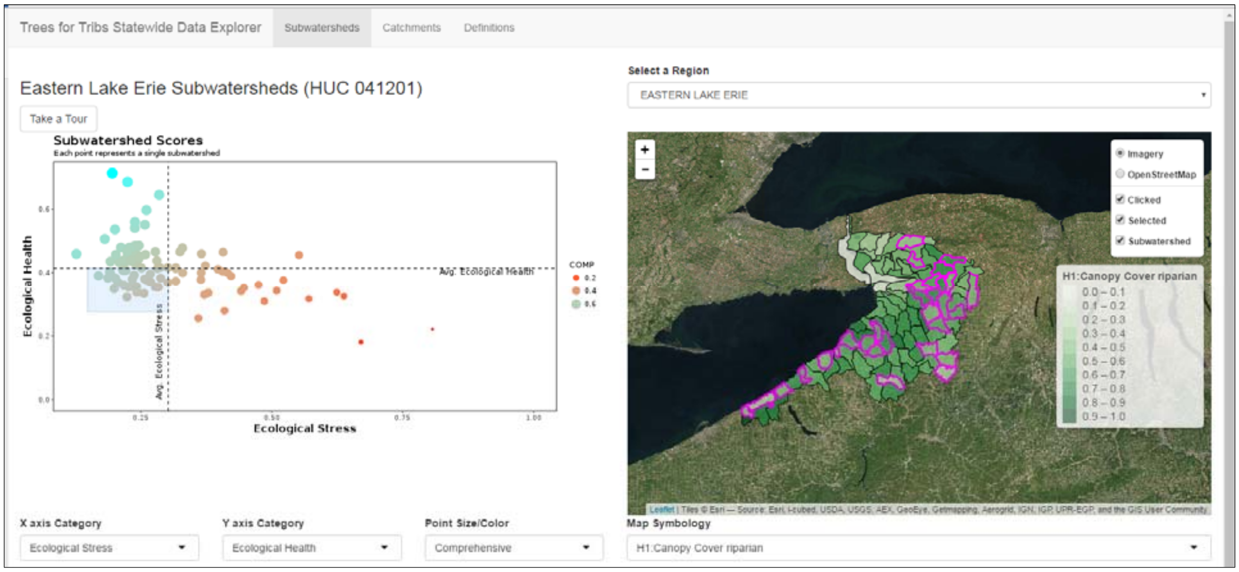

Figure 8. Data Explorer with Eastern Lake Erie region selected and the default X, Y, and Z axes. The points in the lower left quadrant are selected and reflect those sub-watersheds with lower than average Ecological Health scores as well as lower than average Ecological Stress scores. Riparian canopy cover is selected under the Map Symbology drop down and displayed on the map.

Step 1.4. Select individual sub-watersheds of interest and see reported health and stress scores as they compare to the average

You select a single sub-watershed (one that is pink-selected) in the map with lower canopy cover in the riparian zone, and it becomes outlined in black on the map (and its corresponding dot is outlined in black on the bubble plot; Figure 9). After it is selected, the dashboard scores for health and stress change to reflect the selected sub-watershed. Rather than examining each indicator in the AGOL sub-watershed map, the bar plots show us how scores for each indicator in this sub-watershed compare with the statewide average, displayed as a small vertical line on the dashboard plots. You can click several sub-watersheds, one at a time, and see how their scores compare with the statewide average. Figure 9 shows a single selected sub-watershed's dashboard scores, Beeman Creek Sub-watershed. You see on the health score dashboard that the Beeman Creek sub-watershed has higher than average Ecological Significance (as the green shaded area extends to the right of the vertical black line on the dashboard plot for this indicator), signifying either high presence of rare species and natural communities and/or presence of habitat suitable for rare species. However, the predicted BAP water quality score is lower than average and non-point source known water impairments are higher than average. You notice that riparian canopy cover is also lower than average for this sub-watershed. You can repeat this process for various sub-watersheds. The spatial assessment identified Beeman Creek as a strong candidate for riparian buffer restoration in an area with low canopy cover to improve water quality. Let's say you choose to work in this sub-watershed after examining others in the Eastern Lake Erie Basin.

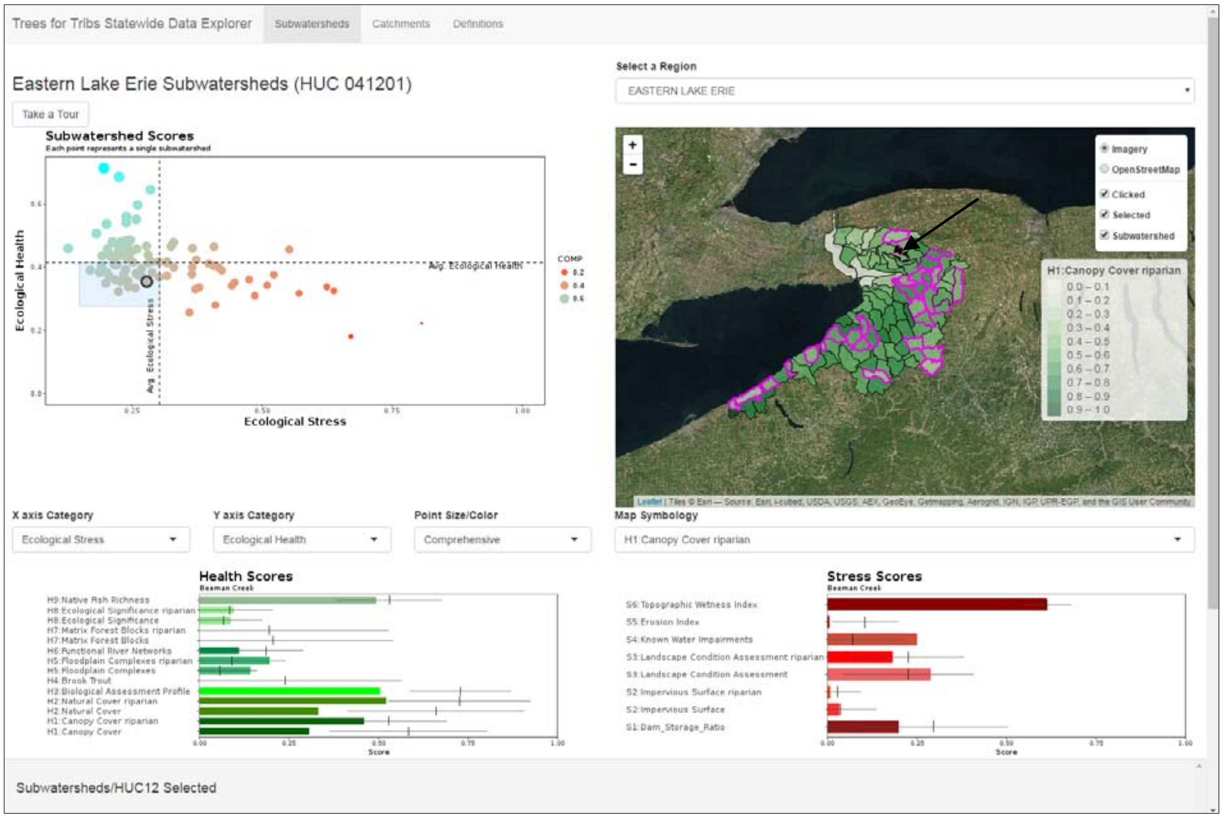

Figure 9. Data Explorer with Eastern Lake Erie region selected and the default X, Y, and Z axes. The points in the lower left quadrant are selected and reflect those sub-watersheds with lower than average Ecological Health scores as well as lower than average Ecological Stress scores. Riparian canopy cover is selected under the Map Symbology drop down and displayed on the map. The Beeman Creek sub-watershed is selected (arrow points to it) and scores are displayed on the dashboards at the bottom.

Step 1.5. Compare relative rankings of catchments

Once a sub-watershed has been chosen for further examination, the next step is to look at how scoring changes within a single sub-watershed. With Beeman Creek Sub-watershed still selected, you click on the "Catchments" tab at the top of the Data Explorer (Figure 10). An important point to note about this new tab is that it also depicts Health, Stress, and Comprehensive scores, but, in this case, these scores are applied to the catchment *and* the scaling of these scores are now scaled to range from 0-1 *within the sub-watershed.* This means that catchments of equivalent color in different sub-watersheds may have different scores. It also means that variation can be depicted within each sub-watershed, which is exactly the goal of the catchment scoring.

You can examine our indicators of interest (riparian canopy cover, ecological significance, known water impairments, etc.) by changing the display of the "map symbology" on the catchment map as well. The drop downs and interactions between the bubble plot and map are the same as at the sub-watershed scale. Themes are available at the catchment scale and can provide further insight in our assessment. In this scenario, you may want to examine the Water Quality theme here in the Data Explorer, which combines and weighs a sub-set of the indicator scores to highlight catchments where conservation could support water quality (Figure 11, see Appendix A for a full description). You can also examine this theme more closely in the AGOL map (see step 1.7).

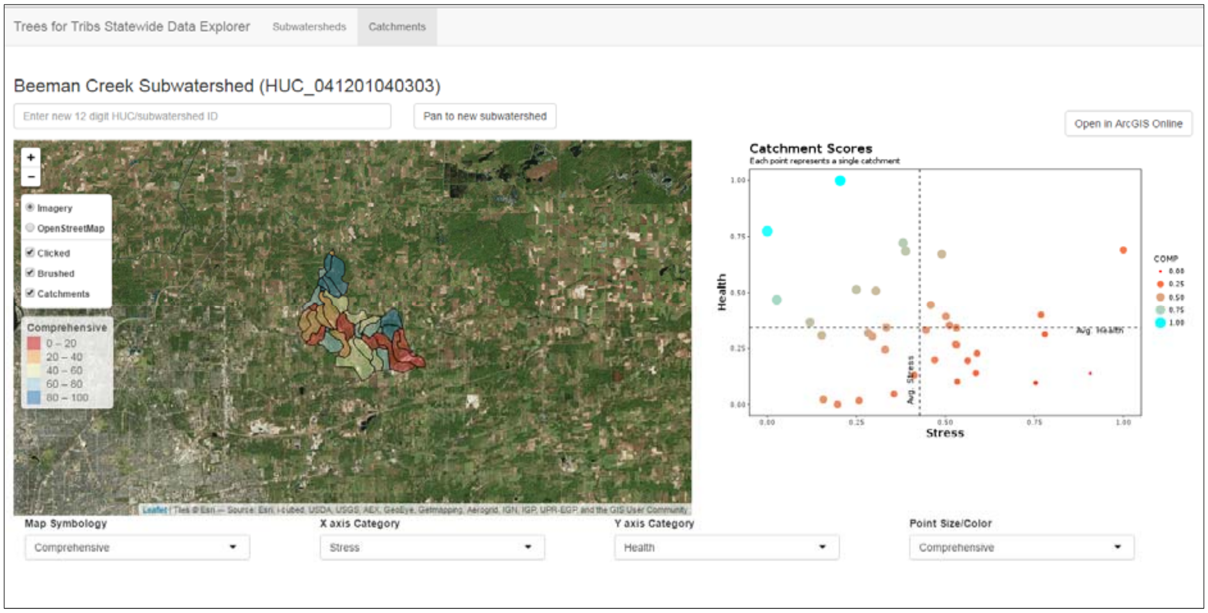

Figure 10. Data Explorer Catchments tab for Beeman Creek Sub-watershed and the default X, Y, and Z axes.

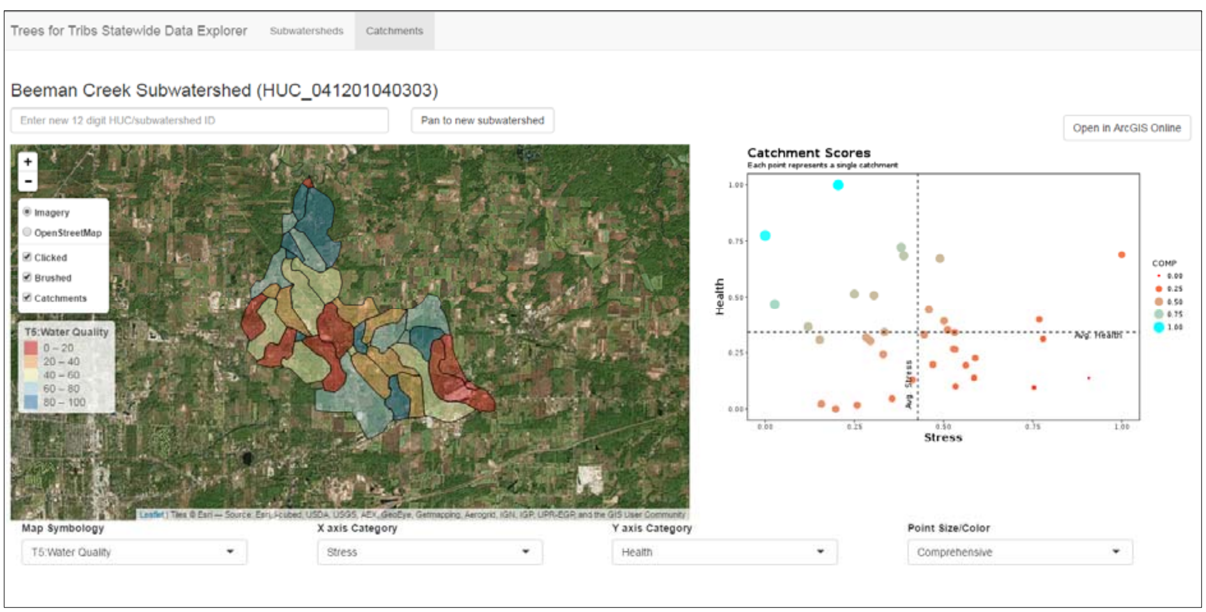

Figure 11. Data Explorer Catchments tab for Beeman Creek Sub-watershed with map symbology changed to Water Quality theme and other axes left at the defaults.

Step 1.6. Examine catchments in single sub-watershed in the AGOL map

You may want to examine the catchments in the Beeman Creek Sub-watershed more closely in the AGOL map. You can easily get to this by clicking on the “Open in ArcGIS Online” button at the top right of the catchments tab in the Data Explorer. This takes you to the AGOL Catchment map, zoomed to our sub-watershed of interest, with the default comprehensive score displayed (Figure 12). You can then click on the content tab, turn off the comprehensive score layer (default) and turn on the Water Quality theme layer, or any indicator, theme, or filter of interest.

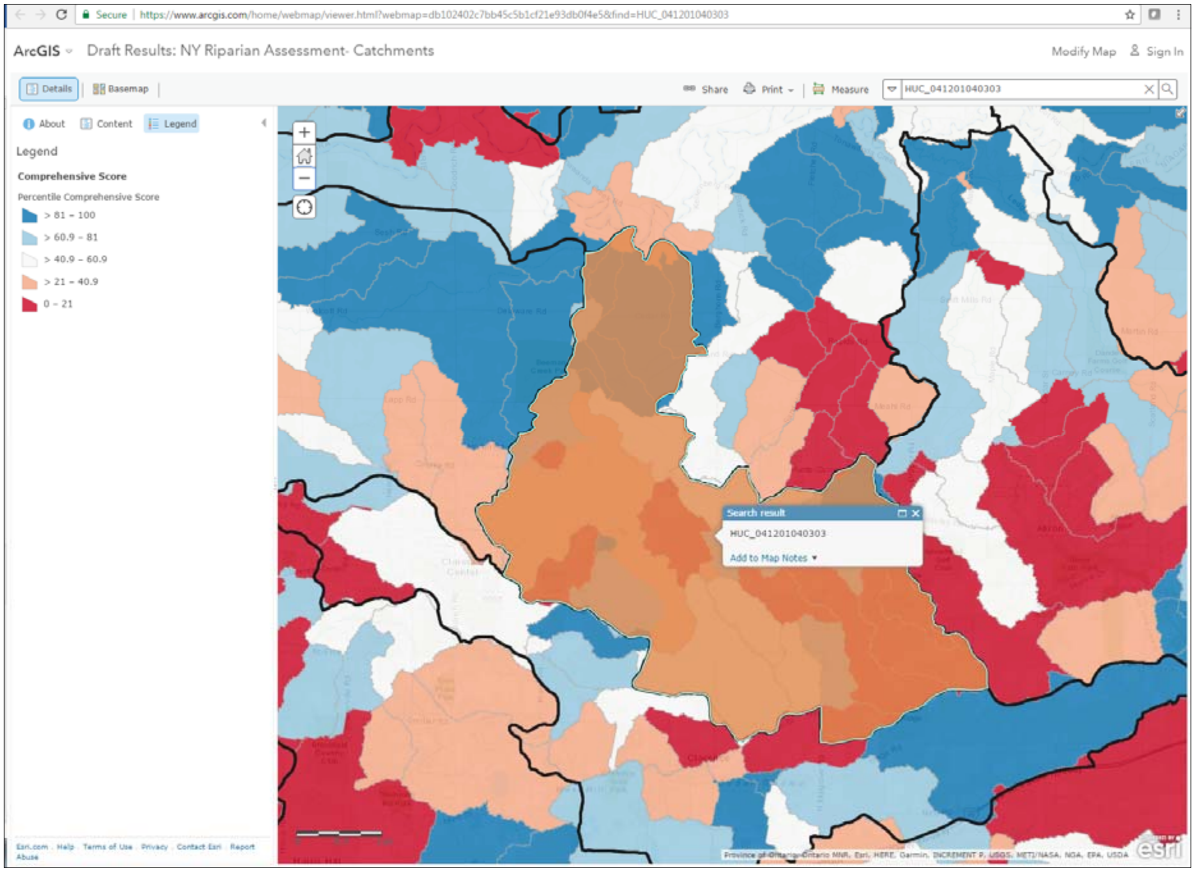

Figure 12. AGOL catchment map, zoomed to sub-watershed HUC_041201040303, Beeman Creek (highlighted in orange) with default comprehensive scores displayed by catchment.

Step 1.7. Examine data from individual indicator, theme, or filter

With the Water Quality theme turned on, you zoom into the map and turn the transparency of this layer to 50% so you can see the topography map below it and see where Beeman Creek is (Figure 13, see Appendix C for instructions on transparency settings). You click on a catchment along the creek where the water quality score is the lowest (indicating greatest need for improvement) and a pop-up window is displayed (Figure 13).

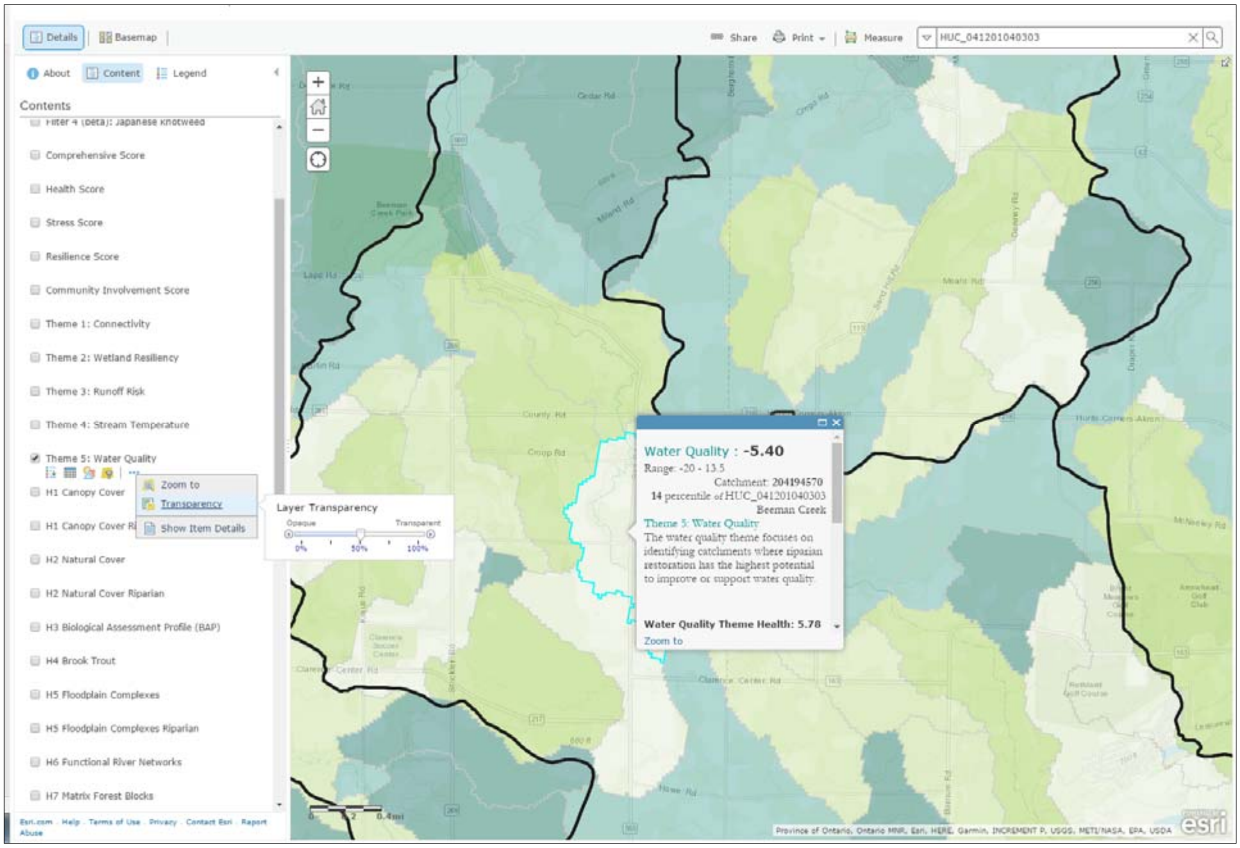

Figure 13. AGOL catchment map, zoomed to sub-watershed HUC_041201040303, Beeman Creek with water quality theme displayed, transparency set to 50% and a single catchment selected, with pop-up data window displayed.

In the pop-up, data is available for the layers that are turned on. Overall score, location, and indicator description information is in the pop-up, but if you scroll down, you can click through (using the arrows), various pie charts showing the contributions of various indicators to the overall score. If you hover over the pie chart, those indicators and contributions are displayed. In addition to examining individual scoring for indicator and theme layers, you can look at public land and agricultural area filters to narrow down your catchment to work in further, by turning these layers on and off (Figure 14). The catchment you initially selected would qualify for funding in this scenario, as it falls on privately-owned agricultural land, but you would need to obtain owner permission.

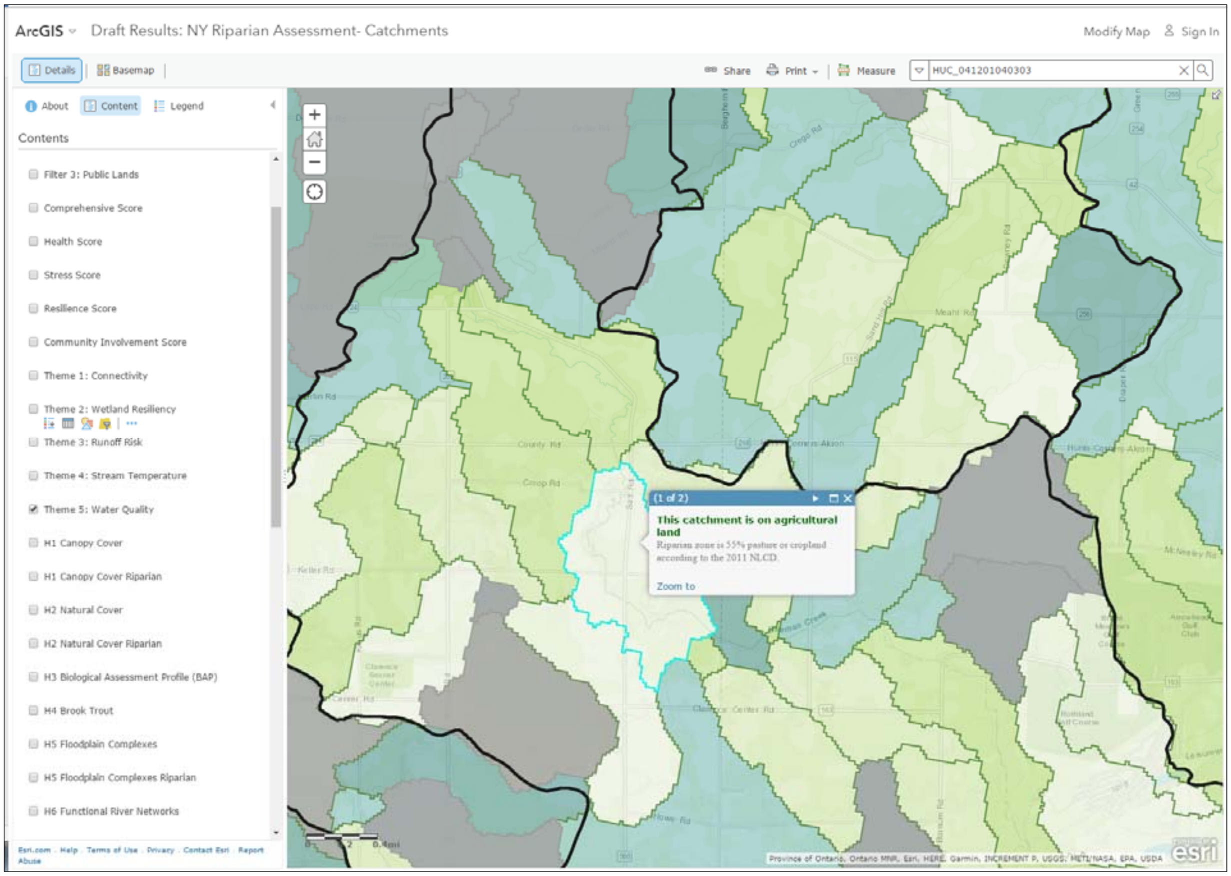

Figure 14. AGOL catchment map, zoomed to sub-watershed HUC_041201040303, Beeman Creek with the agricultural area filter turned on and the water quality theme displayed. A single catchment is selected, with pop-up data window displayed. Only catchments qualifying as ag. land will be displayed when this filter is turned on.

Summary of what you have learned about why this catchment is a priority:

- From the Bubble plot: Beeman Creek sub-watershed ranks in the "lower left" of the bubble plot: with a below average Ecological Health score that indicates it is an area that would benefit from some restoration, and a below average Ecological Stress score that indicates the current levels of stress are not so high as to overwhelm the impact of a modest restoration project.
- From the Sub-watershed Map: The Beeman Creek sub-watershed has lower canopy cover scores than other sub-watersheds in the area, and could benefit from planting trees in the riparian zone.
- From the Health Dashboard: It has higher Ecological Significance than the statewide average, indicating the presence of rare species or habitat suitable for rare species, either of which would benefit from improving the habitat. It has a below average Biological Assessment Profile score- suggesting that water quality could be improved by restoration work.

- From the Stress Dashboard: It has high non-point water impairments, which can be ameliorated by improving the quality of the riparian buffer, to reduce runoff. It also has below average riparian canopy cover, which could be improved directly by a restoration project.
- From the Catchment Map: Within the Beeman Creek sub-watershed, the catchment selected has low scores for the Water Quality theme, making it an ideal target for our project goal of improving stream quality.
- From the Online Map: The chosen area has agricultural land covering 55% of its riparian zone, making it qualified for this particular project. Possible alternative sites would include other catchments on agricultural land that are in the bottom percentile class for the Water Quality theme.

You can also turn on the aerial imagery to see where additional riparian buffers may be possible within catchments of interest. You can further examine where volunteer efforts have taken place in the past with the community involvement score layer to see if there is a volunteer base to draw from.

While our tools will help to narrow down the site or sites which should be of highest priority for a project, not all high priority sites are suitable for restoration, and additional information will be needed to ultimately determine a site's suitability. Once you have one or more catchments (like the example) selected as candidates for work, you can check additional sources using other tools available to you (outside of this project's products), including property ownership layers, etc. You can then schedule a visit to potential sites to verify condition and check their suitability for management actions.

Scenario 2. Report catchment metrics on Trees for Tribs Program application for a potential restoration project site.

You have the goal of performing riparian buffer restoration at a local stream of interest and applying to the NYS DEC's Trees for Tribs Program to accomplish this task. You are going to gather and report catchment metrics on the Trees for Tribs application for a potential restoration project site.

Step 2.1. Zoom to site in AGOL catchment map

In this scenario, you already have a specific stream in mind in which you want to do restoration work by planting trees in the riparian zone with the help of volunteers and supplies as part of the Trees for Tribs Program. You are working at a local scale (stream in a single catchment) rather than a sub-watershed (HUC 12) scale, so will focus on the catchment level assessment products. As an arbitrary example, let's say you want to do this work on Berry Pond Creek in Stephentown near Wyomanock Rd. You open the AGOL catchment map and zoom to Wyomanock Rd. by typing in the box at the top right of the screen (Figure 15). Alternatively, one can continue zooming in on the map until your area is found, using various basemaps available to you on the upper left under the basemap button. See Appendix C for a full description of help for using the AGOL map products. In addition, you can also zoom to coordinates on the map by entering the longitude and latitude in the search window at the top right of the screen. An alternative method to zoom to coordinates, is by clicking on the Measure button, then the Location button, and then watching your Latitude and Longitude change as you pan your mouse across the map.

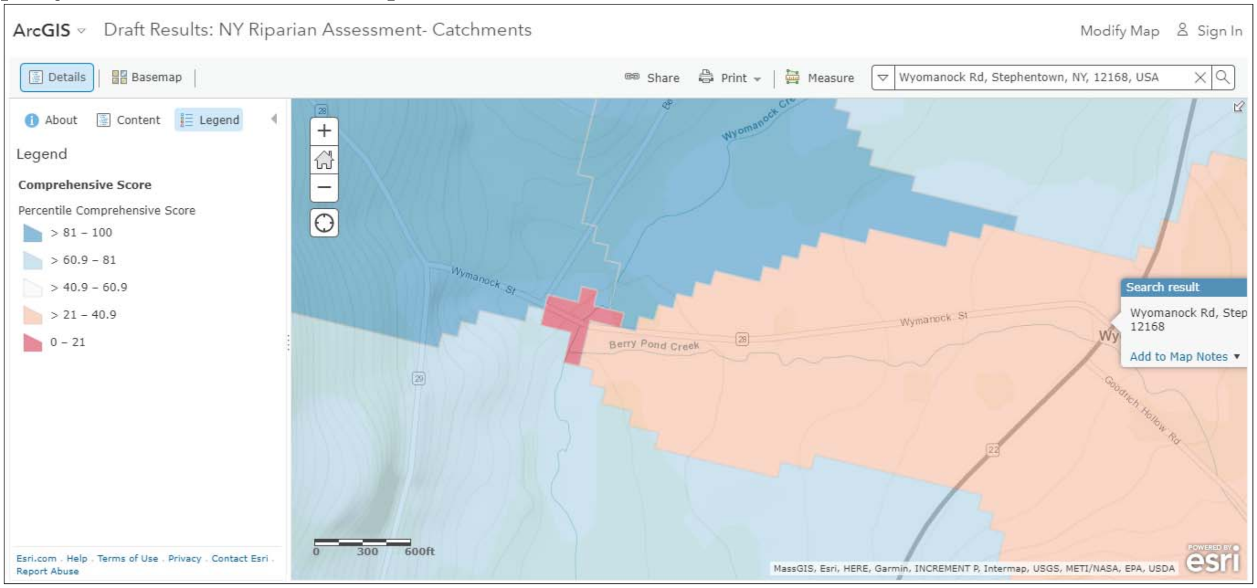

Figure 15. AGOL catchment map with area of interest zoomed to by typing in the search box in the upper right. The default comprehensive scoring is depicted by catchment.

Figure 16. Pop-up window appears showing the score for Ecological Health when a single catchment is clicked on. All layers that are turned on in the “Contents” will have data available in the pop-up.

Step 2.2. Retrieve indicator scores on AGOL catchment map

You are interested in reporting on scores for the indicators on your application for work in this catchment. To get this information, you click on the catchment and retrieve the score data from the pop-up window (Figure 16, Ecological Health score of 3.83). Any layer that is turned on in the “Contents” on the left of the map will have data in the pop-up when the catchment is clicked on. If more than one layer is turned on, you can scroll through the data for each indicator in the pop-up window, by clicking on the arrow at the top of the window. The sub-watershed ID is also given in the window. Remember, all scores reported for the catchment are ranked and scaled *within this sub-watershed*. This means that catchments of equivalent color in different sub-watersheds may have different scores.

Step 2.3. Provide context for our catchment of interest

You want to put your target site in context, so you go to the Data Explorer (https://lab.nynhp.org/trees_tribs_ny/data_explorer/), click on the catchments tab, and copy/paste the HUC ID (from the pop-up window for the catchment in AGOL) into the search box at the top of the map ("HUC_020200060603") and click the "Pan to new subwatershed" button. This zooms right to the sub-watershed, displaying all catchments and you can click on your catchment (202957286, Figure 17). A user guide for the Data Explorer is available in Appendix D.

Figure 17. Data Explorer, catchment tab, showing Wyomanock Creek Sub-watershed, with Catchment 202957286, Berry Pond Creek selected. Default settings for the axes are depicted.

When you click on your catchment of interest on the map on the left of the screen in the Data Explorer, the catchment is highlighted on the bubble plot on the right (Figure 17). You can see that your catchment is in the lower left quadrant, indicating slightly lower than average stressors, but lower than average health relative to other catchments in the sub-watershed. We have already mentioned in Scenario 1, at the sub-watershed level, that sites falling in this quadrant on the bubble plot, may be good targets for restoration work as they may benefit from remediation and have lower exposure to ecological stressors.

Scores of surrounding catchments may also provide context. You can explore the quality of the surrounding catchments by changing the map symbology to display the Ecological Stress or Health scores. If healthy habitat is adjacent to your catchment, improving your stream quality (especially if upstream from it) could benefit other areas and reduce threats for them as well.

You can also describe the status of this area in the context of New York State by clicking on the sub-watershed tab, selecting the Upper Hudson region, and zooming in on the map to click on the Wyomanock Creek sub-watershed (Figure 18). Now you see from the position of the black circle on the bubble plot that this sub-watershed where you want to work has slightly higher than average Health scores, and slightly higher than average Stress relative to the Region. This makes it a sub-watershed of moderate scores, one that could be improved without a great deal of risk from high stressors: A good candidate. You can also see, using the Comprehensive score on the map, that the areas around Wyomanock Creek are slightly darker blue than Wyomanock Creek sub-watershed itself, meaning they are of higher overall quality, so improving this sub-watershed with a Trees for Tribs planting could also protect the neighboring habitat by reducing potential sources of stress. The Health Score Dashboard shows us that Wyomanock Creek has high native fish richness, contains Brook Trout, and has high Biological Assessment Profile scores, all attributes worth protecting. It has slightly below average riparian natural cover, which could be aided by a planting project. As shown on the Stress Score Dashboard, a large source of stress is due to development in the riparian zone (indicated by the greater than average Landscape Condition Assessment riparian score), so any project which ameliorates the impact of development along the streamside would be addressing this impairment.

All of these data can help inform your assessment of the best place in which to work and you can add information to your Trees for Tribs project application (including indicator scores for your catchment of interest).

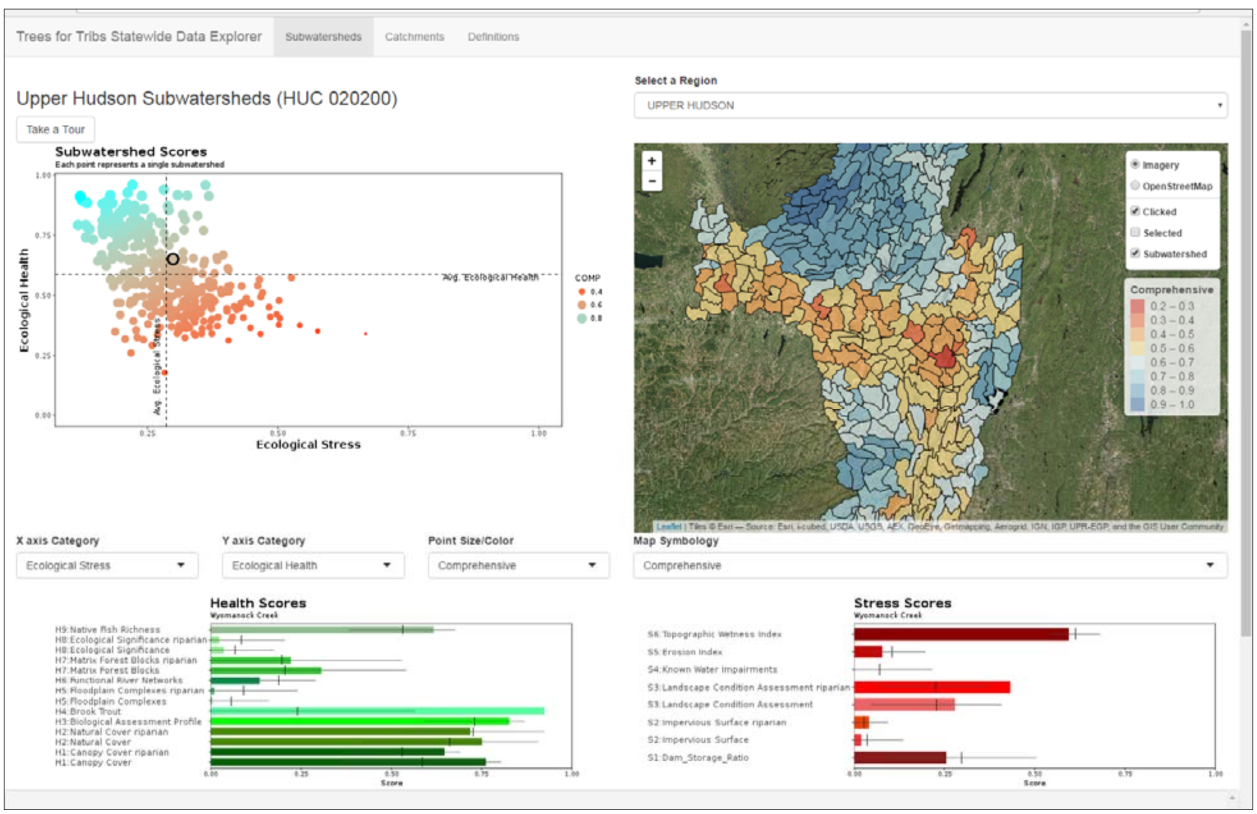

Figure 18. Data Explorer, Sub-watershed tab, showing Wyomanock Creek Sub-watershed selected. Default settings for the axes are depicted.

Summary of what you have learned about how to gather catchment metrics:

- Zoom to a location on the AGOL maps: You can zoom to an area of interest. After opening up the map, you can zoom to a road, place or coordinates by typing in the box at the top right of the screen.
- Obtain metric scores for a catchment: You can turn on any indicator or composite layer in the Contents of the AGOL catchment map. When you click on a catchment of interest, you can retrieve the score data from the pop-up window for any layer that is turned on. (Scores are scaled within that sub-watershed.)
- Use Data Explorer for context: You can zoom to the sub-watershed by typing the HUC 12 number in the search box on the catchment tab and panning to it. You can click on your catchment of interest and see where it plots on the bubble plot. You can explore the quality of surrounding catchments as well, selecting up to three indicators of interest to be displayed on the plot. You can locate the sub-watershed of interest in the sub-watershed tab of the Data Explorer as well and explore the Health Score and Stress Score Dashboards to provide context at the sub-watershed level.

You will also need to check additional sources using other tools available to you (outside of this project's products), including property ownership layers, and schedule a visit to potential sites to verify condition and check their suitability for restoration work. In addition, you will need to check the Trees for Tribs application guidance to ensure your application is complete and that you collect all the necessary information at your proposed project site visits.

Scenario 3. Apply for funding a "non-agricultural nonpoint source abatement and control" project to restore a riparian buffer along an impaired stream.

You are applying for funding through the NYS DEC's Water Quality Improvement Project (WQIP) Program "non-agricultural nonpoint source abatement and control" project to restore a riparian buffer along an impaired stream. Municipalities and soil and water conservation districts are eligible to apply. Projects with waterbodies listed as "impaired", "stressed", or "threatened" as well as Class A or AA streams, according to the DEC's Priority Waterbodies List, are given priority over other projects, according to the grant rfa. The NYS Department of Agriculture and Markets administers funding for a similar program on agricultural lands (Agricultural Nonpoint Source and Abatement Program (AgNPS). For this WQIP grant though, you are interested in a non-agricultural area to qualify.

Step 3.1. Assess condition of sub-watersheds

You first go to the AGOL sub-watershed map to gain a statewide perspective and view details about indicator scores. You refer to Appendix C for user guidance in using the AGOL maps. You turn off the Comprehensive Score indicator (default setting) and turn on the Known Water Impairments indicator layer (Figure 19), which uses data from DEC's Priority Waterbodies List and displays stream impairments. Scoring for the indicator is limited to include only non-point sources of impairment.

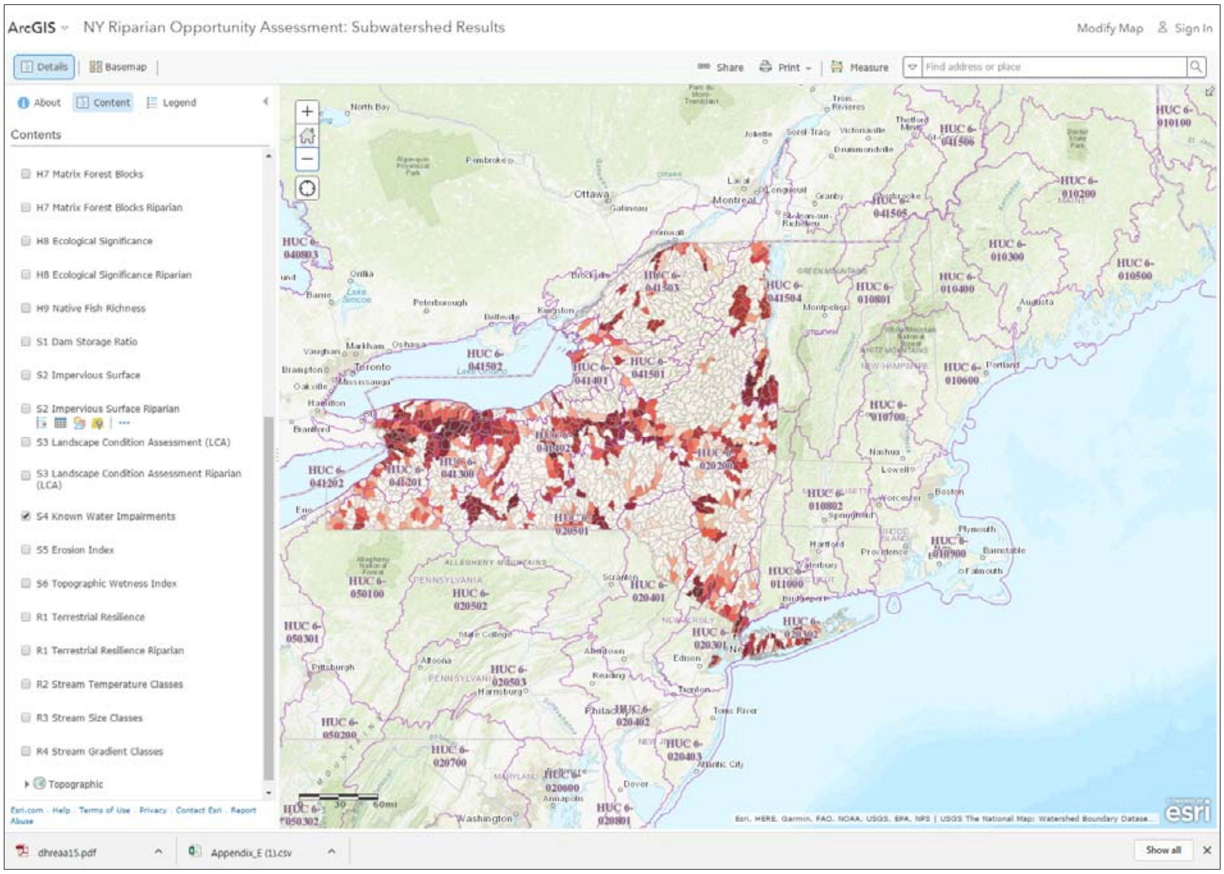

Figure 19. AGOL sub-watershed map with Known Water Impairments layer turned on. Areas with higher non-point source impairment have darker shading.

You get a sense of potential areas of focus from the statewide sub-watershed view. Let's say you have an interest in working on impacted streams in the Finger Lakes near Naples and Middlesex. You decide to take a closer look at the catchment level. Open the AGOL Catchment map. Turn on Known Water Impairments and turn off Comprehensive Score.

Step 3.2. Narrow search to areas with high priority under the grant

You have very specific requirements for this project (needs to be a non-agricultural area and priority for Class A or AA waters), so rather than clicking on catchments one at a time to see if they qualify, you can quickly eliminate unqualified areas using a custom filter. You click on the Known Water Impairments layer name in the contents window, which brings up symbols for more options under the name. You click on the funnel-shaped filter option. In the filter screen (Figure 20), you want to set a filter to select those streams that are Class A or AA and those areas that are not in agricultural areas. You type in F2_AA and select "is blank" from the drop down in the first expression to include Filter 2 Agricultural Areas that are "0", or not agricultural land. You click "add another expression" to add a second criteria, and in this one you type in "Class" in the box on the left, select "contains" from the drop-down, and type in A, then hit the button to Apply Filter and Zoom to.

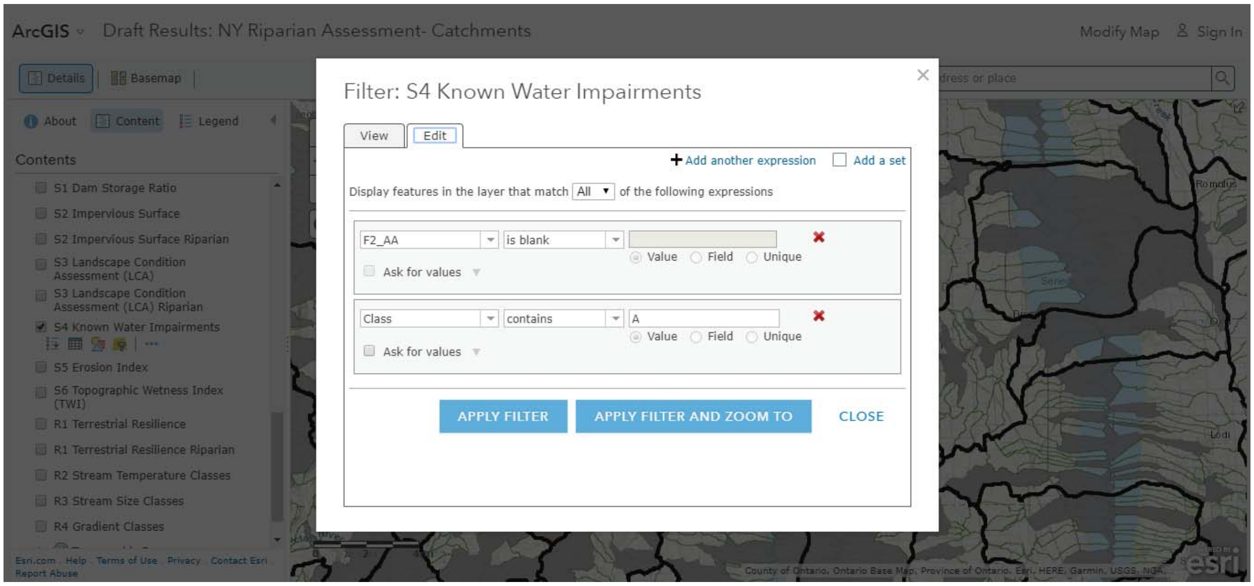

Figure 20. A filter for selecting catchments that are not in agricultural areas and are Class A or AA (or other variations of A) streams.

Step 3.3. Explore catchments meeting filter criteria

This will take you statewide, but the catchments only show up upon zooming in further. Zoom to an area of the state, in this case, you type in Naples in the search window and zoom out a bit. Turn on the Known Water Impairments layer. Let's say you choose the Upper Flint Creek sub-watershed, which shows several qualifying catchments displayed that meet our filter criteria (Figure 21). You can now select an individual catchment and see additional information in the pop-up window pertaining to your score for this indicator (Figure 22). If you scroll to the bottom of the pop-up window, you can see the category of impairment for the catchment, its class, and sources of impairment. Bold, colored values indicate sources of impairment included in our indicator score for this data source. Unbolded values indicate sources of impairment which may be of interest, but aren't directly related to riparian buffer restoration (i.e. impacts due to septic impairments or industrial discharges would not be improved by restoring riparian areas, but it is beneficial to users to understand the cause of an impairment in their watershed of interest, and users can explore alternatives to address these impairments).

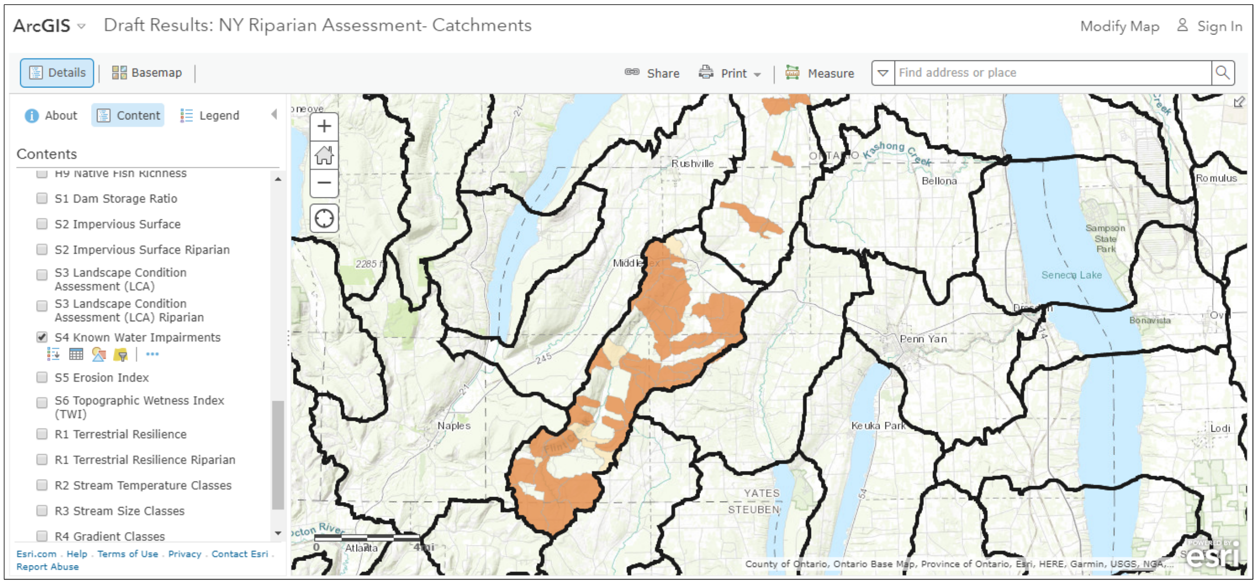

Figure 21. Upper Flint Creek sub-watershed with Known Water Impairments indicator turned on and data filtered as in step 3.2.

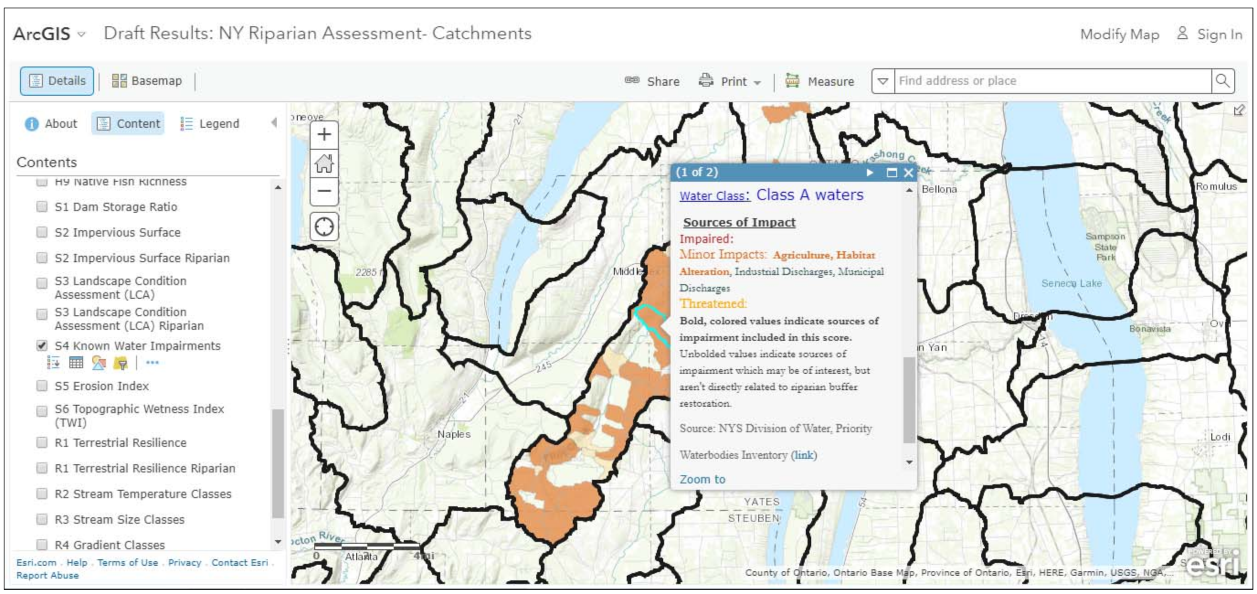

Figure 22. Catchment 204196936 selected and Known Water Impairments indicator turned on. After scrolling down in the pop-up window, Class and Sources of Impact are displayed. Non-point sources included in our analysis are in color and bolded, other sources of impact (not included in our scoring) are listed last in unbolded black ink.

Step 3.4. User assessment and field validation

Summary of what you have learned about screening priority catchments:

- You are able to filter the data on any layer (in this example, the Agricultural Area Filter and the Known Water Impairments indicator) to narrow down your search for candidate catchments in the AGOL catchment map.

- You can screen catchments for candidates for WQIP non-agricultural nonpoint source abatement and control grants. In this example, the Upper Flint Creek sub-watershed may be a good candidate for funding since it is not in an agricultural area and it contains Class A waters.
- You can examine sources of impairment in the pop-up window for the Known Water Impairments indicator after clicking on individual catchments.

You can now assess which catchment to focus your efforts on based on the screening in steps 3.1-3.3. Even if a stream in this catchment has minor impacts, as listed for our example catchment in Figure 22, it may not be given high priority under the grant if it is not listed as "impaired". However, it is a Class A waterbody and nonpoint sources appear to be influencing the water quality here and it may score highly based on other application criteria not discussed here. If you decide to apply for funding for this area, you may need to also address the other sources of impairment for which our riparian buffer may not be able to influence (in this example, industrial and municipal discharges). You will also need to follow WQIP application guidance and refer to their documents to ensure your application is complete (this includes site assessments, permits, feasibility studies, etc.). Our project tools (in steps 3.1-3.4) offer a first screening to simply suggest potential catchments of focus for such a goal. As with all other scenarios, you will need to do a field visit to verify condition and assess the site.

Limitations and assumptions

We recognize that the suite of habitat indicators included in our analysis was by no means comprehensive to all indicators that could prove important to documenting health or stress on an aquatic system. The Steering Committee refined this list throughout the beginning phases of the project, added the resiliency and social indicators, and we feel the list is representative of indicating important aspects of stream condition necessary for restoration and protection goals using an ecosystem based management approach.

Indicator scores are displayed as static values for sub-watersheds and catchments. The analysis does not show the resulting impact of a particular restorative or protective action, but can highlight places where such actions could have the most impact, depending on conservation goals. Therefore, the specific impact of a particular restoration or protection effort is not calculated or provided as one of our products. We hope interested practitioners will explore how the implementation of their project impacts overall comprehensive scores to help identify how these tools can track progress towards improving stream condition.

We further recognize that the accuracy of our compiled Ecological Health, Ecological Stress, and Comprehensive scores are dependent upon the quality of the input data. While we believe all our sources and input data are of high quality, we recognize that through use of this dataset and source datasets, as with any, errors may be revealed. We hope to have the opportunity to correct these in future versions.

Certain indicators, such as BAP, used predictive modeling to derive water quality metric values for previously unsampled streams. Thus, while over 1,700 stream samples were used to model the BAP score, and the model of BAP to stream environmental conditions was relatively robust (White *et al.* 2011), the only way this project could apply data such as these was to use the modeled dataset of predicted BAP scores. Having datasets such as this accessible greatly increases their use and applicability, but also introduces extra uncertainty. This also applies to the National Land Cover Dataset (NLCD), which is a model of land cover types based on satellite imagery and other similar datasets.

The lowest ranked sub-watersheds and catchments should not be interpreted as "bad", and the reasons for a lower ranking can be revealed when looking at component indicator scores and other spatial data layers, such as aerial photography. Those areas scoring as poorer health, or higher stress, are relative ranks to other sub-watersheds and catchments in the basin, but may have ecological benefit or other value not detected by our analysis. Volunteer efforts from past Trees for Tribs planting efforts, CSLAP, and WAVE, are reflected in our social indicator layers at the sub-watershed scale, but we did not include other social, economic, or feasibility (including plant-ability) indicators in this analysis. These factors will need to be weighed with our dataset when making decisions about where to work.

Due to the timeframe and scope of our project, our data-gathering efforts were largely limited to data sources that were already prepared and available statewide for New York, and that could be used to derive indicator scores at the sub-watershed and catchment scales. While some of these indicators may be naturally correlated, those included in the final analysis were selected because they represent sufficiently distinct habitat features relevant to evaluating the health of the riparian zone.

We anticipate, as practitioners begin to use these products, they may suggest additional indicators to include in the assessment. Ideally, we would periodically revisit the assessment so that such improvements, as well as new information on the current suite of indicators, can be included in future versions of this assessment. As one example, NYPAD information used in the Urban Areas filter is updated on a frequent basis and should be updated in our AGOL catchment map at least on an annual basis. Further advancements could be made with indicator datasets available in the Northeast and these should also be assessed for their inclusion in future iterations.

Lastly, as aforementioned, these products are designed to be used in addition to other spatial data layers and information available to practitioners rather than as a stand-alone toolkit. The Steering Committee suggested the following additional data could be used with these products to help address specific project prioritization goals. This list is not comprehensive: Invasive species data (i.e. New York iMapInvasives), forest species data, landowner property boundaries, FEMA flood data, drinking water municipalities/watersheds (i.e. EPA DWMAPS), and environmental justice underserved communities. Finally, site-specific knowledge is imperative and field validation will be a necessary step before actual implementation of conservation actions.

Conclusion and Next Steps

In this project, we provide the Division of Lands and Forests of NYS DEC and other partners with maps detailing summary scores for ecological health, stress indicators and overall comprehensive scores for each sub-watershed and catchment in New York State. This information is accessible to users through the AGOL maps and geodatabase (http://nynhp.org/treesfortribsny). In addition, we provide a Data Explorer, an online prioritization tool, to help users visualize indicator score distributions of their choice. These products were designed to provide an objective procedure of site selection for protection and restoration activities, to be used in conjunction with other information and tools available to conservation practitioners. This report outlines the methodology, describes the products, and walks potential users through various scenarios and examples of how to use these products to answer specific conservation questions.

In addition to being used by NYS DEC's Trees for Tribs program, the data products feed nicely into many other goals identified in New York's Great Lakes Basin Interim Action Agenda, including the identification of priority areas for riparian buffer restoration and protection (goals 2.8, 5.8, 8.2), areas for improving stream corridor connectivity (goal 5.6), and areas to expand green infrastructure in flood-prone areas (goal 7.11). This statewide assessment furthers these and related goals in other Action Agendas and Watershed Management Plans in the state. We anticipate that the results of this project will help inform the strategic allocation of limited conservation resources for a variety of partner organizations and promote ecosystem based management approaches to restoration work.

There is great benefit to updating the above analyses on a periodic basis in the future due to future revisions to our source data and additional data and techniques becoming available in the future and we will seek additional funding with this goal in mind.

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Appendix A. Filters, Composite Scores, Themes and Habitat (Ecological Health and Stress), Resiliency, and Social Indicators: Descriptions, Data Sources, and Raw Score Calculations

	Indicator	Code	Category	Applied to	Data Source	Filter Description	Reasoning	Calculations
Filters	Urban Areas	Filter 1	Filters	Catchment	United States Census Bureau 2010	Only catchments meeting criteria will be visible, all catchments which do not qualify will be turned gray	Filters can help prioritize opportunities for collaboration and overlap with other restoration efforts by identifying areas that meet a specific criterion	We classified catchments in Urban Areas if they intersected with Urbanized Area Polygons or Urban Clusters as defined by the 2010 Census.
	Agricultural Areas	Filter 2	Filters	Catchment	National Land Cover Dataset (U.S. Geological Survey 2011)	Only catchments meeting criteria will be visible, all catchments which do not qualify will be turned gray	Filters can help prioritize opportunities for collaboration and overlap with other restoration efforts by identifying areas that meet a specific criterion	We classified catchments in Agricultural Areas if their riparian zone was composed of more than 25% agricultural land use including Cultivated Crops [type 82]) and Pasture/Hay [NLCD type 81] according to the National Land Cover Dataset (NLCD, U.S. Geological Survey 2011).
	Public Lands	Filter 3	Filters	Catchment	NYPAD (New York Natural Heritage Program 2017)	Only catchments meeting criteria will be visible, all catchments which do not qualify will be turned gray	Filters can help prioritize opportunities for collaboration and overlap with other restoration efforts by identifying areas that meet a specific criterion	We classified catchments as Public Land if they intersected areas designated as such in the NYPAD (New York Protected Areas Database) layer (March 2017 version).
	Comprehensive Score	COMP		Catchment, Watershed	Health, Stress	Higher Scores indicate areas of higher overall ecological health, potential candidates for conservation. Lower scores indicate areas with greater overall ecological stress, possible targets for restoration. Scores in the mid-range indicate areas with less extreme challenges in terms of overcoming sources of high ecological stress; places where a little restoration work may have a large impact. Potential values range from -1 (low) to 1 (high).	Users can see a summary of all the health and stress indicators with the overall Comprehensive Score to preliminarily assess restoration/protection potential in a unit (sub-watershed/catchment). Catchment scores are relative to other catchments within its sub-watershed.	Ecological Stress Score is subtracted from the Ecological Health Score for a given unit.

	Indicator	Code	Category	Applied to	Data Source	Filter Description	Reasoning	Calculations
	Ecological Health Score	H0		Catchment, Watershed	See Below	Higher values indicate sites with higher ecological condition, as described by the "Ecological Health" indicators detailed below. Raw values at the sub-watershed scale range from 0.50 to 9.19. Raw values at the catchment scale range from 0 (low) to 11.7 (high). Potential normalized values range from 0 (low) to 1 (high) at both scales.	Users may look to the overall Ecological Health Score in order to quickly assess the health of a unit (sub-watershed/catchment) which summarizes all health indicator calculations. Catchment scores are relative to other catchments within its sub-watershed.	Individual Ecological Health Indicator scores are normalized on the same scale (0-1) and summed.
	Ecological Stress Score	S0		Catchment, Watershed	See Below	Higher values indicate more stressed habitat, as described by the "Ecological Stress" indicators detailed below. Raw values at the sub-watershed scale range from 0.33 to 5.69. Raw values at the catchment scale range from 0 (low) to 8 (high). Normalized values range from 0 (low) to 1 (high) at both scales.	Users may look to the overall Ecological Stress Score in order to quickly assess the stress on a unit (sub-watershed/catchment) which summarizes all stress indicator calculations. Catchment scores are relative to other catchments within its sub-watershed.	Individual Ecological Stress Indicator scores are normalized on the same scale (0-1) and summed.
	Resilience/Climate Change	R0		Catchment, Watershed	See Below	Higher values indicate areas with greater resilience to climate change as described by the "Resilience" indicators below. Values at the sub-watershed scale range from 0 to 1.84. Values at the catchment scale range from 0 (low) to 2 (high).	Users may examine these data layers to see which units have greater resiliency to climate change to further assist with prioritization of areas to do protection or restoration work. Catchment scores are relative to other catchments within its sub-watershed.	Individual Climate Resilience scores are normalized on the same scale (0-1). Terrestrial indicators (R1_TR, R1_TR_rip) are summed and divided by two. Freshwater indicators (R3_TC, R4_SC, R5_GC) are summed and divided by 3. These mean terrestrial and mean freshwater scores are summed.

	Indicator	Code	Category	Applied to	Data Source	Filter Description	Reasoning	Calculations
	Social/Community Involvement	C0		Watershed	See Below	Higher values indicate areas with greater resilience to climate change as described by the "Resilience" indicators below. Values at the sub-watershed scale range from 0 to 1.84. Values at the catchment scale range from 0 (low) to 2 (high).	Users can see sub-watersheds with existing social involvement in citizen science, which may have higher potential for successful collaborations in future.	Individual Community Involvement scores (the number of CSLAP and WAVE samples, and Trees for Tribs plantings within the sub-watershed and catchment) are summed. See the end of this table for descriptions of each.
Themes	Connectivity	Theme 1	Themes	Catchment	Canopy cover, National Land Cover Dataset (U.S. Geological Survey 2011)	The theme highlights critical gaps in connectivity. To qualify, a catchment must fall in a sub-watershed with "good" riparian canopy cover (>61%) AND have less than 35% canopy cover within the catchment itself. Qualifying catchments are displayed by their riparian canopy cover score (see Canopy Cover below for details), lighter colors represent lower canopy cover , darker shades of brown represent higher canopy cover. Catchments that did not qualify are classified as "Excluded" and colored gray.	The purpose of the connectivity theme is to support stream corridor connectivity and identify areas along streams with united forest tracks and those areas within riparian buffers with gaps in forest cover where planting trees could increase connectivity. We provide this theme with the caveat that any restoration efforts with the primary goal of improving connectivity or identifying critical gaps would benefit highly from further analyses of forest fragmentation and this type of analysis was outside the scope of this project. What we provide here is an indirect indicator of low scoring riparian areas within sub-watersheds with existing good riparian connectivity; possibly locations where restoring the riparian zone of low scoring catchments may eliminate gaps hindering connectivity.	We identified sub-watersheds with high existing riparian connectivity based on selecting those with mean riparian canopy cover scores greater than 61% (1 standard deviation above the mean), that also had at least one catchment with a mean riparian canopy score of less than 25%. We excluded catchments where greater than 50% of the riparian zone was classified as "Open Water" (according to the National Land Cover Dataset). This reduced the likelihood that gaps were due to the presence of ponds, which planting trees would not ameliorate. Catchments entirely under lakes were removed. The upper cutoff value was high enough to identify higher quality sub-watersheds and low enough that it did not limit the qualifying sub-watersheds to solely those found in the Adirondacks. The lower value of 35% was used to identify sub-watersheds with at least 1 catchment with a gap (area of low canopy cover). Within the qualifying sub-watersheds, we selected those catchments with mean riparian canopy cover of 35% or less. Catchments that did not qualify are classified as "Excluded" and colored

	Indicator	Code	Category	Applied to	Data Source	Filter Description	Reasoning	Calculations
								gray. Because of the nature of this theme, not all sub-watersheds qualified, and not all catchments are scored.
Themes	Wetland Resiliency	Theme 2	Themes	Catchment	National Wetlands Inventory (U.S. Fish and Wildlife Service 2015)	Catchments with higher proportions of the riparian zone composed of wetlands are in darker shades of green. Values are reported as a percentage and range from 0-100%.	The purpose of the Wetland Resiliency theme is to identify those areas along streams with greater flood capacity due to the presence of intact wetland habitat. We compared the riparian buffers to the National Wetlands Inventory (NWI) dataset and estimated the relative contribution of wetlands to the area of buffer. The least resilient basins would be those with fewer wetlands in the riparian zone. Conversely, the most resilient basins would be those with the highest proportion of wetlands in the stream corridor.	We computed the area of the riparian buffer for each catchment, and the area of riparian buffer for each catchment that intersected a wetland in the NWI. The ratio of wetland riparian area to buffer area constituted the raw score.
	Runoff Risk	Theme 3	Themes	Catchment	Erosion Risk, National Land Cover Dataset (U.S. Geological Survey 2011), CropScape (USDA National Agricultural Statistics Service 2014)	Larger scores indicate areas where topography in the riparian zone is likely to contribute to high levels of erosion and land use is likely to exacerbate that runoff. Areas at higher risk are darker shades of burnt orange. Raw values range from 0 to 9878.	The purpose of the Runoff Risk theme is to identify areas with potential erosion hotspots that occur on land-use classes with soils likely to contribute to excessive runoff that may be addressed by riparian buffers. We used the erosion index indicator and overlaid this with specific land cover classes from both the 2011 NLCD and the CropScape dataset (USDA National Agricultural Statistics Service 2014) to determine areas with non-natural or agricultural cover with high erosion potential that could benefit from planting.	Using the National Land Cover Dataset, we extracted the developed classes (Developed, Open Space [21]; Developed, Low Intensity [22]; Developed, Medium Intensity [23]; Developed, High Intensity [24]) and the Barren (31) class). From the CropScape 2014 dataset (USDA National Agricultural Statistics Service 2014), we extracted all the classes indicating cover types that suggested regular tilling. Classes not used from the CropScape dataset include orchards, more perennial cover crops (clover/wildflowers, sod, and switchgrass), and classes not occurring in New York State. All the extracted raster cells were merged and assigned a value of 1; the remaining cells were assigned a value of 0. We multiplied this binary layer by the Erosion indicator (riparian),

	Indicator	Code	Category	Applied to	Data Source	Filter Description	Reasoning	Calculations
								which resulted in a range of values for runoff risk that highlights catchments with both high runoff risk and land use likely to contribute to runoff within the riparian zone.
Themes	Stream Temperature	Theme 4	Themes	Catchment	Canopy cover, Funtional River Network, predicted BAP, Brook Trout, Floodplain Complex, Forest Matrix Block, Natural Cover, Landscape Condition Assessment (LCA), Impervious Surface, Erosion Risk, TWI, PWI, Dam Storage Ratio	Larger negative scores indicate areas with poor existing habitat to maintain cool stream temperatures. Larger positive scores indicate areas with more existing habitat features suitable for lowering stream temperature. Lower scoring catchments for each sub-watershed are in light green and higher scoring catchments are in dark teal. Values range from -4 to 14.	The purpose of the Stream Temperature theme is to help identify areas where stream temperature might be decreased by planting trees in the riparian zone. Increasing the canopy cover along streams would make the habitat more suitable for cold-water fish and improve connectivity among already forested, cold-water segments. We used all ecological health and stress indicators within the riparian buffers of streams, but we weighted brook trout, BAP, and canopy cover more heavily than all other indicators.	Stream Temperature Theme Score=4*{Canopy Cover(riparian) + Functional River Network + BAP + Brook Trout + Floodplain Complex(riparian) + Forest Matrix Block (riparian) + Natural Cover(riparian)} + (-1)*{LCA(riparian) + Impervious Surface(riparian) + Erosion + TWI + PWI Water Stress Score + Dam Storage Ratio)}. "Heavily" weighed variables were multiplied by 4. Stress indicators were all multiplied by -1. "Riparian" refers to indicators that were only scored within the riparian zones.
	Water Quality	Theme 5	Themes	Catchment	Impervious surface, LCA, natural cover, wetness index, erosion index, Biodiversity Assessment Profile (BAP), the New York State Protected Waterbodies List (PWL), canopy cover, and floodplain complexes	Larger negative scores indicate areas of high stress for water quality with few sources of natural protection. Larger positive scores indicate areas where water quality is under less stress and has more natural protection. Lower scoring catchments for each sub-watershed are in light green and higher scoring catchments are in dark teal. Values range from -20 to 13.5.	The focus of the Water Quality Theme was to highlight locations where riparian protection or restoration activities could support water quality by using metrics both within the stream buffer and the stream catchment.	Water Quality Theme Score=(-4)*{Impervious Surface (riparian) + LCA (catchment) + LCA(riparian) + TWI + Erosion + PWI Water Stress Score} + 4*{Natural Cover(riparian) + BAP} + 2*{Natural Cover (catchment)} + 1*{Canopy Cover (riparian) + Canopy Cover (catchment) + Floodplain Complex(riparian) + Floodplain Complex (catchment)}. Scores were normalized. "Lightly" weighted variables were multiplied by 1. "Moderately" weighted were multiplied by 2. "Heavily" weighed variables were multiplied by 4. Stress indicators were all multiplied by -1. "Riparian" refers to indicators that were only scored within the riparian zones. "Catchment" refers to scores

	Indicator	Code	Category	Applied to	Data Source	Filter Description	Reasoning	Calculations
								that incorporated the entire catchment area.
Ecological Health	Canopy Cover	H1_Can	Health	Riparian, Catchment, Watershed	National Land Cover Dataset (U.S. Geological Survey 2011)	Higher values indicate greater mean canopy cover. These are represented by darker shades of green. At the sub-watershed scale, values range from 0 to 100%. At the catchment scale, values range from 0 to 90% and for the riparian zone, from 0 to 90.75%.	Streamside forests provide important ecosystem functions, protecting water quality by blocking pollutants, sequestering carbon, and metabolizing organic matter. Unforested streams experience higher maximum summer water temperatures than those under the shade of a full canopy (Sweeney and Newbold 2014). Streams with healthy canopy cover and low temperatures provide excellent habitat for trout (Barton *et al.* 1985). Distribution of areas with low canopy cover indicate areas where the addition of a vegetative buffer may have significant impacts on stream temperature. Greater canopy cover throughout the basin increases transpiration and water retention within the basin, potentially lowering the potential for stream flooding and erosion after rainfall.	Calculated the mean canopy cover value for this NLCD layer within the target area.
	Natural Cover	H2_Nat	Health	Riparian, Catchment, Watershed	National Land Cover Dataset (U.S. Geological Survey 2011)	Higher values indicate greater percentage of natural habitat cover. These are represented by darker shades of green. Values range from 0 to 100% at all scales.	All vegetation, not just forest, can potentially protect water quality by intercepting sediment from disturbances in the watershed (Dosskey *et al.* 2010). This indicator describes the proportion of the landscape composed of non-crop, non-impervious surface, and undeveloped land-use classes, including scrub/shrub, forest, and wetlands.	Calculated the area of natural land (NLDC types: Open Water [11],Barren Land (Rock/Sand/Clay)[31], Deciduous Forest [41], Evergreen Forest [42], Mixed Forest [43], Scrub/shrub [52], Grassland/herbaceous [71], Woody Wetlands [90], Emergent Wetlands [95]) and divided this area by total area in the target area. Thus, the following NLCD class types were excluded: Open Water (11); Developed, Open Space, Low Intensity, Medium Intensity, High

	Indicator	Code	Category	Applied to	Data Source	Filter Description	Reasoning	Calculations
								Intensity (21, 22, 23, 24); Barren Land (31), Pasture/Hay (81), Cultivated Crops (82).
Ecological Health	Predicted Biological Assessment Profile (BAP)	H3_BAP	Health	Catchment, Watershed	NYS Freshwater Blueprint Project (White *et al.* 2011), NYS DEC Stream Biomonitoring Unit, Division of Water (NYSDEC 2010)	Higher values indicate greater predicted diversity of freshwater insects. These are represented by darker shades of green. Values range from 0 to 9.08 at the sub-watershed scale. Values range from 0 to 9.5 at the catchment scale.	Greater richness in certain macroinvertebrate communities is usually an indicator of good water quality and ecosystem health. The Biological Assessment Profile (BAP) is an overall water quality impact score calculated by the NYS DEC's Stream Biomonitoring Unit from their sample data, obtained by plotting biological index values from five water quality indices (NYSDEC 2010). Predicted BAP values were modeled as part of the NYS Freshwater Blueprint Project (White et al. 2011).	Multiplied the length of each segment by its BAP value, and divided the sum of all weighted segments by the total length of BAP streams in the unit.
	Brook Trout	H4_BKT	Health	Catchment, Watershed	Eastern Brook Trout Joint Venture 2015	Higher values indicate larger proportions of a catchment occupied by Brook Trout. These are represented by darker shades of green. Values range from 0 to 1 at both scales.	The confirmed presence of Eastern Brook Trout serves both as an indicator of healthy stream habitat, as well as a parameter of special interest for many potential partners whose work is focused on preserving cold-water fisheries.	Divided area covered by Brook Trout Patches by the total of the target area.
	Floodplain Complex	H5_FC	Health	Riparian, Catchment, Watershed	The Nature Conservancy 2016	Higher values indicate greater proportion of the area within a Floodplain Complex. These are represented by darker shades of green. Values range from 0 to 100% at both scales.	Floodplain complexes describe larger streamside natural upland and wetland patches and provide an indicator of vegetative and riparian connectivity independent of large tracts of forest.	Divided area covered by Floodplain Complexes by the total of the target area.

	Indicator	Code	Category	Applied to	Data Source	Filter Description	Reasoning	Calculations
Ecological Health	Functional River Network	H6_FNR	Health	Catchment, Watershed	NYS Freshwater Blueprint Project (White *et al*. 2011)	Higher values indicate the presence of longer segments of a Functional River Network. These are represented by darker shades of green. Values range from 0 to 117 km at the sub-watershed scale and range from 0 to 35 km at the catchment scale.	An estimate of stream connectivity, Functional River Networks are the larger stream units unbroken by dams. This is a measure of longitudinal connectivity along streams, allowing for movement of organisms, water, sediment, and organic materials (Smith *et al.* 2008).	Summed the total length of Functional River Network Segments within the catchment, watershed.
	Matrix Forest Block	H7_MFB	Health	Riparian, Catchment, Watershed	The Nature Conservancy Eastern Conservation Science and The New York Natural Heritage Program 2006	Higher values indicate a greater proportion of target area included in a Matrix Forest Block. These are represented by darker shades of green. Values range from 0 to 100% at both scales.	The connectivity of vegetation is an indicator of habitat health. Forest blocks describe larger units of contiguous forest, and riparian zones with a higher proportion of area composed of part of a forest block are likely to have better connectivity, and be more resilient to disturbance.	Divided area covered by Matrix Forest Block by total of the target area.
	Ecological Significance	H8_ES	Health	Riparian, Catchment, Watershed	NYNHP Element Occurrences and Element Distribution Models (Conrad *et al.* 2016)	Greater values indicate the presence of more rare species occurrences of higher quality and habitat suitable for rare species. These are represented by darker shades of green. At the sub-watershed scale, values range from 0 to 23.7 and at the catchment scale values range from 0 to 43.29, and to 43.89 for riparian areas.	The presence of rare species often indicates higher biodiversity and thus higher ecological health. This metric also incorporates the condition ranking assigned by the biologist who visited the site, the date the species was last observed at the site, and locations modeled as suitable habitat for a rare species.	Calculated the average value within the target area. We used a scoring matrix that assigned higher scores to more recently observed occurrences, occurrences mapped with higher precision, and occurrences with higher Conservation Status ranks. These scores were combined with a stack of 344 plant and animal species distribution models for a final surface. For this detailed report, contact Nick Conrad, NYNHP, nick.conrad@dec.ny.gov: Conrad, N.B, A.K. Conley, T.G. Howard, and M.D. Schlesinger. 2016. Identifying biodiversity priority areas in New York and its State Parks. New York Natural Heritage Program, Albany, New York, and SUNY College of Environmental Science and Forestry, Syracuse, NY.

	Indicator	Code	Category	Applied to	Data Source	Filter Description	Reasoning	Calculations
Ecological Health	Native Fish Richness	H9_FD	Health	Catchment, Watershed	Tunison Laboratory of Aquatic Science, USGS Great Lakes Science Center (McKenna *et al.* 2015), Eastern Conservation Science team, The Nature Conservancy (Anderson *et al.* 2013a), pers. Comm. Fred Henson and Lisa Holst (NYS DEC Fisheries, 2017)	Higher values and darker shades of green indicate greater predicted presence of native fish species. At the sub-watershed scale, values range from -2.29 to 2.02. At the catchment scale, values range from -3.88 to 3.66.	We calculated native fish richness relative to stream segments within the same size, temperature, and gradient class for a given region. These areas would presumably be higher priorities for protection in conservation work.	We used the 23 stream classes outlined in the Northeast Aquatic Habitat Classification's Aquatic Habitat Guides (Anderson et al. 2013) to compare fish diversity in streams of the same class (based on size, gradient, and temperature variables). From the USGS data, we gathered the number of native species for each catchment (fish richness score). We then ranked native fish richness in a given catchment relative to those stream segments in the same region/watershed of the same stream class. The resulting values are presented as z scores, which indicates how many standard deviations above or below the mean a segment's richness score was, relative to other segments in the region of the same stream class. A catchment's score represents the Z-score value of the stream that passes through it, and the weighted average stream z-score if a catchment intersects multiple streams.

	Indicator	Code	Category	Applied to	Data Source	Filter Description	Reasoning	Calculations
Ecological Stress	Dam Storage Ratio	S1_DSR	Stress	Catchment, Watershed	TNC Freshwater Resiliency (Anderson *et al.* 2013b)	Higher values of dam storage ratio indicate greater risk of flow alteration by dams and impoundments and are displayed by greater percentiles and darker shades of burnt orange. At the sub-watershed scale, values range from 0 to 500. At the catchment scale, values range from 0 to 400.	Streams and rivers naturally meander, and progressive cycles of flooding lead to riparian habitat heterogeneity, making these areas of high diversity. Flow regulation can limit these flooding events. Without the disturbance cycle caused by flooding, there is a reduction in the input of nutrients and soil deposition, and upland species that otherwise would have been held in check by inundation of the shoreline, can begin to dominate, leading to a riparian zone indistinguishable from upland habitat. In addition to reduced diversity, these species are not adapted to flooding, making these areas potentially vulnerable to flooding risks from extreme weather related to climate change (Pringle 2001). We used dam storage ratio as an indicator of potential impacts on connectivity due to the presence and size of dams.	The TNC Freshwater Resilience project developed Dam Storage Ratio scores for each connected stream network. There may be more than one network for each catchment so we calculated a weighted mean within the catchment as follows: for each stream network section, multiply the Dam Storage Ratio score times the length of the network within the catchment divided by the total length of streams within the catchment. Then sum the result for each stream network within the catchment. The Dam Storage Ratio is an estimate of how much of each river's mean annual flow was potentially stored by upstream impoundments. The scores were based on a simplification to place rivers into one of five classes: very low <2%, low 2-10%, moderate 10-30%, high 30-50%, severe 50%+ .
	Impervious Surface	S2_IS	Stress	Riparian, Catchment, Watershed	National Land Cover Dataset (U.S. Geological Survey 2011)	Higher values indicate larger percentage of area covered by impervious surfaces and are displayed by greater percentiles and darker shades of burnt orange. Values range from 0 to 100% at all scales.	Impervious surfaces, like roads and other paved areas, increase the speed and amount of runoff because water cannot be absorbed into the soil. As such, they are an important indicator of ecological stress.	The 2011 NLCD provides a continuous measure of the percent impervious surface area within each 30 m cell. Scores represent the mean value within the target area.

	Indicator	Code	Category	Applied to	Data Source	Filter Description	Reasoning	Calculations
Ecological Stress	Landscape Condition Assessment (LCA)	S3_LCA	Stress	Riparian, Catchment, Watershed	NYNHP, (Feldmann and Howard 2013)	Higher values indicate greater levels of development stress and are displayed by greater percentiles and darker shades of burnt orange. Values range from 0 to 2164 at the sub-watershed scale, 0 to 2980 for the catchment, and 0 to 2842 for the riparian area.	The extent, quality, and distribution of alterations to the landscape surrounding a stream have profound impacts on the health of the habitat (Klein 1979). Runoff from agriculture can cause dangerous levels of sediments, nitrates, and phosphates to flow into rivers. The Landscape Condition Assessment (LCA) incorporates a suite of landscape stressors which describe the distribution and abundance of transportation, urban, industrial, and agricultural land use (Feldmann and Howard 2013).	Calculated the mean value within the target area. For more information, see Feldmann, A. and T. Howard 2013. Landscape Condition Assessment (LCA2) for New York. New York Natural Heritage Program, Albany NY.
	Known Water Impairments (Priority Waterbody List [PWI] Water Quality Assessment)	S4_WQ	Stress	Catchment, Watershed	Priority Waterbodies List (NYS DEC Division of Water 2017)	Higher values indicate a higher degree of water quality impairment and are displayed by greater percentiles and darker shades of burnt orange. At the sub-watershed scale, values range from 0 to 16. At the catchment scale, values range from 0 to 20.	The New York Waterbody Inventory/Priority Waterbodies List is a statewide compilation of water quality information that assesses overall water quality and sources of water quality impairment. Waters classified as “Impaired,” “Waters with Minor Impacts,” and “Threatened” are prioritized for intervention and restoration. “Impaired” waters have frequent and persistent water quality conditions which prevent, limit, or discourage the use of the waterbody. Waterbodies with “Minor Impacts” are considered stressed and have documented water quality impacts less severe than impaired waters. “Threatened” waters have no existing water quality problems but are included in the Priority Waterbodies List due to land use changes in the watershed that are known or strongly suspected to threaten water quality.	We created an index using the classifications of the Priority Waterbodies Inventory stream set, using three risk classes: Streams classified as "Impaired," with "Minor Impacts," and "Threatened". For the purposes of this indicator, we limited the data used to the following sources of impairment: Nonpoint Sources (Agriculture, Urban/Storm Runoff, OnSite Wastewater Treatment/Septic Systems, Silviculture, and Construction) and Physical/Other Alteration Sources (Habitat Alteration, Hydrologic Alteration, Streambank Erosion, Roadbank Erosion). Point Sources, Legacy Sources, and “Other Sources” were not included in our analysis (NYS DEC Division of Water 2015b). Sources included in the score are displayed in the pop-up window when clicking on a unit. Using this subset of the PWI data for nonpoint and physical alteration sources, we added up all impact sources attributed to a segment as follows: 4*(# of sources of impact classified

	Indicator	Code	Category	Applied to	Data Source	Filter Description	Reasoning	Calculations
								as "Impaired)+2*(# of sources of impact classified as "With Minor Impacts")+1*(# of sources of impact classified as "Threatened"). A unit received the sum of all scores for the segment that passes through it, or the weighted average (based on the length of the stream segments) if there were multiple stream segments in a given unit.
Ecological Stress	Erosion Index	S5_EI	Stress	Catchment, Watershed	10 m Digital Elevation Model (NYSDEC 2005), SSURGO soil data (Natural Resources Conservation Service, USDA 2012)	Higher values indicate greater potential for erosion; these areas have steep slopes and high upslope contributing areas and are displayed by greater percentiles and darker shades of burnt orange. At the sub-watershed scale, values range from 0 to 30. At the catchment scale, values range from 0 to 9878.	The Erosion indicator highlights cells that receive runoff waters from large upslope contributing areas and have steep slopes and thus are at greater risk for erosion adjacent to the stream bank (Tomer *et al.* 2003).	We calculated the erosion raster from a 10 m DEM in ArcGIS. After calculating flow accumulation (flow_acc) and degree slope (slope), an erosion raster was created using the formula (Tomer et al. 2003): Erosion_index = (flow_acc*10.0/22.1)^0.4 * (Sin(slope*0.01745)/0.09)^1.4 . We used the Soil Erosion Hazard class in the New York SSURGO data to get a rough indication of potential erosion hazards due to erodibility. The erosion raster was multiplied by the Soil Erosion Class to get the final erosion score. Scores represent the average value within the riparian zone.
	Topographic Wetness Index (TWI)	S6_TWI	Stress	Catchment, Watershed	10 m Digital Elevation Model (NYS DEC 2005)	Higher values indicate areas where water may push across the landscape as a sheet; with high upslope contributing areas and low slopes. These are displayed by greater percentiles and darker shades of burnt orange. At the sub-watershed scale, values range from 0 to 13. At the catchment	For the reduction of sediment and the amelioration of runoff, buffers will be most successful at slowing the speed of surface runoff when they are placed in areas where water collects from a large upslope area and moves across the riparian zone as a distributed flow, like a sheet. This wetness index targets these areas by identifying grid cells that both receive runoff waters from large upslope areas and have low slopes.	Calculated as $W=\ln(A_s/\tan\beta)$, where As is the upslope contributing area and β is the slope (Tomer et al. 2003). We calculated the TWI using a 10 m DEM in ArcGIS. After calculating flow accumulation (flow_acc) and degree slope (slope), a twi raster was created using the ArcGIS Python formula: twi = Ln((flow_acc*100.0)/(Tan(slope))). Scores represent the average value within the riparian zone.

	Indicator	Code	Category	Applied to	Data Source	Filter Description	Reasoning	Calculations
						scale, values range from 0 to 23.9.		
Resiliency to Climate Change	Terrestrial Resilience	R1_TR	Resilien ce	Riparian, Catchment, Watershed	TNC Terrestrial Resilience (Anderson *et al.* 2012)	Higher values indicate greater landform diversity and connectivity and are displayed by darker shades of blue. Values range from -3501 to 2583 for the sub-watershed scale, from -3501 to 3500 for riparian areas, and from -3501 to 3485 for catchments.	A larger variety of landform types and higher connectedness among these types in an area gives species more opportunity to respond to climate change. If plants and animals are provided a larger range of environmental conditions then the populations as a whole are likely to be more resilient to global changes in climate.	Calculated the average resilience score within the target area, which was developed by TNC from their own landscape complexity and local connectedness scores (Anderson et al. 2012).
	Temperature Classes	R3_TC	Resilien ce	Catchment, Watershed	TNC Freshwater Resiliency (Anderson *et al.* 2013b)	Higher values indicate stream networks with more temperature classes, displayed by darker shades of blue. Values range from 0 to 4 at both scales.	Water temperature influences not only which organisms can persist in a stream system, but changes in temperature can cue migration, fecundity, emergence, and development of those organisms. The presence of more temperature classes in a network presumably indicates greater resiliency, offering options for more types of coldwater and/or warmwater species and providing connectivity within appropriate habitats for these species.	The TNC Stream Resilience dataset (Anderson et al. 2013) counts the number of temperature classes for each connected stream network (streams undivided by dams). There may be more than one network for each unit so we calculated a weighted mean within the unit as follows: for each stream network section, multiply the temperature class score times the length of the network within the unit divided by the total length of streams within the unit. The results for each network section are then summed within the unit. The four potential temperature classes are cold, cool transitional, warm transitional, and warm.

	Indicator	Code	Category	Applied to	Data Source	Filter Description	Reasoning	Calculations
Resiliency to Climate Change	Size Classes	R4_SC	Resilience	Catchment, Watershed	TNC Freshwater Resiliency (Anderson et al. 2013b)	Higher values indicate stream networks with more size classes, displayed by darker shades of blue. Values range from 0 to 9 at both scales.	Stream network complexity or the variety of different sized streams and lakes within a network provide for a greater variety of biological assemblages as physical habitats change in aquatic environments with changes in size.	The TNC Stream Resilience dataset (Anderson et al. 2013) counts the number of size classes for each connected stream network. There may be more than one network within each unit so we calculated a weighted mean with the unit using the same method as for Temperature Classes. The nine potential size classes are 11: Headwaters 0<10 sq.km, 12: Creeks >=10 < 100 sq.km., 20: Small Rivers >=100 < 518 sq.km., 31: Medium Tributary Rivers >= 518 - 2590 sq.km., 32: Medium Mainstem Rivers >= 2590 < 10,000 sq.km., 40: Large Rivers >=10,000 - 25,000 sq.km., 50: Great Rivers >= 25,000 sq.km., SL: small-medium lakes 4.1 – 404.7 hectares (10-1,000 acres) , LL: large lakes >404.7 hectares (>1,000 acres).
	Gradient Classes	R5_GC	Resilience	Catchment, Watershed	TNC Freshwater Resiliency (Anderson et al. 2013b)	Higher values indicate stream networks with more gradient classes, displayed by darker shades of blue. At the sub-watershed scale, values range from 0 to 8. At the catchment scale, values range from 0 to 4.	A greater variety of different gradient classes for streams and rivers within a network provide for a greater variety of microclimates, habitats, and flow velocity and therefore a greater diversity of biological assemblages.	The TNC Stream Resilience dataset (Anderson et al. 2013) counts the number of gradient classes for each connected stream network. There may be more than one network within each unit so we calculated a weighted mean within the unit using the same method as for Temperature Classes. The gradient classes are Streams: <0.1 percent, 0.1-0.5 percent, 0.5-2 percent, >2 percent, Rivers: <0.02 percent, 0.02 < 0.1 percent, 0.1 < 0.5 percent, >= 0.5 percent.
Social	Citizens Statewide Lake Assessment Program (CSLAP)	C1_CS	Social	Catchment, Watershed	CSLAP (NYS DEC and NYSFOLA 2016)	Higher values indicate more citizen science activity	Sub-watersheds with existing social involvement in citizen science may have higher potential for successful collaborations in future	Summed the number of CSLAP sampling events within the sub-watershed or catchment.
	Water Assessments by Volunteer Evaluators (WAVE)	C2_WA	Social	Catchment, Watershed	WAVE (NYS DEC Division of Water 2015a)	Higher values indicate more citizen science activity	Sub-watersheds with existing social involvement in citizen science may have higher	Summed the number of WAVE sampling events within the sub-watershed or catchment.

	Indicator	Code	Category	Applied to	Data Source	Filter Description	Reasoning	Calculations
							potential for successful collaborations in future	
Social	Trees for Tribs Plantings	C3_TT	Social	Catchment, Watershed	Trees for Tribs Program (NYS DEC Division of Lands and Forests 2016)	Higher values indicate more citizen science activity	Sub-watersheds with existing social involvement in citizen science may have higher potential for successful collaborations in future	Summed the number of Trees for Tribs planting events within the sub-watershed or catchment.

Appendix B. Analytical Methods for Riparian Buffer Delineation

We utilized the Riparian Buffer Delineation Tool, created by Sinan Abood, to define the riparian boundary. You can request a copy of the tool here: http://www.sfi.mtu.edu/muses/GIS_Riparian.htm. The riparian boundary is defined based on input which includes: a 10 meter Digital Elevation model, a streams layer derived from NHDFlowlines, a lakes layer, a value for the 50 year flood height, a maximum transect length, and a wetlands layer. The tool is available as an ArcGIS toolbox, an example of the interface is shown in Figure 23.

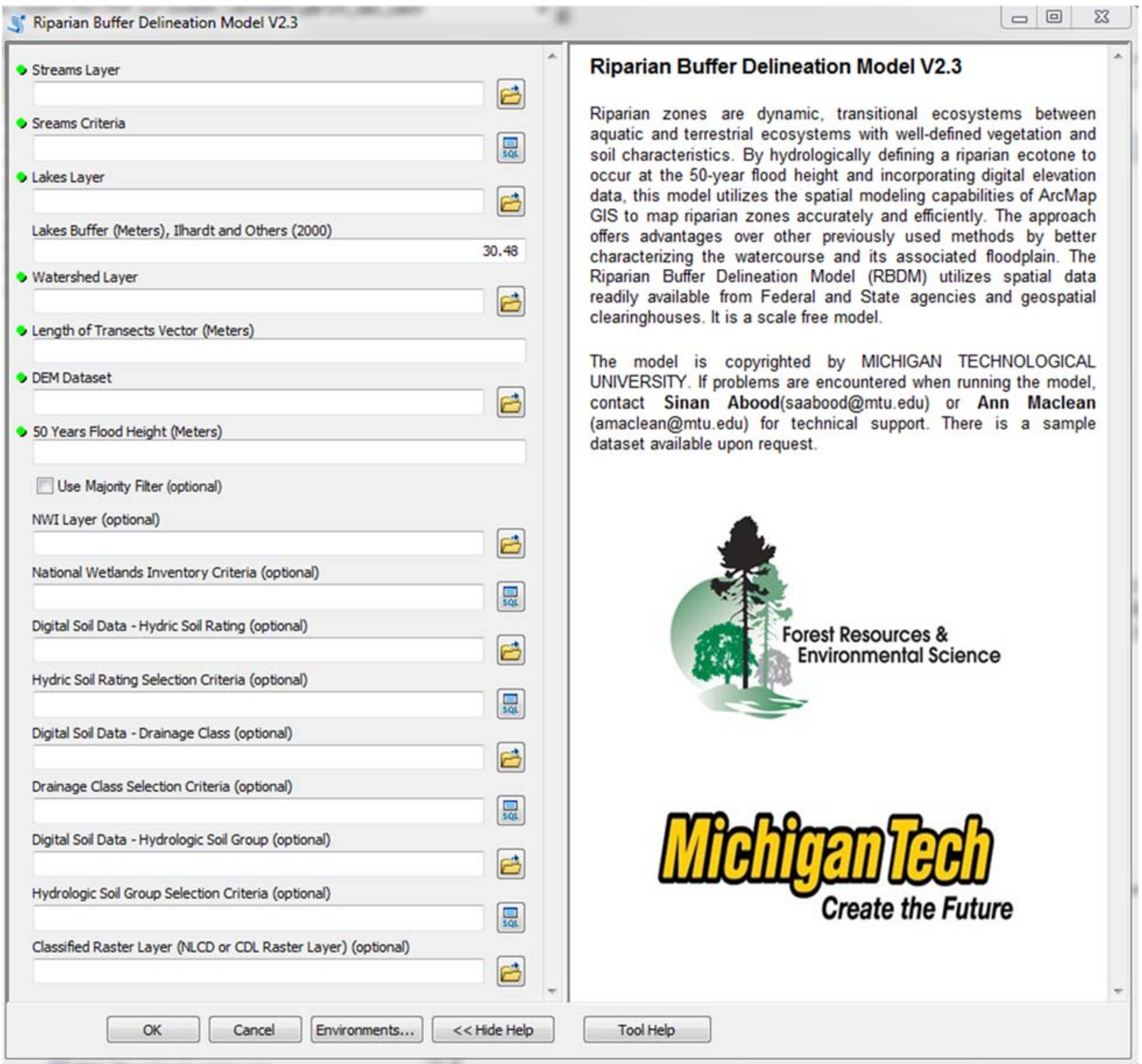


Figure 23. Riparian Buffer Delineation Tool Interface. We used version 2.3.

Calculating 50 Year Flood Height for Gages in basins statewide:

The Riparian Buffer Delineation Tool defines the riparian zone as the area within the 50 year floodplain. This requires an estimate of the 50 year flood height for each area of interest. Estimating the 50 year flood height for each sub-watershed in our study area required gathering flow data about streams throughout New York State. The methods in Abood (2012) describe how to estimate the 50 year flood height from the annual flow data and field measurements available for gaged sites. These data are available from the US Geological Survey's Surface-Water for the Nation web interface: http://waterdata.usgs.gov/nwis/sw.

We downloaded the annual flow data and field measurements for 164 gages in the state and calculated the estimated 50 year flood heights. They are available in Table 4.

Gathering Data on Stream Flow and Channel Width at Ungaged Sites:

Because of the limited availability of gage data in the state, for many sub-watersheds, there was not a gage nearby. Assigning a 50 year flood height based on flow dynamics at the nearest gage, which could be relatively far away, perhaps on a much larger river than any that flows through that sub-watershed, would not likely reflect the flooding dynamics of that area well.

While a complete set of annual and field measurement data were not available for all 1663 sub-watersheds, we were able to collect simple measures of stream size and flow using the USGS StreamStats service. StreamStats provides estimates of flow rates and channel width at ungaged sites throughout the region. StreamStats service can be found here: http://water.usgs.gov/osw/streamstats/.

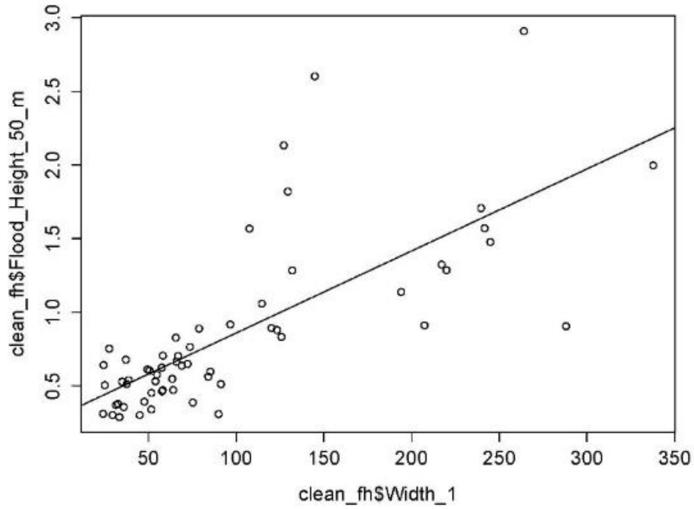
We generated 10 random points on streams in each sub-watershed, and submitted those points to StreamStats. We were returned data on16.706 points, which describe many estimates of flow rates and channel attributes, including the bankfull width.

Estimating Floodheight from Bankful Width:

We calculated the 50 year flood height for the gaged stations in the state and used the results to plot the relationship between 50 year flood height and 1 year flood event channel width.

This relationship was necessary because the kind of annual data and field measurements associated with the gaged data are not available for the stream stats points. In order to leverage the additional information the stream stats points provide us about the distribution of stream size in the region, we needed a way to estimate the 50 year flood height from one of the metrics Stream Stats provides.

Bankfull width was a stream metric delivered by Stream Stats that was most consistently populated for stream points submitted. It represents the stream channel width that contains the flow associated with 1.5 year flood events. From the gage data, we could estimate the relationship between the 50 year flood height and the 1 year channel width for the 50 gages in the area (Figure 24).



$$y = 0.0055717 * x + 0.3016949$$

Figure 24. Plot of 1 year channel width against estimated 50 year flood height based on annual flow data and field measurement for 59 gages in the Great Lakes Basin.

We used the equation of the best fit line to then estimate the 50 year flood height for each Stream Stats point by plugging in the bankfull width value for "x" to get an estimate of 50 year flood height. We used the same equation from the Great Lakes Basin to estimate flood heights for the statewide stream stats points. This allowed for more consistency between the buffers created for the Great Lakes project and the new buffers created for the rest of New York. The estimated flood heights ranged in value from 0.3 to 2.4 meters. Users of should be aware that these are likely conservative estimates of flood heights.

Assigning 50 Year Flood Height Value to HUC 12:

Because the Riparian Buffer Delineation Tool currently uses only a single 50 year flood height to describe an area, we needed to assign a single flood height to each HUC 12 before we could run the tool. We did this using the set of points we had generated for StreamStats and their associated 50 year flood height estimates which we had calculated above. We subdivided the points based on HUC 6 (Regions). This was necessary to ensure each sub-set of points was sufficiently large so that it contained points that described flood heights for streams of varying size, while also ensuring that the flood heights were taken from streams in a sufficiently similar area (we wouldn't want the flow dynamics of the Genesee River to be used to estimate floodplains in the Black River Basin).

Sub-dividing the points allowed us to see the range of estimated flood heights from the random points we had submitted. These came from streams of varying size, and because the majority of these streams are headwaters, the distribution is skewed towards smaller streams. We chose to assign a flood height to a HUC 12 based on the size of the largest stream in the sub-watershed. To estimate relative stream size, we used the StreamOrder function in ArcGIS on the rasterized stream layer. Strahler stream order assigns stream order based on position in a network: the "tips," or headwaters receive a value of 1, and values increase as branches merge together. The highest order stream in our study area had an order of 7.

From the points in each sub-region, we calculated the 25th, 50th (mean), 75th, 90th, 99th, and 99.5th percentile of estimated flood heights (Table 4). The maximum values were not used to avoid having an entire region being skewed by one gage. Based on the maximum stream order of the HUC 12 and the maximum stream order of the HUC 6 (within New York), each HUC 12 was assigned a flood height based on the distribution of estimated 50 year flood heights in its sub-region.

Table 4. Rubric for Assigning 50 Year Flood Heights to HUC 12 Sub-Watersheds based on Stream Order

	Highest Stream Order in HUC 12						
Highest Stream Order in HUC 6	**7**	**6**	**5**	**4**	**3**	**2**	**1**
7	99.5th	99th	95th	90th	75th	50th	25th
6		99.5th	99th	95th	90th	75th	50
5			99.5th	99th	95th	90th	75th
3					99.5th	95th	75th

Cell values refer to percentiles of predicted flood height values within the HUC 6 Region.
Most regions had maximum stream order of 7 or 6, no regions had a maximum stream order of 4.

The assigned flood heights for each HUC 12 can be found in Appendix E which is available as supplemental material on our project webpage (www.nynhp.org/treesfortribsny).

This method involves considerable estimation and extrapolation; however, we considered it the best compromise possible given the nature of the available data, the size of our study area, and the ultimate purpose for the riparian zone we use them to define. It is important to stress that the estimated flood height values have not been verified. **We provide them here to give as much information and transparency as possible about the development of the riparian buffer layer, but they should not be used for other purposes.**

Stream, Wetland, and Lake Selection for Riparian Buffer Delineation Tool:

The NHDFlowlines include some stream segments for waterbodies we considered unsuitable for modeling the riparian zone, such as pipelines and aqueducts. When running the tool, we included only streams with the following “Ftype” codes from the NHDFlowlines data set: Stream/River (460), Coastline (566), Connector (334), and Artificial Path (558).

The Riparian Buffer Delineation Tool takes several additional input layers to describe the riparian zone. We included a wetlands layer from the National Wetland Inventory, including all polygons which were classified as “Riverine”, “Freshwater Emergent Wetland”, and “Freshwater Forested/Shrub Wetland”. Whenever the buffer estimated by the tool intersects an existing wetland polygon, the buffer is expanded to incorporate the entire wetland polygon.

All lakes were supplied as a separate polygon class.

Running the Riparian Buffer Delineation Tool:

We used a filled, 10 meter digital elevation mode, which we subset by HUC 12 as our DEM source. We also subset our streams, lakes, and wetlands layers by HUC 12, and a feature class containing a single HUC 12 polygon was used as the Watershed boundary. We set a sampling distance of 200 meters for the transect vector and assigned 50 year flood heights according to the values in Table 4. We used the recommended lake buffer distance of 30.48 for most lakes and ponds.

The tool was run once for each HUC 12 in the state and the resulting polygons were merged to create the riparian zone layer.

Appendix C. User Orientation Guide to ArcGIS Online Maps (AGOL) maps.

We provide our results as two interactive AGOL maps, one providing results at the sub-watershed or HUC 12 scale (https://arcg.is/0GH18v), and one at the catchment scale (https://arcg.is/0TPKWC). Both may be accessed from our project website at http://www.nynhp.org/treesfortribsny. You can view the map and access any of the functions described below without signing in or creating an account. Please refer to the methods section of this report and associated Appendices for full details on habitat, social, and resiliency indicators included in these results and how they were calculated.

We recommend beginning with the AGOL maps if you want to gain a statewide overview or orientation to the data, view the catchment data from multiple sub-watersheds, view details about indicator scores or data sources, view filter data (Urban, Agricultural, or Public land), explore the connectivity theme or community involvement score.

Initial View

After clicking on the link to the **sub-watershed** map, the initial view is that of New York State with topography as a base layer and the comprehensive score layer displayed on the map with a legend of the color ramp and scoring in the left panel. As detailed in the Methods, scores at the sub-watershed level describe a sub-watershed's condition relative to the scores of all other sub-watersheds in New York State.

After clicking on the link to the **catchment** map, the initial view is that of catchments in the Albany area with topography as a base layer and the comprehensive score layer displayed on the map with a legend of the color ramp and scoring in the left panel. As detailed in the Methods, scores for the catchments were ranked relative to other catchments within the same sub-watershed, not relative to every catchment in the state.

Map Orientation

Within the data frame (map view), you will see a "+" and "-" option in the upper left corner that allows you to zoom in and out of the map and you are able to pan around the state by clicking and dragging your mouse across the screen, just as you would with the google maps application. By clicking on a sub-watershed or catchment with your mouse, you will select it and a box will pop up displaying the HUC 12 ID and name (and catchment number in the catchment map) and scores associated with this unit.

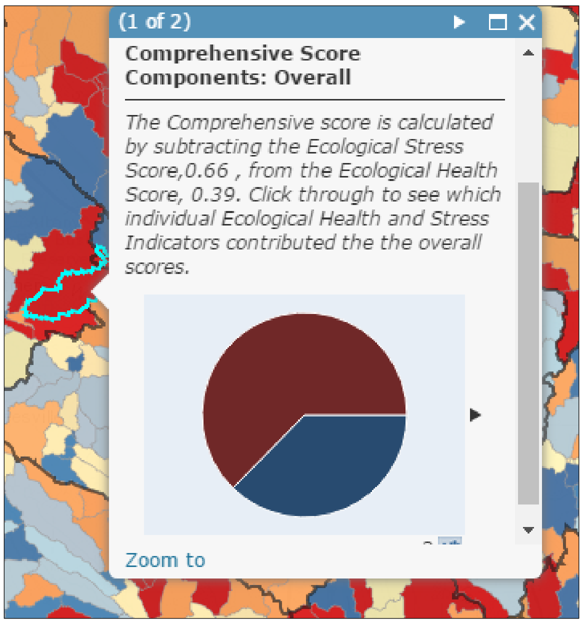
To change your basemap, simply click on the "basemap" button in the upper left of the toolbar. Then select "imagery" for aerial photography, "streets" for a roads layer, or select any other basemap you desire. You will see 12 different options.

You may type in an address, place, or coordinates to zoom to in the search window at the top right of the screen, above the map. An alternative method to zoom to coordinates, is by clicking on the Measure button, then the Location button, and then watching your Latitude and Longitude change as you pan your mouse across the map.

To access all of our data layers, click on the "Content" tab located just under the "basemap" button, at the top of the left panel. You will see a list of all the indicators and metrics listed in order of their code (found next to each indicator in Appendix A). Here you can click on the checkbox to turn layers on, and uncheck the box to turn them off again. Clicking on the "…" that appears when you hover over the layer name will reveal the "Transparency" option, that allows you to adjust the layer's transparency.

Filters are available in the catchment map only and are described in more detail in the Methods and Appendix A. When these layers are turned on, any areas not meeting the filter's criteria will be displayed in gray.

By clicking on a unit (sub-watershed or catchment, depending on the map) with your mouse, you will select it and a box will pop up displaying the scores associated with this unit for any layer turned on. In the pop-up window, you will be able to see the raw score for the unit, the catchment number (if applicable), sub-watershed name and ID, the percentile this unit score ranks in for the area, and a description of the layer's purpose and source data. Also included for any composite score (those scores calculated using a combination of layers in the map) is a pie chart, visually summarizing components within the aggregated score. Viewing this information usually requires scrolling down the pop-up window. Or you can hit the “maximize” icon to make the window much larger. For instance, if you click on a catchment with the comprehensive score layer turned on, you will see a pie chart in the pop-up window depicting the relative contributions of stress and health component indicators to the overall score. Below the chart, in the lower right corner, is a small plot icon with a number ‘3’. This indicates that there are 3 informative charts for this score. Clicking on the small black arrow to the right of the chart will allow you to view charts describing the relative contributions of individual indicators to the Health and Stress scores respectively. If more than one layer is turned on when you click on a unit, you will be able to scroll through this summary information for each layer by clicking on the white arrow at the top of the pop-up window:

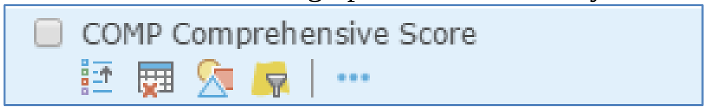


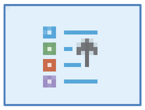
Due to the precision of the cursor, at some scales clicking on a unit will select units that are adjacent to it. Clicking through the pop-ups using the white arrow in the blue bar at the top of the window will also cycle through the scores for all units selected.

You can zoom tightly in on a unit from the pop-up window by clicking “Zoom to” in the lower left.

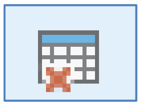
When a filter is turned on (in the catchment map), the pop-up window will display whether the catchment meets the criteria.

If you click on the name of the layer (i.e. COMP Comprehensive Score), you will also see several icons below the name, offering options available to you. These are described below.

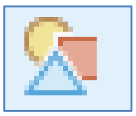




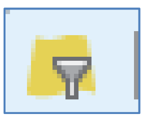
Show/hide legend



Show/hide Data Table. This allows you to see the data associated with the layer in tabular form. You will see the unit names and all the scores for individual metrics for an indicator. You can select rows in the table and show additional columns by going to the "options" drop down in the top right corner of the table, you have options to "show selected records", "center on selection", "clear selection", "show/hide columns", or "filter" on a specified expression.



Change style; select a different drawing style than the default one displayed. For the sake of consistency, we present the data classified according to percentiles in most cases. All the Health indicators are presented in shades of green, Stress indicators in red, Resilience indicators in Blue, and Community and Social Involvement indicators in Purple.



Filter; specify a particular expression to filter the data on

Zoom to this layer, set transparency (for instance if you want to be able to see the basemap below it or other data layers).

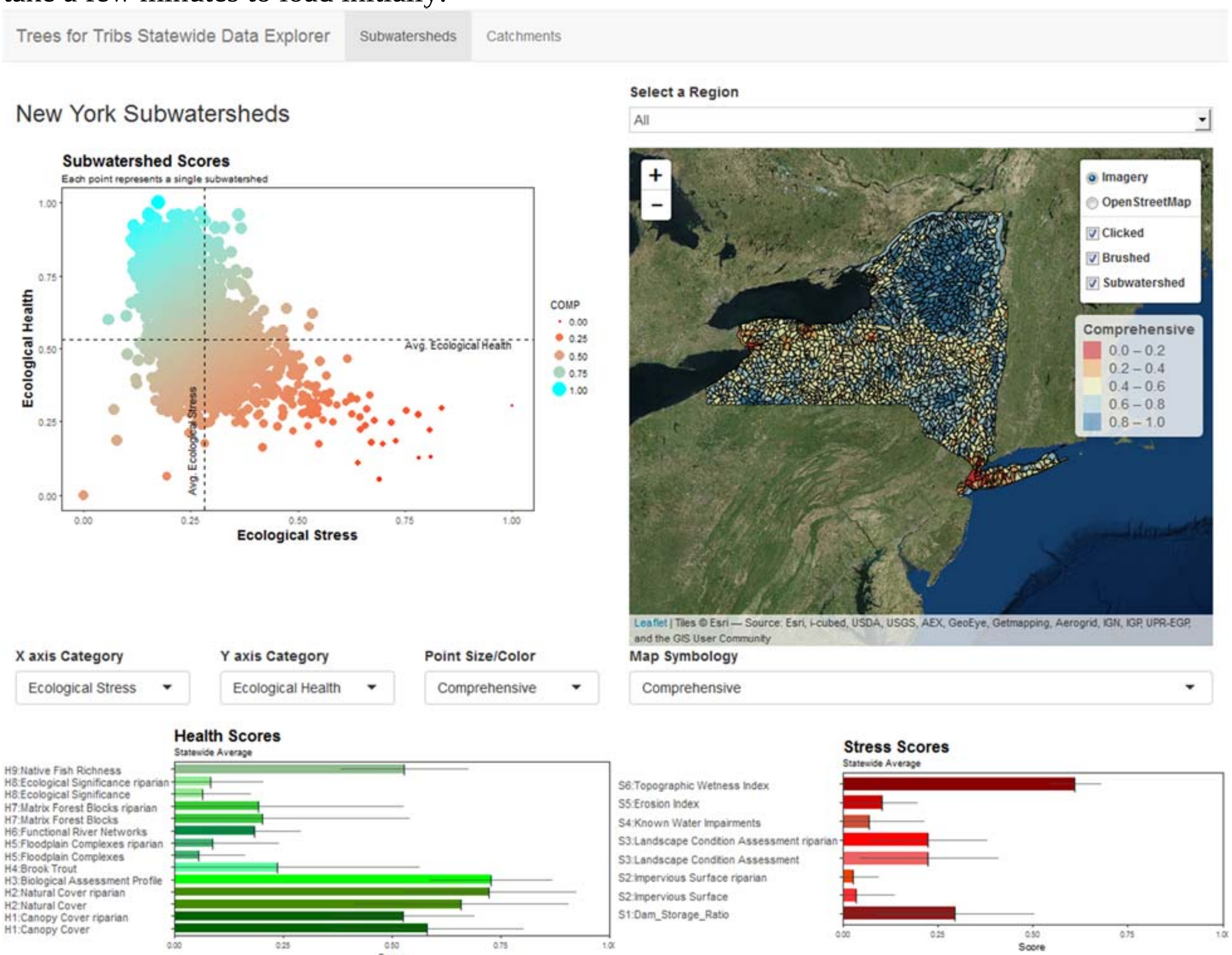
The Indicator table in Appendix A contains the descriptive information for each habitat, resiliency, and social indicator and metrics (including themes-catchment map only), containing a justification for including the indicator in the analysis and a summary our calculations.

Appendix D. User Orientation Guide to Data Explorer

Features Overview

We designed the Data Explorer as an additional way to view the results of the NY Riparian Opportunity Assessment and use them to assist with prioritizing locations for conservation management.

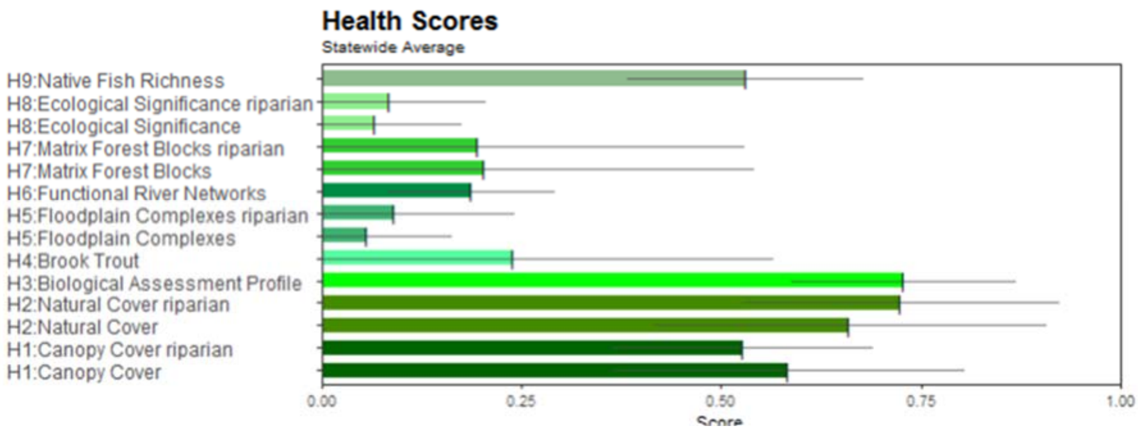
You can access the Data Explorer at lab.nynhp.org/trees_tribs_ny/data_explorer. It works best using the Firefox browser. Internet Explorer should be avoided at this time. Depending on the connection speed it may take a few minutes to load initially.

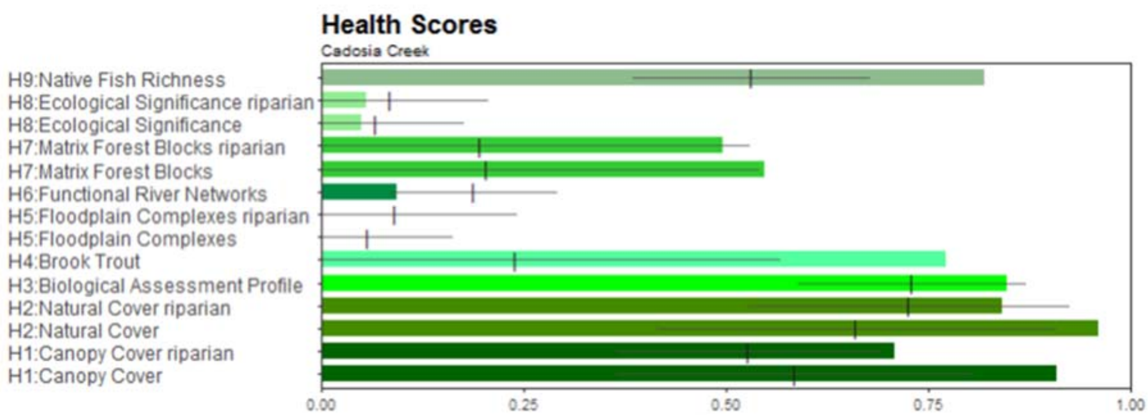


The Data Explorer primarily consists of two elements: an **online map** (top right above) and **an interactive "bubble plot"** (top left above). The map displays the outlines and assessment scores for sub-watersheds, like a simplified version of the ArcGIS Online (AGOL) map. It can also subset the data to focus on a region of interest. The map is zoomable and is built with two base layers- an aerial imagery layer and the Open Street Map. The bubble plot displays sub-watershed scores as points on a scatter plot. Both elements are customizable; users can choose from a set of drop down menus to adjust which region is displayed, which indicator values determine polygon color or the color and size of the points on the plot, and which values are plotted on the x and y axes. The elements also interact with each other- clicking on a sub-watershed on the map will add a bold dashed outline to that polygon and circle the point on the bubble plot that corresponds to that sub-watershed; selecting a group of points on the plot will also highlight their polygons on the map in bright pink.

The Data Explorer has two tabs- whose names are visible in the bar at the top of the page, one for data at the sub-watershed level and one for catchment level scores. Both tabs display maps and bubble plot information. The sub-watershed tab opens automatically and can show data for all sub-watersheds in NY or only those in a specific region. The catchments tab shows all catchment polygons and scores for only one sub-watershed at a time. Selecting a sub-watershed by clicking on it in the first tab will automatically display the data for that sub-watershed in the catchments tab. There is also a field on the catchments tab where users can manually switch the data displayed to that of another sub-watershed by entering its 12 digit HUC number.

The sub-watershed tab also has a dashboard at the bottom that displays each of the health and stress indicator scores for the sub-watershed on two bar plots. The dashboard allows users to see all of a sub-watershed's scores at a glance-rather than turning on and off layers on the AGOL map or the Symbology drop down menu. The statewide mean is displayed as a small vertical line on the plots, the standard deviation represented as grey whiskers, so users can get a rough idea of how a sub-watershed's score compares to the rest of the state. If a bar on the plot extents to the right of the vertical line, the sub-watershed scored higher than the state average. If the bar fails to reach the vertical line, the sub-watershed scored below the state average. In cases where a sub-watershed's score is zero, for example if there are no floodplain complexes, the bar will be absent. If no sub-watersheds have been clicked, or if a user clicks outside the polygons, the dashboard reflects the statewide average.



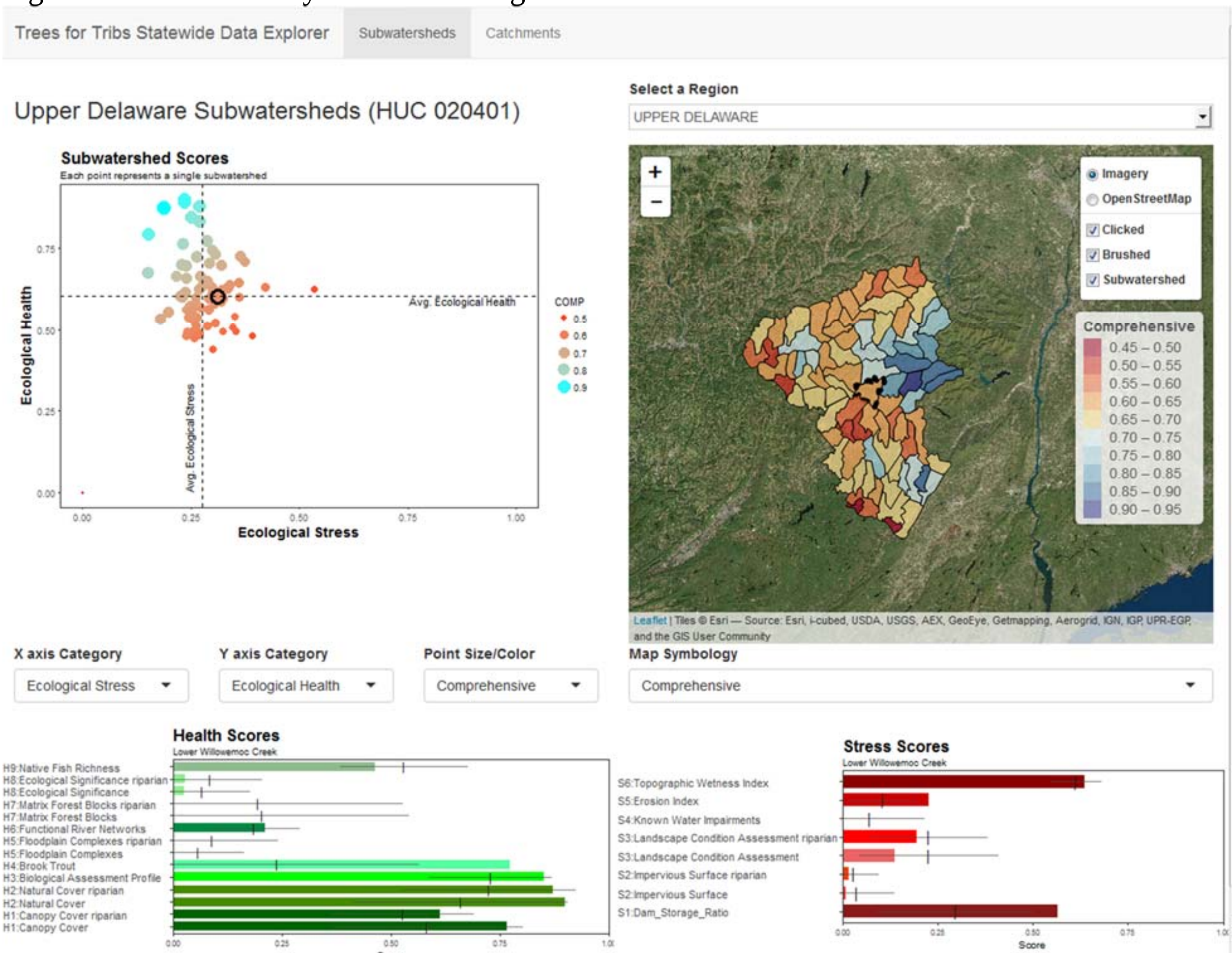


Use Guide

What questions are best answered using the AGOL Map rather than the Data Explorer: The ArcGIS Online maps at the sub-watershed and catchment levels remain the best tools for doing **broad scale assessment**. If a project is asking questions that encompass the entire state, or you are **just starting out in a project** and are using our results to orient yourself by learning about which parts of the state are the most stressed, resilient, or healthy, then viewing the results using the online maps will be most effective. The statewide maps have more detailed polygons, and full descriptions of the environmental variables and metadata involved in the analysis.

Using the Data Explorer to prioritize within a region

The Data Explorer becomes more useful for projects where users may already have an idea about which region in New York they will be working.



In the example above, we have selected the “Upper Delaware” region from the dropdown menu above the map. This has changed the bubble plot so that only the values for the Upper Delaware HUC 6 are shown, and the map has limited the polygons displayed to those in the Upper Delaware region and zoomed to them. It is important to note that the map also automatically scales the colors, with the maximum and minimum values reflecting not the statewide maximum and minimums, but just the scores within the selected region. This can be helpful if you are more interested in knowing “where are the highest or lowest scores in this area” as opposed to “where are the highest scoring areas in the state”?

Using the bubble plot to prioritize based on general Health and Stress values

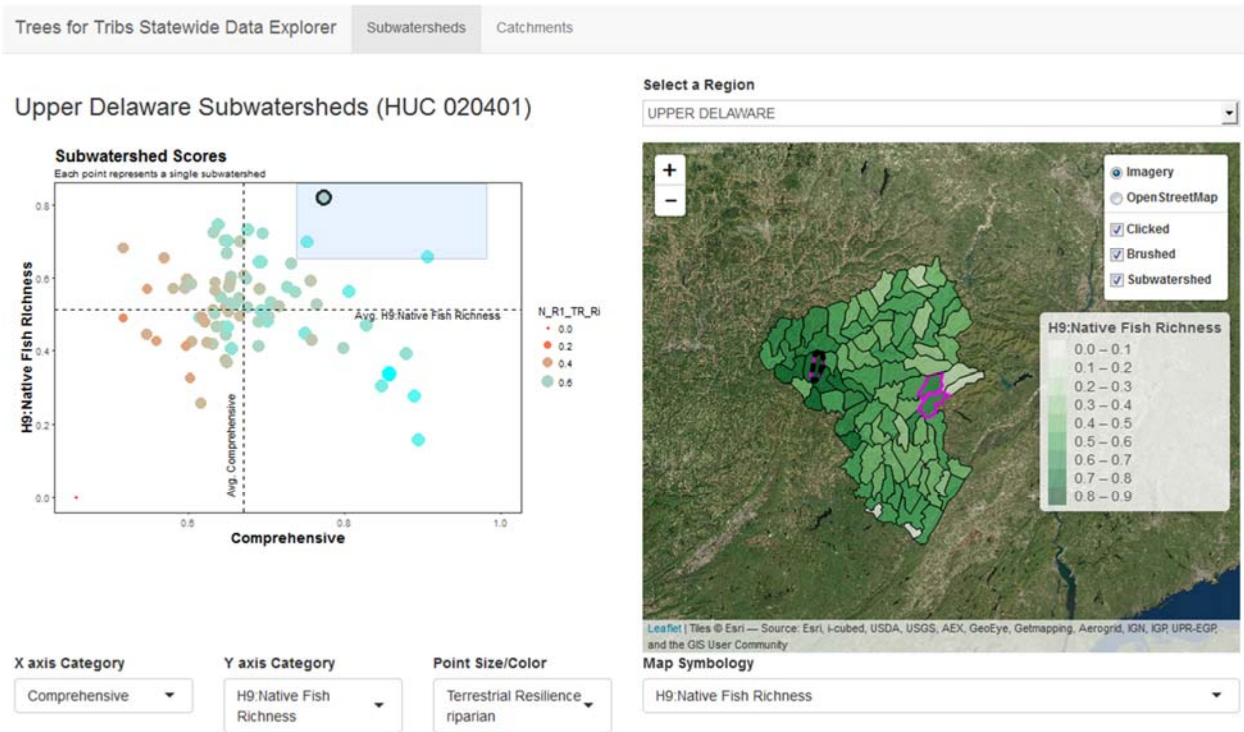
The bubble plot’s default setting plots Ecological Stress along the x axis and Ecological Health along the y axis. The plot is divided by a dashed vertical line that represents the average Stress score in the region. Points to **the left** of that line **are less stressed** than average, and points to **the right** of that line are **more stressed** than average. The plot is also divided by a dashed horizontal line that represents the average Health score in the

region. Points falling **above this line** are doing **better than average**, points falling **below this line scored worse than average**.
In this initial setup, the lines can handily divide the plot into quadrants for prioritization.

- Points that fall into the **upper left quadrant** have higher than average Health scores and lower than average Stress scores. These areas are doing well, relative to the rest of the region. They might **make good targets for protection**. To see where these areas are in space, we can select the points by clicking and dragging on the plot to make a box, and those points selected will be highlighted in pink on the map.
- Points that fall in **the lower right quadrant** are the most stressed and least healthy sub-watersheds in the region. These are the areas in **greatest need of restoration.** However, in areas with particularly high levels of ecological stress, it is **more challenging** for any single conservation management project to have an impact. But this quadrant may identify areas that could be targeted by multiple partners, particularly in areas that lay adjacent to high scoring habitat. Improving these areas may not be successful in returning them to a pristine state, but even small improvements may reduce the threat to existing healthy habitat in adjacent sub-watersheds.
- Points that fall in **the lower left quadrant** could also benefit from remediation, but are at less risky target due to lower exposure to ecological stressors. These sites may provide **good "bang for your buck"** in terms of riparian buffer planning.
- Points that fall in the **upper right** have both higher than average health scores and are also being influenced by higher than average levels of ecological stress. While appearing to do well, these may also be priority targets for restoration or protection, because the high stress levels pose a risk to the existing healthy habitat.

Customizing the bubble plot: Topic of interest

Another way to quickly assess areas of greatest need is to plot the Comprehensive Score along the X axis, and then plot the value for an indicator of interest, for example, Native Fish Richness, along the Y axis. Using the Comprehensive score is a quick way to get an overview of a sub-watershed's overall condition and then you can use the distribution along the Y axis to focus on a value closely correlated with your project.



In this setup, points that lay to the right of the dashed lined labeled “Avg Comprehensive” have the highest comprehensive scores, and points to the left have the lowest. And points that lie near the top of the plot have the highest values for Native Fish Richness. If you wanted to target your protection activities in areas with overall good health and high existing native fish richness, you would focus on those points in **the upper right hand quadrant**.

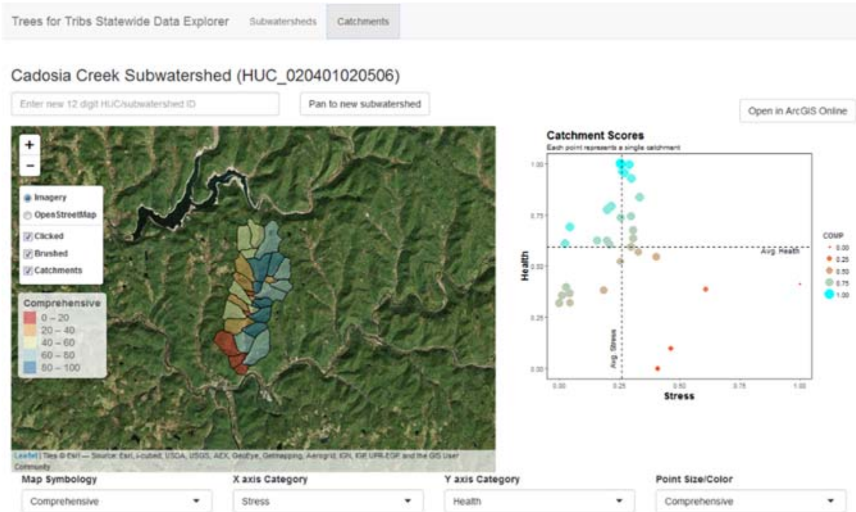
Adding in additional criteria using point size/color and map color

Say you *also* wanted to focus your efforts on areas that are likely to be resilient to climate change. Particularly in the riparian zone. You can use the Point Size/Color drop down menu to change the point size to reflect the score for terrestrial resilience in the riparian zone. Now points that are larger and bluer will be the most resilient, while their position on the plot will tell you their overall health, and native fish richness.

In the example above, we have highlighted the most resilient sub-watersheds (biggest and bluest points) that also have higher than average comprehensive scores and higher than average native fish richness. They are displayed on the map in pink. We also changed the color of the map to reflect the native fish richness score, but you could also use the Map Symbology drop down to see the values for a different variable, like where Community involvement might be high, providing you a potential source of volunteers to help with your project. We have clicked on the darkest polygon, with the highest native fish richness value, which is circled in black on the plot. It is also outlined on the map, in case you forget which polygon you clicked on.

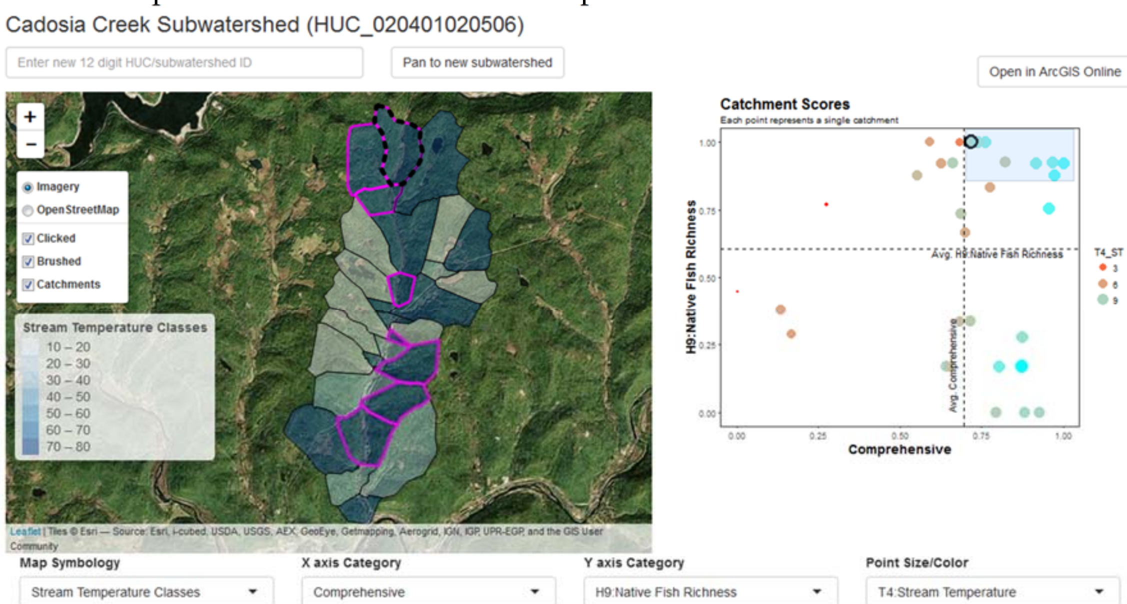
Catchment Prioritization

If you click on a sub-watershed in the main page, then click on the Catchments tab, you are taken to a new tab that shows all the catchments for the sub-watershed you selected using the tools on the sub-watershed tab.

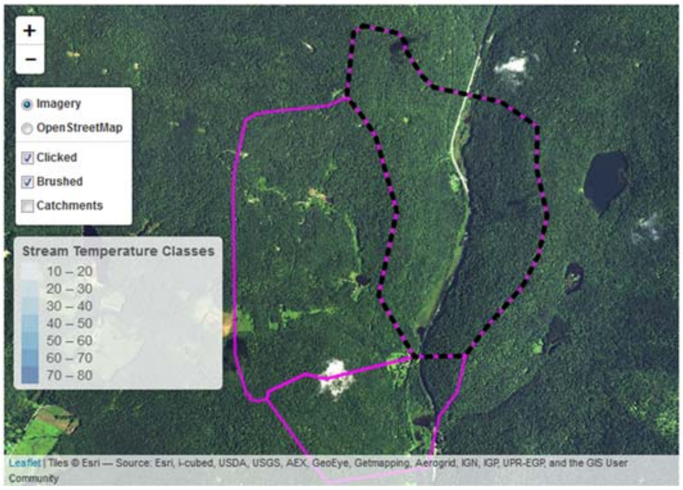


You can use the same tools at the catchment level to prioritize work within the sub-watershed that you did to prioritize which sub-watershed to evaluate.

In this case (below), we once again used the Comprehensive Score and the Native Fish Richness score to set up the bubble plot, to identify those catchments in the sub-watershed in overall good condition and high native fish richness. Stream temperature is an important habitat feature for some fish species, so we used the Stream Temperature theme to control bubble size and color. We chose to symbolize the colors of the catchments per their score in the Stream Temperature Classes resilience indicator.



We can also zoom in to get a better idea of what is happening on the ground by looking at imagery or the street map. In this case, unchecking the "catchments" layer will hide the colored polygons, allowing us to focus on the areas we have prioritized using the bubble plot. Clicking on the box next to "Catchments" will bring that layer back.



Now that we have an idea of which catchments might be our best targets, we can find more complete information and use the filter layers by looking at them in the ArcGIS Online map. Instead of trying to zoom to them manually, we can automatically look at the area by clicking on the "Open in ArcGIS Online" button in the upper right of the tab. This will open and load the complete AGOL map and zoom to the currently selected sub-watershed. Be aware that since the Data Explorer works with a simplified version of the catchments polygons, the AGOL catchments will have more detailed outlines. If you already have the AGOL map open in another window, you can more quickly zoom in to your target by copying the HUC ID number that is displayed in parentheses on the catchment tab and then pasting that value into the Search Field in the upper right corner of the AGOL map. This avoids the time it requires to load the map afresh.