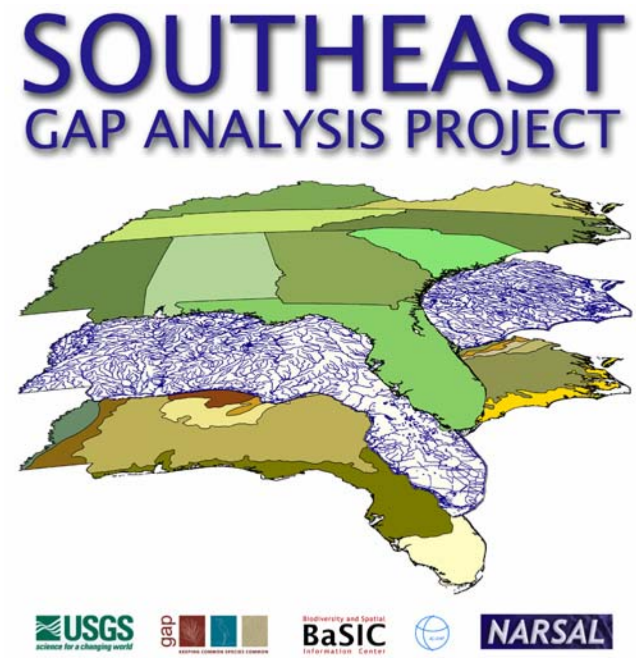
SOUTHEAST GAP ANALYSIS PROJECT ANCILLARY DATA DEVELOPMENT AND USE IN PREDICTED DISTRIBUTION MODELING



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INTRODUCTION

Models of presence/absence for a species' predicted distribution may include a number of spatially explicit data sources. GAP models typically involve land use/land cover data as the primary input. However, other environmental features that make up the landscape constituting species' habitats can be valuable inputs to modeling. The SE-GAP project has attempted to use a number of data layers (ancillary data) other than land cover to develop species models. Many of these data layers act as surrogates for one or more aspects of a species' habitat that may only be inferred from available, remotely sensed information. The following document is meant to describe these data layers and their development, their range of parameters, and usage in modeling species' predicted distributions.

NOTE: The term "map unit" will be used throughout the document to mean the individual class or category mapped to represent land use and land cover, i.e. ecological systems.

LAND COVER / LAND USE

Development

Ecological systems and land use mapped for the SE-GAP project are the primary input to species models. The development of these data is described in detail in subsequent documents. However, derivatives of these data were developed separately to further refine species models.

Primary and secondary (auxiliary) map units, and patch size (contiguous and non-contiguous patches) are parameters utilized as a model proceeds. That is, they are not stand-alone, independently created data layers. As such, they would not be considered “ancillary” data.

Usage in Modeling

Primary & Secondary Map Units
Primary Map Units
Primary map units are those land cover types critical for nesting, rearing young, and/or optimal foraging.

Auxiliary Map Units
Secondary or auxiliary map units are those land cover types generally not critical for breeding, but are typically used in conjunction with primary map units for foraging, roosting, and/or sub-optimal nesting locations. These map units are selected only when located within a specified distance from primary map units.

Patch Size
The type and size of clusters of habitat can be assessed with spatial modeling. As a final step to the distribution modeling process, we used these parameters for species shown to require minimum amounts of habitat. This includes not only directly adjacent habitats, but those that are contextually adjacent. Both these parameters are utilized as the final step in a predicted distribution and therefore incorporate all other modeling inputs.
Contiguous Patch

- **Minimum Size (ha) –** This parameter is set using the most conservative values explicitly stated in the literature. It applies only to the Southeastern portion of a species’ range.
- **FROM Buffer –** 0, 30, 60, 120, 250, 500, 1000 meters
- **INTO Buffer –** 0, 30, 60, 120, 250, 500, 1000 meters

Non-Contiguous Patch
The non-contiguous patch parameter is used to imply landscape context, i.e utilized habitats within a matrix of other habitats. It is measured as a percentage within a given area.

Forest & Edge Habitats
The edge or ecotone between forested and non-forested environments can be a critical aspect of the habitat landscape. We grouped map units into forested, non-forested, and shrubland/woodland land cover types to create unique data layers. These data layers can then be buffered at specified distances to identify species' habitats.

Development

All map units categorized as forest, non-forest, and shrubland/woodland were aggregated into separate data layers. Aggregated map units can be compared and contrasted to identify areas of transition between these broad categories. They can also be used to identify "core" areas or contiguous blocks of similar type (i.e. interior) through buffering procedures.

Forested map units were defined as those ecological systems and land uses that correspond to the National Land Cover Dataset (NLCD) forest/woodland classes (Homer et al. 2004) (Appendix A). These included NLCD classes "deciduous forest", "evergreen forest", "mixed forest", "palustrine forested wetland", and "estuarine forested wetland" (class values 41, 42, 43, 91 and 93 respectively). Non-forested map units were defined as those ecological systems and land uses not categorized as forest using the criteria stated above. Woodland/shrubland map units were defined as those ecological systems and land uses containing a majority of short, scrubby, woody vegetation or sparsely canopied treed vegetation (Appendix B). Unlike the forested map units, the woodland/shrubland layer was not explicitly derived from NLCD classes but was selected individually based on attributes defined by the systems and land uses.

Once these data layers were created, buffering procedures created unique datasets containing unique categories of distance: > 4000, 4000, 2000, 1000, 500, 250, 120, 60, and 30 meters into and away from the specified feature.

Usage in Modeling

<u>Forest Interior</u>
This data layer constitutes unique aggregations of forest and non-forest map units. Non-forest map units include water, pasture/hay, agricultural areas, urban/developed, marshes, beaches, etc…

- **Utilizes Forest Interior –** For species that require interior forest. Buffer distances must be identified to utilize this input.
- **Avoids Forest Interior –** For species that avoid interior forest. Buffer distances must be identified to utilize this input.
- **FROM Buffer –** 0, 30, 60, 120, 250, 500, 1000, 2000, 4000, and 9999 (> 4000 m)(Figure 1.)
- **INTO Buffer –** 0, 30, 60, 120, 250, 500, 1000, 2000, 4000, and 9999 (> 4000 m) (Figure 1.)

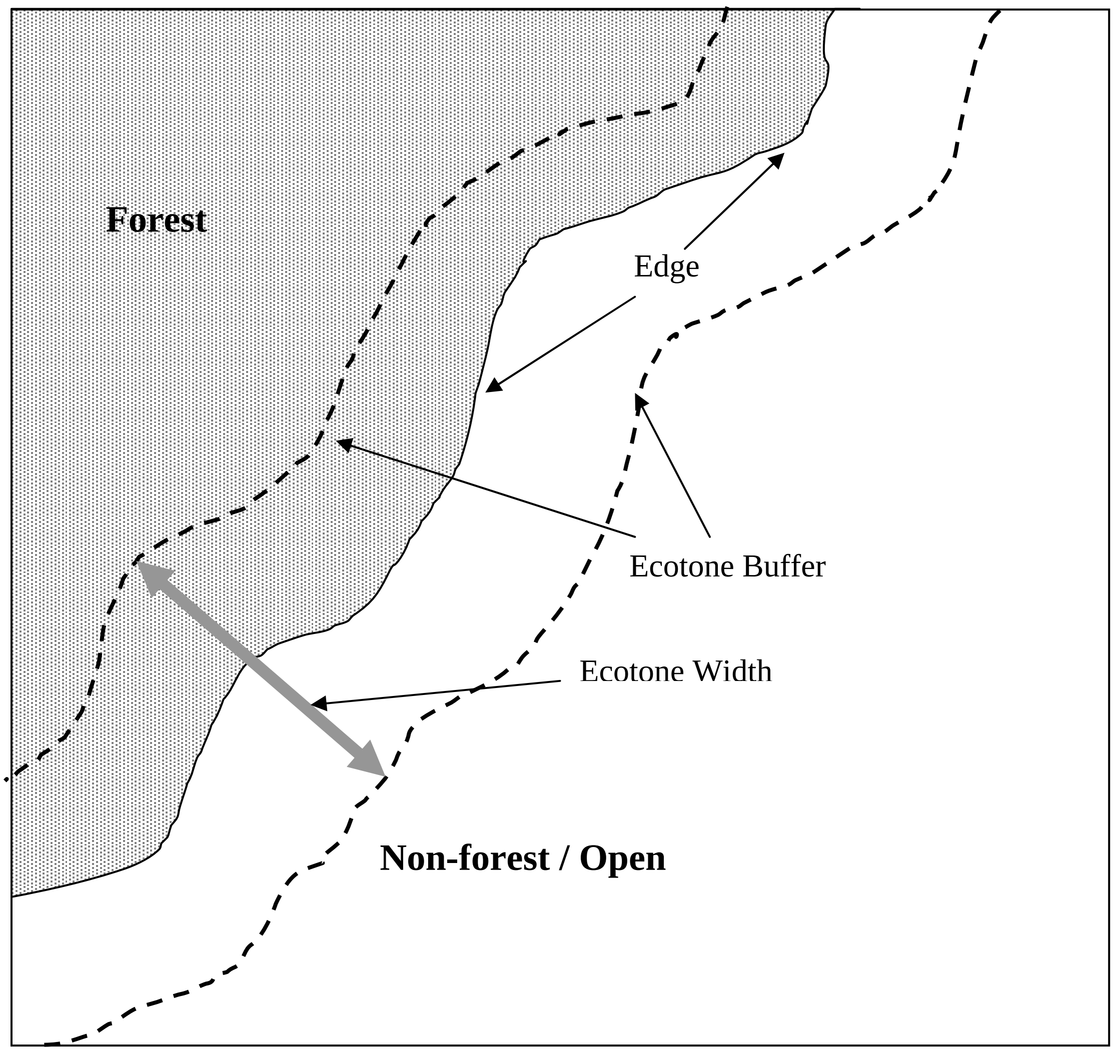
<u>Edge/Ecotone Type & Widths</u>

- **Forest/Open Ecotone Only –** This data layer represents the transitional areas between forest and open, non-forested habitats. Open, non-forested habitats include water, pasture/hay, prairies, agricultural areas, urban/developed, marshes, beaches, etc…

Forest/Open Ecotone + Woodlands/Shrublands – The forest/open only ecotone does not consider environments with sparse canopies or scrubby vegetation. In order to account for these additionally complex ecotones, this data layer includes woodland and shrubland map units that would otherwise be ignored.

Ecotone Width – This distance represents a swath of symmetrically buffered edge. The parameter is measured in increments of 0, 30, 60, 120, 250, 500, and 1000 meters. For example, an ecotone width of 500 meters includes 250 meters into forest and 250 meters into open (Figure 1).

Figure 1. Example of an ecotone/edge buffer on forest/non-forested environments.



SPECIES GEOGRAPHIC RANGES

Development

All 606 terrestrial vertebrate species' geographic range extents were delineated as single or multiple polygons. Breeding ranges were delineated for the majority of species (587), but for 26 species (25 birds, mostly waterfowl, and one bat); their wintering range only was delineated. Additionally, seven species had their wintering range delineated separately from their breeding range (five species of waterfowl and two bats). Processes used to create range polygons were unique because information on the current geographic range of a species varies widely. However, a generalized approach used a variety of sources to develop species' ranges. These sources consisted of information in two broad categories: species location records and range maps available digitally and in print, and digital spatial data of environmental parameters described in later sections of this document.

Usage in Modeling

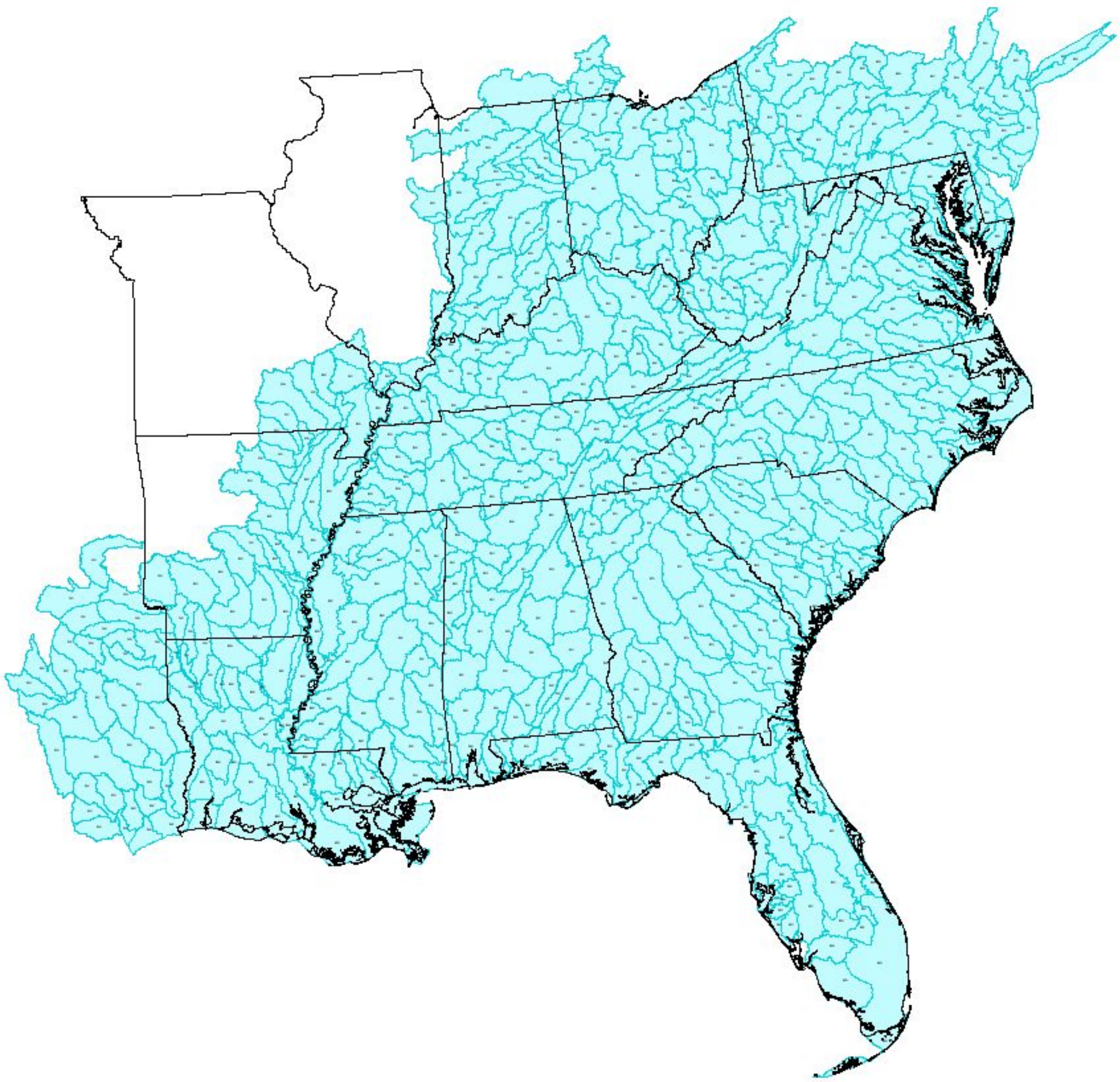
Species ranges were used as model delimiters in predicted distribution models.

HYDROLOGIC UNIT CODES (HUCs)

Development

The HUC is part of a hierarchical classification system for surface water drainage in the US (Seaber et al. 1987). The numerical code represents a “cataloging unit” of delineation approximately larger than 1800 square kilometers. Within the SE-GAP project boundary there are 577 8-digit HUCs (Figure 2). Vector format (i.e. polygon) data were compiled from United States Geological Survey (USGS) sources. No ancillary data was produced directly from HUCs, but they were utilized in numerous other ancillary data layer processes. Most notably, HUCs allow for partitioned processing when scripting complex spatial analysis tasks.

Figure 2. The 577 8-digit HUCs in the SE-GAP project region.



Usage in Modeling

HUCs were not used directly in species modeling. However, some species' geographic ranges were developed using the 8-digit hydrologic unit code polygons. This was only appropriate for species whose ranges would conceivably be limited to certain watershed drainages and their associated topographic distinctions. In most cases, these species were partially or entirely aquatic during some part of their life history (e.g. salamanders, turtles).

ECOREGIONS

Development

Ecoregions developed by Omernik (1987, 1995) and available from the U.S. Environmental Protection Agency (US EPA 2007) were produced through an analysis of biotic and abiotic patterns relating to ecosystem differentiation. Although no ancillary date were created directly from ecoregions, they were utilized in numerous other primary and ancillary data layer processes including land cover/ecological systems, species' ranges, and landforms.

Usage in Modeling

Ecoregions were not used explicitly in predicted distribution models. However, Omernik Level III and Level IV ecoregions were used to help define polygon boundaries for some species' geographic ranges when appropriate. Some species are clearly restricted to the physiographic and geographic patterns and boundaries that ecoregions define. For these species, ecoregions were used as all or a portion of the polygon(s) delineation. If there was a doubt as to the limitations imposed by such boundaries, ecoregions were not used.

SOILS

Development

State geographic soils database (STATSGO) soil units polygons were developed by the U.S. Department of Agriculture's Natural Resource Conservation Service (NRCS) at a scale of 1:250,000 for the conterminous U.S. (USDA 1995). Although no ancillary date were created directly from soils, they were utilized in numerous other primary and ancillary data layer processes including land cover/ecological systems, species' ranges, and landforms.

Usage in Modeling

Soils were not used explicitly in predicted distribution models. However, soils were used to help define polygon boundaries for some species' geographic ranges when appropriate. Although ecoregions consider soils as an abiotic factor in their delineation, for certain species it was necessary to focus more narrowly on soil type to help define a range polygon. For species whose habitat requirements are restricted to certain soil types (particularly some reptiles), soil polygons were used to help delineate all or a portion of their range.

ROADS

Development

Roads data were compiled from the U.S. Census Bureau's TIGER/Line files (USCB 2007). As a preliminary and stand alone layer, road density grids were created so that they could be used for production of imperious surface data layers and, by proxy, land cover/land use map units, as well as in production of an avoidance mask for vertebrate modeling. Part of the procedure to develop road density required the summarization of the attribute code 'CFCC' within the TIGER database (see technical documentation for TIGER/Line files at the URL listed in the Literature Cited section for more information). In general, seven codes were combined into three road category types (Table 1). A line density algorithm was used to calculate the linear length of roads within a circular neighborhood. The algorithm utilized a kernel smoothing function on a 30 meter cell size within a 564.19 meter radius (1 km^2).

Table 1. TIGER/Line attribute codes and descriptions and corresponding SE-GAP summarized categories used to develop road density for the southeast region.

Code Description	CFCC Code	SE-GAP Category
Primary highway with limited access	A1	US Highway
Primary road without limited access	A2	State Route
Secondary and connecting road	A3	State Route
Local, neighborhood, and rural road	A4	Secondary
Vehicular trail	A5	Secondary
Roads with special characteristics	A6	Secondary
Road as thoroughfare	A7	Secondary

Usage in Modeling

Roads were not used explicitly in predicted distribution models. However, the road density data layer derived from roads was used to develop an avoidance mask as an index to human disturbance (see **URBAN ENVIROMENTS** section in this document).

ELEVATION

Development

Elevation data are often represented in digital elevation models (DEMs). SE-GAP utilized the USGS compiled National Elevation Dataset (NED) as a primary source (USGS 2003). However, because of the varying quality of the data, it was necessary to incorporate other datasets to create an improved, region wide product. These included data from NASA's Shuttle Radar Topography Mission (SRTM) at 30 meter resolution (NASA 2007), Light Detection and Ranging (LIDAR) data from the North Carolina Floodplain Mapping Program (NCFMP 2007), and hypsography data from the USGS's Digital Line Graphs (DLGs) at 1:24,000 and 1:100,000 scales (USGS 2007a). Areas of inconsistent, erroneous, or systematically flawed data were identified visually and "tagged" for fixing. A number of algorithms were then used to reassign elevation values using interpolations based on the higher quality data. This essentially promoted the best available information for a given area using a number of sources, as opposed to re-interpolating data from the same flawed source.

Usage in Modeling

Some species respond to environments directly related to altitudinal variation. Elevation is easily implemented in spatial modeling by limiting the model to the **minimum** and **maximum** values explicitly stated in the literature. DEMs are utilized directly and are measured in meters above mean sea level.

LANDFORMS

Development

Landforms are derived from DEMs, ecoregions and hydrography using a complex model of slope, aspect, location, elevation, flow direction and accumulation, and a variety of other interpolated data. These are meant to incorporate a mixture of environmental inputs important for species.

The general steps involved in creating landforms are as follows:
1. Extract data inputs for a given region to process (mapping zones for example).
2. Subdivide into smaller processing units (HUCs for example) that can be overlapped during iteration loops to facilitate merging during production of the final output.
3. Calculate Topographic Relative Moisture Index (TRMI) based on a DEM and hydrography. TRMI is an estimate of potential moisture at a specific location created by combining relative slope position, aspect, slope and curvature from the DEM, and defining valley bottoms that correspond to high resolution hydrography data.
4. Process the moisture index grid to reclassify it into binary categories of moist and dry; smoothing the output with a majority filter to remove single cells and linear artifacts.
5. Calculate land position based on the inverse distance weighted elevation of each cell in relation to its neighbors.
6. Calculate the landform for each processing unit by combining the moisture, land position, slope and aspect.
7. Create the final landform for the region by combining landforms of overlapping processing units into a single output.

Usage in Modeling

<u>Landform Type</u>
Species distributions are restricted to the selected landforms. Landforms include:
Cliffs, Steep Slopes, Slope Crests, Side Slopes, Upper Slopes, Flat Summits, Coves, Slope Bottoms, Moist Flats, Dry Flats, and Wet Flats.

HYDROGRAPHY

Development

Water and its location on the landscape is a very important aspect of species' habitats. SE-GAP used a number of water related data layers to refine species models. These include water type (i.e. flowing or open/standing), distance to and from water, and stream flow and underlying gradient.

The source for hydrographic data was the USGS National Hydrography Dataset (NHD)(USGS 2007b). The NHD is composed of the most up-to-date nationwide data of surface waters compiled at two scales: 1:24,000 and 1:100,000. SE-GAP began acquiring NHD data in 2003. At the time, NHD was available only in ArcInfo coverage format organized by 8-digit Hydrologic Unit Code (HUC). NHD 8-digit HUCs are a complex mixture of polygon and arc (and point) features with numerous related tables of attributes. These coverage data are vector data types, i.e. arcs, polygons, nodes etc. with their incumbent data tables.

<u>Water Type</u>

We divided hydrographic features from NHD into three types: flowing water, standing water, and wet vegetation. These feature types were extracted from the NHD by selecting corresponding codes (the FCODE attribute) in data tables and creating separate datasets for each data type. To facilitate their use in spatial modeling, these feature types were converted to grids and combined into 16 categories where feature types overlapped (Table 2).

Flowing Water

Flowing water represents hydrographic features such as streams, rivers, springs, etc... NHD was developed as a value added product to allow users to performing tasks such as routing, classification, segmentation, etc…Therefore, arcs which flow into waterbodies such as reservoirs need to be continuous from their origin to their terminus. These "connectors" or "artificial paths" were also extracted from the data to represent flowing water. Flowing water can be arc or polygon feature classes. This is particularly true for large rivers that are wide enough to be digitized as long, narrow polygons.

Standing Water

Standing water represents hydrographic features such as lakes, ponds, reservoirs, bays, inlets, etc… Standing water can be arc or polygon feature classes. Some canals and ditches are represented as arcs. However, most standing water features are polygons.

Wet Vegetation

Wet vegetation represents hydrographic features such as swamps, marshes, Carolina bays, etc… It is represented only as the polygon feature class.

Table 2. Grid cell values for NHD hydrographic features assembled by 8-digit HUC.

Basic Features	
Grid Cell Value	*Description*
0	No Features
1	Flowing Water Arcs
2	Flowing Water Polygons
4	Standing Water Arcs OR Standing Water Polygons
8	Wet Vegetation
Combination of Features	
3	Flowing Water Arcs & Polygons
5	Flowing Water Arcs AND {Standing Water Arcs OR Standing Water Polygons}
6	Flowing Water Polygons AND {Standing Water Arcs OR Standing Water Polygons}
7	Flowing Water Arcs & Polygons AND Standing Water Arcs & Polygons
9	Flowing Water Arcs AND Wet Vegetation
10	Flowing Water Polygons AND Wet Vegetation
11	Flowing Water Arcs & Polygons AND Wet Vegetation
12	{Standing Water Arcs OR Standing Water Polygons} AND Wet Vegetaton
13	Flowing Water Arcs AND {Standing Water Arcs OR Standing Water Polygons} AND Wet Vegetation
14	Flowing Water Polygons AND {Standing Water Arcs OR Standing Water Polygons} AND Wet Vegetation
15	All Types of Hydro

<u>Distance INTO and FROM Water Features</u>

We used 18 categories of distance from the water features flowing water, standing water and wet vegetation. A process was used to buffer hydrography at various distances and code grid cells based on a defined set of distances. Table 3 summarizes the 18 code categories for buffer grids. Each water type has a region wide grid coded for buffer distance from that type of hydrography.

Table 3. Coding for 9 unique categories of buffer distance from hydrography.

Buffer Distance from Hydrographic Feature (meters)	*Recoded Cell Value*
Exterior Buffers (from feature)	
> 4000	0
+ 4000	1
+ 2000	2
+ 1000	3
+ 500	4
+ 250	5
+ 120	6
+ 60	7
+ 30	8

Interior Buffers (into feature)	
- 30 [0]	9
- 60	10
- 120	11
- 250	12
- 500	13
- 1000	14
- 2000	15
- 4000	16
< 4000	17

<u>Velocity (Stream Gradient)</u>
Stream velocity (or more appropriately stream gradient) was derived from a combination of streams and slopes calculated from a digital elevation model (DEM). A process was developed that determined the cell-to-cell drop in elevation along a stream grid based on flow direction. The process created three categories of slope calculations for use as a surrogate for stream gradient/velocity (Table 4). A double pass focal majority function was used to "smooth" the output.

Table 4. Coding for 3 unique categories of stream slope / gradient and corresponding velocity surrogate.

Cell-to-Cell Slope (degrees)	*Cell-to-Cell Slope (%)*	*Assumed Velocity*	*Cell Value*
<= 0	0	Slow	0
0 - 3	0 – 5.2	Moderate	1
>= 3	> 5.2	Fast	2

<u>Flow Accumulation</u>
Flow accumulation is a derivative of DEMs. Flow accumulation algorithms using DEMs calculate flow direction and aggregation of each grid cell compared with its eight adjacent neighbors (D-8). Stream delineation using flow accumulation grids is simply a matter of defining an accumulation threshold. In essence this threshold is akin to setting a minimum area required to initiate flowing surface water and in turn relates to stream order and size.

In an attempt to model stream hierarchy and its subsequent implementation in species' distribution models, flow accumulation outputs were assembled into 15 categories (Table 5).

Table 5. Coding for 15 categories of flow accumulation. Cell value ranges indicate the number of cells flowing to the specified cell based on D-8 flow direction.

Flow Accumulation Lower Value	*Flow Accumulation Upper Value*	*Recoded Cell Value*
0	25	0
25	50	1
50	100	2

100	500	3
500	1000	4
1000	2500	5
2500	5000	6
5000	10000	7
10000	25000	8
25000	50000	9
50000	100000	10
100000	200000	11
200000	500000	12
500000	1000000	13
1000000	99999999	14

Usage in Modeling

Water Type

Flowing Water – This includes streams, rivers, springs, seeps, ditches with moving water etc…
Open/Standing Water – This includes bays, estuaries, ocean, lakes, ponds, reservoirs, ditches with stagnant water etc…
Wet Vegetation – This includes a collection of map units representing seasonally or tidally inundated woody and non-woody plants.

Distance INTO and FROM Water Features
Interior (INTO) and **Exterior (FROM)** buffers on water features measured in meters and represented as discrete, cumulative distances. For example, a 250 meter exterior buffer on flowing water includes all areas up to 250 meters from the flowing water feature.

FROM Buffer – 0, 30, 60, 120, 250, 500, 1000, 2000, 4000, and 9999 (> 4000 m)
INTO Buffer – 0, 30, 60, 120, 250, 500, 1000, 2000, 4000, and 9999 (> 4000 m)

Velocity (Stream Gradient)
For some aquatic species, this can represent an important aspect of their habitat such as oxygenation levels, presence of invertebrate prey, and amount of sediment within the water column and on streambed substrates.

Slow Only – For species that require slow moving or almost stagnant sections of streams or rivers. Typically these are areas where the underlying topography is flat (0 % gradient).
Fast Only – For species that require high velocity sections of streams or rivers. Typically these are areas where the underlying topography is steep. A threshold of > 5 % gradient was used.
All Tyes – Species can utilize either fast or slow sections of streams or rivers.

Flow Accumulation

Since this layer is derived and produces data values not encountered in the literature, it can be unfamiliar and difficult to interpret. The **minimum** and **maximum** parameters for this input refer to the number of grid cells flowing into any given cell. Low values (25 – 1000) are typical for small, 1^{st} order type streams. Larger rivers typically have cell accumulation values >100,000.

SALINITY

Development

Water salinity is a major factor when considering habitat conditions for many species. However, the dynamic and complex nature of water systems makes the development of a highly refined and reliable datalayer impractical, if not impossible. Therefore, we developed three general categories to include in species habitat models.

Zones of water salinity were hand digitized using NLCD map units as a guide. All palustrine and upland map units were identified, as were all estuarine map units. A line was digitized between non-estuarine and estuarine map units and served as the boundary between fresh and brackish water. An additional line was digitized across all ocean inlets, essentially the shortest distance between two bodies of land. This second line served as the boundary between brackish and salt water.

Usage in Modeling

Freshwater Only – For species requiring water, this includes only fresh water.
Brackish/Salt Water Only – For species requiring water, this includes only brackish/salt water.
All Water – For species requiring water, this includes both brackish/salt water as well as freshwater.

URBAN ENVIRONMENTS

Development

Environments dominated by human disturbance such as roads, cities, and the constructed materials that support human habitation have profound effects on species' distributions. Map units derived for SE-GAP include three categories of development intensity – high, medium and low. These classes rely on spectral signatures from satellite data in association with measurements of impervious surface. SE-GAP created an urban/avoidance data layer using a combination of road density (see **ROADS** section above) and the three map units of development intensity. In effect, the derived data layer acts as an index for a species' **intolerance** to human environments.

Usage in Modeling

For most species, this data layer was used to "mask out" or **exclude** species from a portion of the landscape (see Figure 3). However, some species respond favorably to human habitats. In this later case, the data layer was used in an **inclusionary** manner see (Figure 4).

<u>Level of Tolerance/Intolerance</u>
This parameter is ranked at three levels: high, medium, and low. No selection of this parameter indicates the species' model is not contingent on an index of human disturbance.

- **High –**
  - **Exclusionary -** For species that are *very intolerant* of human disturbance. *All* portions of the landscape identified as being directly influenced by human disturbance are <u>eliminated</u> from the predicted distribution.
  - **Inclusionary -** For species that are associated with high levels of human disturbance. The predicted distribution is <u>limited to</u> all portions of the landscape identified as being directly influenced by human disturbance.
- **Medium –**
  - **Exclusionary -** For species that are *moderately intolerant* of human disturbance. Only portions of the landscape identified as being *highly or moderately* influenced by human disturbance are <u>eliminated</u> from the predicted distribution.
  - **Inclusionary –** For species that are associated with moderate levels of human disturbance. The predicted distribution is <u>limited to</u> only portions of the landscape identified as being *moderately or partially* influenced by human disturbance.
- **Low –**
  - **Exclusionary -** For species that are *partially intolerant* of human disturbance. Only portions of the landscape identified as being *highly* influenced by human disturbance are <u>eliminated</u> from the predicted distribution.
  - **Inclusionary -** For species that are associated with partial levels of human disturbance. The predicted distribution is <u>limited to</u> only portions of the landscape identified as being *partially* influenced by human disturbance.

Figure 3. The index of human disturbance at three levels: light gray = low; gray = medium; black = high. Using an exclusionary mask, the predicted distribution of a species is excluded from the black areas and limited to the white areas at intolerance levels of high, medium and low (top to bottom).

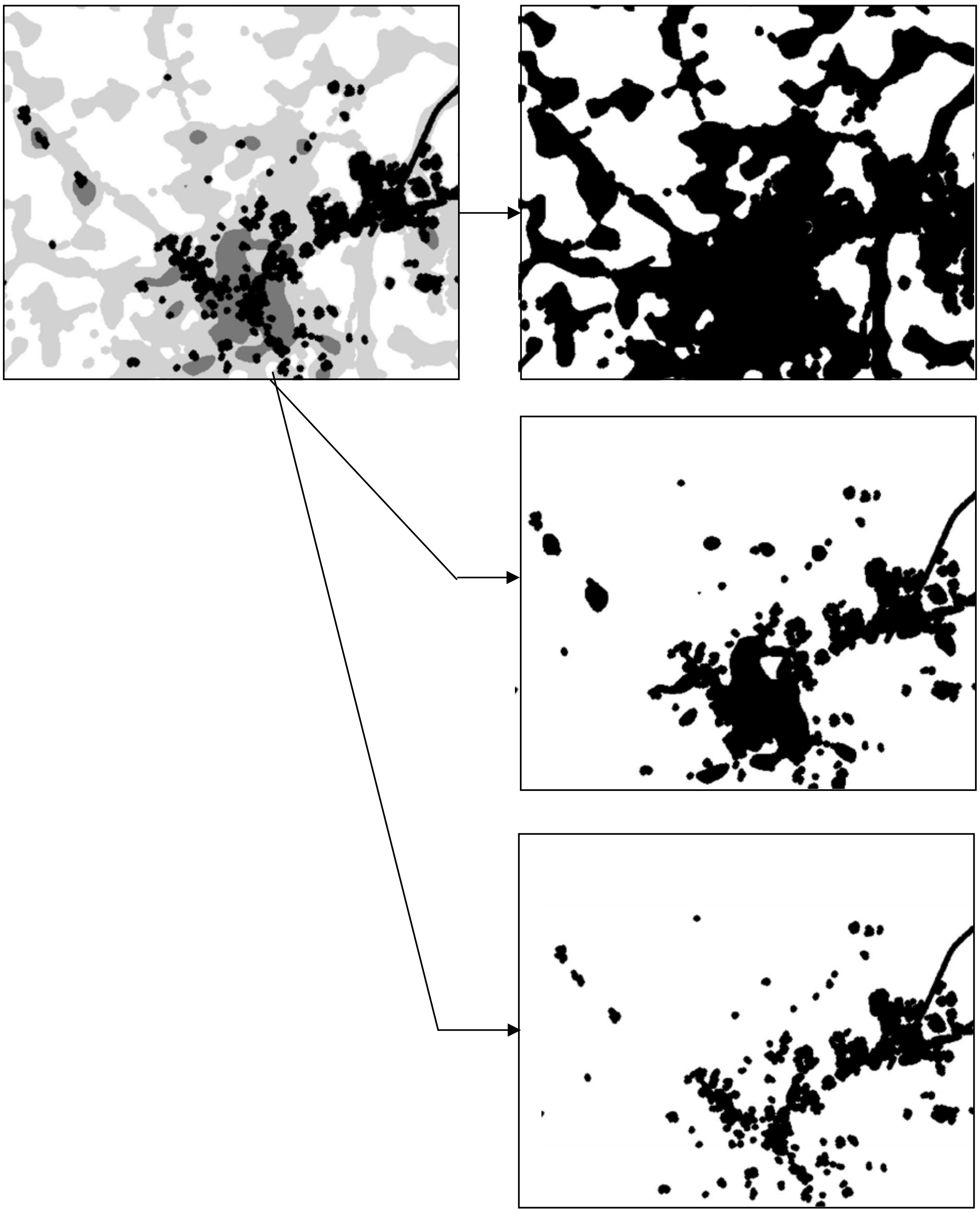
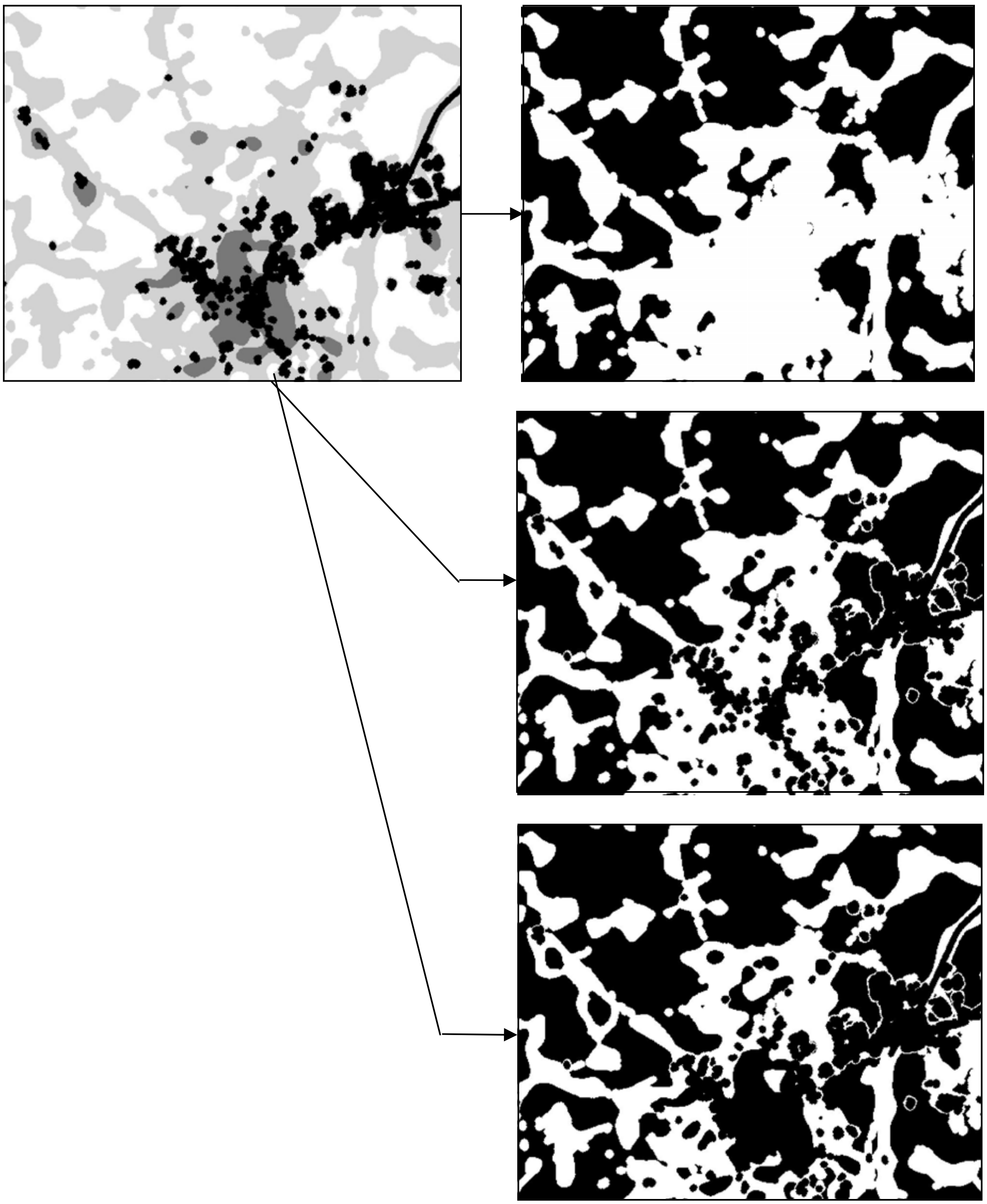


Figure 4. The index of human disturbance at three levels: light gray = low; gray = medium; black = high. Using an inclusionary mask, the predicted distribution of a species is excluded from the black areas and limited to the white areas at tolerance levels of high, medium and low (top to bottom).



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APPENDIX A

Table of forested map units (ecological system) corresponding to National Land Cover Dataset (NLCD) classes.

Ecological System Group Name	NLCD Class Name	NLCD Class Value
Southern Piedmont Dry Oak-Heath Forest - Hardwood Modifier	DECIDUOUS FOREST/WOODLAND	41
Southern Piedmont Dry Oak-Heath Forest - Virginia/Pitch Pine Modifier	EVERGREEN FOREST/WOODLAND	42
Southern Piedmont Dry Oak-Heath Forest - Mixed Modifier	MIXED FOREST/WOODLAND	43
Central and Southern Appalachian Spruce-Fir Forest	EVERGREEN FOREST/WOODLAND	42
Central and Southern Appalachian Northern Hardwood Forest	DECIDUOUS FOREST/WOODLAND	41
Southern Piedmont Seepage Wetland	PALUSTRINE FORESTED WETLAND	91
Southern Piedmont Small Floodplain and Riparian Forest	PALUSTRINE FORESTED WETLAND	91
Southern Piedmont Large Floodplain Forest - Forest Modifier	PALUSTRINE FORESTED WETLAND	91
Southern Appalachian Low Mountain Pine Forest	EVERGREEN FOREST/WOODLAND	42
Southern Piedmont/Ridge and Valley Upland Depression Swamp	PALUSTRINE FORESTED WETLAND	91
Southern Piedmont Dry Oak-(Pine) Forest - Hardwood Modifier	DECIDUOUS FOREST/WOODLAND	41
Southern Piedmont Dry Oak-(Pine) Forest - Loblolly Pine Modifier	EVERGREEN FOREST/WOODLAND	42
Southern Piedmont Dry Oak-(Pine) Forest - Mixed Modifier	MIXED FOREST/WOODLAND	43
Southern Piedmont Mesic Forest	DECIDUOUS FOREST/WOODLAND	41
Allegheny-Cumberland Dry Oak Forest and Woodland	DECIDUOUS FOREST/WOODLAND	41
Allegheny-Cumberland Dry Oak Forest and Woodland - Hardwood Modifier	DECIDUOUS FOREST/WOODLAND	41
Allegheny-Cumberland Dry Oak Forest and Woodland - Pine Modifier	EVERGREEN FOREST/WOODLAND	42
Southern and Central Appalachian Cove Forest	DECIDUOUS FOREST/WOODLAND	41
Southern Ridge and Valley Dry Calcareous Forest	DECIDUOUS FOREST/WOODLAND	41
Southern Ridge and Valley Dry Calcareous Forest - Pine Modifier	EVERGREEN FOREST/WOODLAND	42
Southern Ridge and Valley Dry Calcareous Forest - Hardwood Modifier	DECIDUOUS FOREST/WOODLAND	41
Southern Piedmont Northern Triassic Basin Dry Forest	DECIDUOUS FOREST/WOODLAND	41
Central Appalachian Oak and Pine Forest	MIXED FOREST/WOODLAND	43
Northeastern Interior Dry Oak Forest-Hardwood Modifier	DECIDUOUS FOREST/WOODLAND	41
Northeastern Interior Dry Oak Forest - Virginia/Pitch Pine Modifier	EVERGREEN FOREST/WOODLAND	42
Northeastern Interior Dry Oak Forest - Mixed Modifier	MIXED FOREST/WOODLAND	43
Appalachian Hemlock-Hardwood Forest	MIXED FOREST/WOODLAND	43
Central and Southern Appalachian Montane Oak Forest	DECIDUOUS FOREST/WOODLAND	41
North-Central Appalachian Acidic Swamp	PALUSTRINE FORESTED WETLAND	91
North-Central Interior and Appalachian Rich Swamp	PALUSTRINE FORESTED WETLAND	91
Central Appalachian Floodplain - Forest Modifier	PALUSTRINE FORESTED WETLAND	91
Central Appalachian Riparian - Forest Modifier	PALUSTRINE FORESTED WETLAND	91
South-Central Interior Large Floodplain - Forest Modifier	PALUSTRINE FORESTED WETLAND	91
South-Central Interior Small Stream and Riparian	PALUSTRINE FORESTED WETLAND	91
Southern and Central Appalachian Oak Forest	DECIDUOUS FOREST/WOODLAND	41
South-Central Interior Mesophytic Forest	DECIDUOUS FOREST/WOODLAND	41
South-Central Interior Highlands Dry Oak Forest	DECIDUOUS FOREST/WOODLAND	41
Atlantic Coastal Plain Northern Mixed Oak-Heath Forest	DECIDUOUS FOREST/WOODLAND	41
Mississippi River Riparian Forest	PALUSTRINE FORESTED WETLAND	91
Mississippi River Low Floodplain (Bottomland) Forest	PALUSTRINE FORESTED WETLAND	91
Atlantic Coastal Plain Southern Tidal Wooded Swamp	ESTUARINE FORESTED WETLAND	93
Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	DECIDUOUS FOREST/WOODLAND	41
Atlantic Coastal Plain Mesic Hardwood and Mixed Forest	DECIDUOUS FOREST/WOODLAND	41

Ecological System Group Name	NLCD Class Name	NLCD Class Value
Atlantic Coastal Plain Clay-Based Carolina Bay Forested Wetland	PALUSTRINE FORESTED WETLAND	91
Atlantic Coastal Plain Blackwater Stream Floodplain Forest - Forest Modifier	PALUSTRINE FORESTED WETLAND	91
Atlantic Coastal Plain Brownwater Stream Floodplain Forest	PALUSTRINE FORESTED WETLAND	91
Atlantic Coastal Plain Small Blackwater River Floodplain Forest	PALUSTRINE FORESTED WETLAND	91
Atlantic Coastal Plain Small Brownwater River Floodplain Forest	PALUSTRINE FORESTED WETLAND	91
Southern Coastal Plain Nonriverine Cypress Dome	PALUSTRINE FORESTED WETLAND	91
Atlantic Coastal Plain Fall-Line Sandhills Longleaf Pine Woodland - Loblolly Modifier	EVERGREEN FOREST/WOODLAND	42
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Offsite Hardwood Modifier	DECIDUOUS FOREST/WOODLAND	41
Atlantic Coastal Plain Central Maritime Forest	EVERGREEN FOREST/WOODLAND	42
Atlantic Coastal Plain Northern Tidal Wooded Swamp	ESTUARINE FORESTED WETLAND	93
East Gulf Coastal Plain Tidal Wooded Swamp	ESTUARINE FORESTED WETLAND	93
Atlantic Coastal Plain Northern Maritime Forest	EVERGREEN FOREST/WOODLAND	42
Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest - Oak Dominated Modifier	PALUSTRINE FORESTED WETLAND	91
Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest - Taxodium/Nyssa Modifier	PALUSTRINE FORESTED WETLAND	91
East Gulf Coastal Plain Near-Coast Pine Flatwoods - Offsite Hardwood Modifier	PALUSTRINE FORESTED WETLAND	91
Southern Coastal Plain Nonriverine Basin Swamp	PALUSTRINE FORESTED WETLAND	91
East Gulf Coastal Plain Southern Mesic Slope Forest	DECIDUOUS FOREST/WOODLAND	41
East Gulf Coastal Plain Northern Mesic Hardwood Forest	DECIDUOUS FOREST/WOODLAND	41
East Gulf Coastal Plain Black Belt Calcareous Prairie and Woodland - Forest Modifier	DECIDUOUS FOREST/WOODLAND	41
East Gulf Coastal Plain Northern Loess Bluff Forest	DECIDUOUS FOREST/WOODLAND	41
East Gulf Coastal Plain Northern Loess Plain Oak-Hickory Upland - Hardwood Modifier	DECIDUOUS FOREST/WOODLAND	41
East Gulf Coastal Plain Northern Loess Plain Oak-Hickory Upland - Juniper Modifier	EVERGREEN FOREST/WOODLAND	42
East Gulf Coastal Plain Northern Dry Upland Hardwood Forest	DECIDUOUS FOREST/WOODLAND	41
East Gulf Coastal Plain Northern Dry Upland Hardwood Forest - Offsite Pine Modifier	EVERGREEN FOREST/WOODLAND	42
East Gulf Coastal Plain Large River Floodplain Forest - Forest Modifier	PALUSTRINE FORESTED WETLAND	91
Lower Mississippi River Bottomland Depressions - Forest Modifier	PALUSTRINE FORESTED WETLAND	91
Southern Coastal Plain Blackwater River Floodplain Forest	PALUSTRINE FORESTED WETLAND	91
Southern Coastal Plain Oak Dome and Hammock	EVERGREEN FOREST/WOODLAND	42
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Loblolly Modifier	EVERGREEN FOREST/WOODLAND	42
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Offsite Hardwood Modifier	DECIDUOUS FOREST/WOODLAND	41
Southern Coastal Plain Hydric Hammock	PALUSTRINE FORESTED WETLAND	91
East Gulf Coastal Plain Limestone Forest	DECIDUOUS FOREST/WOODLAND	41
East Gulf Coastal Plain Maritime Forest	EVERGREEN FOREST/WOODLAND	42
Southern Coastal Plain Seepage Swamp and Baygall	PALUSTRINE FORESTED WETLAND	91
East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest - Mixed Modifier	MIXED FOREST/WOODLAND	43
East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest - Hardwood Modifier	DECIDUOUS FOREST/WOODLAND	41
East Gulf Coastal Plain Interior Shortleaf Pine-Oak Forest - Pine Modifier	EVERGREEN FOREST/WOODLAND	42
Lower Mississippi River Bottomland and Floodplain Forest	PALUSTRINE FORESTED WETLAND	91
Mississippi Delta Maritime Forest	EVERGREEN FOREST/WOODLAND	42
Atlantic Coastal Plain Northern Basin Swamp and Wet Hardwood Forest	PALUSTRINE FORESTED WETLAND	91
Atlantic Coastal Plain Northern Basin Peat Swamp	PALUSTRINE FORESTED WETLAND	91
Atlantic Coastal Plain Southern Maritime Forest	EVERGREEN FOREST/WOODLAND	42
East Gulf Coastal Plain Northern Seepage Swamp	PALUSTRINE FORESTED WETLAND	91
East Gulf Coastal Plain Southern Loess Bluff Forest	DECIDUOUS FOREST/WOODLAND	41

Ecological System Group Name	NLCD Class Name	NLCD Class Value
East Gulf Coastal Plain Southern Loblolly-Hardwood Flatwoods	PALUSTRINE FORESTED WETLAND	91
East Gulf Coastal Plain Small Stream and River Floodplain Forest	PALUSTRINE FORESTED WETLAND	91
Southern Coastal Plain Dry Upland Hardwood Forest	DECIDUOUS FOREST/WOODLAND	41
South Florida Hardwood Hammock	EVERGREEN FOREST/WOODLAND	42
South Florida Cypress Dome	PALUSTRINE FORESTED WETLAND	91
South Florida Bayhead Swamp	PALUSTRINE FORESTED WETLAND	91
Southwest Florida Coastal Strand and Maritime Hammock	EVERGREEN FOREST/WOODLAND	42
Southeast Florida Coastal Strand and Maritime Hammock	EVERGREEN FOREST/WOODLAND	42
South Florida Willow Head	PALUSTRINE FORESTED WETLAND	91
South Florida Pond-Apple/Popash Slough	PALUSTRINE FORESTED WETLAND	91
Deciduous Plantations	DECIDUOUS FOREST/WOODLAND	41
Evergreen Plantations	EVERGREEN FOREST/WOODLAND	42

APPENDIX B

Table of woodland/shrubland map units (ecological system) and corresponding National Land Cover Dataset (NLCD) classes.

Ecological System Group Name	NLCD Class Name	NLCD Class Value
Central Interior Highlands and Appalachian Sinkhole and Depression Pond	PALUSTRINE SHRUB/SCRUB WETLAND	92
Ridge and Valley Calcareous Valley Bottom Glade and Woodland	MIXED FOREST/WOODLAND	43
Southern Piedmont Mafic Hardpan Woodland	DECIDUOUS FOREST/WOODLAND	41
Southern Appalachian Grass and Shrub Bald - Shrub Modifier	SHRUB/SCRUB	52
Southern and Central Appalachian Bog and Fen	PALUSTRINE SHRUB/SCRUB WETLAND	92
Southern Piedmont Longleaf Pine Woodland	EVERGREEN FOREST/WOODLAND	42
Southern Piedmont Glade and Barrens	MIXED FOREST/WOODLAND	43
Southern Appalachian Montane Pine Forest and Woodland	EVERGREEN FOREST/WOODLAND	42
Nashville Basin Limestone Glade	MIXED FOREST/WOODLAND	43
Cumberland Sandstone Glade and Barrens	MIXED FOREST/WOODLAND	43
Alabama Ketona Glade and Woodland	MIXED FOREST/WOODLAND	43
Appalachian Serpentine Woodland	EVERGREEN FOREST/WOODLAND	42
Southern and Central Appalachian Mafic Glade and Barrens	DECIDUOUS FOREST/WOODLAND	41
Central Appalachian Montane Rocky Bald - Shrub Modifier	SHRUB/SCRUB	52
Appalachian Shale Barrens	MIXED FOREST/WOODLAND	43
Central Appalachian Pine-Oak Rocky Woodland	MIXED FOREST/WOODLAND	43
Central Appalachian Alkaline Glade and Woodland	MIXED FOREST/WOODLAND	43
North-Central Appalachian Seepage Fen	PALUSTRINE SHRUB/SCRUB WETLAND	92
Central Interior Highlands Calcareous Glade and Barrens	MIXED FOREST/WOODLAND	43
Central Interior Highlands Dry Acidic Glade and Barrens	MIXED FOREST/WOODLAND	43
Bluegrass Basin Savanna and Woodland	GRASSLAND/HERBACEOUS	71
Florida Peninsula Inland Scrub	SHRUB/SCRUB	52
Atlantic Coastal Plain Streamhead Seepage Swamp, Pocosin, and Baygall	PALUSTRINE FORESTED WETLAND	91
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Open Understory Modifier	EVERGREEN FOREST/WOODLAND	42
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland - Scrub/Shrub Understory Modifier	EVERGREEN FOREST/WOODLAND	42
Atlantic Coastal Plain Northern Wet Longleaf Pine Savanna and Flatwoods	PALUSTRINE FORESTED WETLAND	91
Atlantic Coastal Plain Peatland Pocosin	PALUSTRINE FORESTED WETLAND	91
Atlantic Coastal Plain Longleaf Pine Woodland	EVERGREEN FOREST/WOODLAND	42
Central Florida Upland Longleaf Pine Island - Open Understory Modifier	EVERGREEN FOREST/WOODLAND	42
Central Florida Upland Longleaf Pine Island - Scrub/Shrub Understory Modifier	EVERGREEN FOREST/WOODLAND	42
East Gulf Coastal Plain Near-Coast Pine Flatwoods - Open Understory Modifier	PALUSTRINE FORESTED WETLAND	91
East Gulf Coastal Plain Near-Coast Pine Flatwoods - Scrub/Shrub Understory Modifier	PALUSTRINE FORESTED WETLAND	91
Central Florida Pine Flatwoods	PALUSTRINE FORESTED WETLAND	91
East Gulf Coastal Plain Interior Shrub Bog	PALUSTRINE SHRUB/SCRUB WETLAND	92
East Gulf Coastal Plain Black Belt Calcareous Prairie and Woodland	GRASSLAND/HERBACEOUS	71
East Gulf Coastal Plain Jackson Plain Dry Flatwoods - Open Understory Modifier	DECIDUOUS FOREST/WOODLAND	41
East Gulf Coastal Plain Jackson Plain Dry Flatwoods - Scrub/Shrub Understory Modifier	DECIDUOUS FOREST/WOODLAND	41
South-Central Interior/Upper Coastal Plain Wet Flatwoods	PALUSTRINE FORESTED WETLAND	91
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Open Understory Modifier	EVERGREEN FOREST/WOODLAND	42
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland - Scrub/Shrub Modifier	EVERGREEN FOREST/WOODLAND	42
Panhandle Florida Limestone Glade	GRASSLAND/HERBACEOUS	71
Atlantic Coastal Plain Southern Wet Pine Savanna and Flatwoods	PALUSTRINE FORESTED WETLAND	91
East Gulf Coastal Plain Jackson Prairie and Woodland	GRASSLAND/HERBACEOUS	71

Ecological System Group Name	NLCD Class Name	NLCD Class Value
South Florida Mangrove Swamp	ESTUARINE FORESTED WETLAND	93
South Florida Dwarf Cypress Savanna	PALUSTRINE FORESTED WETLAND	91
South Florida Pine Rockland	EVERGREEN FOREST/WOODLAND	42
South Florida Pine Flatwoods	PALUSTRINE FORESTED WETLAND	91
Southwest Florida Perched Barriers Salt Swamp and Lagoon - Mangrove Modifier	ESTUARINE FORESTED WETLAND	93