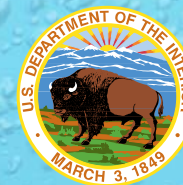


MAXENT AQUATIC SPECIES MAPPING





Maxent

- Use maximum entropy modeling to map the predicted distribution of aquatic species statewide in North Carolina.
 - Originally run only in Western North Carolina
 - Later expanded to include the entire State



Maxent

- Stands for Maximum Entropy
 - Develops unbiased probability distributions on the basis of partial knowledge.
- Maxent software for species habitat modeling developed by Dr. Robert E. Schapire et al. (Princeton University)
 - Full featured software
 - Free!



Maxent Requirements

- Presence Only Data
 - Drawn from source habitat rather than sink
 - if known
- Environmental Data
 - Same geographic area
 - Same resolution (pixel size)
 - Categorical or Continuous data
- Presence data and Environmental data from same/similar time periods.



Aquatic Species Mapping

- Use Maxent to map a wide variety of aquatic species
 - GIS data need
 - Use common modeling framework
 - Compare maps
 - Run a large number of species
 - Compile individual results
 - Easier updating with new data

Aquatic Species Mapping

- Used aquatic species mapping framework developed/Used by the following:
 - Florida Freshwater and Tidal Stream Fish Distribution Mapping
 - Ohio Aquatic Gap
 - Iowa Aquatic Gap



Aquatic Species Mapping

- Occurrence Data
- Environmental Variables
- Running Maxent
- Interpreting Output
- Examples of Use



Occurrence Data

- NC Wildlife Resources Commission
 - Coldwater Fish Sampling
 - Priority Species Monitoring
- NC Museum of Natural Science Research and Collections Section
- North Carolina Natural Heritage Program
Element Occurrence



Occurrence Data

- Use segment representation instead of actual points
 - If it falls in a segment, segment is identified for that species
- Using location information only from 2000+



Environmental Variables

- 16 different variables
 - 6 Stream Based
 - 7 Landcover Based
 - Disturbed Riparian Assessment
 - Geology Map
 - River Basins





Digital Stream Dataset

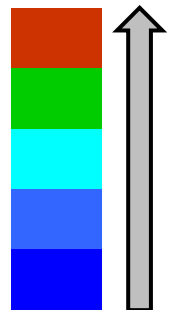
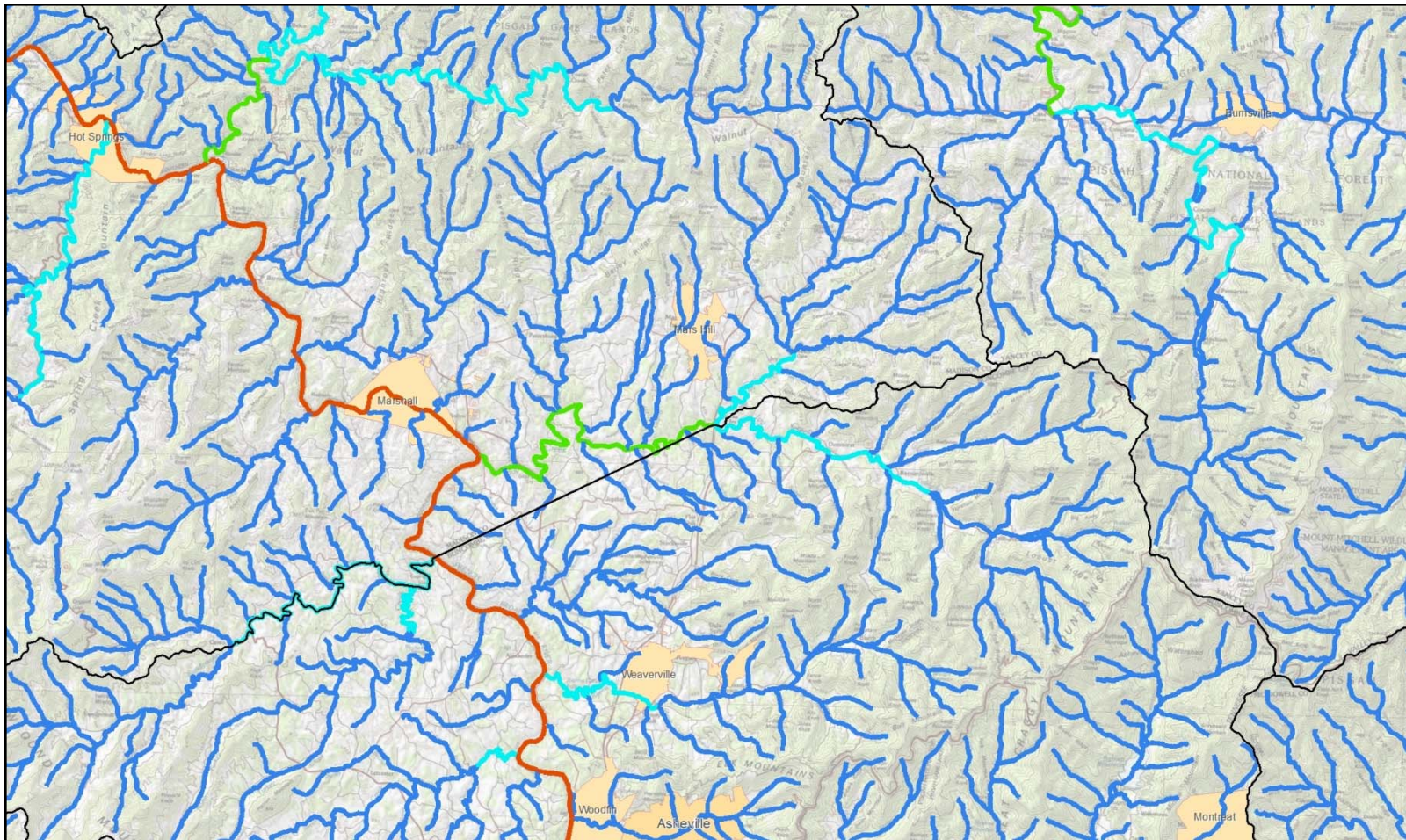
- NHD Plus
 - Nationwide medium resolution stream dataset created by the USGS
 - Maps all surface water in the US based on 1:100,000 scale topographic maps
 - Plus part adds a wide variety of attribute information to the line and polygon data

Environmental Variables

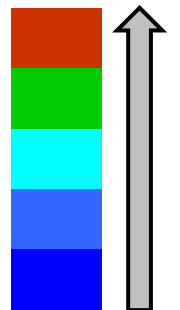
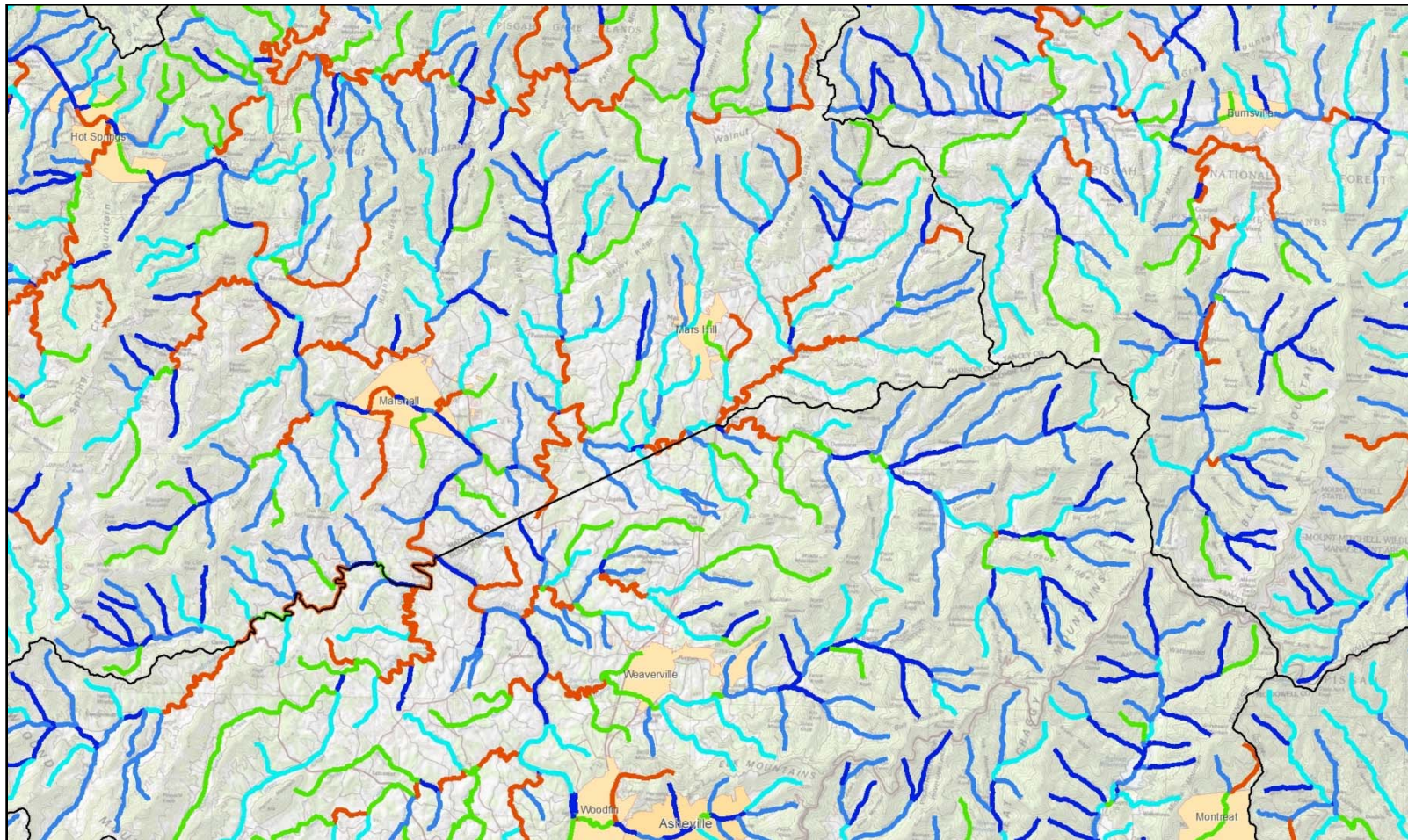
- NHDPlus Stream Segment Characteristics
 - Drainage Area
 - Cumulative drainage area in km^2
 - Flow
 - Mean annual flow in cubic feet per second
 - Computed using unit runoff method
 - Velocity
 - Mean annual velocity (fps)
 - Computed using the Jobson Method
 - Strahler Stream Order
 - Gradient
 - Slope of stream segment
 - Sinuosity



Drainage Area



Sinuosity



Environmental Variables

- Landuse/Landcover – SEGAP
 - Categorized by Catchment
 - % Barren land
 - % Cropland
 - % Forest land
 - % Pasture land
 - % Shrub land
 - % Wetland

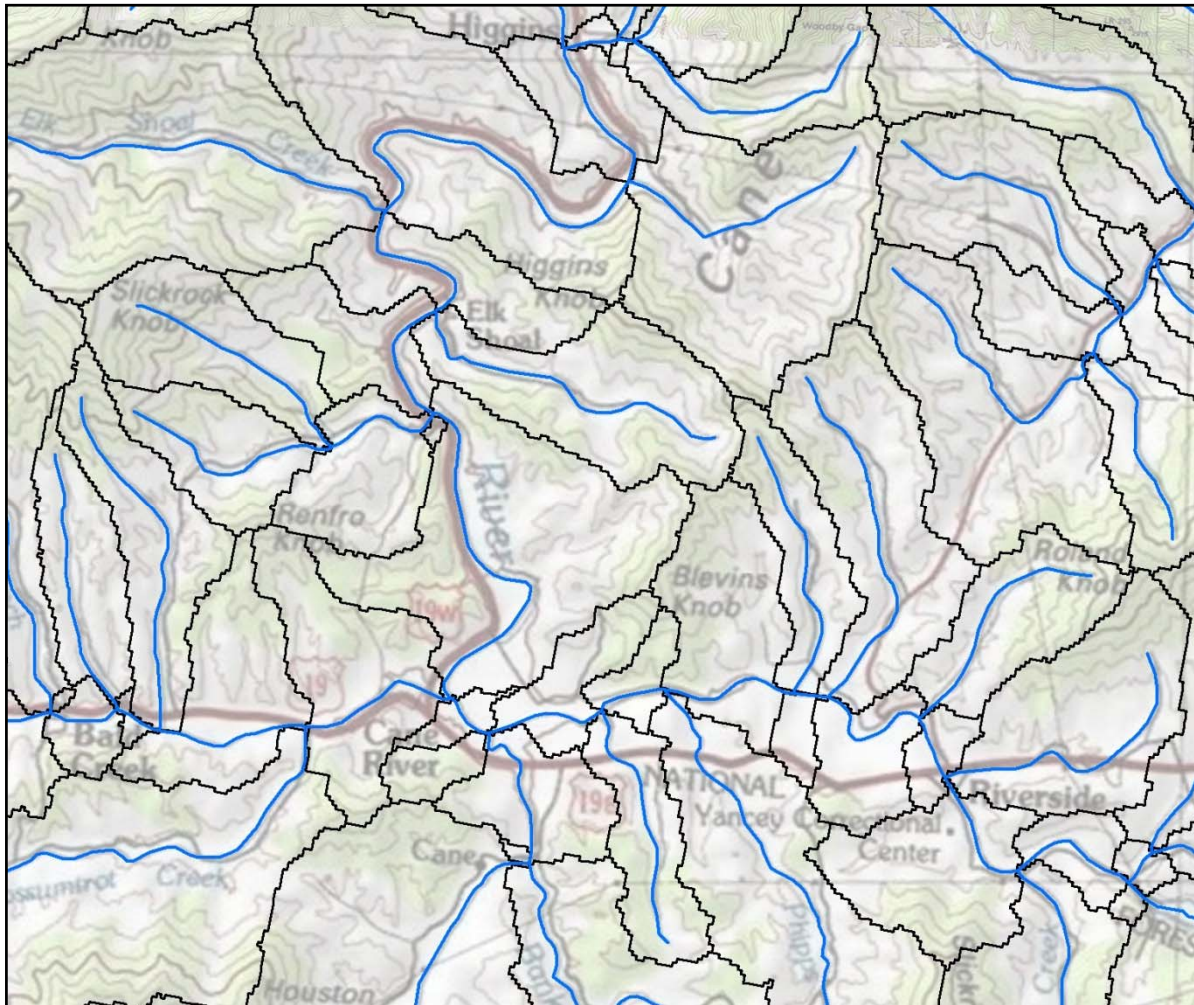


Southeast Gap Landcover



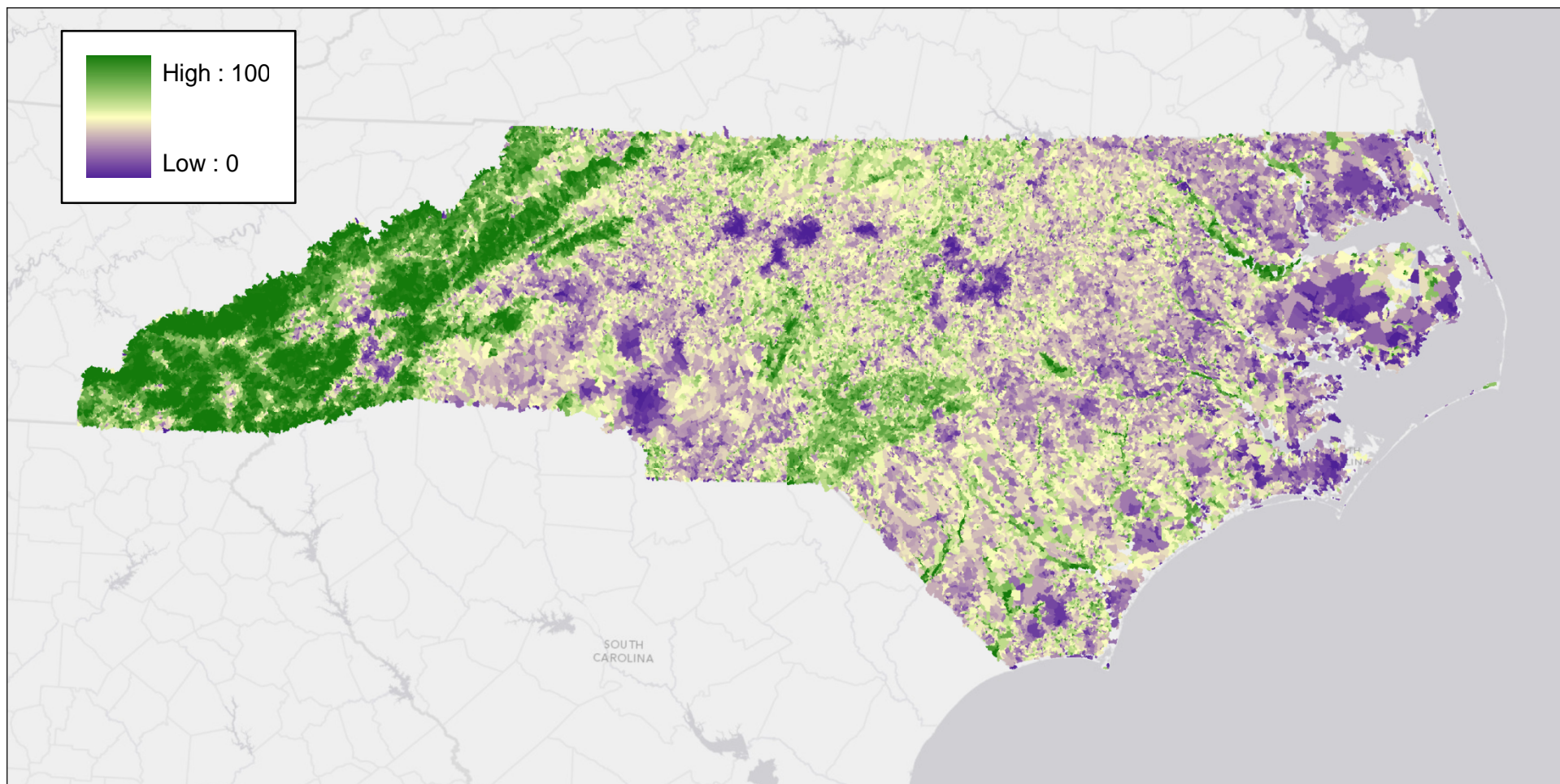
- Landcover Map for SE
 - Based on 2000 imagery
 - 194 different landcover classes
 - 82 landcover classes in NC

Catchments

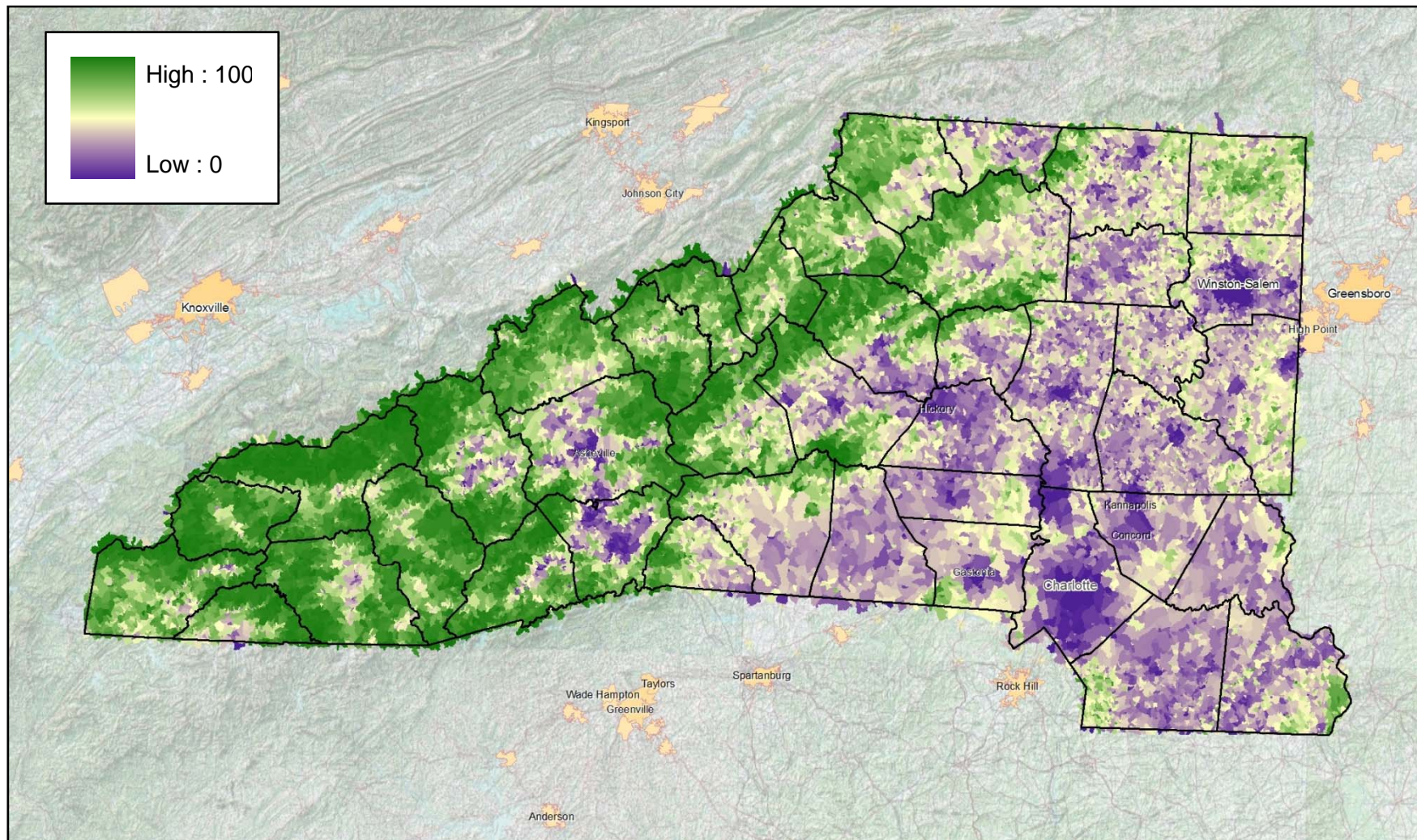


- Identifies the drainage area for each stream segment

% Forest by Catchment



% Forest by Catchment

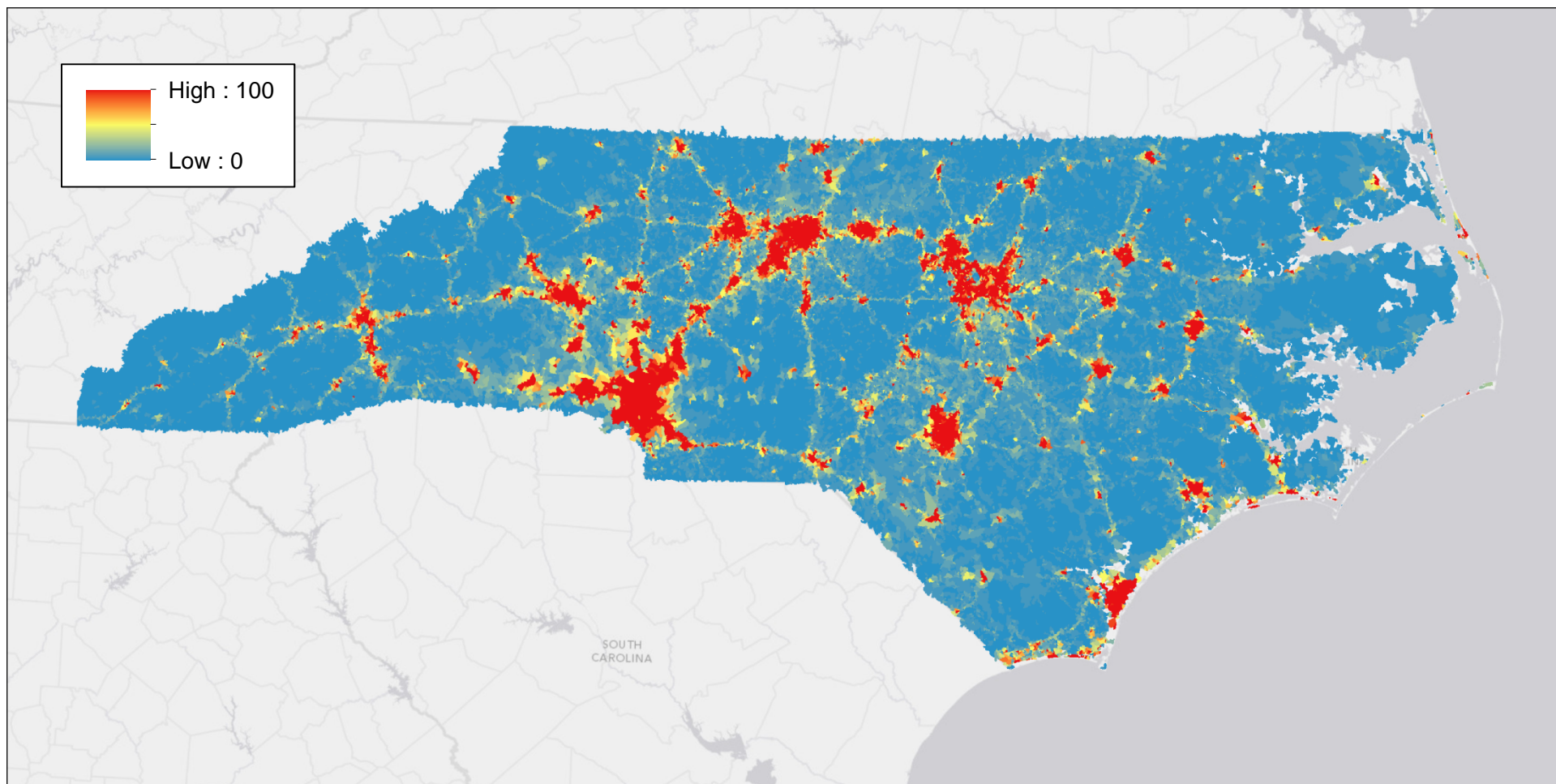




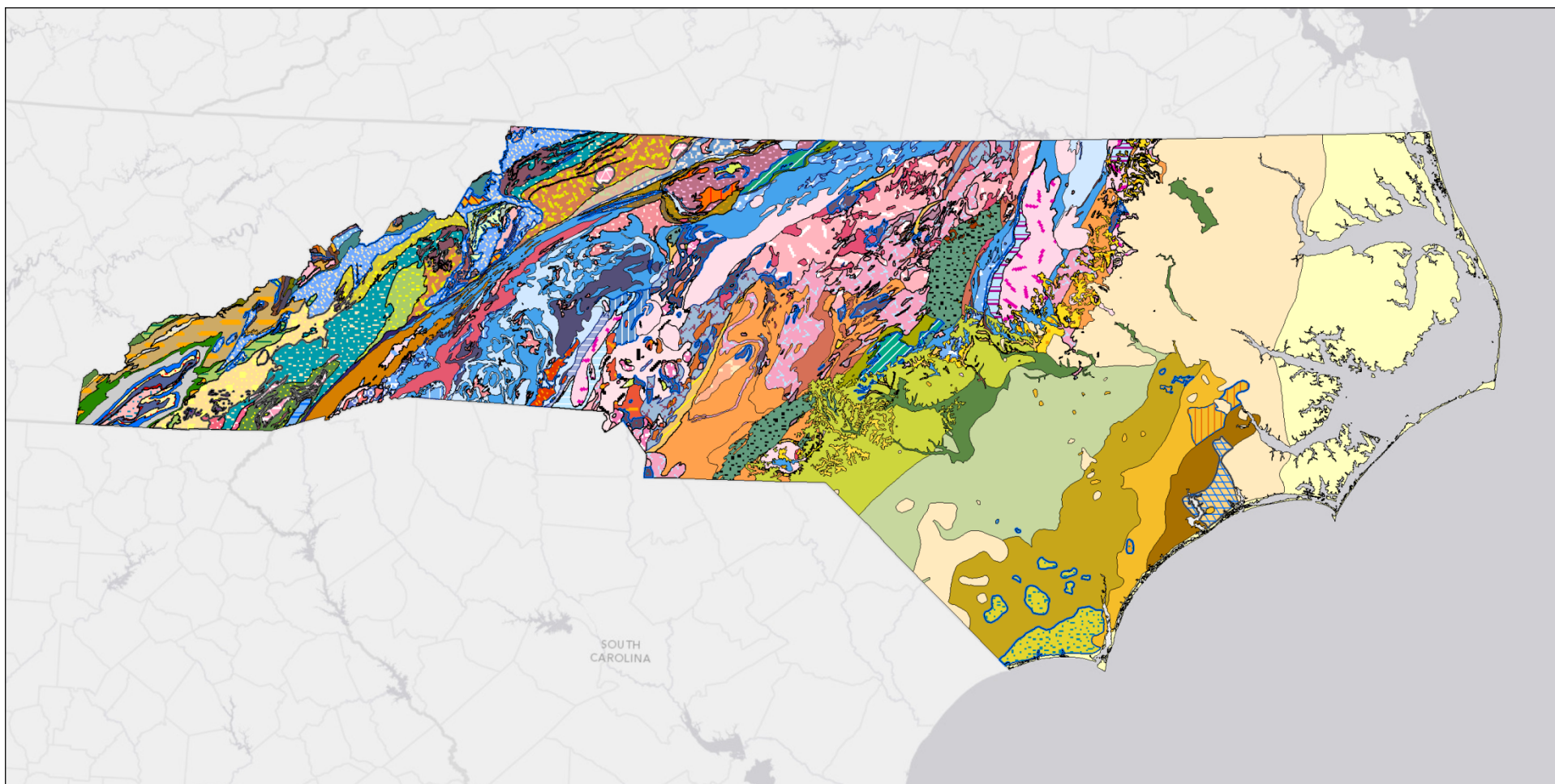
Environmental Variables

- National Land Cover Dataset
 - % Impervious
 - Categorized by Catchment
- Geology
 - USGS geology map of North Carolina
 - 1:250,000
- SARP Riparian Assessment % Disturbed
 - Recreated for NHDPlus dataset
- River Basin

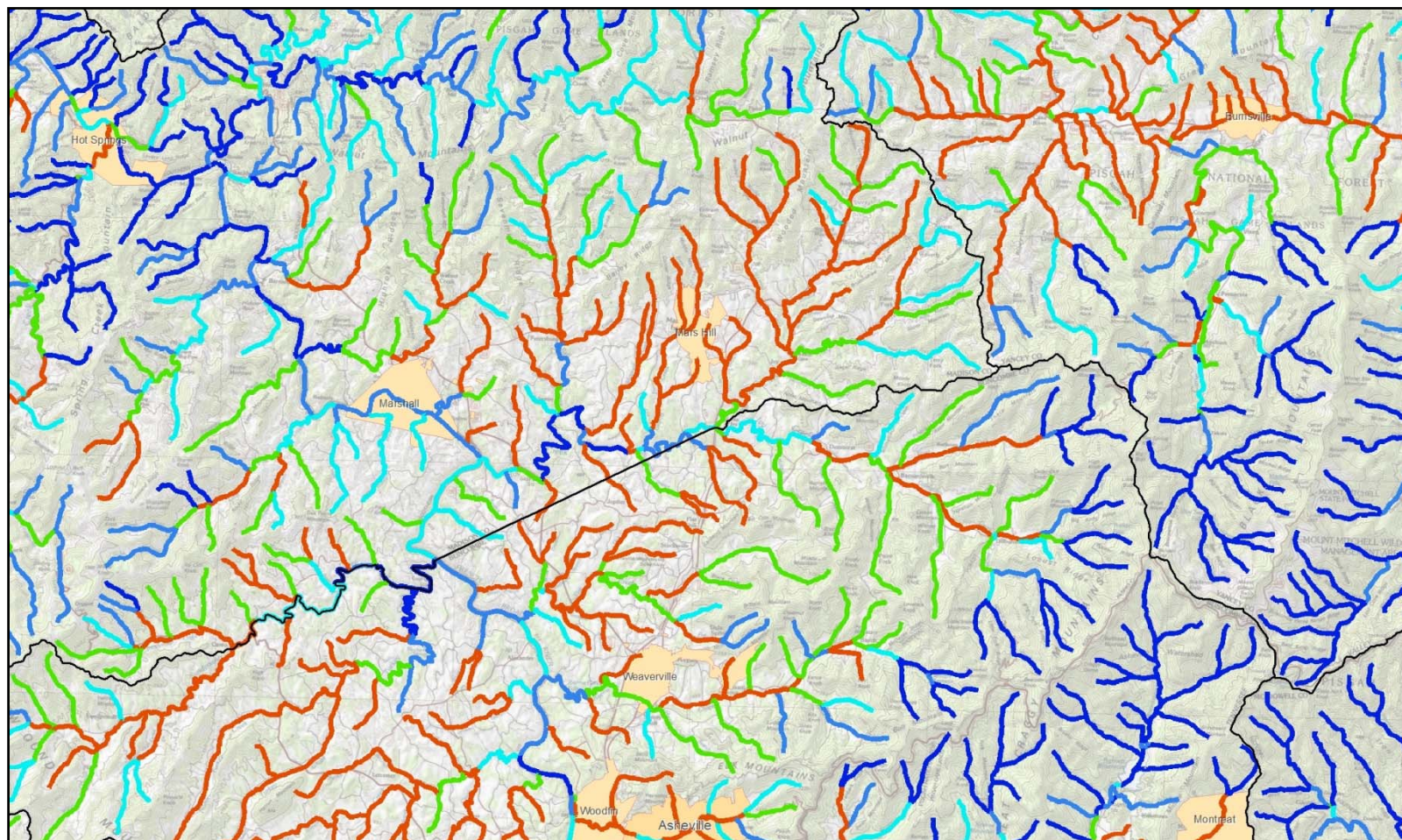
NLCD % Impervious



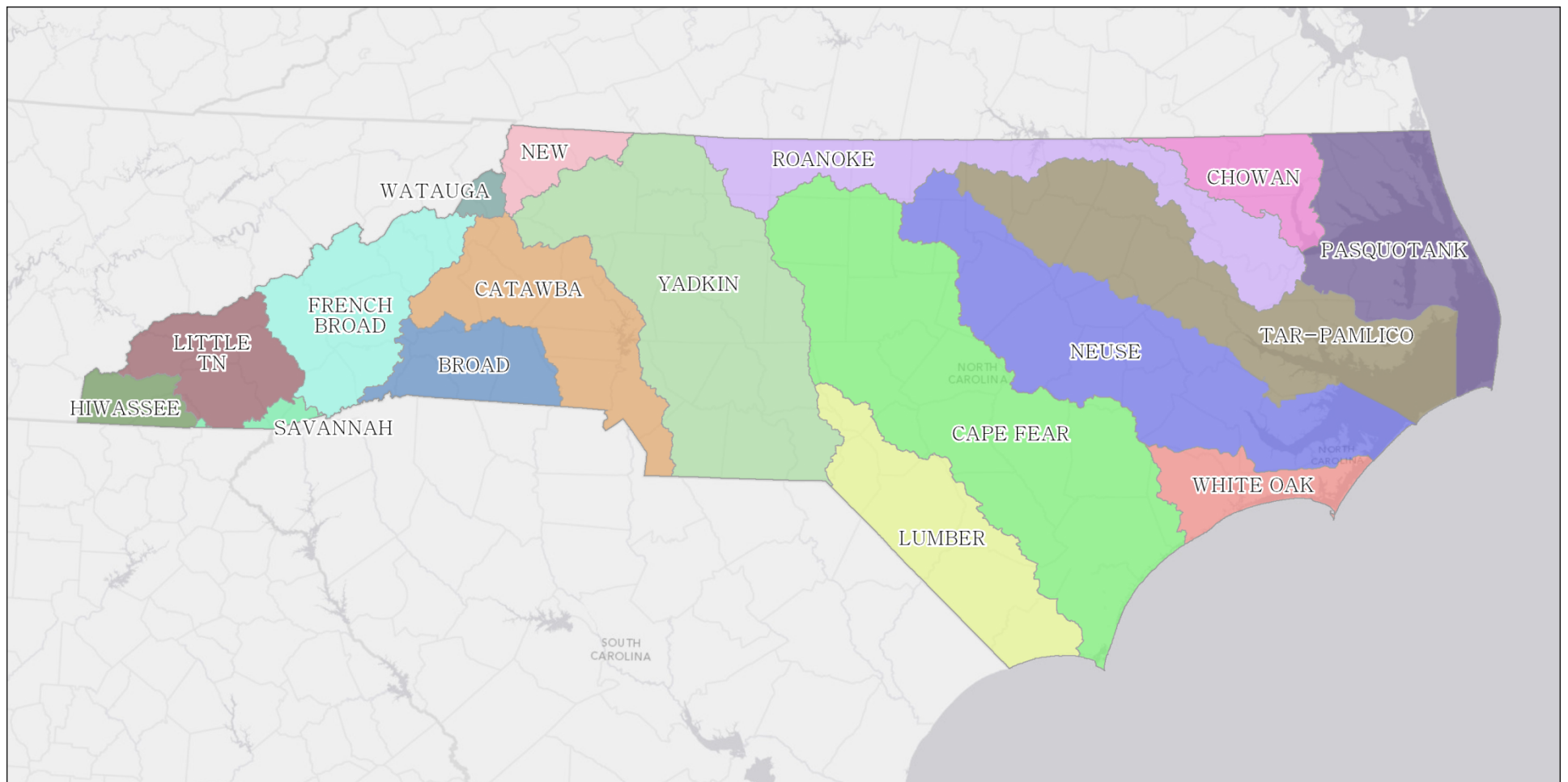
Geology



Disturbed Riparian



River Basin





Running Maxent

- Uses point presence data
 - Model runs using 75% of points (training points)
 - Remaining 25% of points used for testing
- Environmental Data
 - Continuous or categorical
- 3 Output formats possible
 - Raw
 - Cumulative
 - Logistic
 - Estimate of 0 - 1
 - Estimates probability of presence assuming typical presence localities have a probability of presence of ~ 0.5

Running Maxent

Maximum Entropy Species Distribution Modeling, Version 3.3.3e

Samples

File: MaxEnt_FishMaxEntPtLayers\Elktoe.c Browse

☒ Appalachian_Elktoe

Environmental layers

Directory/File: Requests\MaxEnt_FishMaxEntEnvLayers Browse

<input checked="" type="checkbox"/> grainsize	Continuous
<input checked="" type="checkbox"/> flow	Continuous
<input checked="" type="checkbox"/> forest	Continuous
<input checked="" type="checkbox"/> geol	Categorical
<input checked="" type="checkbox"/> gradient	Continuous
<input checked="" type="checkbox"/> human	Continuous
<input checked="" type="checkbox"/> imperv	Continuous
<input checked="" type="checkbox"/> natural	Continuous
<input checked="" type="checkbox"/> pasture	Continuous
<input checked="" type="checkbox"/> shrub	Continuous
<input checked="" type="checkbox"/> strahlerc	Continuous

Select all Deselect all

☒ Linear features ☒ Create response curves

☒ Quadratic features ☒ Make pictures of predictions

☒ Product features ☒ Do jackknife to measure variable importance

☒ Threshold features

☒ Hinge features

☒ Auto features

Output format: Logistic

Output file type: asc

Output directory: Browse

Projection layers directory/file: Browse

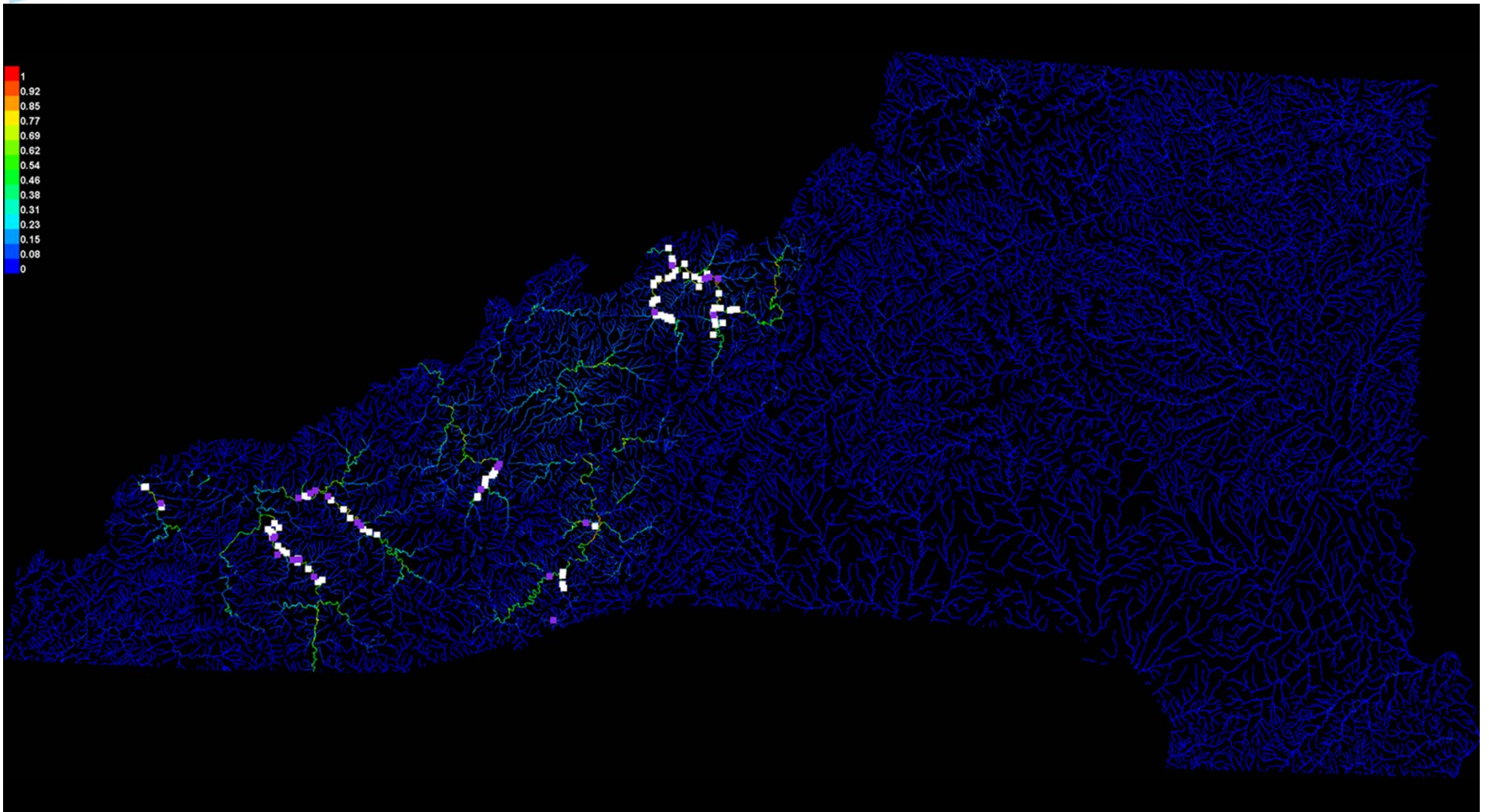
Run Settings Help



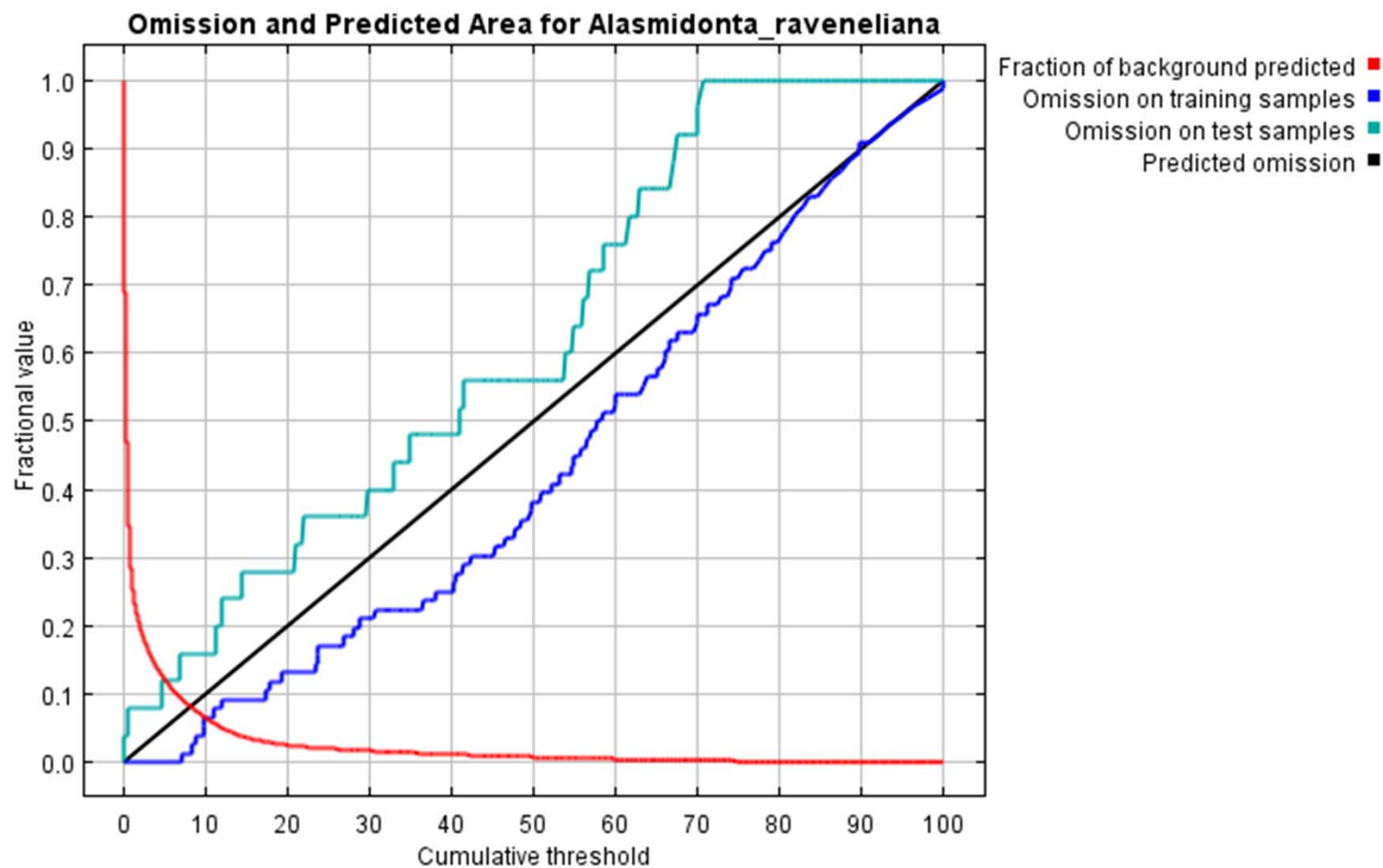
Running Maxent

- Multiple output files
 - Raster image of model predictions
 - Statistical analyses
 - Omission of test samples
 - Receiver operating curve of training and testing data
 - Statistical significance of the prediction
 - Estimate of variable contribution
 - Jackknife tests
 - Response curves
- Appalachian Elktoe Example

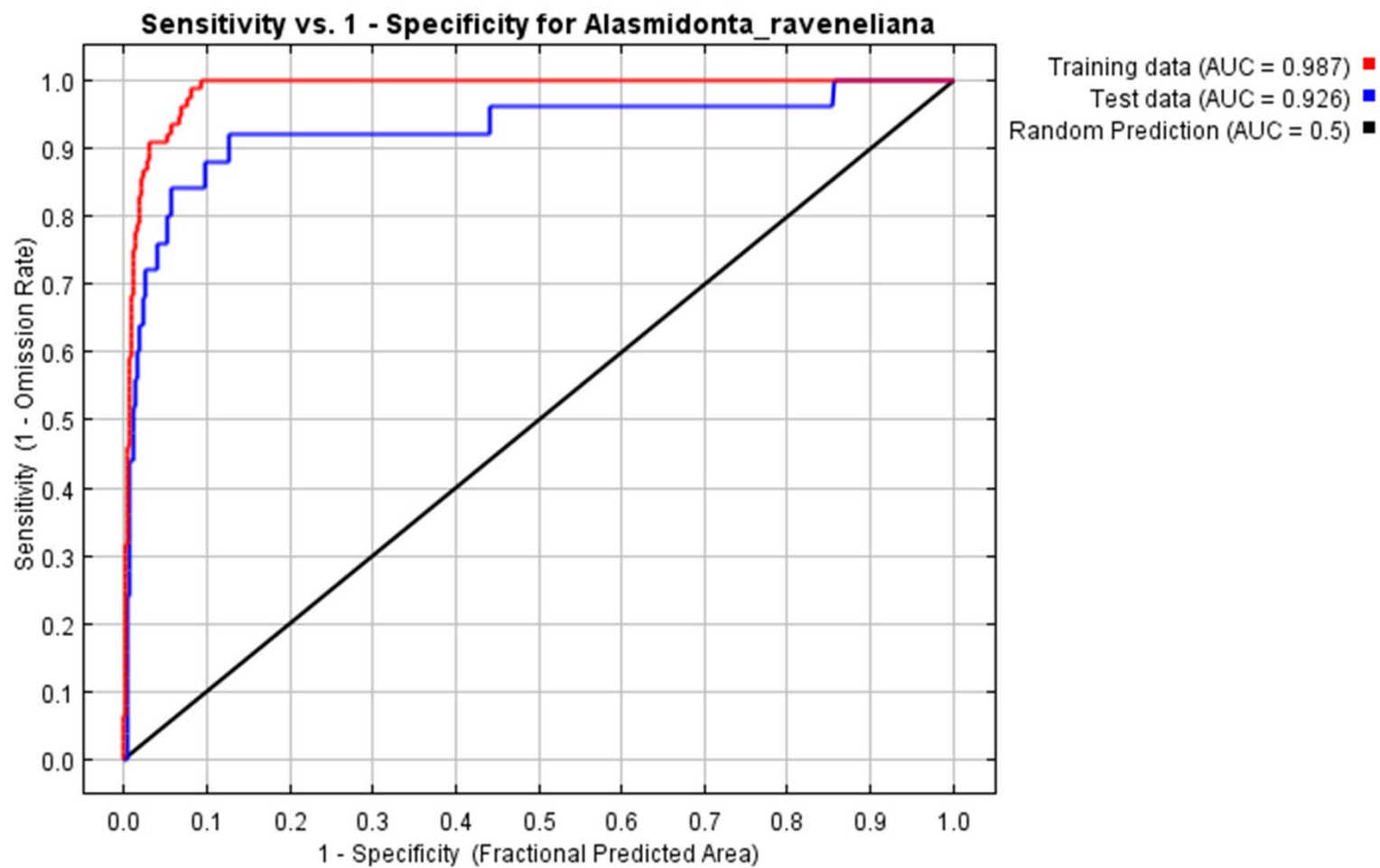
Picture of the Model



Omission of Test Samples



Receiver Operator Curves



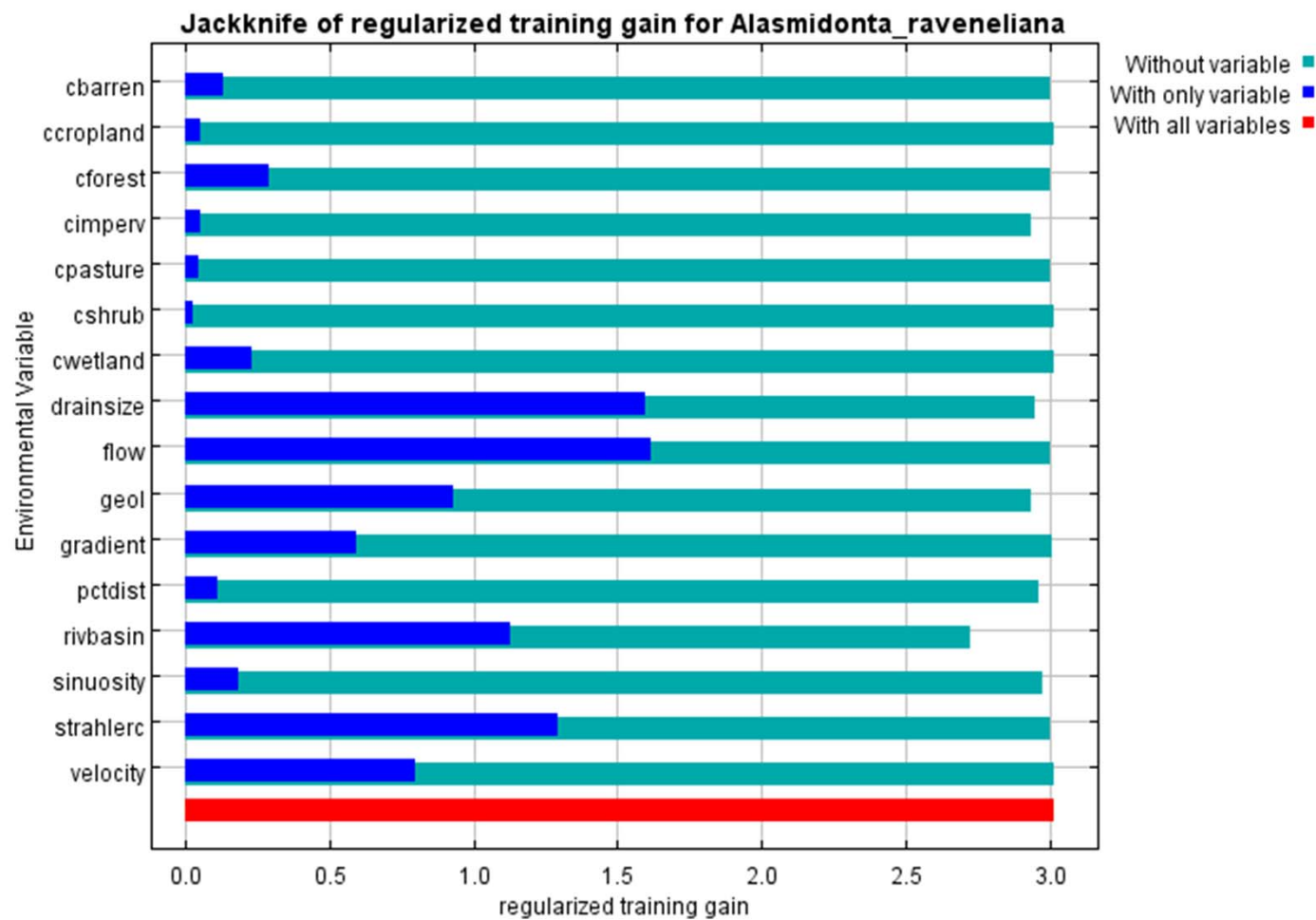
Statistical Output

Cumulative threshold	Logistic threshold	Description	Fractional predicted area	Training omission rate	Test omission rate	P-value
1.000	0.004	Fixed cumulative value 1	0.263	0.000	0.080	7.625E-12
5.000	0.030	Fixed cumulative value 5	0.122	0.000	0.120	1.222E-17
10.000	0.058	Fixed cumulative value 10	0.066	0.066	0.160	1.413E-21
7.183	0.042	Minimum training presence	0.093	0.000	0.160	1.735E-18
17.385	0.186	10 percentile training presence	0.030	0.092	0.280	1.964E-22
9.977	0.058	Equal training sensitivity and specificity	0.066	0.066	0.160	1.504E-21
7.183	0.042	Maximum training sensitivity plus specificity	0.093	0.000	0.160	1.735E-18
5.118	0.031	Equal test sensitivity and specificity	0.120	0.000	0.120	8.872E-18
4.677	0.028	Maximum test sensitivity plus specificity	0.127	0.000	0.080	5.959E-19
3.328	0.019	Balance training omission, predicted area and threshold value	0.155	0.000	0.080	5.458E-17
12.266	0.078	Equate entropy of thresholded and original distributions	0.050	0.092	0.240	2.112E-20

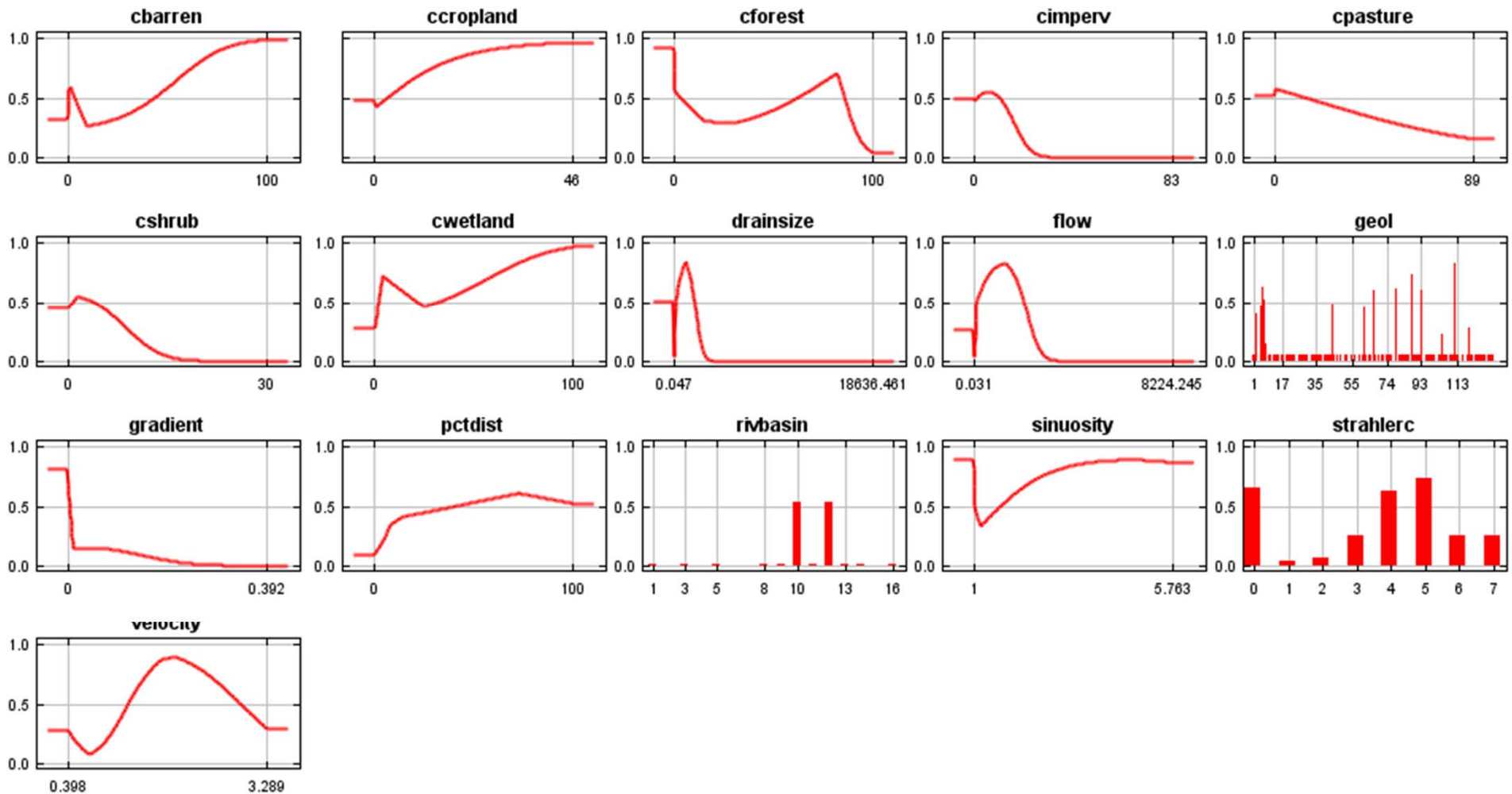
Estimate of Variable Contribution

Variable	Percent contribution	Permutation importance
flow	39.7	1.2
rivbasin	32.8	40.5
drainsize	8.6	12.2
geol	4.9	2.8
pctdist	3.4	8.1
sinuosity	2.4	0.7
cimperv	2.2	25.4
strahlerc	1.8	0.2
cbarren	1.5	0.4
cforest	1.1	5.9
cpasture	0.6	2
cwetland	0.4	0
gradient	0.4	0.4
ccropland	0.3	0.1
cshrub	0	0
velocity	0	0

Jackknife Tests



Response Curves - Individual





Maxent Results

- Maxent model for 226 different species statewide
 - 27 Crayfish
 - 39 Mussels
 - 158 Fish
 - 1 Amphibian
 - 1 Plant
- A species required at least 20 occurrences to run



Maxent Results

- Data Storage
 - Initial output
 - 16,000 files, 450 gigabytes
 - Complete dataset reduced to 2.6 gigabytes
 - Distilled spatial data down to a single vector file
 - 200 megabytes in size
 - Each record is single species model predictions with attribute data.



Maxent Results

- Predicted NHD Line Segments Attributes
 - Scientific Name
 - Common Names
 - Phylum
 - G Rank
 - Federal Status
 - Count
 - Number of segments identified
 - Training AUC
 - Test AUC



Limitations

- Sampling on private lands
- No cumulative effects with environmental data
- Errors in data
- Stream data 1:100,000 scale
 - 1:24,000 scale coming



Example of Use

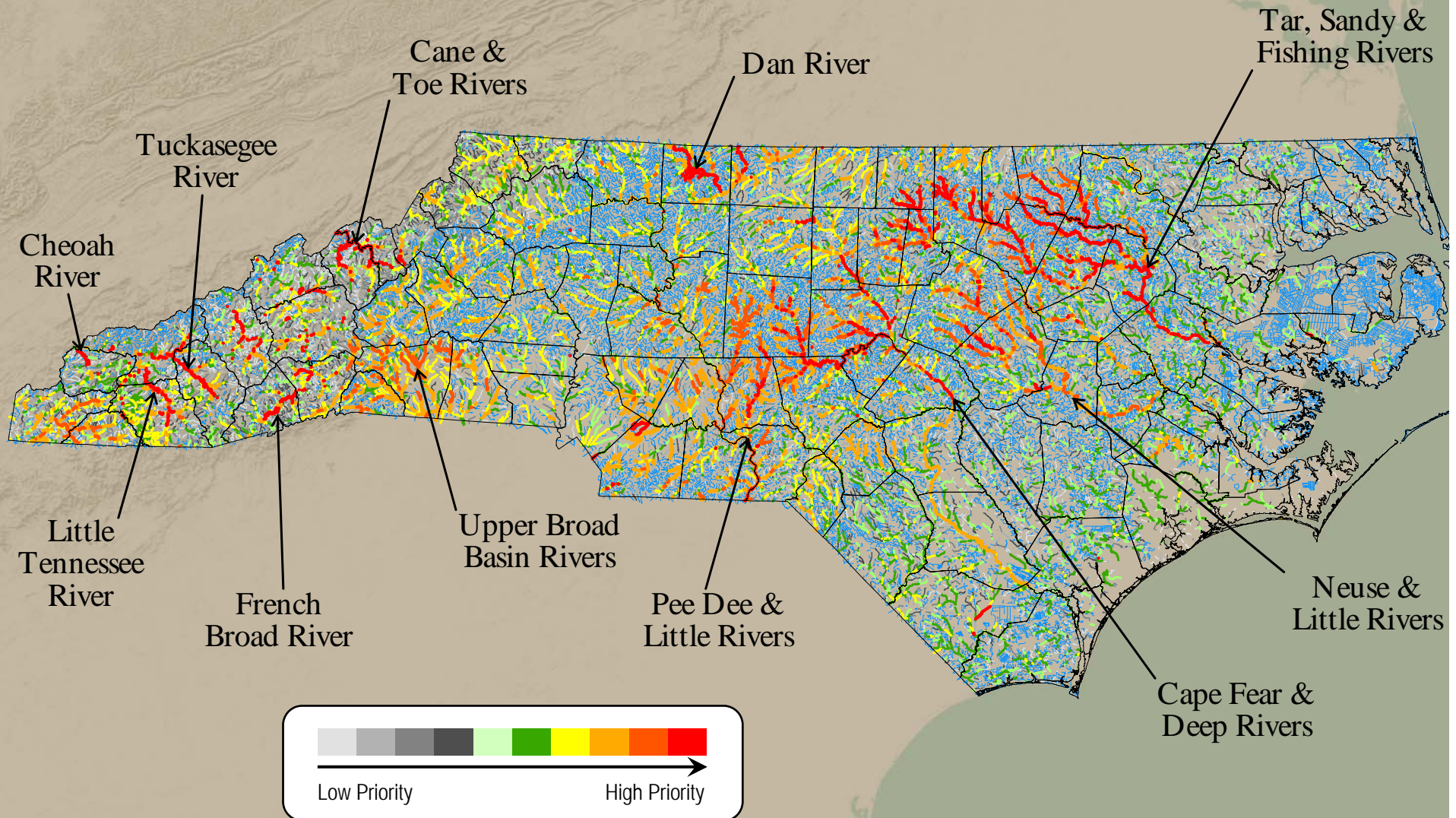
- Helps to Convey Information
 - GIS Assessments/Prioritizations
- Area wide stream prioritization
- Fish Reintroduction
 - Richland Creek upstream of Lake Juanaluska



Statewide Prioritization

- Rank and scale single map based on species Global Rank and Diversity
 - Assessment of the condition of the species across its entire range
 - G1 - Critically Imperiled
 - G2 - Imperiled
 - G3 - Vulnerable
 - G4 - Apparently Secure
 - G5 - Secure

Statewide Prioritization





Examples of Use

- Helps to Convey Information
 - GIS Assessments/Prioritizations
- Area wide stream prioritization
- Fish Reintroduction
 - Richland Creek upstream of Lake Juanaluska



Species to be Reintroduced

1. Warpaint Shiner, *Luxilus coccogenis*
2. Tennessee Shiner, *Notropis leuciodus*
3. Saffron Shiner, *Notropis rubricroceus*
4. Mirror Shiner, *Notropis spectrunculus*
5. Telescope Shiner, *Notropis telescopus*
6. River Chub, *Nocomis micropogon*
7. Mottled Sculpin, *Cottus bairdi*
8. Rock Bass, *Ambloplites rupestris*
9. Fantail Darter, *Etheostoma flabellare*
10. Greenfin Darter, *Etheostoma chlorobranchium*
11. Tuckasegee Darter, *Etheostoma gutselli*

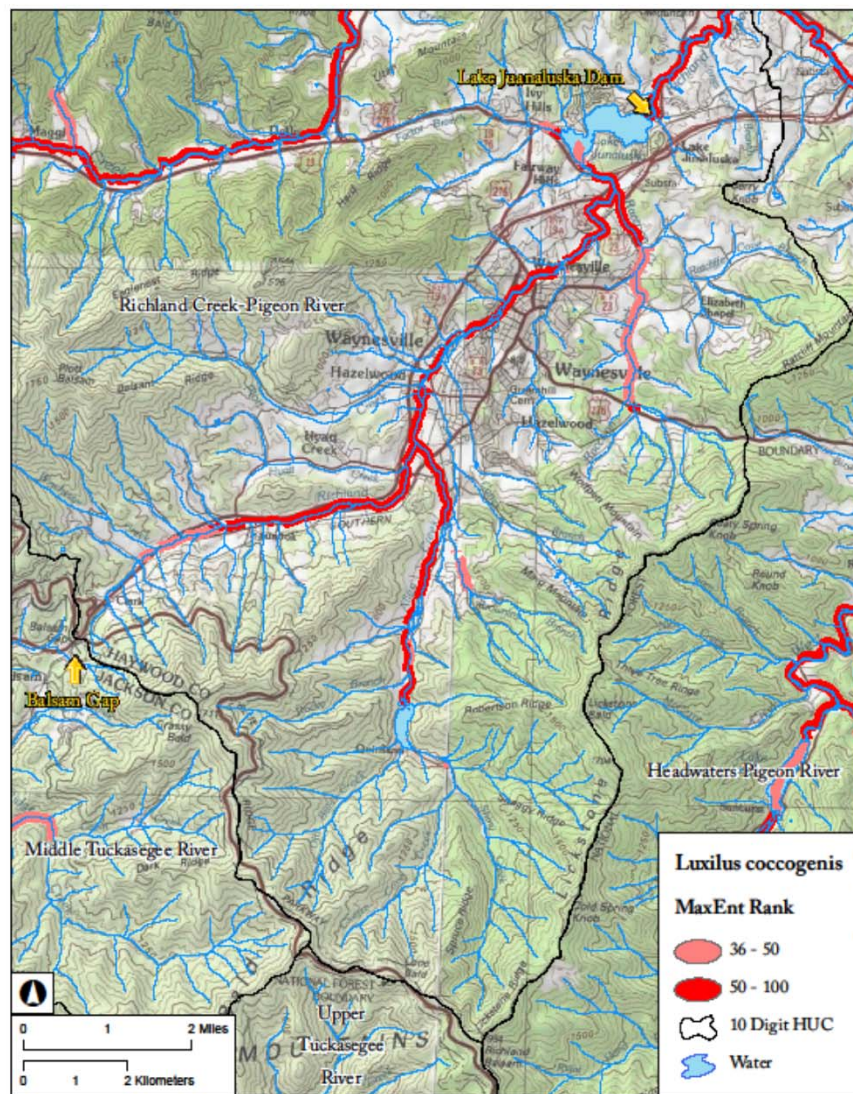


Examples of Use

- Is the reintroduction at a location where the species might not survive in the long term.
 - Is the area appropriate for all species?
 - Are there specific areas where they could focus their efforts?
- Maxent models can help provide that information

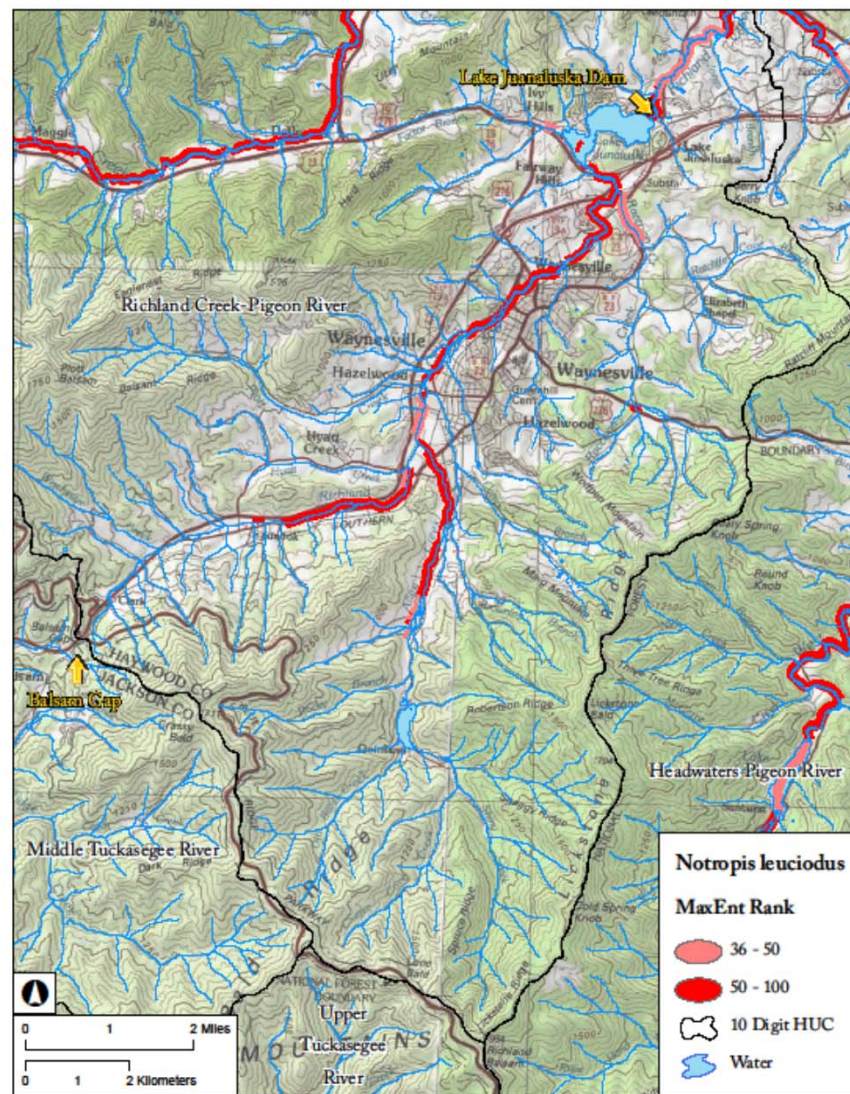
Warpaint Shiner

MaxEnt Predictive Species Map - Richland Creek Watershed



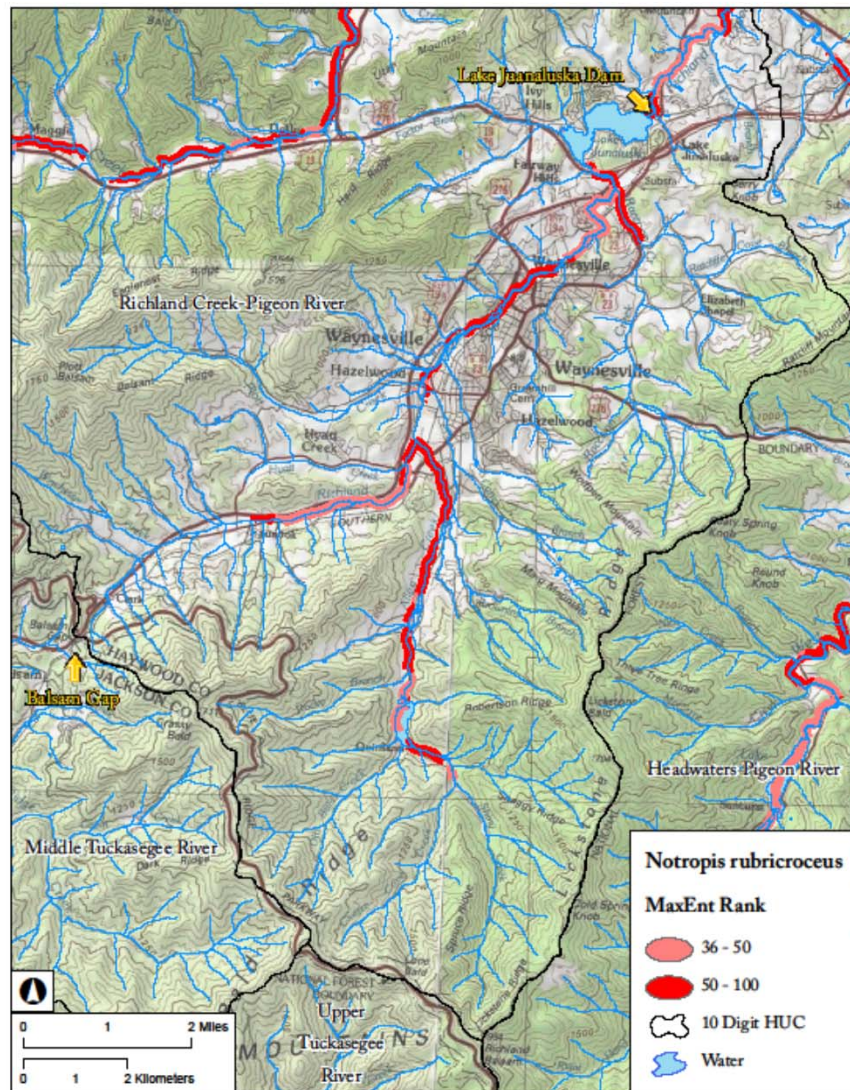
Tennessee Shiner

MaxEnt Predictive Species Map - Richland Creek Watershed



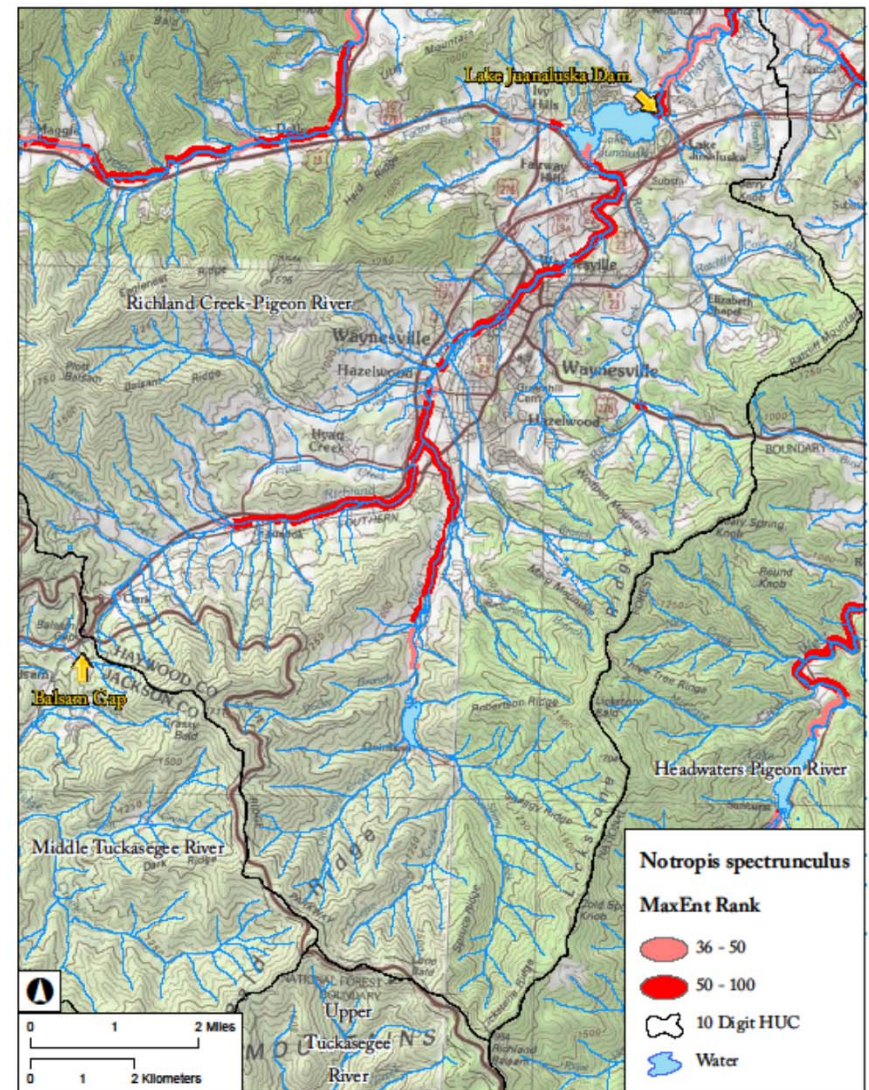
Saffron Shiner

MaxEnt Predictive Species Map - Richland Creek Watershed



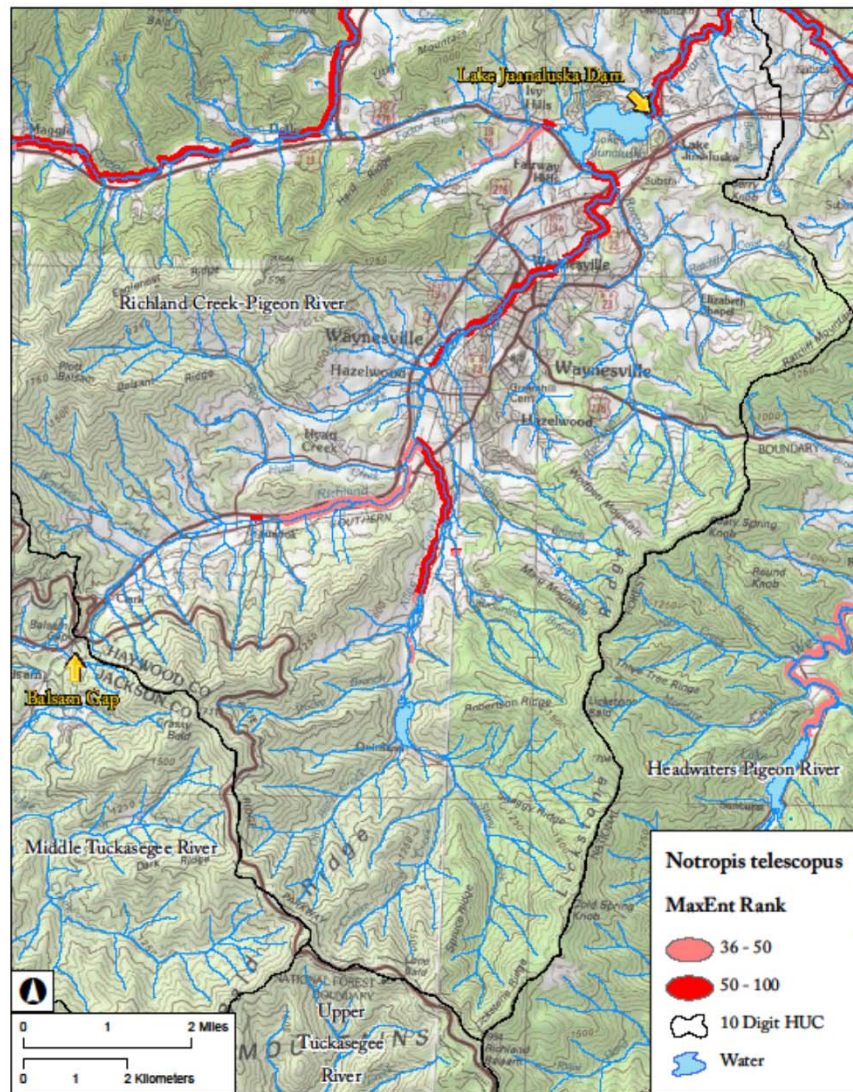
Mirror Shiner

MaxEnt Predictive Species Map - Richland Creek Watershed



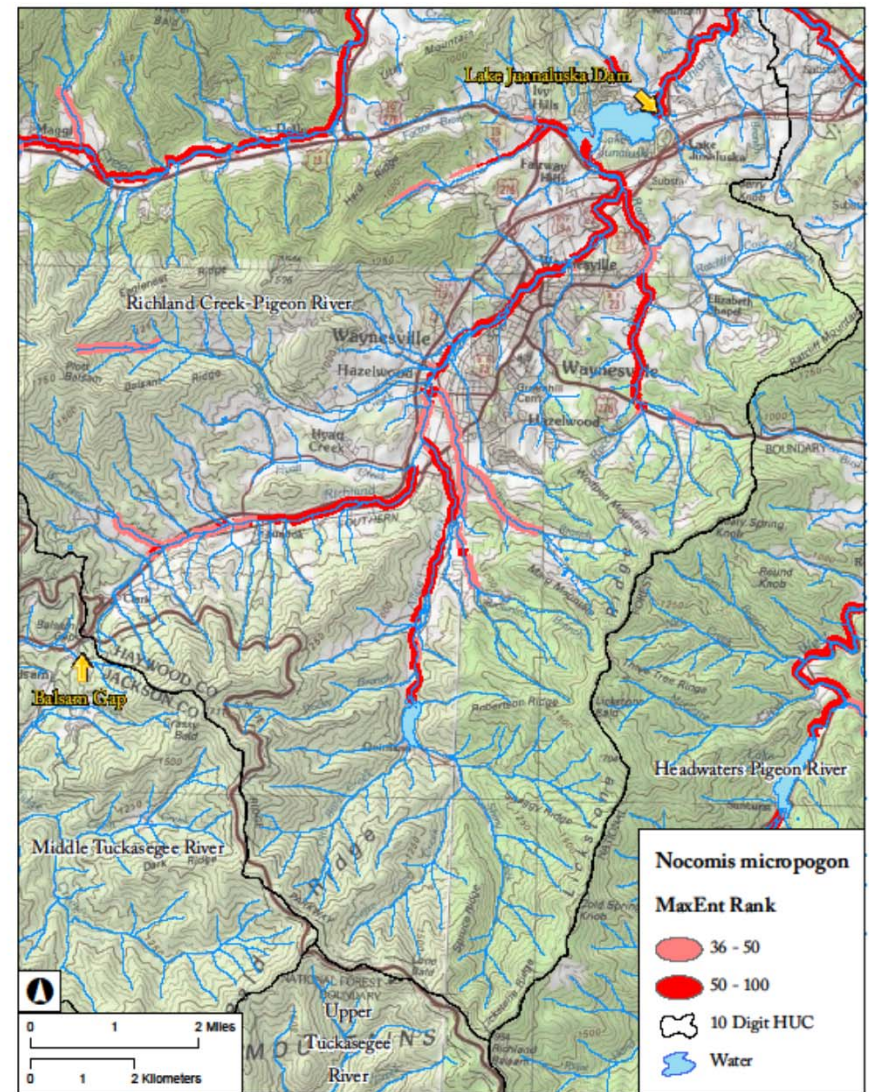
Telescope Shiner

MaxEnt Predictive Species Map - Richland Creek Watershed



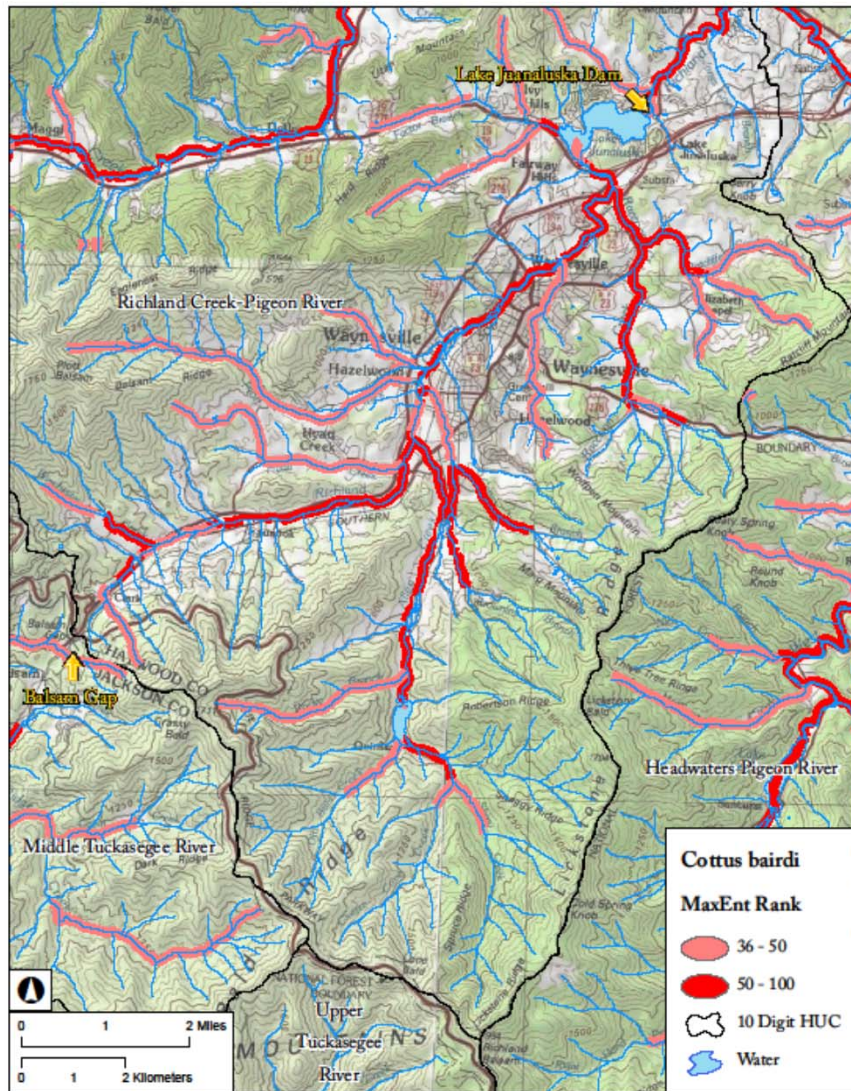
River Chub

MaxEnt Predictive Species Map - Richland Creek Watershed



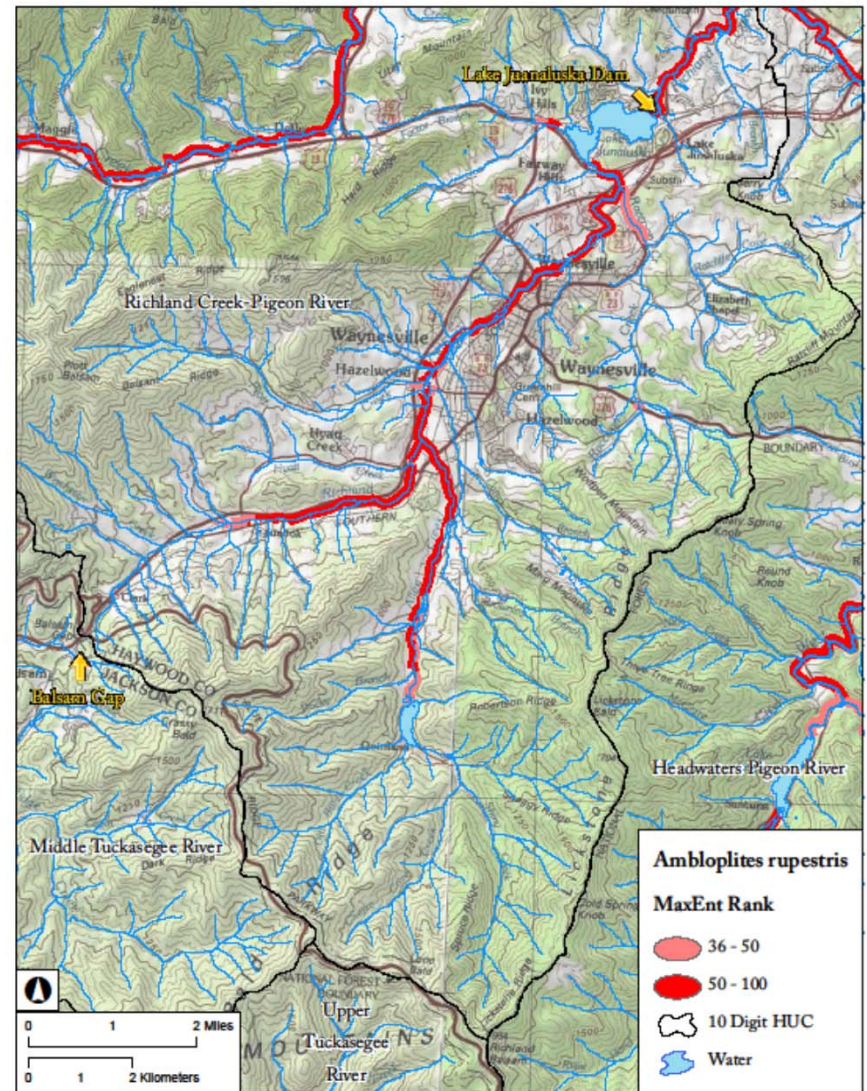
Mottled Sculpin

MaxEnt Predictive Species Map - Richland Creek Watershed



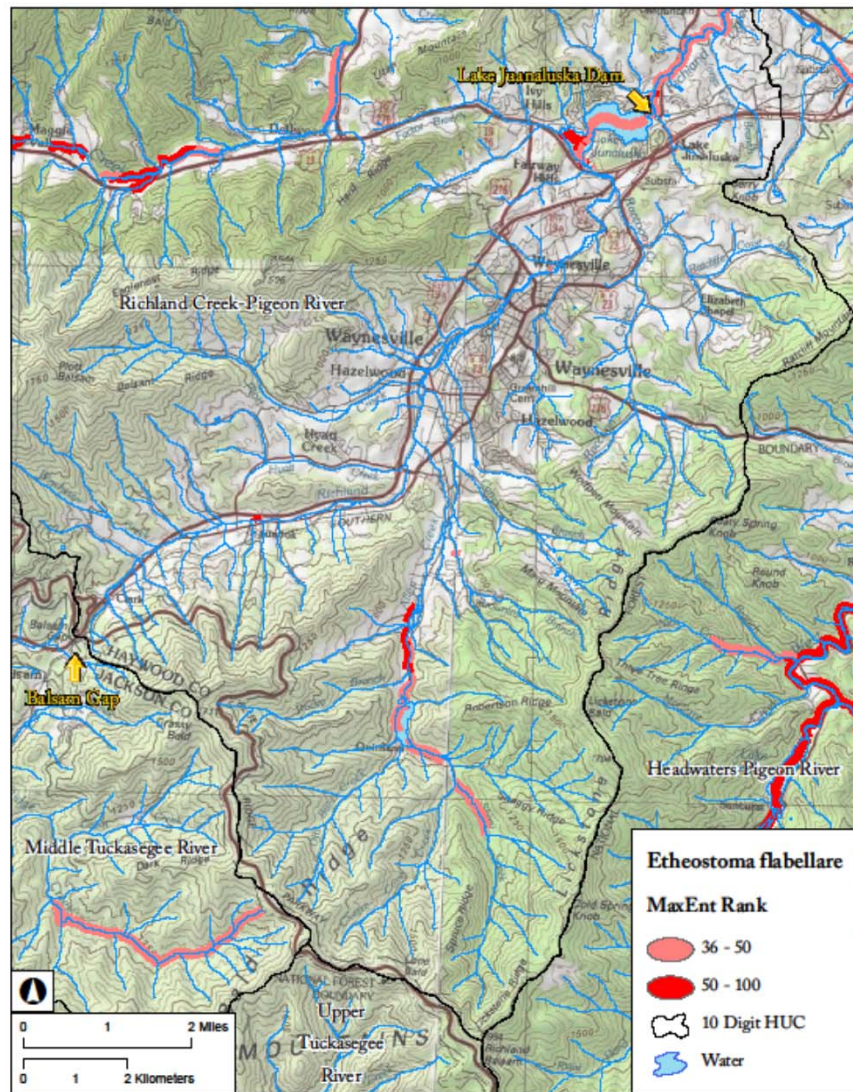
Rock Bass

MaxEnt Predictive Species Map - Richland Creek Watershed



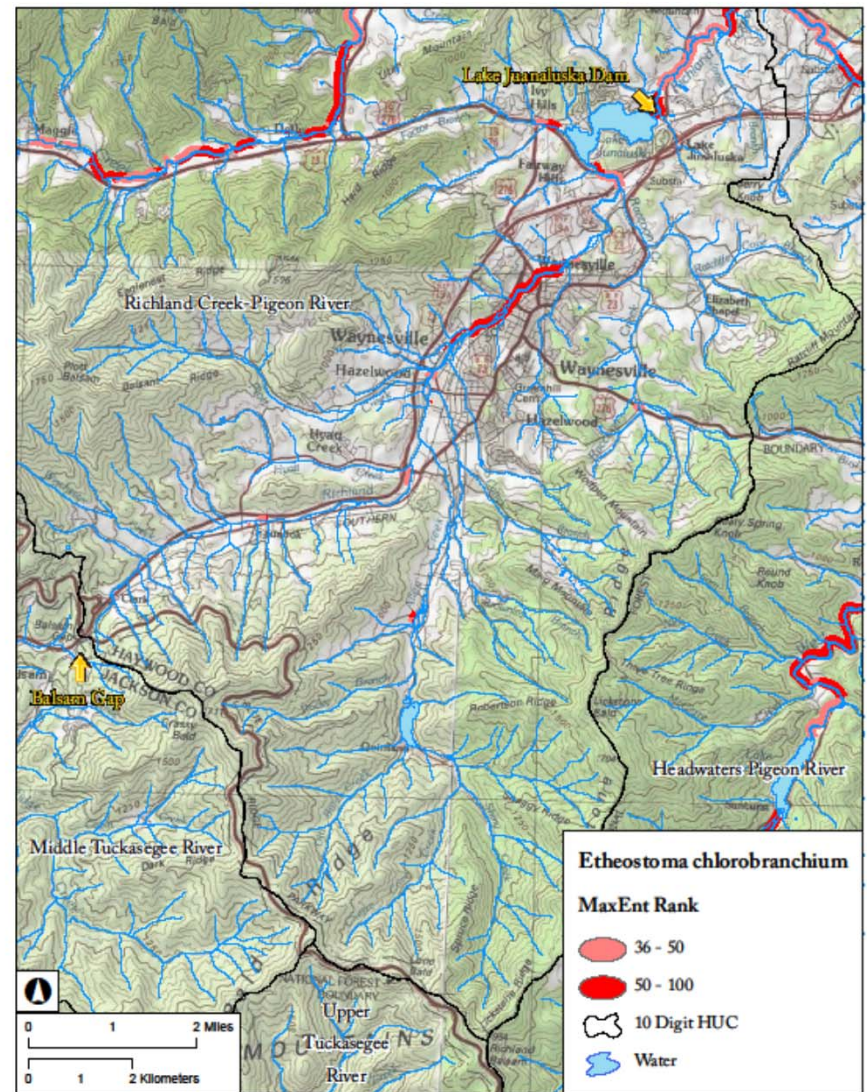
Fantail Darter

MaxEnt Predictive Species Map - Richland Creek Watershed



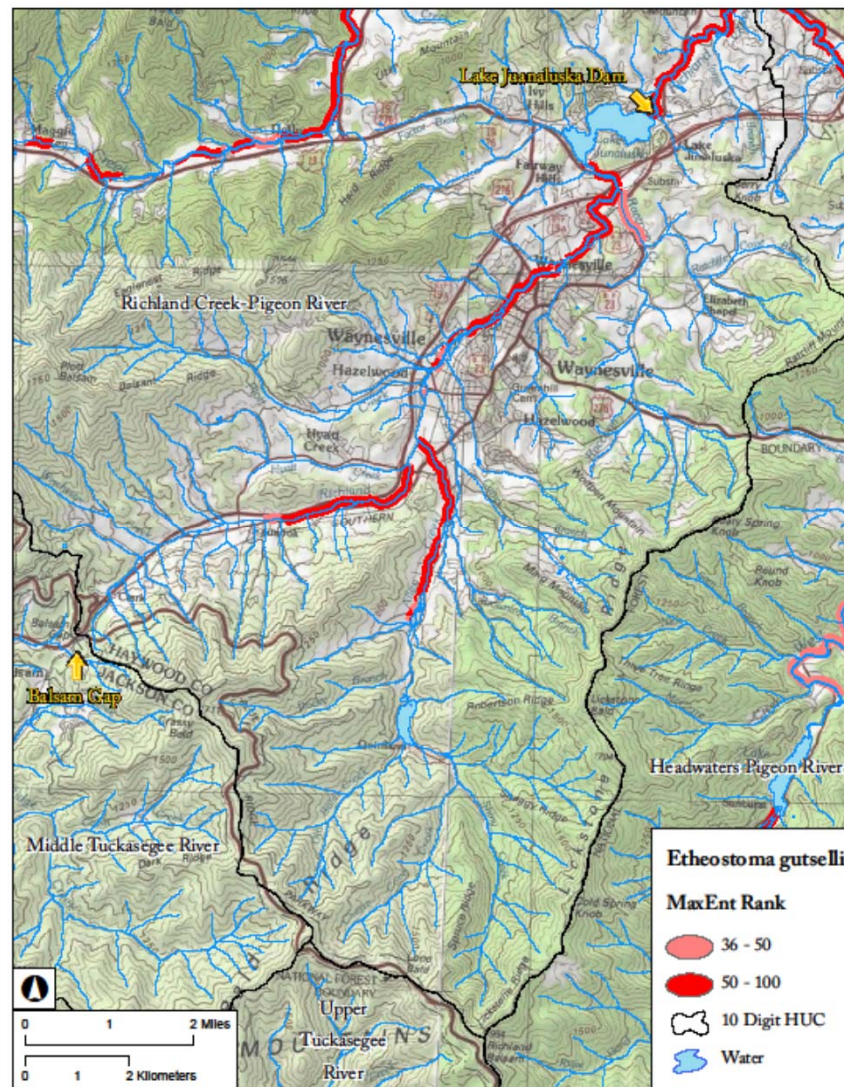
Greenfin Darter

MaxEnt Predictive Species Map - Richland Creek Watershed



Tuckasegee Darter

MaxEnt Predictive Species Map - Richland Creek Watershed





Examples of Use

- Study designed so that it can be replicated anywhere in the lower 48 states, Hawaii, Puerto Rico and the Virgin Islands

MAXENT AQUATIC SPECIES MAPPING



mark_endries@fws.gov

<http://www.fws.gov/Asheville/htmls/Maxent/Maxent.html>