Threats to Ecological Systems in the South Atlantic Landscape Conservation Cooperative area

Final Report

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Prepared for:

South Atlantic Landscape Conservation Cooperative

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30 September 2014

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Introduction

Ecosystems of the southeastern United States face a large number of threats to their ecological integrity, including loss of habitat, climate change, exotic species invasion, and many more. NatureServe staff, in conjunction with the South Atlantic Landscape Conservation Cooperative (SALCC), have compiled this report in order to better understand how these threats impact ecosystems and the level of impact to these ecosystems, thereby addressing a key information need identified by the SALCC.

We have organized the threats according to the first and second level threats classification of the Conservation Measures Partnership (Salafsky et al. 2008). The Conservation Measures Partnership maintains a standard nomenclature of conservation terms to promote effective conservation, and this nomenclature is widely used for conservation projects in the United States and internationally.

We then developed and refined a list of all ecosystems within the SALCC footprint using NatureServe's Ecological Systems; a standard vegetation classification system. Ecological Systems are mid-scale ecological community classification units developed by NatureServe, which incorporate similar vegetation, environmental site characteristics and disturbances (Comer et al. 2003). Ecological Systems have been used as land cover mapping units regionally in the southeastern United States by the USGS GAP Analysis Program, nationally by the interagency Landfire program, and by NatureServe via its National Map of Ecological Systems, which is a seamless combination of GAP and Landfire datasets.

The footprint of the study area is the South Atlantic Landscape Conservation Cooperative area, which includes the Piedmont and Coastal Plain of the southeastern United States, from southern Virginia to northern Florida, east of the Apalachicola River. It includes most of North Carolina, South Carolina, and Georgia (Figure 1).

Figure 1 - South Atlantic LCC Project Area

NatureServe used standard methods to assign threats information to the Ecological Systems of the project area, following NatureServe's Global Status Review process (Faber-Langendoen et al. 2012, Master et al. 2012). As part of the 2012 study, we identified over 1200 combinations of level one and two threats to specific ecological systems in the region. In 2012, we assigned each threat to an Ecological System with a threat impact level specific to that Ecological System, from low to high or very high (Master et al. 2012). Highly and very highly threatened Ecological Systems are influenced by a large number of threats, and these threats tend to have high and very high threat impacts. We highlight the fourteen Ecological Systems documented as the most highly threatened in this report and its appendices.

Methods

Ecological Systems of the South Atlantic Landscape Conservation Cooperative area

We used NatureServe's Ecological Systems Classification as the habitat classification system for this project. Ecological Systems are mid-scale, multi-factor ecological community classification units which incorporate similar vegetation, environmental site characteristics and natural disturbance dynamics (Comer et al. 2003). Ecological Systems were developed in the early 2000s and were further updated by NatureServe over the past decade. NatureServe maintains the current Ecological Systems Classification as part of its central enterprise database, using the Biotics 5 database software, and produces regional or project area classifications on a regular basis (NatureServe 2014). Ecological Systems have been used as land cover mapping units regionally in the southeastern United States by the USGS GAP Analysis Program, nationally by the interagency Landfire program (Rollins et al. 2009), and by NatureServe which shares its National Map of Ecological Systems. The link to the systems map is at:

http://www.natureserve.org/conservation-tools/data-maps-tools/terrestrial-ecological-systems-united-states

General information about Ecological Systems is available online at NatureServe Explorer at:

http://explorer.natureserve.org/servlet/NatureServe?init=Ecol

Over the past decade, NatureServe's Ecological System Classification has also been used as the habitat classification for many conservation planning efforts within the South Atlantic Landscape Conservation Cooperative area, such as Ecoregional Conservation Plans developed by The Nature Conservancy, and the US Forest Service's National Forest Land and Resource Management Plans.

NatureServe created a preliminary list or set of Ecological Systems based on NatureServe's Ecological Systems distribution data, the mapped area of the South Atlantic Landscape Conservation Cooperative, and the states and ecoregions which comprise this area. This preliminary set of Ecological Systems was reviewed and amended by NatureServe ecologists to use as the project area set of Ecological Systems, which were then used for the development of the threats to Ecological Systems information.

NatureServe's Global Status Assessment Methodology and Rank Factors

NatureServe's global status assessment methodology (Faber-Langendoen et al. 2012) and rank factors (Master et al. 2012) together constitute a standardized approach to the status assessment of rare

species and ecosystems, specifically the assessment of extinction risk of species and elimination risk of ecosystems. This approach is used by NatureServe and NatureServe's network partner programs to assess extinction risk of species and elimination risk of ecosystems in a standardized, repeatable manner based on the current conservation science, practice and knowledge. NatureServe and its hemisphere-wide network of natural heritage programs are the leading source for information about rare and endangered species and threatened ecosystems. There are eight status rank factors, in three categories (rarity, threats, and trends). Together these eight status rank factors can inform and lead to a global conservation status rank for species or ecosystems, such as critically imperiled (G1) or imperiled (G2) to demonstrably secure (G5). By researching and recording information on the conservation status rank factors, we can assign a conservation status rank using supporting documentation. We can also assess conservation status rank in the same manner, at the national or state/province levels.

There are two main tools for conducting the global conservation status assessments. The first tool is a rank calculator to automate the assignment of status ranks, based on the information available and used and the values of the eight status rank factors. The other main tool is NatureServe's Biotics 5 enterprise database, used for managing the conservation status information (Faber-Langendoen et al. 2012) and other biodiversity data.

Development of Threats Information

NatureServe ecologists used expert knowledge and conducted literature review for the threats to Ecological Systems of the South Atlantic Landscape Conservation Cooperative project area. We used this information to assign threats according to the Conservation Measures Partnership threats nomenclature (Salafsky et al. 2008), following NatureServe's standardized approach to the status assessment of rare species and ecosystems (Faber-Langendoen et al. 2012), and assignment of rank factors (Master et al. 2012). The Conservation Measures Partnership supports this effort with information on their website at:

http://cmp-openstandards.org/using-os/tools/threats-taxonomy/

The development of threats information is a key step in the overall conservation status assessment process. Although it was not within the scope of this project to complete final conservation status assessments, the threats information we have generated are vital for any conservation status assessment of ecological systems in the Southeast (table 1).

Table 1 - Summary of NatureServe Conservation Status Factors (Master et al. 2012)

Factor Category	Factor	Condition (Rule)
Rarity	Range Extent	Always use, if available
	Area of Occupancy	Always use, if available
	Population	Always use, if available (species only)
	Number of Occurrences	Always use, if available
	Number of Occurrences or Percent Area with Good Viability/Ecological Integrity	Always use, if available
	Environmental Specificity	Only use if both the Number of Occurrences and Area of Occupancy are Unknown or Null
Trends	Long-term Trend	Always use, if available
	Short-term Trend	Always use, if available
Threats	Threats	Always use, if available
	Intrinsic Vulnerability	Only use if Threats is Unknown or Null

NatureServe ecologists have also developed additional information for highly threatened Ecological Systems of the United States as part of the IUCN Red List of Ecosystems project (Keith et al. 2013). We reviewed, edited, and updated data developed through the IUCN Red List of Ecosystems work, which pertained to the threats to Ecological Systems of the South Atlantic LCC area as part of this South Atlantic LCC project work.

Table 2 - Classification of Threats from Conservation Measures Partnership (Master et al. 2012, Salafsky et al. 2008)

Threat No.	Threat Description	Scope	Severity	Impact	Timing
1	Residential & Commercial Development				
1.1	Housing & Urban Areas				
1.2	Commercial & Industrial Areas				
1.3	Tourism & Recreation Areas				
2	Agriculture & Aquaculture				
2.1	Annual & Perrenial Non-Timber Crops				
2.2	Wood & Pulp Plantations				
2.3	Livestock Farming & Ranching				
2.4	Marine & Freshwater Aquaculture				
3	Energy Production & Mining				
3.1	Oil & Gas Drilling				
3.2	Mining & Quarrying				
3.3	Renewable Energy				
4	Transportation & Service Corridors				
4.1	Roads & Railroads				
4.2	Utility & Service Lines				
4.3	Shipping Lanes				
4.4	Flight Paths				
5	Biological Resource Use				
5.1	Hunting & Collecting Terrestrial Animals				
5.2	Gathering Terrestrial Plants				
5.3	Logging & Wood Harvesting				
5.4	Fishing & Harvesting Aquatic Resources				
6	Human Intrusions & Disturbance				
6.1	Recreational Activities				
6.2	War, Civil Unrest & Military Exercises				
6.3	Work & Other Activities				

Threat No.	Threat Description	Scope	Severity	Impact	Timing
7	Natural System Modifications				
7.1	Fire & Fire Suppression				
7.2	Dams & Water Management/Use				
7.3	Other Ecosystem Modifications				
8	Invasive & Other Problematic Species & Genes				
8.1	Invasive Non-Native/Alien Species				
8.2	Problematic Native Species				
8.3	Introduced Genetic Material				
9	Pollution				
9.1	Household Sewage & Urban Waste Water				
9.2	Industrial & Military Effluents				
9.3	Agricultural & Forestry Effluents				
9.4	Garbage & Solid Waste				
9.5	Air-Borne Pollutants				
9.6	Excess Energy				
10	Geological Events				
10.1	Volcanoes				
10.2	Earthquakes/Tsunamis				
10.3	Avalanches/Landslides				
11	Climate Change & Severe Weather				
11.1	Habitat Shifting & Alteration				
11.2	Droughts				
11.3	Temperature Extremes				
11.4	Storms & Flooding				

Table 2 (cont.). Classification of Threats from Conservation Measures Partnership (Master et al. 2012, Salafsky et al. 2008)

For each Ecological System in the South Atlantic LCC area, we assigned the relevant level one and level two threats (Table 2) based on available information such as published literature and expert knowledge. For each of the noteworthy threats to a particular Ecological System, we indicated the scope, severity and timing related to that threat for that Ecological System. Set terms for the scope, severity and timing (Master et al. 2012) are used from a list of defined values available in the conservation status rank calculator, which ensures data consistency and facilitates the sharing of information pertaining to the threats.

Table 3 - Conservation Measures Partnership (CMP) Individual Threat Scoring Values (Master et al. 2012)

CMP Individual Threats Scoring Values			
Scope	Severity	Impact	Timing
Pervasive	Extreme	Very High	High
Large	Serious	High	Moderate
Restricted	Moderate	Medium	Low
Small	Slight	Low	Insignificant/Negligible

In addition to the threats information documented in the status rank calculator as part of the status assessment process, we edited and updated other information pertaining to threats to Ecological Systems in an Ecological Systems report document. This report includes a variety of information on each of the Ecological Systems of the South Atlantic LCC area. The main text fields are Concept Summary, Distribution, Environment, Key Processes and Interactions, Threats/stressors, Ecosystem Collapse Thresholds, and literature cited. The data complement each other, and there is some redundancy between the Ecological Systems threats information in text fields in the report (presented here as an appendix), and the tabular data pertaining to threats which was developed using the conservation status rank calculator. In the Ecological Systems report, the "Threats/stressors" field includes a general statement on the important or most significant threats for an Ecological System and included are references cited for certain threats, from the scientific literature. The "Ecosystem Collapse Thresholds" field describes the conditions under which examples of the ecological system collapse and become another Ecological System or a novel ecosystem (Hobbs et al. 2006) and are only restorable with extraordinary ecological restoration methods and effort. We developed these text fields in the Ecological Systems report in partnership with the IUCN as part of the Red List of Ecosystems project, and they were all fully reviewed and edited where necessary for the South Atlantic LCC project.

Regional Spatial Analysis

We completed a series of spatial analyses better quantify certain threats to the Ecological Systems mapped in the South Atlantic LCC area. For this step, we intersected a list of the Ecological Systems with the total mapped area for the South Atlantic LCC (based on v3.0 of the NatureServe National Map of Ecological Systems) with spatial data for Fire Regime Condition Class, probability of urbanization, level of land protection for conservation, oil and natural gas resources in certain Mesozoic basins, and wind resource potential. We compiled the regional spatial analyses results and summarized data in a separate file in Microsoft Excel Workbook (.xlsx) format. Four of these five threats correspond to level 1 or level 2 threats following the Conservation Measures Partnership classification (Salafsky et al. 2008). Ecological Systems within Protected Areas can be considered a measure of the reduction of multiple threats for an Ecological Systems, and does not correspond to level 1 or level 2 threats (Table 4).

Table 4 - Spatial Analysis threat names and Conservation Measures Partnership Threats

Spatial Analysis Threat Name	Conservation Measures Partnership Threat Number	Conservation Measures Partnership Threat Description
Fire Regime Condition Class	7.1	Fire & fire suppression
Urbanization	1	Residential & commercial development
Ecological Systems within Protected Areas	Does not correspond to a particular threat	Does not correspond to a particular threat
Assessed Oil and Gas Resources	3.1	Oil & gas drilling
Wind Resources	3.3	Renewable energy

Fire Regime Condition Class

Fire Regime Condition Class (FRCC) is an assessment system which connects understanding of fire regimes, ecological departure from reference conditions, and efforts to maintain sustainable landscapes. It provides tools for fire regime and vegetation assessment at the stand and landscape scales. A natural fire regime is a general classification of the role fire would play across a landscape in the absence of modern human intervention but including the possible influence of aboriginal fire use (Barrett et al. 2010). In the southeastern coastal plain, wildland fire was promoted by lightning and the use of fire by Native Americans. In the FRCC documentation, the terms “historical,” “reference,” and “natural” all refer to native ecosystems as they existed prior to EuroAmerican settlement(Barrett et al. 2010). As one example, longleaf pine Ecological Systems in the southeastern coastal plain likely burned with low intensity fire every one to four years, prior to EuroAmerican settlement. Certain methods have been used to describe the general fire regime and vegetation characteristics for the historical (or reference conditions) and the current conditions to produce estimates of departure from the reference (i.e. historical or natural) conditions (Barrett et al. 2010). FRCC has been found to be applicable to most wildland settings in the United States (Barrett et al. 2010), and is part of the interagency Landfire spatial data (Rollins et al. 2009).

There are three Fire Regime Condition Classes which we analyzed spatially for the South Atlantic LCC footprint area (FRCC 1, FRCC 2, and FRCC 3). FRCC 1 represents ecosystems with low (<33 percent) departure from a defined reference period – that is, landscapes still (under current conditions) are within the natural or historical range of variation based on the general fire regime and vegetation characteristics for the historical, natural or reference conditions; FRCC 2 indicates ecosystems with moderate (33 to 66 percent) departure; and FRCC 3 indicates ecosystems with high (>66 percent) departure from reference conditions (Barrett et al. 2010). An example of FRCC 1 within the South Atlantic LCC footprint area, could be longleaf pine woodlands which retain mature uneven aged trees and are burned with low intensity prescribed fire every one to four years.

Urbanization

To assess vulnerability to conversion, we used the SLEUTH data for urbanization probabilities in 2010 and in 2050. This data predicts the likelihood of urban growth, with results reported as the probability of conversion of lands to urban land (Belyea and Terando 2012). For more information, see:

http://www.basic.ncsu.edu/dsl/urb.html

SLEUTH data were summarized for both 2010 and 2050 with three attributes: (1) the percent of the Ecological System extent with a probability of urbanization > 0% for the given time step, (2) the percent of the Ecological System extent with a probability of urbanization > 50% for the given time step, and (3) the mean probability of urbanization for all pixels mapped as that Ecological System. Note that both SLEUTH mapped data and National Map of Ecological Systems are modeled products with variable accuracy. Caution should be taken in interpreting the data, particularly for small patch Ecological Systems, those which naturally occur in small areas. For example, Southwest Florida Beach (CES411.276) is mapped with an 80% mean probability of conversion, but if you take a look at the source data tab (SERAP2010) it is apparent that this is because 7200 of the 9000 square meter mapped extent was classified as already converted in 2010.

Ecological Systems within Protected Areas

We analyzed the percent of each Ecological System within protected conservation areas spatially using the intersections of v3.0 of the NatureServe National Map of Ecological Systems and the USGS PAD 3.0 spatial data of protected conservation land areas. The USGS PAD 3.0 spatial data is the official inventory of protected open space in the United States. It includes mapped public conservation lands of federal, state and some local government ownerships and some private lands which are formally dedicated to conservation at certain levels of protection, such as by nonprofit conservation organizations. The PAD 3.0 protection categories were grouped up to Strict (Gap Analysis Program Status 1 & 2), and Inclusive (Gap Analysis Program 1, 2, and 3). Gap Analysis Program status 1 and 2 provide protection for biodiversity conservation, and Gap Analysis Program Status 3 indicates multiple use lands which may allow for resource extraction (Gergely and McKerrow 2013). One of the purposes of the PAD 3.0 dataset is the identification of lands that need conservation to protect and restore ecosystems.

Assessed Oil and Gas Resources

The oil and gas resources information provided is based on a USGS assessment of oil and gas resources of the East Coast Mesozoic Basins (Milici et al. 2012). Information on the assessment, as well as a map of the basin locations (in pdf format), can be found here:

http://pubs.usgs.gov/fs/2012/3075/

We merged shapefiles which represented the distinct Mesozoic basins discussed in the report. Of the five East Coast Mesozoic basins assessed (chosen due to the demonstrated potential for generating and accumulating hydrocarbons within those basins), three fell at least partially within the South Atlantic LCC. Of these, the Deep River Basin and Taylorville Basin (which barely extends into the South Atlantic LCC from the north) were identified as likely to possess the potential to produce the most hydrocarbons.

During the past few years, the Deep River Basin has been an area of interest for the natural gas industry, and leasing activity for the development of the natural gas resources is ongoing. The USGS assessment indicates that there is a 50% chance that there is at least 1.5 trillion cubic feet of natural gas in the Deep River Basin which is technically recoverable (Milici et al. 2012). Three additional unassessed basins were mapped digitally by the USGS in the South Atlantic LCC region. These are the Cumberland-Marlboro basin, the Florence basin, and the South Georgia basin. A fourth, the North Florida basin, is shown on paper maps, but we could not find a digital (raster or vector) representation of it in the available spatial data. The North Florida basin is in the SW corner of the South Atlantic LCC area, in southwest Georgia and the adjacent Florida Panhandle, mainly east of the Apalachicola River (Milici et al. 2012).

We assessed the total extent of mapped Ecological Systems distributions (1) in any basin, (2) in only those basins with the highest potential for oil and natural gas development (i.e. Deep River and Taylorville basins), (3) in basins with moderate potential for oil and natural gas development (i.e. Dan River basin), and (4) in the unassessed basins only.

Wind Resources

The data used to represent the presence of wind resources is the National Renewable Energy Laboratory (NREL) 50-meter height state-level shapefile. These data provide an estimate of annual average wind resource for specific states or regions. Data was not available for Florida or Alabama, so all calculations apply to only the extent of the Ecological System outside of those states. More information on the data, its origins and limitations can be found here:

http://www.nrel.gov/gis/data_wind.html

We assessed the percent of area for each of the NREL wind resource categories (0 – Unassessed, 1 – Poor, 2 – Marginal, 3 – Fair, 4 – Good, 5 – Excellent, 6 – Outstanding, 7 – Superb) by Ecological System. The data were summarized to the percent of area mapped of each Ecological System classified for wind resource as 3 - Fair or above (including 4 – Good, 5 - Excellent and 6 – Outstanding). Wind class 3 – Fair and above are suitable for most utility-scale wind turbine projects.

Other Threats Considerations

There are eleven level 1 threats in the Conservation Measures Partnership threats classification (Salafsky et al. 2008), and several more specific level 2 threats nested under each level 1 threat. The threats classification is designed to be comprehensive, but some of the threats are correlated with each other or influence each other. There are some threats related to urbanization which are correlated with each other. For instance, the level 2 threats Roads and railroads (4.1) and in some cases Invasive non-native/alien species (8.1) are often associated with Residential and commercial development (1) a level 1 threat (Surrette & Brewer 2008). These threats are all associated with the regional spatial analysis we did for urbanization. Another level 2 threat that needs clarification for the South Atlantic LCC region is Fire & fire suppression (7.1). In the South Atlantic LCC area, this threat nearly always refers to the lack of fire in Ecological Systems which had frequent fire as part of a historic, natural or reference fire regime (Barrett et al. 2010). The lack of fire, and the Fire & fire suppression (7.1) threat is also associated with urbanization, the level 2 threat Roads and railroads (4.1), and the level 1 threat Residential and

commercial development (1). Outside of urban areas, high traffic roads can constrain prescribed fire activities, due to smoke related safety concerns. Smoke related issues with wildland fire may also increase in the future, especially with more urbanization within the South Atlantic LCC area. The Air-Borne Pollutants (9.5) threat was not often listed, but when metropolitan areas are declared non-attainment areas under the federal Clean Air Act, restrictions on the use of prescribed fire as a land management tool often follow. Some of the relationships between threats are referred to in the comments field in the threats data. Since Fire & fire suppression (7.1) and Housing & urban areas (1.1) are the two threats which are most often listed as having a high or very high threat impact to Ecological Systems in the South Atlantic LCC, it is worthwhile to give these threats special consideration in conservation planning. In coastal areas, there are also a set of correlated threats. These include the level 1 threats Residential and commercial development (1), Transportation & service corridors (4), Natural system modifications (4), and Climate change & severe weather (11). The threat from Climate change & severe weather (11) and related sea-level rise to low elevation coastal Ecological Systems is increased due to coastal development patterns and coastal engineering such as beach armoring, seawalls, jetties and other structures which interfere with sand movement and natural shoreline migration (Defeo et al. 2009).

Results

Ecological Systems

We developed threats data for 72 Ecological Systems of the South Atlantic LCC area, using NatureServe's Ecological Systems classification (Comer et al. 2003) and the standard threats classification of the Conservation Measures Partnership (Salafsky et al. 2008) and followed the established methods of NatureServe's Global Status Assessment Methodology and Rank Factors (Faber-Langendoen et al. 2012, Master et al. 2012).

The threats data has been put into NatureServe's Biotics 5 enterprise database and a project database, which is also included as an additional file for the South Atlantic LCC, in Microsoft Access (.accdb) format.

Threats

The threats data include over 1200 instances of Ecological System and standard threat combinations. We describe the most highly threatened Ecological Systems, and their threats. We also provide separate standalone reports for each of the 14 most highly threatened Ecological Systems, in Microsoft Word (.docx) format. Furthermore, we elaborate on the most significant threats across all the South Atlantic LCC Ecological Systems. Invasive exotic species threaten many Ecological Systems, and we provide additional information and analysis pertaining to the prevalent invasive exotic species which threaten the South Atlantic LCC Ecological Systems.

Most significant threats to the 14 most highly threatened project area Ecological Systems

Based on an analysis by NatureServe, 14 of the 72 Ecological Systems which occur in the South Atlantic LCC area are highly or very highly threatened (table 5). Of these 14, six are coastal plain systems dominated by Longleaf Pine (*Pinus palustris*) or other fire-dependent pine species. This includes both three dry upland (including sandhills) and three mesic to wetland (flatwoods and savanna) Ecological Systems.

Table 5 - Ecological Systems in the South Atlantic LCC area with the highest overall threat impact

Scientific Name	Element ID	Elcode	Overall Threat Impact	Calculated Overall Threat Impact
East Gulf Coastal Plain Maritime Forest	723085	CES203.503	Very High	Very High
East Gulf Coastal Plain Savanna and Wet Prairie	723248	CES203.192	Very High	Very High
Southeastern Coastal Plain Interdunal Wetland	723228	CES203.258	Very High	Very High
Southern Atlantic Coastal Plain Maritime Forest	723065	CES203.537	Very High	Very High
Southern Coastal Plain Blackland Prairie and Woodland	723108	CES203.478	Very High	Very High
Southern Coastal Plain Dry Upland Hardwood Forest	723044	CES203.560	Very High	Very High
Southern Piedmont Dry Oak-(Pine) Forest	723166	CES202.339	Very High	Very High
Southern Piedmont Glade and Barrens	723175	CES202.328	Very High	Very High
Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland	723231	CES203.254	Very High to High	Very High to High

Central Atlantic Coastal Plain Wet Longleaf Pine Savanna and Flatwoods	723221	CES203.265	Very High to High	Very High to High
East Gulf Coastal Plain Interior Upland Longleaf Pine Woodland	723090	CES203.496	Very High to High	Very High to High
East Gulf Coastal Plain Near-Coast Pine Flatwoods	723141	CES203.375	Very High to High	Very High to High
Florida Longleaf Pine Sandhill	723204	CES203.284	Very High to High	Very High to High
Southern Atlantic Coastal Plain Xeric River Dune	723089	CES203.497	Very High to High	Very High to High

In addition, also included in the 14 are maritime forests (two), prairies and glades (two), upland hardwood and mixed forests (two), one interdunal wetland and one "xeric river dune".

In terms of the collective threats to these 14 most highly threatened Ecological Systems, the top ten applied to Ecological Systems (at any rating) are housing and urban areas (used 14 times), invasive non-native/alien species (14), commercial and industrial areas (12), roads and railroads (12), and fire and fire suppression (11). The next five are wood and pulp plantations (8), tourism and recreation areas (8), logging and wood harvesting (8), livestock farming and ranching (7), and dams and water management/use (6).

Table 6 - Most common threats to the 14 most threatened South Atlantic LCC area ecological systems

Threat No.	Level two Threat Description	Number of the 14 Highly Threatened Systems impacted	Percent of the 14 Highly Threatened Systems impacted
1.1	Housing & urban areas	14	100.0%
8.1	Invasive non-native/alien species	14	100.0%
1.2	Commercial & industrial areas	12	85.7%
4.1	Roads & railroads	12	85.7%
7.1	Fire & fire suppression	11	78.6%
2.2	Wood & pulp plantations	9	64.3%
1.3	Tourism & recreation areas	8	57.1%
5.3	Logging & wood harvesting	8	57.1%
2.3	Livestock farming & ranching	7	50.0%
7.2	Dams & water management/use	6	42.9%

Among all of the 159 threat-system combinations for the 14 most highly threatened systems, there are 25 instances in which threats are rated as having a very high or high impact. Among these 25 combinations, fire and fire suppression is listed nine times; housing and urban areas five times; problematic native species three times; commercial and industrial areas, other ecosystem modifications, invasive non-native/alien species two times each; and annual and perennial non-timber crops and habitat shifting and alteration one time each.

Table 7 - Threats rated high or very high for the 14 Ecological Systems

Threat No.	Threat Description	Times with high impact
7.1	Fire & fire suppression	9

1.1	Housing & urban areas	5
8.2	Problematic native species	3
1.2	Commercial & industrial areas	2
7.3	Other ecosystem modifications	2
8.1	Invasive non-native/alien species	2
2.1	Annual & perennial non-timber crops	1
11.1	Habitat shifting & alteration	1
	Total	**25**

Most significant threats across all project area Ecological Systems

It is also useful to look at the most significant threats to all of the 72 systems evaluated for the South Atlantic LCC project area.

Table 8 - Most significant level two threats (very high or high in one or more cases) for all 72 systems

Threat No.	Level two Threat Description	Number of all 72 Systems impacted	Percent of all 72 Systems impacted
8.1	Invasive non-native/alien species	72	100.0%
1.1	Housing & urban areas	56	77.8%
2.2	Wood & pulp plantations	49	68.1%
7.2	Dams & water management/use	47	65.3%
5.3	Logging & wood harvesting	45	62.5%
7.1	Fire & fire suppression	35	48.6%
1.2	Commercial & industrial areas	33	45.8%
9.3	Agricultural & forestry effluents	22	30.6%
11.1	Habitat shifting & alteration	21	29.2%
8.2	Problematic native species	20	27.8%
7.3	Other ecosystem modifications	20	27.8%
2.1	Annual & perennial non-timber crops	18	25.0%

When all 763 level 2 threat-system combinations for all 72 Ecological Systems are analyzed, only 36 are rated as very high or high. Among these 36 combinations, fire and fire suppression is used 14 times; housing and urban areas five times; problematic native species four times; commercial and industrial areas, other ecosystem modifications, invasive non-native/alien species, and habitat shifting and alteration two times each; and annual and perennial non-timber crops, wood and pulp plantations, logging and wood harvesting, dams and water management use, and agriculture and forestry effluents one time each.

Table 9 - Threats rated high or very high for all 72 Ecological Systems

Threat No.	Threat Description	Times with high impact
7.1	Fire & fire suppression	14
1.1	Housing & urban areas	5
8.2	Problematic native species	4
1.2	Commercial & industrial areas	2
7.3	Other ecosystem modifications	2
8.1	Invasive non-native/alien species	2
11.1	Habitat shifting & alteration	2
2.1	Annual & perennial non-timber crops	1
2.2	Wood & pulp plantations	1
5.3	Logging & wood harvesting	1
7.2	Dams & water management/use	1
9.3	Agricultural & forestry effluents	1
	Total	**25**

Table 10 - All threats: total number of times used; numbers of times used at each level; factor; and 'threat rank'

Threat No.	Threat Description	# times used	Very High # (A)	High # (B/BC)	Medium # (C/CD)	Low # (D)	Negligible etc. # (X)	factor	threat rank
1	Residential & commercial development	58	0	7	21	26	4	1.50	CD
1.1	Housing & urban areas	55	0	5	19	27	4	1.43	CD
1.2	Commercial & industrial areas	32	0	2	7	19	4	1.20	D
1.3	Tourism & recreation areas	35	0	0	7	24	4	1.07	D
2	Agriculture & aquaculture	50	0	2	10	38	0	1.21	D
2.1	Annual & perennial non-timber crops	18	0	1	1	13	3	1.00	D
2.2	Wood & pulp plantations	46	0	1	10	35	0	1.18	D
2.3	Livestock farming & ranching	17	0	0	0	17	0	1.00	D
2.4	Marine & freshwater aquaculture	3	0	0	0	2	1	0.67	DE
3	Energy production & mining	24	0	0	2	14	8	0.73	DE
3.1	Oil & gas drilling	15	0	0	1	8	6	0.63	DE
3.2	Mining & quarrying	10	0	0	1	6	3	0.80	D
3.3	Renewable energy	2	0	0	0	1	1	0.50	DE
4	Transportation & service corridors	45	0	0	3	38	4	0.96	D
4.1	Roads & railroads	41	0	0	3	35	3	0.98	D

4.2	Utility & service lines	15	0	0	0	10	5	0.67	DE
4.3	Shipping lanes	9	0	0	0	9	0	1.00	D
4.4	Flight paths	1	0	0	0	0	1	0.00	E
5	Biological resource use	52	0	1	8	41	2	1.09	D
5.1	Hunting & collecting terrestrial animals	12	0	0	3	3	6	0.63	DE
5.2	Gathering terrestrial plants	5	0	0	0	5	0	1.00	D
5.3	Logging & wood harvesting	42	0	1	10	29	2	1.17	D
5.4	Fishing & harvesting aquatic resources	11	0	0	0	10	1	0.91	D
6	Human intrusions & disturbance	32	0	0	3	25	4	0.95	D
6.1	Recreational activities	30	0	0	3	25	2	1.02	D
6.2	War, civil unrest & military exercises	2	0	0	0	0	2	0.00	E
6.3	Work & other activities	1	0	0	0	1	0	1.00	D
7	Natural system modifications	66	2	16	16	26	6	1.70	CD
7.1	Fire & fire suppression	33	2	12	7	8	4	1.98	C
7.2	Dams & water management/use	45	0	1	9	29	6	1.10	D
7.3	Other ecosystem modifications	19	0	2	5	8	4	1.26	CD
8	Invasive & other problematic species & genes	71	1	2	18	50	0	1.65	CD
8.1	Invasive non-native/alien species	70	0	2	15	53	0	1.23	D
8.2	Problematic Native Species	20	2	2	2	13	1	1.55	CD
9	Pollution	41	0	1	2	38	0	1.09	D
9.1	Household sewage & urban waste water	27	0	0	3	23	1	1.07	D
9.2	Industrial & military effluents	8	0	0	0	8	0	1.13	D
9.3	Agricultural & forestry effluents	21	0	1	0	20	0	1.10	E
9.4	Garbage & solid waste	14	0	0	0	14	0	1.00	D
9.5	Air-borne pollutants	2	0	0	0	1	1	0.50	DE
11	Climate change & severe weather	47	0	2	9	15	21	0.83	D
11.1	Habitat shifting & alteration	21	0	2	9	8	2	1.50	CD
11.2	Droughts	17	0	0	0	1	16	0.06	E
11.3	Temperature extremes	11	0	0	0	4	7	0.36	DE
11.4	Storms & flooding	26	0	0	0	13	13	0.50	DE

All threats: total number of times used; numbers of times used at each level (very high, etc,); factor (point system of how high for each system divided by the number of times used; and 'threat rank' (how highly the threat is ranked, overall across all systems)

Certain threats were never listed for South Atlantic LCC area Ecological Systems. These include the level 1 threat Geological Events (10) and all level 2 threats under Geological Events (10). These are Volcanoes (10.1), Earthquakes/Tsunamis (10.2), and Avalanches/Landslides (10.2). These threats are associated with geologically active regions, and are not issues in the southeastern Piedmont and Atlantic Coastal Plain areas. The Excess Energy (9.6) threat is defined as "inputs of heat, sound, or light that disturb

wildlife or ecosystems" (Salafsky et al. 2008). Introduced Genetic Material is defined as "human-altered or transported organisms or genes" (Salafsky et al. 2008). Both of these threats may be present in the South Atlantic LCC area, but currently we have found no evidence that they are significant threats to any of the South Atlantic LCC area Ecological Systems. As genetically modified crops and organisms become more prevalent in commercial lands, this may quickly change.

Table 11 - Level two threats not assigned to any ecological systems of the South Atlantic LCC area

Threat Number	Threat Description
8.3	Introduced Genetic Material
9.6	Excess Energy
10.1	Volcanoes
10.2	Earthquakes/Tsunamis
10.3	Avalanches/Landslides

Invasive exotic species mentioned as threats

Exotic species were listed as high or moderate level threats in 147 cases. The species mentioned in the comments were ranked as to their frequency of inclusion (table 12).

Table 12 - Exotic species mentioned in comments; for all systems for which exotic species are of high or moderate threat

species name	common name	plant/animal	# of times mentioned	% of times mentioned out of all threats
Sus scrofa	Wild Boar	animal	103	70%
Triadica sebifera	Chinese Tallow	plant	35	24%
Ligustrum sp.	Privet	plant	24	16%
Lonicera japonica	Japanese Honeysuckle	plant	22	15%
Imperata cylindrica	Cogongrass	plant	20	14%
Phragmites australis	Common Reed	plant	19	13%
Lespedeza cuneata	Chinese Bushclover	plant	16	11%
Felis domestica	Domestic Cat	animal	15	10%
Solenopsis invicta	Fire Ant	animal	15	10%
Lygodium sp.	Climbing Fern	plant	14	10%
Myocastor coypus	Nutria	animal	14	10%
Canis latrans	Coyote	animal	13	9%
Lespedeza bicolor	Shrub Lespedeza	plant	10	7%
Vitex rotundifolia	Roundleaf Chastetree	plant	9	6%
Microstegium vimineum	Nepalese Browntop	plant	8	5%
Ailanthus altissima	Tree-of-Heaven	plant	6	4%
Casuarina equisetifolia	Beach She-oak	plant	6	4%
Hydrilla verticillata	Water-thyme	plant	6	4%

Panicum repens	Torpedo Grass	plant	6	4%
Albizia julibrissin	Silktree	plant	4	3%
Elaeagnus umbellata	Autumn-olive	plant	4	3%
Lonicera spp. [shrubs]	Honeysuckle	plant	4	3%
Melia azedarach	Chinaberrytree	plant	4	3%
Urena lobata	Caesarweed	plant	4	3%
Celastrus orbiculatus	Asian Bittersweet	plant	3	2%
Arthraxon hispidus	Small Carpgrass	plant	2	1%
Centaurea sp.	Knapweed	plant	2	1%
Lantana camara	Hedgeflower	plant	2	1%
Melinis repens	Rose Natal Grass	plant	2	1%
Paulownia tomentosa	Princess-tree	plant	2	1%
Pinus thunbergiana	Japanese Black Pine	plant	2	1%
Rosa rugosa	Rugosa Rose	plant	2	1%
Alliaria petiolata	Garlic Mustard	plant	1	1%
Hedera helix	English Ivy	plant	1	1%
Canis familiaris	Domestic Dog	animal	0	0%

These results are not definitive, because particular species were not always listed in the comments, and the listings were not necessarily exhaustive. In addition, the effects of some exotic species on ecological communities are better documented than are others. These data do provide some indication of the relative impact of these species on the region's vulnerable ecological communities.

Feral hogs (*Sus scrofa*) are present across the landscape of the southeastern United States, particularly on public lands, where their proliferation is virtually unchecked. They are often intentionally released or spread by hunters, in a misguided attempt to increase game animals. Their impacts are particularly felt in diverse Longleaf Pine forests, seepage wetlands and in floodplain forests, and their density and range are increasing in the southeastern United States (Bevins et al. 2014).

The plant listed as a threat most frequently is Cogongrass (*Imperata cylindrica*), which threatens Longleaf Pine forests regionwide. Its notorious flammability, even when green, means that its presence can alter fire regimes in these systems, thereby negatively impacting biodiversity and stand structure in these ecosystems. It is difficult to control and eradicate.

Regional Spatial Analysis

We completed regional spatial analyses to spatially quantify certain threats to the Ecological Systems mapped in the South Atlantic LCC area. The threats which were examined through spatial analysis represent a small selection of the threats, and the available spatial data related to these threats in the South Atlantic LCC area. We compiled and summarized the results data from the regional spatial analyses in separate worksheets in a spreadsheet in Microsoft Excel Workbook (.xlsx) file format.

SALCC Threats - Tabular Results.xlsx

We intersected a list of the Ecological Systems with the total mapped area for the South Atlantic LCC (based on v3.0 of the NatureServe National Map of Ecological Systems), with spatial data for the threats (detailed previously. Results in the Summary worksheet are percent of areas of each Ecological System in the South Atlantic LCC area, in the various categories (columns) pertaining to these five major threat related categories. We caution users to consider that these are modeled datasets, so their application to small patch Ecological Systems may be less valid due to "error amplification".

Fire Regime Condition Class

This is the only analysis not based on the Ecological Systems distributions as mapped in v3.0 of NatureServe's National Map of Ecological Systems. Landfire Existing Vegetation Type (EVT) is the source data for the Ecological Systems distributions, and Landfire FRCC is the source for fire condition of the land. If Ecological Systems were not mapped by Landfire as EVT within in the South Atlantic LCC footprint, there will not be information for the FRCC variables. In the Summary worksheet, the percent of the areas of Ecological Systems within the South Atlantic LCC footprint which are in the FRCC 1 (Low Departure), FRCC 2 (Moderate Departure), and FRCC 3 (High Departure) are provided in three columns (F, G and H). Many of the wetland Ecological Systems were mapped as broad aggregate wetland map units by Landfire. For these wetland Ecological Systems, be aware that the Threats Results table reports the percentages calculated for the aggregate as a whole, not for the extent of just that Ecological System. All Ecological Systems where the results are reported for the aggregate are indicated with a footnote after the Ecological System name in that table. Southeastern Interior Longleaf Pine Woodland is an example of an Ecological System which has a very high amount of its mapped area in the South Atlantic LCC region mapped as FRCC 3 – High Departure from historic or reference conditions. Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland is an example of an Ecological System which has a very high amount of its mapped area in the South Atlantic LCC region mapped as FRCC 2 – Moderate Departure from historic or reference conditions.

Urbanization

The regional spatial analysis showed that Central Atlantic Coastal Plain Maritime Forest is an Ecological System within the South Atlantic LCC area which has very high percent loss (by year 2010) and threat of future loss (by 2050) of percent area from urbanization. The most extensive Ecological System which is threatened by urbanization is the Southern Piedmont Dry Oak-(Pine) Forest, which is a forest type found in rapidly urbanizing areas of the Piedmont of the Carolinas and Georgia. While today it is mapped on 46,505 square kilometers, it is threatened with 21% to 26% loss from urbanization by 2050. This equates to a loss of about 10,000 square kilometers of Southern Piedmont Dry Oak-(Pine) Forest to urbanization by the year 2050.

Ecological Systems within Protected Areas

Ecological Systems which occur on more than 1,000 square kilometers and have the highest amount of their area within the South Atlantic LCC on protected lands at the inclusive level (Gap Analysis Program levels 1, 2 and 3) are East Gulf Coastal Plain Near-Coast Pine Flatwoods (58.3%), Southern Coastal Plain Nonriverine Basin Swamp (52.4%), Atlantic Coastal Plain Peatland Pocosin and Canebrake (32.9%), Southern Atlantic Coastal Plain Salt and Brackish Tidal Marsh (32.6%), Southern Coastal Plain

Nonriverine Cypress Dome (27.3%), Southern Coastal Plain Blackwater River Floodplain Forest (25.2%), Southern Atlantic Coastal Plain Nonriverine Swamp and Wet Hardwood Forest (23.0%), Southern Atlantic Coastal Plain Maritime Forest (20%), and Atlantic Coastal Plain Small Brownwater River Floodplain Forest (18.2%). In contrast to these highly protected Ecological Systems which are mostly wetlands, the least protected Ecological Systems are mostly upland forests (Table 13).

Table 13 - Least Protected Ecological Systems (of those mapped on > 1,000 km2 in the SALCC area)

Least Protected Ecological Systems	Area Mapped in SALCC (km^2)	Percent Protected Inclusive (GAP 1, 2, and 3)
Southern Piedmont Mesic Forest	5,760	3.4%
Southern Piedmont Dry Oak-(Pine) Forest	46,505	3.3%
Southern Piedmont Small Floodplain and Riparian Forest	3,806	3.8%
Southern Atlantic Coastal Plain Mesic Hardwood Forest	1,562	1.6%
Southern Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest	9,704	2.4%
Atlantic Coastal Plain Blackwater Stream Floodplain Forest	6,924	3.9%

Some rare Ecological Systems (those mapped only in small areas of the South Atlantic LCC) which have very low percentages on protected lands in the South Atlantic LCC area include Southern Coastal Plain Herbaceous Seep and Bog and Southern Atlantic Coastal Plain Xeric River Dune.

Assessed Oil and Gas Resources

Ecological Systems which occur in both the assessed and unassessed Mesozoic basins and have most of their mapped area within the South Atlantic LCC also occurring in these hydrocarbon basins were dominated by coastal Ecological Systems, especially Southern Atlantic Coastal Plain Salt and Brackish Tidal Marsh (Table 14).

Table 14 - Ecological Systems with high percent of their areas within hydrocarbon basins

Ecological System	Area Mapped in SALCC (Sq. KM)	Amount in Gas Basins
Southern Atlantic Coastal Plain Xeric River Dune	207	82.6%
Southern Atlantic Coastal Plain Wet Pine Savanna and Flatwoods	787	60.3%
Southern Atlantic Coastal Plain Sea Island Beach	33	76.0%
Southern Atlantic Coastal Plain Salt and Brackish Tidal Marsh	2,717	70.8%
Southern Atlantic Coastal Plain Maritime Forest	1,233	69.2%
Southern Atlantic Coastal Plain Fresh and Oligohaline Tidal Marsh	635	57.1%

Within the Dan River Basin, which has moderate potential for natural gas resource development, the following Ecological Systems have mapped areas that overlap the most with that basin; Piedmont Upland Depression Swamp, and Southern Piedmont Large Floodplain Forest. According to this spatial

analysis, within the Dan River basin, these forested wetlands could be threatened by natural gas resource development.

Within the hydrocarbon basins which have high potential for natural gas resource development (the Deep River basin and Taylorville basin), the following Ecological Systems have mapped areas that overlap the most with the extent of these two hydrocarbon basins, Southern Piedmont Large Floodplain Forest, Southern Piedmont Small Floodplain and Riparian Forest, Atlantic Coastal Plain Fall-line Sandhills Longleaf Pine Woodland, and Atlantic Coastal Plain Streamhead Seepage Swamp, Pocosin and Baygall.

Wind Resources

Coastal areas have many Ecological Systems which have their mapped areas highly overlapping with areas of fair or better wind resource potential. There is coastal wind resource potential within the South Atlantic LCC area, but it is not rated as excellent or outstanding by the National Renewable Energy Laboratory (NREL). The only Ecological Systems which are significantly overlapping with wind resource areas rated as excellent or outstanding by the National Renewable Energy Laboratory (NREL) are those which are peripheral to the South Atlantic LCC area, and more typically occur in the Appalachian Mountains region, these are Central and Southern Appalachian Montane Oak Forest, and Southern Appalachian Montane Cliff and Talus, which are mapped on less than 1 km^2 within the South Atlantic LCC area.

Table 15 - Ecological Systems with high percent of area with wind resource potential

Ecological System	Area Mapped in SALCC (km^2)	Percent of Area with Fair or better Wind Resource Potential
Southern Atlantic Coastal Plain Dune and Maritime Grassland	81	75.77%
Central Atlantic Coastal Plain Sandy Beach	1	50.71%
Atlantic Coastal Plain Embayed Region Tidal Salt and Brackish Marsh	439	48.20%
Northern Atlantic Coastal Plain Dune and Swale	10	35.22%
Southern Atlantic Coastal Plain Sea Island Beach	33	21.55%
Northern Atlantic Coastal Plain Tidal Salt Marsh	121	19.55%
Northern Atlantic Coastal Plain Tidal Swamp	29	19.21%
Southern Atlantic Coastal Plain Florida Beach	15	17.98%
Northern Atlantic Coastal Plain Maritime Forest	16	13.87%
Central Atlantic Coastal Plain Maritime Forest	128	11.88%

Discussion

One of the 14 most highly threatened Ecological Systems was also considered to be the least protected according to our analysis. This Ecological System, the Southern Piedmont Dry-Oak (Pine) Forest, has both a high level of threats (including development pressure), and a very low percentage of its acreage in conserved lands. As a result, it may be important to further research this Ecological System and determine whether there are pathways to address key threats (such as urbanization) by increasing the amount of protected examples.

In thinking about next steps for work on threats, we fell it will be important to continue to examine the potential effects of development of wind resources and oil/gas resources in the South Atlantic LCC. As can be seen above, some Ecological Systems fall primarily within the footprints of areas most likely to be considered for energy development. For the long term conservation of these Ecological Systems, special conservation and mitigation efforts may be needed in areas where energy development occurs.

The Ecological Systems of the South Atlantic LCC area provide a natural legacy which harbors incredible biological diversity, beauty, outdoor recreational opportunities, natural resources, and ecosystem services. We hope that documentation and knowledge of the threats to each of these Ecological Systems can serve to better inform land managers, planners and decision makers.

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