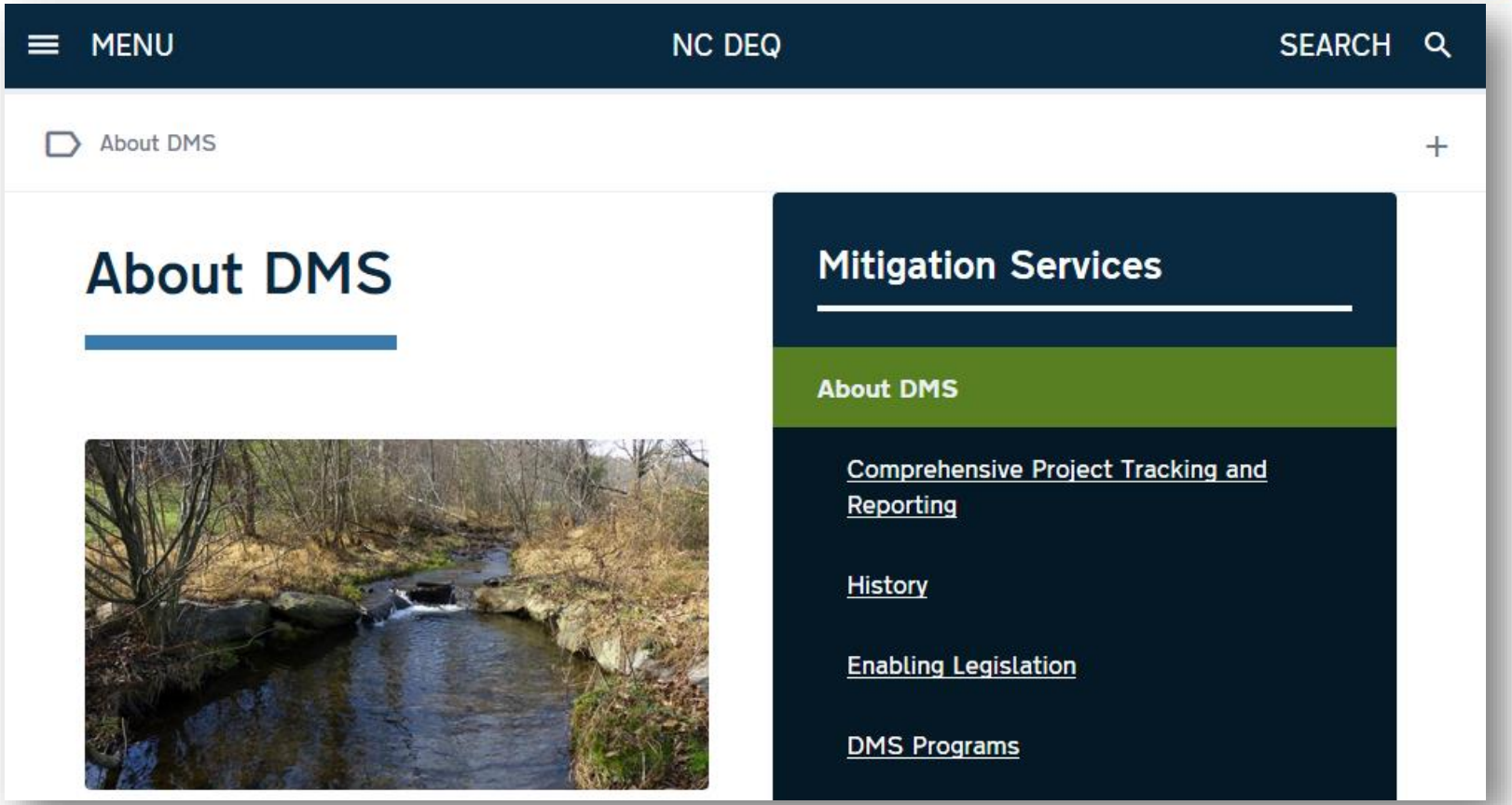
NC Habitat Prioritization Tool
&
Geospatial Wetland Evaluation Tool ("GeoWET")

TOOLS AND WORKFLOW OVERVIEW

FEB, 2017

Environmental Quality

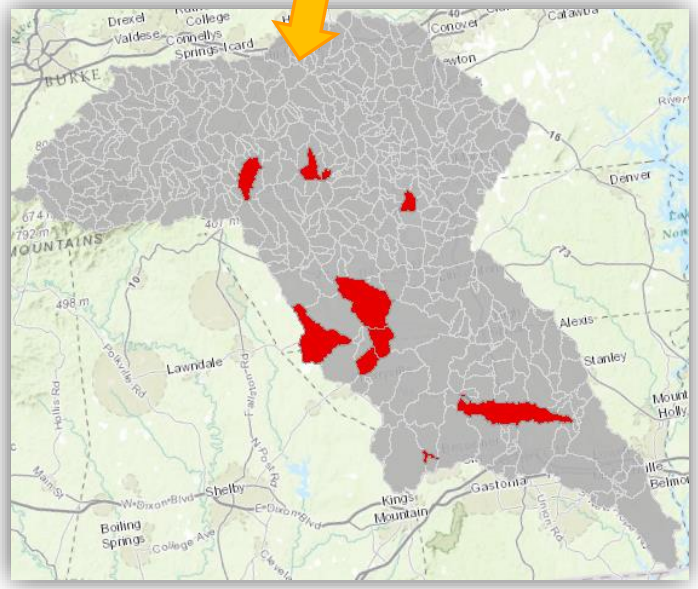
Ecosystem Enhancement PROGRAM



http://deq.nc.gov/about/divisions/mitigation-services

Project Objective

Identify where mitigation activities will have the most benefit on streams.



- Riparian buffer afforestation
- Wetland expansion/restoration
- Stream course alteration
  - Decrease max flow
- Avoided urban expansion
- Stream cooling
- Nutrient reduction

- **Aquatic habitat**
- Hydrology
  - erosion
  - streamflow regime
  - flood frequency
- Water quality

Basic Approach

1. Assess current habitat condition:

For all catchments within a HUC 8, what is the current likelihood of finding various indicator species?

- Create **species distribution models** for select indicator species.
- Average the predicted species habitat likelihood across these target species.
- *High average likelihood is an indicator of high aquatic habitat quality.*

2. Assess potential for *uplift*:

What is the change in species likelihoods if you simulate various management actions (e.g. riparian buffering).

- Project species distribution models onto environmental variables altered to reflect various management scenarios…
- Improvements in species likelihoods among target species suggest a positive response to the management activity, or "**uplift**".

1. Assessing Current Conditions (overview)

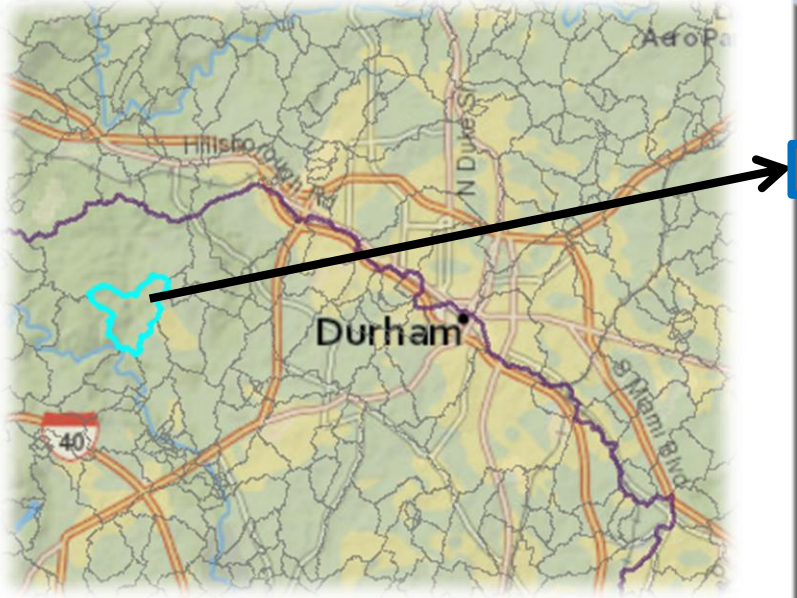
A. The datasets used to drive the analysis
   - Catchment attribute table 
   - Species occurrence table

B. Selecting the species and building the habitat models

C. Modeling catchment status under current conditions

Catchment Attribute Table

"A table listing all catchments [within a HUC 6] and numerous **biophysical attributes** measured within each catchment…"



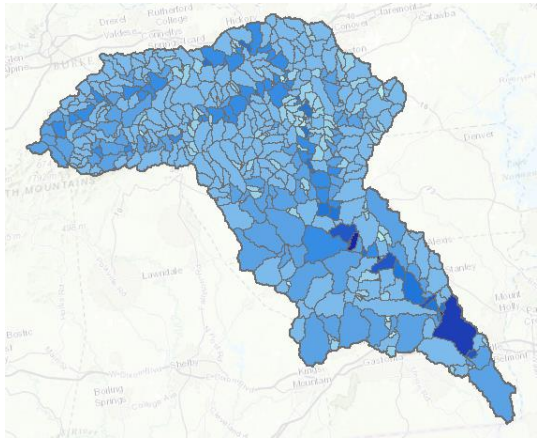
EnvStats

OBJECTID *	Shape *	GRIDCODE *	FEATUREID *	SOURCEFC	AreaSqKM	Shape_Length	Shape_Area	LENGTHKM
1	Polygon	2293133	9095630	NHDFlowline	6.6393	22440.000628	6639299.985359	-9999
16290	Polygon	2315415	9660802	NHDFlowline	0.3123	2999.999789	312300.030231	0.747
16312	Polygon	2315437	9660784	NHDFlowline	0.0981	1740.000095	98100.006522	0.363
16334	Polygon	2315459	9660788	NHDFlowline	1.7667	9180.000479	1766700.034537	2.467
16335	Polygon	2315460	9660786	NHDFlowline	0.1026	1740.000095	102599.979189	0.435
16368	Polygon	2315494	9660800	NHDFlowline	0.1269	2459.999849	126899.984286	0.742
16376	Polygon	2315502	9660782	NHDFlowline	0.0198	1079.99988	19800.000931	-9999
16528	Polygon	2315656	25779512	NHDFlowline	0.1404	2459.999649	140399.984785	0.741
17028	Polygon	2316536	9645025	NHDFlowline	0.0216	720.000053	21599.997198	-9999
17029	Polygon	2316792	9644961	NHDFlowline	0.0036	240.000151	3600.004533	-9999
17031	Polygon	2317293	9627231	NHDFlowline	7.5258	18000.000032	7525799.99759	-9999
2520	Polygon	2301397	9755514	NHDFlowline	3.9636	14820.00043	3963600.010755	1.291
3850	Polygon	2302740	9735184	NHDFlowline	0.9927	6119.999953	992699.995956	1.304
4212	Polygon	2303111	9733166	NHDFlowline	0.2826	2999.999789	282599.985336	0.201
4416	Polygon	2303319	9734970	NHDFlowline	1.2636	6780.000269	1263600.02806	1.539
4593	Polygon	2303499	9734266	NHDFlowline	0.9531	6239.999929	953100.018094	1.335
4675	Polygon	2303581	9734810	NHDFlowline	0.4833	4079.999769	483300.001045	0.566

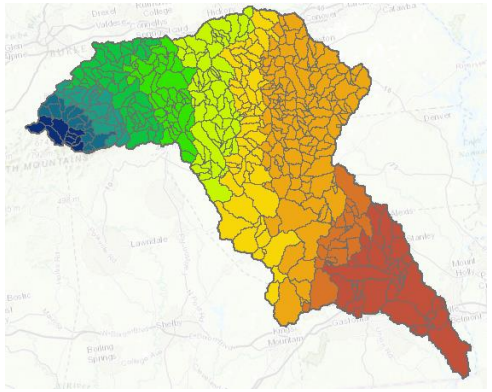
Catchment Attribute Table

Flowline attributes (NHD+)

- Flowline length (km)
- Path length (km)
- Arbolate sum (km)
- Stream order (Strahler)
- Feature type (stream, canal, artificial path, etc.)
- Slope (m/m)
- Flow (cfs)
  - mean annual
  - min. monthly
  - max. monthly
- **Mean annual velocity (fps)**



Catchment attributes (NHD+)

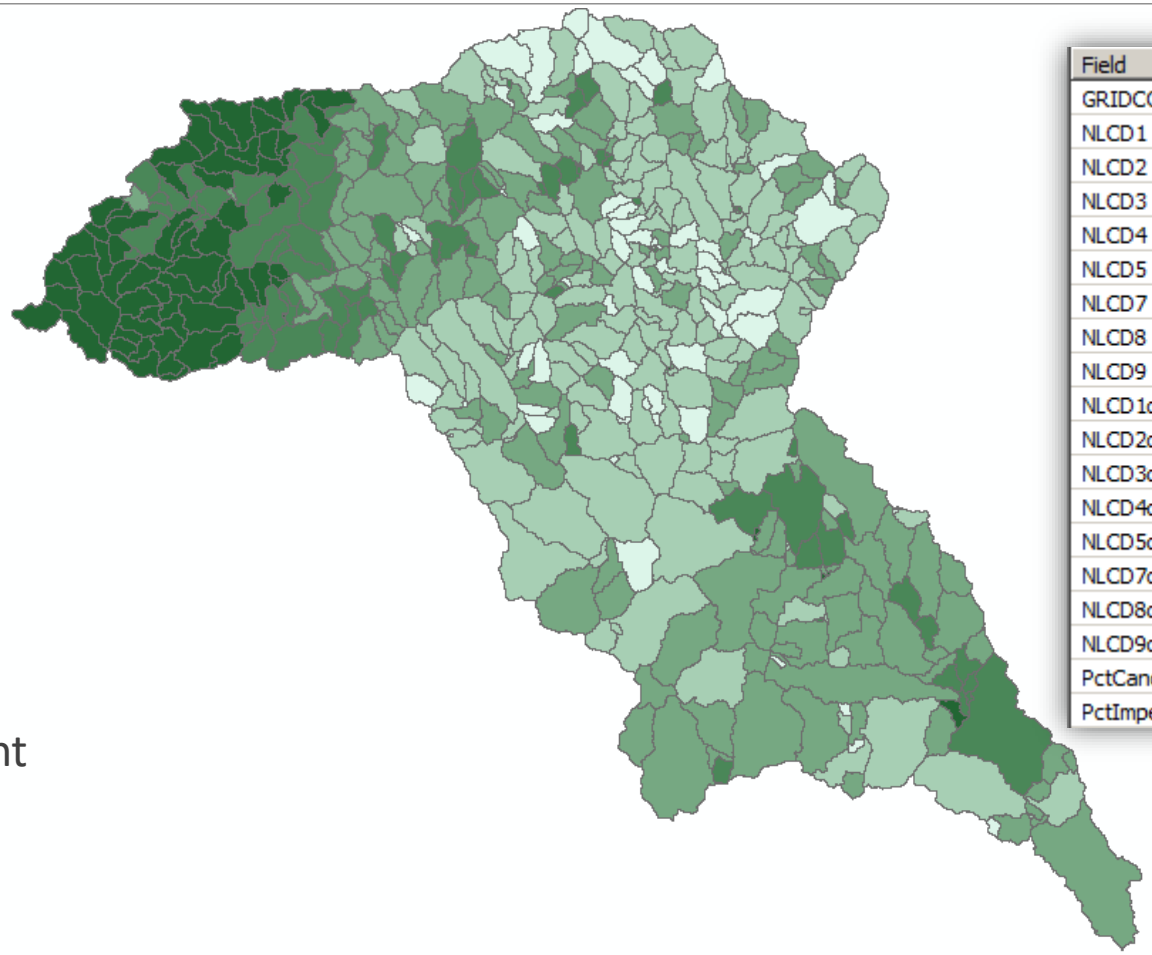


- Area (km^2)
- Total upstream area (km^2)
- Temperature (°C * 100)
  - Mean annual, within catchment
  - Min. & Max. monthly, within catchment
  - Mean annual, upstream of catchment
- Precipitation (mm * 100)
  - **Mean annual, within catchment**
  - Min. & Max. monthly, within catchment
  - Mean annual, upstream of catchment
- Runoff (mm)
  - Mean annual in area of catchment
  - Min & Max. monthly in catchment
- Potential evapotranspiration (mm)

Catchment Attribute Table

Land cover (NLCD – level 1)

- Catchment area (km²) classified as:
  - Water
  - Developed
  - Barren
  - Forest
  - Shrubland
  - Herbaceous
  - Cultivated
  - Wetland
- Upstream area [classified as above]
- Percent impervious surface of catchment
- **Percent canopy cover of catchment**



Field	Value
GRIDCODE	2301450
NLCD1	0.0081
NLCD2	0.8559
NLCD3	0.0135
NLCD4	6.1272
NLCD5	5.0175
NLCD7	0.7812
NLCD8	4.0149
NLCD9	0.0054
NLCD1c	0.0081
NLCD2c	0.8559
NLCD3c	0.0135
NLCD4c	6.1272
NLCD5c	5.0175
NLCD7c	0.7812
NLCD8c	4.0149
NLCD9c	0.0054
PctCanopy	54.449689
PctImpervious	1.039163

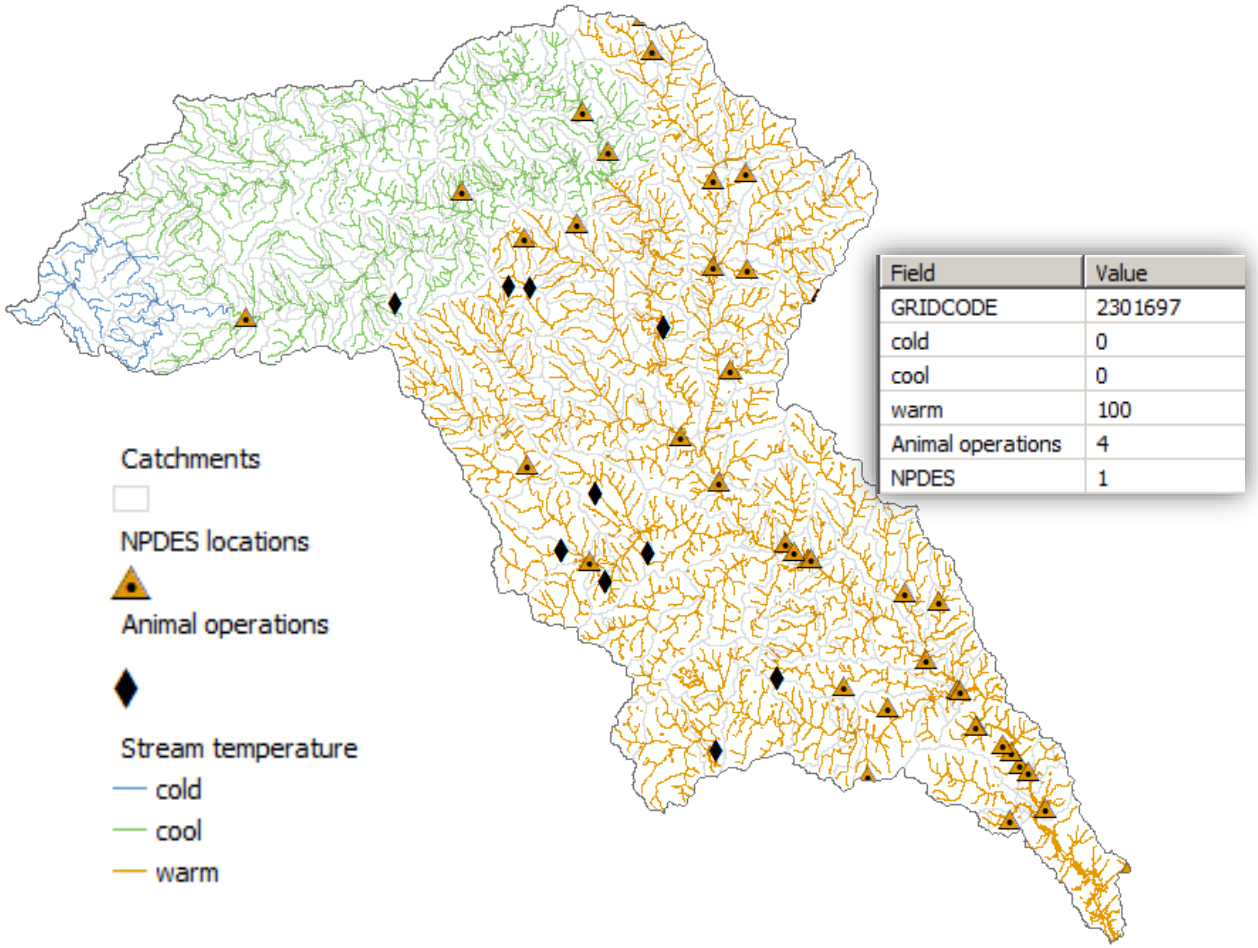
Catchment Attribute Table

Stream temperature (NCCGIA)

- Flowline length (km) classified as:
  - Cold
  - Cool
  - Warm

Other (NC OneMap)

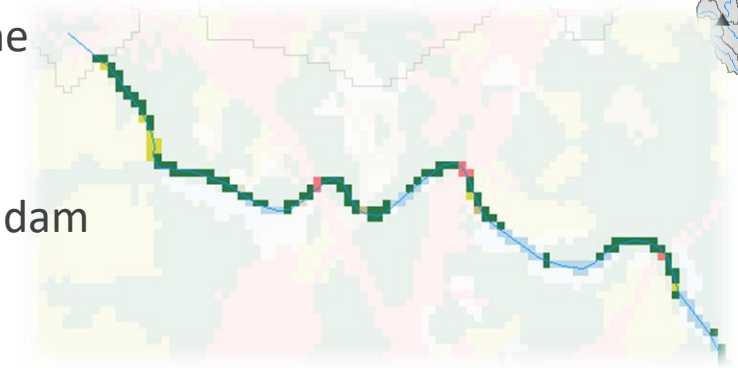
- NPDES within the catchment
- Animal operation permits within the catchment

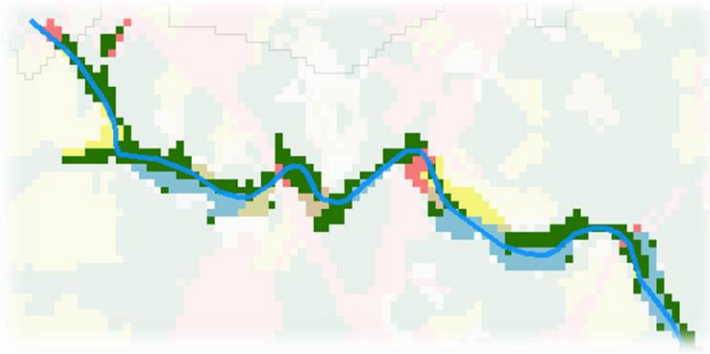


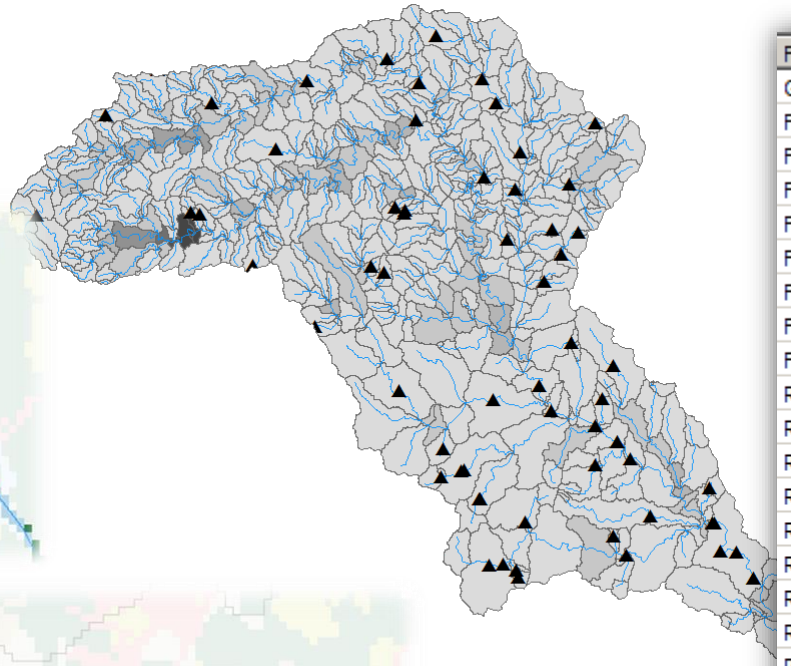
Catchment Attribute Table

Derived attributes

- Land cover along flow path (km^2)
- Land cover within riparian zone
  - Total area in catchment (km^2)
  - Percentage of riparian area
- Flow path distance to nearest dam
  - Upstream (km)
  - Downstream (km)







Field	Value
GRIDCODE	2301680
FLNLCD_1	0
FLNLCD_2	1800
FLNLCD_3	0
FLNLCD_4	77400
FLNLCD_5	0
FLNLCD_7	1800
FLNLCD_8	2700
FLNLCD_9	0
Riparian_1A	0
Riparian_2A	5400
Riparian_3A	0
Riparian_4A	121500
Riparian_5A	900
Riparian_7A	6300
Riparian_8A	10800
Riparian_9A	0
Riparian_1P	0
Riparian_2P	0.037267
Riparian_3P	0
Riparian_4P	0.838509
Riparian_5P	0.006211
Riparian_7P	0.043478
Riparian_8P	0.074534
Riparian_9P	0
downstreamDist...	21.71708
upstreamDistanc...	2.3

Identifying tags

- NHD+ common id (ComID)
- NHD+ ReachCode (HUC 14)

Catchment Attribute Table

~80 different attributes for each catchment

Field	Value
GRIDCODE	2301786
FEATUREID	9745348
SOURCEFC	NHDFlowline
AreaSqKM	4.6845
LENGTHKM	2.988
REACHCODE	03050102000354
FTYPE	StreamRiver
FCODE	46006
StreamOrde	1
Pathlength	599.489
ArbolateSu	2.988
TotDASqKM	4.6845
SLOPE	0.045157
Q0001E	2.91
V0001E	0.96505
Qincr0001E	2.90971
TEMP0001	13.89722
PPT0001	1315.0271
PET0001	748.4801
QLOSS0001	0
Q0001E_min	0.504
Q0001E_max	8.596
TempVC	1389.760009
TempMA	1389.760009
Temp_min	303.752014
Temp_max	2427.090087

Field	Value
Temp_min	303.752014
Temp_max	2427.090087
PrecipVC	131503
PrecipMA	131503
Precip_min	9710.379882
Precip_max	12896.5
RunOffMA	554.684997
RunOff_min	8.006719
RunOff_max	87.6594
NLCD1	0
NLCD2	0.1926
NLCD3	0.0018
NLCD4	4.3155
NLCD5	3.7287
NLCD7	0.0333
NLCD8	0.0423
NLCD9	0
NLCD1c	0
NLCD2c	0.1926
NLCD3c	0.0018
NLCD4c	4.3155
NLCD5c	3.7287
NLCD7c	0.0333
NLCD8c	0.0423
NLCD9c	0

Field	Value
FLNLCD_1	0
FLNLCD_2	10800
FLNLCD_3	0
FLNLCD_4	71100
FLNLCD_5	900
FLNLCD_7	18900
FLNLCD_8	11700
FLNLCD_9	0
Riparian_1A	0
Riparian_2A	27900
Riparian_3A	0
Riparian_4A	126900
Riparian_5A	2700
Riparian_7A	20700
Riparian_8A	12600
Riparian_9A	0
Riparian_1P	0
Riparian_2P	0.146226
Riparian_3P	0
Riparian_4P	0.665094
Riparian_5P	0.014151
Riparian_7P	0.108491
Riparian_8P	0.066038
Riparian_9P	0
LongestSegment	768.425499
MeanShadeLength	65.414256

Field	Value
cold	0
cool	100
warm	0
PctCanopy	94.508742
PctImpervious	0.287608
Animal operations	0
NPDES	0
downstreamDistance_km	27.12932
upstreamDistance_km	2.988

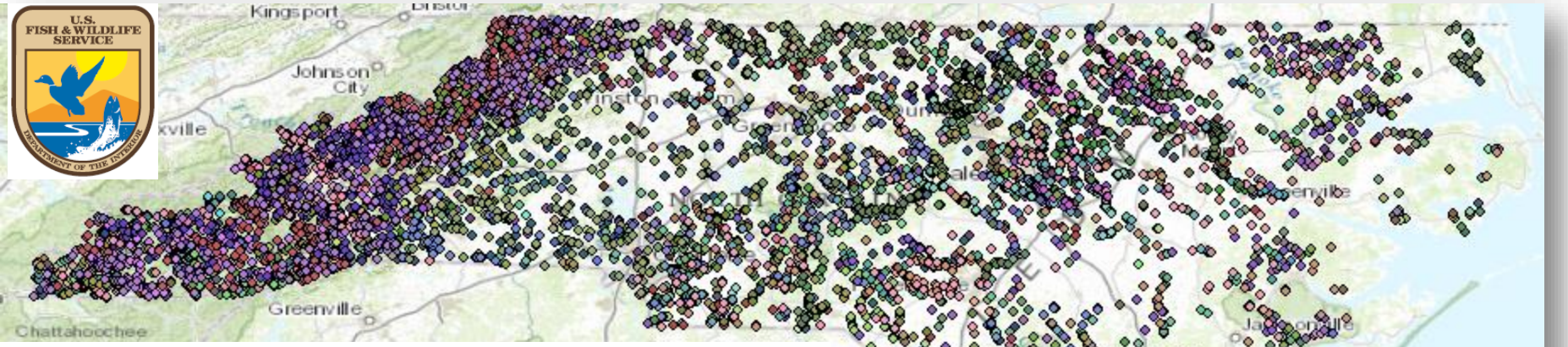
1. Assessing Current Conditions (overview)

A. The datasets used to drive the analysis
   - Catchment attribute table
   - Species occurrence table 

B. Selecting the species and building the habitat models

C. Modeling catchment status under current conditions

Species Occurrence Table



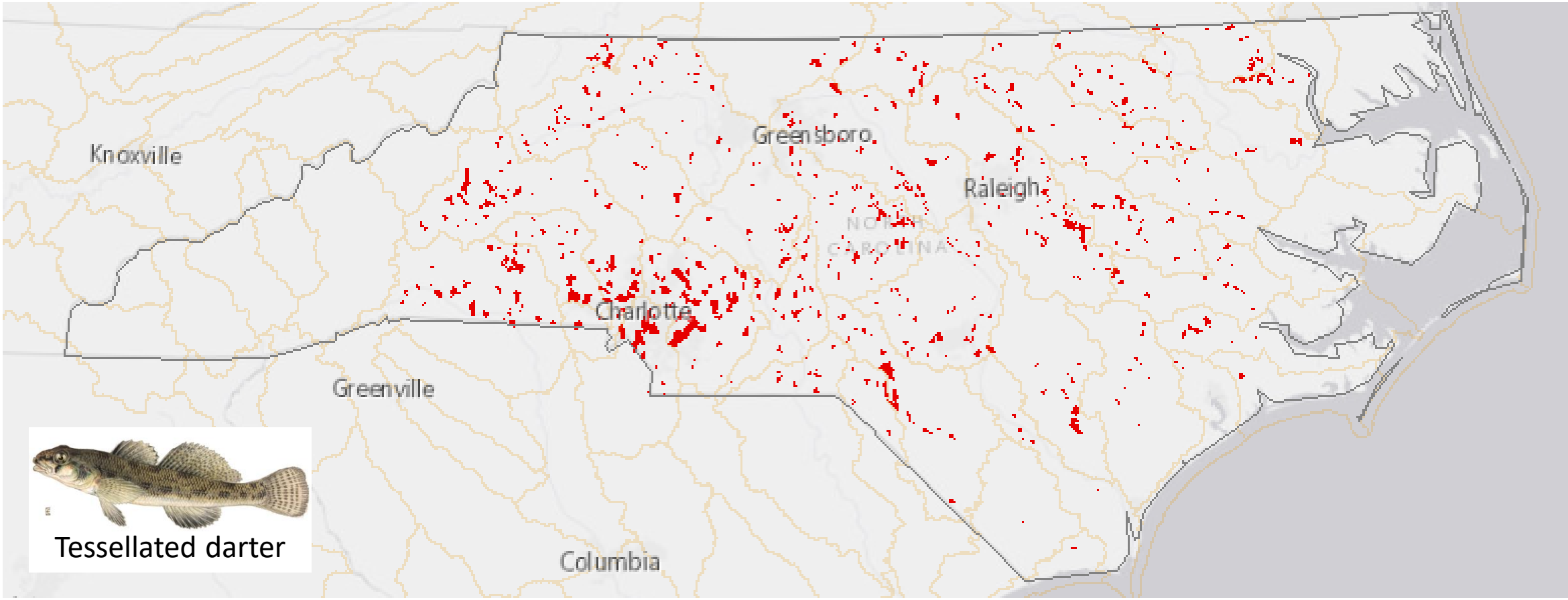
Aquatic Species Mapping in North Carolina Using Maxent

Mark Endries
U.S. Fish and Wildlife Service, Ecological Services Field Office, Asheville North Carolina

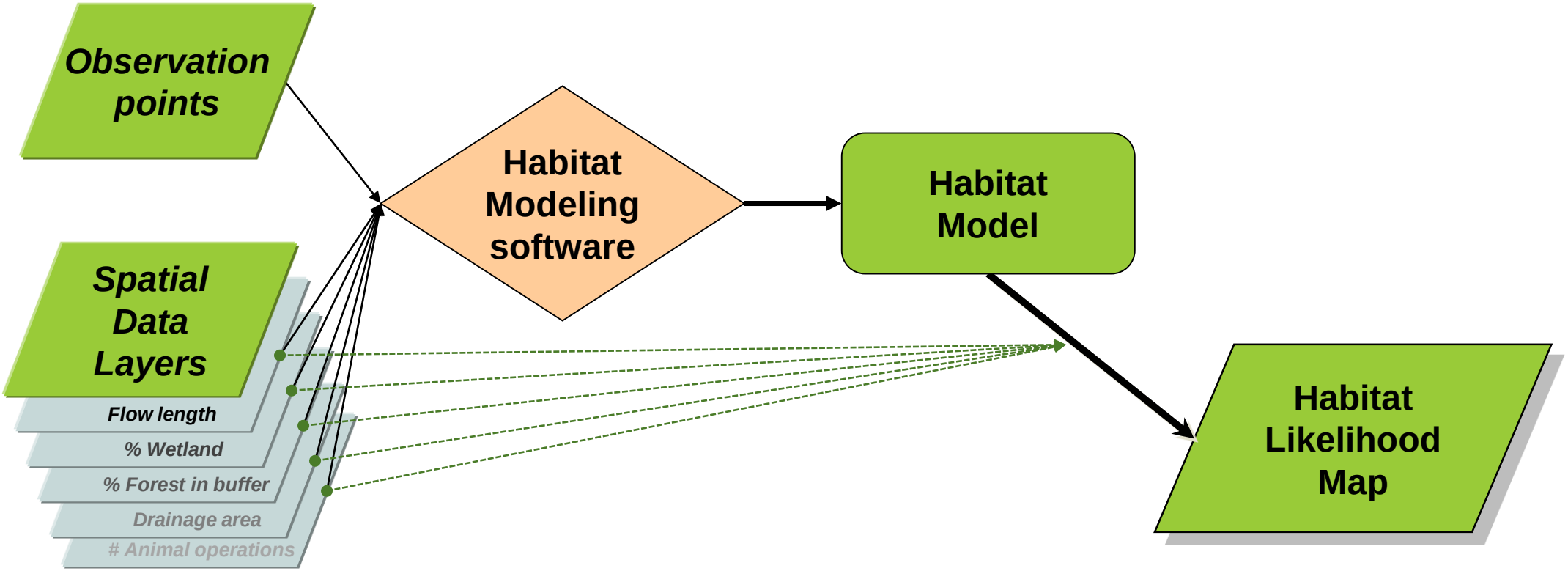
Species occurrences by catchment

GRIDCODE	REACHCODE	Acantharchus pomotis	Acipenser oxyrinchus	Alasmidonta heterodon	Alasmid
2240265	03020101000534	<Null>	<Null>	<Null>	<Null>
2240266	03020101000594	<Null>	<Null>	<Null>	<Null>
2240267	03020101000800	<Null>	<Null>	<Null>	<Null>
2240268	03020101000660	<Null>	<Null>	<Null>	<Null>
2240269	03020101000716	1	0	0	
2240270	03020101000807	<Null>	<Null>	<Null>	<Null>
2240271	03020101000807	<Null>	<Null>	<Null>	<Null>
2240272	03020101000790	<Null>	<Null>	<Null>	<Null>
2240273	03020101000898	<Null>	<Null>	<Null>	<Null>

Species Occurrence Table



Habitat- Models

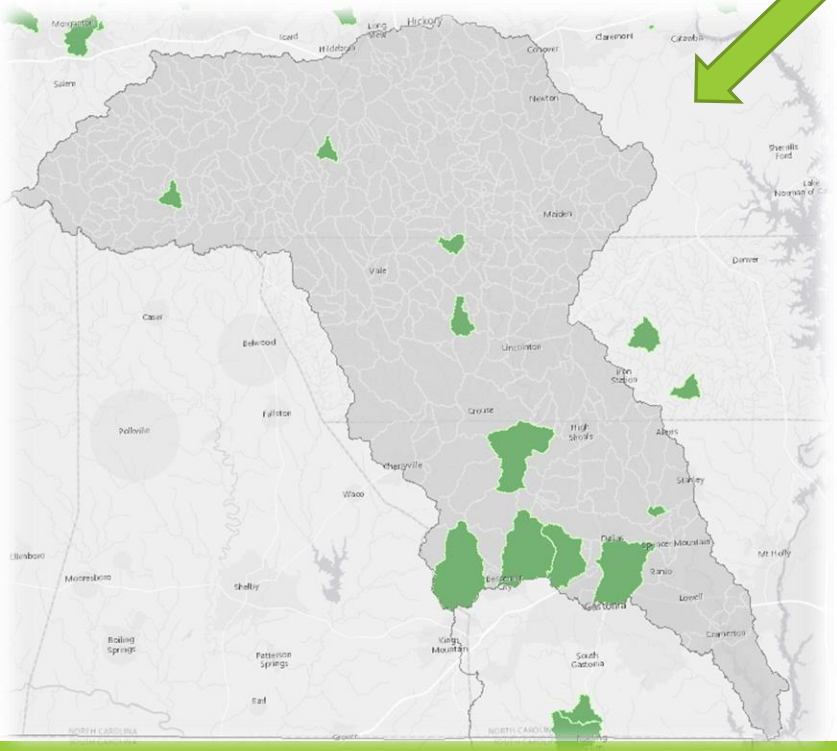


Habitat Modeling: Focal Species

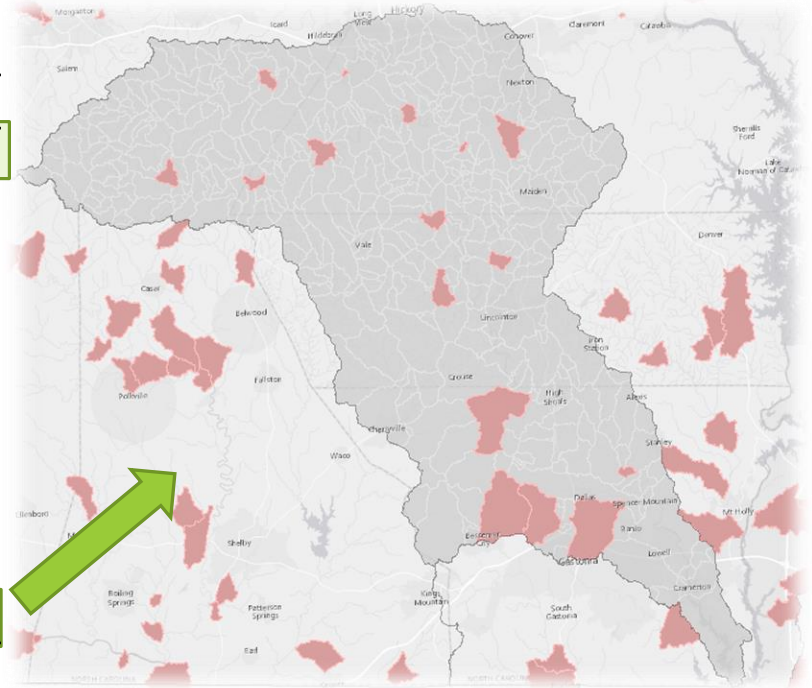
	A	B	C	D
1	Level III Ecoregion	Rank	Species	Indicator Comments
2	Mountains	1	Mottled Sculpin (where native)	Fast cobble riffles; umbrella for Longnose Dace, Northern Hog Sucker
3		2	Warpaint Shiner (where native)	Pools and runs
4		3	Tennessee Shiner (where native)/New River Shiner	Pools and runs, endemic (New River Shiner)
5		4	Rainbow Trout	Surrogate for our native Southern Appalachian Brook Trout, cold, clear water
6		5	River Chub/Bluehead Chub/Bigmouth Chub	Stream engineer; important for colonial nesters
7		6	Greenfin Darter/Redline Darter	Fast cobble riffles, cool-cold water
8		7	Longnose Dace	Fast riffles, clear cool water
9		8	Northern Hog Sucker (where native)	Fast cobble riffles
10		9	Kanawha Darter/Swannanoa Darter	Endemic (Kanawha Darter), cobbler riffles
11		10	Mountain Brook Lamprey	Silts and cobble riffles
12				
13	Piedmont	1	Bluehead Chub	Stream engineer; important for colonial nesters
14		2	Fantail Darter/Carolina Fantail Darter	Unembedded and clean flat rocks needed for nests
15		3	Pirate Perch	Rocky pools and undercut banks
16		4	Margined Madtom	Cobble substrate
17		5	Notchlip Redhorse	Deeper pools and runs
18		6	Redlip Shiner (where native)/Greenhead Shiner/Piedmont Shiner	Colonial nesters
19		7	Whitemouth Shiner/Swallowtail Shiner (where native)	Sandy, gravelly pools
20		8	Chainback Darter/Piedmont Darter	Cobble riffles
21		9	Redbreast Sunfish	Snags and pools; can be dominant in urban streams
22		10	Highfin Shiner	Rocky pools
23		11	Rosyside Dace	Snags and undercut banks, pools
24		12	Tessellated Darter/Johnny Darter	Widely distributed, varied habitats
25				
26	Mid-Atlantic Coastal Plain	1	American Eel	Catadromous; distrbution fragmented by dams
27		2	Eastern Mudminnow	Undercuts and cover
28		3	Dusky Shiner/Swallowtail Shiner/Ironcolor Shiner/Highfin Shiner	Pools and runs
29		4	Redfin Pickerel	Shallow flats and undercuts
30		5	Creek Chubsucker/Spotted Sucker	Deeper pools with snags and undercuts
31		6	Tadpole Madtom	Cover
32		7	Pirate Perch	Roots and undercuts
33		8	Mud Sunfish	Cover
34		9	Bluespotted Sunfish	Cover
35		9	Tessellated Darter	Widely distributed, varied habitats
36				
37	Southeastern Plains	1	American Eel	Catadromous; distrbution fragmented by dams
38		2	Eastern Mudminnow	Undercuts and cover
39		3	Dusky Shiner/Swallowtail Shiner/Ironcolor Shiner/Highfin Shiner	Pools and runs
40		4	Redfin Pickerel	Shallow flats and undercuts
41		5	Creek Chubsucker/Spotted Sucker	Deeper pools with snags and undercuts
42		6	Tadpole Madtom	Cover
43		7	Pirate Perch	Roots and undercuts
44		8	Mud Sunfish	Cover
45		9	Bluespotted Sunfish	Cover
46		10	Tessellated Darter	Widely distributed, varied habitats

- Focal species area selected to represent each ecoregion.
- Finding these species within a catchment reflects that catchment's health.
- Habitat models identify the catchment attributes associated with known occurrences of a species.
- The likelihood of finding a species in other catchments is estimated by applying the habitat model to attributes in that catchment.
- A higher likelihood of finding focal species in a catchment suggests the catchment is healthy.

Focal species: Piedmont (S. Fork Catawba)

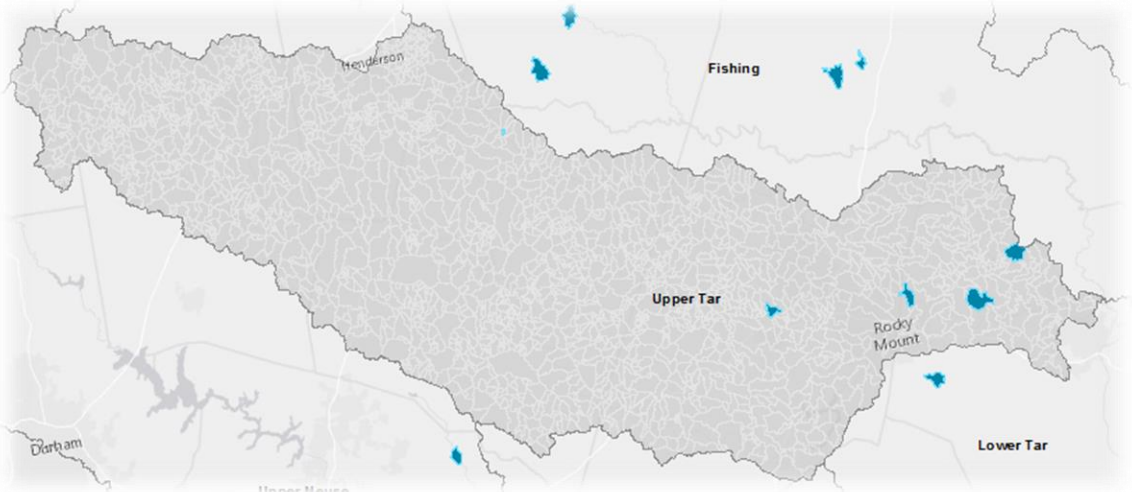


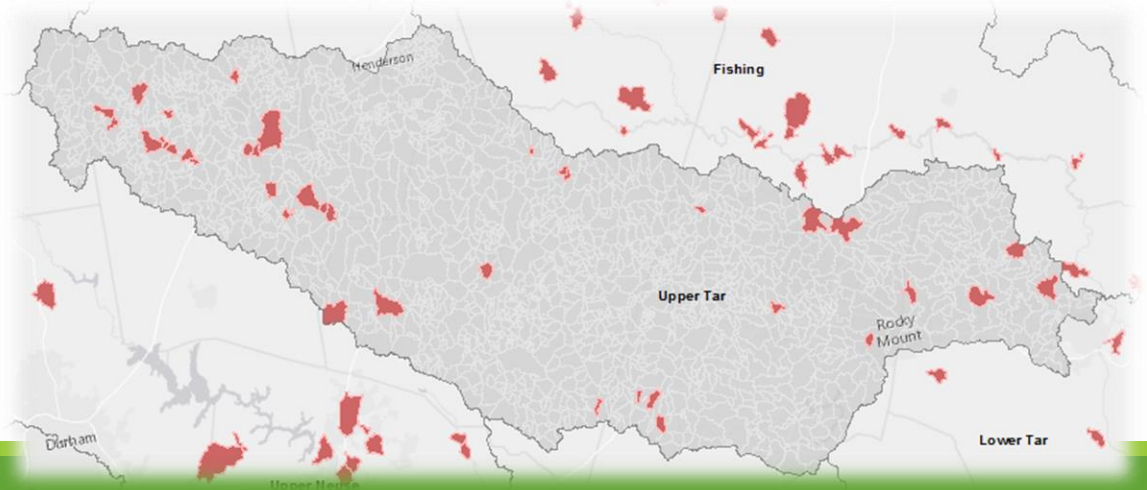
Common name	Scientific name
Bluehead Chub	Nocomis_leptocephalus
Fantail Darter	Etheostoma_flabellare
Pirate Perch	Aphredoderus_sayanus
Margined Madtom	Noturus_insignis
Notchlip Redhorse	Moxostoma_collapsum
Whitemouth Shiner	Notropis_alborus
Chainback Darter	Percina_nevisense
Redbreast Sunfish	Lepomis_auritus
Highfin Shiner	Notropis_altipinnis
Rosyside Dace	Clinostomus_funduloides
Tessellated Darter	Etheostoma_olmstedi



Focal species: MACP (Upper Tar)

Common name	Scientific name
American Eel	Anguilla_rostrata
Eastern Mudminnow	Umbra_pygmaea
Dusky Shiner	Notropis_cummingsae
Redfin Pickerel	Esox_americanus
Creek Chubsucker	Erimyzon_oblongus
Tadpole Madtom	Noturus_gyrinus
Pirate Perch	Aphredoderus_sayanus
Mud Sunfish	Acantharchus_pomotis
Bluespotted Sunfish	Enneacanthus_gloriosus
Tessellated Darter	Etheostoma_olmstedi

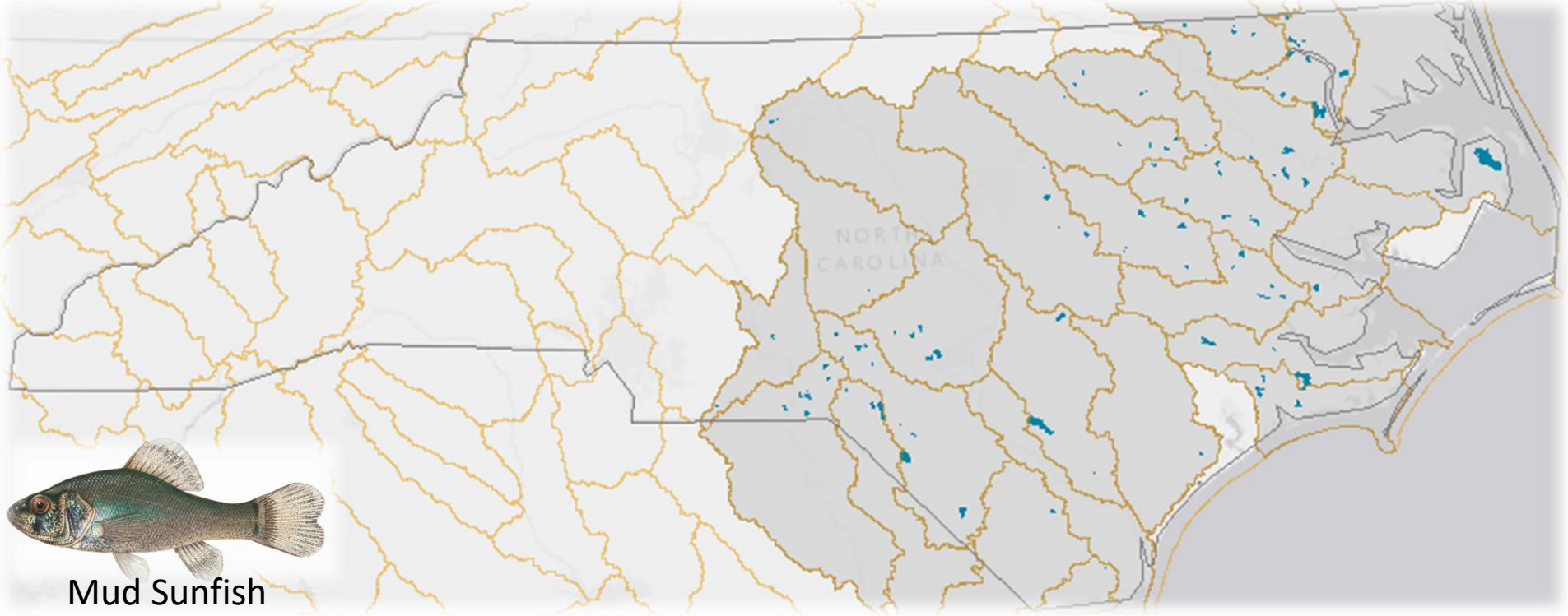




Habitat Models – Screening Inputs

Geographic screening:

Narrow modeling to catchments within the HUC8s in which the species exists.



Mud Sunfish

Habitat Models – Screening Inputs

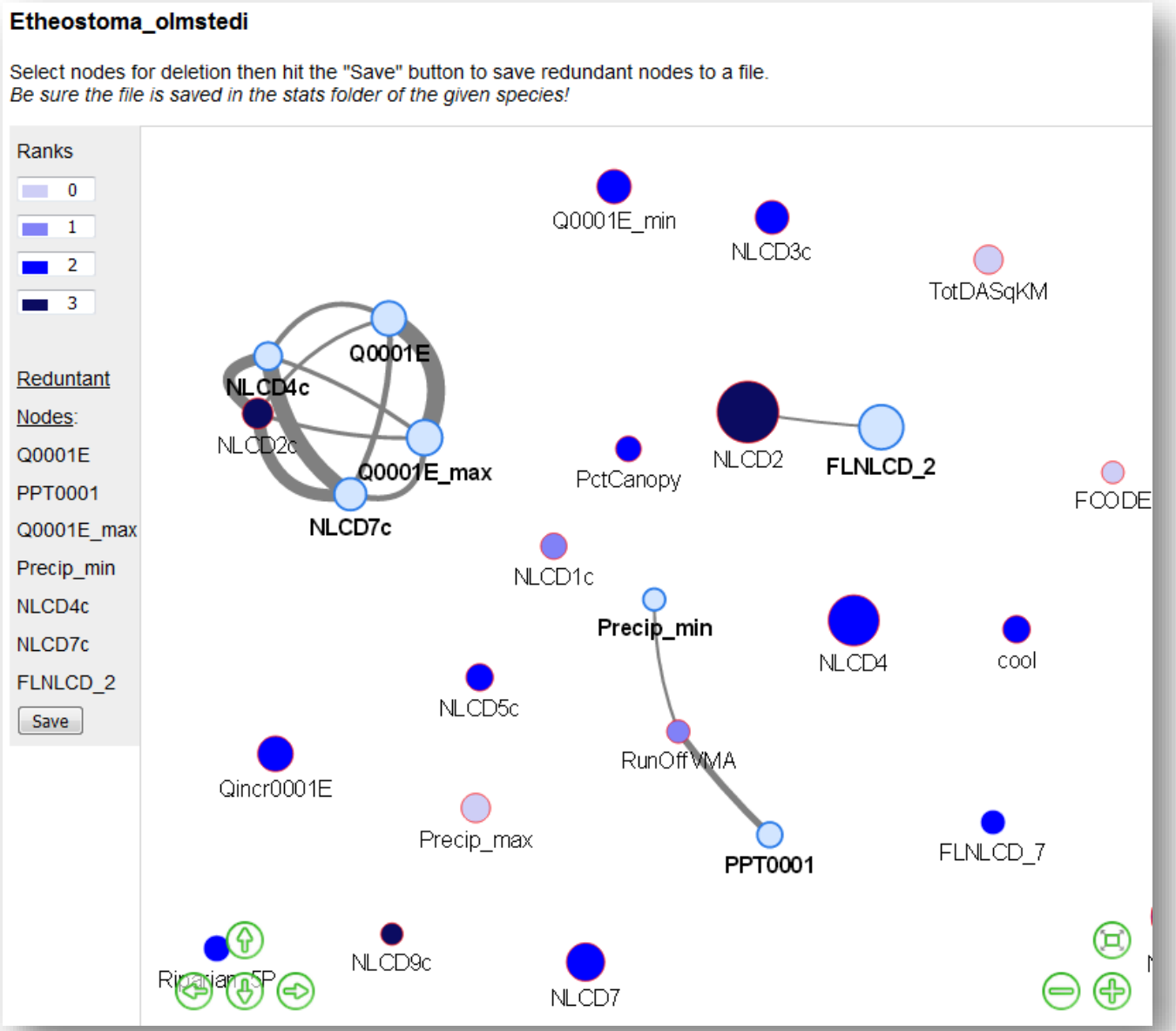
Attribute screening:

Eliminate irrelevant and redundant catchment attributes from the analysis

- Identify catchment attributes not significantly correlated with species occurrence.

- Identify catchment attributes that are correlated with each other (i.e. are redundant), and remove one of the pair…

variable	coef	p_value
~~AreaSqKM~~	~~0.0515~~	~~0.285~~
LENGTHKM	0.0494	0
FCODE	-0.012	0.008
~~StreamOrde~~	~~0.016~~	~~0.58~~
Qincr0001E	0.0414	0
PET0001	0.009	0.045
Temp_max	0.01	0.026
NLCD2	0.0225	0
NLCD3	0.0164	0
NLCD4	0.0385	0



Redundant Variable Screening Tool

- *Catchment attributes shown as circles*
  - **Size** reflects strength of correlation with species occurrence (larger → more correlated).
  - **Color** reflects the attributes association with management actions (darker → more direct association with management action)
  - **Red borders** indicate the attributes is from primary data (e.g. NHD, NLCD).
- *Lines joining variables indicate redundancy*
  - The size of the line reflects the strength of the correlation (thicker → more correlated).

➔ Users select redundant variables for elimination based on the parameters above and on knowledge of what's likely to be important to the species.

Habitat Models – Screening inputs

EnvStats

OBJECTID *	Shape *	GRIDCODE *	FEATUREID *	SOURCEFC	AreaSqKM	Shape_Length	Shape_Area	LENGTHKM
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16312	Polygon	2315437	9660784	NHDFlowline	0.0981	1740.000095	98100.006522	0.363
16334	Polygon	2315459	9660788	NHDFlowline	1.7667	9180.000479	1766700.034537	2.467
16335	Polygon	2315460	9660786	NHDFlowline	0.1026	1740.000095	102599.979189	0.435
	Polygon	2315494	9660800	NHDFlowline	0.1269	2459.999849	126899.984286	0.742
	Polygon	2315502	9660782	NHDFlowline	0.0198	1079.99988	19800.000931	-9999
	Polygon	2315656	25779512	NHDFlowline	0.1404	2459.999649	140399.984785	0.741
	Polygon	2316536	9645025	NHDFlowline	0.0216	720.000053	21599.997198	-9999
		2316792	9644961	NHDFlowline	0.0036	240.000151	3600.004533	-9999
	Polygon		9627231	NHDFlowline	7.5258	18000.000032	7525799.99759	-9999
	Polygon	2301397	9755514	NHDFlowline	3.9636	14820.00043	3963600.010755	1.291
	Polygon	2302740	9735184	NHDFlowline	0.9927	6119.999953	992699.9	
	Polygon	2303111	9733166	NHDFlowline	0.2826	2999.999789	282599.9	
4416	Polygon	2303319	9734970	NHDFlowline	1.2636	6119.000269	1263600	
4593	Polygon	2303499	9734266	NHDFlowline	0.9531	6239.999929	953100	
4675	Polygon	2303581	9734810	NHDFlowline	0.4833	4079.999769	483300	

Catchment Attributes

Select species

Catchment Species List

Identify HUC 8s

Select records in HUC 8s

Remove fields with NAs

Remove fields not correlated with presence

Identify redundant fields

Final field list

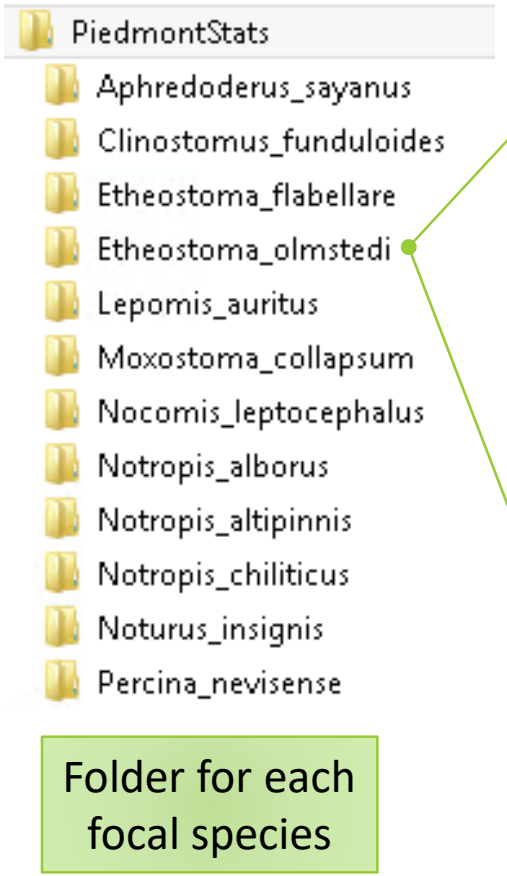
TID *	GRIDCODE	FEATUREID	Alasmidonta varicosa	Ambloplites rupestris	Ameiurus brunneus
58	2298816	9752140	0	0	0
59	2298816	9752140	0	0	0
60	2298824	9751576	0	1	0
61	2298824	9751576	0	0	0
62	2298838	9755474	0	0	0
63	2298838	9755474	0	0	0
64	2298838	9755474	0	0	0
65	2298838	9755474	0	0	0
66	2298838	9755474	0	0	0
67	2298838	9755474	0	0	0
68	2298838	9755474	0	0	0
69	2298863	9750410	0	1	0
70	2298864	9752394	0	0	0
71	2298874	9751628	1	0	0
72	2298874	9751628	0	0	0
73	2298875	9751698	1	0	0
74	2298875	9751698	1	0	0

Remove redundant fields

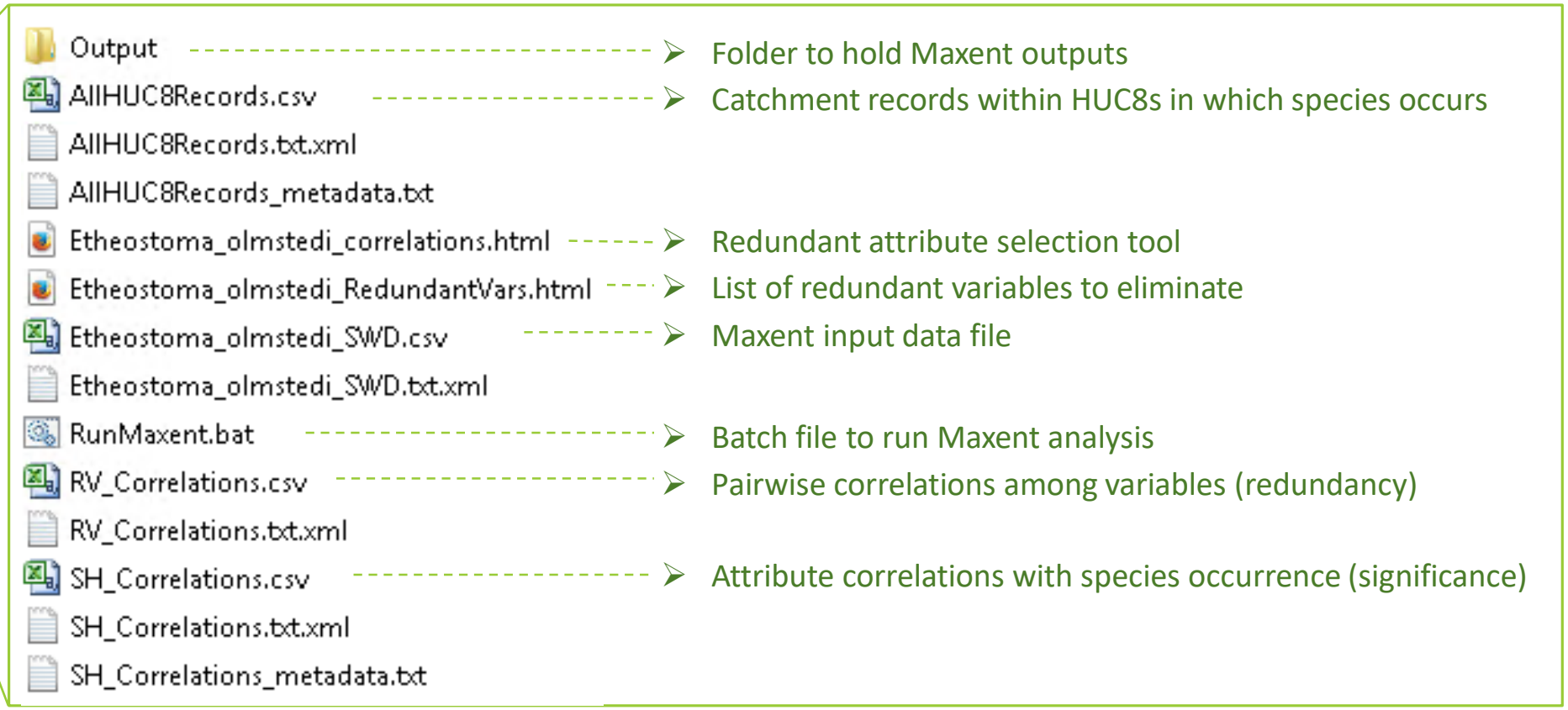
MaxEnt SWD

GLM inputs

Habitat Models – Maxent Model Inputs

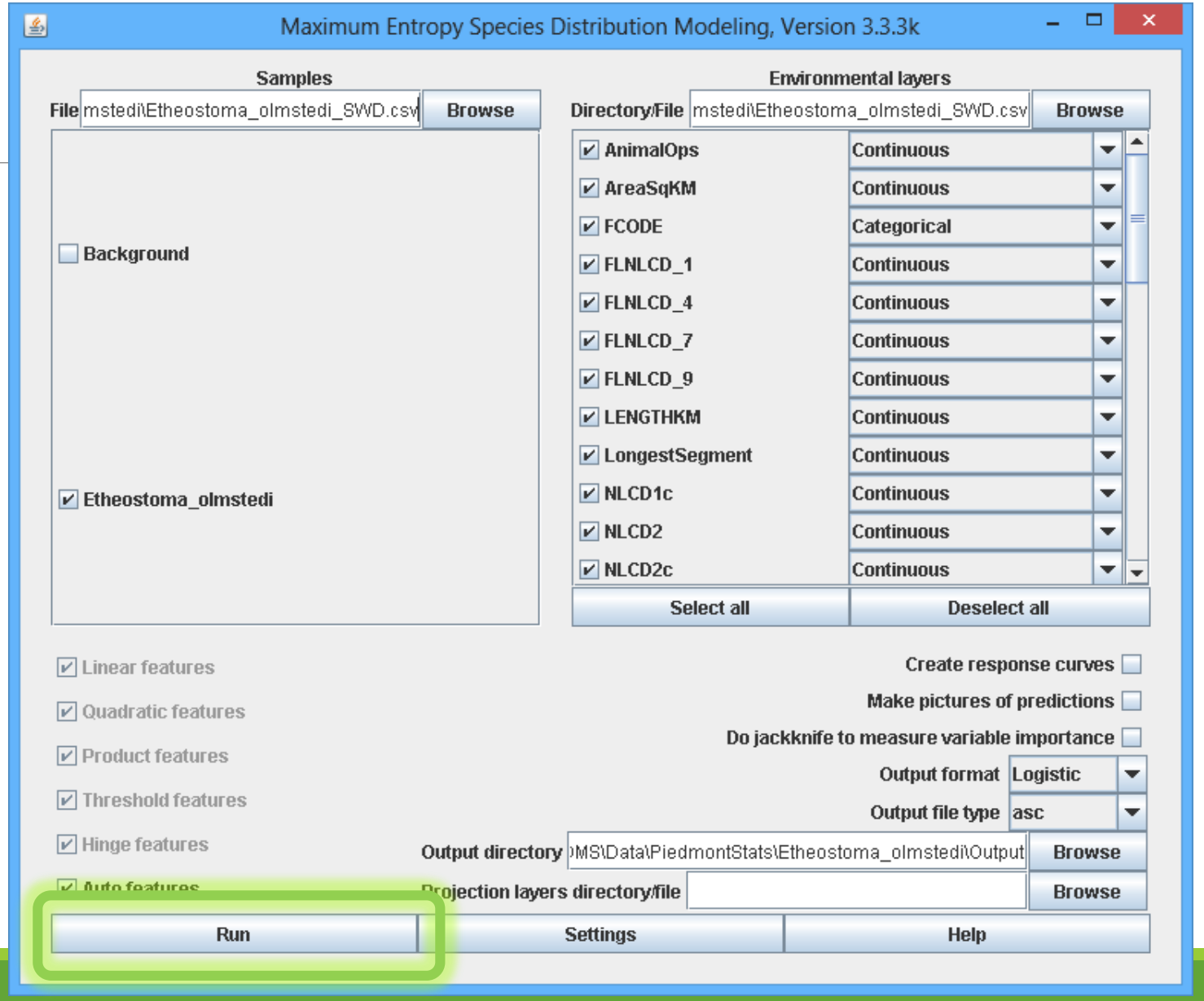


Folder for each focal species



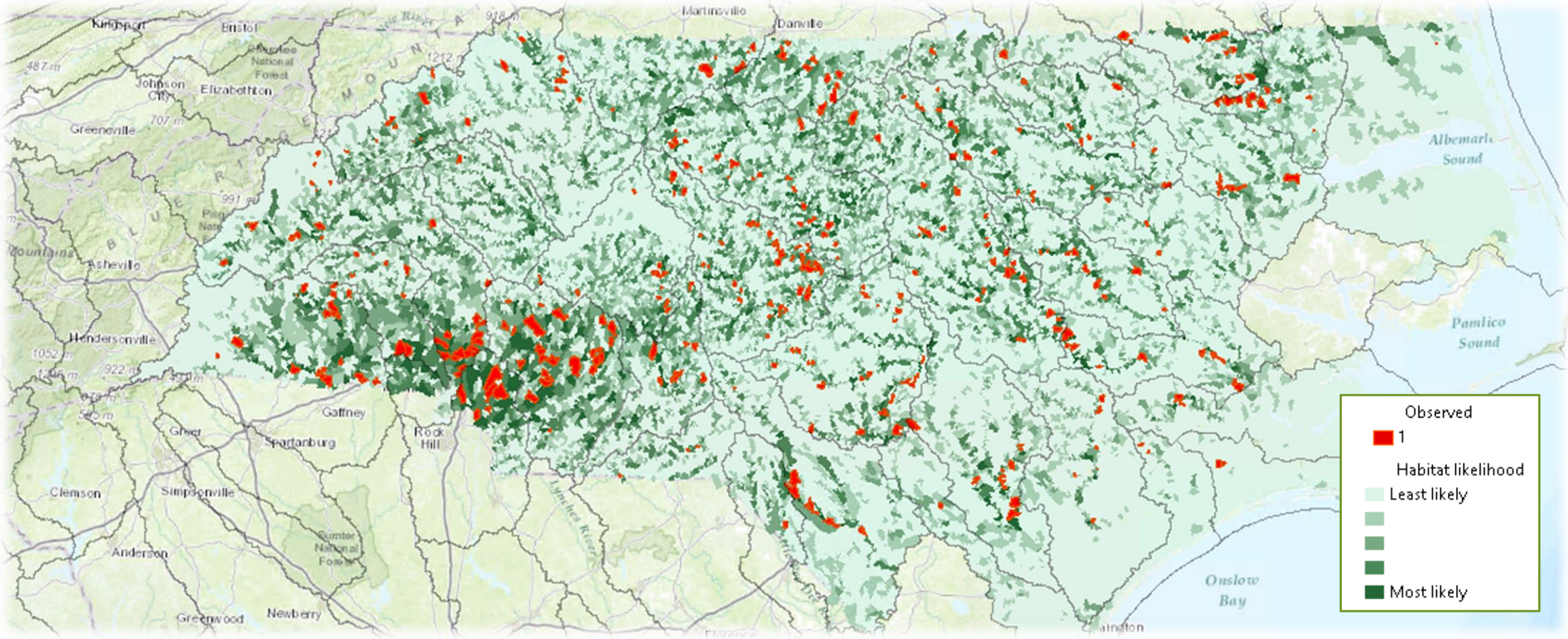
Running Maxent

- Output
- AllHUC8Records.csv
- AllHUC8Records.txt.xml
- AllHUC8Records_metadata.txt
- Etheostoma_olmstedi_correlations.html
- Etheostoma_olmstedi_RedundantVars.html
- Etheostoma_olmstedi_SWD.csv
- Etheostoma_olmstedi_SWD.txt.xml
- RunMaxent.bat
- RV_Correlations.csv
- RV_Correlations.txt.xml
- SH_Correlations.csv
- SH_Correlations.txt.xml
- SH_Correlations_metadata.txt

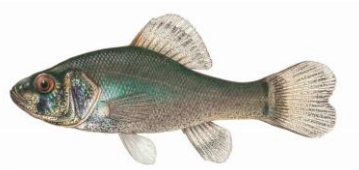


Current Conditions

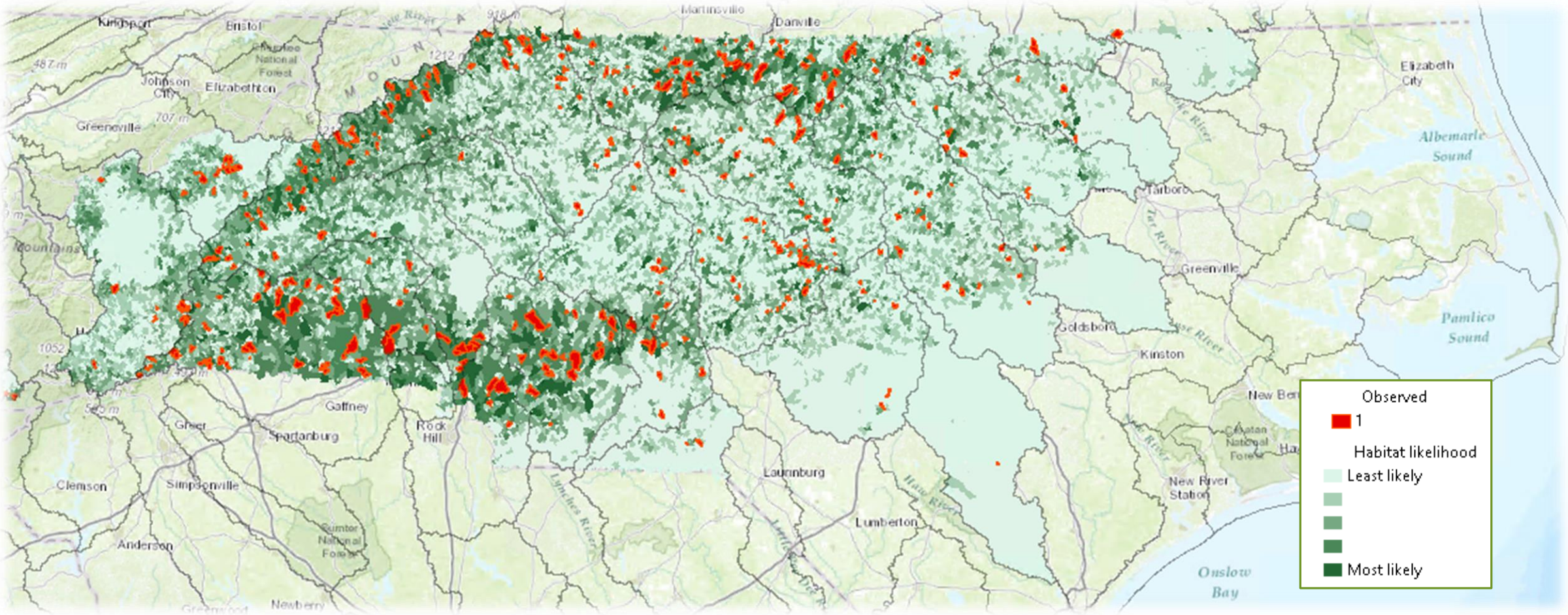
Tessellated darter



Current Conditions



Bluehead chub

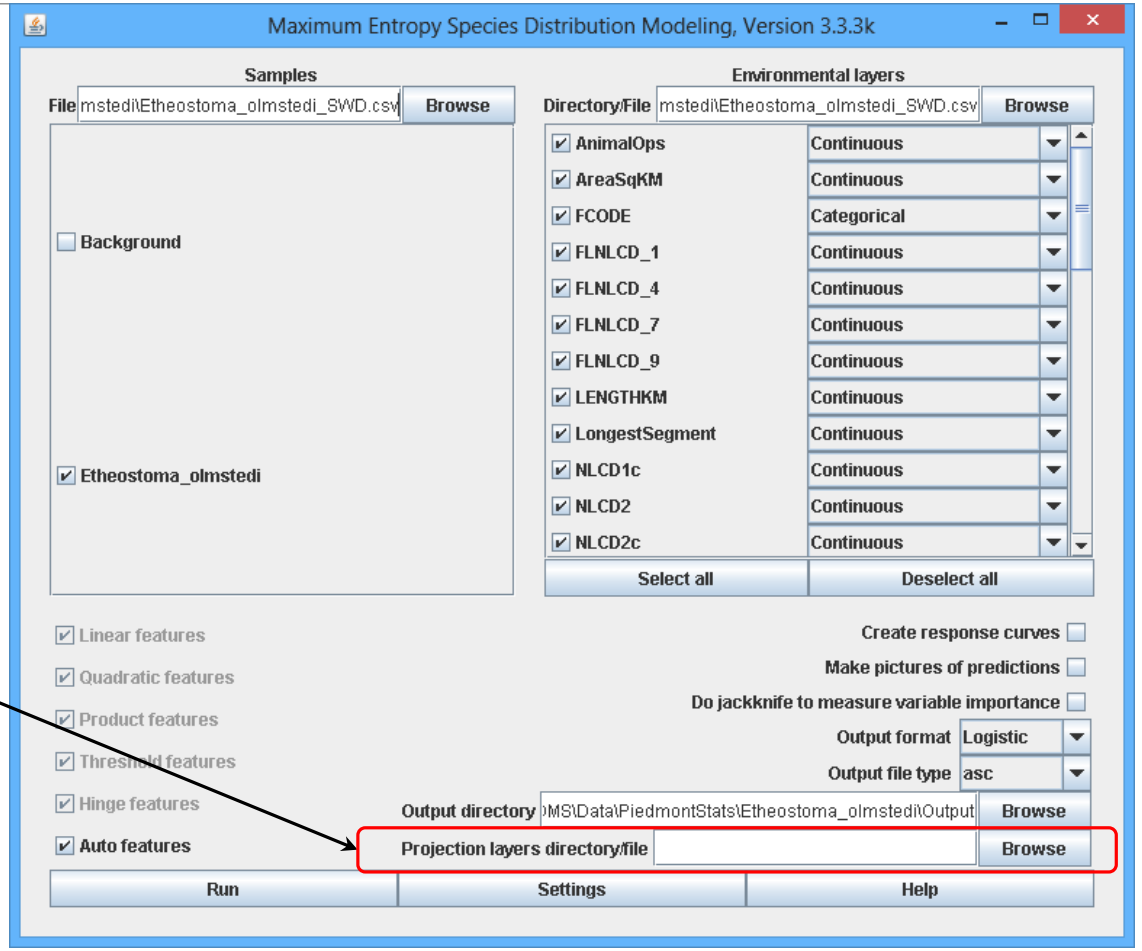


Habitat Modeling – *Projecting* Maxent

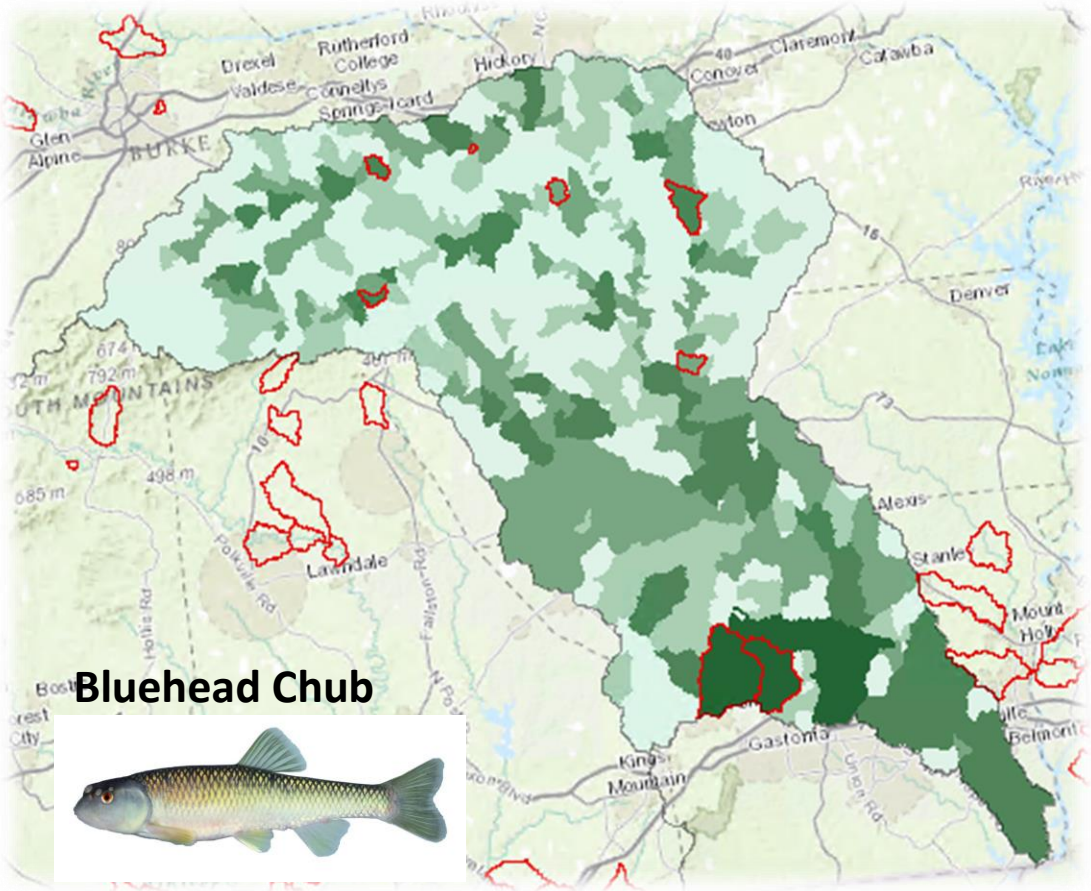
To use the Maxent model to predict habitat likelihood in HUC8s where we have no observations, we ***project*** the model to these locations.

Projecting is as simple as feeding Maxent a table of catchment attributes for the HUC 8 we want to model.

[Spoiler Alert]:
Projecting is important when we compute uplift…



Habitat current conditions: *S. Fork Catawba*



Bluehead Chub

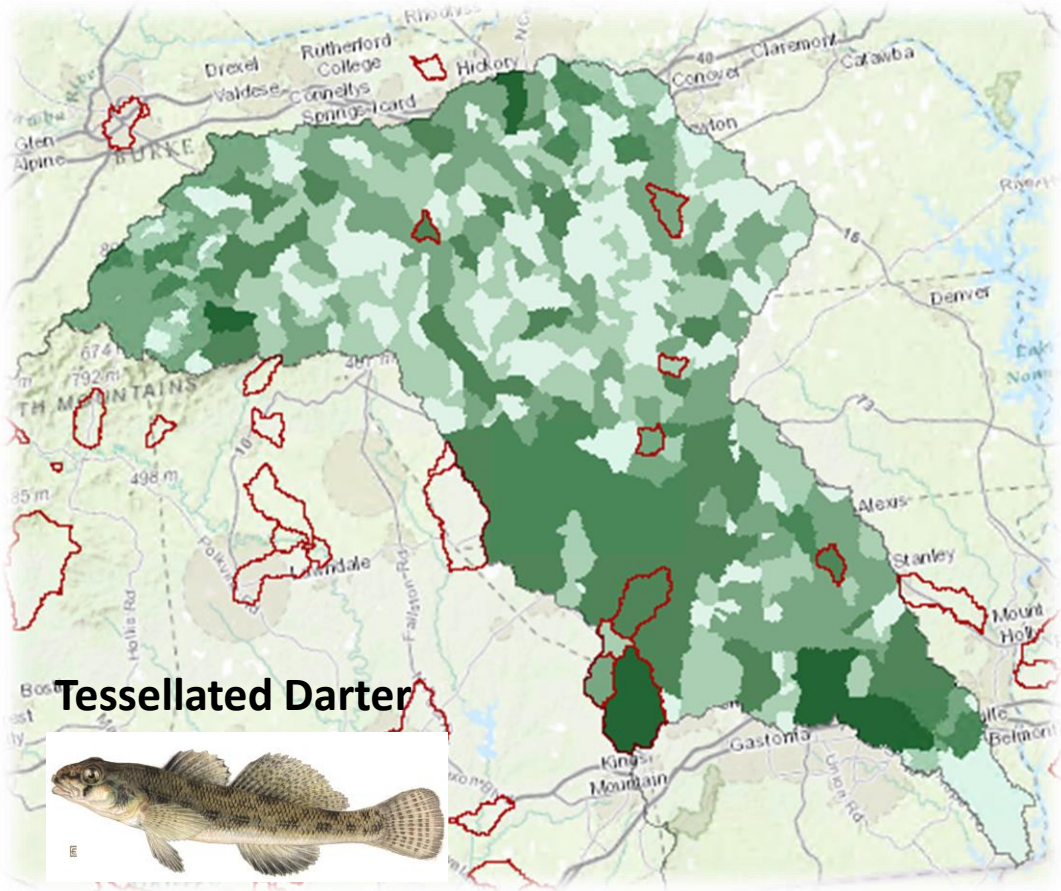
Observed

1

Habitat likelihood

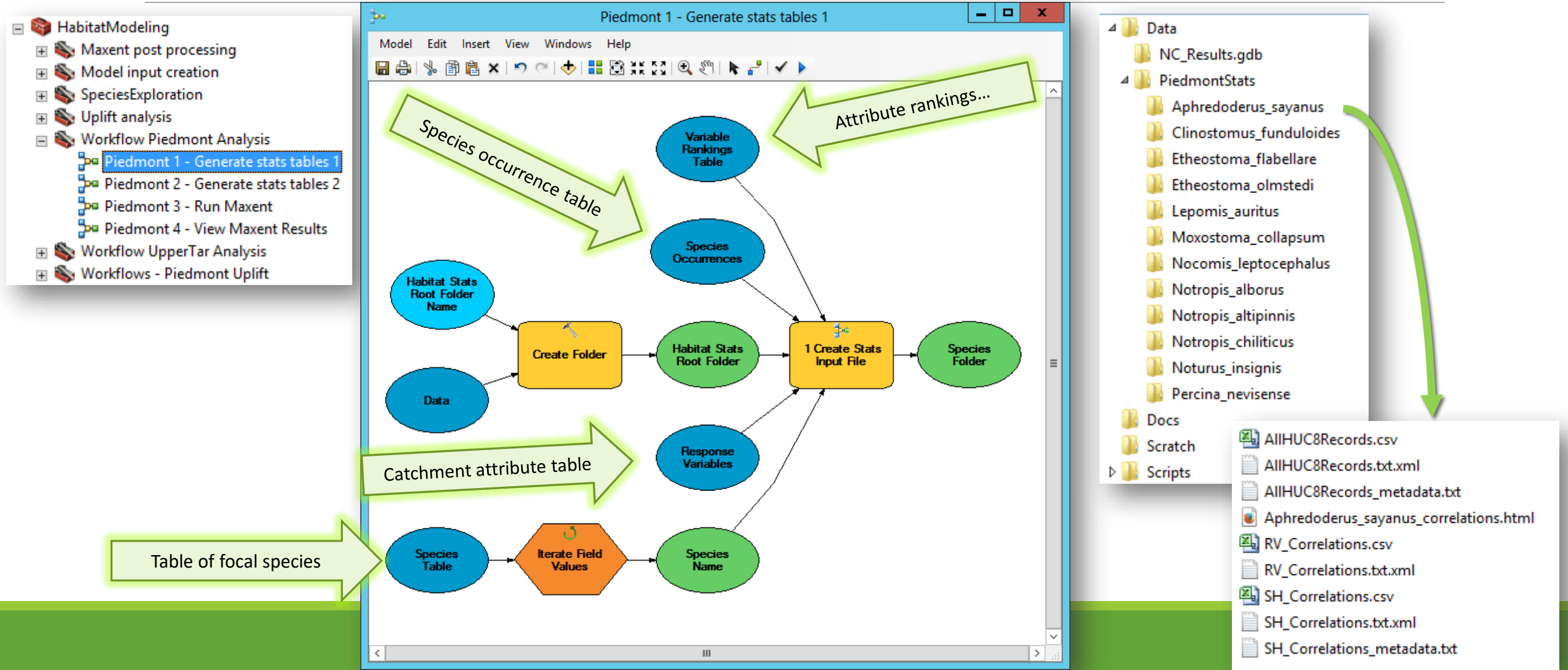
Least likely

Most likely

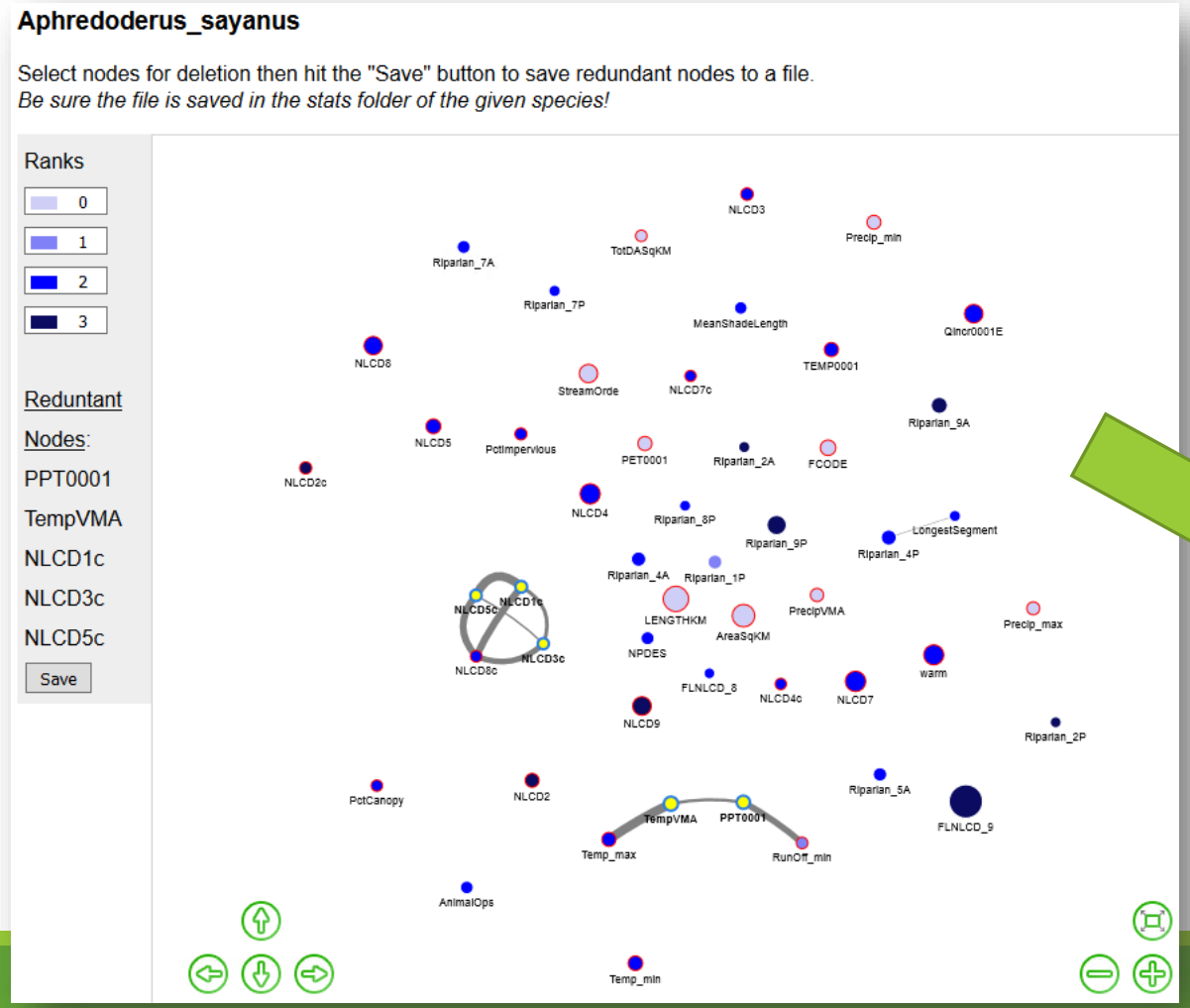


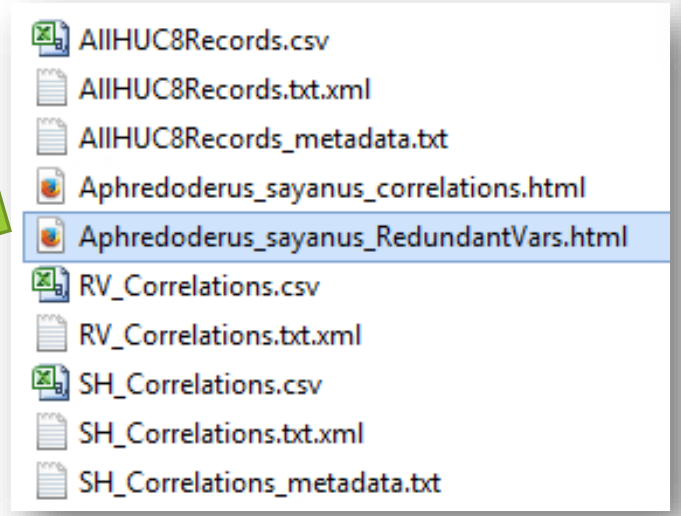
Tessellated Darter

Habitat Modeling Toolkit (step 1)



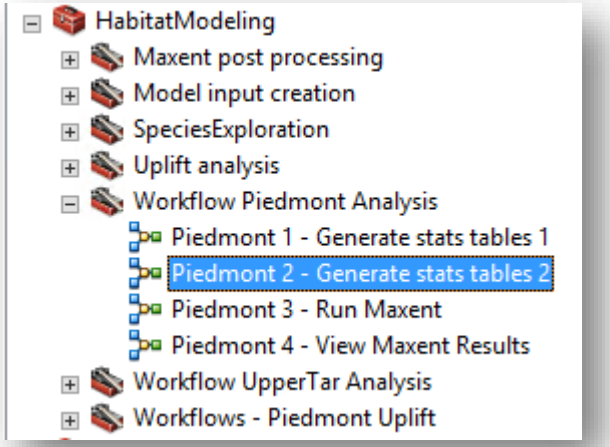
Habitat Modeling Toolkit (step 2)

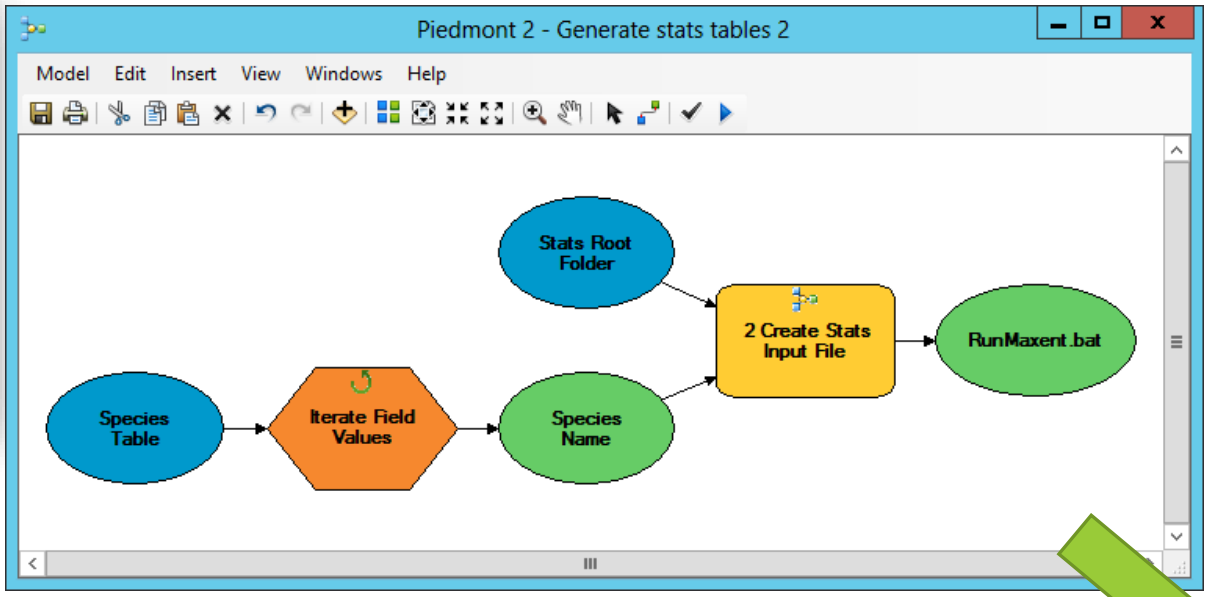


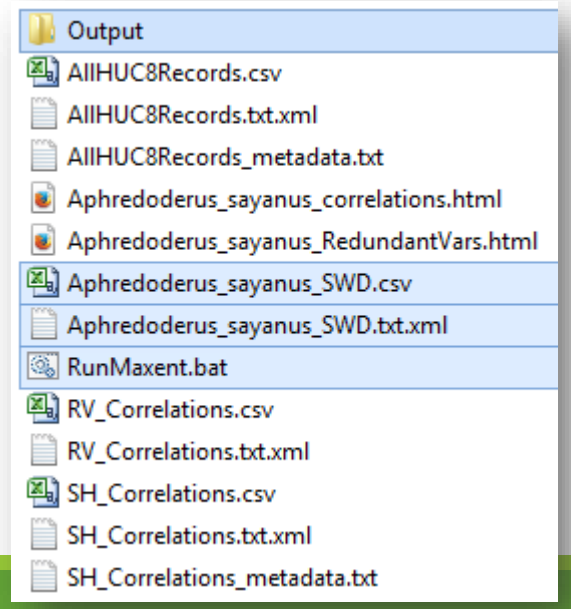


Reduntant Nodes:
PPT0001
TempVMA
NLCD1c
NLCD3c
NLCD5c

Habitat Modeling Toolkit (step 3)

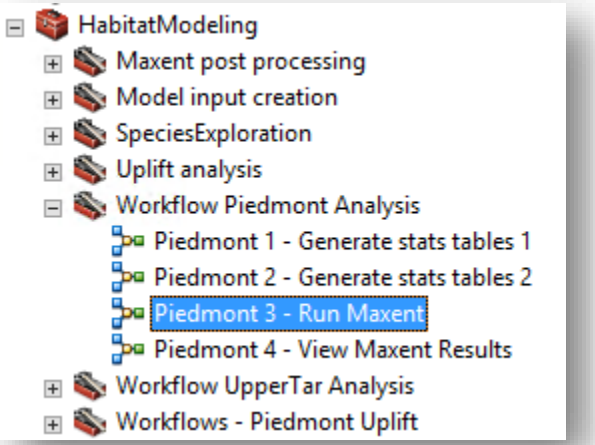


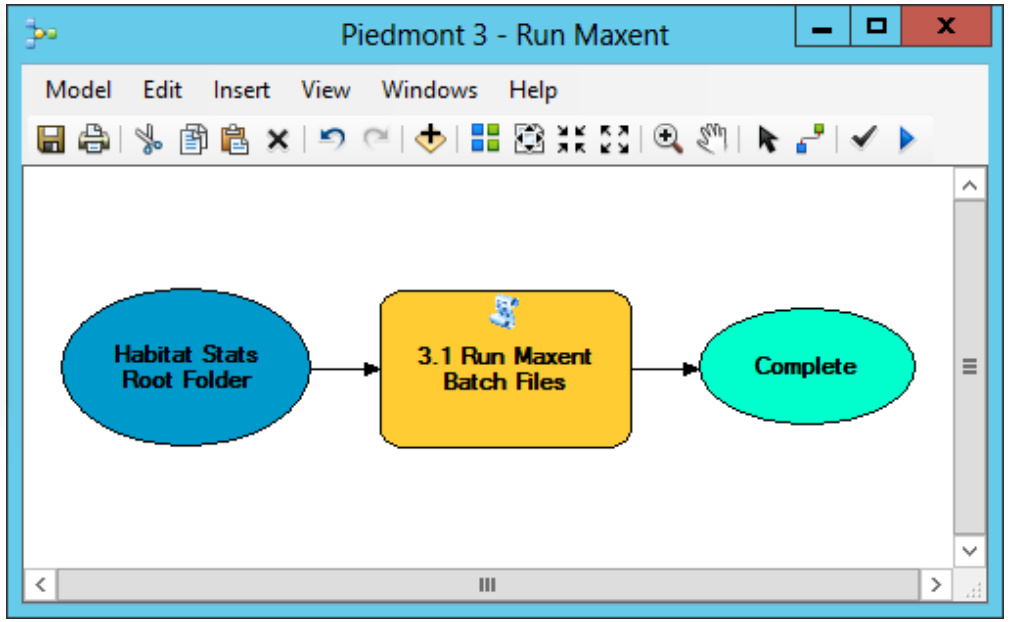


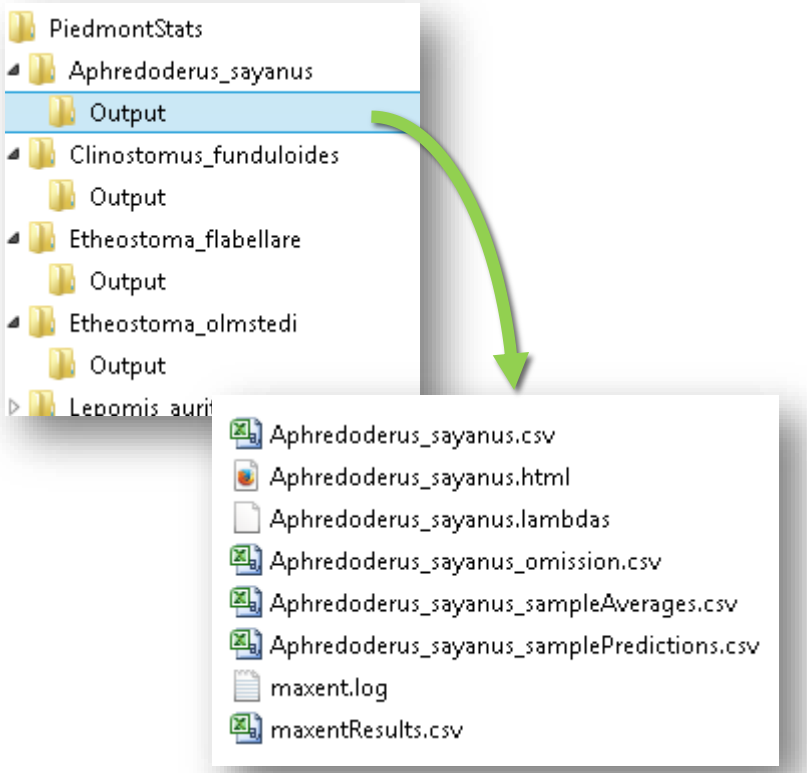


- Iterates through each focal species in the ecoregion species table:
  - Selects records from the complete list of HUC8 catchments.
  - Removes attributes with insignificant correlations with occurrence.
  - Removes catchment attributes identified as redundant.
  - Reformats the data to be compatible with Maxent's "SWD" format.
  - Generates a batch file to run Maxent analysis with preset settings.
  - Creates an output folder to contain Maxent default run results

Habitat Modeling Toolkit (step 4)

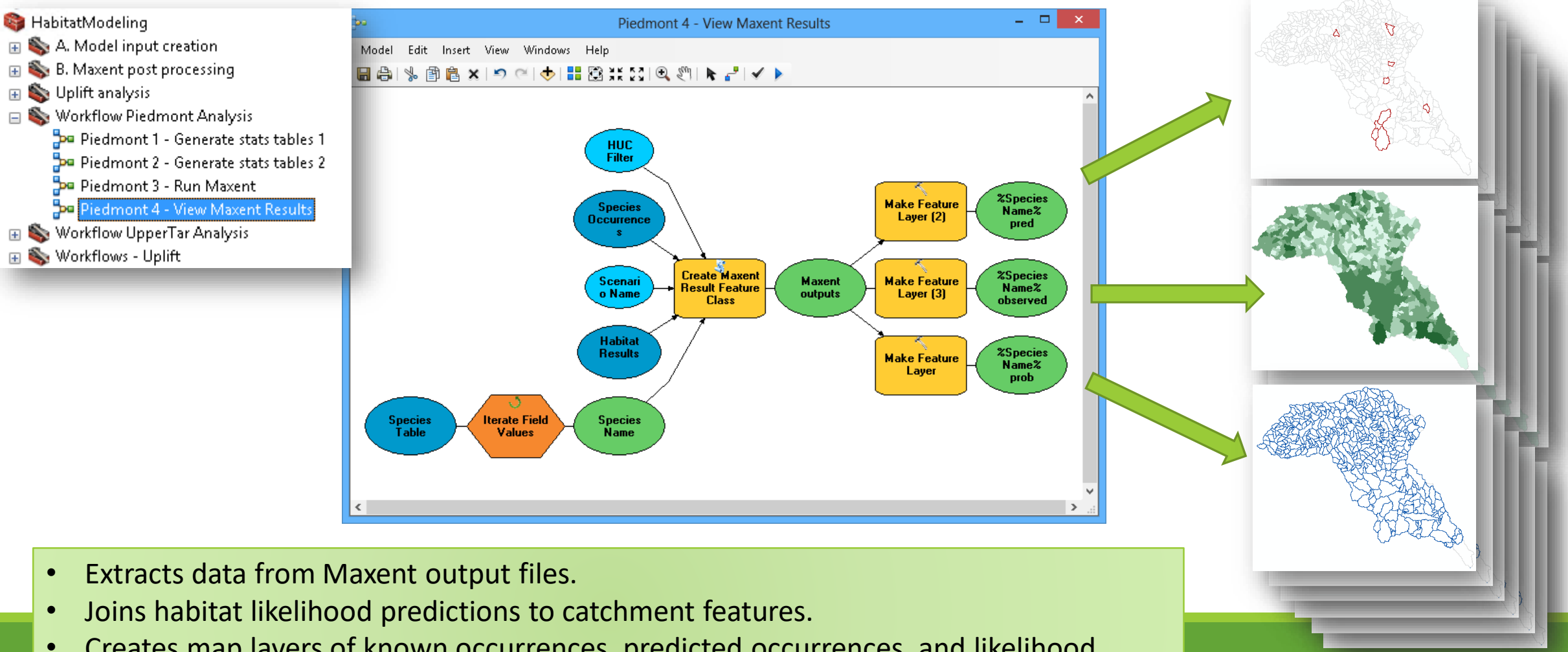






- Locates all RunMaxent.bat batch files among the species sub-folders.
- Executes each to run the Maxent model on baseline conditions.
- Maxent output is saved to the Output folder.

Habitat Modeling Toolkit (step 5)



- Extracts data from Maxent output files.
- Joins habitat likelihood predictions to catchment features.
- Creates map layers of known occurrences, predicted occurrences, and likelihood

Habitat Modeling – Updating the data

Biophysical parameters

- The modeling toolkit is structured so that the additional catchment attributes can be added to the statewide *CatchmentAttributes* dataset or that existing attributes can be modified.
- If a new catchment attribute is added, the only other modification to make in the toolkit is in the *ResponseVariables.xlsx* file where the attribute's name and ranking (for redundancy evaluation) should also be added.
- After changes are made to the *CatchmentAttributes* dataset, the entire toolkit can be re-run to produce updated maps of current conditions.

Habitat Modeling – Updating the data

Species Occurrence Data/Focal Species Selection

- To change the suite of focal species used in analysis for an ecoregion, you simply edit the table in the *Fish Indicator Species for EEP.xlsx* table.
- To update the *SpeciesOccurrence* dataset with revised species occurrence data, you simply need to modify the values in the column for that species (e.g. add new observations by setting the value in the catchments where it was observed to ‘1’).
- To add new species to the analysis, you simply add a new column to the *SpeciesOccurrence* dataset, setting values in the catchments in which it was observed to ‘1’.

Biophysical response variables (gray text are not management handles)

Variable	Description
AreaSqKM	Catchment area in square kilometers
LENGTHKM	Flowline length
FCODE	Numeric code for feature attributes in the NHDFCode lookup table
StreamOrde	Strahler Stream order
Pathlength	Distance to the terminal Flowline feature downstream along the main path
ArbolateSu	Km of stream upstream of the bottom of the NHDFlowline feature
TotDASqKM	Total Upstream Cumulative Drainage Area (km2) at the downstream end of the NHDFlowline feature
SLOPE	Slope of flowline (meters/meters) based on smoothed elevations
Q0001E	Mean annual flow from gage adjustment (cfs)
V0001E	Mean annual velocity from gage adjustment (fps)
Qincr0001E	Mean annual incremental flow from gage adjustment (cfs)
TEMP0001	Mean annual catchment temperature (Deg. C)
PPT0001	Mean annual catchment precipitation (mm)
PET0001	Mean annual catchment PET (mm)
QLOSS0001	Mean annual catchment flow loss from Excess ET (cfs)
Q0001E_min	Min. monthly flow (cfs)
Q0001E_max	Max. monthly flow (cfs)
TempVC	Mean annual temp. upstream of the catchment (°C * 100)
TempVMA	Mean annual temperature within the catchment (°C * 100)
Temp_min	Min. monthly mean temperature w/in the catchment (in °C * 100)
Temp_max	Max. monthly mean temperature w/in the catchment (in °C * 100)
PrecipVC	Mean annual precipitation upstream of catchment (mm * 100)
PrecipVMA	Mean annual precipitation w/in the catchment (mm * 100)
Precip_min	Min. monthly mean precipitation w/in the catchment (mm * 100)
Precip_max	Max. monthly mean precipitation w/in the catchment (mm * 100)
RunOffVMA	Mean annual runoff in the area of the catchment (mm)
RunOff_min	Min. monthly mean runoff (mm)
RunOff_max	Max. monthly mean runoff (mm)
NLCD1	Upstream area (km2) classified as open water
NLCD2	Upstream area (km2) classified as developed
NLCD3	Upstream area (km2) classified as barren
NLCD4	Upstream area (km2) classified as forested
NLCD5	Upstream area (km2) classified as shrubland
NLCD7	Upstream area (km2) classified as grassland
NLCD8	Upstream area (km2) classified as cultivated
NLCD9	Upstream area (km2) classified as wetland
NLCD1c	Catchment area (km2) classified as open water
NLCD2c	Catchment area (km2) classified as developed
NLCD3c	Catchment area (km2) classified as barren
NLCD4c	Catchment area (km2) classified as forested

Variable (cont)	Description (cont)
NLCD5c	Catchment area (km2) classified as shrubland
NLCD7c	Catchment area (km2) classified as grassland
NLCD8c	Catchment area (km2) classified as cultivated
NLCD9c	Catchment area (km2) classified as wetland
FLNLCD_1	Flowline length (m) falling within NLCD open water
FLNLCD_2	Flowline length (m) falling within NLCD developed
FLNLCD_3	Flowline length (m) falling within NLCD barren
FLNLCD_4	Flowline length (m) falling within NLCD forested
FLNLCD_5	Flowline length (m) falling within NLCD shrubland
FLNLCD_7	Flowline length (m) falling within NLCD grassland
FLNLCD_8	Flowline length (m) falling within NLCD cultivated
FLNLCD_9	Flowline length (m) falling within NLCD wetland
Riparian_1A	Area (km2) of riparian zone classified as open water
Riparian_2A	Area (km2) of riparian zone classified as developed
Riparian_3A	Area (km2) of riparian zone classified as barren
Riparian_4A	Area (km2) of riparian zone classified as forested
Riparian_5A	Area (km2) of riparian zone classified as shrubland
Riparian_7A	Area (km2) of riparian zone classified as grassland
Riparian_8A	Area (km2) of riparian zone classified as cultivated
Riparian_9A	Area (km2) of riparian zone classified as wetland
Riparian_1P	Percent of riparian zone classified as open water
Riparian_2P	Percent of riparian zone classified as developed
Riparian_3P	Percent of riparian zone classified as barren
Riparian_4P	Percent of riparian zone classified as forested
Riparian_5P	Percent of riparian zone classified as shrubland
Riparian_7P	Percent of riparian zone classified as grassland
Riparian_8P	Percent of riparian zone classified as cultivated
Riparian_9P	Percent of riparian zone classified as wetland
LongestSegment	The length (m) of the longest shaded flowline segment
MeanShadeLength	Average length (m) of all the shaded segments w/in a catchment
cold	Percent of stream classified as cold
cool	Percent of stream classified as cool
warm	Percent of stream classified as warm
PctCanopy	Percent canopy cover within the catchment area
PctImpervious	Percent catchment area that is impervious
AnimalOps	Number of animal operation permits issued in catchment
NPDES	Number of NPDES with catchment
downstreamDistance_km	Distance to nearest downstream dam
upstreamDistance_km	Distance to nearest upstream dam

Potential for Uplift

SENSITIVITY TESTING

Habitat Uplift and Sensitivity Scenarios

Uplift Scenario	Opportunity	Sensitivity
Buffer	x	x
Avoided Conversion	x	x
Temperature		x
Stream alteration		x (Δ velocity)
Volume		x
Increased wetland	x	x
Dam/barrier removal		x
Nutrient reduction (animal ops, direct loading)		x

Biophysical response variables are used in uplift models for potential uplift in habitat suitability – EXAMPLE BUFFERS

Variable	Description
AreaSqKM	Catchment area in square kilometers
LENGTHKM	Flowline length
FCODE	Numeric code for feature attributes in the NHDFCode lookup table
StreamOrde	Strahler Stream order
Pathlength	Distance to the terminal Flowline feature downstream along the main path
ArbolateSu	Km of stream upstream of the bottom of the NHDFlowline feature
TotDASqKM	Total Upstream Cumulative Drainage Area (km2) at the downstream end of the NHDFlowline feature
SLOPE	Slope of flowline (meters/meters) based on smoothed elevations
Q0001E	Mean annual flow from gage adjustment (cfs)
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Q0001E_min	Min. monthly flow (cfs)
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Temp_min	Min. monthly mean temperature w/in the catchment (in °C * 100)
Temp_max	Max. monthly mean temperature w/in the catchment (in °C * 100)
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PrecipVMA	Mean annual precipitation w/in the catchment (mm * 100)
Precip_min	Min. monthly mean precipitation w/in the catchment (mm * 100)
Precip_max	Max. monthly mean precipitation w/in the catchment (mm * 100)
RunOffVMA	Mean annual runoff in the area of the catchment (mm)
RunOff_min	Min. monthly mean runoff (mm)
RunOff_max	Max. monthly mean runoff (mm)
NLCD1	Upstream area (km2) classified as open water
NLCD2	Upstream area (km2) classified as developed
NLCD3	Upstream area (km2) classified as barren
NLCD4	Upstream area (km2) classified as forested
NLCD5	Upstream area (km2) classified as shrubland
NLCD7	Upstream area (km2) classified as grassland
NLCD8	Upstream area (km2) classified as cultivated
NLCD9	Upstream area (km2) classified as wetland
NLCD1c	Catchment area (km2) classified as open water
NLCD2c	Catchment area (km2) classified as developed
NLCD3c	Catchment area (km2) classified as barren
NLCD4c	Catchment area (km2) classified as forested

Variable (cont)	Description (cont)
NLCD5c	Catchment area (km2) classified as shrubland
NLCD7c	Catchment area (km2) classified as grassland
NLCD8c	Catchment area (km2) classified as cultivated
NLCD9c	Catchment area (km2) classified as wetland
FLNLCD_1	Flowline length (m) falling within NLCD open water
FLNLCD_2	Flowline length (m) falling within NLCD developed
FLNLCD_3	Flowline length (m) falling within NLCD barren
FLNLCD_4	Flowline length (m) falling within NLCD forested
FLNLCD_5	Flowline length (m) falling within NLCD shrubland
FLNLCD_7	Flowline length (m) falling within NLCD grassland
FLNLCD_8	Flowline length (m) falling within NLCD cultivated
FLNLCD_9	Flowline length (m) falling within NLCD wetland
Riparian_1A	Area (km2) of riparian zone classified as open water
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Riparian_3A	Area (km2) of riparian zone classified as barren
Riparian_4A	Area (km2) of riparian zone classified as forested
Riparian_5A	Area (km2) of riparian zone classified as shrubland
Riparian_7A	Area (km2) of riparian zone classified as grassland
Riparian_8A	Area (km2) of riparian zone classified as cultivated
Riparian_9A	Area (km2) of riparian zone classified as wetland
Riparian_1P	Percent of riparian zone classified as open water
Riparian_2P	Percent of riparian zone classified as developed
Riparian_3P	Percent of riparian zone classified as barren
Riparian_4P	Percent of riparian zone classified as forested
Riparian_5P	Percent of riparian zone classified as shrubland
Riparian_7P	Percent of riparian zone classified as grassland
Riparian_8P	Percent of riparian zone classified as cultivated
Riparian_9P	Percent of riparian zone classified as wetland
LongestSegment	The length (m) of the longest shaded flowline segment
MeanShadeLength	Average length (m) of all the shaded segments w/in a catchment
cold	Percent of stream classified as cold
cool	Percent of stream classified as cool
warm	Percent of stream classified as warm
PctCanopy	Percent canopy cover within the catchment area
PctImpervious	Percent catchment area that is impervious
AnimalOps	Number of animal operation permits issued in catchment
NPDES	Number of NPDES with catchment
downstreamDistance_km	Distance to nearest downstream dam
upstreamDistance_km	Distance to nearest upstream dam

Uplift example for habitat models: Buffer

Catchment attributes (*current*)

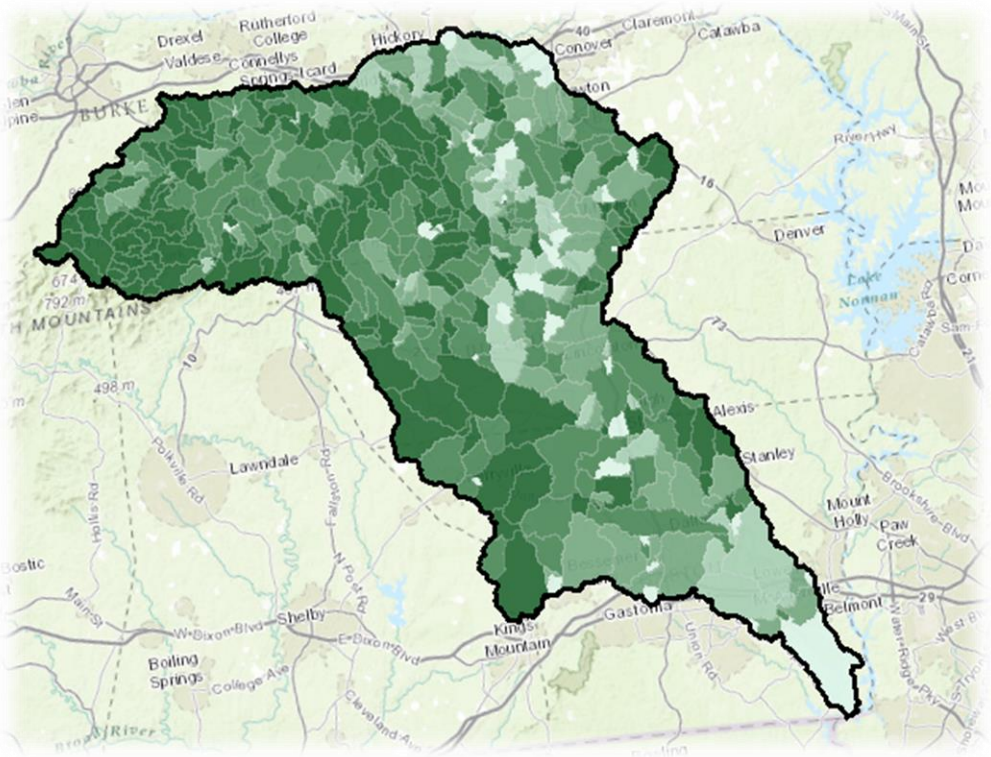
Variable	Description	Flow length (m)
FLNLCD_1	Flowline length (m) falling within NLCD open water	50
FLNLCD_2	Flowline length (m) falling within NLCD developed	50
FLNLCD_3	Flowline length (m) falling within NLCD barren	0
FLNLCD_4	Flowline length (m) falling within NLCD forested	50
FLNLCD_5	Flowline length (m) falling within NLCD shrubland	10
FLNLCD_7	Flowline length (m) falling within NLCD grassland	10
FLNLCD_8	Flowline length (m) falling within NLCD cultivated	50
FLNLCD_9	Flowline length (m) falling within NLCD wetland	50
SUM		270

Catchment attributes (*revised*)

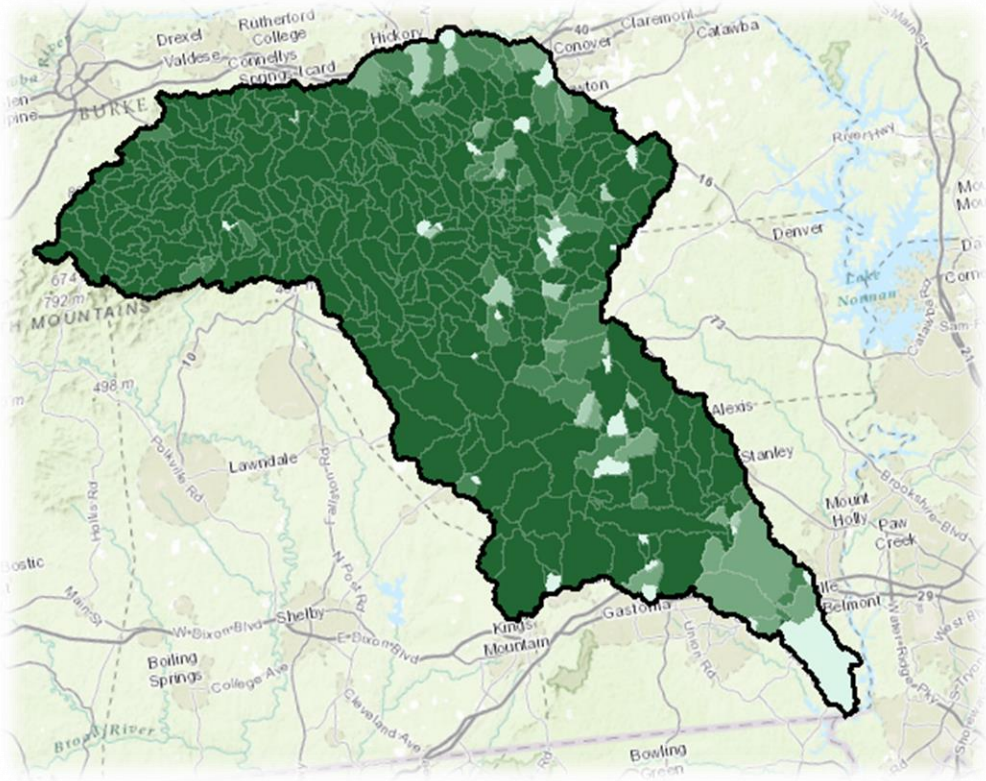
Variable	Description	Flow length (m)
FLNLCD_1	Flowline length (m) falling within NLCD open water	50
FLNLCD_2	Flowline length (m) falling within NLCD developed	50
FLNLCD_3	Flowline length (m) falling within NLCD barren	0
FLNLCD_4	Flowline length (m) falling within NLCD forested	120
FLNLCD_5	Flowline length (m) falling within NLCD shrubland	0
FLNLCD_7	Flowline length (m) falling within NLCD grassland	0
FLNLCD_8	Flowline length (m) falling within NLCD cultivated	0
FLNLCD_9	Flowline length (m) falling within NLCD wetland	50
SUM		270

Use existing Maxent models *project* the habitat likelihoods of each focal species under these altered conditions…

Habitat uplift-Buffer expansion-Catawba



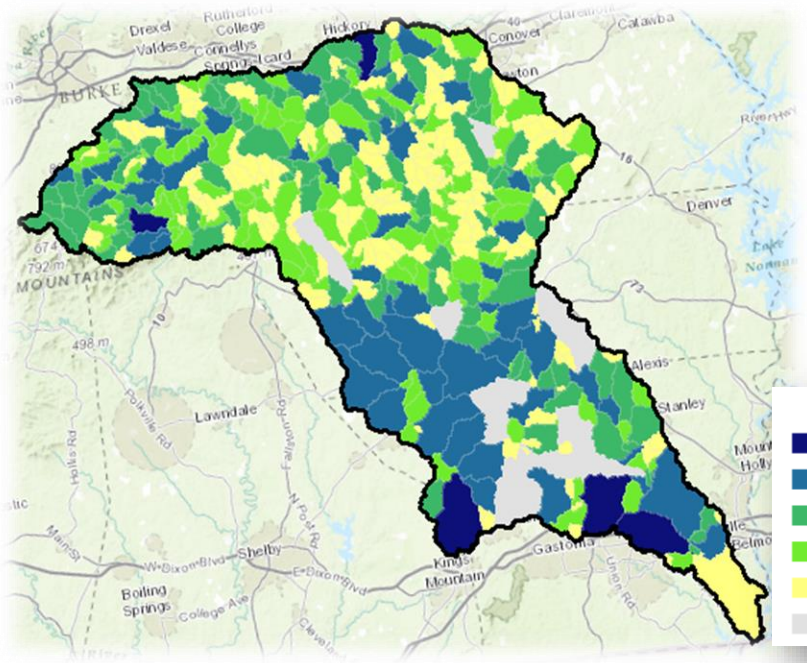
Current conditions



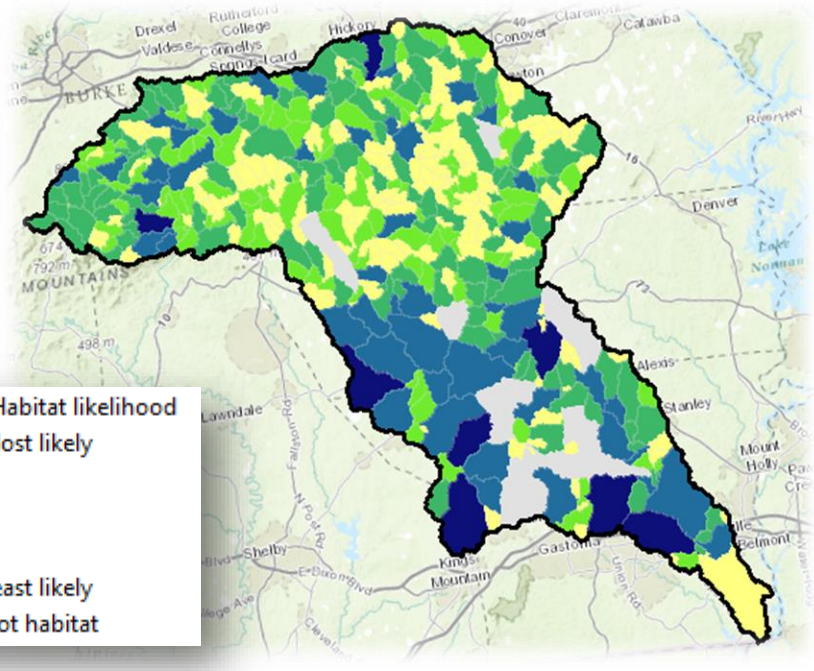
Convert all non-urban riparian cells to forest

Habitat uplift-Buffer expansion-Catawba

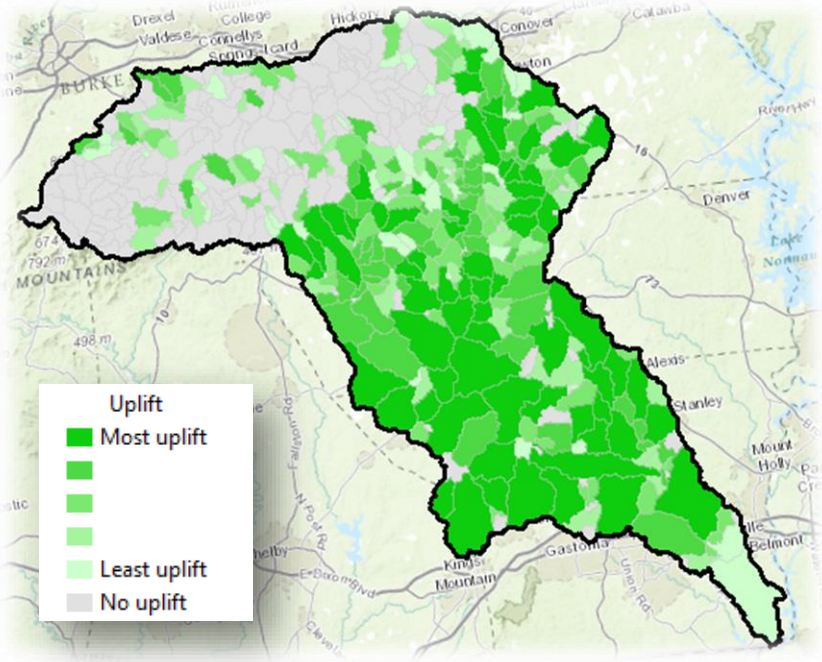
Bluehead Chub



Habitat likelihood:
Current conditions

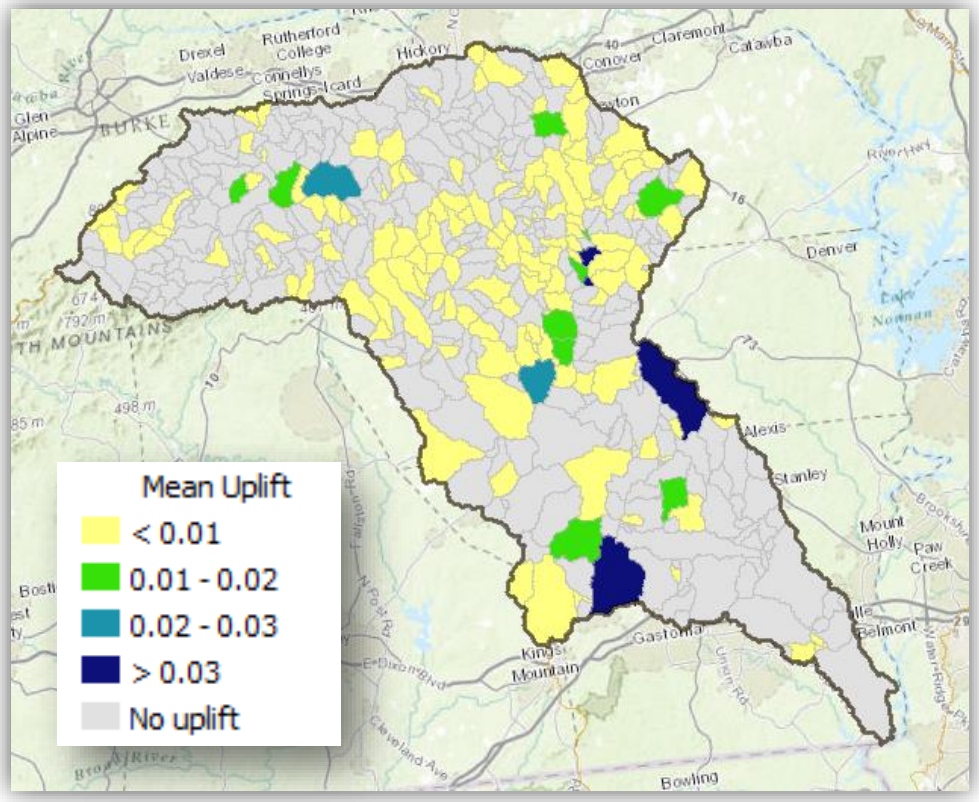


Habitat likelihood:
Altered conditions

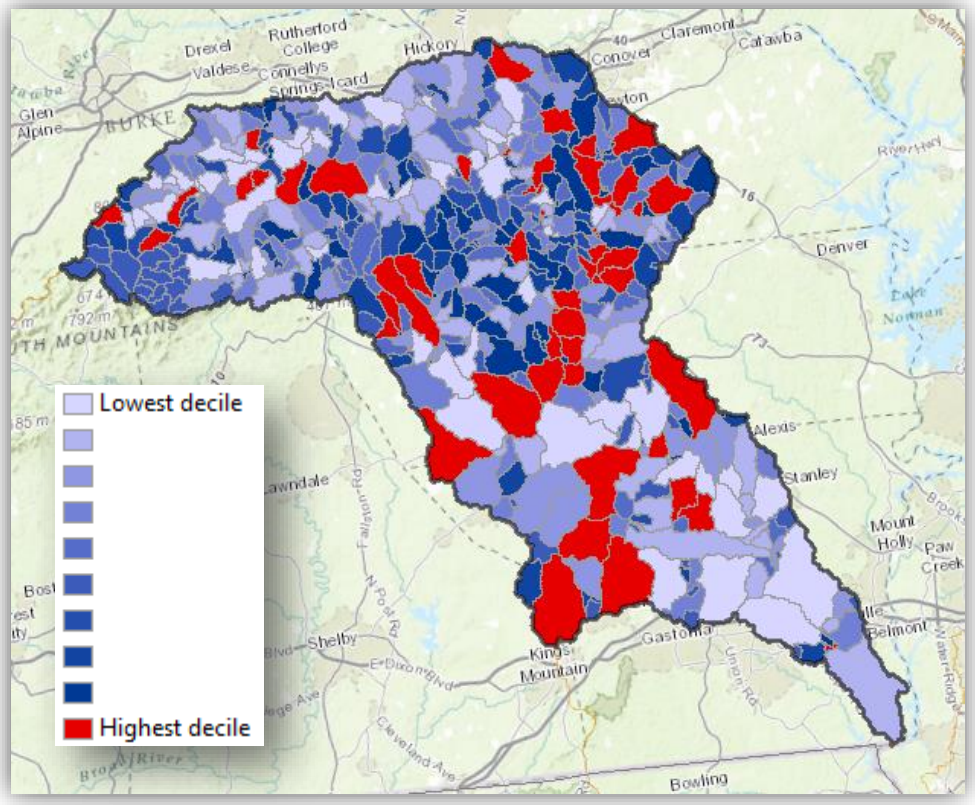


Potential uplift:
(Altered – Current = Uplift)

Habitat uplift-Buffer expansion-Catawba

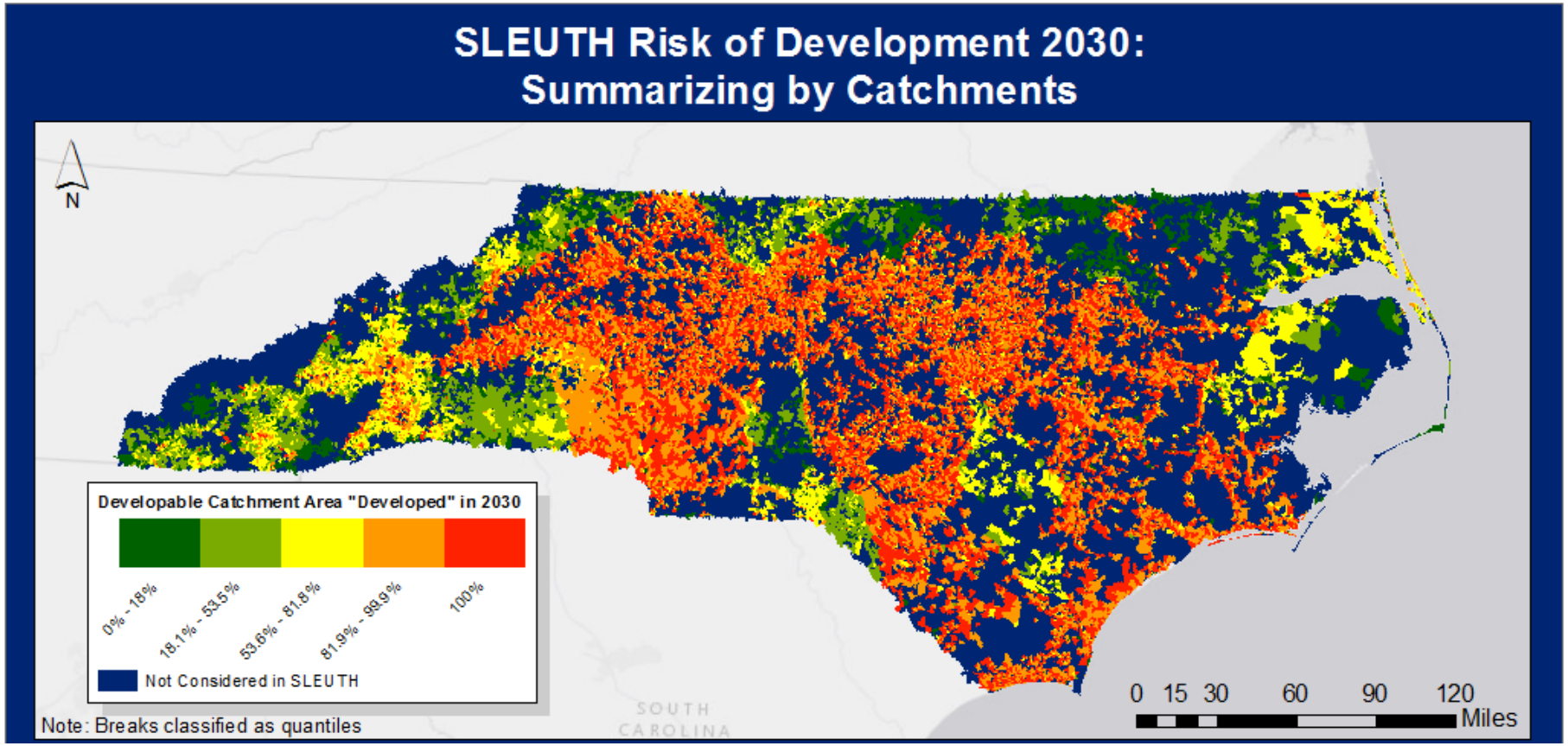


Uplift – averaged across all species (N = 12)



Catchments ranked by uplift

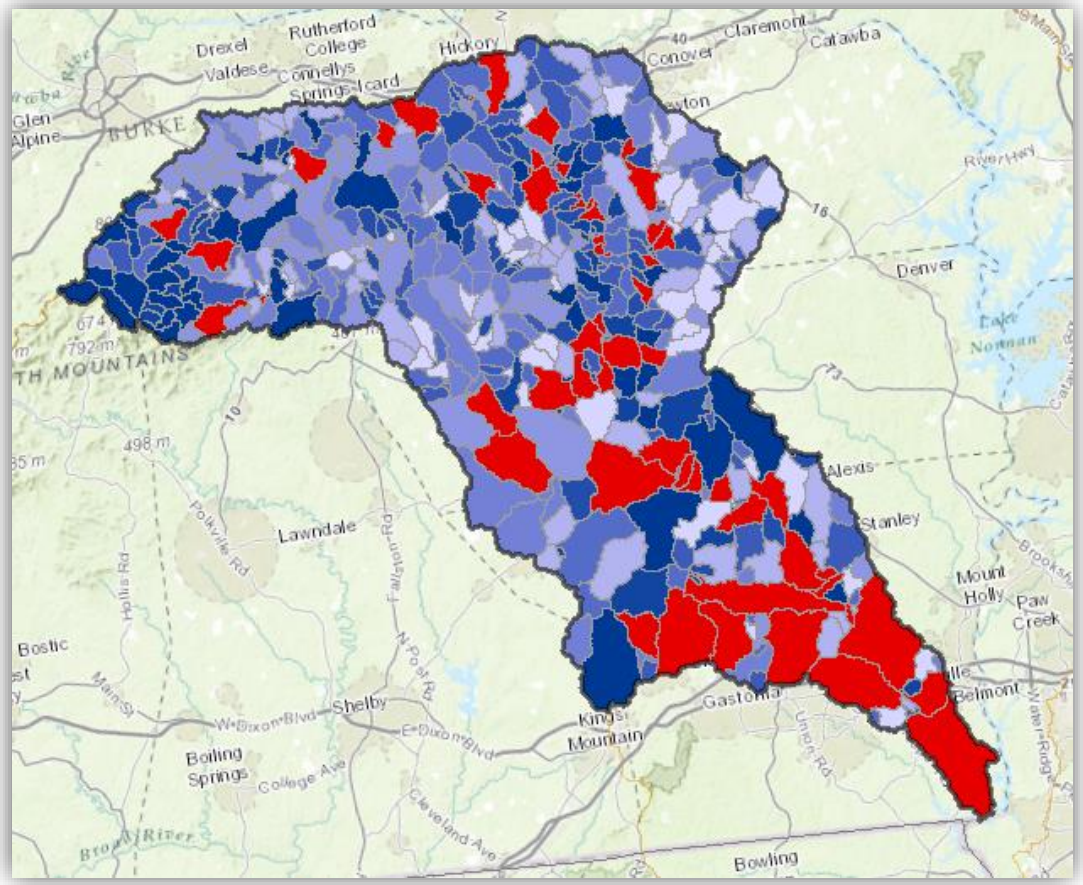
SLEUTH model threshold



Uplift results: Avoided Conversion

- Compute land cover in 2030
  (using SLEUTH model output overlaid on NLCD 2011)
- Revise NLCD-related catchment attributes
- Project Maxent model onto these revised attributes.

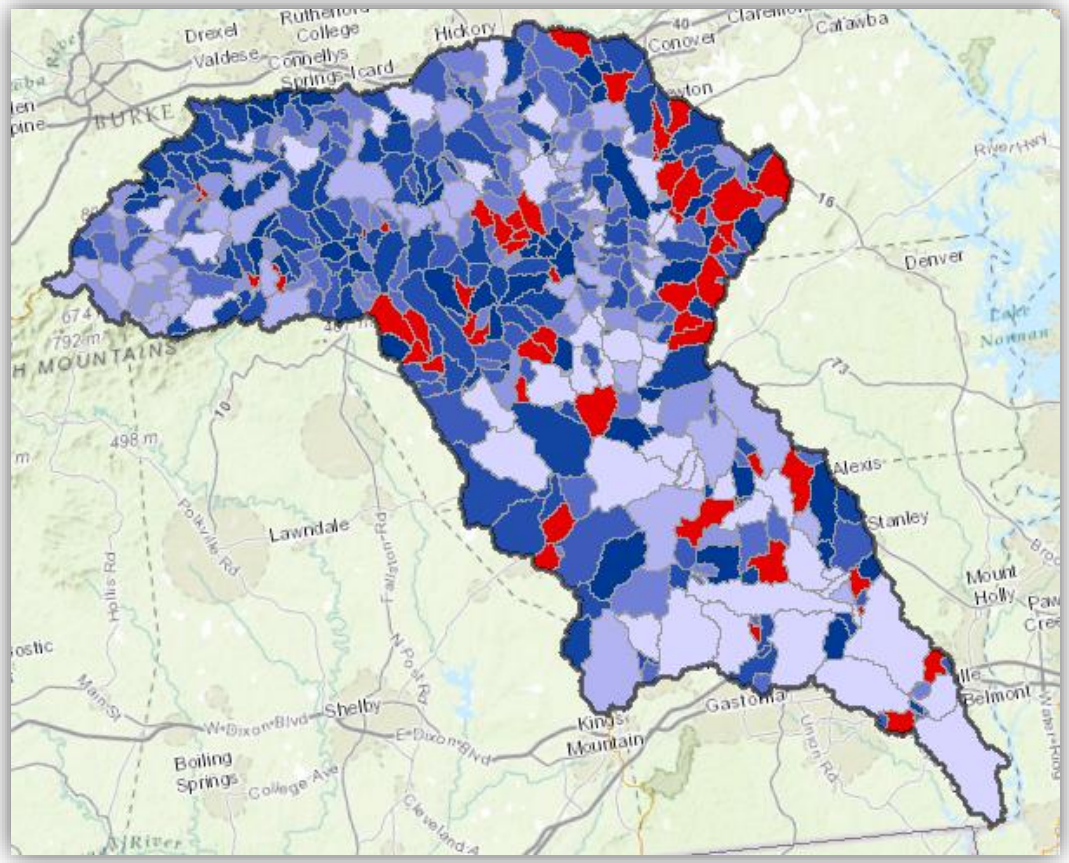
- *Large decreases in mean habitat likelihood from current conditions to 2030 conditions imply that preventing development will avoid large negative impacts.*



Uplift results: Wetland expansion

- Reclassify land cover in pixels intersecting hydric soils as wetland (keep water and urban classes unchanged).
- Revise NLCD-related catchment attributes
- Project Maxent model onto these revised attributes.

- *Large increases in mean habitat likelihood between current conditions and modified conditions imply relatively high sensitivity to wetland creation.*

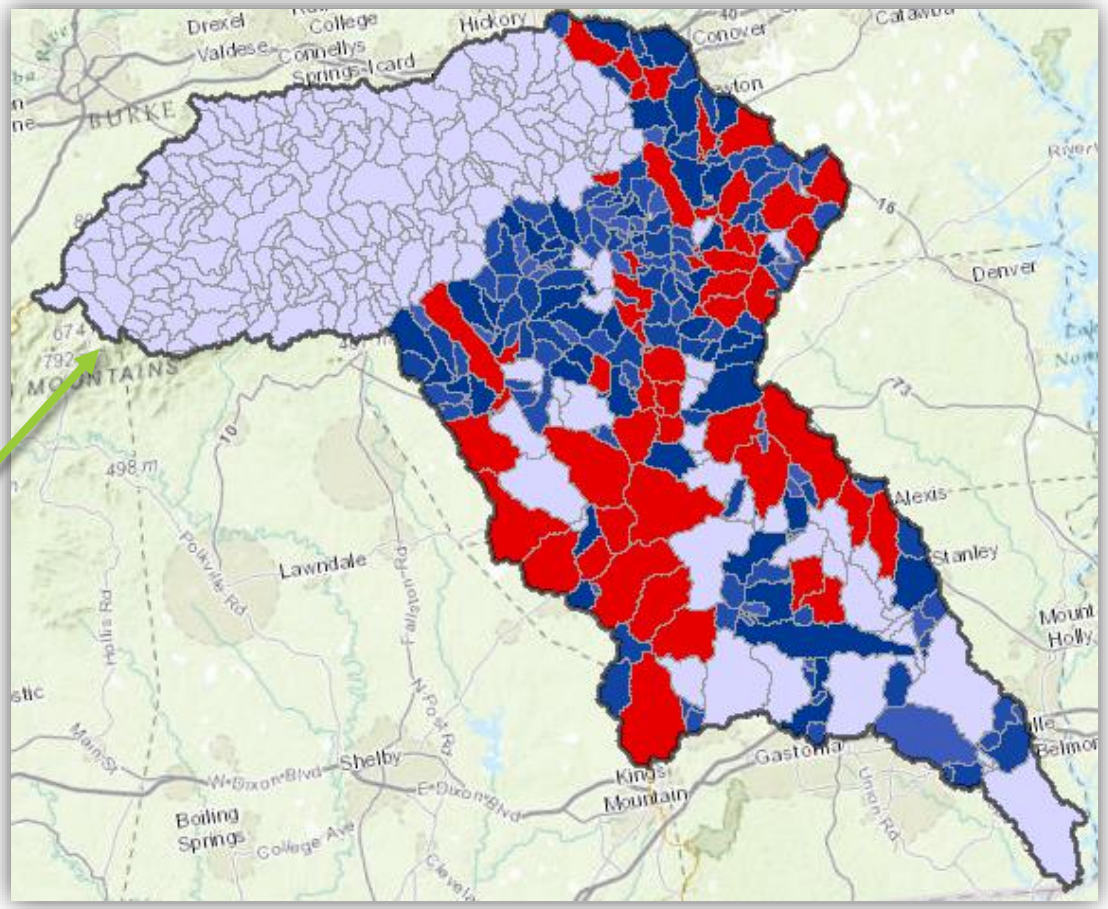


Uplift results: Stream cooling

- Set all “warm” stream lengths to “cool”
- Cold stream lengths remain unchanged.
- Project Maxent model onto these revised attributes.

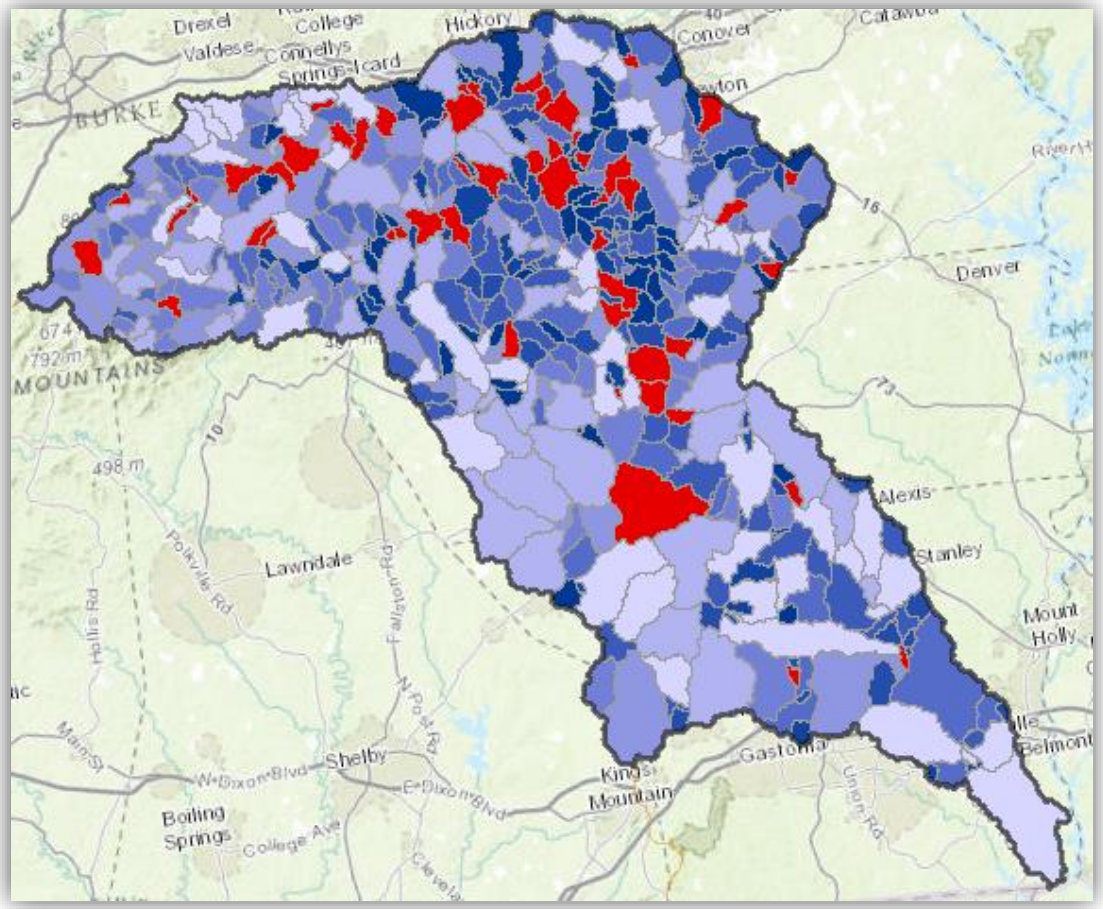
- *Large increases in mean habitat likelihood between current conditions and modified conditions imply relatively high sensitivity to stream cooling.*

No warm streams to “cool”, thus no uplift



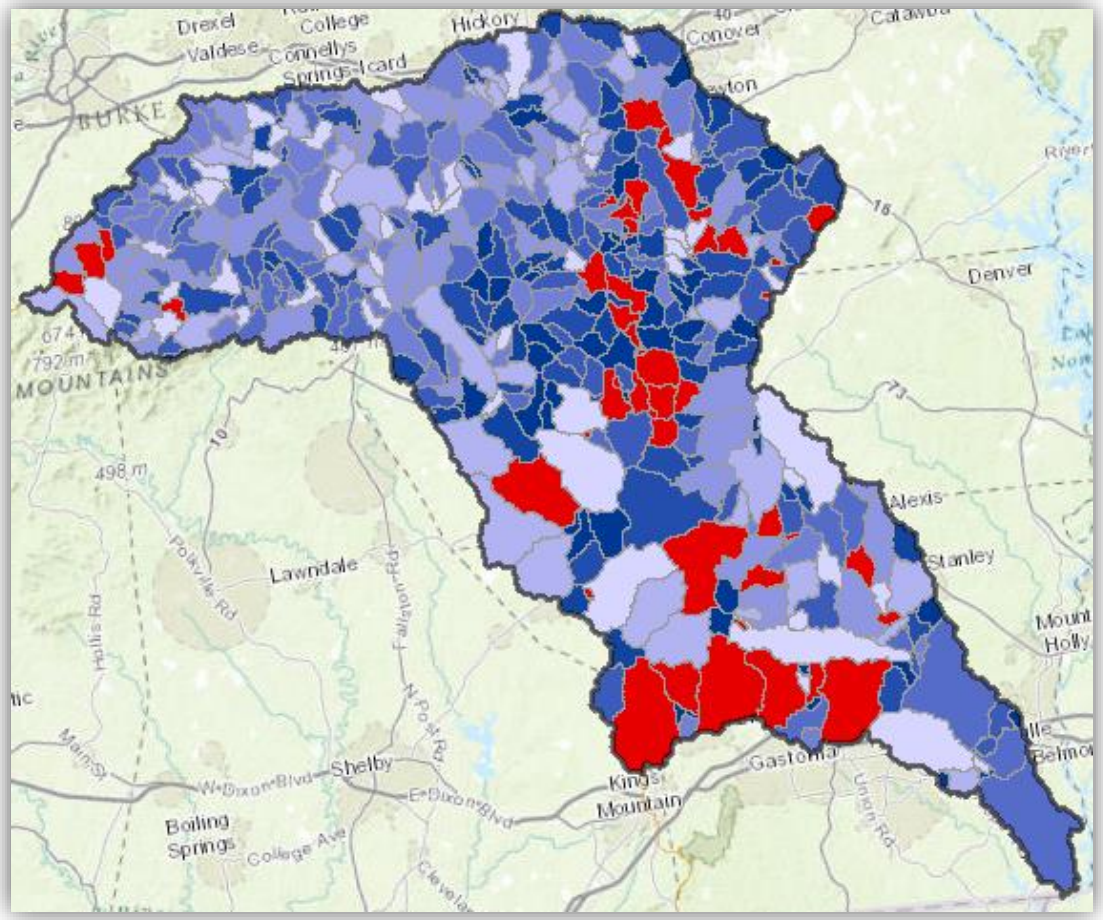
Uplift results: Stream alteration

- Reduce stream velocity by 10%
- Project Maxent model onto these revised attributes.
- *Large increases in mean habitat likelihood between current conditions and modified conditions imply relatively high sensitivity to management activities that reduce stream velocity.*



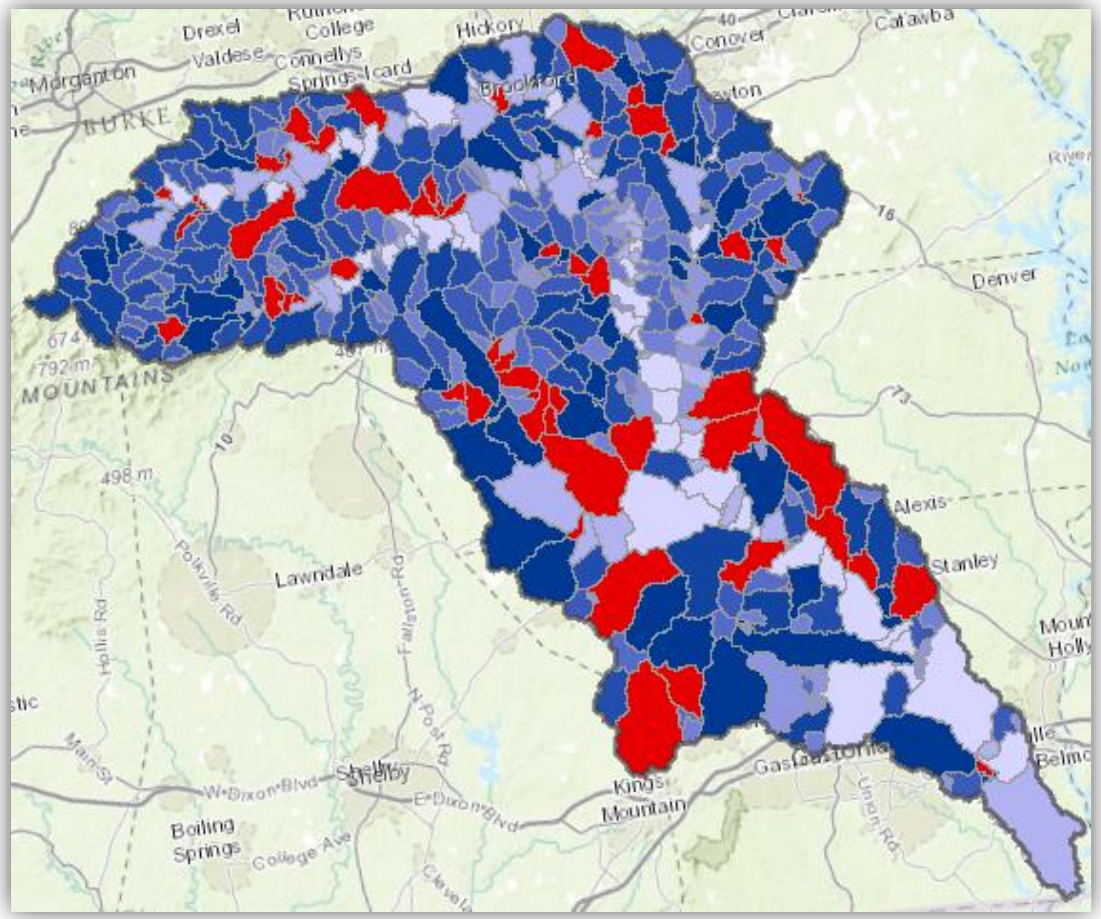
Uplift results: Decrease max. stream flow

- Reduce maximum stream flow (highest monthly mean flow) by 10%.
- Project Maxent model onto these revised attributes.
- *Large increases in mean habitat likelihood between current conditions and modified conditions imply relatively high sensitivity to management activities that reduce maximum stream flow.*



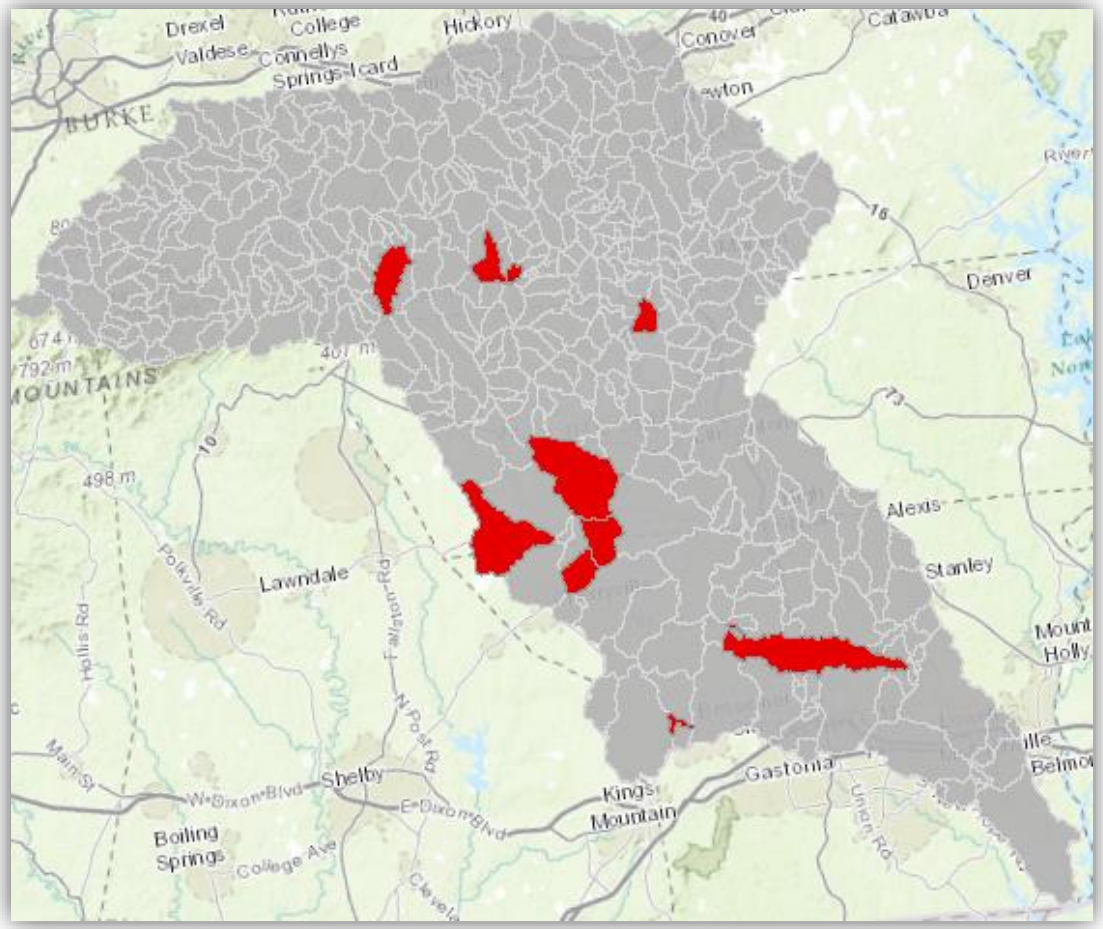
Uplift results: Increase min. stream flow

- Increase minimum stream flow (lowest monthly mean flow) by 10%.
- Project Maxent model onto these revised attributes.
- *Large increases in mean habitat likelihood between current conditions and modified conditions imply relatively high sensitivity to management activities that increase minimum stream flow.*



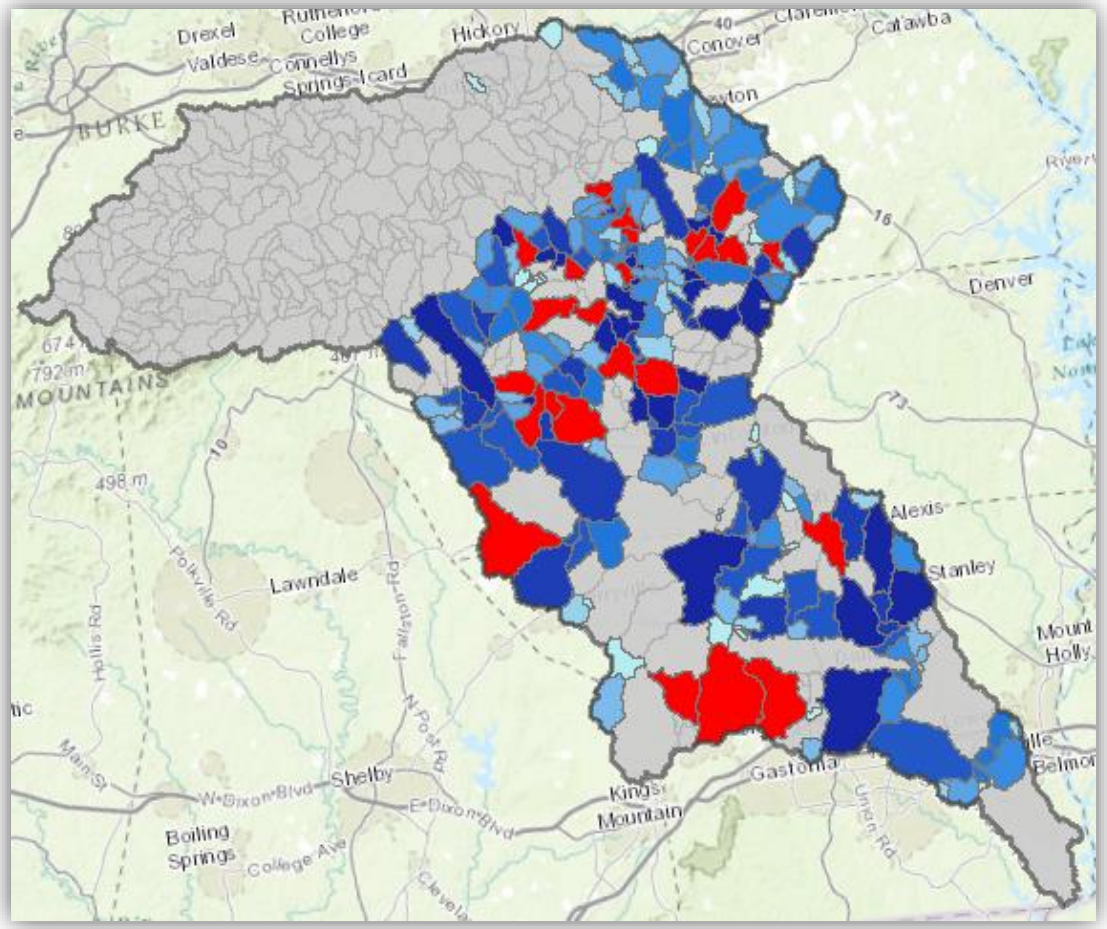
Uplift results: Nutrient Reduction

- Decrease the number of animal operations by 1 (unless already zero)
- Project Maxent model onto these revised attributes.
- *Uplift is only observed in catchments with more than one current animal operation permit.*



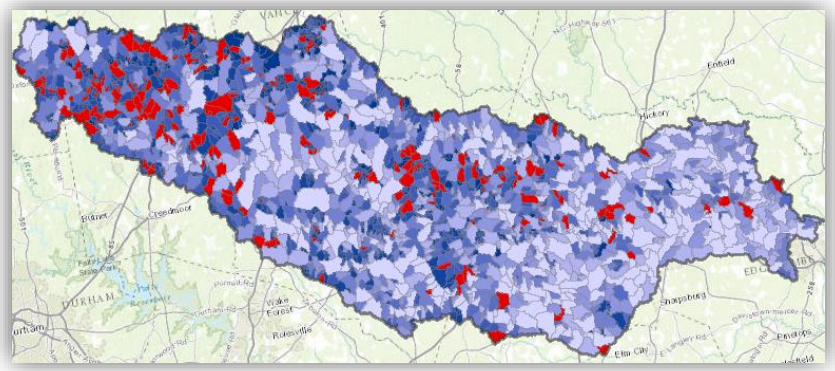
Uplift results: Downstream Connectivity

- Increase the distance from each catchment flowline centroid to the nearest dam by 10%.
- Project Maxent model onto these revised attributes.
- *Increases in habitat likelihood infer a more positive response to downstream dam removal.*

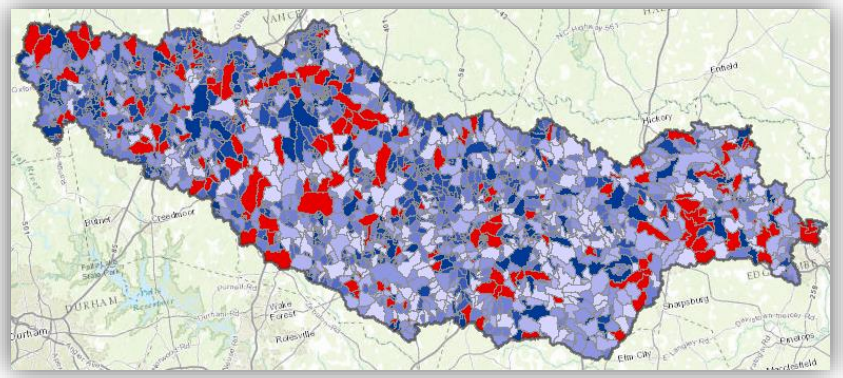


Results – Upper Tar

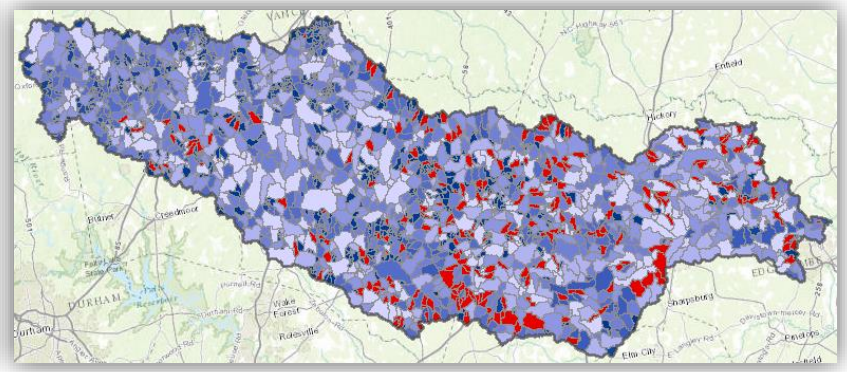
Buffer afforestation



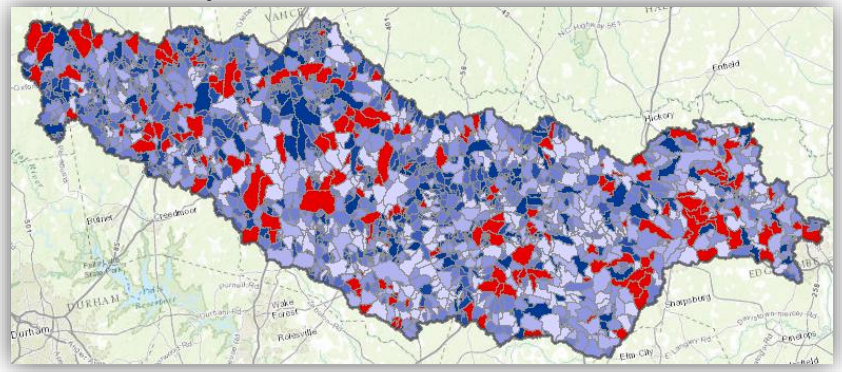
Wetland expansion



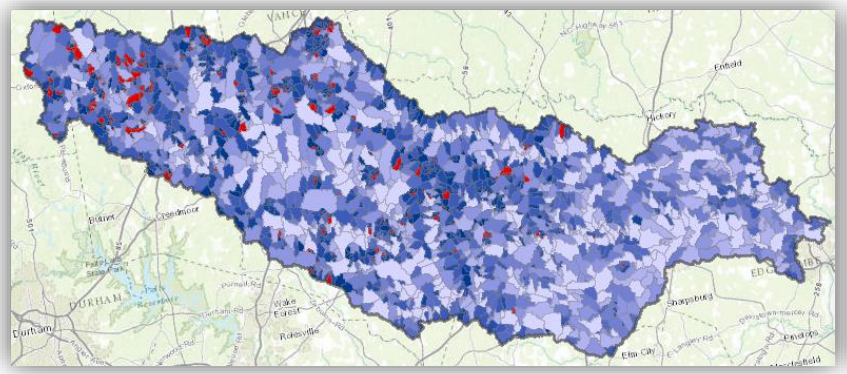
Decreased max. flow



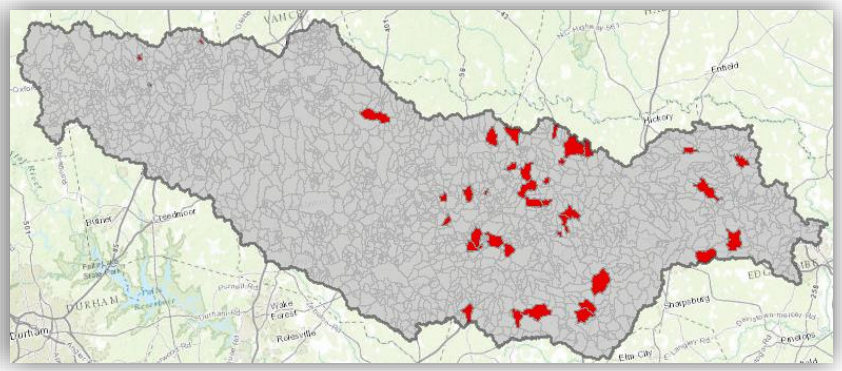
Urban expansion/Avoided conversion



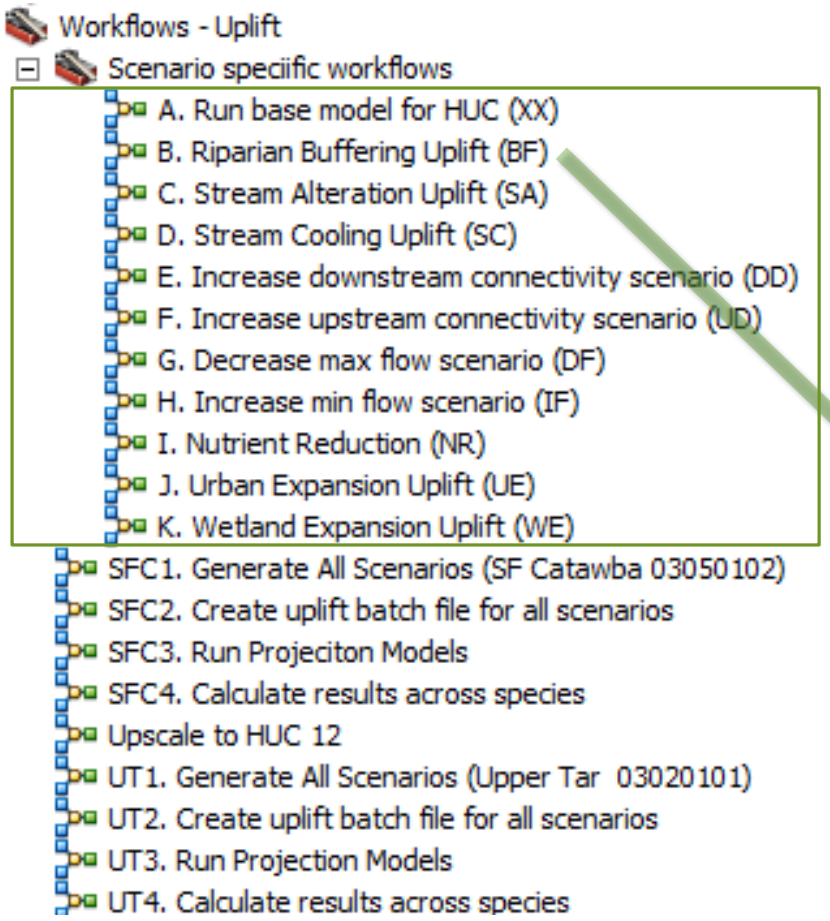
Stream cooling



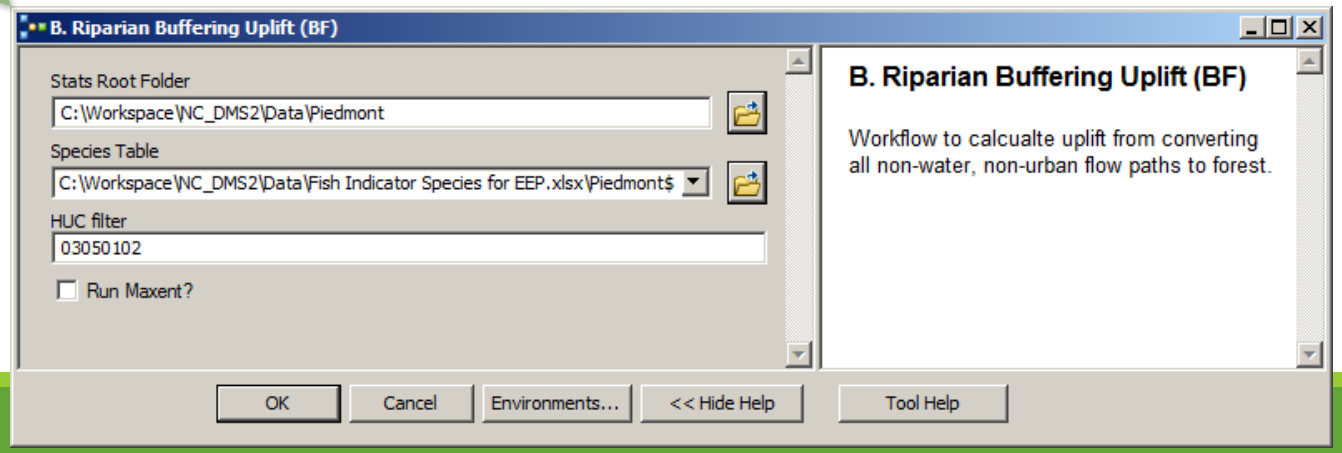
Nutrient reduction



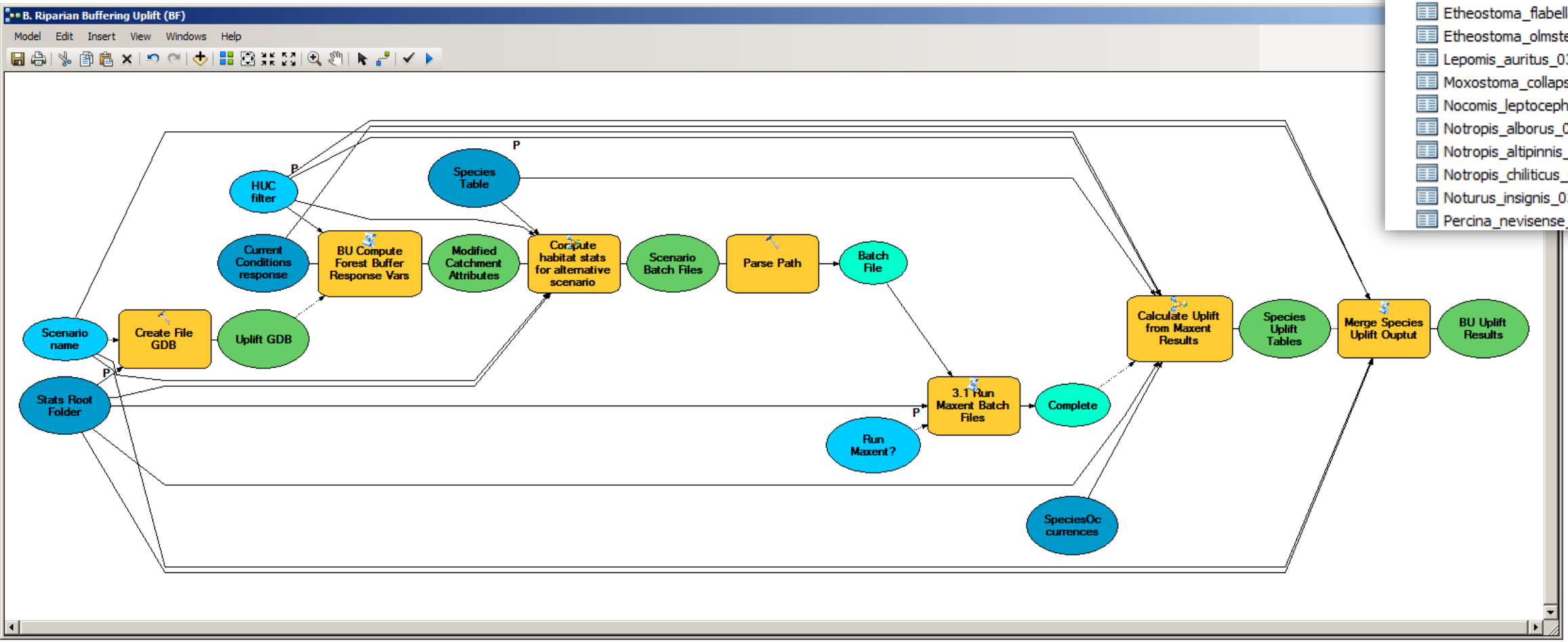
Habitat uplift- The Toolkit

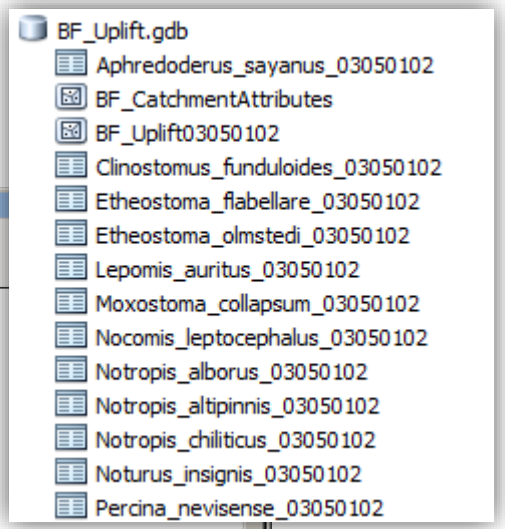


- A tool for each management scenario
  - Set the “Stats root folder” (where the files reside)
  - Set the table listing the focal species.
  - Specify a HUC to process
  - Set to run Maxent analysis
- Modifies the current conditions catchment attribute table
- Runs Maxent for all focal species, projecting results onto modified catchment attributes…



Habitat uplift- The Toolkit

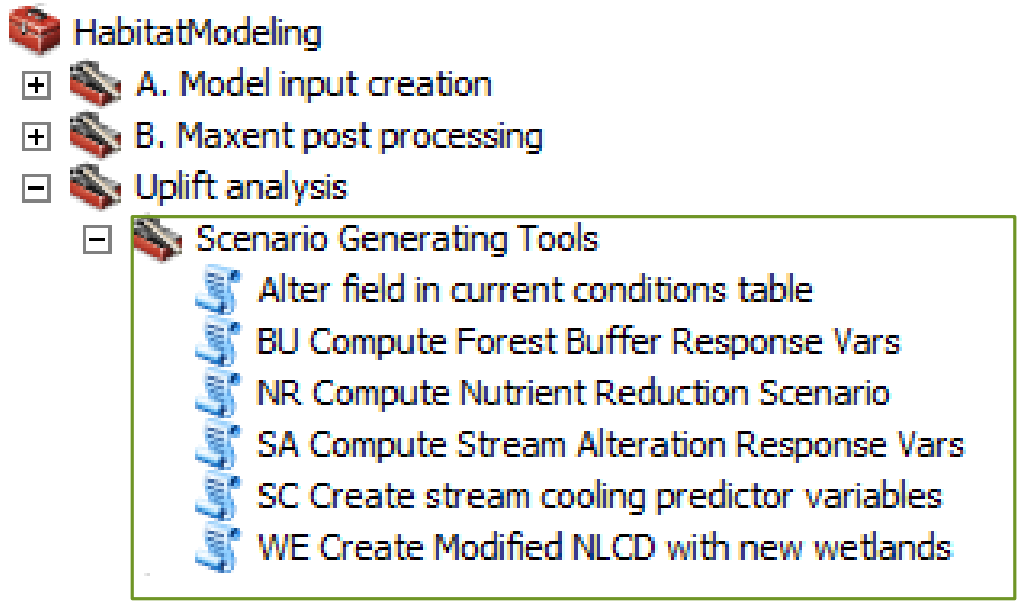




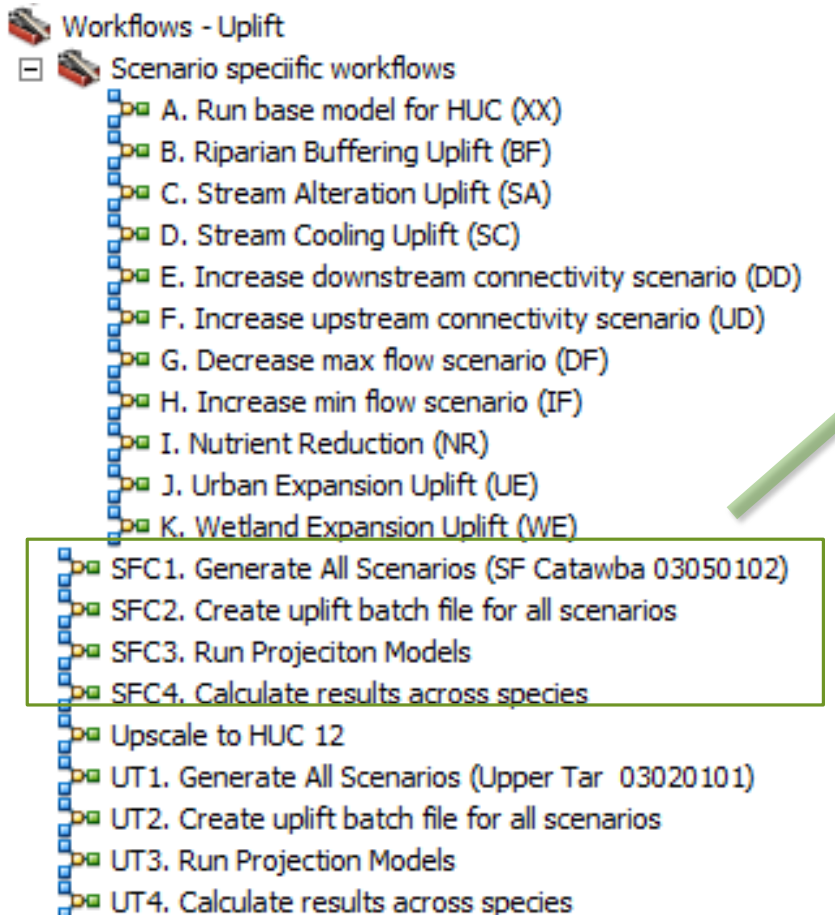
Habitat uplift- The Toolkit

Tools exist to modify the existing catchment attributes to reflect the various management scenarios

Additional tools to reflect other management scenarios can easily be developed…



Habitat uplift- The Toolkit



- We also provide tools to run the entire suite of management scenarios “from soup to nuts” for a given HUC
  - Generate Maxent projection datasets for all scenarios
  - Create Maxent batch files to run all scenarios at once
  - Run the scenarios (~1.5 hrs to complete for a HUC8)
  - Process results for all species, generating maps of uplift