United States Department of Agriculture
Forest Service

Francis Marion National Forest

Draft Forest Plan Assessment

Francis Marion National Forest, Berkeley and Charleston Counties, South Carolina

2.1 Terrestrial Ecosystems, Aquatic Ecosystems, and Watersheds

December 2013

Francis Marion National Forest
Draft Forest Plan Assessment
Berkeley and Charleston Counties, South Carolina

Lead Agency:	**USDA Forest Service**
Responsible Official:	**John Richard Lint, Forest Supervisor** **Francis Marion and Sumter National Forests**
For Information Contact:	**Mary Morrison, Forest Planner** **4931 Broad River Road** **Columbia, SC 29212** **803-561-4000**
Email Comments or Questions to:	**fmplanrevision@fs.fed.us**
Documents are Posted at:	**http://www.fs.usda.gov/scnfs**

Table of Contents

2 Assessing the Ecological Sustainability and Diversity of Plant and Animal Communities

2.1 Terrestrial Ecosystems, Aquatic Ecosystems, and Watersheds

2.1.1 Terrestrial Ecosystems

2.1.1.1 Summary of Key Findings

Longleaf Pine Ecosystems

▶**Ecological classification and modeling conducted in 2013 predicts that longleaf pine-dominated ecosystems once occurred on 56 percent of our Forest (144,492 acres), including 21 percent (53,857 acres) as upland longleaf woodlands and 35 percent (90,735 acres) as wet pine savannas and flatwoods.** Although we have met our short-term objective in the 1996 revised Forest plan for longleaf pine-dominated forests (44,700 acres), we have not met our long-term objective (53,500 acres). In the 1996 revised Forest plan, the Forest Service estimated the range of longleaf pine at between 37,000 and 75,000 acres, and contained a goal for longleaf expansion of 21 percent. Based on dominant forest types in the Forest Service vegetation database in 2013, 49,102 acres are dominated by longleaf pine or mixtures with loblolly pine (19 percent of the Forest).

▶**Lack of frequent (1 to 3 year) prescribed fire is the primary threat to longleaf-associated ecosystems and at-risk species on the Forest, and throughout the range of longleaf pine, particularly at the wildland urban interface.** Between 2005 and 2012, 36 percent of our Upland Longleaf and 15 percent of our Wet Pine Savanna ecosystems were prescribed burned at a frequency consistent with the ecological role of fire (at least 3 times during that time frame, or a 2.7-year frequency). Between 2005 and 2012, we prescribed burned 80,397 acres on at least a 3-year frequency (31 percent of our forested acres). Monitoring data collected with species and ecosystem experts in 2012 and 2013 suggest that designated botanical areas and rare plant species populations have declined since 1996 due to lack of frequent prescribed fire; those in greatest decline occur at the wildland urban interfaces.

▶**Open park-like savanna and woodland conditions, including two-tiered or uneven-aged canopy structures and diverse herbaceous understories, are key ecosystem characteristics of Longleaf Pine Ecosystems.** Overly dense canopies of loblolly pine and successional woody and shrub vegetation, which both shade out the understory and draw down the water table, threaten several high quality wet pine savannas, native ecosystems, and at-risk species on the Forest. The 1996 Forest plan did not contain objectives for maintaining savanna or woodland structural classes, nor herbaceous understory conditions. Both Natureserve (2012) and the Longleaf Partnership Council (2013) describe longleaf pine canopy structure as two tiered or uneven-aged, with longleaf pine basal area of 40 to 70 square feet (25 to 60 percent cover) and a lower range down to 10 square feet (5 to 25 percent cover) for wet savanna communities. Methods for managing timber in the 1996 Forest plan were even-aged, particularly within 0.5 mile of red-cockaded woodpecker clusters and on soils classified as very poorly, or poorly drained due to operational constraints. Thirty-four percent of our longleaf ecosystems have open canopies (woodland, savanna, or grassland) based on analysis of LiDAR data.

►**Several studies of longleaf pine-associated vegetation have concluded that Longleaf Pine Woodlands and Savannas are among the most species rich ecosystems in North America, and they are also among the most endangered.** Rangewide threats to longleaf ecosystems, based on America's Longleaf Conservation Plan (2009), are fragmentation, unsustainable harvest, conversion to other land uses and vegetation types, invasive species, and exclusion of natural fire regimes. Other threats on the Forest include displacement and rutting of soil, lack of frequent prescribed fire, overly dense canopy cover, and an over-abundance of woody hardwood or shrub successional vegetation.

►**Based on the longleaf assessment conducted in 2010 with the South Carolina Nature Conservancy, the majority (53 percent) of our existing and restorable longleaf pine ecosystems (47,086 acres) are in the "restore all condition class."**

►**Ecological departure matrices (Low et al. 2010) used to compare forest structural data derived from GIS and LiDAR with LANDFIRE biophysical settings models, suggests that landscapes on the Francis Marion deviate moderately from reference conditions in regard to structure, and the National Forest has relatively low levels of late-successional open conditions.**

►**Loblolly pine or loblolly pine/hardwood forests currently occupy 104,376 acres including 25,673 acres on upland longleaf sites, 50,760 acres on wet pine savanna sites, and 23,310 acres on nonriverine swamp sites.** Both longleaf pine and fire were discouraged by turn-of-the-century forest management practices. According to historic records, the percentage of loblolly pine-dominated forest has increased by upwards of 16 percent since the Forest was acquired in 1936. Natural community and ecosystem descriptions by State heritage programs and by Natureserve suggest that loblolly pine was most common as a component of bottomland hardwood and nonriverine swamp forest ecosystems historically.

►**Possible old growth forests, dominated by longleaf pine or mixtures (>100 years and those on unsuitable lands) increased from 3,583 acres in 1996 to 3,668 acres in 2013 (which represents 2.5 percent of the total acres predicted for the two ecosystems combined in 2013).** Possible old growth forest addressed in the 1996 FEIS included 527 acres older than 100 years in age, and 3,141 acres on lands unsuitable for timber production. In 2013 the acreage in possible old growth longleaf using even-aged age criteria alone from FSVEG (≥100 years in age, or ≤ age year 1913), includes 3,668 acres and remains at 1.4 percent of the total potential longleaf acreage (upland and wet pine savanna and flatwoods ecosystems combined). The analysis of old growth conditions in both 1996 and in 2013, does not consider old growth condition, nor the distribution of possible old growth among small, medium, or large patches sizes.

►**Management area 26 does not reflect our landscapes most suited for maintaining and restoring longleaf ecosystems.** In the 1996 Forest plan, the Forest emphasized longleaf pine ecosystem restoration in management area 26 (sandy ridges and sideslopes) and contained a standard to prescribed burn this management area on a 2- to 3-year rotation. Although the majority of our upland longleaf ecosystems occur in in this management area, the majority of our wet pine savannas occur in management area 28 (flatwoods and loamy ridges), where loblolly pine forests were emphasized. Because of smoke management concerns in the wildland-urban interface less than half (34 percent) of management area 26 has been burned on at least a 3-year rotation (from 2005 to 2012).

▶**Nonnative invasive species have increased to threaten all ecological systems on the Forest, and were not addressed in the 1996 Revised Plan.** Several nonnative invasive species threaten Longleaf Pine Ecosystems, most notably cogongrass, Japanese climbing fern, and feral hogs. On the Francis Marion, 32 nonnative invasive plants have been documented and since 2002, Japanese climbing fern, which has the potential to disrupt natural fire regimes, has been documented from over 3,000 occurrences. Cogongrass, a federally-listed noxious weed discovered on the Forest in 2007, remains at controllable levels (one site). Other nonnative invasive plant species, based on lists maintained by the South Carolina and Southeast Exotic Pest Plant Councils, include State aquatic nuisance species Chinese tallow and common reed (*Phragmites* spp.), Japanese honeysuckle, Chinese privet, Japanese stiltgrass, Sericea and bicolor lespedeza, tall fescue, mimosa, small carpet grass, Chinaberry, kudzu, tree-of-heaven, and Chinese wisteria. Since 2001, the Forest has selectively and chemically treated over 1,500 acres for nonnative invasive plants.

▶**Landscape connectivity is important for facilitating gene flow, mitigating effects of climate change, promoting terrestrial and aquatic lifecycles for species, and for maintaining associated fire-adapted and dependent plant and animal habitats, communities, and ecosystems.**

Hardwood Forests

▶**Upland hardwood forests (dry-mesic oak and mesic slope forests), occurred on less than 1 percent of the forest historically based on ecological modeling conducted in 2013.** The 1996 revised Forest plan contained an objective to have 20 percent of forested acres typed and managed as potential hard mast-producing hardwoods in the next 10 years, with an emphasis on management area 27. Analysis of dominant forest types using the FSVEG database in 2013 shows only 6.6 percent of our forest types typed with oak. Oak species can occur as a component of several of our native ecosystems, but are often not common enough to be detected in FSVEG as dominants or co-dominants within stands.

▶**Mesic slope forests dominated by American beech occur in portions of the Huger Creek drainage basin and in proximity to the Santee River (Everett 2012; McMillan et al. 2001; Porcher 1995).** Some of these uncommon forests associated with high calcium and limestone or phosphate deposits were recognized in the 1996 revised Forest plan as designated botanical areas, and monitoring suggests they are threatened by dense canopies of loblolly pine, prescribed fire that is too frequent or intense, nonnative invasive plant species, and feral hogs.

▶**Forested wetlands occur on 118,730 acres or 45.8 percent of the Forest, of which nonriverine swamp forests are the most abundant.** The 1996 revised plan addressed swamp forests dominated by bald cypress and swamp tupelo, “brush” vegetation, and bottomland hardwoods, without consideration of landscape position, riparian function, structure, or disturbance dynamics. Vegetation in nonriverine swamp forests, the second most abundant ecosystem on the forest, can range from a wetter group with bald or pond cypress and swamp gum, to a drier group with bottomland oak species and loblolly pine—sometimes occurring with evergreen bay and pond pine vegetation, depending on fire frequency and hydrology. More work is needed on refinements of nonriverine swamp forest vegetation and disturbance dynamics.

▶**Ecological departure rankings (Low 2010) suggest that the structure of the majority of our forested wetlands are moderately departed from reference conditions.** Small blackwater river and stream floodplain forests, and possibly nonriverine swamp forests have much fewer late-successional open forests and more late-successional closed forests compared to reference conditions. Large river floodplain forests had a much higher percentage of late-successional closed forests and fewer early-successional forests than predicted.

▶**The majority of our possible old growth (stands aged >100 years in FSVEG) in 2013 occurs as forested wetlands, including bald cypress and swamp tupelo forests (13,276 acres), bottomland hardwood forests (6,557 acres), and sweetbay-swamp tupelo-red maple or pond pine and mixtures (5,030 acres).**

Depression Ponds, Carolina Bays, Pocossins, and Seepage Slopes

▶**Many of the Carolina bays and depression ponds on the Francis Marion National Forest are imbedded within upland pine terraces (Cordesville, Pamlico, and Princess Anne Marine Terraces) where prescribed fire would have occurred frequently across the landscape.**

▶**Depression ponds and Carolina bays contain some of our highest biological diversity, specifically those dominated by pond cypress savannas and herbaceous meadow vegetation.** Studies have shown that highest levels of plant species richness occur in the non-hydric ecotone of Carolina bays and depression ponds, where they intersect with fire-maintained upland longleaf and wet pine savannas. Hydrology, prescribed fire, and landscape setting are drivers in determining vegetation dynamics (DeSteven and Harrison 2006).

▶**Many Carolina bays, depression ponds, and seepage slopes on the Francis Marion National Forest are threatened by feral hogs, successional vegetation, and lack of frequent prescribed fire, particularly at pond ecotones and sand rims; some are threatened by illegal all-terrain vehicle traffic and illegal plant collecting (Everett 2012; Glitzenstein 2012).**

Maritime Forests and Saltwater Marsh

▶Maritime forests and saltwater marsh are relatively rare but important ecosystems on the forest, and several new tracks of land containing maritime fringe and salt marsh have been acquired since 1996 "Charleywood Plantation". Ecological departure rankings suggest that our maritime forests are moderately departed structurally from reference conditions; we have higher levels of early succession and in mid-closed conditions, and lower levels of late-successional closed conditions, compared to reference conditions. Many of our maritime fringe forests are threatened by past management practices which included ditching and diking for the production of rice (Porcher 2005), planting of loblolly pine, nonnative invasive species, and hurricanes. In the future, they are the most likely to be threatened by sea-level rise and climate change.

2.1.1.2 Changing Conditions

Ecological Integrity and Ecosystem Diversity

This section of the assessment is intended to provide information to formulate plan components to maintain or restore ecological integrity and ecosystem diversity.

Ecosystem Diversity

In 2009, the Forest Service entered into a national memorandum of understanding with Natureserve to cooperate in the development and application of ecological classification and mapping standards, and in biodiversity conservation information. Several state classifications of natural vegetation are available and were consulted in development of a revised ecosystem framework and at-risk species groups including those for South Carolina (Nelson 1986), North Carolina (1990), and Georgia (Edwards et al. 2013). The Natureserve Ecological System Framework (2012) is a mid-scale ecosystem classification which is based on the International

Vegetation Classification System, and forms the basis of LANDIFRE (Landscape Fire and Resource Management Planning Tools) and Southeast Gap Analysis Project collaborative vegetation mapping tools. Natureserve's ecosystem classification is informed by previous vegetation classification efforts, and incorporates physiognomy, biogeography, and hydrology into one classification, representing the next step in ecological classification.

Geographic Information Systems (GIS) Data used in the Analysis

The following are some of the digital data sources considered in the analysis of ecological integrity of terrestrial ecosystems on the Francis Marion National Forest.

- FS VEG: The Forest Service internal 'stands' database. Stands are typically 10 acres or larger in scale; vegetation is relatively similar in condition and age, and is mapped and described in terms of dominant tree species, condition, and age; recent data on unmanaged stands is limited;
- Ecological modeling (1st approximation): LiDAR Hillshade, 5-foot Digital Elevation Terrain Models, ecological systems classified from vegetation field data, Carolina Vegetation Survey (CVS) vegetation plot data, Natural Resources Conservation Service (NRCS)-derived soils;
- Threatened, endangered, and rare species occurrence data (Forest Service internal databases, State Heritage biological conservation database);
- Invasive plant species infestations (Forest Service internal databases). These databases includes a limited number of areas that have been surveyed for invasive plants on the Forest;
- Prescribed fire history, 2005 to 2012 (Forest Service internal databases);
- Canopy cover derived from LiDAR Hillshade (Forest Service internal databases);
- Rare and natural community occurrence data, including natural areas, rare communities tracked by the South Carolina Heritage Program, and rare communities acquired through various survey efforts;
- Ecological subregions: Sections and subsections of the conterminous United States (1:3,500,000) (CD-ROM).

Ecological Classification

The national framework of ecological units developed by the USDA Forest Service in 1993 (Cleland et al. 1997) specifies the consideration of landform, soils or geology, and potential natural vegetation in the classification of ecological units and ecological potential at various scales. Those scales most relevant to forest planning are the landtype association and the landtype scale.

Ecological classification system was used in development of land allocation options for the 1996 revised Forest plan (Final Environmental Impact Statement, 1996, pages II-2-3 and appendix B) based on soil drainage and texture, landform, geology, and dominant tree species to define ecological units. Given the new information and technology available since 1996, a revised ecological classification units for the Francis Marion National Forest, at both the landtype association level (LTA), and the landtype (LT) level were developed in 2013 (Simon and Hayden 2013). This information will be referred to throughout the analysis. Landtype associations for the Francis Marion National Forest include the Cordesville, Pamlico, Princess Anne, and Talbot Marine Terraces, and the Santee River and Major Tributaries (Figure 2-1).

At the finer scale of landtype and landtype phase, Simon and Hayden (2013) modeled ecological systems and acreage using the Natureserve Ecosystem framework. Figure 2-2 shows the acreage of each ecosystem predicted based on a first draft of ecological modeling efforts and based on sampling of vegetation at over 1,000 locations (Simon and Hayden 2013). Detailed descriptions of each are available on request (Natureserve 2012), and will be referred to throughout this document. Descriptions of structure and disturbance regimes for ecological systems are addressed in the relevant biophysical setting descriptions from LANDFIRE (www.landfire.gov/).

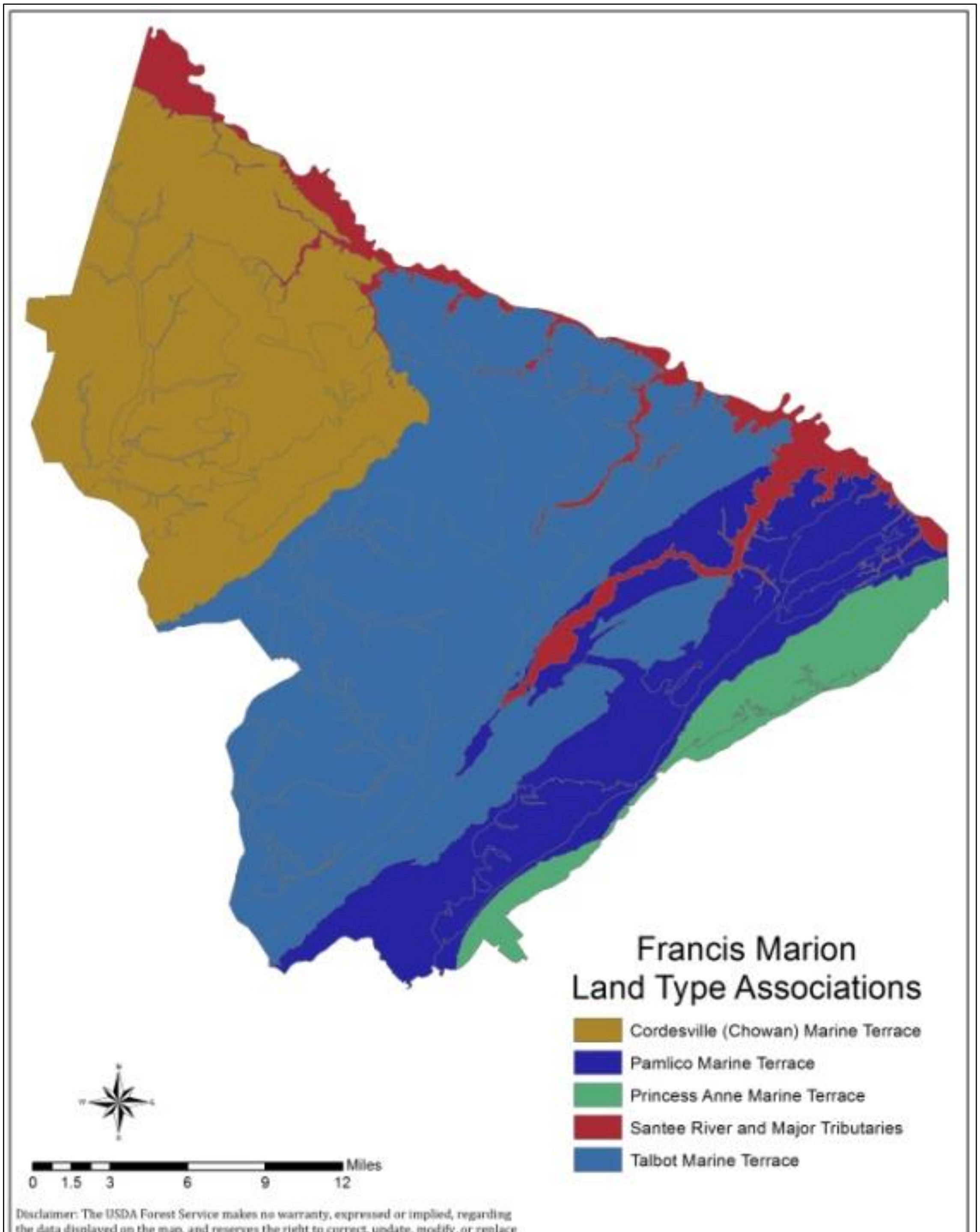

Figure 2-1. Land type associations on the Francis Marion National Forest (2013)

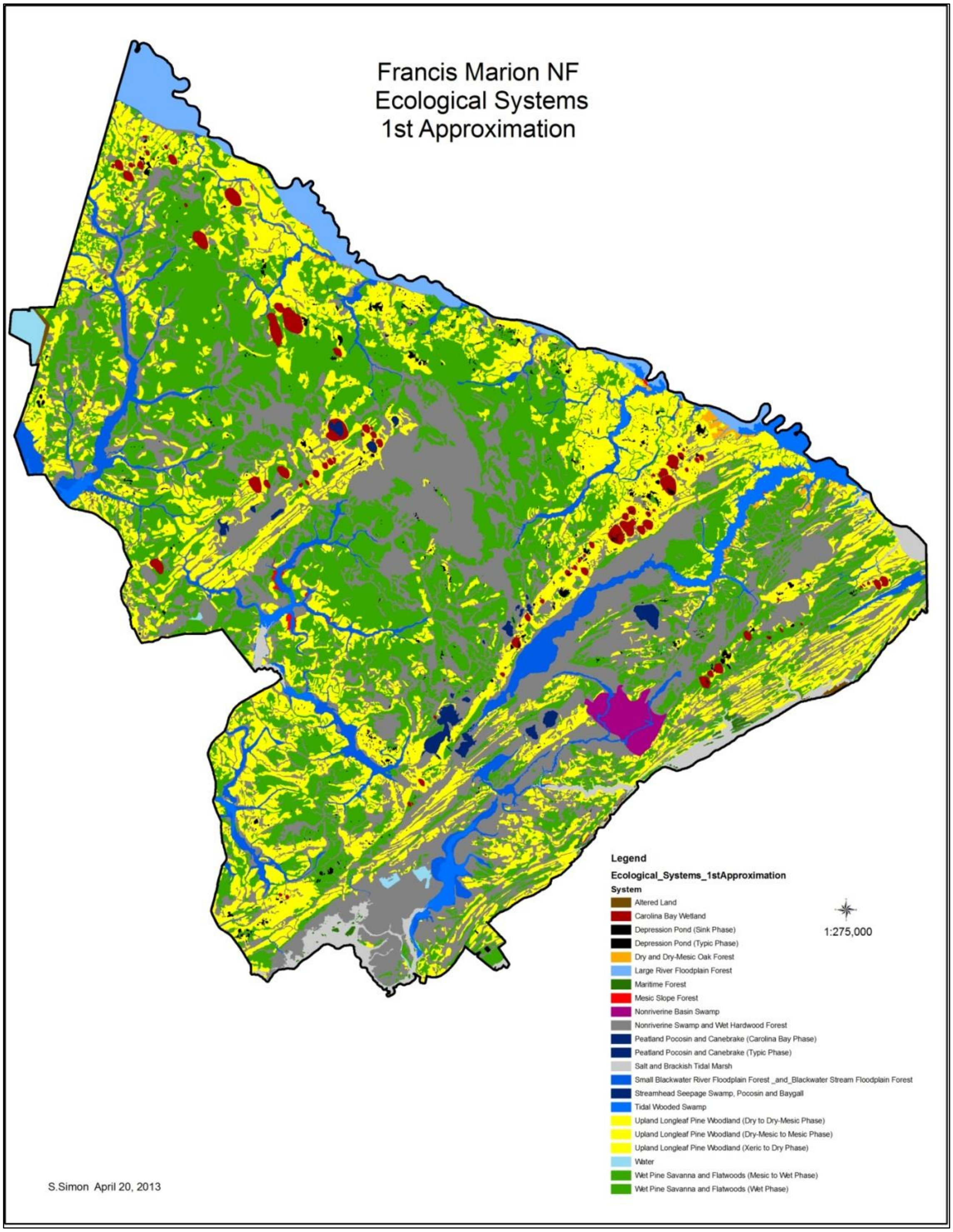

Figure 2-2. Terrestrial ecosystems within the Francis Marion proclamation boundary

Table 2-1. Terrestrial ecosystem acreage, both within proclamation and administrative boundaries

Ecological System	Acreage within Proclamation Boundary	# map units	Acreage within Administrative Boundary
Upland Longleaf Pine Woodland (total acres)	106,130		53,857
Upland Longleaf Pine Woodland (xeric_dry phase)	15,540		8,529
Upland Longleaf Pine Woodland (dry_dry-mesic phase)	20,630		7,944
Upland Longleaf Pine Woodland (dry-mesic_mesic phase)	69,960		37,384
Maritime Forest	476	82	416
Dry and Dry-Mesic Oak Forest	1,110	55	885
Mesic Slope Forest	225	21	214
Blackwater Stream Floodplain & Blackwater River Floodplain	19,100		11,374
Large River Floodplain	8,680		3,710
Tidal Wooded Swamp	7,865		5,217
Nonriverine Swamp and Wet Hardwood Forest	113,770		80,602
Peatland Pocosin and Canebrake	2,030	15	2,027
"Pocosin in Carolina Bay"	270	3	252
Streamhead Seepage Swamp, Pocosin and Baygall	75	19	76
Nonriverine Basin Swamp	2,745		2,483
Carolina Bay Wetland	4,510	83	3,264
Depression Pondshore	2,095	435	1,331
"Depression Pondshore Small Sinks"	330	923	204
Wet Pine Savanna and Flatwoods (total acres)	138,320		90,735
Wet Pine Savanna and Flatwoods (mesic_wet phase)	92,750		55,516
Wet Pine Savanna and Flatwoods (wet phase)	45,570		35,219
Fresh and Oligohaline Tidal Marsh	0		
Salt and Brackish Tidal Marsh	6,660	41	2,568
"Altered Land"	550		77
"Water"	1,650		55
Total	**416,600**		**259,345**

2.1.1.4 Information Provided by Interested Parties

To develop the first draft of ecological systems, we worked with internal Forest and regional personnel, with Natureserve representatives (Milo Pyne and Carl Nordman), and with ecological contractors Steve Simon and Larry Hayden, and met in the field on November 7–9, 2012, and again on April 10–11, 2013. The 1st approximation of the ecological systems map was released to both Forest Service and to Natureserve representatives for comment on April 24, 2013, to interested internal personnel for comment; and to the South Carolina Nature Conservancy (SCTNC). The Forest met with the Southern Research Station and the Santee Experimental Station to discuss influence and approaches for addressing hydrology within the ecological classification on February 5, 2013. Preliminary findings related to longleaf pine ecosystems were presented to the Sewee Longleaf Conservation Cooperate (June 4, 2013). The Forest Service with SCTNC and the Coastal Conservation League presented preliminary findings related to longleaf pine ecosystems at an Ecological Sustainability Forum on August 6, 2013. Interaction with species and ecosystem experts and Agency personnel is ongoing throughout the planning process.

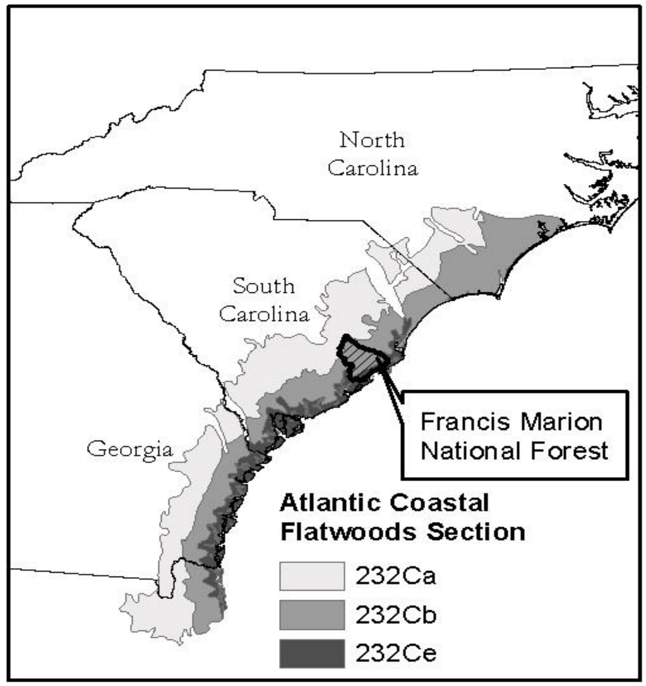

Figure 2-3. Atlantic Coastal Flatwoods Ecological Section

2.1.1.5 Broader Landscape

The Francis Marion National Forest occurs within the outer Atlantic Coastal Plain, also known as the Atlantic Coastal Flatwoods Section (Figure 2-3) and includes portions of upper terraces (232Ca), lower terraces (232Cb) and coastal marsh and island (232Ce) subsections. The Atlantic Coastal Plain Flatwoods Section is characterized by weakly dissected, flat alluvial plains of well drained deep sands with local areas of highly organic soils (Cleland et al. 2007).

The Francis Marion National Forest is considered a significant landscape for longleaf pine conservation by America’s Longleaf, a collaborative effort of multiple public and private sector partners that actively supports rangewide efforts to restore and conserve Longleaf Pine Ecosystems (ALRI 2009). Longleaf pine forests, woodlands, and savannas were once among the most extensive ecosystems in North America. Prior to European settlement, these forests occupied more than 90 million acres in the southeastern United States (Frost 1993; Brockway et al. 2002; ALRI 2009). Today, there are an estimated 3,404,143 acres, with the majority occurring on private lands. Table 2-2, taken from the Range-Wide Conservation Plan for Longleaf Pine (2009), shows that in 2009, the majority (55 percent) of South Carolina’s longleaf pine forests occurred on private lands.

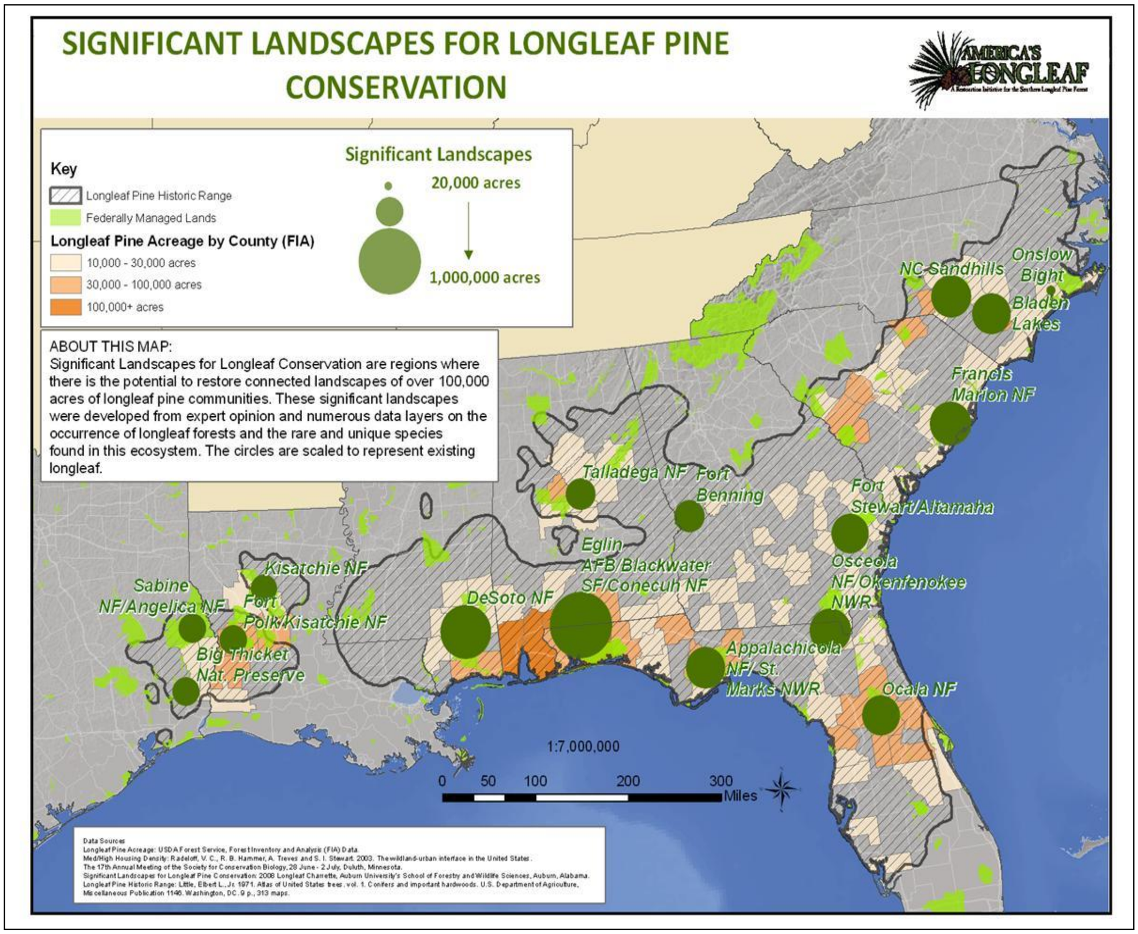

Figure 2-4. America's longleaf significant landscapes for longleaf pine conservation

Table 2-2. Estimates of existing acres of longleaf forest type by ownership category

State	Total	NFS	USFWS	DOD	Other Federal	State	County & Munic-ipal	Private
Georgia	460,109	609	10,500	40,000	6,000	6,000	0	397,000
North Carolina	220,338	15,088	300	34,000	0	33,000	2,000	136,000
South Carolina	401,980	36,980	42,000	46,000	3,000	51,000	0	223,000
Total	**1,082,427**	**52,677**	**52,800**	**120,000**	**9,000**	**90,000**	**2,000**	**756,000**

2.1.1.6 Past and Likely Future Trends

Upland Longleaf Pine Woodlands and Wet Pine Savannas and Flatwoods

Key Ecosystem Characteristics

Relative Abundance, Condition, and Landscape Pattern. The Francis Marion National Forest contains two longleaf-dominated native matrix ecological systems, Upland Longleaf Pine Woodlands, and Wet Pine Savannas and Flatwoods. Upland Longleaf Ecosystems occur on sandy ridges, and are typically dominated by longleaf pine; Whereas Wet Pine Savanna And Flatwoods Ecosystems occur on wet, seasonally saturated, mineral soils, and can be dominated by longleaf pine, pond pine, or loblolly pine on wetter sites. Variants within each type can be recognized that differ in structure, in associated understory and woody species, and in soils and subtle changes in landform.

In their travels, Bartram (1791) described over half of the upland landscape from Virginia to Texas as a "…vast forest of the most stately pine trees that can be imagined…" and Sargent (1884) described longleaf pine as the "prevailing growth" on the uplands (Frost 1993). The demise of the Longleaf Pine Ecosystem throughout the Southeast resulted from land clearing; the introduction of hogs and feral livestock into the woods that feasted on longleaf pine seedlings; the turpentine industry; regeneration of loblolly pine in place of longleaf pine; and fire suppression. By 1900 it was evident that longleaf pine replaced itself only sporadically in a tiny percentage of its former landscape (Frost 1993). The near elimination of once-dominant Longleaf Pine Ecosystems was perhaps the greatest ecosystem alteration resulting from intensive forest management and land use conversion in the South (Wear and Greis 2012).

The 1996 revised Forest plan recognized the importance of the Longleaf Pine Ecosystems, but estimated the range of longleaf pine historically on the Francis Marion National Forest at between 37,000 and 75,000 acres, and the goal for Longleaf Pine Ecosystem expansion at 21 percent of the Forest (1996 revised plan, page1-6; and ROD, page18). Restoration, expansion, and maintenance of Longleaf Pine Ecosystems and related fire-dependent communities were emphasized within management area 26 (sandy ridge and sideslopes). Though not formally recognized as a matrix ecosystem in the 1996 revised Forest plan, the majority of the Wet Pine and Flatwoods Ecosystem was placed in management area 28, "Flatwoods and Loamy Ridges", a management area with no single goal emphasis, and where "loblolly pine is the dominant species on the upland sites" (Table 2-3). The revised plan did include objectives to identify and maintain plant communities including pine and pond cypress savannas; several high quality examples are captured on a GIS coverage or as designated botanical areas for the Forest (Gaddy et al. 2012; Glitzenstein and Streng 2010; Everett 2010; Porcher 1995). Monitoring of the few designated botanical areas in pine savannas (Awendaw Savanna and Big Opening of Hell Hole, for instance) suggests that there have been declines in their condition due to lack of frequent prescribed fire, and the resulting succession by woody species.

In 2010, as part of a longleaf assessment process, the USDA Forest Service with the South Carolina Nature Conservancy identified two matrix longleaf ecosystems on the forest: an Upland Longleaf Woodland Ecosystem and a Wet Pine Savanna and Flatwoods Ecosystem. It was predicted at that time that the extent of existing and restorable longleaf pine was closer to 130,000 acres. As a result of ecological modeling in 2013, Simon and Hayden have identified 53,857 acres in the Upland Longleaf Pine Woodland Ecosystem, but an additional 90,735 acres in Wet Pine Savanna and Flatwoods (144,592 acres total). The Wet Pine Savanna and Flatwoods Ecosystem is now recognized as the most dominant ecological system historically on the Forest, representing 55 percent of the total Forest acreage.

Table 2-3 shows the existing and potential Upland Longleaf and Wet Pine Savanna Ecological systems by 1996 Forest Plan management area.

Table 2-3. Upland longleaf and wet pine savanna ecological systems by 1996 management area based on 2013 ecological modeling

	Upland Longleaf Woodlands		Wet Pine Savanna and Flatwoods		
Management Area	**Acres**	**% of Total**	**Acres**	**% of Total**	**Grand Total**
1	236	0.44	402	0.45	638
2	391	0.73	478	0.53	869
4	1,303	2.43	2,281	2.53	3,584
8	868	1.62	397	0.44	1,265
26	42,852	79.94	35,206	38.99	78,058
27	1,893	3.53	8,548	9.47	10,441
28	5,512	10.28	39,444	43.68	44,956
29	552	1.03	3,542	3.92	4,094
Grand Total	**53,607**	**100.00**	**90,297**	**100.00**	**143,904**

In 2010, in conjunction with the South Carolina Nature Conservancy, the Forest collected information on the condition of Longleaf Pine Ecosystems on the Forest, which included consideration of overstory, midstory, and understory conditions. Condition classes included the following (from America's Longleaf, Rangewide Conservation Plan, [2009]):

> *Maintain* = Forest canopy and understory conditions that currently will provide ecosystem functions, processes, and assemblages of representative species of plants and animals. The maintain condition class was grouped to include maintain, improve ground only, improve mid-story only, improve canopy only, and restore canopy only management classes.
>
> *Improve* = Longleaf pine may be present, but lack significant components of understory communities and fire regimes to support representative communities. Tree cover may be dense.
>
> *Restore* = Stands do not currently support a longleaf pine canopy nor understory, but could be reintroduced based on ecological modeling or presence of representative soils.

Using the results of the 2010 longleaf assessment, which included field assessments, and then intersecting this information with the modeled data for Longleaf Ecosystems, of a total 129,492 acres evaluated, 19,663 acres (13.6 percent) of our Longleaf Ecosystems were in good condition (i.e., "maintain" class) in 2010, including 8,213 acres in upland longleaf (15.2 percent) and 8,639 acres (9.5 percent) in Wet Pine Savanna and Flatwood Ecosystems (Table 2-4). This suggests that we are currently maintaining 13.6 percent of our Longleaf Pine Ecosystems in conditions that will provide ecosystem functions, processes, and assemblages or representative species of plants and animals, compared to the goal for Longleaf Pine Ecosystem expansion for 21 percent of the Forest (1996 revised plan, page1-6; and ROD, page18).

Table 2-4. Longleaf condition classes from 2010 longleaf assessment, by Longleaf Ecosystem type (in acres)

Condition Class	Upland Longleaf	Wet Pine Savanna	Other[1]	Total
Improve	8,551	10,336	3,568	22,455
Maintain	8,213	8,639	2,811	19,663
Restore	12,458	28159	6,469	47,086
No condition class	78	198	31	306
Total	**29,299**	**47,331**	**12,879**	**89,510**

[1] Represents other ecosystems included within stands inventoried as part of the longleaf assessment.

Since 1996, several initiatives have encouraged expansion of longleaf pine and associated ecosystems on the Forest. The 15-year goal for America's Longleaf Conservation Plan (2006) is to more than double the longleaf acreage in significant landscapes in maintain, improve, and restore categories, and in ways to support a majority of ecological and species (page 5-6, ALRI, 2009). The Sewee Longleaf Conservation Cooperative encourages government agencies, nongovernmental organizations, private landowners, practitioners and other stakeholders to re-establish, maintain, and enhance the Longleaf Pine Ecosystem in the Sewee landscape (centered in and around the Francis Marion National Forest) through resource sharing, collaboration, and applied learning. These partnership efforts—which include the U.S. Fish and Wildlife Service, the National Wild Turkey Federation, the Southeastern Association of Fish and Wildlife Agencies, the South Carolina Forestry Commission, and the Department of Defense, among others—lend support to increasing longleaf pine ecosystems and restoration efforts on the Forest in the future.

Longleaf pine may be most suitable for climate change mitigation, due to superior tolerance to both drought and low soil nutrition; greater resistance to insects, diseases, and wind damage; long rotations and long-term carbon storage; and less energy inputs relative to more intensively loblolly pine (Samuelson et al. 2012). Predictions on the incidence of savannas are mixed; one prediction is that reductions in the frequency of fires and hurricanes associated with global warming may push southeastern pine savannas towards a forested state with an increased overstory density and reduced understory component. Another prediction is that closed-canopy forests may be converted to savanna, woodland, or grassland under temperature-induced drought stress and a significant increase in the intensity of fire disturbance.

Landscape pattern which connects fire-maintained longleaf ecosystems with associated depression ponds, pocossins, seepage slopes, and Carolina bays is important for maintaining native biodiversity; and for promoting gene flow and for species migrations, particularly in the face of climate change, for re-colonization of species following interruption of fire regimes, and for maintaining the life cycles of aquatic and terrestrial at-risk species. The 1996 revised Forest plan provided connectivity for longleaf ecosystems within management area 26, but this management area does not well reflect all the diversity of longleaf ecosystems on the Forest and our ability to maintain them. One should consider the distribution of existing and restorable longleaf pine ecosystems in the improve and maintain condition class, distributions of fire-dependent and associated at-risk plants and wildlife, forest burn blocks, and possible old-growth longleaf pine, to identify our best opportunities for connecting longleaf pine fragments and providing for large and medium-sized blocks for maintaining and restoring ecosystem processes and function. The revised recovery plan for the red-cockaded woodpecker includes guidance that foraging habitat is not separated by more than 200 foot of non-foraging habitat (Recovery

Standards for the Red-Cockaded Woodpecker, USDI Fish and Wildlife Service [2003]; pages 188–189).

Possible Old Growth. Old growth forests suggest large trees, accumulations of large-sized dead standing and fallen trees, canopy gaps and multiple canopy layers, and wide variation in tree sizes and spacing (USDA Forest Service 1997). Characteristics specific to longleaf forests include open park-like stands of pine with species-rich herbaceous layer dominated by grasses. Canopies are believed to naturally be two-aged or uneven-aged, consisting of a fine mosaic of small even-aged groves driven by gap phase regeneration. Given the land use history of Southern forests, very little true old growth exists today, yet restoration of old growth for future generations is desirable for biological, social, or spiritual reasons. Minimally to moderately disturbed second growth longleaf pine forests could make an important contribution to old-growth resources in the future (Walker 1999).

The minimum age for longleaf pine old growth ranges from 150 to 200 years (USDA Forest Service 1997), though Walker (1999) notes that old-growth characteristics can be observed in stands as young as 100 years. In a working draft of maintenance condition class definitions for longleaf-association communities (2013), the longleaf partnership council identifies the presence of the following in addition to other maintenance condition class criteria, as evidence of old growth characteristics in longleaf pine community types/stands: (1) Large trees present (≥20 square feet/acre of trees ≥14 inch dbh class), and (2) flat top trees (old individuals) present in the canopy.

Old growth was evaluated in the 1996 FEIS (pages III-33–36) to include forested stands greater than 100 years and stands withdrawn from timber production. There was little old growth direction in the Forest plan specific to the distribution of old growth, relationship to community or ecosystem type, and consideration of characteristics of old growth other than age and suitability. It was assumed that even-aged stands managed for red-cockaded woodpecker would provide suitable old-growth conditions in the future.

We will follow the process for providing for old growth included in the "Guidance for Conserving and Restoring Old-Growth Communities on National Forests in the Southern Region", which represents a coordinated effort within the Southern Region for consistently addressing the old-growth resources during Forest and project-level planning (USDA Forest Service 1997). The guidance recommends that a network of old-growth areas of various sizes be developed which consider a representation of all potential old-growth forest community types, that linkages among old-growth patches be considered, and that old-growth amounts allocated within the Forest plan consider public input and issues. Consistent with this guidance, a preliminary inventory of possible old growth is being conducted using available forest vegetation data. To assess the areas on the Forest meeting the criteria for possible old growth based on the guidance, we looked at stands on the Forest meeting a minimum age criteria of ≥110 years (age year ≤1903), which is the minimum half-life for our predominant longleaf communities based on the old growth guidance, as well as those meeting age criteria of ≥100 years.

The 1996 FEIS displayed 3,668 acres of old-growth longleaf forest types, including mixtures of other species. Using stand age and forest type criteria from FS VEG in 2013, 3,583 acres of longleaf pine stands are ≥100 years and 795 acres are ≥110 years in FS VEG (Table 2-5). Stands modeled as longleaf pine ecosystems and meeting the age criteria of 110 years, recommended in the Southern Old Growth Guidance, occur on 2 and 1.1 percent, respectively, of Upland Longleaf and Wet Savanna and Flatwoods Ecological System sites (Table 2-6). This information does not address structure, function, or composition above and beyond age of the oldest age class of trees.

Table 2-5. Trends in possible old growth in longleaf forest types

	1996 FEIS		2013	
	Suitable Lands >100 years	Unsuitable Lands	≥110 years	≥100 years
Longleaf Pine and mixtures	527	3,141	795	3,583

Table 2-6. Possible old growth (≥110 years) by Longleaf Pine Ecological System

Ecological System	Total Acres	Percent of Total Old Growth	Percent of Total for Ecological System	Associated Forest Types
Upland Longleaf Pine Woodland	1,106	11.0%	2.0%	Longleaf pine; loblolly pine; loblolly pine-hardwood; sweetgum-oak; sweetbay-swamp tupelo-red maple; bald cypress-water tupelo; oak hammock
Wet Pine Savanna and Flatwoods	975	9.7%	1.1%	Bald cypress-water tupelo; bottomland hardwood-yellow pine; loblolly pine-longleaf pine; longleaf pine; loblolly pine

Fire Regime. Lack of frequent prescribed fire is a primary threat to Longleaf Pine Ecosystem integrity particularly herbaceous understory communities. The Forest Service recognized the importance of frequent prescribed fire in maintaining Longleaf Ecosystems in 1996, and included a standard that management area 26 be prescribed burned on a 2- to 3-year rotation. However, from 2007 through 2011, less than half of management area 26 had been prescribed burned on a 3-year rotation (25 percent in 2007, 44 percent in 2008, 48 percent in 2009, 29 percent in 2010, and 25 percent in 2011). In response to smoke management concerns in the wildland-urban interface, in 2007 the district developed a "core burn area" within which frequent fire was more commonly practiced. More recent research shows an increase in plant species richness across a 1- to 3-year-fire-regime interval depending on openness of the canopy, and greatest herbaceous dominance at 1- to 2-year-fire-return intervals, particularly in Wet Pine Savannas and Flatwoods where the potential for competition by woody shrubs is highest (Glitzenstein and Streng 2003; Glitzenstein et al. 2012).

Table 2-7 shows prescribed burning frequencies for all ecosystems, including potential and existing Upland Longleaf and Wet Pine Savannas on the Forest (this table will be referred to in the analysis for all ecosystem sections). Between 2005 and 2012, 19,597 acres (36 percent) of potential and existing upland longleaf woodlands and 27,138 acres (15 percent) of the Wet Pine Savanna and Flatwoods Ecosystem were burned three or more times (2.6 year burning rotation). The total acres prescribed burned on the Forest have remained fairly constant, but have not met the long-term objectives (see section 3.4 "Wildland Fire and Fuels") for total burning and growing season burning within longleaf pine forest types.

Table 2-7. Prescribed fire in ecological systems on the Francis Marion National Forest (2005–2012)

	1 Burn	2 Burns	2 Burns; 1 or More Growing Seasons	3 Burns	3 Burns; 1 or More Growing Seasons	More Than 3 Burns	Total Acres Ecological System Prescribed Burn ≥3 Times	% Ecological System Prescribed Burn ≥3 Times
Carolina Bay Wetland	530	6	52	231	96	339	666	20%
Depression Pond	348	49	98	120	122	270	512	38%
Dry and Dry-Mesic Oak Forest	125	3	31	116		549	665	75%
Large River Floodplain Forest	1,234			22		376	398	11%
Mesic Slope Forest	9	5	8	8			8	0%
Nonriverine Basin Swamp	29					19	19	1%
Nonriverine Swamp and Wet Hardwood Forest	9,199	4,744	5,657	2,164	13,986	8,754	24,904	31%
Peatland Pocosin and Canebrake, inclunding Streamhead Pocossin	477	22	67		1,251	116	1,367	65%
Small Blackwater River Floodplain Forest _and_Blackwater Stream Floodplain Forest	1,189	572	201	367	539	579	1,485	13%
Tidal Wooded Swamp	28	14		648	54	2,102	2,804	54%
Upland Longleaf Pine Woodland (TOTAL)	5,973	2,612	77.94	5,754	4,392	9,451	19,597	36%
Upland Longleaf Pine Woodland (Xeric_Dry_Phase)	1,699	421	326	1,812	352	1,933	4,097	48%
Upland Longleaf Pine Woodland (Dry_Dry-Mesic phase)	640	120	78	100	273	2,326	3,699	29%
Upland Longleaf Pine Woodland (Dry-Mesic_Mesic _Phase)	3,633	2,071	3,579	2,842	3,768	5,192	11,802	14%
Wet Pine Savanna and Flatwoods (Total)	14,847	4,144	5,792	3,368	9,999	13,771	27,138	15%
Wet Pine Savanna and Flatwoods (Mesic_Wet Phase)	9,171	2,590	3,874	2,200	5,455	7,633	15,288	14%
Wet Pine Savanna and Flatwoods (Wet Phase)	5,676	1,554	1,918	1,167	4,544	6,139	11,851	17%
Grand Total	**33,985**	**12,170**	**15,890**	**12,797**	**30,439**	**36,326**	**79,563**	**31% of Total Forest Area**

Structural Diversity and Natural Range of Variation (NRV). Natural Upland Longleaf Pine Woodland Ecosystem canopies are open and park-like, but many-aged, consisting of a network of forest patches at various ages. Gap phase regeneration produces a forest structure of even-aged patches within an uneven-aged mosaic (Longleaf Partnership Working Draft 2013; Natureserve 2012; Brockway et al. 2002; Landfire Biophysical Setting Models for Atlantic Coastal Plain Upland Longleaf Pine Woodland and for Southern Atlantic Coastal Plain Wet Pine Savanna and Flatwoods). Within a natural disturbance regime of frequent fire, woodlands (26 to 60 percent forest cover) and savannas (5 to 25 percent forest cover) structural classes were predominant across much of the landscape. In a working draft of maintenance condition class definitions by the Longleaf Partnership Council (2013), minimum standards for achieving the "maintenance condition" for longleaf-associated communities is a longleaf pine canopy which is two-tiered age, or uneven-aged in structure, with longleaf pine basal area of 40 to 70 square feet, with a lower range down to 10 square feet for wet savanna communities. Other metrics identified include a basal area of canopy hardwoods or off-site pines <10 square feet/acre, shrubs averaging ≤30 percent cover, and mid-story ≤20 percent cover, continuous herbaceous cover ≤65 percent, and advance longleaf regeneration around 10 percent.

In the 1996 revised Forest plan, timber management was typically even-aged, particularly within 0.5 mile of red-cockaded woodpecker clusters and on soils classified as very poorly, or poorly drained due to operational constraints (FEIS, page II-40). The recovery plan for the red-cockaded woodpecker was revised in 2003 and recommends that foraging habitat (within 0.5 miles of the center of active clusters) contain a basal area of all pines ≥10 inches dbh of at least 40 square feet/acre; native herbaceous groundcovers which total at 40 percent; no hardwood midstory, and if present, that it be sparse and less than 7 feet in height. The plan also recognizes that extremely dry and extremely wet longleaf habitats may be unable to support these characteristics (USDI Fish and Wildlife Service 2003). Table 2-8, which will be referred to in the analysis for all sections, shows the acres in early succession, savanna, woodland, and forested ecosystems, for each of our modeled ecosystems, based on LIDAR analysis of canopy cover, where early succession equals 0–5 percent canopy cover, savanna equals 5–26 percent canopy cover, woodland equals 26–60 percent canopy cover, and forest equals 60–100 percent canopy cover. This table suggests that on the Francis Marion National Forest, 27.5 percent of our forests have open canopies, including 34 percent of our longleaf ecosystems. On the Francis Marion National Forest, 22,727 acres (9 percent of the Forest) are in early successional or savanna condition (less than 26 percent canopy cover). The 1996 revised plan contained an objective to maintain 5,000 to 10,000 acres in early successional habitat, suggesting that objective has been met and exceeded.

Ecological departure rankings in regard to vegetation structure alone were calculated using a process described by Low et al. (2010) and relevant BioPhysical Settings models from LANDFIRE (LANDFIRE a and g, 2006). Both Southern Atlantic Coastal Plain Wet Pine Savanna and Flatwoods (biophysical settting Model 5814500) and Atlantic Coastal Plain Upland Longleaf Pine Woodland (biophysical setting 581347), were used in this analysis. We compared vegetation classes from the biophysical settings models, including age class and structural breakouts to define each class, to those found on the Forest using Forest FS VEG even-aged age class data, and LIDAR shade data to quantify canopy opening. Then, ecological departure rankings were calculated based on Low et al. (2010), by summing the lowest range of variables and subtracting from 100, where low departures = 033 percent, medium = 34–66 percent, and high = 67–100 percent. Table 2-9 suggests that our landscapes on the Francis Marion deviate moderately in regard to structure, and that we have low levels of late open conditions compared to reference conditions as described in LANDFIRE biophysical settings models.

Table 2-8. Acreage in grassland, savanna, woodland, and forest structural classes by ecological system based on LIDAR-derived canopy cover using GIS

Ecological System	Grassland (0–5%)	Savanna (5–25%)	Woodland (26–60%)	Forest (>60%)	Total
Altered Land	2	5	19	50	76
Carolina Bay Wetland	154	381	663	2,022	3,220
Depression Pond (Sink Phase)	3	13	45	141	202
Depression Pond (Typic Phase)	20	71	241	988	1,321
Dry and Dry-Mesic Oak Forest	5	16	130	733	885
Large River Floodplain Forest	20	25	147	3,428	3,620
Maritime Forest	45	39	61	269	415
Mesic Slope Forest	0.06	0.4	5	208	214
Nonriverine Basin Swamp		0.3	14	2,469	2,483
Nonriverine Swamp and Wet Hardwood Forest	1,048	4,259	9,760	65,586	80,653
Peatland Pocosin and Canebrake (Carolina Bay Phase)	9	34	56	151	250
Peatland Pocosin and Canebrake (Typic Phase)	980	770	201	77	2,027
Salt and Brackish Tidal Marsh	2,135	164	86	90	2,476
Small Blackwater River Floodplain Forest and Blackwater Stream Floodplain Forest	26	124	445	10,765	11,360
Streamhead Seepage Swamp, Pocosin and Baygall	22	25	17	12	75
Tidal Wooded Swamp	48	55	148	4,951	5,203
Upland Longleaf Pine Woodland (Dry to Dry-Mesic Phase)	82	343	1,819	5,662	7,906
Upland Longleaf Pine Woodland (Dry-Mesic to Mesic Phase)	538	2,645	10,897	23,210	37,290
Upland Longleaf Pine Woodland (Xeric to Dry Phase)	96	385	3,334	4,731	8,546
Water	8	6	13	27	54
Wet Pine Savanna and Flatwoods (Mesic to Wet Phase)	914	3,987	13,711	36,562	55,174
Wet Pine Savanna and Flatwoods (Wet Phase)	702	2,532	6,574	25,227	35,035
Grand Total	**6,857 (3%)**	**15,880 (6%)**	**48,386 (19%)**	**187,360 (72%)**	**258,482**

Table 2-9. Ecological departure rankings for Upland Longleaf and Wet Pine Savanna ecosystems[1]

Ecological System	Early-Class A		Mid-Closed		Mid-Open		Late-Closed		Late-Open		Ecological Departure
	Current	Predicted	Current	Predicted	Current	Predicted	Current	Predicted	Current	Predicted	
Upland Longleaf	8	13	47	5	22	40	15	2	7	40	56
Wet Pine Savanna and Flatwoods	9	15	45	5	13	35	23	10	9	35	53

[1] Low = 0–33%, medium = 34–66%, and high = 67–100% levels of departure.

Herbaceous Understories. The high diversity of herbaceous understory plants per unit area make Longleaf Pine Ecosystems among the most species-rich outside the tropics (Peet and Allard 1993). Understory grasses facilitate the ignition and spread of prescribed fire and form the base of the food chain for numerous wildlife species, particularly birds and pollinator species. The 1996 revised plan did not directly address conditions for herbaceous groundcover. Ecological integrity indices for longleaf pine ecosystems, developed in a working draft for the Southern Region by the Forest Service in conjunction with Natureserve in 2011 (by Forest contractor Dr. Jean Everett) for wet savannas on the Francis Marion National Forest in 2010, and through a working draft of the Longleaf Partnership Council in 2013, include consideration of abundance and diversity of herbaceous groundcover. Everett included rankings for assessing native grass and forb diversity, native grass and forb abundance, and rare species diversity and abundance in an ecological integrity ranking for wet pine savannas. In a working draft of maintenance condition class definitions by the Longleaf Partnership Council (2013), minimum standards for achieving the "maintenance condition" for longleaf-associated communities is a continuous herbaceous cover ≥65 percent.

Stressors and Threats

Nonnative Invasive Species. Nonnative invasive species, though not addressed in the 1996 revised Forest plan, are a primary threat to Longleaf Ecosystems, particularly those undergoing restoration (Natureserve and USDA-Forest Service 2011; Natureserve 2012; Degarady 2013). Feral hogs and cogongrass are most commonly cited threats, but on the Francis Marion National Forest, Japanese climbing fern is also a major concern. Japanese climbing fern, which has the potential to disrupt fire regimes, was identified as an early detection and rapid response species by the South Carolina Exotic Pest Plant Council (se-eppc.org), and is now the most common invasive plant species on the Forest (68 percent or 1,888 of 2,769 records in Longleaf Ecosystems).

The establishment of saturation densities of feral hogs is one of the primary agents responsible for the demise of the Longleaf Ecosystem (Frost 1993), and they continue to impact our longleaf forests and associated wetlands today. Cogongrass, a Federal and state noxious weed, occurs at three locations on the Forest, and is near controllable levels, but statewide surveys for cogongrass continue to be a priority for the South Carolina Cogongrass Task Force, and for the Forest Service.

Table 2-10, which will be used in the analysis of all sections, shows terrestrial invasive plant species documented within all ecological systems. See the invasive species section for a complete listing of all nonnative invasive plants documented to date on the Forest. Species with five or more records within Longleaf Pine Ecosystems include Japanese climbing fern, Japanese honeysuckle, Chinese privet, Japanese stiltgrass, Sericea lespedeza, tall fescue, mimosa, small carpet grass, Chinaberry, Chinese wisteria, autumn olive, and Chinese tallow.

The South Carolina Comprehensive Wildlife Strategy (2011) includes as a high priority conservation action preventing the spread of existing invasive and nonnative species, and eliminating them, where possible. Invasive plant species are expected to increase with changes in climate (South Carolina Department of Natural Resources [SCDNR] 2013), and will increasingly threaten ecological integrity of Longleaf Pine Ecosystems in the future.

Table 2-10. Invasive plant species counts by ecological system

Ecological System	Count
Altered Land	5
Depression Pond (Sink Phase)	28
Depression Pond (Typic Phase)	41
Dry and Dry-Mesic Oak Forest	102
Large River Floodplain Forest	897
Maritime Forest	9
Mesic Slope Forest	34
Nonriverine Swamp and Wet Hardwood Forest	413
Salt and Brackish Tidal Marsh	2
Small Blackwater River Floodplain Forest and Blackwater Stream Floodplain Forest	168
Tidal Wooded Swamp	369
Upland Longleaf Pine Woodland (Dry to Dry-Mesic Phase)	472
Upland Longleaf Pine Woodland (Dry-Mesic to Mesic Phase)	1,278
Upland Longleaf Pine Woodland (Xeric to Dry Phase)	36
Wet Pine Savanna and Flatwoods (Mesic to Wet Phase)	678
Wet Pine Savanna and Flatwoods (Wet Phase)	305
Grand Total	**4,837**

Dense Canopies of Loblolly Pine. Although the acreage in loblolly pine forest types on the Forest has declined from 114,917 acres in 1985 (FEIS, 1985 and "Forest Products" section), this decline represents a shift to changes from pure loblolly pine to mixtures with hardwoods. Loblolly pine is currently the most abundant tree species on the Francis Marion National Forest occupying over 104,376 acres (includes mixtures with hardwoods), and much of this occurs as forests >60 percent canopy cover. The majority of our loblolly pine forests occur on longleaf pine ecosystem sites, including 25,673 acres on upland longleaf sites, 50,760 acres on wet pine savanna sites (Table 2-11).

Early in the history of the Forest, the emphasis was on sustained yield and on cooperation with timber companies, who controlled the majority of the forest land in the coastal pine belt (Hector 1979). Several large timber companies began building mills and buying up land and stumpage in the area in and around the Francis Marion National Forest around 1899. Within a decade timber companies owned most of the forest land in Berkeley, Georgetown, and upper Charleston counties, and Atlantic Coast Lumber Corporation was considered one of the largest producers of timber on the Eastern seaboard. In consultation with the new Federal Bureau of Forestry, longleaf and hardwoods were eliminated and replaced with loblolly pine whenever possible, mainly because loblolly pine grew and reproduced rapidly, and fire was to be kept out of the woods completely to allow loblolly to reproduce to its full potential (Hector 1997). Given their influence on ecosystem composition, structure, function, and connectivity, their abundance on the Forest is evaluated based on their threat to the ecological integrity of longleaf pine ecosystems. Table 2-11 shows existing vegetation on the Forest using forest type groups from FSVEG, and may also be referred to in other sections.

Table 2-11. Acres by forest type group from FSVEG, 2013, and by ecological system

Forest Type Group	Bottomland Hardwood (including Oak) or Mixed Hardwood/ Yellow Pine or Sweetgum	Loblolly Pine and Mixtures with Hardwood (No Oak Listed)	Longleaf Pine and Mixtures with Loblolly or Slash Pine	No Forest Type Group	Pond Cypress and/or Bald Cypress	Pond Pine, Pond Pine/Hardwood, Brush Species, Undrained Flatwoods, Sweetbay, Swamp Tupelo, Red Maple	Upland Hardwood (including Oak) or Mixed Hardwood/Yellow Pine or Shortleaf Pine	Grand Total
Forest Type	46, 61, 62, 63, 64	13, 31	21, 22, 27, 29	(blank)	23, 24, 67	18, 36, 40, 68, 98, 99	10, 11, 44, 47, 48, 49, 53, 57, 58, 77	
Altered Land	20	24	24	6	2			76
Carolina Bay Wetland	147	1,189	251	2	602	1,027	2	3,220
Depression Pond (Sink Phase)	9	98	75	1	9	8	2	202
Depression Pond (Typic Phase)	38	471	304	11	350	130	14	1,318
Dry and Dry-Mesic Oak Forest	40	476	110	18	76	9	155	885
Large River Floodplain Forest	722	161	1	4	2,585	165	4	3,642
Maritime Forest	93	137	12	130		13	32	416
Mesic Slope Forest	120	49			16		28	214
Nonriverine Basin Swamp	1,248	96			1,130	3	5	2,483
Nonriverine Swamp and Wet Hardwood Forest	11,601	23,310	7,070	115	17,166	20,180	844	80,287
Peatland Pocosin and Canebrake (Carolina Bay Phase)	123	11				116		250
Peatland Pocosin and Canebrake (Typic Phase)		1	5		16	2,006		2,027
Salt and Brackish Tidal Marsh	92	245	14	1,058		1,088	55	2,551
Small Blackwater River Floodplain Forest and	3,938	1,257	101	40	2,284	3,484	238	11,341

Forest Type Group	Bottomland Hardwood (including Oak) or Mixed Hardwood/ Yellow Pine or Sweetgum	Loblolly Pine and Mixtures with Hardwood (No Oak Listed)	Longleaf Pine and Mixtures with Loblolly or Slash Pine	No Forest Type Group	Pond Cypress and/or Bald Cypress	Pond Pine, Pond Pine/Hardwood, Brush Species, Undrained Flatwoods, Sweetbay, Swamp Tupelo, Red Maple	Upland Hardwood (including Oak) or Mixed Hardwood/Yellow Pine or Shortleaf Pine	Grand Total
Blackwater Stream Floodplain Forest								
Streamhead Seepage Swamp, Pocosin and Baygall	1	2	18		3	52		75
Tidal Wooded Swamp	1,340	412	14	62	3,226	91	69	5,214
Upland Longleaf Pine Woodland	2,443	25,673	20,096	651	1,069	2,487	964	53,383
Water	4	6	12	17	7	9		54
Wet Pine Savanna and Flatwoods	6,135	50,760	20,993	318	4,318	6,530	686	89,842
Total	28,115	104,376	49,102	2,533	32,858	37,398	3,098	257,479

Dry and Dry Mesic Oak Forests and Mesic Slope Forests

Key Ecosystem Characteristics

Relative Ecosystem Abundance and Condition. Both dry and dry-mesic oak forests and mesic slope forests are relatively uncommon on the Forest, and would have historically been limited in distribution to fire-sheltered areas such as slopes adjacent to river terraces, islands in swamps, or on upper terraces adjacent to streams within dissected landscapes, as fire is naturally infrequent in these ecosystems (Natureserve 2012). The 1996 revised Forest plan contained an objective to identify and maintain calcareous mesic forests, and several examples of mesic slope forests are influenced by marl or calcareous geology (McMillan et al. 2001) and were addressed as natural areas in the 1996 revised plan (Everett 2012; Porcher 1995). Mesic slope forests (also known as Southern mixed hardwood forests) occur on slopes or river terraces near the Santee River and Echaw Creek, Awendaw Creek, and within dissected landscapes near Nicholson, Huger, and Turkey Creeks. Simon and Hayden (2013) estimated 214 acres in mesic slope forests in their 1st approximation, but the Forest vegetation database shows 164 acres in beech-magnolia or sugar maple-beech, and the rare community coverage (internal GIS database) includes 11 sites in calcareous mesic hardwood or 380 acres.

The 1996 revised plan emphasized mast-producing hardwoods in management area 27, and contained a Forestwide objective to have 48,000 acres (20 percent of forested acres) typed and managed as potential hard mast-producing hardwoods in the next 10 years. The 1996 FEIS (page III-40) stated that mast-producing hardwood occurred on less than 13 percent of the forested acres. The current forest vegetation database shows 3,022 acres in upland hardwood (Table 2-11) including 2,606 acres in upland oak or oak-pine, and 28,115 in bottomland hardwood or mixed with pine (which includes 14,027 acres in a bottomland hardwood oak or oak-pine). The two combined are 31,213 in upland or bottomland hardwood (12.1 percent of forested acres) or 17,049 acres with oak (6.6 percent of forested acres), below the 1996 Forestwide objective (48,000 acres) for mast-producing hardwoods.

Table 2-12. Percent of stands typed and managed as potential hard-mast producing hardwoods, as a percent of total forested acres

Ecological System	1996	2013
Upland Dry-Mesic Oak		1.0
Bottomland Hardwood Oak Forests		5.4
Total	**<13**	**6.6**

The 2011 Annual Monitoring Report emphasized mixed pine/hardwood types and did not specifically address hard-mast producing species, though monitoring questions address an objective of 30 percent of dominant and codominant canopy classes in mast-producing hardwoods within management area 27. Several oaks can occur as components of upland longleaf woodlands (turkey oak, runner oak, blackjack oak, bluejack oak), nonriverine swamp forests, blackwater stream and river forests, and mesic forests, but may not be abundant enough in the canopy to be typed in the Forest Service vegetation database. Simon and Hayden (2013) estimated potential for just 885 acres of dry and dry-mesic oak forests, though of that acreage 54 percent is dominated by loblolly pine or mixtures with hardwoods, with no mention of oak species.

Structural Diversity and NRV. Most natural disturbances have led to small gap openings within these ecological systems, though oak regeneration can be problematic (Johnson 1979; Collins and Battaglia 2008). Table 2-13 shows a comparison of our ecological departure in regard to the structure of these ecosystems structural classes for the upland hardwood ecosystems, in comparison to conditions described in Atlantic Coastal Plain Dry and Dry-Mesic Oak Forests and Atlantic Coastal Plain Mesic Hardwood Forest biophysical settings models from ANDFIRE (2006). This suggests that our upland hardwood forests are moderately departed in structure compared to reference conditions, with a relatively low percentage in late successional open conditions.

Table 2-13. Ecological departure rankings for upland hardwood ecosystems on the Forest, where low=0–33%, medium=34–66%, and high=67–100% levels of departure

Eco-logical System	Early-Class A		Mid-Closed		Mid-Open		Late-Closed		Late-Open		Eco-logical Depar-ture
	Current	Predicted	Current	Predicted	Current	Predicted	Current	Predicted	Current	Predicted	
Dry and Dry-Mesic Oak	2	11	28	17	4	37	54	12	9	23	56
Mesic Slope Forest	0	10	74	35	2	15	23	30	1	10	39

Old Growth. The forest vegetation database shows 939 acres in upland hardwood (≥100 years) including 739 acres in upland oak or oak-pine and no mesic slope forests meeting the age criteria.

Stressors and Threats

Mesic slope and dry and dry-mesic oak forests are threatened by nonnative invasive plant species, dense loblolly pine plantation forestry which promote loblolly pine, and in some cases, fire regimes which are too frequent.

Too frequent fire regimes and overly dense canopies of loblolly pine can threaten hardwood forests. Approximately 75 percent of the modeled dry and dry-mesic oak acres have been prescribed burned three or more times between 2005–2012 (Table 2-7) which is a higher frequency than one would predict under natural disturbance regimes (LANDFIRE predicts a 5- to 10-year-return interval for dry mesic oak forests, and a 35-year interval for mesic slop forests). Several of our modeled hardwood stands and mesic slope forests are dominated by loblolly pine, or have more loblolly pine than existed prior to European settlement (LANDFIRE Biophysical Setting Models, Atlantic Coastal Plain Dry and Dry-Mesic Oak Forest, and Atlantic Coastal Plain Mesic Hardwood Forest 2006). Conner (2011) notes that severe droughts in more upland areas have caused mortality of oaks and hickories in many states, but observed very little mortality of oaks at his study sites in South Carolina.

Forested Wetlands

Note: Forested wetlands include blackwater stream floodplain and blackwater river floodplain forest, large river floodplain forests, tidal wooded swamp forests, nonriverine swamp and wet hardwood forests, and nonriverine basin swamp forests.

Key Ecosystem Characteristics

Relative Ecosystem Abundance and Condition. The composition, structure, and function of forested wetlands were not well addressed in the 1996 revised Forest plan. On the Francis Marion National Forest, forested wetlands conservatively occupy 118,730 acres or 45.8 percent of forested acres (based on ecological modeling). See Natureserve (Ecological Systems of

Francis Marion National Forest; 1 November 2012) for a more complete description of ecological systems containing forested wetlands which differ in composition, structure, and natural disturbance dynamics.

Several forested wetland ecosystems occur on the Francis Marion National Forest, including blackwater stream floodplain and blackwater river floodplain forests, large river floodplain forests, tidal wooded swamp forests, nonriverine swamp and wet hardwood forests, and nonriverine basin swamp forests. Forested wetlands support a high density and diversity of flora and fauna, help protect the quality of water and habitat in adjacent streams, and serve as flood water storage areas.

The Forest Vegetation database (Table 2-11) shows bald and pond cypress as the most dominant forest types (22 percent), followed by loblolly pine or mixtures with non-mast producing hardwoods (21.2 percent), pond pine and bay vegetation (20.1 percent), bottomland hardwoods including oak species (15.9 percent), longleaf pine and mixtures (6 percent), and upland hardwoods including oak (1 percent). The majority of our forested wetlands are classified as nonriverine swamps, which occur on poorly drained, organic, or mineral soil flats and are saturated by rainfall and seasonally high water tables without the influence of river or tidal flooding. The lower strata have affinities with pocossin or baygall systems rather than river floodplain systems, which have affinities with the canopy, and differ from pocossins in being relatively nutrient rich (Richardson and Gibbons 1993). A wetter group has communities with bald or pond cypress and swamp gum, and a drier group is associated with bottomland oak species. The Southeast GAP project [http://www.basic.ncsu.edu/segap/] from 1999–2001 imagery, predicted that there were 48,454 acres of nonriverine swamps on the Forest, with 35 percent occupied by the drier, oak-dominated type.

Flooding and Hydrology. Forested wetlands can be quite variable depending on flooding regime, and whether they have been exposed to prescribed fire. Low areas having long hydroperiods and areas protected from the spread of prescribed fire by streams, backswamps, and oxbows were virtually fire free (LandFire Biophysical Settings Model–Gulf and Atlantic Coastal Plain Small Stream Riparian Systems). Many of our forested wetlands were ditched and drained for the culture of inland rice prior to the end of the Revolutionary War (Porcher and Rayner 2001), and channeling and ditching for road infrastructure, as well as industrial logging and high-grading of bald cypress from forested wetlands in South Carolina, were common practices at the turn of the century (Hester 1997; Conner et al. 2011). Salt water intrusion associated with Hurricane storm surges and as predicted by climate change models are likely to impact species associated with tidal forested wetlands in the future, particularly bald cypress (Krauss et al. 2009).

Fire Regime. Fire would have occurred relatively infrequently in nonriverine swamp systems, tidal wooded swamps, and large floodplains, but would have played a role in shaping associated ecosystem, particularly when associated with longleaf ecosystems. Indicators that fire played a role in maintaining these ecosystems include the presence of native cane (*Arundinaria tecta*), spruce pine, and pond pine. Fire likely occurred at a frequency ranging from about 3 to 8 years in streamside hardwood/canebrake or pine, to 25 years or more in hardwood litter. Table 2-7 suggests 31 percent of our nonriverine swamps systems and 54 percent of our tidal wooded swamps were prescribed burned three or more times, between 2005–2012, though this may overestimate the actual burn acres within the unit, since acres burned are calculated for entire landscape burn blocks, regardless of whether they burned or not.

Vegetation changes in southeastern peatlands, marshes and swamps along gradients of burning frequency and depth of organic soil (Frost 1995). On moderately fertile sites, prescribed burning on a 1- to 3-year basis can result in open bogs with low shrubs, pitcher plants, grasses and sedges, intermediate burns can increase the incidence of native canebrakes, and burning on a 25 year or higher rotation or greater can result in forested mosaics with cypress, pond pine, loblolly pine, swamp gum, bay forests, and pocossin-like vegetation. He suggests that forested wetlands have replaced peatland and fluvial canebrakes on these forested wetland sites which originally experienced landscape-scale fires. Sharitz and Gibbons (1982) note that poorly drained interstream areas of the Coastal Plain were historically covered by broadleaf swamp forests, but fires by Native Americans may have changed many swamp forests to pocossins.

Structural Diversity and NRV. Many forested wetlands exist naturally as multi-aged older forests driven by gap-phase regeneration (Natureserve 2012), though there is significant variation in composition with hydrology, landscape position, and past land management. The following LANDFIRE Biophysical Settings models (2006) were consulted in this analysis: Gulf and Atlantic Coastal Plain Small Stream Riparian Systems; Gulf and Atlantic Coastal Plain Floodplain Systems, and Gulf and Atlantic Coastal Plain Swamp Systems. Ecological departure rankings suggest that small blackwater river and stream floodplain forests, tidal wooded swamps, and nonriverine basin swamps on the Francis Marion National Forest have low levels of ecological departure in regard to structure, but large river floodplains and nonriverine and nonriverine swamp and wet hardwood forests are moderately departed. Small blackwater river and stream floodplain forests have much fewer late successional open forests and more late successional closed forests compared to reference conditions. Large river floodplain forests had a much higher percentage of late-successional closed forests and fewer early successional forests than predicted.

The Gulf and Atlantic Coastal Plain Swamp Forest Biophysical Setting models were used as a comparison model for Non-riverine Swamp and Hardwood Ecosystems, but this model predicts a very disturbance regime which would result in very little open forest. A model which addresses the natural disturbance variation in nonriverine swamp forests is needed.

Table 2-14. Structural ecological departure rankings for forested wetlands on the national forest, where low=0–33%, medium=34–66%, and high=67–100% levels of departure

Ecological System	Early-Class A		Mid-Closed		Mid-Open		Late-Closed		Late-Open		Ecological Departure
	Current	Predicted	Current	Predicted	Current	Predicted	Current	Predicted	Current	Predicted	
Small Blackwater River and Stream Floodplain Forests	1	10	29	25	2	5	65	40	2	20	30
Large River Floodplain Forest	1	21	3	31	0	0	89	28	4	20	64
Tidal Wooded Swamp	3	10	17	17	1	0	76	73	2	0	7
Nonriverine Basin Swamp	0	10	3	17	0	0	97	73	0	0	24
Nonriverine Swamp and Wet Hardwood	7	10	45	17	8	0	35	73	3	0	41

Forest[1]											

[1] The Gulf and Atlantic Coastal Plain Swamp Systems BpS model was referred to because no other model was available.

Old Growth Forests. Based on analysis of age data in FSVEG, approximately 2,784 acres (7.8 percent) of these forests are ≥110 years, and 13,276 acres of swamp forests (which include nonriverine and basin swamps) are ≥100 years. Bald cypress the dominant tree is very long-lived, sometimes approaching 1,200 years (USDA Forest Service 1997).

Table 2-15. Possible old growth forested wetlands

	Suitable Lands >100 years	Unsuitable Lands	≥110 years	≥100 years
	1996 FEIS	**1996 FEIS**	**2013**	**2013**
Sweetbay-Swamp Tupelo-Red Maple	0	276	1,286	5,030
Bottomland Hardwood	897	1,816	3,144	6,557
Swamp Hardwood	2,933	12,334	4,230	13,276
Total	**3,830**	**14,426**	**8,660**	**24,864**

Stressors and Threats

Nonnative Invasive Species. Japanese climbing fern, Chinese tallow, feral hogs, and laurel wilt pose the greatest threats to forested wetlands on the Forest. Due to their relative inaccessibility for inventory, monitoring, and treatment, invasive species are likely to increase in forested wetlands in the future, though forest management activities, which provide microsites for possible invasion, are likely to be limited.

Dense Canopies of Loblolly Pine. Although loblolly pine can be a natural component of these ecosystems, following Hurricane Hugo areas experiencing the greatest increase in loblolly pine were wetter sites associated with bottomland hardwoods, as well as upland sites where loblolly outgrew hardwood sprouts and saplings (FEIS, page III-27), and high tree densities could draw down the water table. Nonriverine swamps contain the highest proportion of loblolly pine, sometimes with hardwoods other than oak (23,130 acres or 29 percent of this type). Dense canopies of loblolly pine will use more water than hardwood forests, and thereby draw down the water table compared to reference conditions.

Diking, Ditching, or Rutting of Sensitive Soils. Globally wetlands are threatened by hydrologic modifications, development, and conversion to agricultural production. At the time of European settlement, it is estimated that approximately 80 million hectares of forested freshwater wetlands existed in the coterminous United States, though draining and clearing of forested wetlands for agriculture beginning in the mid-1800s, accounts for at least 87 percent of wetland loss (Journal of the Society of Wetland Scientists 1989). The Francis Marion National has much evidence of diking, ditching and rutting of sensitive soils when wet, which can cause irreversible modifications in hydrologic function.

Sea-level rise will threaten these ecosystems in the future. Populations of bald cypress may be particularly vulnerable to future changes in climate including sea-level rise.

Peatland Pocosin and Canebrakes, and Streamhead Seepage Swamp, Pocosin, and Baygalls

Key Ecosystem Characteristics

Relative Ecosystem Abundance and Condition. Atlantic Coastal Plain Peatland Pocosin and Canebrakes are evergreen shrub-dominated ecosystems, where the accumulation of organic matter exceeds decomposition, resulting in the accumulation of up to 10 feet or more of peat over a period of decades. Examples of this ecological system occur in broad wetland areas which include some areas on histosol (organic) soils, including peat filled Carolina bays (Little Ocean Bay, Big Ocean Bay, Pamlico soil series), but is more often found on wet sandy soils on poorly drained flats, and also along drainages that have been subjected to wildland fire (Natureserve 2012). Streamhead seepage swamp, pocossin, and baygall occur within dissected landscapes on sites saturated with shallow groundwater. For additional information on the structure, and composition, and function of these ecosystems, see Natureserve (2012), Richardson and Gibbons (1993), and Sharitz and Gibbons (1982).

The 1996 revised Forest plan contained an objective to "[I]dentify and maintain existing acreage in ...bay swamp pocosin,..". Select seepage bogs and portions of a few pocossins were included as designated botanical areas in the 1996 revised plan (Little Ocean Bay, Morgan Creek Bog, and Halfway Creek Pocossin, for example). Sweet pitcher plant (*Sarracenia rubra*) was identified as a management indicator species, a carnivorous perennial plant of the bogs and moist soil margins of pocossins, bays and cypress-tupelo ponds of the coastal plain.

Based on LiDAR, Simon and Hayden (2013) predict a relatively modest acreage in peatland pocosin and canebrakes (2,027 acres), pocossin vegetation in Carolina bays (252 acres), and streamhead seepage swamp, pocosin, and baygalls (76 acres). There is a fair amount of uncertainty in predicting streamhead seepage swamp, pocossin, and baygalls, and more work is required to reduce the uncertainty. In 2013 use of LIDAR and soils suggests that raised peat accumulation typical of natural pocossins is uncommon on the Forest. Vegetation typical of pocossins may be found in association with nonriverine swamp forest or depression pond ecotones (not to be addressed here), and can also contain abundant pond pine.

Monitoring or designated botanical areas and associated at-risk species, including sweet pitcher plant, suggests that there have been declines in a subset of seepage bogs and pocossin ecotones, due to succession, lack of frequent fire, feral hogs, and poaching of associated pitcher plants (Everett 2012).

Fire Regime. Prescribed fire and flooding are the most important processes influencing the composition of these ecological systems. Natural fire return intervals for peatland pocossins are not well known, but are probably on the order of a decade or two in the wettest areas, though peripheral areas may be subject to fire as often as the surrounding vegetation burns, which may naturally have been an average of 3 years (Natureserve 2012). Openings created by prescribed fire, are important for many at-risk species. Streamhead seepage swamp, pocossin, and baygalls would have burned more frequently, particularly when imbedded within a landscape of fire-maintained vegetation. Everett (2012) recommended annual burning to restore herbaceous diversity at Morgan Creek Bog, and in pocossin ecotones.

Stressors and Threats

Feral hogs have been documented as threats, as has succession, lack of frequent or intense fire, poaching of associated pitcher plants, and diking or drainage on soils when wet potentially impacting hydrology. In the absence of prescribed fire, these ecosystems will succeed to tall pocossin, pond pine, and swamp forest ecosystems.

Carolina Bay Wetlands and Depression Ponds

Key Ecosystem Characteristics

Relative Ecosystem Abundance and Condition. The 1996 revised Forest plan contained an objective to, "[I]dentify and maintain existing acreage in pond cypress/swamp tupelo pond, and pond cypress and pine savannas…" and select Carolina bays and depression ponds were included as designated botanical areas. Bennett and Nelson (1991) identified only 30 Carolina bays in Berkeley County and 13 in Charleston County. De Steven and Harrison (2006) noted 187 natural depressions on the Forest of which nearly 50 percent were <1 acre in size. With the use of LiDAR Simon and Hayden (2013) identified 83 Carolina bays and 435 depression ponds within the Forest proclamation boundary.

Carolina bays and depression ponds are palustrine wetlands contain a variety of vegetation types depending on fire regime and flooding depth and duration. Bennett and Nelson (1991) identified nine community types in Carolina bays, including pocossins, pond cypress and swamp tupelo ponds, pond cypress savannas, and non-alluvial swamps, but in the lower coastal plain, pond cypress ponds and pond cypress savannas were most common. DeSteven (2006) found few herb-dominated depression ponds, and that most of them were forested.

Pond cypress savanna, depression ponds, limesinks, and pond cypress ponds are all vegetation types represented as designated botanical areas in the 1996 revised Forest plan, which occur within this group. Monitoring of many is threatened by successional vegetation, lack of frequent prescribed fire, feral hogs, and poaching of associated pitcher plants and orchids (Everett 2012; Glitzenstein 2012).

Landscape Connectivity and Fire Regime. Frequent prescribed fire is an important process for maintaining and restoring an herbaceous component within Carolina bays and depression ponds. Numerous depressional wetlands and Carolina bays are imbedded within Pleistocene terraces where fire would have occurred frequently, burning into the ecotones and often through the pond. Isolated wetlands and Carolina bays were historically protected from fire, and old firelines can still be seen within the ecotone. In the absence of frequent fire, particularly during periods of drought, isolated wetlands acquire an evergreen shrub component, and both loblolly pine and swamp tupelo can become establish, shading out the herbaceous understory.

Herbaceous Understory. Carolina bays and depression ponds provide critically important habitat for at-risk plant and amphibian species and rare plant communities. Much of the biodiversity is associated with the fire-maintained ecotones (Kirkman et al. 1998), but also as open water breeding habitat for amphibians. Pond cypress savanna vegetation is likely the most diverse (Gramling 2003; Bennett and Nelson 1991). Many at-risk species are associated with herbaceous understories, yet successional dynamics are poorly understood (Natureserve 2012). Climate change could lead to more forested and fewer herbaceous depressions, although the potential for more fires might be a counteracting force (De Steven and Toner 2004). Everett (2012) recommends annual burning, to restore herbaceous diversity along ecotones, interiors, and sand rims.

Stressors and Threats

Some of our cypress savannas and other depressions and Carolina bays on the Forest, particularly in the wildland-urban interface, have declined due to a combination of lack of frequent prescribed fire and drought leading to growth of a high density of tree species, including loblolly pine, which further draws down the water table and outcompetes herbaceous ground cover (Everett 2012; Glitzenstein 2012). Everett (2012) and Glitzenstein (2012) note feral hog damage in many or our depression ponds and Carolina bays associated with at-risk plants, and Chinese tallow has been observed within some of our depression ponds. With changes in climate, annual temperature and drought frequency are expected to increase which could favor succession to forests in these ponds (Stroh et al. 2008). Other threats to depression ponds and Carolina bays on the Forest include illegal all-terrain vehicle use in proximity to Halfway Creek Road.

Of 2,651 Carolina bays identified by Nelson and Bennett, the majority (15 percent) were in Horry County, and of those sampled, 97 percent exhibited some type of disturbance. At the landscape scale, Carolina bays and depression ponds that receive surface water and ground water from surrounding uplands may be most sensitive to land disturbances and climate change (Lu et al. 2009).

Maritime Forests, Saltwater and Freshwater Marsh

Key Ecosystem Characteristics

Relative Ecosystem Abundance and Condition. The 1996 revised Forest plan contained an objective to, "[I]dentify and maintain existing acreage in maritime forest. Only a coastal fringe of maritime forest is identified through current mapping efforts in 2013 (416 acres), and both freshwater marsh and saltwater marsh were relatively uncommon (0 and 2,568 acres). Salt marsh and freshwater marsh ecosystems were not addressed in the 1996 revised Forest plan. Several areas containing maritime fringe and salt marsh have been acquired by the Forest since 1996 in the vicinity of Guerin Bridge Road, much in bedded loblolly pine (Porcher 2005). One maritime forest containing habitat for the sensitive *Agrimonia incisa* was included as a designated botanical area, though monitoring suggests the site is threatened by dense canopies of loblolly pine (Everett 2012).

Structural Diversity and NRV. We compared vegetation classes from the biophysical settings models (Biophysical Setting 5813610–Central Atlantic Coastal Plain Maritime Forest), including age class and structural breakouts to define each class, to those found on the Forest using Forest FS VEG even-aged age class data, and LIDAR shade data to quantify canopy opening. Maritime forests on the Forest have a higher percentage of early succession and in mid-closed conditions and less in late-closed conditions than would be expected compared to reference. This is in part due to the severity of Hurricane Hugo which relatively recently impacted the Forest.

Table 2-16. Structural ecological departure rankings for maritime forests on the national forest, where low=0–33%, medium=34–66%, and high=67–100% levels of departure

Eco-logical System	Early-Class A		Mid-Closed		Mid-Open		Late-Closed		Late-Open		Eco-logical Depar-ture
	Current	Predicted	Current	Predicted	Current	Predicted	Current	Predicted	Current	Predicted	
Maritime Forest	20	7	45	22	8	7	0	13	12	51	52

Old Growth. There is no maritime forest that qualifies as possible old growth.

Stressors and Threats

Many of our maritime fringe forests are threatened by past management practices which included ditching and diking for the production of rice (Porcher 2005), planting of loblolly pine, nonnative invasive species, and hurricanes. In the future, they are the most likely to be threatened by sea-level rise and climate change.

2.1.1.7 Information Needs

Future trends in existing ecosystems and in their condition, including herbaceous understory communities.

Refinements of LANDFIRE biophysical models would be useful which address old growth and nonriverine swamp forests vegetation, relevant to ecosystems on the Francis Marion National Forest.

Suitable methods could be identified for restoring wet pine savanna and flatwoods, mesic slope forests, dry and dry mesic oak forests, maritime forests, depression ponds, and Carolina bays.

Monitoring indices for assessing ecosystem integrity of all our ecosystems are needed which are practical, reliable, and address trends in key ecosystem characteristics.

2.1.1.8 Levels of Uncertainty

The ecological model used in this analysis is a first draft. Monitoring information in regard to the condition of terrestrial ecosystems is generally very limited.

2.1.2 Aquatic Ecosystems

2.1.2.1 Preliminary Findings

▶**The 1996 Francis Marion Forest Plan has limited direction on the viability of aquatic species and communities, aquatic habitat, and riparian area management.** In addition, the plan allows the removal of wood from streams through South Carolina's Best Management Practices for Forestry (2003). Most streams and riparian areas were not recognized as aquatic ecosystems and were included in management area 27, which is suitable for timber management. The 2012 Planning Rule requires better direction associated with aquatic ecosystems.

▶**In a recent inventory of prescribed burning effects on large wood loading on the Forest, data revealed that in over 20 kilometers of headwater stream sections, the largest, most stable instream wood was deficient (USDA SRS Center for Aquatic Technology Transfer, Draft).** Instream habitat diversity is dependent on large wood input from the riparian area.

▶**The National Hydrography Database represents far less stream miles than the new remote sensing technology of LIDAR.** The LIDAR mapping for the Forest is somewhat inconsistent due to the lack of road culvert location data and other stream barriers. Existing riparian mapping is based on soil indicators and 29-acre catchment areas and may exclude some headwater streams. Designation of riparian areas, acres of riparian area, and density of roads within riparian areas are likely to change as a more accurate stream layer map becomes available.

▶**Threats to aquatic habitats include stream flow modification, sedimentation and water quality modification from roads and trails, dams, drought and forestry management practices.**

▶**There has been very little change in fish diversity in headwater streams across the Forest over the sampling years.** Headwater stream sampling was conducted in 1993 and repeated five times from 2002 to 2010 across ten watersheds on the Forest. Thirty-five species were captured in the 1993 inventory. Thirty-seven species were captured in the 2002 to 2010 samples. Fish abundance recorded in 2010 was noticeably less than in previous inventory years, most likely due to drought conditions (Krause and Roghair 2010).

►**Existing population conditions and trends are unknown for crayfish and mollusk.** Crayfish and mollusk surveys were conducted across all Forest watersheds in 2011. A total of 84 streams was sampled for crayfish. Crayfish were collected in 72 of these streams. A total of 38 streams was sampled for mollusk species. Mollusk species were found in 26 streams. Thirteen mussel species, three clam species and eight snail species were collected in 2011. The Catena Group report (2011) concluded that mussel diversity was low within stream reaches on the Forest, which is considered typical of tannic, swamp water streams along the Atlantic Slope. However, a few streams characterized as having wide, natural riparian buffers contained very high densities of mussels.

►**Of the 28 aquatic nuisance species listed by the South Carolina Aquatic Invasive Species Management Plan (2008), 8 are known to occur on the Forest. SCDNR reports that there has been an increase in plant and animal nuisance species in freshwater and marine habitats and are already impacting native animals and their habitats.** The SCDNR climate report (http://www.dnr.sc.gov/pubs/CCINatResReport.pdf), also states that as climate changes, an increasing number of nuisance species likely will migrate to South Carolina. In the event that water temperatures were to increase in the State, existing nuisance species that are sensitive to cooler water temperatures may have better survival rates and proliferate.

2.1.2.2 Direction in the 1996 Francis Marion Forest Plan

Forest Wide Goal G-7 Protect and Manage Habitat for Sustainable Populations of Native Wildlife (page 1-2, Forest plan) "The Francis Marion is home to many different species of wildlife. Our goal is to provide for wildlife resource needs while servicing public interests and uses through habitat management that supports viable populations of all existing native wildlife species and where opportunities exist, to enhance habitat for populations of animals that are commonly viewed, photographed, hunted or fished."

Forest Desired Future Condition, Soil and Water (page1-5, Forest plan) "The streams, ponds, wetlands, and riparian areas of the Forest reflect healthy, functioning ecosystems. Natural woody debris is found in streams. This debris serves an important ecological function. It maintains channel stability, stores and routes sediment, and provides habitat requirements for anadromous and resident fish. Riparian areas with diverse stands of trees provide streamside vegetation that helps to maintain stream temperatures needed for fish habitat. High water quality is maintained and in some cases improved. Streams have little sediment because of careful management of timber harvest activities, roads, and similar soil disturbing activities. Aquatic ecosystems remain intact and serve as habitat for a variety of fish and invertebrates. Wetlands are protected and continue to serve as vital functioning ecosytems".

Forest Desired Future Condition, Wildlife and Fisheries (page 1-7, Forest plan) "High-quality aquatic habitat is maintained. Streams and ponds are relatively free from sediment. Tessellated darters and speckled madtoms are common. High populations of popular game fish such as the largemouth bass and redbreast sunfish ensure ample fishing opportunities. Both anadromous and resident fish populations are thriving."

Forest Objective O-13 (page 2-2, Forest plan) "Maintain or expand existing proposed, endangered, threatened and sensitive (PETS), and Management Indicator Species and communities (MIS)."

Forest Objective O-15 (page 2-2, Forest plan) "On managed Forest ponds, sustain 200-300 pounds/acre of bass and bluegill at a ratio of 1:6 bass to bluegill."

Forest Standards and Guidelines, Insects and Diseases, FW-70 (R8-SPB) (page 3-7, Forest plan) "Riparian ecosystems that encompass floodplains and wetlands will receive appropriate protection. As a minimum, riparian areas will extend 100 feet from the edge of all perennial streams and other perennial water bodies, including lakes. Site investigations to identify riparian areas and floodplains will consider the soil and plant characteristics of the site, and will be guided by appropriate Forest Service direction and state requirements. Roads that cross riparian areas will be stabilized with rip-rap, vegetative establishment, or other appropriate methods."

Forest Standards and Guidelines, Soil and Water, FW-97 (R8-VM) (page 3-10, Forest plan) "Mechanical equipment is not allowed in any defined stream channel except to cross at designated points, and may not expose more than 10 percent mineral soil in filter strips along lakes, perennial or intermittent springs and streams, wetlands, or water-source seeps. The strip's width in feet is at least 30 plus 1.5 times the percent slope. Soil and debris are not deposited in lakes, streams, wetlands, springs, or seeps."

Forest Standards and Guidelines, Soil and Water, FW-99 (R8-VM) (page 3-10, Forest plan) "Channel stability of perennial and intermittent streams is protected by retaining all woody understory vegetation within at least 5 feet of the bank and by keeping slash accumulations out of the stream."

Forest Standards and Guidelines, Soil and Water, FW-100 (R8-VM) (page 3-10, Forest plan) "No herbicide is aerially applied within 100 horizontal feet, nor ground-applied within 30 horizontal feet, of lakes, wetlands, or perennial or intermittent springs and streams. No herbicide is applied within 100 horizontal feet of any public or domestic water source. Selective treatments (which require added site-specific analysis and use of aquatic-labeled herbicides) may occur within these buffers only to prevent significant environmental damage such as noxious weed infestations. Buffers are clearly marked before treatment so applicators can easily see and avoid them."

Forest Standards and Guidelines, Soil and Water, FW-101 (page 3-10, Forest plan) "Avoid construction (roads, trails, recreational sites, etc.) in floodplains and wetlands whenever there is a practical alternative."

Forest Standards and Guidelines, Soil and Water, FW-107 (page 3-11, Forest plan) "Avoid direct application of fertilizer to water bodies including streams (unless prescribed for wildlife habitat improvement)."

Forest Standards and Guidelines, Soil and Water, FW-109 (R8-VM) (page 3-11, Forest plan) "In each project, water quality is protected from nonpoint-source pollution through use of preventive "best management practices" (BMP's). Implementation of BMP's, monitoring and evaluation of their application and effectiveness, and adjustment of practices as needed are done to protect beneficial water uses and comply with State water quality laws. BMP's are applied to all activities. In each project, site-specific conditions must be assessed, and the BMP's needed to meet state water quality standards must be employed."

Forest Standards and Guidelines, Soil and Water, FW-115 (page 3-11, Forest plan) "Maintain a near continuous (unbroken) canopy of vegetation for 30 feet on both sides of perennial streams and water bodies. Resource management activities may be implemented if riparian conditions are maintained or improved and the natural supply of large woody debris into the streams and water bodies is not impaired.

Timber harvest methods that ensure a residual basal area of 50 percent can be utilized when managing a zone from 40-70 feet on perennial streams and water bodies and 40 feet on either side of intermittent streams. Use of mechanical equipment will be limited to protect the riparian and water resources. Additional zones adjacent to riparian areas and ephemeral streams can be established as necessary to meet site specific conditions and management objectives. The width of the zones will depend on slope, vegetation and soil conditions. These zones will be managed to protect soil and water resources by the types of management activities in these zones and controlling the use of equipment."

Forest Standards and Guidelines, Wildlife and Fisheries, FW-154 (page 3-16, Forest plan) "Lime and fertilize managed ponds based on established procedures to meet the management indicator objectives for fisheries."

Management Area Prescription 27 (page 4-13, Forest plan) "This area includes portions of the loamy ridges/flats, river/creek bottoms and swampy flats. This management area includes areas of the Forest containing a network of creeks, streams and transitional areas where there is a potential for developing mixed stands and high quality mast and timber producing hardwoods."

2.1.2.3 Aquatic Ecosystems on the Francis Marion National Forest

Aquatic ecological systems are stream and lake networks representing a range of areas with distinct geomorphological patterns tied together by similar environmental processes such as hydrologic, nutrient, and temperature regimes. They form a distinct unit or hydrography map. Freshwater ecosystem attributes such as water-body size, hydrological and temperature regime, chemistry, drainage network position, local connectivity, elevation, and gradient can result in distinct aquatic assemblages and population dynamics between and within streams and lakes (Palmer et al. 2005). Streams and rivers are considered together as an aquatic ecosystem for this analysis given the similarity of the hydrology, water quality, habitat and biota across 6th-level hydrological watersheds on the Forest. Lentic systems are considered as a separate aquatic ecosystem for this analysis.

Streams and Rivers

Coastal plain stream systems consist of rivers that often originate in the Blue Ridge or Upper Piedmont and blackwater streams that originate in the Coastal Plain or Lower Piedmont (McDougal et al. 2001). Tannic stained blackwater streams are the most common stream type on the Francis Marion National Forest and originate in the Coastal Plain, primarily on the Forest itself. The Santee River borders the north end of the Forest and originates in the mountain region of South Carolina. The West Fork Cooper River is adjacent to the southern border of the Forest and headwaters partially on the Forest but completely in the Coastal Plain. For this assessment, streams and rivers include fresh, tidal and brackish flowing waters. Streams and rivers are in the process of being mapped and it is possible that watershed boundaries may be adjusted through the mapping process.

Lentic Systems

Lentic systems are water bodies of non-flowing water. On the Forest, aquatic species inhabit ponds, swamps, ditches, springs, wetlands, marshes, Carolina bays, sloughs, and oxbows. These include fresh and brackish waters and can be influenced by flooding and tidal waters. Ponds are primarily borrow pits excavated for road construction that are stocked and managed for recreational fishing opportunities. There are 15 recreational fishing ponds on the Francis Marion consisting of a total of 41 acres. Ditches are also man made and occur across the Forest, but are primarily located along roads. Crayfish species utilize the road ditches as well as some fishes, such as pygmy sunfish species. The remaining lentic systems are nested within the various terrestrial ecosystems (see section 2.1.1 “Terrestrial Ecosystems”).

2.1.2.4 Habitat Structure

Coastal Plain blackwater streams are low-gradient warm water streams consisting primarily of pool habitat and very little riffle habitat. They are tannic stained and generally exhibit very slow flows, although larger streams may have moderate currents. These stream systems lack the turbidity of systems that originate outside the Coastal Plain area. Stream substrate is primarily sand or organic soils prone to displacement during storms. There is very little rock substrate in these streams, therefore logs and debris piles are essential for aquatic fauna habitat. Wood is an important component to instream habitat for aquatic species refuge, foraging areas and food and also hydrological functions (McDougal et al. 2001). Most coastal plain streams that receive ample sunlight are well vegetated with aquatic macrophytes. These streams are often associated with lentic backwaters and swamps (http://www.dnr.sc.gov/cwcs/pdf/habitat/CoastalPlainAquatics.pdf). The Santee River is classified as a brown-water stream with turbid waters and generally more sediments. Flows vary in the river associated with hydroelectric dam management upstream of Forest lands and downstream from tidal cycles. Streams are primarily freshwater, but some tributary streams of the Santee, West Cooper, and Wando rivers contain brackish waters during tidal cycles. Streams and rivers on the Forest typically have access to their floodplain, but many have been affected by channelization, ditching, and dikes that limit or control flooding and water movement. Floodplains are discussed in more detail in section 2.4 “Water Resources and Quality”.

Recreational fishing ponds consist of sand and organic substrates and aquatic vegetation. These ponds were formed from old borrow pits created for road construction materials. Pond habitat is enhanced manually with brush and trees. The ponds are periodically limed to improve the water quality associated with aquatic productivity. Ditches contain vegetation which provides cover and foraging areas for a variety of aquatic species. Road ditches are maintained through maintenance which diminishes the vegetative habitat for short periods of time.

2.1.2.5 Habitat Connectivity

The physical structure of aquatic habitats is a major factor in the continuity between and heterogeneity within aquatic habitats that supports the local diversity of fauna and flora. Connectivity of streams with rivers and of streams and rivers with floodplains are a basic characteristic of aquatic systems that is fragmented by such barriers as dams and inadequate road and trail crossings. The physical configuration of streams and rivers provides a rich diversity of habitats such as banks, riffles, and deep pools where fish and other fauna feed, rest, and breed. Alterations to the hydrologic and energy regimes of streams or rivers affect the physical structure of aquatic habitats (Palmer et al. 2005).

The Santee Dam hinders the migrations of native anadromous fish to their historic spawning grounds in the piedmont. These include shad, striped bass, and sturgeon. In addition to the large dam on the Santee River, there are numerous smaller dams and dikes throughout Forest watersheds that are barriers to fish movement. These smaller dams also create impoundments in natural stream systems. This results in a loss of habitat through the conversion of lotic habitat to lentic habitat, which favors competitive and often predacious species like largemouth bass and other centrarchids. Stream habitat below impoundments can be impacted through altered hydrology and water temperatures, modified stream channel morphology, and increased erosion and sedimentation. These impacts reduce suitable habitat for native aquatic fauna (http://www.dnr.sc.gov/cwcs/pdf/habitat/CoastalPlainAquatics.pdf). Dams are present in each of the 28 subwatersheds that contain Forest Service land. The number of dams range from 1 to 216 in a single watershed with the majority of watersheds containing more than 10 structures (Francis Marion and Sumter National Forests GIS 2013).

Hydrological modifications impacting stream systems on the Forest also include road and trail crossings. Roads act as dikes and block or alter the natural flow of floodplains and swamps. Aquatic passage exists with road bridge crossings, but no aquatic organism passage surveys have been conducted on the over 500 miles of Forest Service roads on the Forest. Additional crossings occur on private lands and on over 200 miles of state and Federal roads in Forest watersheds. Connectivity may occur between streams during periods of rain through road ditches. Connectivity is greatest during high rainfall years when the Forest floods. Road density ranged from 0.55 to 5.97 miles per square mile; with four watersheds containing less than 2 road miles per square mile and 24 watersheds having greater than 2 road miles per square mile. Eight watersheds contained greater than 3 road miles per square mile. Within 100 foot riparian areas, four watersheds had less than 1 percent in total acres of road and 24 watersheds had greater than 1 percent in total acres of road. Riparian area road acres ranged from 0.58 percent to 4.27 percent.

Recreational fishing ponds are completely contained with no connection to each other or to stream systems. Many road ditches connect streams. These ditches are often deep and wide and when filled with water may provide a conduit for aquatic species movement from one stream to another.

2.1.2.6 Threats and Stresses

A threat is an unacceptable alteration to any of the key ecological attributes necessary to support aquatic system function (hydrological and energy regime, physical habitat structure, water quality and biota). A stress is that activity leading to the unacceptable alteration such as damming of rivers and streams, and excessive siltation and contaminants from practices associated with development, agriculture, forestry and mining. A single threat can have multiple stresses (Palmer et al. 2005). Threats and stresses are addressed in relation to habitat and species for this analysis. Stream flow modification, sedimentation, and water chemistry modification are the most prevalent threats to aquatic ecosystems on the Forest. Several stressors are present for each of those threats and discussed below.

Habitat Threats

Stream Flow Modification. Stream flow modification causes changes in the pattern of flow that is characteristic for a stream or river. Due to watershed characteristics such as slope, soil type and precipitation patterns, there is a typical season, frequency, duration, magnitude, and rate of change of water level fluctuations. Hydrologic regimes are a driving factor in aquatic ecosystems. Activities that create barriers to flow, excessive withdrawals or discharges of water, or in other ways alter the pattern of flow are threats to aquatic habitats (Palmer et al. 2005). These activities or stresses are identified as roads and trails, dams, drought, and forestry management practices for Forest aquatic systems.

Sedimentation. Siltation resulting from clearing forests, tilling soils and channelization of coastal plain streams has altered stream morphology. Modern soil conservation practices and reduced channelization have reduced those impacts, but sedimentation from nonpoint and point sources remains a significant detriment to streams today. Ground disturbance from development, agriculture, and silviculture are primary sources of erosion that lead to sedimentation in streams. Stream bank erosion due to loss of riparian areas, livestock grazing and altered hydrology also contribute to sedimentation in streams. During the past century, many streams in the coastal plain were channelized to improve drainage of croplands. The result of channelization changed many streams into straight shallow ditches with severely depressed populations of aquatic fauna (http://www.dnr.sc.gov/cwcs/pdf/habitat/CoastalPlainAquatics.pdf). Stresses identified for sedimentation on the Forest include roads and trails and forestry management practices.

Water Chemistry Modification. Good water quality is critical to the sustainability of aquatic biota. Temperature, dissolved oxygen concentration, acidity, and salinity are common attributes of natural water quality conditions that are affected by water management structures and polluted discharges. Some constituents in the water, such as sediments, heavy metals and nutrients, may occur in low levels in natural systems, but they are usually considered pollutants when concentrations rise above biologically tolerable levels. Chemicals such as pesticides, hormones, and petroleum products are not found in natural systems and their presence indicates threats to aquatic habitats from inadequate enforcement of permitted discharges and improperly managed stormwater runoff (Palmer et al. 2005).

The coastal plain has a modest amount of permitted discharges and concentrated animal feeding operations which are a significant threat to aquatic habitats. Water quality in the coastal plain at sites sampled by the South Carolina Department of Health and Environmental Control (SCDHEC) has the highest impairment rate of the four ecoregions in the state. Recreational uses were impaired at some sites sampled due to the presence of high concentrations of fecal coliform bacteria. Approximately one-fourth of streams sampled by SCDHEC within the ecoregion did not support aquatic life uses, indicating the streams do not possess sufficient water quality to maintain a balanced aquatic community of plants and animals. Mercury contamination is abundant in the coastal plain. This contamination indicates a serious threat not only to aquatic fauna but also to human health and recreational uses. Fish consumption advisories have been issued for nearly every major water body in the Coastal Plain due to mercury contamination in fish tissue sampled by SCDHEC (http://www.dnr.sc.gov/cwcs/pdf/habitat/CoastalPlainAquatics.pdf). Stresses for water chemistry modification on the Forest are identified as dams, drought, and forestry management practices.

Habitat Stresses

Roads and Trails. Roads and trails are identified as stresses for stream flow modification and sedimentation. Stream road crossings can create barriers to aquatic organism movement, effectively fragmenting linear habitat. They also can affect channel morphology and geomorphic processes, causing incision and erosion. Road crossings change the natural shape of the stream and how the stream is allowed to flow through the barrier. This has the potential to affect sediment transport and deposition and the movement and migration of aquatic species (http://ice.ucdavis.edu/waf/model/indicator/aquatic-habitat-barriers).

Roads, recreational trails, and mechanical fire lines within riparian areas and floodplains are constant sources of sediments to stream systems. Maintenance practices, undersized culverts, use of fords and rotation cycle disturbance of fire lines increase sediment input. Road density in riparian areas and in watersheds was discussed under “Habitat Connectivity.”

Dams. Dams are identified as a stress for stream flow modification and water chemistry modification. Dams are discussed in this section under “Habitat Connectivity.”

Drought. Drought is identified as a stress for stream flow modification and water chemistry modification. Drought in streams may be viewed as a disturbance in which water inflow, stream flow and water availability fall to extremely low levels for extended periods of time. Impacts can range from flow reduction to loss of surface water and stream connectivity. This results in loss of habitat for aquatic organisms. Other impacts may include deterioration of water quality, alteration of food sources, and changes in the strength and structure of interspecific interactions. Droughts have effects on density and diversity of aquatic communities and the ecosystem processes that support them. Organisms can avoid some drought conditions by the use of refugia such as deeper pool habitat or spring fed areas (Lake 2003). Streams on the Forest have been under the stress of summer drought over the past decade. Observations of small headwater streams include completely dry stream beds to stream beds with some amount of water in deeper pool habitats. These areas are often confined to excavated areas around bridges and culverts. With increased rainfall, aquatic organisms move back upstream as stream flows increase and connectivity is reestablished.

Water withdrawal for irrigation is a common practice in the ecoregion. With the rapidly increasing populations along the coast, demand for freshwater will increase dramatically and water withdrawal from streams and rivers as well as interbasin water transfers will be a serious threat to aquatic habitats and their natural communities (http://www.dnr.sc.gov/cwcs/pdf/habitat/CoastalPlainAquatics.pdf).

Forestry Management Practices. Forestry management practices have been identified as a stress for stream flow modification, sedimentation, and water chemistry modification. Forestry practices can impair aquatic habitat through the manipulation of riparian vegetation. Loss of canopy results in increased water temperatures that will limit the amount of available habitat for some species like striped bass (http://www.dnr.sc.gov/cwcs/pdf/habitat/CoastalPlainAquatics.pdf). Large wood, detritus and leaf litter recruitment is also compromised with the loss of canopy resulting in a decrease of instream habitat complexity and macroinvertebrate food sources. Removal of riparian vegetation and disturbance within riparian areas can lead to erosion and chemical inputs to surface and ground waters. Incompatible forestry practices also include those that convert the natural architecture, composition, and structure of riparian habitats and their watersheds to even-aged, monocultures of off-site species (Palmer et al. 2005).

Fire is used as a tool on the Forest to maintain red-cockaded woodpecker pine habitat and to reduce fuels. Streams are used a natural fire breaks and riparian areas are burned. This often leads to the charring and loss of large wood within stream channels, particularly where riparian areas are small and during drought years when streams are burned over. Impacts on canopy cover within burned riparian areas have not been assessed. Fire lines are occasionally mechanically constructed across streams and through riparian areas.

2.1.2.7 Species Threats and Stresses

The aquatic biota in a stream is a function of the habitat conditions outlined above, as well as the successful completion of life cycles and sustainable populations. Sources of stress that alter the abundance and diversity of species or the interactions among species include factors that do not necessarily directly alter aquatic habitats. For example, invasive species are a very serious threat to aquatic biota (Palmer et al. 2005).

Aquatic Nuisance Species

Introductions of nonnative species have had a significant impact on native aquatic fauna in the Coastal Plain Ecoregion. Common carp, flathead catfish, and blue catfish are established in several drainages. Flathead catfish are known to prey on bullheads, darters, shad, suckers and sunfish. Declines in native species have been observed after the introductions of flathead catfish. Common carp occur in every South Carolina drainage and are considered a pest, but their impact on native fauna is not well known. Common carp disrupt aquatic habitats by rooting around in the substrate, which uproots aquatic plants and increases turbidity and siltation. Common carp have also been shown to prey on the eggs of other fish species (http://www.dnr.sc.gov/cwcs/pdf/habitat/CoastalPlainAquatics.pdf). Grass carp are used as biological control agents for nuisance aquatic vegetation in South Carolina. This species is regulated and tested by the SCDNR as they are brought in by growers from other states. Only triploid grass carp are permitted. This insures that they are sterile and cannot reproduce if escapement occurs (South Carolina Aquatic Invasive Species Management Plan 2008). No reproducing populations of grass carp occur on the Forest, but sterile grass carp have been stocked in the past to control aquatic vegetation in recreational fishing ponds.

The Asian clam has been introduced and has widely spread throughout the United States, including South Carolina. The effects of the Asian clam on native species are not particularly well understood. Three invasive snail species (*Viviparus georgianus*, *V. purpureus*, and *Bellamya/Cipangopaludina japonica*) are present in Lakes Marion and Lake Moultrie just west of the Forest; however, their impact on native fauna is not known (http://www.dnr.sc.gov/cwcs/pdf/habitat/CoastalPlainAquatics.pdf). The island applesnail has been found in the South Carolina coastal plain, but not yet reported from the Forest. Potential impacts of introduced populations of the island applesnail are broad reaching and can even have human health implications. Because they eat such a wide range of aquatic plants, they are a potential threat to South Carolina aquatic ecosystems. Infestations can be very dense and cover large areas, causing harm to the aquatic environment by destroying native plant species and drastically affecting the food web through their ability to kill or out-compete native snail species (http://www.dnr.sc.gov/water/envaff/aquatic/snail.html).

The red swamp crayfish has been introduced to South Carolina and has been observed at several locations in the southeastern plains and coastal plain, but it is unclear how widespread it is in the State. The lack of survey work since its introduction and the difficulty distinguishing the red swamp crayfish from a native crayfish (eastern red swamp crayfish) have made it particularly difficult to determine the extent of its introduced range (http://www.dnr.sc.gov/cwcs/pdf/habitat/CoastalPlainAquatics.pdf). It is possible that the red swamp crayfish occurs on the Forest, and it would be expected to occur in the types of habitat where the Eastern red swamp crayfish has been collected. The two are very closely related species and have similar habitat requirements. The red swamp crayfish has been introduced as an aquaculture species within the range of Eastern red swamp crayfish in South Carolina, but little is known about the distribution of escaped the red swamp crayfish populations in South Carolina (Jones and Eversole 2011).

Alligatorweed is found throughout South Carolina. It spreads rapidly by fragmentation. Alligatorweed displaces native vegetation, and disrupts navigation, recreation, and water flow by the formation of impenetrable mats. It decreases uptake for agricultural, municipal, and industrial purposes and expands human health risks with increases in mosquito breeding habitats. Alligatorweed has been documented from one recreational fishing pond on the Forest (Bales 2009). Water primrose is found throughout the State in man-made impoundments, but is most problematic from the Fall Line to the coast. There are problem populations in Back River Reservoir, Goose Creek Reservoir, and the Santee Cooper lakes. Water primrose is an emergent perennial that grows to 3 feet tall, but its stems may be many feet long when floating on the water. This shoreline plant is very difficult to control due to extensive underground rhizomes. Unlike most shoreline species, new shoots can float on the water surface and extend far from shore. Adverse impacts include restricted public access to waterways and use of shoreline areas, impaired navigation in small channels, restricted water flow, formation of free-floating mats, and clogging of water intakes. Water primrose has been documented from one recreational fishing pond on the Forest (Bales 2009). Phragmites is more commonly found in freshwater impoundments along the coast and in estuaries and marsh ecosystems. It is not good waterfowl food and it outcompetes native plants that provide food and habitat for waterfowl (South Carolina Aquatic Invasive Species Management Plan 2008). Phragmites has been documented on the Forest (Robin Mackie, *personal communication*).

The Asian tiger mosquito now occurs statewide. This species is a competent vector of many viruses including dengue fever, Eastern equine encephalitis, potentially St. Louis and La Crosse encephalitis, as well as dog heartworm. The life cycle of this species is closely associated with human habitat and it breeds in containers of standing water. It is a very aggressive daytime biter with peaks generally occurring during early morning and late afternoon. It feeds on a number of hosts, including man, domestic, and wild animals. Its generalized feeding behavior contributes to its vector potential (South Carolina Aquatic Invasive Species Management Plan 2008).

The following table contains a list of aquatic nuisance species that either occur or may occur in the future on the Forest (South Carolina Aquatic Invasive Species Management Plan 2008).

The USDA Forest Service Southern Region Aquatic Nuisance Species Strategy, Aquatic Animals (Leftwich 2013) provides guidance for managing nuisance species and supports the South Carolina Aquatic Invasive Species Management Plan 2008. State agencies are recognized as the lead agency in controlling the establishment of aquatic nuisance species and managing established aquatic nuisance species both on and off the Forests.

Table 2-17. Occurrence of nuisance species on the Francis Marion National Forest

Aquatic Nuisance Species		Forest Occurrence	
Common Name	**Scientific Name**	**Present**	**Future Potential**
Fish			
Spotted bass	*Micropterus punctulatus*		x
Flathead catfish	*Pylodictis olivaris*	x	
Blue catfish	*Ictalurus furcatus*	x	
Green sunfish	*Lepomis cyanellus*		x
Northern snakehead	*Channa argus*		x
Asian swamp eel	*Monopterus albus*		x
Silver carp	*Hypopthalmichthys molitrix*		x
Bighead carp	*Hypophthalmichthys nobilis*		x
Black carp	*Mylopharyngodon piceus*		x
Grass carp (non-triploid)	*Ctenopharyngodon idella*		x
Mammals			
Nutria	*Myocastor coypus*		x
Red-eared slider	*Trachemys scripta elegans*		x
Plants			
Hydrilla	*Hydrilla verticillata*		x
Water hyacinth	*Eichhornia crassipes*		x
Phragmites	*Phragmites australis*	x	
Water lettuce	*Pistia stratiodes*		x
Giant salvinia	*Salvinia molesta*		x
Alligatorweed	*Alternanthera philoxeroides*	x	
Brazilian elodea	*Egeria densa*		x
Water primrose	*Ludwigia uruguayensis*	x	
Insects			
Asian tiger mosquito	*Aedes albopictus*	x	
Asian mosquito	*Ochlerotatus japonicus*		x
Crustaceans			
Red swamp crayfish	*Procambarus (Scapulicambarus)clarkii*		x
Mollusks			
Viviparid snail	*Viviparus subpurpureus*		x
Viviparid snail	*Bellamya japonica*		x
Island applesnail	*Pomacea insularum*		x
Zebra mussel	*Dreissena polymorpha*		x
Asian clam	*Corbicula fluminea*	x	

Aquatic Nuisance Species and Climate Change. Increased temperatures, changes in rainfall and other environmental factors affected by climate shifts or change can create ideal conditions for proliferation of invasive plant and animal species, including parasites and pathogens. An increase in the number and diversity of native and non-indigenous invasive plant and animal species has been documented in South Carolina terrestrial, freshwater, and marine habitats. Some of these species may have been released accidently, but others are likely migrating northward from more tropical climates as a result of warming temperatures. Regardless of the manner in which they have become established, these species already are impacting native animals and their habitats. As climate changes, an increasing number of exotic species likely will migrate to South Carolina. Habitats can be destroyed as resources are over-utilized. Invasive and non-indigenous species have the potential to outcompete native species for food and other resources.

Tilapia is a warmwater, non-indigenous group of fish that extensively are stocked under permit in the State to control algae in private ponds. With few notable thermal refuges excluded, tilapia will die from cold stress in a typical South Carolina winter when water temperatures drop below 50 °F (10 °C). Historically, south coastal South Carolina water temperatures routinely drop to 45 to 50 °F (7 to 10 °C) during the winter. Tilapia could overwinter in the State if waters were to become warmer. Tilapia currently overwinters in Florida and has become an invasive species and a major management problem. If tilapia were to routinely overwinter in South Carolina it would result in direct competition with native and existing species for space, food, habitat and spawning areas, which could drastically alter natural fish communities. The destruction that non-indigenous peacock bass (*Cichla* spp.) can cause to native fish communities is well documented. In Florida, these fish currently are widespread, but are very temperature dependent and do not typically survive in waters cooler than 60 °F (16 °C). Given current South Carolina winter low temperatures, tilapia is much more of an eminent threat than peacock bass. However, if winter temperatures increase, peacock bass could become a threat in South Carolina. Other invasive fish that are common in Florida and could become established in South Carolina include various cichlids, pleco (*Hypostomus plecostomus*), Asian swamp eel (*Monopterus albus*), walking catfish (*Clarias batrachus*), various piranha and oscar (*Astronotus ocellatus*). All of these fish could, like tilapia, compete with native species for habitat, food and spawning resources (http://www.dnr.sc.gov/pubs/CCINatResReport.pdf).

The primary threats to lentic systems include sedimentation and water chemistry modification. Stresses include roads, drought, forestry management practices, and aquatic nuisance species. Road maintenance decreases vegetative growth in ditches where aquatic species forage and find refuge. Sediments are also added to the ditches with road grading activities. Impacts from forestry management practices are similar to those discussed for streams and rivers. Both plant and animal aquatic nuisance species can have huge impacts on contained pond systems where native species have no escape route. Drought conditions have been prevalent over the past decade on the Forest impacting pond water levels, water quality and populations.

2.1.2.8 Key Ecosystem Characteristics

Key ecological attributes for aquatic systems fall into these general categories: hydrological and energy regime, physical habitat structure, water quality and biota. These attributes constitute the critical components of aquatic system function. Any missing or altered characteristics would result in the loss of system function over time (Palmer et al. 2005). For this assessment, the key ecosystem characteristics are biological, physical (hydrological function, instream habitat, riparian areas) and chemical (water quality).

Biological

There are 73 species of fish that range in streams and rivers on the Forest. Some are entirely freshwater species, while others move between brackish and freshwater habitats and marine and freshwater habitats. There are an additional 37 marine, estuarine or anadromous fishes that have been recorded in tidal freshwaters of South Carolina (Rohde et al. 2009). There are five known crayfish species occurring on the Forest (Jones and Eversole 2011). All of these species occur in flowing waters as well as a variety of lentic habitats. Twenty-four mollusk species are known to occur within Forest waters, all but two recorded in streams or rivers (The Catena Group 2011). There is little known about aquatic insect populations on the Forest.

Fish inventory sampling in Francis Marion headwater streams was conducted in 1993 by Hansbarger and Dean (1994). A total of 53 stream sites was sampled across the Forest post Hurricane Hugo, yielding 35 fish species. Stream monitoring efforts in some of these same streams were conducted for 5 years between 2002 and 2010. Repetitive sampling in streams varied from year to year due to drought conditions or above average rainfall. Dry stream channels were encountered with drought and below average rainfall. Stream channels were indiscernible with the swampy conditions produced by above average rainfall during one sampling year. Thirty-five of the original stream sites have been resurveyed, along with the 2 additional headwater streams, yielding 37 fish species. Nine species captured in 1993 were not present in later sampling years. Nine different species captured in later sampling years were not present in the 1993 sampled streams. Fish abundance recorded in 2010 was noticeably less than in previous inventory years, most likely due to drought conditions (Krause and Roghair 2010). The number of species captured by watershed is displayed in Table 2-18.

Table 2-18. Table number of fish species captured per Forest watershed.

Watershed	Species Captured					
	1993	2002	2003	2004	2006	2010
Awendaw Creek	12	14	NS[1]	NS	8	5
Wando River	4	NS	4	6	12	7
Quinby Creek	11	4	10	NS	9	6
Huger Creek	12	1	4	NS	8	10
Wadboo Creek	17	NS	4	NS	7	12
Wedboo Creek	13	14	8	NS	14	8
Dutart Creek	3	NS	2	NS	8	0
Echaw Creek	19	4	13	NS	11	12
Red Bluff Creek	7	NS	9	NS	8	7
Wambaw Creek	14	10	8	NS	19	12

[1] NS = Not sampled.

Existing population conditions and trends are unknown for crayfish and mollusk. Crayfish and mollusk surveys were conducted across all Forest watersheds in 2011. A total of 84 streams were sampled for crayfish. Crayfish were collected in 72 of these streams. A total of 38 streams were sampled for mollusk species. Mollusk species were found in 26 streams. Thirteen mussel species, three clam species and eight snail species were collected in 2011.

The Catena Group report (2011) concluded that mussel diversity was low within stream reaches on the

Forest, which is considered typical of tannic, swamp water streams along the Atlantic Slope. However, a few streams characterized as having wide, natural riparian buffers contained very high densities of mussels.

There are 62 species of fish that range in lentic systems on the Forest, including those systems nested within the various terrestrial ecosystems (see section 2.1.1 “Terrestrial Ecosystems”). Some are entirely freshwater species, while others also occur in brackish and marine habitats (Rohde et al. 2009). There are five known crayfish species occurring on the Forest (Jones and Eversole 2011). All of these species occur in a variety of lentic habitats as well as flowing waters. One burrowing species is found in wet powerline corridors. Eleven mollusk species have been recorded in lentic systems (The Catena Group 2011).

The primary game fish managed in recreational fishing ponds include largemouth bass, bluegill and redear sunfish. Catfish are occasionally stocked in some ponds for public fishing events. Sterile grass carp have been stocked in the past to control aquatic vegetation. Water quality and fish populations were monitored in November 2009 (Bales 2009). Aquatic plants were identified as well as the percent coverage of plants on the pond. The populations in the majority of ponds were out of balance, crowded with underweight bass. Bluegill have since been stocked at recommended rates. Twelve of the ponds had low alkalinity and needed to be limed for aquatic species productivity.

Physical

The hydrological condition of Forest streams has been discussed in this section under connectivity of habitat in relation to dams, roads, and trails. Density of these structures across the Forest indicate that all Forest watersheds will be ranked as highly modified by these physical structures. Aquatic organism passage will be assessed in the future for road crossings when funding becomes available. In addition, more information on hydrological function and characteristics is discussed in section 2.1.3 “Watersheds,” section 2.2.3 “Water Resources and Quality”, and section 2.2.5 “Riparian Areas, Wetlands and Waters.”

Riparian areas are integral to aquatic ecosystems in that they maintain certain functions essential to healthy streams and species diversity. Riparian areas influence temperature, habitat diversity, channel morphology, productivity and species diversity. Water temperature is sustained by riparian canopy cover. Riparian areas also function as filters to water bodies from sediments and other pollutants. Riparian areas and associated floodplains are inhabited by some crayfish species as well as a number of wildlife species. The hardwood component of the riparian provides readily available food sources to the macroinvertebrate community through leaf litter and detritus. Canopy component diversity is important because the leaves of different tree species break down at various rates and are used by macroinvertebrates for food and shelter. Instream habitat diversity is dependent on large wood input from the riparian area. Larger wood is more stable and most likely to create and maintain habitat diversity in a stream. Therefore canopy age becomes an important factor for instream habitat. Replacement of the hardwood component in riparian areas impacts instream wood recruitment and longevity. Hardwood tends to decay slower than pine species in the stream environment and pine needles are not as desirable a food source as hardwood leaves. Wood is also used as cover from predators and can provide drought refuge when deeper pool habitat is created. In a recent inventory of prescribed burning effects on large wood loading on the Forest, data revealed that in over 20 kilometers of headwater stream sections, the largest, most stable wood was deficient (USDA FS SRS Center for Aquatic Technology Transfer, Draft).

Fire in riparian areas has been discussed in this section under threats and stresses. Loss of riparian vegetation and instream large wood from burning may have an impact on aquatic systems. Riparian extent on the Forest has been mapped using soil indicators and 29 acre catchment areas, due to the lack of an accurate stream layer map. Present unmanaged riparian extent is small (approximately 30 feet) on headwater streams and somewhat larger on streams with more floodplain area. In addition, mechanical construction and reconstruction of fire lines through riparian areas and across streams may be a source of stream sediment, may produce passage barriers and may crush aquatic species without the ability to move from the area. More information on riparian function and characteristics is discussed in section 2.2.5 “Riparian Areas, Wetlands and Waters”.

Riparian areas are important to lentic systems in the same manner discussed above for streams.

Chemical

Aquatic species usually have a tolerance range for certain water quality parameters such as temperature, dissolved oxygen, pH and alkalinity. These parameters may be impacted by human activities (riparian disturbance and pollutants) and natural disturbances (drought and flooding). Fecal coliform and methyl mercury are a problem in coastal streams and are discussed more in section 2.1.3 “Watersheds.” Tributary streams in the lower Santee River may be experiencing an increase in salinity due to the dam and diversion canal modifications of the river system. With less freshwater river flow, tidal waters move further up river and into tributaries such as Wambaw Creek. This can restrict the amount of freshwater habitat available in these streams.

Where lentic systems are not associated with floodplains, they are completely dependent upon rainfall to maintain physical and chemical integrity.

In addition to the Forest Desired Future Condition, FW-70, FW-109, FW-115 and management area 27 direction, the following Forest standards and guidelines apply to this key ecosystem characteristic. Forest Standards and Guidelines, Soil and Water, FW-100 states no aerial herbicide application within 100 horizontal feet and no ground application within 30 horizontal feet of lakes, wetlands, or perennial or intermittent springs and streams except for selective treatments using aquatic labeled herbicides. This applies to both aquatic ecosystems. Forest Standards and Guidelines, Soil and Water, FW-107 avoids direct fertilizer application to water bodies unless prescribed for wildlife habitat improvement. This applies to both aquatic ecosystems.

Climate Change

Impacts to native aquatic species from nuisance species increase due to climate change is discussed in this section under “Threats and Stresses.”

Climate change and increasing climate variability will contribute to changes in water quantity and water quality in the southern United States. Changes in seasonal precipitation on the Forest showed a slight upward trend in falls and winters over the last six decades and a downward trend in springs and summers. Therefore climate warming potentially may bring more spring and summer droughts to the area. This could have a great impact on aquatic ecosystems during summer drought periods when there are high evapotranspiration demands. Freshwater aquatic systems are susceptible to changes in precipitation. Streams, rivers, lakes and ponds are dependent upon both precipitation and groundwater recharge to maintain flow and water levels. Changes in surface and groundwater levels can affect the species assemblages and migration in freshwaters throughout the State (www.dnr.sc.gov/pubs/CCINatResReport.pdf). As climate changes, further habitat fragmentation will restrict movement of animals, limiting or preventing the critical ability to migrate to more favorable habitats.

Changes in the location of the saltwater/freshwater interface will affect many freshwater and diadromous fish species. As sea level rises, saltwater will move further up the river systems of the State. Species with low salt tolerances and diadromous fish will be limited in their ability to move upstream into better quality habitat due to dams and hydroelectric reservoirs constructed on most South Carolina riverine systems. The amount and distribution of aquatic vegetation also will change in response to increases in salinity, limiting cover and food sources for aquatic organisms. Additionally, the potential exists for increased demand for water releases from reservoirs to fight the salt wedge that will be moving inland (www.dnr.sc.gov/pubs/CCINatResReport.pdf).

Management options suggested for aquatic ecosystems in the face of climate change include the following from Adams (http://www.fs.fed.us/ccrc/topics/aquatic-ecosystems/warmwater-aquatic-fauna.shtml#f-tabs-5).

- Maintain natural hydrograph.
- Maintain groundwater levels and identify and conserve critical groundwater-dependent ecosystems.
- Protect and restore habitat and water quality.
- Maintain or restore habitat connectivity.
- Manage for robust and redundant populations.
- Reevaluate fisheries management strategies.
- Unite planning for conservation and human water supply.

2.1.2.9 Natural Range of Variability

The reference condition for watershed, hydrological, and aquatic conditions is pre-Columbian, before nonnative human influences that began about 500 years ago. This period fell within the Little Ice Age, when weather conditions were more humid and colder from about 150 to 650 years ago. There were colder or warmer weather cycles during the period, but the effects to North America were less. Sea levels were approximately 2 feet lower. Beaver were abundant but trapped out by the 1700s, making it initially locally wetter. This period is before roads, dams, dikes, railroads, drainage ditches, stream channelization, rural and urban development, air pollution from burning coal, etc. Since most post-Columbian anthropogenic hydrologic modifications directly or indirectly helped drain or control flooding and tidal influence of the land, the conditions would have likely been less runoff, more flooding, greater hydroperiods, higher evaporation, increased hydration of floodplains, and probably increased stream permanence. There were localized to extensive riparian bottomland and wetland forests of varying sizes and types, and some increases in their extent would be reasonable to assume. Primary disturbance regimes included intensity, frequency and disturbance from fire, flooding, and severe wind. Other natural surface and hydrologic disturbance included beaver, deer, elk as well as some local buffalo presence. Due to the low gradient characteristic of most of the topography, sinuous stream types dominated. The low gradients with vegetation and rooting density provided resilient and highly stable stream channels.

2.1.2.10 Information Needs

Road culvert inventory and stream layer map.

- GIS information by watershed based on a stream layer map: riparian acres; stream miles broken into perennial, intermittent and ephemeral; road and trail density; road and trail density in riparian area.
- Aquatic organism passage survey and mapping.

2.1.3 Watersheds

2.1.3.1 Preliminary Findings

▶The U.S. Geologic Survey and USDA Natural Resources Conservation Service in cooperation with other agencies have classified the hydrologic units (HUCs) across South Carolina (Eidson et al. 2005). The categories classified, each with a two digit code, were region, subregion, basin, subbasin, watershed, and subwatershed. Figure 2-5 has the 8-digit subbasin codes and the 4-digit watershed and subwatershed codes included for the Forest vicinity. The subbasins associated with the Francis Marion flow to Cooper River, Santee River and Atlantic Ocean coast (including the Atlantic Intercoastal Waterway). The hydrologic boundaries were extended into the ocean based on bathymetric indicators. The Francis Marion National Forest proclamation boundary and ownership are included in Figure 2-5.

▶Nationwide efforts for the assessment and improvement of watershed condition were developed in 2011. The application of this direction continues to be refined as implemented. This is another step to further recognize the importance of water to not only national forest resources, but also the needs for the economic and public benefit of water in development and growth. It provides a rating system to compare watershed condition and be able to track them over time as watershed improvements are made. Consistent with new national direction, additional procedures to assess watershed condition began in 2011 by an integrated approach by the Forest personnel. The Forest analysis of the watershed condition of the Francis Marion subwatersheds classified them to be in class 2, fair condition for watersheds which exhibit moderate geomorphic, hydrologic, and biotic integrity relative to their natural potential condition (USDA Forest Service 2011c). The 12-digit subwatershed codes with names and the ratings of watershed condition indicators and attributes are included on Watershed Condition Summary Figure 2-6. However, the 2011 Forest analysis of the watershed condition did not have the LiDAR and recent information obtained.

▶The current assessment of watershed conditions has the potential to be refined and improved based on information being found with LiDAR and other analyses (USDA Forest Service 2011c; Hansen et al. 2013). Although the presence of hydrologic, channel geomorphic and riparian modifications were generally known in 1985 and 1996, the frequency and extent of these modifications were not. The average watershed has about 100 potential modifications to stream channels from road crossings and dikes, not counting ditching and channel straightening. With this knowledge, ratings of various watershed condition indicators and attributes may change upon reevaluation.

▶Hydrologic boundaries and stream extent and location in former plans were based on the 10-foot USGS topographic contour maps. Due to the relatively flat terrain and dense vegetation, there was a substantial amount of uncertainty associated with estimating their location (Eidson et al. 2005; Amatya et al. 2008, 2011, 2013). Improvements in the boundary and stream coverages are needed to reflect the LiDAR and other associated available information. The U.S.

Geological Survey has been contacted and willing to test/apply Forest Service information as perhaps an example or a pilot for other coastal areas. These changes are needed for Forest as well as project planning.

▶Watersheds were not evaluated in 1985 or 1996 relative to their condition. In the watershed condition ratings (USDA Forest Service 2011c), all subwatersheds rated in fair condition in about the middle of the fair rating category between 1.7 and 2.2. The primary individual attributes that averaged poor conditions across the Forest were the water quality impairment or problems from primarily methyl mercury and/or fecal coliform, aquatic habitat fragmentation, lack of large woody debris, and road density and maintenance. The extent of hydrologic modifications may have influenced attributes such as channel form and riparian function. As a result, there is some uncertainty about the ratings. The Forest plan is an appropriate place to address watershed conditions and apply integrated watershed planning as a tool to address a variety of resources and issues.

2.1.3.2 Direction in the 1996 Francis Marion Forest Plan

The former Forest land and resource management plans did not directly address watershed condition (USDA Forest Service 1985, 1996a, 1996b). Watershed planning was an available option, and the Forest analysis did have access to basin and subbasin assessments conducted by the State. Approximate watershed and subwatershed divisions were present for both plans. However, there have always been uncertainty with boundary and stream location (Eidson et al. 2005; Amatya et al. 2011, 2013).

Available information on coastal watersheds has been limited, and that was why the Santee Experimental Forest Hydrometerological Studies were elevated nationally as the coastal ecohydrologic research area. At the time of the 1985 and 1996 plans, there had been only limited emphasis to consider analyzing by watershed, and the preference was to use ecological landtypes in 1996.

During these plans, the standard topographic information was the USGS topographic maps which used 10-foot contours and identified only the primary streams and wetland areas. One must consider that details such as the smaller stream locations were hidden under a heavy canopy, midstory trees, and other vegetation. Drainage boundaries were also uncertain in the relatively flat terrain. The primary hydrologic divisions addressed for the 1996 plan were at the basin or subbasin scale that divided areas draining to the Santee River, Cooper River, and Atlantic Coast. Information on 5^{th}- and 6^{th}-level watersheds was seldom used unless as a descriptive tool, and these smaller hydrologic units were more of a project-level tool, rather than a Forest-level planning tool. However, fish species sampling in 1993 and 1994 with Dr. John Dean (University of South Carolina) considered watershed and subwatershed boundaries, geology, soil, channel types and other information in stratifying the Forest to better sample and document these differences in condition with respect to fish. Most current activities use the subwatershed or watershed boundaries to define analysis areas for environmental assessment. Analysis is also done relative to ecological boundaries.

Since the 1996 plan, a substantial amount of data and experience has been gained in analyzing by hydrologic units of various sizes. In addition, recent developments in applying LiDAR, flow accumulation models, GIS and other tools have made a big difference in estimating hydrologic boundaries, stream, wetland, and riparian locations, and increasing assessment and analysis capability and capacity (Hansen et al. 2013). Most planning analysis in 1985 and 1996 was done by dividing the land into compartments and stands, the local timber management units. These units are still included.

In 1996, the Francis Marion was also divided in the major ecological management units including sandy ridges and sideslopes; loamy ridges, flats and river/creek bottoms; flatwoods and loamy ridges; and swamps and swampy flats. Other management areas concentrated on special areas, wilderness, the Santee Experiment Station and research natural areas. The red-cockaded woodpecker recovery plan was highly important and integrated throughout the plan. Riparian areas and wetlands were primarily protected by standards and best management practices, but mostly managed as suitable for timber production with limited roads and other major activities. However, the South Carolina Forestry Best Management Practices were mandatory on the Forest and included as direction in both 1985 and 1996 plans (South Carolina Forestry Commission 1976, 1994, 2000).

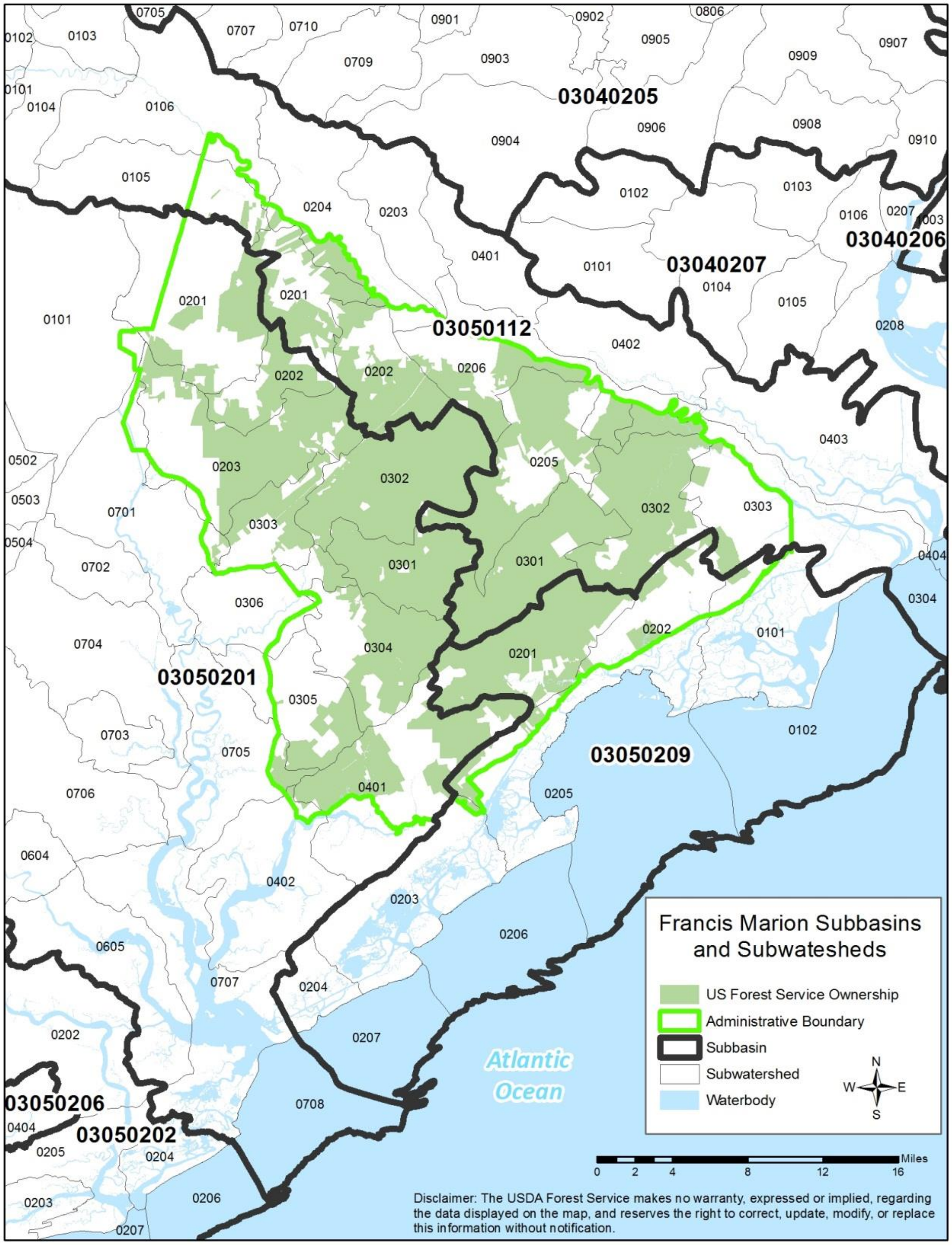

Figure 2-5. Francis Marion National Forest subbasin and subwatershed boundaries

2.1.3.3 New Policy or Direction Since 1996

Since the 1996 plan, a substantial number of forests have developed more demanding and inclusive prescriptions to address watershed conditions addressing riparian areas, wetlands and aquatic ecosystems in more detail (Holcomb 1999). Nationwide efforts for the development of best management practices and watershed condition assessment and improvements were developed and implementation has begun. Many of these efforts have gone further to recognize the importance of watersheds and water to not only national forest resources, but also the needs for the economic and public benefit of water in development and growth (USDA Forest Service 2011a, 2011b).

In 2011, all national forests began a process to evaluate and begin to address watershed condition within the national forests using the newly developed protocols (USDA Forest Service 2011a, 2011b). The Forest interdisciplinary resource team used existing information and national guidance to evaluate watershed condition indicators and attributes to help rate the watershed conditions for the 22 Francis Marion subwatersheds (6^{th}-level hydrologic unit code [HUC]) with over 5 percent National Forest ownership. The results of this analysis for the 16 subwatersheds with 24 percent or more National Forest ownership are presented in Figure 2-6 and Figure 2-7 (USFS 2011c).

At this time, no subwatersheds on the Francis Marion have been identified by the Forest leadership to receive priority improvement. Needs on the Sumter National Forest have initially been a higher priority in South Carolina. However, the intent is for at least one priority watershed that needs improvement to be identified on each ranger district. The subwatersheds on the Francis Marion identified in 2012 for potential consideration for improvement were Turkey Creek of East Fork Cooper River and Headwaters of Wambaw Creek, tributary to the Santee River.

Turkey Creek was recommended as a potential priority subwatershed because of additional funding opportunity with approximately 20 timber sales tied to the Hellhole and Honey Hill EAs, probably the most available information with ongoing hydrological and ecological research, and portions are inside the core burning area with associated proposed, endangered, threatened, and sensitive species including red-cockaded woodpecker.

Headwaters of Wambaw Creek was recommended due to its presence in wilderness with intermittent dam effects from salt water entry, ongoing small craft motorized boating, substantial soil and water restoration potential given the amount of land and stream alteration, portions are contained within core burn area, abundant unique proposed, endangered, threatened, and sensitive species, and threat from wild hogs.

Within the watershed condition framework and analysis, a variety of issues were identified in interdisciplinary analysis in the effort to help estimate and rate watershed conditions using the national protocol. The system used a numerical rating system based on poor to good categories for a number of watershed indicators and associated attributes that contribute to the rating of these indicators. The ratings of the indicators were weighted on watershed importance, and are compiled numerically into an overall watershed score, that can fall into one of three categories. Good watershed condition with a score between 1.0 to 1.6 is considered properly functioning, as these watersheds exhibit high geomorphic, hydrologic, and biotic integrity relative to their natural potential condition (USDA Forest Service 2011a). Fair watershed condition with a score of 1.7 to 2.2 is declining or functioning at risk, and these watersheds exhibit moderate geomorphic, hydrologic, and biotic integrity relative to their natural potential condition. Poor watershed conditions with scores of 2.3 to 3.0 are not functional, with watersheds that exhibit low geomorphic, hydrologic, and biotic integrity relative to their natural potential condition. There are a variety of resource issues that were compiled within the watershed condition analysis, and readily available information and knowledge was used (USDA Forest Service 2011c). The Forest evaluation of watershed condition was primarily internal, using existing information with limited public involvement in this process. However, future watershed condition evaluations will be more collaborative with public input and involvement. The plan has increased level of public involvement and collaboration, so added awareness, attention and review of watershed condition and evaluation is intended. Efforts should take advantage of key agency contacts, partnerships or other agreements, awareness education and technology transfer of watershed conditions, including discussion of techniques used, identifying resource areas needing improvement and opportunities to improve them.

The ratings of watershed attributes and indicators for the 16 subwatersheds with 24 percent or more ownership on the Francis Marion are summarized in Figure 2-6 and Figure 2-7. The ratings varied from 1.7 to 2.0, which is considered class 2 or fair watershed conditions. The primary individual attributes that averaged poor conditions across the Forest were the water quality impairment or problems attributes from methyl mercury, fecal coliform, aquatic habitat from fragmentation, lack of large woody debris and road maintenance. Road density was contributory for some. The analysis of watershed issues lacked detail associated with indicators of excessive sediment and channel form, which the assessment and plan analysis will address in more detail. The extent of hydrologic modifications and how these may have influenced indicators and attributes was not fully realized in 2011 Watershed Condition Analysis. It is likely that a few of these attributes are in poorer condition than realized. Besides affecting aquatic, wetland, and riparian habitat, the hydrologic modifications may have influenced the transport of fecal coliform, methyl mercury, or other pollutants to downstream areas. In some instances, the hydrologic modifications were used to limit the extent of tidal influence, and several subwatersheds have been affected by salinity increases due to much lower than natural flows in the Santee River that allows for tidal effects to a historically freshwater system. In other instances, the modifications were also used to retain water for rice culture management, reduce flooding, drain wetlands, or increase water-based access to fresh and tidal waters.

Watershed condition and health also includes other factors such as fire condition class, insects and disease (forest health), invasive species, and spread and riparian/wetland vegetation. For the Francis Marion subwatersheds (6^{th}-level HUCs), these factors generally rated fair. However, LiDAR detail that has been used to detect and highlight about 100 hydrologic modifications per subwatershed could be linked to aquatic fragmentation, riparian health and channel form was not available at that time of initial watershed condition assessment. Refinement of surface features including watershed boundaries, stream locations and extent, soil boundaries, wetlands, riparian areas, ecological classification and tidal influence are expected. These refinements continue to be developed and realized.

There will be ongoing efforts to improve information available for Forest plan analysis and get it incorporated into official data bases such as the National Hydrology Database or Watershed Boundary Database. Contacts have been with the U.S. Geological Survey made to formalize these data base improvements as they are critical to many of the analyses that will be conducted. Improvements in ecological classification based on Nature Serve Classification (Pyne and Nordman 2012) and refined delineation (Simon and Heyden 2013) are expected to improve analysis capability. There could be other inventory updates, information improvements, or improved understanding that may influence the integrated analysis and rating of watershed conditions.

However, the hydrologic modifications have been so extensive on the landscape, resulting from roads, trails, trams, farming, forestry, development, and water management structures or activities (including dams, dikes, canals, stream relocation and straightening), and have potential to modify watershed condition and function in ways that were not considered. Draining wetlands for farming or to improve sites for pine management were once common practices, encouraged and/or supported by the State and others (South Carolina Regulations, Title 49, 1911, 1920 to 1962, Berkeley County et al. 1963). Early farming crops included rice plantations which often used dikes to manage the extent and amount of fresh water. As mentioned, some structures were used to limit tidal influence or contain freshwater for flushing freshwater during especially high or wind driven tides.

The entry of salt water up the Santee River system after the development of the Santee Cooper Project was one of the various reasons for abandonment of the rice culture plantations along the lower Santee River according to Will Doar, South Carolina Geologist (2013). Some of these former rice culture areas were modified for wildlife habitat improvements which may have enhanced local recreational uses as hunting, fishing and/or bird watching. In all probably, without some continuing maintenance, many of these structures may have failure points, but still be partially effective at altering conditions. Other modifications may have improved commercial or recreational navigation access to tidal or non-tidal waters. Evaluations considering these items were limited in past Forest plans as well as watershed condition assessment.

Watershed condition changes are being influenced by a number of factors that the plan assessment has found that were probably not evaluated. Other factors of consideration include but are not limited to the following:

1. The area population growth and expansion has implications.
2. Increase in intensity of forest thinning and management for forest health after Hurricane Hugo.
3. Increase in use of fire and other tools to manage fuel hazards in the wildland-urban interface and address associated habitat needs.
4. Beaver are naturally returning in some stream systems.
5. Wild hogs have been a historic issue that causes watershed damage.
6. Sea-level rise induced by climate change.
7. Pressures associated with population increase and localized urbanization.

Many of these same issues are also present on private lands, but were not specifically assessed in the Forest-level watershed condition analysis. The relative effects on private lands were estimated based on indicators from Brown and Froemke (2010). Their work addressed a variety of stressors that were not specifically addressed in the Watershed Condition Framework, but are indicators of relative differences in other stressors and a reference for comparison. Some of their stressors, such as population in the watershed, may have implications to consider for this assessment. The Brown and Froemke approach was used to rate and compare expected management and conditions on both National Forest and private lands for each watershed across the Nation. The overall watershed condition considered if the Brown and Froemke rating of private lands were better, about the same, or in a poorer condition in comparison to the national forest lands. In most instances, the private lands within the watersheds rated the same as the national forest lands. Guerin Creek (Wando River) within the East Fork of the Cooper River was the only one with showed a poorer condition using this rating system, and this may have been due to the population growth and urbanizing development in this area. However, the data used in their assessment may be dated, so it may not account for some recent growth experienced in the urban interface.

The watershed condition assessment is a tool to use to identify, address, and integrate a variety of resource areas that influence watershed health issues. There is national direction to not only use this tool, but track watershed condition improvements over time. The existing Watershed Condition Action Plans on the Sumter National Forest in South Carolina have tended to concentrate on and address the indicators or attributes in the poor category, resulting in improvements primarily in the areas of water quality (erosion and sediment reduction), aquatic habitat (large wood), prescribed burning, thinning, road maintenance, road closure, and treatment of nonnative invasive species. Factors that are currently in fair or good conditions are to be maintained or improved as appropriate to be consistent with other resource needs. A similar integrated approach at addressing problem areas for project-level work will probably be used for any priority watersheds identified on the Francis Marion National Forest.

Figure 2-6 shows summary data from watershed condition assessment, developed by the Forest interdisciplinary team in 2011.

Figure 2-7 shows summary data from watershed condition assessment, developed by the Forest interdisciplinary team in 2011. Table is color coded relative to watershed outlet is the Cooper River, then Atlantic Ocean. Attribute values of 1=good, 2=fair, and 3=poor. Indicators are the average of their attributes, watershed score a weighted average of all the indicators. See also Watershed Condition Framework and Implementation Guidance documents (USDA Forest Service 2011). Several smaller subwatersheds with less than 24 percent Forest Service ownership were removed for easier viewing. More detail is available in the process record.

HUC12_Code	030501120201	030501120202	030501120205	030501120206	030501120301	030501120302	030502090201
Subwatershed, HUC 12 Name	Wedboo Creek	Savanna Creek	Echaw Creek	Dutart Creek-Santee River	Headwaters Wambaw Creek	Outlet Wambaw Creek	Awendaw Creek
Watershed_Score_FS_Avg	1.8	1.7	1.9	1.9	1.8	1.9	1.9
Total Watershed_Score	1.8	1.7	1.9	1.9	1.8	1.9	1.9
Total_Watershed_Area_Acres	15499	17246	28411	29210	21530	24588	25686
FS_Area_Acres	8419	12888	19761	10781	20434	21332	22010
FS_Area_Percent	54	75	70	37	95	87	86
1 Indicator_Aq_Phys_Water_Qual	2	2	3	3	2	3	3
1.1 Attribute_Impaired_Waters	1	1	3	3	1	3	3
1.2 Attribute_Water_Qual_Probs	3	3	3	3	3	3	3
2 Indicator_Aq_Phys_Water_Qnty	2	2	3	2	2	3	2
2.1 Attribute_Flow_Characteristics	2	2	3	2	2	3	2
3 Indicator_Aq_Phys_Habitat	2	2	2.3	2.3	2.3	2.3	2.3
3.1 Attribute_Hab_Fragmentation	2	2	2	2	2	2	2
3.2 Attribute_Large_Woody_Debris	2	2	3	3	3	3	3
3.3 Attribute_Channel_Shape_Func	2	2	2	2	2	2	2
4 Indicator_Aq_Bio_Biota	1.3	1.3	1.3	1.3	1.3	1.3	1.3
4.1 Attribute_Life_Form_Presence	1	1	1	1	1	1	1
4.2 Attribute_Native_Species	1	1	1	1	1	1	1
4.3 Attribute_Aq_Invas_Species	2	2	2	2	2	2	2
5 Indicator_Aq_Bio_Rip_Veg	2	2	1	2	2	1	2
5.1 Attribute_Riparian_Veg_Cond	2	2	1	2	2	1	2
6 Indicator_Terr_Phys_Road_Trail	2	1.8	2	1.8	1.8	2	2
6.1 Attribute_Open_Road_Density	3	2	2	2	2	2	2
6.2 Attribute_Road_Maintenance	3	3	3	3	3	3	3
6.3 Attribute_Proximity_Water	1	1	2	1	1	2	2
6.4 Attribute_Mass_Wasting	1	1	1	1	1	1	1
7 Indicator_Terr_Phys_Soils	1.3	1.3	1.3	1.3	1.7	1.7	1.7
7.1 Attribute_Soil_Productivity	2	1	1	1	2	2	2
7.2 Attribute_Soil_Erosion	1	1	1	1	1	1	1
7.3 Attribute_Soil_Contamination	1	2	2	2	2	2	2
8 Indicator_Terr_Bio_Fire	3	2	1	2	2	1	2
8.1 Attribute_Fire_Cond_Class	3	2	1	2	2	1	2
9 Indicator_Terr_Bio_ForCover	1	1	1	1	1	1	1
9.1 Attribute_Forest_Cover	1	1	1	1	1	1	1
10 Indicator_Terr_Bio_Range	na	na	na	na	na	na	na
10.1 Attribute_Range_Veg_Condtion	na	na	na	na	na	na	na
11 Indicator_Terr_Bio_Invasive	1	1	2	2	1	1	1
11.1 Attribute_Extent_SpreadRate	1	1	2	2	1	1	1
12 Indicator_Terr_Bio_ForHealth	2	1.5	1.5	1.5	1	1	1.5
12.1 Attribute_Insects_Disease	3	2	2	2	1	1	2
12.2 Attribute_Ozone	1	1	1	1	1	1	1
Special designations			Intermittent tidal	Short nose sturgeon, Atlantic sturgeon, manatee	Wambaw Swamp Wilderness	Wambaw Creek Wilderness, intermittent tidal	Coastal Shellfish, tidal, boating, Little Wambaw Swamp Wilderness
Flows to Santee River, then Ocean							
Flows to Ocean							

Figure 2-6. Francis Marion National Forest, summary data from watershed condition assessment

HUC12_Code	30502010201	030502010202	030502010203	030502010301	030502010302	030502010303	030502010304	030502010305	030502010401
Subwatershed, HUC 12 Name	Walker Swamp	Cane Pond Branch	Wadboo Creek	Turkey Creek-East Branch Cooper River	Nicholson Creek	Gough Creek	Quinby Creek	French Quarter Creek	Guerin Creek (Wando River)
Watershed_Score_FS_Avg	2	1.8	2	1.8	1.9	1.8	1.9	1.8	2
Total Watershed_Score	2	1.8	2	1.8	1.9	1.8	1.9	1.8	2.6
Total_Watershed_Area_Acres	37202	10755	34431	16516	29253	12460	22693	19354	40024
FS_Area_Acres	8912	7572	20965	16153	28501	6429	14081	4968	16819
FS_Area_Percent	24	70	61	98	97	52	62	26	42
1 Indicator_Aq_Phys_Water_Qual	3	2	3	3	2.5	2	2	2	3
1.1 Attribute_Impaired_Waters	3	1	3	3	2	1	1	1	3
1.2 Attribute_Water_Qual_Probs	3	3	3	3	3	3	3	3	3
2 Indicator_Aq_Phys_Water_Qnty	2	2	2	2	2	2	2	2	2
2.1 Attribute_Flow_Characteristics	2	2	2	2	2	2	2	2	2
3 Indicator_Aq_Phys_Habitat	2.3	2	2.7	2.3	2.3	2.7	2.7	2.3	2.3
3.1 Attribute_Hab_Fragmentation	3	2	3	2	2	3	3	2	2
3.2 Attribute_Large_Woody_Debris	2	2	3	3	3	3	3	3	3
3.3 Attribute_Channel_Shape_Func	2	2	2	2	2	2	2	2	2
4 Indicator_Aq_Bio_Biota	1.7	1.3	1.7	1.3	1.3	1.7	1.7	1.3	1.3
4.1 Attribute_Life_Form_Presence	1	1	1	1	1	1	1	1	1
4.2 Attribute_Native_Species	2	1	2	1	1	2	2	1	1
4.3 Attribute_Aq_Invas_Species	2	2	2	2	2	2	2	2	2
5 Indicator_Aq_Bio_Rip_Veg	2	2	2	1	2	1	2	2	2
5.1 Attribute_Riparian_Veg_Cond	2	2	2	1	2	1	2	2	2
6 Indicator_Terr_Phys_Road_Trail	2.3	2.3	2.3	2	2	2.3	2.3	2.3	2
6.1 Attribute_Open_Road_Density	3	3	3	2	2	3	3	3	2
6.2 Attribute_Road_Maintenance	3	3	3	3	3	3	3	3	3
6.3 Attribute_Proximity_Water	2	2	2	2	2	2	2	2	2
6.4 Attribute_Mass_Wasting	1	1	1	1	1	1	1	1	1
7 Indicator_Terr_Phys_Soils	1.3	1.3	1.3	1.7	1.7	1.3	1.3	1.3	2
7.1 Attribute_Soil_Productivity	1	1	1	2	2	1	1	1	3
7.2 Attribute_Soil_Erosion	1	1	1	1	1	1	1	1	1
7.3 Attribute_Soil_Contamination	2	2	2	2	2	2	2	2	2
8 Indicator_Terr_Bio_Fire	3	3	2	1	2	2	2	3	3
8.1 Attribute_Fire_Cond_Class	3	3	2	1	2	2	2	3	3
9 Indicator_Terr_Bio_ForCover	1	1	1	1	1	1	1	1	1
9.1 Attribute_Forest_Cover	1	1	1	1	1	1	1	1	1
10 Indicator_Terr_Bio_Range									
10.1 Attribute_Range_Veg_Condtion									
11 Indicator_Terr_Bio_Invasive	1	1	1	1	1	1	1	1	1
11.1 Attribute_Extent_SpreadRate	1	1	1	1	1	1	1	1	1
12 Indicator_Terr_Bio_ForHealth	2	2	1.5	1.5	1.5	1	1.5	1.5	1.5
12.1 Attribute_Insects_Disease	3	3	2	2	2	1	2	2	2
12.2 Attribute_Ozone	1	1	1	1	1	1	1	1	1
Special designations				Experimental watersheds, Research	Hellhole Bay Wilderness, Experimental watersheds, Research				Some tidal influence
Flows to Cooper River, Ocean									

Figure 2-7. Francis Marion National Forest, summary data from watershed condition assessment

2.1.3.4 Stressors or Threats

There are a variety of stressors and threats that exist or could materialize to influence watershed condition. Many of them are addressed within the watershed condition framework and analysis, or have been mentioned. Most will be directly or indirectly addressed in other sections with national forest land and resource planning and management documents. Stress or threats include population growth and urban expansion, climate change, hurricanes, floods, droughts, wildfire, insects and disease, nonnative invasive species, roads, motorized trails, a variety of land use based ground-disturbing activities, atmospheric deposition (e.g., mercury), fecal pollutants, and hydrologic modifications. Some of the watersheds are being affected by sea-level rise and tidal changes. The degree to which watersheds are stressed or threatened vary. Most watersheds have been substantially modified in comparison to what one would expect of a national forest, yet their resiliency promotes the production of many goods, services, and public benefits. The low gradient and rapid vegetation response help in their recovery after disturbance, and it is relatively easy to think that all things are well. But the variety of hydrologic modifications from dams, dikes, canals, dredged channels, ditches, site bedding, severe ruts, road crossings, trams, frequent as well as lack of fire, and firelines are complex to understand and evaluate. It would take a close integrated look, but the desired conditions spoken to in the 1996 plan for resilient, properly functioning aquatic, riparian and wetland systems has not been fully realized or addressed. Much of this awareness of these shortcomings is based on recent information and analysis, and failing to act on these issues was not intentional.