SOUTH CAROLINA'S
STATE WILDLIFE ACTION PLAN
(SWAP)
2015

SOUTH CAROLINA
DEPARTMENT OF NATURAL RESOURCES
1000 ASSEMBLY STREET
P.O. BOX 167
COLUMBIA, SC 29202

FINAL
OCTOBER 14, 2014

FOREWORD

South Carolinians are proud of the wealth of natural resources in our state: over two million acres of conservation land statewide, 11,000 miles of rivers, 30,000 miles of streams, 11 major lakes, and a degree of plant and animal diversity that is one of the highest in the nation. In fact, the Jocassee Gorges area in the Upstate contains the highest number of salamanders found anywhere on Earth. Our nation just celebrated the 40th anniversary of the Endangered Species Act in 2013 and the 75th anniversary of the Pittman-Robertson Wildlife Restoration Act in 2012. However, there is another program that has created funding for our wildlife and habitats, especially those that have been traditionally underfunded and yet are of utmost conservation concern. This relatively new program, State Wildlife Grants, helped produce our first Action Plan in 2005: the Comprehensive Wildlife Conservation Strategy (CWCS). Following the recommendations outlined within the Strategy, the South Carolina Department of Natural Resources was able to complete 35 grants for research survey, and habitat enhancement projects across South Carolina benefiting our species of greatest conservation need; another 18 more projects are in progress. Our Strategy has since undergone a name change to the South Carolina State Wildlife Action Plan, or SWAP, for short.

The Agency has undergone name changes as well over its 108 year history, but its mission is still "to serve as the principal advocate for and steward of South Carolina's natural resources." However, it has been said that in order for a wildlife institution to remain relevant in this day and age, it must be willing to embrace change. South Carolina has a strong fishing and hunting heritage but there is also a growing constituency of outdoor enthusiasts such as birdwatchers, hikers, and wildlife watchers. Ensuring diversity just like in our public's recreational preferences, is the premise of the SWAP; they are conservation plans encompassing the full array of species and their habitats. Breaking down artificial divisions between "game" and "non-game" allows for a more holistic view of managing the system.

Through the SWAP we are taking a proactive approach to conservation instead of a reactionary one, and to that end, we have identified 825 animal and plant species that need additional attention in order to maintain healthy populations. Many of these species may be candidates for listing under the Endangered Species Act if we do not mitigate for impacts now. Stressors include habitat loss or conversion, environmental contamination persecution by humans, illegal harvest, non-native invasive species, emerging diseases, and climate change. Sometimes it is a lack of knowledge of the species and its habits that is the concern which can be a limitation to our ability to manage for it.

This Action Plan is a guide for addressing limiting factors affecting species persistence on the South Carolina landscape. Strategies and tools are discussed that can be implemented by SCDNR and its partners. The Plan emphasizes a cooperative, proactive approach to conservation inviting local governments, businesses, and conservation-minded organizations and individuals to join in the task of maintaining the wildlife and plant resources that are so important in our lives. It is my hope that you will study the Action Plan carefully and join us in helping implement its recommendations.

Alvin A. Taylor
Director
South Carolina Department of Natural Resources

ACKNOWLEDGEMENTS

South Carolina's State Wildlife Action Plan represents the hard work of many individuals; without their efforts, this work would not have been possible. The South Carolina Department of Natural Resources owes its gratitude to all of these people. Thanks are due to the members of the Taxa Committees; these individuals are identified in Chapter 2. SCDNR biologists, partners, and volunteers that staffed the Taxa Committees spent many hours reviewing and discussing the thousands of species that inhabit this state in order to determine our priority species and develop the lists that are included in this Plan. Many of these individuals went on to write the detailed reports that are included in the Supplemental Volume and from which all recommended priority actions were developed. Many additional professionals donated their time to help author reports, and their names appear at the top of each species or guild account. Those generous individuals who provided photographs for this Plan are identified as well.

SCDNR biologists chaired most of the Taxa Committees, including Felicia Sanders (birds), Steve Bennett, ret. (amphibians and reptiles), Mark Scott (freshwater fishes), Bill Post (diadromous fishes), Mike Denson (marine fishes), Peter Kingsley-Smith (marine invertebrates), and Herrick Brown (plants). Bill Poly, formerly with SCDNR, chaired the committees on crayfish, freshwater snails, leeches, and freshwater mussels. Jim Glover of Clemson University chaired the insect committee while Steve Fields (Culture and Heritage Museums) chaired the mammal committee. These individuals were responsible for coordinating their committees, assisting in the generation of a priority species list, and helping develop conservation actions. The SWAP would not have been possible without their efforts and the support of their supervisors. At the SCDNR, these included Wildlife and Freshwater Fisheries Assistant Deputy Director Ken Prosser; Wildlife Chiefs Derrell Shipes and Tim Ivey (ret.); Freshwater Fisheries Chief Ross Self and Assistant Chief Lynn Quattro; and Marine Resources Assistant Deputy Director David Whitaker.

Members of the Conservation Action Committees, which are identified in Chapter 4: Statewide Conservation Strategies, provided overarching views of our action areas. These views translated into statewide priority actions that go beyond individual habitats or species. For their dedication to the stewardship of South Carolina's natural resources, these committee members are thanked.

Thanks are also due the members of the original Development Committee, without which we would not have had such a nice framework from which to develop the 2015 edition. These members included: Lynn Quattro, Thomas Kohlsaat (ret.), Jennifer Rinehart, Anna Huckabee Smith, Elizabeth Cuizio, Walter Meitzen, and Rebecca Campbell. The Revision Committee involved the talents of Anna Huckabee Smith (chief editor), Leslie Hawkins, and Barry Beasley. These individuals coordinated the project and all associated meetings, reviewed all species/guild reports, consolidated the information, and produced the report you see here. Lynda Holseberg helped create the spreadsheets used for several appendices while Geoff Schwitzgebel created the maps.

Lastly, we would like to thank the citizens of South Carolina that attended public meetings and reviewed the online draft and made comments. Your continued devotion to the natural resources of this state is extremely important and needed. Thank you.

EXECUTIVE SUMMARY

In May of 2002, the South Carolina Department of Natural Resources (SCDNR) began a process to develop the Comprehensive Wildlife Conservation Strategy (CWCS) that was funded through the State Wildlife Grants (SWG) program. The SCDNR committed to developing the Strategy and begin implementing the conservation actions by October 1, 2005. The Strategy was to be cooperative in nature with partnerships formed among agencies, non-governmental organizations, and conservation-minded citizens of our great State. South Carolina's 2005-2010 Strategy was accepted in January 2006.

In 2010, a revision process was initiated and the CWCS was subsequently renamed the State Wildlife Action Plan (SWAP). Due to the rapidly evolving changes in knowledge of the various priority species ("species of greatest conservation need") and Agency personnel changes, the final draft of the 2015 SWAP was accepted in September 2015.

The diversity of animals in South Carolina is vast. Habitats in this state range from the mountains to the ocean and include many different taxonomic animal groups. SCDNR wanted to address as many of those groups as possible for inclusion in the list of priority species for the SWAP; as such, 14 taxonomic groups are included in the Strategy: mammals, birds, reptiles, amphibians, freshwater fishes, diadromous fishes, marine fishes, marine invertebrates, crayfish, freshwater mussels, freshwater snails, leeches (both aquatic and terrestrial), insects (both freshwater and terrestrial), and plants. Plants are new to the SWAP and were added as they are essential to habitats and ecosystems as a whole.

The SCDNR identified 825 species of flora and fauna to include on the State's List of Species with the Greatest Conservation Need. Reports were prepared for each species or guild (minus plants); in these reports, authors described the species, their status, population and abundance, habitat needs, challenges, conservation accomplishments and conservation actions. This approach allows for identification of both general conservation strategies for wildlife and habitats in South Carolina, as well as development of species-based conservation strategies. The latter allows for management of particular species within a given habitat. A separate document, the Supplemental Volume: Species Accounts, contains these reports in their entirety. The SCDNR also identified habitats critical for the priority species considered in the SWAP. Both terrestrial and aquatic habitats were considered and a spreadsheet was prepared for approximately 50 distinct habitat types (terrestrial and marine) organized within five ecoregions, as well as 4 ecobasins which characterize the freshwater aquatic habitats of the State.

As conservation strategies were developed for each species, it became evident that they could be separated into nine overarching categories which we have designated as Conservation Action Areas (CAAs).These nine CAAs are: Education and Outreach; Habitat Protection; Invasive and Non-native Species; Private Land Cooperation; Public Land Management; Regulatory Actions; Survey and Research Needs; Urban and Developing Lands; and Climate Change. Within each CAA, conservation actions were condensed from the recommendations prepared for each animal on South Carolina's priority species list. Some of the actions identified will affect all species included in the SWAP; others may affect only a few species. Each of these actions was prioritized and measures that indicate success of implementing the action were identified.

It is also critical that we monitor priority species, their habitats, and the effectiveness of the actions that are implemented to conserve them. SWG projects are monitored to make sure data yields are expanding our knowledge base and on-the-ground habitat work is truly producing results. SC's Comprehensive Monitoring Program, outlined in Chapter 6, describes strategies to encourage data storage, data sharing, implementation of objectives, and expanding the use of citizen science networks.

From the beginning of the SWAP effort back in 2005, SCDNR and the planning team sought to realize successful partnerships and public involvement in the development of the Plan. Those relationships carried over into the implementation of the SWAP and the latest revision process. It is understood that successful conservation is furthered by the existence of a strong collaborative involvement between all resource stakeholders, private or public, governmental or nongovernmental. Back in 2005, task forces were convened to assist in determining important natural resource issues in South Carolina. Taxa teams were assembled in 2005 and again in 2013 to determine challenges to species and conservation actions to address those challenges. Public meetings were held in both 2005 and 2012 to gather input from the citizens of the State on various topics.

Although several species have been removed from the priority list this time around and others have been added, the common themes remain the same. It has been determined that in order to sustain South Carolina's diverse wildlife resources in the future, the following actions are critical: (1) increase baseline biological inventories with emphasis on natural history, distribution and status of native species; (2) increase commitment by natural resource agencies, conservation organizations and academia toward establishing effective conservation strategies; (3) increase financial support and technological resources for planning and implementation of these strategies; and (4) create public-private partnerships and educational outreach programs for broad-scale conservation efforts. South Carolina's SWAP is a step toward instituting these actions.

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CHAPTER 1: INTRODUCTION

Problem and Need

Wildlife conservation responds to the challenges of the times. The original wildlife conservation movement began in the first half of the twentieth century in response to unregulated harvest for sporting and commercial purposes. During this period, a number of landmark federal laws were enacted, notably the Migratory Bird Treaty Act, the Pittman-Robertson Federal Aid in Wildlife Restoration Act, the Lacey Act, and the Dingell-Johnson Sport Fisheries Restoration Act. All were created following education campaigns by the conservation community.

State and federal fish and wildlife agencies grew rapidly, supported by increases in state and federal conservation funding. The US Bureau of Sport Fisheries and Wildlife (now the US Fish and Wildlife Service) was formed and state fish and wildlife agencies either developed from scratch or became greatly centralized and expanded, using revenue from a combination of state license fees and federal funding from excise taxes on sporting equipment. The resulting state fisheries and wildlife management programs were well established by the late 1960s and early 1970s and were largely game-oriented.

As times and conditions changed, new laws were enacted. In the early 1970s, the Endangered Species Act, Clean Water Act, and Clean Air Act all were developed and companion state laws and programs were enacted. In order to provide early direction to the South Carolina Department of Natural Resources (SCDNR) Nongame and Endangered Species Program, a statewide symposium on endangered species was held in 1976. At that meeting, committees of specialists in vertebrate taxa (mammals, birds, herpetofauna, fish) were formed to provide information about species that had uncertain status or were believed to be in jeopardy (Forsythe and Ezell 1976). Out of this meeting came the formation of the nation's first Heritage Trust Program wherein the taxa committees continued to meet periodically and update the species lists. Rare plants were also added to the list of species tracked.

As the economic changes begun in the 1970s progressed, many states, including South Carolina, entered a period of rapid economic expansion and human population growth that continues to this day. South Carolina has one of the fastest rural-to-urban conversion rates and is the 9th ranked state in terms of total land area developed annually (Miley, Gallo and Associates LLC 2008). In 2010, South Carolina was ranked as the 24th most populated state in the nation at 153.9 people per square mile (US Census Bureau 2012) and one of the fastest growing in the nation (Miley, Galo and Associates LLC 2008). By 2030, the projected housing density is expected to reach anywhere from 16 to 128 housing units per square kilometer throughout much of the state (Hammer and Radeloff 2003) as the population nears five million (Miley, Gallo and Associates LLC 2008). The biggest population increases currently occurring are in the Upstate, coastal counties, and around the capital (Lexington and Richland Counties) (SCFC 2010).

The conversion of prime forest and agricultural land to residential uses is changing the landscape of South Carolina. In addition, rising costs coupled with falling prices are creating hardships for many family farms. Long-term declines in farmland are dramatic: in 1920, 192,693 farms were producing goods in South Carolina, and 63.7% of the land in the State consisted of farms (US

Bureau of the Census 1954). By 2006, the number of farms in the state had been reduced to 24,700 (Miley, Gallo and Associates LLC 2008). Over 13 million acres of forests, which cover two thirds of South Carolina's total land area, are also at risk for development since 11 million acres are in private ownership (Miley, Galo and Associates LLC 2008; SCFC 2010).

As land use is converted from rural to urban uses and the population of South Carolina increases, new challenges arise for fish and wildlife species in the state. Long-standing downward trends in numbers of some species that previously had been overlooked have become evident. In a state-by-state analysis of biodiversity conducted for The Nature Conservancy, South Carolina ranked 14th among all states in species diversity and 15th in terms of risks to native species (NatureServe 2002). In a planning exercise conducted in 1994, SCDNR biologists estimated that as many as one third of the State's vertebrate species are now—or soon will be—experiencing serious declines (SCDNR 1994). The South, as a whole, has already lost an estimated 614 species to extinction—64 terrestrial vertebrates and 550 vascular plants (Wear et al. 2012).

The SCDNR continues to support a large number of conservation initiatives on public and private lands, including habitat protection; technical guidance and cost sharing; and education. Farm Bill programs have helped provide assistance to landowners across the State, positively affecting 264,950 acres as of 2007 (USDA-ERS 2013). A statewide wildlife strategy would align all conservation activities with common goals that can be consulted by all South Carolinians, especially resource managers, local governments, and the scientific community. The State Wildlife Grants program provides a vehicle to create such a strategy.

In order to sustain South Carolina's diverse wildlife resources in the future, the following actions are critical: (1) increase baseline biological inventories with emphasis on natural history, distribution, and status of native species; (2) increase commitment by natural resource agencies, conservation organizations, and academia toward establishing effective conservation strategies; (3) increase financial support and technological resources for planning and the implementation of these strategies; and (4) create public-private partnerships and educational outreach programs for broad-scale conservation efforts. This Action Plan is a first step toward instituting these actions.

Legislative Mandate and Guidance

The charge to state wildlife agencies to develop comprehensive strategies had its origins in the Wildlife Conservation and Recreation Program (WCRP) that was created in the federal Appropriations Act of 2001. Appropriations language provided that funds may be used for "...the planning and implementation of [a state's] wildlife conservation and restoration program and wildlife conservation strategy, including wildlife conservation, wildlife conservation education, and wildlife-associated recreation projects" (114 STAT. 2762A -118 PUBLIC LAW 106–553 — APPENDIX B — Title IX).

The WCRP appropriations language challenged the states to develop projects in the three major areas anticipated in the Teaming with Wildlife initiative: conservation, education, and recreation. WCRP appropriations language also provided that "Within five years of the date of the initial apportionment, [the states shall] develop and begin implementation of a wildlife conservation strategy based upon the best available and appropriate scientific information and data …."

Specific criteria for the wildlife conservation strategies were developed. South Carolina committed to developing its "wildlife conservation strategy" within the required five years in order to qualify for WCRP funds.

WCRP was only funded for one year and was replaced in 2002 and subsequent years by the State Wildlife Grants Program (SWG), also through the appropriations process. Unlike WCRP, the SWG program emphasizes conservation projects alone and charges the states "…to develop by October 1, 2005, a comprehensive wildlife conservation plan [strategy], consistent with criteria established by the Secretary of the Interior, that considers the broad range of the State, territory, or other jurisdiction's wildlife and associated habitats, with appropriate priority placed on those species with the greatest conservation need and taking into consideration the relative level of funding available for the conservation of those species…" (115 STAT. 414 PUBLIC LAW 107-63 — APPENDIX A). The document that all states ultimately prepared in response to this mandate was referred to as a Comprehensive Wildlife Conservation Strategy (CWCS). The 2005 version of South Carolina's document was therefore named accordingly. Over time, the Strategy became referred to internally as well as in other states as the State Wildlife Action Plan or SWAP. Thus, the 2015 iteration of this document underwent a name change to this more familiar title.

As per Element 6 of the original legislation, all states made a commitment to review and revise their plans within 10 years. South Carolina began the review process in September 2010. Due to personnel turnover and emerging issues (e.g. the spread of white-nose syndrome), the completion of the final version was delayed until 2014. These revisions were completed in accordance with the current SWG Guidance Document (2007). Any significant changes to the Strategy/Action Plan and an up-to-date public review process were documented. Congress' version identified the required elements for strategies in the WCRP legislation. The USFWS adopted those same elements for the SWG required SWAP, so one document will satisfy both needs. The SWAP must identify and be focused on the "species in greatest need of conservation," yet address the "full array of wildlife" and wildlife-related issues. They must provide and make use of the elements identified in Box 1-1: The Eight Required Elements. This original guidance has been expanded considerably during the course of SWAP preparation; however the eight elements remain the core standard for the strategies.

Box 1-1: The Eight Required Elements

1) Information on the distribution and abundance of species of wildlife, including low and declining populations as the State fish and wildlife agency deems appropriate, that are indicative of the diversity and health of the State's wildlife.
2) Descriptions of locations and relative condition of key habitats and community types essential to conservation of species identified in (1).
3) Descriptions of problems, which may adversely affect species identified in (1) or their habitats, and priority research and survey efforts needed to identify factors, which may assist in restoration and improved conservation of these species and habitats.
4) Descriptions of conservation actions determined to be necessary to conserve the identified species and habitats and priorities for implementing such actions.
5) Descriptions of the proposed plans for monitoring species identified in (1) and their habitats, for monitoring the effectiveness of the conservation actions proposed in (4), and for adapting these conservation actions to respond appropriately to new information or changing conditions.
6) Descriptions of procedures to review the Strategy/Plan at intervals not to exceed ten years.
7) Descriptions of the plans for coordinating, to the extent feasible, the development, implementation, review, and revision of the Plan/Strategy with Federal, State, and local agencies and Indian tribes that manage significant land and water areas within the State or administer programs that significantly affect the conservation of identified species and habitats.
8) Descriptions of the necessary public participation in the development, revision, and implementation of the Plan/Strategy.

Roadmap to the Required Elements in South Carolina's SWAP

As part of the additional guidance received, States were instructed to highlight the location of information specific to the eight elements for reviewers of the SWAP. Therefore, Table 1-1: Roadmap to the Required Elements presents this information.

TABLE 1-1: ROADMAP TO THE REQUIRED ELEMENTS

ELEMENT	SC SWAP CHAPTER	LOCATION
1. Distribution and abundance of species	Chapter 2	Throughout chapter
	Chapter 3	Throughout chapter
	Appendices 1 A-D	Entire appendices
	Supplemental Volume	Entire volume
2. Location and relative condition of key habitats	Chapter 2	Throughout chapter
	Chapter 4	Throughout chapter
	Supplemental Volume	Entire volume
3. Problems that affect species	Chapter 3	Throughout chapter
	Chapter 5	Throughout chapter
	Supplemental Volume	Entire volume
4. Conservation actions described	Chapter 5	Throughout chapter
	Chapter 6	Throughout chapter
	Chapter 9	Throughout chapter (completed actions described)
	Appendix 2	Entire appendix
	Supplemental Volume	Entire volume
5. Plans for monitoring and adaptive management	Chapter 5	Throughout chapter
	Chapter 6	Throughout chapter
	Appendix 2	Entire appendix
	Appendix 7	Entire appendix
	Supplemental Volume	Entire volume
6. Review and revise Plan	Chapter 8	Throughout chapter
7. Coordinating with federal, state, and local agencies as well as Indian tribes.	Chapter 3	Throughout chapter (taxa teams)
	Chapter 7	Throughout chapter
	Appendix 3	Entire appendix
	Supplemental Volume	Entire volume appendix
8. Public participation	Chapter 7	Throughout chapter
	Supplemental Volume	Entire volume (see contributions to data)

SWAP Organization

The SWAP, or Action Plan, is organized to first make the reader aware of the need for a strategy then to discover how the actual Action Plan was developed and presented. In the **Introduction**, a discussion of the need for the SWAP and the legislative mandate that allows SCDNR to develop and implement the strategy is presented. The selection of South Carolina's priority wildlife species is discussed in **Chapter 2: SC's Priority Species** while the methods for prioritizing those species and the challenges they face are detailed in **Chapter 3: Taxonomic Groups**. The condition and location of habitats and challenges to the management of those habitats is presented in **Chapter 4: South Carolina's Landscape**. Appendices 1 A-D are spreadsheets that list the species of concern and their habitat associations. The conservation strategies that will be implemented to address the challenges identified in the three previous chapters is discussed in detail in **Chapter 5: Statewide Conservation Strategies**; the nine conservation action areas around which strategies have been constructed are also presented in that chapter. After listing conservation actions to address species and habitat challenges, the manner in which they will be monitored is contained in **Chapter 6: SC's Comprehensive Monitoring Program**. Strategies for monitoring the effectiveness of conservation actions are also discussed. The SCDNR formed extensive partnerships during the initial development of the SWAP and has retained them through the revision process. These partnerships are discussed in **Chapter 7: Seeking Public Input and Maintaining Partnerships**. The public input process is also summarized. The manner in which the SCDNR prioritized conservation actions, will implement the conservation actions in the SWAP, and adapt the Action Plan as new information becomes available is presented in **Chapter 8: Implementation and Adaptive Management**. Since the original Plan was completed in 2005, the State Wildlife Grants (SWG) that have resulted from the implementation of that Plan are summarized in **Chapter 9: SWG Project Summaries**. Finally, we include a list of references in the **Literature Cited** as well as provide a **Glossary** and **Appendices** associated with the SWAP. The last Appendix (8) is a list of acronyms used within the SWAP and Supplemental Volume.

A **Supplemental Volume: South Carolina's Priority Species** is submitted with this Action Plan. The Supplemental Volume contains reports for the species of greatest conservation need (hereafter also referred to as priority species) included on South Carolina's Priority Species List. Each of these reports includes a description of the distribution and abundance of each species and its habitat requirements, the challenges that the species faces, and specific conservation actions for addressing those challenges. Additionally, some of these reports discuss ways to work with public and private entities toward conservation as well as strategies for monitoring species, habitats, and effectiveness of conservation actions.

The Supplemental Volume to South Carolina's SWAP provides a unique look into challenges and conservation actions that pertain to each of the species on this state's Priority Species List. By providing species-specific actions, the SCDNR can use the Action Plan in two ways: (1) to manage species of concern over large areas or habitat and (2) to manage particular species in any habitat where that species occurs, no matter the size of the management area. Further, the species-specific approach in the Supplemental Volume allowed for development of very concise conservation actions for each species, which are expected to permit SCDNR or its partners to easily convert those actions to project proposals/plans.

Authority and Capability of the SCDNR to Prepare and Implement the SWAP

Article III, Section 34, South Carolina Constitution, 1895, as revised, states in relevant part: "that the General Assembly is empowered to divide the State into as many game zones as may appear practicable, and to enact legislation that may appear proper for the protection of game in the several zones."

Legislation creating the SC Department of Natural Resources and governing its activities is covered under Titles 48 and 50 of the SC Code of Laws. The entire code covers the generalities of operating the agency, as well as special laws pertaining to certain species, penalties, and subdivisions of the state. The most concise, broad charge to the SCDNR is found in the following sections:

> §48-4-10 provides that "The South Carolina Department of Natural Resources is created to administer and enforce the laws of this State relating to wildlife, marine resources, and natural resources and other laws specifically assigned to it."
>
> §48-4-80. Provides for the creation of a Board to serve as "the governing body of the agency."
>
> §50-3-80 provides that the Department shall continuously investigate the game and fish conditions of the State and the laws relating thereto. It shall annually make report of its activities to the General Assembly and recommend legislation and other action by the General Assembly in its judgment conducive to the conservation of wildlife.

Subsequent legislation provides assent to federal fish and wildlife restoration acts and authorizes the SCDNR to "perform such acts as they be necessary to the conduct and establishment of cooperative fish and wildlife restoration project(s) as defined in such act(s) of Congress…" Authorities under Title 50 include jurisdiction over saltwater fish and related activities.

In addition, Title 50 authorizes SCDNR to promulgate regulations relating to hunting, fishing, the taking and possession of wildlife, and provides for penalties relating thereto. Authorization is further extended to SCDNR to acquire and dispose of property, conduct hearings, and "own, sell, lease, exchange, transfer or rent real property" for purposes of carrying out its authorities. Concerning recreation, this authority extends to "furnishing the people of the State with hunting areas and fishing facilities."

The South Carolina Nongame and Endangered Species Conservation Act (§50-15-10 et seq.) authorizes the Department to "…conduct investigations on nongame wildlife in order to develop information relating to population, distribution, habitat, needs, limiting factors and other biological and ecological data to determine management measures necessary for their continued ability to sustain themselves successfully." The Act further authorizes SCDNR to issue regulations and "develop management programs designed to insure the continued ability of nongame wildlife to perpetuate themselves successfully."

Subsequent sections of the Act set forth administrative procedures for developing regulations—penalties for taking and possession of nongame wildlife considered by SCDNR under this Act to be endangered. The Act also provides that the agency will maintain lists of endangered species and amend them periodically. The Act further authorizes SCDNR to establish programs, including "acquisition of land or aquatic habitat, as are deemed necessary for management and endangered wildlife." Further, SCDNR is authorized to enter into cooperative agreements for purposes of carrying out its responsibilities under the Act.

Criteria for listing species as endangered under the state statute closely follow those for the federal Endangered Species Act. A second category, "Species in Need of Management," is also provided for recognizing and providing less stringent protection for species whose status does not warrant listing as endangered. Under the "species in need of management" category, SCDNR is charged with conducting ongoing investigations of nongame wildlife in order to determine which species are in need of management and for developing programs for their management in order to "sustain themselves successfully." This section of the statute roughly parallels that of the federal statute dealing with threatened species; however, the intent of the state statute is not only to provide listing authority, but also to establish authority for SCDNR to engage in conservation activities in addition to or in lieu of, formal listing and regulatory actions.

A closely related statute establishes the South Carolina Heritage Trust Program (§51-17-10 et seq.). This legislation designates SCDNR as the lead agency to develop and conduct a program whose purpose is "protecting lands and making them available to state agencies, educational institutions and public and private groups" for a number of conservation purposes. The statute authorizes SCDNR to conduct inventories of lands having natural significance, acquire fee simple lesser interest in land, and establish strong legal protections for property thus acquired.

In 1994, the legislative mandate of the SCDNR was updated in a general reorganization of state government. Subsequently, SCDNR adopted the following mission statement:

> *The South Carolina Department of Natural Resources (SCDNR) is the advocate for and the steward of the state's natural resources.*

Within five divisions are numerous individual programs that are responsible for executing the mission in areas such as wildlife and fisheries management, endangered species management, marine fisheries conservation, education, ground and surface water management, soil and water conservation, habitat protection, and a broad array of law enforcement activities in addition to enforcement of fish and game laws. Therefore, from a legal and organizational standpoint, SCDNR was well equipped to lead the development and execution of the SWAP and now the revision of it.

Changes to This Edition of the SWAP

The 2005 version of South Carolina's document was named the Comprehensive Wildlife Conservation Strategy (CWCS). Over time, the Strategy became referred to internally as the State Wildlife Action Plan, or SWAP, for ease of discussion and to match terminology with

neighboring states. Thus, the 2015 iteration of this document underwent a name change to this more familiar title.

The changes to the **mammals** section of the Plan included the listing of 8 new species, all bats. The additional species included all of South Carolina's colonial cavity roosting and foliage roosting bats. Upon the discovery of White-nose Syndrome (WNS) in 2006 and subsequent confirmation in South Carolina in 2013, these bats were immediately considered at risk due to their roosting and swarming behavior and were placed in the "highest" priority category within the SWAP. WNS is caused by the fungus, *Pseudogymnoascus destructans* (formerly *Geomyces destructans*). Other changes in the mammals section involved correcting the listing of the subspecies name of the fox squirrel to the Southern fox squirrel. The Atlantic right whale was also renamed to specify that the North Atlantic right whale was the priority species.

Birds had 48 new species added to the list this iteration (including subspecies) while 42 species underwent priority reassignments. Changes in priority ranking were due, in part, to the methodology change for species selection, but also new trends in populations for these species have become available and are documented in various national plans.

Changes made to the 2015 list of priority **herpetofauna** included some removals and additions. The canebreak rattlesnake was removed from the list as it was not supposed to be included as a separate species of the timber rattlesnake. Hellbender and southern dusky salamander were also removed due to recent research showing they are not naturally found in South Carolina. Painted turtle was added to the priority list as it had been inadvertently left off the first time. New species that were recently discovered included the patch-nosed salamander and dwarf black-bellied salamander, both of which earned a place on the list in the "highest priority" and "high priority" categories, respectively. The Eastern box turtle was also added to the list since recent concerns over the pet trade put it at risk. Other changes to the priority list included 10 priority ranking changes—upgrades to a higher priority listing or downgrades to a lower listing due to more available data on the species.

Freshwater fishes underwent several changes due to improved knowledge of the species' populations and ranges learned through the most recent South Carolina Stream Assessment (2006-2011) funded by State Wildlife Grants. There were 9 new additions to the list; one in the "highest priority" category and the rest in the "moderate priority" category. There were 3 fish that had corrections to their common names. One species, the Saluda Darter, is now considered synonymous with the Carolina Darter. South Carolina's form of what was formerly the Sailfin Shiner is now recognized as the Lowland Shiner (*Pteronotropis stonei*). The Lowland Shiner was a Priority species in 2005 and remains one in 2015. The Bluefin Killifish and Banded Darter are considered introduced species in South Carolina, and although rare, do not warrant priority status. Five fish species were removed from the list altogether. No existing listed priority species were demoted or promoted to other categories.

In the **diadromous fish** category, the American Eel and American Shad have now been given a status in the State of South Carolina as a "species of concern" while the Atlantic sturgeon has since been listed as Federally and State Endangered.

Changes to the **crayfish** list for South Carolina included the addition of 2 new species, the endemic Carolina needlenose crayfish and *Cambarus* sp. “B”. The latter species has yet to be described and fully understood. The Oconee stream crayfish was renamed the Chauga crayfish. Additionally, 10 other species received common names in this iteration of the SWAP. The latest stream surveys also indicated that the Pee Dee lotic crayfish and Carolina Sandhills crayfish (formerly simply called the Sandhills crayfish) were more abundant than first realized and were thus demoted to the “moderate priority” category. The Ohio River **shrimp**, first discussed in the 2005 version of the SWAP in the marine invertebrates section, was moved to the freshwater section because of its association with rivers.

The **freshwater mussel** list underwent some changes such as the renaming of the Carolina Slabshell (*Elliptio canagarea*) as Carolina Elephantear. The reason for the change was due to the fact that the shell was not shaped like other typical slabshells. Likewise, the Southern Rainbow (*Villosa vibex*) was renamed the Eastern Rainbow (*V. modioliformis*). The Atlantic Spike moved up in priority ranking from ‘moderate’ to ‘high’ due to new information available on the status and distribution of the species. A new species this iteration is the Altamaha Arcmussel (*A. arcula*). Eastern Lampmussel (formerly mislabeled in the text as Eastern Lampshell) and the Rayed Pink Fatmucket have been broken out into separate species, *L. radiata* and *L. splendita*, respectively. In 2011, 4 mussel species that occur in South Carolina were proposed as candidates for listing as Federally Threatened or Endangered species (USFWS 2011).

Freshwater snails underwent a few changes as well. *Somatogyrus sp.* (a pebblesnail) was given a formal name, panhandle pebblesnail, and downgraded to “high priority” due to better knowledge of population estimates. The "*Physa* species A" mentioned in the previous (2005) version of the SWAP was formally described as *Physa carolinae* by Wethington, Wise, and Dillon in 2009. *Physa carolinae* is actually rather common, and does not merit any special conservation concern (R. Dillon, pers. comm.).

A new taxa category was added to cover **freshwater, marine and terrestrial leeches** to which 4 species were added. The 2006-2011 South Carolina Stream Assessment, although not specifically designed to target leeches, documented the occurrence of the New England medicinal leech, which was previously not known to occur in the State.

For **marine fish and invertebrates**, the priority species lists were substantially shortened this iteration of the Plan from 938 down to 91 to make them more manageable. Initially, the marine taxa team had considered all species for which information was lacking. This iteration, however, they used a feasibility of study filter to make prioritizations. Some species received new state and global ranks (S and G ranks), and all were able to be priority ranked for the first time. All received species or guild accounts in the Supplemental Volume this iteration.

In the first edition of the SWAP, 15 **insects** were highlighted. Since that time, there have been additions to state species records along with new species descriptions. Therefore, in the 2015 version, 32 were highlighted because the taxonomic committee felt there was enough information to discuss them. In the past, no S-ranks existed for insects in South Carolina. Where knowledge was sufficient, based on the opinions of the various experts, S-ranks were included

for certain groups in this iteration of the Plan, but these should be considered approximations. None of the insects can be ranked as highest, high, or moderate priority at this time.

A major component of this revision includes updates to the current landscape or habitat chapter (Chapter 4) that provide a more comprehensive way of describing and mapping priority habitats within the State. For the initial SWAP preparation (previously referred to as the CWCS), the principal source of information for terrestrial habitat definitions was Nelson's (1986) classification of South Carolina's natural communities. In the previous edition, no GIS supporting maps were included in the Plan. Habitats within the chapter were described in narrative form and were not mapped within the ecoregions. Given the utility that GIS support maps provide, we felt that their addition was an appropriate measure to update our plan that would also echo neighboring states' efforts.

As GAP data has been criticized for its low accuracy rate, it was proposed to use it as a support system for land cover types, which were loosely based on Nelson's *Natural Communities of South Carolina*, and not as the sole basis for classifications. Utilizing our Technology Development Program staff, SC GAP data were isolated by ecoregion and then re-classified to "fit" into the original habitat classes creating the crosswalk table seen in Appendix 4. SC GAP habitat class descriptions—found in the 2001 final report entitled, *"A GAP Analysis of South Carolina"*—and expertise from the Heritage Trust staff were used to justify merging of the GAP map units into their respective SWAP original habitats. SC GAP data actually identified more land cover types within the ecoregions, therefore, providing a more comprehensive overview of the actual habitats present.

The 2005 Plan's Chapter 2 detailing South Carolina's priority species was split into two chapters in this revision and the prioritization process for species and Conservation Action Areas (CAAs) more succinctly defined. The statewide conservation strategies chapter (Chapter 5) was updated to include measures of success that had occurred under each CAA since 2005. A new ninth CAA was added to cover the emerging issue of climate change. South Carolina's Monitoring Program chapter (Chapter 6) was also updated with the latest accomplishments.

The newest public input received is discussed in Chapter 7 and came in the form of climate change workshops. Strategies developed from theses workshops as well as a new Agency climate change guidance document were incorporated in Chapter 5's CAAs. The draft 2015 SWAP was posted to the SCDNR website, advertised, and the suggestions received from the public and our partners incorporated into Chapters 5 and 7.

Now that the SWAPs from the states are actively being implemented, an updated explanation of that process is discussed in Chapter 8. An altogether new chapter was added at the end of the document, Chapter 9: State Wildlife Grant Project Summaries. This chapter highlights the 33 grant projects funded through SWG as part of the implementation of the SWAP that have been completed since 2005. Subjects range from research and survey to habitat enhancement projects.

In the Supplemental Volume's species/guild accounts, some of the conservation recommendations have been accomplished and were thus moved to/discussed in the species/guild's conservation accomplishments section. In addition, any ongoing or new

recommendations were kept or added. The habitat section of the Supplemental Volume was incorporated into Chapter 4: SC's Landscape of the main document and thus removed from the Supplement altogether.

CHAPTER 2: SOUTH CAROLINA'S PRIORITY SPECIES (SPECIES OF GREATEST CONSERVATION NEED)

In setting priorities for the SWAP, two separate but equally important prioritization processes were conducted. It was necessary to determine which species in the State should be placed on the list of South Carolina's priority species—"species of greatest conservation need" (SGCN)— and those species would need to be ranked based on existing data and expertise associated with those species. Additionally, the priority for implementing conservation actions to address challenges to SGCN needed to be determined. The following identifies how the South Carolina Department of Natural Resources (SCDNR) conducted the prioritization process of both species and conservation actions to address the needs of those species.

Species Prioritization

The State Wildlife Grants (SWG) program established funding for species not traditionally covered under federal funding programs. To qualify for these funds, each state was mandated to develop a strategy/plan with a focus on "species of greatest conservation concern;" guidance was provided to the states to begin identifying these species. For the first iteration of the Plan, completed in 2005, SCDNR recognized the importance of including species that are currently rare or designated as at-risk, those for which we have knowledge deficiencies, and those that have not received adequate conservation attention in the past. Additionally, SCDNR included species for which South Carolina is "responsible," that is, species that may be common in our state, but are declining or rare elsewhere. SCDNR also included species that could be used as indicators of detrimental conditions. These indicator species may be common in South Carolina; however, changes in their population status would likely indicate stress to other species that occur in the same habitat.

The diversity of animals in South Carolina is vast (Fig. 2-1). Habitats in this state range from the mountains to the ocean and include many different taxonomic animal groups. SCDNR wanted to address as many of those groups as possible for inclusion in the list of priority species (also referenced as SGCN) for the SWAP. Therefore, 15 taxonomic groups are included in the Strategy: mammals, birds, reptiles, amphibians, freshwater fish, diadromous fish, marine fish, marine invertebrates, crayfish, freshwater shrimp, freshwater mussels, freshwater snails, leeches (freshwater, marine, and terrestrial), insects (freshwater and terrestrial), and plants. Both leeches and plants are new additions to the 2015 SWAP. Though not a requirement of the SWG program, the inclusion of plants is a proactive response to the need for landscape-level management, wherein plants are an integral component. Plants are not eligible for funding under the SWG Program but are of concern nonetheless. Other taxonomic groups that are excluded from this version of the SWAP may be included in future revisions of the Action Plan as additional information and experts specific to those groups are identified.

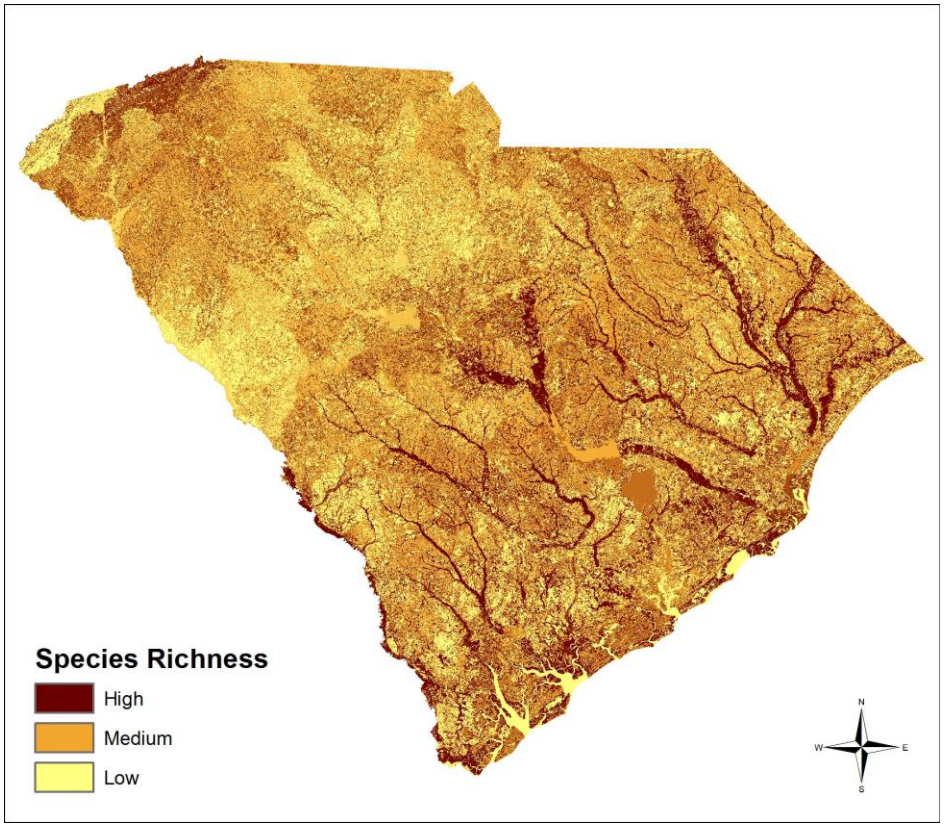


FIGURE 2-1: Total species richness in South Carolina

After the 15 taxonomic groups were identified, a taxa leader was appointed that managed the process for identifying priority species for conservation within that group. This leader formed a committee of experts for the particular taxa. First, the committee reviewed a list of all known species within that group that are found in South Carolina. The SCDNR maintains lists of rare, threatened and endangered plants and animals as part of the Heritage Trust and Endangered Species programs. One list comprises species that are officially designated as endangered or in need of management (threatened). This list was created under the SC Nongame and Endangered Species Act, and applies only to animals; it can only be modified through the regulatory process. The second list comprises species, both plants and animals, thought to be rare, declining, or their population status is unknown. These are termed "Species of Concern," and correspond to the "Watch List" species in other states. The Species of Concern list does not carry the weight of law and is used only as a conservation tool to assist in protection planning and to direct research and survey efforts.

There are various other definitions assigned to species indicating rarity, extinction risk, or trends that may be discussed within the various species or guild accounts in the SWAP's Supplemental Volume and may cause some confusion for the reader. Within the federal government, there are Threatened and Endangered species which are protected under the Endangered Species Act (ESA). In addition, other designations exist. "At-Risk Species" are those species (plants and animals) that have either been proposed for listing, are candidates for listing, or have been petitioned for listing under the ESA. Candidate species are those species (plants and animals) for which the Service has sufficient information on their biological status and threats to propose

them as Threatened or Endangered under the ESA but for which the development of a proposed listing regulation is precluded by other higher priority listing activities. Candidate species receive no statutory protection under the ESA, but the Service encourages their consideration in environmental planning. Although not required by law, it is the Service's policy to monitor candidate species. Organizations also have their own priority designations such as Partners In Flight's (PIF) Watch List species, the International Union for Conservation of Nature's (IUCN) Red List Species, and NatureServe's state and global rankings (S and G ranks). Various reports also include their own scoring systems with associated tiers of species.

After the species lists were assembled, SCDNR developed a list of 9 criteria for consideration in the determination of priority species and are presented in Box 2-1. It should be noted that some taxa groups had more data available than others to utilize when listing and ranking their species of concern so more than these 9 factors could be considered by the various taxa groups when making their decisions.

BOX 2-1: NINE CRITERIA USED FOR DETERMINATION OF SGCN

- State and federal protection status: endangered, threatened, rare or special concern
- South Carolina Natural Heritage Program state rank: S1 through S5
- Degree of exploitation/harvest: high, medium or low
- Availability of past or current funding to address species challenges
- Feasibility measure: the likelihood that conservation activities in South Carolina can make a difference for this species
- Knowledge of the species' population status: status mostly known, slightly known or unknown
- Knowledge of species' distribution in the state: distribution mostly known, slightly known or unknown
- Knowledge of limiting factors affecting the species: limiting factors mostly known, slightly known or unknown
- Population status (trend): population decreasing, stable or increasing

The process for determining priority species by each taxa committee is identified herein for each taxa group and was utilized in 2005 and in the 2015 revision. South Carolina's Priority Species List is presented in its entirety in Appendix 1 A-D which also details each species' priority habitat associations as determined by the taxa committees and consulting the texts of Hamel (1992), Trani et al. (2007), and Wilson (1995). Appendix 1 is broken into terrestrial ecosystems (1-A), freshwater ecobasins (1-B), marine habitats (1-C), and plant ecoregion associations (1-D).

After determining which species would be included on South Carolina's Priority Species List, taxa committees categorized species into three groups: Highest, High and Moderate Priority. Once the lists were complete, species or guild/group accounts were prepared for each animal on South Carolina's Priority Species List, with the exception of plants. Specific accounts were not prepared for plants due to the large number of species and the limited knowledge for those species.

For those species that received an account in the Supplemental Volume, each followed the following format: authors described the species, their status, population size and distribution, habitat requirements, challenges faced, conservation accomplishments and conservation recommendations. This approach allowed for identification of both general conservation strategies for wildlife and habitats in South Carolina, as well as development of species-based conservation strategies. The latter allows for management of particular species within a given habitat. The separate volume, **Supplemental Volume: Priority Species and Habitat Accounts**, contains these reports in their entirety. Authors were often taxa team members, but not necessarily; they may have been consultants.

The total number of species included in South Carolina's 2015 SWAP is 493 members of the animal kingdom and 332 plants for a grand total of 825. Table 2-1 identifies the number of species included in each taxa group. Additionally, Table 2-2 presents the list of species that were prioritized by taxa committees. As with first drafts, mistakes were made in the 2005 version of the Plan in the form of typographical errors, incorrect nomenclature, or inaccurate guild placement. These were corrected for the 2015 revision of the SWAP. Within the Supplemental Volume's species/guild accounts, changes have been made. Species S and G ranks have been updated along with the newest available data to report. New threats were identified in some cases (i.e. see bats and Eastern woodrat). Some of the conservation recommendations have been accomplished and were thus moved to/discussed in the species/guild's conservation accomplishments section. In addition, any ongoing or new recommendations were kept or added.

TABLE 2-1: NUMBER OF SOUTH CAROLINA SPECIES OF GREATEST CONSERVATION NEED BY TAXA

Taxa	No. of Species
Mammals (Terrestrial and Marine)	32
Birds	161
Reptiles and Amphibians	53
Freshwater Fish	57
Diadromous Fish	6
Crayfish (Freshwater and Terrestrial)	24
Freshwater Shrimp	1
Freshwater Mussels	28
Freshwater Snails	3
Leeches	4
Marine Fish	37
Marine Invertebrates	55
Insects	32
Plants (not eligible for funding under SWG)	*332*
Total Number of Animals Species	**493**
Grand Total of All Species (including plants)	**825**

TABLE 2-2: CATEGORIZED PRIORITY SPECIES (SGCN)

Taxa	Highest Priority	High Priority	Moderate Priority
Mammals (32)	Big Brown Bat Florida Manatee Eastern Small-footed Myotis Hoary Bat Little Brown Bat Northern Long-eared Bat Northern Yellow Bat Rafinesque's Big-eared Bat Red Bat Seminole Bat Silver-haired Bat Southeastern Bat Tri-colored Bat	Appalachian Cottontail Bottlenose Dolphin Carolina Red-backed Vole Dwarf Sperm Whale Hairy-tailed Mole Humpback Whale Masked Shrew Meadow Vole Mink North Atlantic Right Whale Pygmy Sperm Whale Star-nosed Mole Swamp Rabbit	Black Bear Eastern Spotted Skunk Eastern Woodrat Pygmy Shrew (Southern) Southern Fox Squirrel Woodland Jumping Mouse
Birds (162)	American Bittern American Black Duck American Golden Plover American Kestrel American Oystercatcher Bachman's Sparrow Black-crowned Night Heron Black Rail Black Scoter Black Skimmer Black-throated Green Warbler Buff-breasted Sandpiper Cerulean Warbler Clapper Rail Common Ground-dove Common Tern Golden-winged Warbler Grasshopper Sparrow Green Heron Gull-billed Tern Henslow's Sparrow Horned Grebe King Rail Least Bittern Least Tern Lesser Scaup Little Blue Heron Loggerhead Shrike Long-billed Curlew Marbled Godwit Northern Bobwhite Northern Pintail Painted Bunting (Eastern) Pied-billed Grebe Piping Plover Purple Gallinule Red-cockaded Woodpecker Red Crossbill Red Knot Reddish Egret Royal Tern Ruddy Turnstone Ruffed Grouse Rusty Blackbird Sanderling	Acadian Flycatcher American Avocet Bald Eagle Baltimore Oriole Belted Kingfisher Black-and-white Warbler Black-bellied Plover Black-billed Cuckoo Brown Pelican Canvasback Chimney Swift Chuck-will's-widow Dunlin Eastern Kingbird Eastern Meadowlark Eastern Towhee Eastern Wood-pewee Field Sparrow Forster's Tern Great Egret Greater Scaup Greater Yellowlegs Kentucky Warbler Least Sandpiper Lesser Yellowlegs Louisiana Waterthrush Mallard Prairie Warbler Purple Martin Purple Sandpiper Redhead Royal Tern Semipalmated Sandpiper Sora Stilt Sandpiper Tricolored Heron Virginia Rail Whip-poor-will (Eastern) White-winged Scoter Willet Wood Duck Wood Thrush Yellow-billed Cuckoo Yellow-breasted Chat Wilson's Snipe	American Coot American Woodcock Anhinga Baird's Sandpiper Barn Owl Bewick's Wren Black-throated Blue Warbler Blue Grosbeak Blue-winged Teal Blue-winged Warbler Broad-winged Hawk Brown-headed Nuthatch Brown Thrasher Carolina Chickadee Carolina Wren Chestnut-sided Warbler Common Gallinule Common Loon Common Raven Dark-eyed Junco Dickcissel Downy Woodpecker Glossy Ibis Golden-crowned Kinglet Gray Kingbird Great Blue Heron Hooded Warbler Indigo Bunting Long-billed Dowitcher Macgillivray's Seaside Sparrow Mottled Duck Northern Parula Orchard Oriole Pectoral Sandpiper Peregrine Falcon Pileated Woodpecker Pine Warbler Prothonotary Warbler Red-bellied Woodpecker Red-breasted Nuthatch Red-headed Woodpecker Red-shouldered Hawk Ring-necked Duck Roseatte Spoonbill

Taxa	Highest Priority	High Priority	Moderate Priority
Birds (continued)	Sandwich Tern Sedge Wren Short-billed Dowitcher Solitary Sandpiper Swainson's Warbler Swallow-tailed Kite Upland Sandpiper Wayne's Black-throated Green Warbler Western Sandpiper Whimbrel White Ibis Wilson's Plover Wood Stork Wood Thrush Yellow-crowned Night Heron Yellow Rail		Scarlet Tanager Semipalmated Plover Snowy Egret Spotted Sandpiper Summer Tanager Tundra Swan White-eyed Vireo White-rumped Sandpiper Worm-eating Warbler Yellow-throated Vireo Yellow-throated Warbler
Reptiles and Amphibians (53)	Bog Turtle Broad-striped Dwarf Siren Chamberlain's Dwarf Salamander Coal Skink Coral Snake (Harlequin) Flatwoods Salamander (Frosted) Florida Green Watersnake Gopher Frog (Carolina) Green Salamander Green Sea Turtle Gopher Tortoise Hawksbill Sea Turtle Island Glass Lizard Kemp's Ridley Sea Turtle Leatherback Sea Turtle Loggerhead Sea Turtle Milk Snake (Eastern) Mimic Glass Lizard Patch-nosed Salamander Pine Barrens Treefrog Pine Snake (Northern) Pine Snake (Florida) Shovel-nosed Salamander Southern Hognose Snake Tiger Salamander Webster's Salamander	Black Swamp Snake Diamondback Terrapin Dwarf Black-bellied Salamander Eastern Diamondback Rattlesnake Florida Softshell Turtle Four-toed Salamander Mud Salamander (Gulf Coast) Pickerel Frog Pine Woods Snake Seepage Salamander Spotted Turtle Timber Rattlesnake Wood Frog Yellow-bellied Slider	American Alligator Bird-voiced Treefrog Chicken Turtle Eastern Box Turtle Northern Cricket Frog Painted Turtle (Eastern) River Cooter Florida Cooter Slender Glass Lizard Snapping Turtle (Common) Spiny Softshell Turtle Striped Mud Turtle Upland Chorus Frog
Freshwater Fishes (57)	"Bartram's" Redeye Bass Bluebarred Pygmy Sunfish Bridle Shiner "Broadtail" Madtom Carolina Pygmy Sunfish Christmas Darter Highfin Carpsucker Robust Redhorse Sandhills Chub Savannah Darter "Thinlip" Chub	Bannerfin Shiner Blackbanded Sunfish Carolina Darter Carolina Fantail Darter "Carolina" Redhorse Piedmont Darter Pinewoods Darter Quillback Santee Chub Seagreen Darter "Smoky" Sculpin Turquoise Darter	Banded Killifish Banded Sunfish Blacknose Dace Central Stoneroller Comely Shiner Eastern Brook Trout Everglades Pygmy Sunfish Fieryblack Shiner Flat Bullhead Florida Gar Greenfin Shiner Highback Chub Highfin Shiner Ironcolor Shiner Lowland Shiner

			Mirror Shiner Notchlip Redhorse Redlip Shiner Rosyface Chub Rosyside Dace Sandbar Shiner Satinfin Shiner Sawcheek Darter Snail Bullhead Striped Bass Swallowtail Shiner Swampfish Tennessee Shiner Thicklip Chub V-lip Redhorse Warpaint Shiner White Catfish Whitemouth Shiner Whitetail Shiner
Diadromous Fishes (6)	American Eel American Shad Atlantic Sturgeon Blueback Herring Hickory Shad Shortnose Sturgeon		
Crayfish (24)	"A Crayfish" (*Cambarus* sp. nov. "B") Chauga Crayfish Edisto Crayfish Mimic Crayfish Newberry Burrowing Crayfish Pine Savannah Crayfish Red Burrowing Crayfish Saluda Burrowing Crayfish	Broad River Spiny Crayfish Piedmont Prairie Burrowing Crayfish Waccamaw Crayfish	Black Mottled Crayfish Brushnose Crayfish Carolina Needlenose Crayfish Carolina Sandhills Crayfish Cedar Creek Crayfish Coastal Plain Crayfish Ditch Fencing Crayfish Hummock Crayfish Pee Dee Lotic Crayfish Rocky River Crayfish Santee Crayfish Shaggy Crayfish Wandering Crayfish
Freshwater Shrimp (1)			Ohio River Shrimp
Freshwater Mussels (28)	Atlantic Pigtoe Barrel Floater Brook Floater Brother Spike Carolina Creekshell Carolina Heelsplitter Creeper Eastern Rainbow Notched Rainbow Savannah Lilliput Triangle Floater Waccamaw Spike Yellow Lampmussel	Alewife Floater Altamaha Archmussel Atlantic Spike Eastern Lampmussel Eastern Pondmussel Northern Lance Pod Lance Rayed Pink Fatmucket Roanoke Slabshell Tidewater Mucket	Carolina Elephantear Carolina Lance Eastern Creekshell Eastern Elliptio Variable Spike
Freshwater Snails (3)		Buffalo Pebblesnail Panhandle Pebblesnail Ridged Lioplax	
Freshwater, Marine, and Terrestrial Leeches (4)		"A terrestrial leech" (*Haemopis septagon*) New England Medicinal Leech	Biannulate Leech "A marine leech" (*Branchellion ravenelii*)

Marine Fish (37)	Carolina Hammerhead Gafftopsail Catfish Hardhead Catfish Scalloped Hammerhead Southern Flounder	Bonnethead Cobia Mummichog Tarpon Weakfish	Atlantic Bumper Atlantic Croaker Atlantic Menhaden Atlantic Spadefish Black Drum Blackcheek Tonguefish Blacktip Shark Bluefish Bull Shark Cownose Ray Fringed Flounder Gag Hogchoker King Mackerel Lemon Shark Off-shore Tonguefish Red Snapper Sheepshead Silver Perch Smooth Dogfish Southern Kingfish Spanish Mackerel Spinner Shark Spot Striped Mullet Tiger Shark Tomtate
Marine Invertebrates (55)	Atlantic Blue Crab Atlantic Horseshoe Crab	Crested Oyster	"A polychaete" (*Aphelochaeta* sp.) "A polychaete" (*Arabella mutans*) "A polychaete" (*Capitella capitata*) "A polychaete" (*Caulleriella* sp.) "A polychaete" (*Drilonereis longra*) "A polychaete" (*Glycera americana*) "A polychaete" (*Glycera dibranchiata*) "A polychaete" (*Laeonereis culveri*) "A polychaete" (*Mediomastus* sp.) "A polychaete" (*Monticellina* sp.) "A polychaete" (*Paraonis fulgens*) "A polychaete" (*Scolelepis* sp.) "A polychaete" (*Streblospio benedicti*) "A polychaete" (*Tharyx acutus*) "An amphipod" (*Acanthohaustorius millsi*) "An amphipod" (*Ampelisca abdita*) "An amphipod" (*Neohaustorius schmitzi*) "An amphipod"

			(*Parahaustorius longimerus*) "An amphipod" (*Protohaustorius wigleyi*) "An amphipod" (*Rhepoxynius hudsoni*) "An isopod" (*Cyathura* sp.) "An oligochaete/sludge worm" (*Tubificoides* sp.) "An oligochaete/sludge worm" (*Tubificoides wasselli*) "An amphipod" (*Lepidactylus dytiscus*) Atlantic Brief Squid Atlantic Ghost Crab Atlantic Mud Crab Atlantic Sand Fiddler Crab Brackish Grass Shrimp Brown Shrimp Cannonball Jellyfish Channeled Whelk Colorful Sea Whip Common Southern Clamworm Coquina Clam Daggerblade Grass Shrimp Dwarf Surf Clam Eastern Oyster Florida Stone Crab Knobbed Whelk Lightning Whelk Marsh Grass Shrimp Marsh Periwinkle Mud Fiddler Crab Northern Pink Shrimp Northern Quahog Northern White Shrimp Red-jointed Fiddler Crab Ribbed Mussel Southern Quahog Tellin Clam species (*Tellina* sp.)
Plants of Concern (332) *(do not qualify for funding under the SWG Program)*	Black-spored Quillwort Bog Asphodel Bunched Arrowhead Canby's Dropwort Chaffseed Dwarf-flowered Heartleaf Georgia Aster Harperella Miccosukee Gooseberry Michaux's Sumac Mountain Sweet Pitcher-plant Persistent Trillium Pondberry Pool Sprite Reflexed Blue-eyed Grass Relict Trillium Rocky Gnome Lichen	Alexander's Rock Aster American Ginseng Appalachian Lophocolea Awned Meadowbeauty Bay Starvine Beak Rush Biltmore Sedge Blue Ridge St. John's-wort Blue-Ridge Bittercress Bog Spicebush Boykin's Lobelia Broad-leaved Tickseed Brown Beaked-rush Bryocrumia Moss Carey Saxifrage Carolina Bird-in-a-nest Carolina Bugleweed	Acid-swamp Yellow-eyed Grass Aethusa-like Trepocarpus Alabama Black Cherry Algae-like Pondweed American Bog Violet American Golden-saxifrage American Lily-of-the-valley American Water-pennywort Appalachian Pellia Appalachian Sedge Ashy-hydrangea Bartram's Rose-gentian Beakrush Bearded Milk-vetch Biennial Gaura Bigleaf Magnolia

	Rough-leaved Loosestrife Schweinitz's Sunflower Seabeach Amaranth Small Whorled Pogonia Smooth Coneflower Swamp-pink White Fringeless Orchid	Carolina Campylopus Moss Carolina Dropseed Carolina Goldenrod Carolina Grass-of-parnassus Chapman's Redtop Chapman's Sedge Chapman's Yellow-eyed Grass Ciliate-leaf Tickseed Climbing Fetter-bush Clingman's Hedge-nettle Creeping St. John's-wort Crestless Plume Orchid Cypress-knee Sedge Dune Bluecurls Earleaf Foxglove Elliott's Croton Evan's Cheilolejeunea False Dandelion Florida Dropseed Florida Thorough-wort Fort Mountain Sedge Fraser Loosestrife Georgia Oak Georgia Plume Giant Spiral Ladies'-tresses Godfrey's Privet Godfrey's Stitchwort Gorge Leafy Liverwort Granite Dome Goldenrod Granite Rock Stonecrop Harper's Fimbry Harper's Yellow-eyed Grass Hooker's Milkwort Incised Groovebur Lance-leaf Seedbox Large-leaved Grass-of-parnassus *Lejeunea blomquistii* ("A Liverwort") *Lobelia sp. 1* Long Beach Seedbox Many-flower Grass-pink May White Mountain Wavy-leaf Moss Mountain Witch-alder Narrow-fruited Beaksedge Narrow-leaved Trillium Oconee-bells Oglethorpe's Oak Open-ground Whitlow-grass Ovate Catchfly Pale Beakrush Panhandle Lily Piedmont Azalea Piedmont Cowbane Piedmont Quillwort Piedmont Ragwort Piedmont Strawberry Piedmont Water-milfoil Pine Barren Gentian Pine Barrens Boneset	Black Huckleberry Black-stem Spleenwort Blue-grass Bluff Oak Bog Oat-grass Bottom-land Post Oak Bradley's Spleenwort Bristle-fern Bulblet Fern Canada Burnet Canada Lily Carolina Dog-hobble Carolina Fluff Grass Carolina Larkspur Carolina Lilaeopsis Carolina St. John's-wort Carolina Whitlow-grass Catawba Rhododendron Cayaponia Cliff-brake Fern Coastal Plain False-foxglove Coastal-plain Thorough-wort Coastal-plain Water-hyssop Corymb Fiddleleaf Crinkled Hairgrass Culver's-root Deep-root Clubmoss Deer-haired Bulrush Dutchman's Breeches Dwarf Juniper Dwarf Milkwort Eared Goldenrod Early Buttercup Eastern Wahoo Eel-grass Eggert's Sunflower Elliott's Bluestem Elliott's Milkpea Elliott's Sedge Engelmann's Quillwort False Rue-anemone Featherfoil Fernleaf Phacelia Florida Adder's-mouth Florida Bladderwort Georgia Beargrass Georgia Leadplant Glade Fern Golden-heather Goldie's Woodfern Gopher-apple Granite-loving Flatsedge Grassleaf Arrowhead Gray-head Prairie Coneflower Great Indian Plantain Greater Bladderwort Gum Bully Gum Bumelia Hairy Fever-tree Harper Beakrush Harper's St. John's-wort James' Sedge

		Pineland Dropseed Pineland Plantain *Plagiochila sharpii* ("A Liverwort") *Plagiochila sullivantii* ("A Liverwort") Pringle's Moss Plymouth Gentian Pondspice Purple Balduina Radford's Sedge Rain Lily Reclined Meadow-rue Rose Coreopsis Sandhills Heartleaf Sandhills Milkvetch Sharp's Leptohymenium Moss Shiny Spikegrass Shoals Spider-lily Small-flowered Buckeye Small's Purslane Southern Nodding Trillium Spatulate Seedbox Spring-flowering Goldenrod Sun-facing Coneflower Sweet Pinesap Sweet White Trillium Taylor's Fern Venus' Fly-trap Wateree Trillium White-wicky Winter Quillwort Wire-leaved Dropseed	Kidneyleaf Mud-plantain Kidney-leaf Twayblade Lace-lip Ladies'-tresses Lance-leaf Loosestrife Large Twayblade Large-flower Milkweed Large-flower Trillium Large-fruited Sanicle Large-stem Morning-glory Leafless Swallow-wort Least Trillium Leconte Flatsedge Limestone Petunia Lobed Spleenwort Long Sedge Long-beaked Baldrush Long-horn Orchid Longleaf Cupgrass Long-spike Fluff Grass Longstalk Sedge Longstem Adder's-tongue Fern Manhart Sedge Marshland Flatsedge Missouri Rock-cress Mohr's Three-awn Grass Mullein Foxglove Myrtle-leaf Oak Narrow-leaved Vervain Needle Palm Nodding Pogonia Nuttall Warea Ogeechee Tupelo Ovate Marsh Fern Pale Jewel-weed Pale Manna Grass Piedmont Cucumber Tree Pine-barrens Reed-grass Pineland Yellow-eyed Grass Pinelands Mountain Mint Pocosin Beaksedge *Porella japonica* ssp. *appalachiana* ("A Liverwort") Prairie Goldenrod Prairie Rosinweed Pretty Sedge Purple-stem Cliff-brake Pyramid Magnolia Ravenel's Eryngo Rayner's Blueberry Reticulated Nutrush Rock Clubmoss Rose Balm Rough Thoroughwort Running Pine Rusty Lyonia Salt-marsh False-foxglove Sampson Snakeroot Sandhills Rosemary Sandhills Wild Petunia Savannah Yellow-eyed Grass

			Schwerin Indigobush Shooting-star Short-bristle Baldrush Shortleaf Sneezeweed Short-leaved Yellow-eyed Grass Short-spike Bluestem Single-haired Mountain-mint Single-sorus Spleenwort Slender Gayfeather Slender Naiad Slender Sedge Small Sundrops Small-head Gayfeather Small's Bog Button Smooth Hedge-nettle Smooth Three-parted Violet Social Sedge Soft Groovebur Soft-hair Coneflower Soft-haired Thermopsis Southern Horse-balm Southern Privet Southern Thimble-weed Spike-rush Spinulose Shield Fern Spoon-flower Stiff Dogwood Swamp White Oak Sweet Fern Tall Bellflower Texas Pipewort Thread-leaf Sundrops Tuberous Gromwell Tunbridge Fern Tussock Sedge Twig Rush Twisted Yellow-eyed-grass Two-leaf Bishop's-cap Two-wing Silverbell Vahl Fimbry Virginia Spiderwort Virginia Stickseed Viviparous Spike-rush Wagner's Spleenwort Walter's Iris Well's Pixie-moss West Indian Meadow-beauty Whisk Fern White Beakrush White Colicroot White False-asphodel White-leaved Sunflower Whorled Horse-balm Wild Bleeding-heart Wing-podded Purslane Winter Grape-fern Woods-rush Woody Goldenrod Woolly Dutchman's-pipe Woolly Huckleberry Yellow Birch

			Yellow Fringeless Orchid Yellow Sunnybell Yellowwood

Table 2-3 contains those priority insect species that are unable to be ranked at this time but for which species accounts are available in the Supplemental Volume.

TABLE 2-3: UNRANKED PRIORITY INSECT SPECIES* (32)

"A Mayfly" *(Acanthametropus Pecatonica)*	Elephant (Tree Hole Mosquito) *(Toxorhynchites rutilus septentionalis)*
"A Mayfly" *(Arthroplea bipunctata)*	Forestiera Lace Bug *(Leptoypha elliptica)*
"A Mayfly" *(Barbaetis benfieldi)*	Forestiera Lace Bug *(Leptoypha ilicis)*
"A Mayfly" *(Heterocloeon berneri)*	Hairy Springfly
"A Mayfly" *(Homoeoneuria dolani)*	Moretti's Protoptila Caddisfly
"A Mayfly" *(Maccaffertium lenati)*	Pointy-Lobed Firefly
"A Mayfly" *(Tsalia berneri)*	Pyramid Ant *(Dorymyrmex bureni)*
"A Moth" *(Agnorisma bolli)*	Pyramid Ant *(Dorymyrmex medeis)*
"A Mayfly" *(Siphlonurus decorus)*	Sandhills Earth Boring Scarab Beetle
American Sand Burrowing Mayfly	Savannah Willowfly
Arogos Skipper	Smokies Needlefly
Black Fly	Smokies Stripetail
Blackwater Sallfly	Two-Spotted Skipper
Calvert's Emerald	White Beach Tiger Beetle
Coyle's Purseweb Spider	Zigadenus Sawfly
Diana Fritillary	
Elephant (Tree Hole Mosquito) *(Toxorhynchites rutilus rutilus)*	

* Due to a lack of data, these species cannot be ranked at this time. However, species/guild accounts are provided in the Supplemental Volume.

During the public comment period for the draft 2015 SWAP, concern was raised about the inclusion of game animals on the list of species in greatest need of management. Many of South Carolina's species hold a significant place in our hunting heritage. However, sound science should prevail over culture. Therefore, the SCDNR closely monitors the impact of hunting on both common and priority species. While other states have placed a moratorium on Bobwhite quail hunting, documented harvest rates on quail in SC, based on fall covey count data and harvest data, has ranged from <1% to nearly 30%. It is unclear if hunting has a marked influence on quail numbers. Habitat restoration is thus preferred. Ruffed grouse, another priority species, is rarely hunted in SC and is thus assumed to not be under immediate threat. Waterfowl trend graphs, similarly, show no hunting impact on populations in SC. Black bear, despite increases in hunting pressure, are in fact increasing in number and have become a nuisance in some parts of the State. Public alligator hunts have been allowed since 2008 (private land hunts since 1995) now that the population appears recovered and stable, but a management plan for the species is in progress (Clemson University graduate work) which will help to analyze and guide the long-term effects and direction of the hunting program.

Conservation Action Prioritization

Once species were prioritized, it was necessary to determine the priority of conservation actions that need to be implemented to conserve those species. The vast number of species in the SWAP and conservation actions necessary for each of those species is staggering. It is apparent that all of the species in the Plan are important to the natural diversity of South Carolina and should be conserved. However, it is also apparent that it would be impossible to immediately implement all the conservation actions developed for inclusion in the SWAP. Therefore, conservation actions were consolidated because it was necessary to use a realistic approach to determine which conservation actions would be implemented first; that is, which actions would receive the highest priority in South Carolina. SCDNR's goal was to identify conservation actions that could realistically be executed and benefit the most priority species. A steering committee was thus formed in 2005 in order to accomplish conservation action prioritization. This committee consisted of senior personnel within the SCDNR. The members of this committee were asked to consider the 6 criteria when ranking conservation actions, which are presented in Box 2-3. For this current iteration of the Action Plan, no new steering committees were formed as the previously set objectives and goals are still in place. Each of the priority conservation actions identified were then attempted over the years and the measures of success documented in Chapter 5: Statewide Conservation Strategies.

BOX 2-3: SIX CRITERIA USED FOR DETERMINATION OF PRIORITY CONSERVATION ACTIONS

- **Feasibility:** Challenges can be mitigated, solutions are apparent. SCDNR can feasibly staff and implement the action and the results will be beneficial.
- **Opportunity**: SCDNR is able to implement the conservation action (i.e., opportunities exist; SCDNR has the authority to carry out the action).
- **Benefit**: Implementation of the action will result in benefits to the natural diversity of South Carolina. Benefits are considered in terms of unit of effort to achieve those benefits; that is, implementation results in multiple benefits to a given species or multiple species are benefited by a single action.
- **Proactive**: Implementation will result in proactive changes to address challenges; actions are more than a reactive response to ongoing challenges.
- **Partnerships**: Partnership opportunities exist for implementation, which provides the ability to leverage other resources.
- **Funding**: Implementation is eligible for SWG funding and/or matching funds exist.

CHAPTER 3: TAXONOMIC GROUPS

This chapter contains an introduction to each taxonomic group considered in the SWAP. The species selection process used by each committee is also included. Although some had enough reliable data to make solid decisions on what species to include and what priority to rank them (highest, high, or moderate), some committees mainly used expert discretion and therefore their methodologies are not as replicable as others. However, the nine criteria discussed in Chapter 2 were utilized to make a decision as to a species' inclusion in the list. Many existing conservation plans were consulted during the selection process and are listed in Appendix 2. Finally, a summary of the threats for each taxonomic group is listed in this chapter. Lack of knowledge of population size, distribution, and life histories was considered a challenge to many of the species in South Carolina's SWAP.

Mammals

According to the American Society of Mammalogists, South Carolina is home to approximately 101 native species of mammals with a higher diversity found in the Coastal Plain and the Mountains (Fig. 3-1). The largest group of mammals in the Southeast is the rodents at around 36 members. However, back in colonial times, South Carolina was also home to several additional species including the buffalo, elk, red wolf, gray wolf, and eastern cougar. Overhunting, persecution, and habitat changes eventually led to their extinction in the region. Declines in other species such as white-tailed deer in sections of the State prompted the creation of restocking programs beginning in 1951 and ending in 1989 which were extremely successful. Because all 642 deer were not brought in from other states in order to accomplish this, the genetic integrity of the species was retained (C. Ruth, pers. comm.). Beavers, which had been extirpated in the 1800s, were reintroduced to the Pee Dee region in the 1940s by the US Fish and Wildlife Service. Fox squirrels have also been translocated from healthy populations in the State to depauperate areas in the Coastal Plain by SCDNR, the University of Georgia, and other private entities (B. Dukes, pers. comm.). We are now experiencing changes in the State's mammalian assemblage once again as new species colonize the landscape. Some have been introduced by humans, as in the case of coyotes and feral pigs, while others have made it here on their own such as the nine-banded armadillo.

The following mammal species are legally classified as furbearers and may be taken by hunting or trapping during the open season by those with a valid license: bobcat, coyote, red fox, gray fox, opossum, raccoon, otter, mink, weasel, striped skunk, spotted skunk, muskrat and beaver. All of these species, except for the coyote, are also classified as small game. Although the spotted skunk, mink, Appalachian cottontail, swamp rabbit, Southern fox squirrel, and black bear are considered priority species for the purposes of the SWAP, they are still game animals capable of being harvested. Their populations are currently stable and hunting has not been found to be a threat to their continued existence in the State. They are monitored here due to concerns about potential population fluctuations.

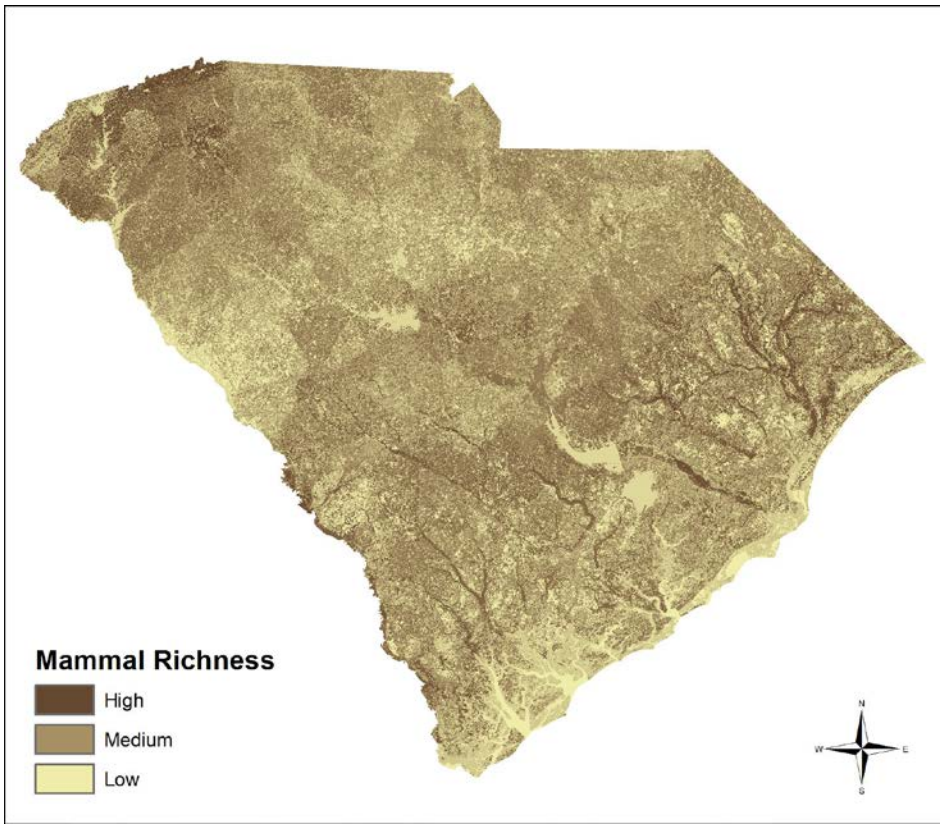


FIGURE 3-1: Mammal richness in South Carolina

Species Selection Process

State and regional experts periodically review rankings and designations for all mammal species in South Carolina. The last terrestrial mammal review, conducted in 2001, had 39 species listed for discussion. Included among those were 4 subspecies, an extirpated species, some species never reported in South Carolina but found in neighboring states, and all of the mammalian species tracked by the SCDNR's Heritage Trust database. For the purposes of the 2005 Plan, the list was narrowed to 27 mammals and was sent to experts for review in this conservation planning process. Ultimately, 24 mammals were chosen for inclusion on South Carolina's Priority Species List.

In 2012, the final list was revisited by the new taxa committee. There were no deletions to the list and 8 additions. The additional species included all of South Carolina's colonial cavity roosting bats and foliage roosting bats. Upon the discovery of White-nose Syndrome (WNS) in 2006, these bats were immediately considered at risk due to their roosting and swarming behavior and were placed in the "highest" priority category within the SWAP. In addition, the subspecies name of the fox squirrel, the Southern fox squirrel, was corrected in the listing. The Atlantic right whale was also renamed to specify that the North Atlantic right whale was the priority species being considered here.

Many of the experts contacted in this process have previously participated in reviews of mammal rankings and designations for South Carolina; several were involved in conservation

prioritization in neighboring states. The information about mammals contained in the SWAP was supplied by the expertise of several biologists who formed our Mammal Taxonomic Committee. The members of that committee invested considerable time to the development of the SWAP and are graciously thanked for their efforts; these individuals are listed in Table 2-3. Other sources of information included published literature and unpublished data from a number of sources.

TABLE 3-1: MAMMAL TAXONOMIC COMMITTEE
(Committee members – 2005 only; *2015 only*; **2005 & 2015**)

Name	Affiliation
Craig Allen	South Carolina Cooperative Fish and Wildlife Res. Unit
Buddy Baker	South Carolina Department of Natural Resources
Judy Barnes	South Carolina Department of Natural Resources, ret.
Mary Bunch	South Carolina Department of Natural Resources
Jay Butfiloski	South Carolina Department of Natural Resources
Julia Byrd	South Carolina Department of Natural Resources
John Cely	South Carolina Department of Natural Resources, ret.
Mary K. Clark	North Carolina State Museum Natural Science/consultant
David Cupka	South Carolina Department of Natural Resources
Rickie Davis	Clemson University
Steve Fields	Culture & Heritage Museums
Mark Ford	United States Forest Service
Wendy Hood	Coastal Carolina University
Susan Loeb	United States Forest Service, Southern Research Station
David Leput	Clemson University
Rudy Mancke	University of South Carolina
Alex Menzel	United States Fish and Wildlife Service
Stanlee Miller	Clemson University Campbell Museum of Natural History
Wayne McFee	National Oceanic and Atmospheric Administration
Chris McGrath	North Carolina Wildlife Resources Commission
Sally Murphy	South Carolina Department of Natural Resources, ret.
Jim Ozier	Georgia Department of Natural Resources
Steve Platt	Wildlife Conservation Society
Toni Piaggio	University of Colorado, Boulder
Travis Perry	Furman University
Edward Pivorun	Clemson University
Doug Rayner	Wofford College
Perry Shatley	United States Forest Service
James Sorrow	South Carolina Department of Natural Resources, ret.
High 'Skip' Still	South Carolina Department of Natural Resources, ret.
Johnny Stowe	South Carolina Department of Natural Resources
Heather Thomas	Auburn University
William David Webster	University of North Carolina Wilmington

Because South Carolina started the 2005 prioritization process after the same process was well underway in North Carolina and Georgia, SCDNR was able to benefit from the information those states had accumulated and shared. In 2012, we again consulted with our partners in other states and utilized similar methods for species prioritization.

Reviewers were asked to rank each species using the nine criteria for consideration in species prioritization outlined in Chapter 2. Species or subspecies were added or dropped from the list if two or more reviewers suggested the addition/deletion. If one reviewer clearly stated the group

should keep a species on the list and another suggested dropping the species, the species remained on the list. Potential species (those without museum records in South Carolina) were dropped from the list. Species/guild accounts can be found in the Supplemental Volume and habitat associations in Appendix 1-A.

The intent of the conservation planning process is to periodically revisit the priority list and adjust it as more is learned about each species, as was the case with the bats. With this group in particular, more acoustical research had been conducted in the interim since the 2005 Plan to provide us with better baseline data for prioritization which will be beneficial in tracking future population decreases due to white-nose syndrome. South Carolina plans to initiate a statewide bat acoustic survey using North American Bat Monitoring Program (NABat) protocols starting in 2015.

Challenges

One of the major challenges to mammals in South Carolina is loss, fragmentation and/or alteration of habitat. As urban development expands in this state, changes to forests and grasslands often lead to outright loss or degradation of foraging, roosting (bats), and denning/nesting habitat. Additionally, habitats are fragmented by development. Roads can limit movement of many species and often result in mortality to individuals. Coastal development can adversely affect marine mammals by increasing exposure to pollutants in stormwater runoff.

Destruction of habitat can also come in the form of wind turbines. The blades often affect bats directly when they collide with them or receive lung damage due to the pressure changes associated with the spinning turbines. One estimate suggests that the growing number of wind turbines of the Mid-Atlantic Highlands alone may cause the death of 33,000-111,000 bats annually by the year 2020 (USGS 2011 referencing Kunz et al. 2007).

Pollutants from a variety of sources can impact mammals. The mink occupies a niche at or near the top of the food chain; therefore, this species is especially vulnerable to environmental contamination, particularly from mercury and PCBs. Contamination in stormwater runoff can also pollute feeding grounds for marine mammals. Trash and litter pose challenges to both terrestrial and aquatic mammals. Small mammals can become trapped in bottles and other litter while foraging. Marine mammals can mistake plastic debris for food items; ingestion of this litter can result in death. One of the greatest challenges to marine mammals and manatees is boat strikes. An additional threat to these animals is entrapment in fishing gear, including hook and line as well as trawls.

Two diseases, raccoon roundworm and Sudden Oak Death (SOD), can adversely affect mammals in South Carolina. Raccoon roundworm can cross species boundaries to infect other mammals, resulting in death. It has been suspected in the decline of the Eastern woodrat in some states. The disease is undergoing a range expansion and may impact counties outside of the Appalachians in the near future. SOD attacks and destroys oak trees which are vital mast producers used as food sources by several mammals on South Carolina's Priority Species List including the Eastern woodrat. In addition, Hemlock Wooly Adelgid has defoliated and killed hemlocks in South

Carolina, altering hemlock coves which are important to some small mammals such as masked and pygmy shrews.

Another emerging disease, WNS, affects bats. On February 21, 2013, a tri-colored bat was found dead at Table Rock State Park. Testing by the Southeastern Cooperative Wildlife Disease Study in Athens, GA confirmed that the bat had WNS, the first case in South Carolina. In April 2013, an Eastern small-footed myotis infected with the fungus was found in a more southerly portion of the same state park. The count continues. To date, 5.7 million bats have died from WNS nationwide (BCI 2012), with a decline of 70% in bat populations in the Northeast alone (USGS 2011). Bats provide pest control services to the agricultural industry in the United States, saving farmers approximately $3 billion a year (USGS 2011). For example, a single little brown bat can consume 4-8 g (0.14-0.28 oz.) of insects a night. With the threat of WNS, the US could stand to gain an additional 1,455 tons (1,320 metric tons) of insects in the Northeast alone if there are no bats to eat them (USGS 2011). Then there are the myriad of forest insects that impact the timber industry; bats also eat these.

Introduced and non-native species can adversely affect South Carolina's mammals. Predation by domestic or feral cats and dogs can reduce population numbers. One study estimated that free-ranging domestic cats kill approximately 6.9-20.7 billion mammals each year in the United States (Loss et al. 2013). Feral hogs can destroy habitat for many species, particularly those found in wetland habitats. Gypsy moths, like SOD, can eliminate food sources for mammals by destroying important tree species. Thankfully, no gypsy moth outbreaks have been recorded in South Carolina to date although the species has been in the State since 1998.

Several species of mammals are regarded by humans as "pests;" this view can lead to persecution of these species. Examples include moles, mice, squirrels, skunks, raccoons, and bats. Black bears have increased in numbers in recent years in both the mountain and coastal population centers and they are expanding their home ranges as a result. However, this puts them in contact with people more frequently, sometimes leading to conflicts.

Finally, global warming could shift suitable high elevation habitat farther north and into higher elevations not found in South Carolina (W. Mark Ford, pers. comm.). This would affect the woodland jumping mouse and both species of moles on South Carolina's priority list.

Birds

As of 2011, 427 species of birds have been documented in South Carolina of which over 181 are classified as breeders (Cely 2003; CBC 2013), the newest being the Reddish Egret (Ferguson et al. 2005). This number may be higher due to the lack of coverage of the Breeding Bird Atlas to adequately survey the breeding distribution of colonial nesting wading birds and shorebirds. The total number of species present is comprised of resident and migrant birds with the majority of taxonomic orders of birds found in the United States being represented (Sibley 2000). South Carolina supports a high diversity of birds during breeding, wintering and migration likely due to the State's varied environments and habitats (Cely 2003). Figure 3-2 shows the bird richness in South Carolina. The National Audubon Society lists 45 sites in the State as Important Bird Areas (IBAs), 16 of which are recognized to be of global importance.

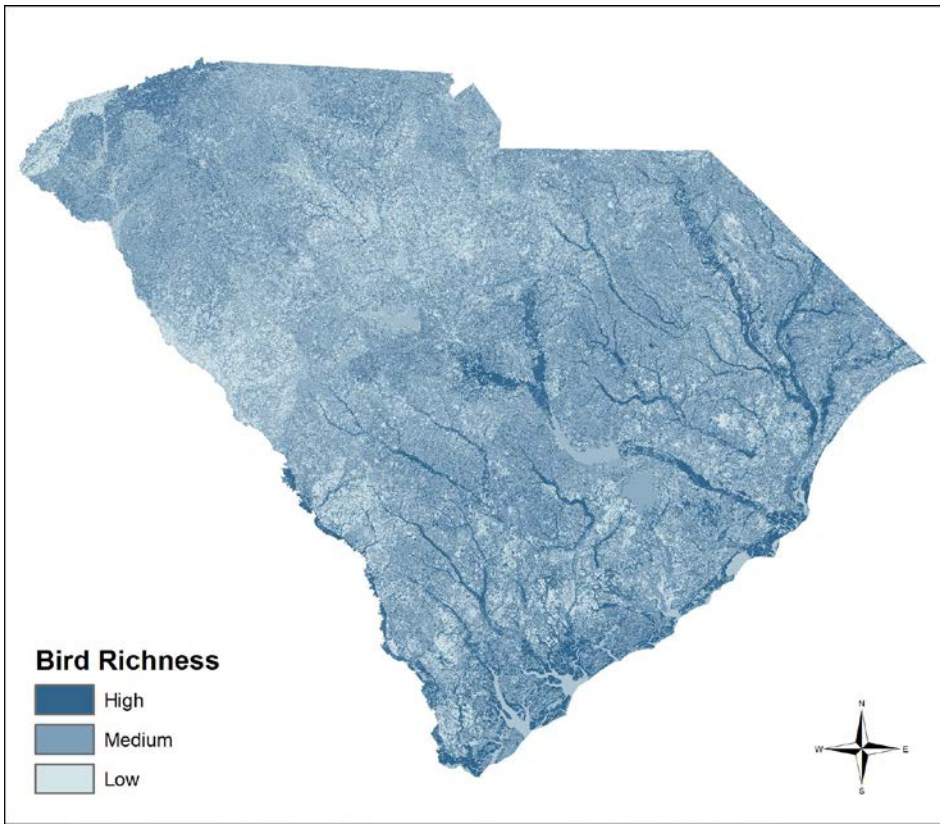


FIGURE 3-2: Bird richness in South Carolina

Three different Bird Conservation Regions (BCRs) transect South Carolina: the Southeastern Coastal Plain, Appalachian Mountains, and Piedmont. Bird Conservation Regions are a single application of a scale-flexible hierarchical framework of nested ecological units based upon the Commission for Environmental Cooperation. BCRs were adopted to provide a single map of biological units for all bird initiatives to use to attain a regional-based approach to bird conservation (US NABCI 2000). BCRs can be partitioned into smaller ecological units to facilitate finer scale planning and implementation or aggregated to facilitate greater cooperation and partnerships across political boundaries in order to recognize the migratory nature and vast annual ranges of some species.

The Appalachian Mountain BCR spans the Blue Ridge, the Ridge and Valley Region, the Cumberland Plateau, the Ohio Hills, and the Allegheny Plateau (US NABCI 2000). The Appalachian mountain BCR contains the headwaters of several major river systems (US NABCI 2000). A portion of the Blue Ridge transects three counties in the northwestern corner of South Carolina; this diverse temperate forest ecosystem supports habitats found nowhere else in the State (Barry 1980). A number of bird species are found in this portion of South Carolina that are not found elsewhere in the State including Peregrine Falcon, Ruffed Grouse, Common Raven, Red-breasted Nuthatch, Golden-crowned Kinglet, Black-throated Blue Warbler, Yellow Warbler, Chestnut-sided Warbler, Red Crossbill and Dark-eyed Junco (Cely 2003). This region also supports some of the highest breeding densities in the State of Scarlet Tanager, Louisiana Waterthrush, Worm-eating Warbler, and Black-throated Green Warbler (Cely 2003).

The Piedmont BCR is geographically part of Southern Appalachia and makes up the transitional area between the mountains and the flat coastal plain spanning from New Jersey to Alabama (US NABCI 2000). Approximately one-third of the State of South Carolina is comprised of this ecological unit (Cely 2003). This area is best characterized by oak-hickory dominated forests with associations of shortleaf and loblolly pine, black gum and sweetgum (Barry 1980). The once fertile and highly productive soils have been reduced due to past mismanagement, and the area is now subject to intensified agriculture and forest management practices (Barry 1980). The Piedmont is the main breeding area in South Carolina for several grassland and scrub/shrub birds such as Killdeer, House Wren, American Goldfinch, Song Sparrow, Field Sparrow and Grasshopper Sparrow (Cely 2003). Interior wetlands, reservoirs, and riverine systems provide migration and wintering habitat for waterfowl and some shorebirds (US NABCI 2000).

The Southeastern Coastal Plain is a huge area composed of both the South Atlantic Coastal Plain and the East Gulf Coastal Plain physiographic areas (Pashley et al. 2000). In South Carolina, the western boundary is at the Fall Line marking the edge of the hilly Piedmont; the eastern boundary is the Atlantic Ocean (Pashley et al. 2000). The major habitat types include longleaf and loblolly pine interspersed with Carolina bays and pocosins, bottomland hardwoods and maritime forests (Barry 1980). Priority species dependent upon pine habitats include Red-cockaded Woodpecker, Bachman's Sparrow, Brown-headed Nuthatch, Henslow's Sparrow and Painted Bunting (Pashley et al. 2000). Bottomland forests support high breeding densities of many Neotropical migrants including Acadian Flycatcher, White-eyed Vireo, Prothonotary Warbler, Hooded Warbler and Northern Parula (Cely 2003). The coastal intertidal habitats provide critical wintering and breeding areas for American Oystercatcher, important wintering and spring migration for Short-billed Dowitcher and Dunlin, and important fall staging areas for Red Knot (US NABCI 2000). Offshore islands and coastal areas provide important nesting and foraging habitats for Brown Pelicans, various ducks, terns, herons, egrets, ibis and other species (US NABCI 2000). Impounded wetlands (old rice fields) and backwaters are particularly important for nesting and foraging wading birds. Many impoundments are managed for waterfowl but also benefit wading birds and shorebirds. Most wading bird rookeries (excluding the Great Blue Heron) are located in the Coastal Plain, and wading birds utilize a variety of types of wetlands in this region.

In the past, the Eastern Wild Turkey would have been included in the SWAP had it not been for the efforts of the SCDNR and its partners. From 1951-2004, a total of 3,542 turkeys were restocked to 204 depauperate areas of the State under the "Turkey Project". Because all of the birds used in the program were not brought in from other states in order to accomplish this, the genetic integrity of the species was retained. Turkeys are now present in all 46 counties in South Carolina and all counties are open for hunting. This represents a great accomplishment for wildlife management in the State. [C. Ruth, pers. comm.]

Species Selection Process

The information about birds contained in the SWAP was mostly supplied by the expertise of several biologists who formed the Bird Taxonomic Committee. It was a relatively subjective review of current listings from various national plans, Partners in Flight data, and others. The

members of that committee invested considerable time in the development of the SWAP and are graciously thanked for their efforts; these individuals are listed in Table 3-2. Other sources of information included published literature and unpublished data from a variety of sources.

TABLE 3-2: BIRD TAXONOMIC COMMITTEE

(Committee members – 2005 only; *2015 only*; **2005 & 2015**)

Name	Affiliation
John Cely	South Carolina Department of Natural Resources
Elizabeth Ciuzio	Kentucky Dept for Natural Resources / US Fish and Wildlife Service
Nathan Dias	Cape Romain Bird Observatory
Billy Dukes	South Carolina Department of Natural Resources
Dennis Forsythe	The Citadel
John Gerwin	North Carolina Museum of Natural Sciences
Lex Glover	South Carolina Department of Natural Resources
Paige Grooms Koon	South Carolina Department of Natural Resources
Christy Hand	South Carolina Department of Natural Resources
Chris Hill	Coastal Carolina University
Anna Huckabee Smith	South Carolina Department of Natural Resources
Chuck Hunter	United States Fish and Wildlife Service
John Kilgo	United States Forest Service
Drew Lanham	Clemson University
Steve Lohr	United States Forest Service
Mary Catherine Martin	South Carolina Department of Natural Resources
Ken Meyers	Avian Research and Conservation Institute
Laurel Moore-Barnhill	South Carolina Department of Natural Resources
Tom Murphy	South Carolina Department of Natural Resources
Bob Perry	South Carolina Department of Natural Resources
Jamie Rader	South Carolina Department of Natural Resources
Jamie Rotenberg	University of North Carolina
Felicia Sanders	South Carolina Department of Natural Resources
Nick Wallover	South Carolina Department of Natural Resources
Craig Watson	United States Fish and Wildlife Service
Tim Jones	United States Fish and Wildlife Service
Dean Harrigal	South Carolina Department of Natural Resources

Species prioritization for birds in the first iteration of the SWAP relied heavily upon the Partners in Flight prioritization process. Partners in Flight (PIF) was initiated in the early 1990's and drew together many knowledgeable groups and individuals focused on "keeping common birds common" (Pashley et al. 2000). The first step in the PIF planning process was to set priorities (Pashley et al. 2000). The conservation assessment process evaluates species vulnerability and was developed based entirely on biological criteria (Hunter et al. 1993; Carter et al. 2000; Panjabi et al. 2001). The prioritization process is based upon 6 factors that measure aspects of vulnerability and the scores for each factor reflect the degree of each species' risk of significant population decline or range-wide extinction at the global level (Rich et al. 2004). In some cases, global assessment scores do not provide accurate prioritization lists at the bird conservation region or smaller ecological unit level. In order to accurately develop smaller scale priority lists; regional scores based on local data are needed (Hunter and Demarest 2005).

The PIF prioritization process allows species to be ranked into conservation tiers based upon combined scores. Species are also assigned a conservation action level that indicates the relative level and immediacy of conservation action based upon the sum of the assessment scores. For the

purposes of this Plan, the majority of the species selected are Tier I species of high concern and Tier II species needing additional stewardship with a conservation action level of immediate management or long-term planning and responsibility. Species selected that are in Tier III and IV represent species that are state or federally listed and/or are of local or regional interest.

Waterbird, shorebird and waterfowl conservation priority selections depended heavily on national and international conservation plans. Birds were chosen based on their continental priority listing as well as professional review of South Carolina's ecological role in the continued conservation of these birds. Plans consulted include the North American Bird Conservation Initiative (NABCI), South Atlantic Migratory Bird Initiative (SAMBI), North American Waterfowl Management Plan (NAWMP), North American Waterbird Conservation Plan (NAWCP) and the United States Shorebird Conservation Plan (USSCP). Thirty-year continental population trend data for waterfowl species was also obtained from the USFWS and professionally reviewed by committee to establish conservation priorities for migratory waterfowl. More detailed justifications for selections are included in species accounts for individuals and guilds of birds. In summary, 110 species of birds were selected for inclusion in the 2005 version of the SWAP.

The 2015 iteration of the SWAP took the original list of birds and reviewed their priority listings. In an attempt to standardize the selection process, the bird taxa committee decided to use pre-existing ranking methods of PIF, Waterbird and Shorebird Plans to reclassify the SWAP species in a comparable way. For landbirds, those with PIF categories of Critical Recovery (CR) or Immediate Management (IM) were recommended for the "highest priority" category under the SWAP. Management Attention (MA) species were put into the "high" category, and Planning and Responsibility (PR) designees went under "moderate priority" status. The database used for this purpose was the PIF species assessment for BCRs 27, 28, and 29.

Waterbirds were determined in this way: "highest priority" went to CR, IM, and MA species. "High priority" species included those in the Additional Stewardship (AS) category. "Moderate priority" species came from the listings for species that were of (1) Additional High National Responsibility and (2) Other Local or Regional Interest Species. The database used was Table 1 in the 2006 Southeast US Waterbird Conservation Plan. Shorebirds were scored based on the data in Table 1 of the 2004 US Shorebird Conservation Plan (High Priority Shorebirds section). Those of "highest" concern in the SWAP were those the Shorebird Plan considered Highly Imperiled or of High Concern. SWAP High concern species were from the Shorebird Moderate Concern list while the SWAP "moderate" listings were those of Low Concern in the Shorebird Plan.

Waterfowl ranks did not change much and roughly coincided with prioritizations by Waterfowl Conservation Region (WCR) in the North American Waterfowl Management Plan (ACJV Implementation Plan Revision, June 2005). Five ducks changed priority ranking in the 2015 iteration of the Plan.

After re-evaluation of the 2005 list of priority bird species, 48 new species were added (including subspecies) while 28 species underwent priority reassignments, including 5 ducks, 5 wading birds, 13 songbirds, and 5 miscellaneous species. The changes in priority ranking were due, in

part, to the methodology change for species selection, but also new trends in populations for these species have become available. Some species, like the Rosette Spoonbill and Reddish Egret, are becoming more common in South Carolina and thus deserve to be considered for prioritization. Mottled Ducks, though not a native species, have a large, self-sustaining population here in South Carolina and may possibly have become established here anyway as ranges expanded (D. Harrigal, pers. comm.).The total number of birds included in the 2015 edition of the SWAP is 164. Species/guild accounts are found in the Supplemental Volume, and habitat associations are in Appendix 1-A.

Challenges

One of the major challenges to birds in South Carolina is outright loss, fragmentation, and/or alteration of habitat. Land use changes and urban development are often to blame. Birds in this state depend upon varied habitats from the mountains to the coast; changes to habitats can result in loss of feeding or nesting habitat for these species. Wetland habitats, which are important to many members of this taxa have been destroyed by draining and filling throughout the State. Even small alterations to wetlands can make the habitat unsuitable for use by these species as water levels change and prey species disappear. Nesting habitat is also affected.

Conversion of prime habitat to agricultural fields poses another challenge to birds. For example, longleaf pine habitat has been greatly reduced both in extent and in quality; vast acreages of longleaf pine have been converted to agriculture and/or loblolly pine plantations in South Carolina. The loss or degradation of longleaf pine habitat results in the loss of key components necessary for success of the animals that live in that habitat.

Fire suppression contributes to habitat loss for bird species that require an understory with a diverse herbaceous plant layer that is maintained by routine burning. In recent years, the use of prescribed fire as a management tool has decreased in the State due to an increase in housing density. This has resulted in successional changes that render the habitat unsuitable for some animal species.

Human disturbance represents a significant challenge to birds in South Carolina. Nesting success of many birds can decrease when people frequent breeding bird congregation areas. Further, wakes from boats can destroy nests and interrupt feeding for many shorebirds. Because there are a limited number of islands that can be utilized for nesting purposes, disturbances are often profound since the birds cannot simply go somewhere else. In addition, pelicans, terns, and skimmers nest colonially so many nests can be affected each time the colony is disturbed.

Chemical contamination often threatens many carnivorous bird species, particularly those that consume fish and other aquatic organisms. Persistent organo-chlorine pesticides and heavy metals, such as lead and mercury, can result in poisoning. Barbiturate poisoning of Bald Eagles has also been an issue in South Carolina and elsewhere. Phenobarbital, which is used to euthanize animals, can be ingested by eagles that feed on carcasses that have been disposed of in landfills. The Center for Birds of Prey in Awendaw, SC has treated several Bald Eagles for such poisoning in the past. New regulations require disposal of euthanized animals in a dedicated

section of landfills and then they are covered to a certain depth in order to minimize scavenger deaths.

Several diseases and parasites can affect bird populations directly. These include West Nile virus, Avian Vacuolar Myelinopathy, cholera, botulism, and soft tick infestation. Indirect effects on bird populations include disease outbreaks in important nesting substrates or forage plants. Examples include Sudden Oak Death (SOD) and Hemlock Wooly Adelgid infestations which greatly alter the characteristics of the forest type and therefore bird habitats.

Additionally, an over-population of white-tailed deer can be detrimental to bird habitat. In areas of high densities (greater than 7.9 deer/km^2), herbivores browse the understory such that nesting and foraging substrates are greatly reduced (NatureServe 2004).

Non-native predators can also decimate bird populations. In particular, predation by domestic and feral cats is problematic for songbirds. In 2013, researchers reported that an estimated 1.4-3.7 billion birds are killed each year in the United States (Loss et al. 2013.) Additionally, wind turbines kill or maim approximately half a million birds every year (ABC 2013). Nighttime migrants and raptors are especially vulnerable. It is estimated that by 2030, the total number of wind turbines in the US could grow to more than 100,000, essentially doubling the number of bird strikes (ABC 2013). Wind farms themselves also destroy habitat as vegetation is removed and towers are erected. By 2030, 20,000 $mi.^2$ of terrestrial habitat and 4,000 $mi.^2$ of marine habitat may be impacted.

Collisions with glass buildings claim around 300 million to 1 billion birds each year (ABC 2013). Communication tower strikes take an additional 7 million birds per year (ABC 2013). Nocturnal migrants often become confused by the red lights of communication towers and hit the guy wires or the towers themselves. In a report by the American Bird Conservancy (Shire et al. 2000), the number one species killed was the Ovenbird, followed closely by many other neotropical migrant songbird species.

Migratory species like songbirds, shorebirds, and waterfowl will be highly affected by climate change. Already researchers have noted that ducks migrating to their wintering grounds are leaving later and later while Canada geese are cutting short their trip south along the Central Flyway (BPC 2012). Migrations and breeding are timed to coincide with abundant prey. If the timing of spawning and/or insect hatching is decoupled from the arrival of the birds along the migration, routes, these birds could face higher mortality during migration and lower productivity on the breeding grounds. As droughts dry up critical stopover habitat, ducks are forced to overfly these dry pools in search of available water. Migration stress leads to more casualties along the way and lower numbers next year. Breeding grounds are also in trouble. The prairie pothole region could dry up, threatening 69% of the region's breeding ducks (BPC 2012). Although the northern boreal forests and parklands can provide additional breeding habitat, these areas are under threat as well from warming trends (D. Harrigal, SCDNR, pers. comm.).

Breeding bird ranges have begun to shift north as is evident by tropical species establishing themselves along the Gulf Coast. As temperatures increase, bird species in remnant boreal forests will have nowhere to go but up until the habitat runs out. In addition, sea level rise will

destroy foraging habitat used by waterfowl and wading birds by changing salinity levels and aquatic plant species composition. A multitude of nesting shorebirds will be affected by sea level rise as former nesting habitat is inundated.

Wading birds will be affected by drought conditions as prey abundance in nontidal wetlands diminishes. When wading birds are required to fly greater distances to find food, droughts can result in nesting failures or lower productivity (C. Hand, SCDNR, pers. comm.). In addition, lower water levels can make nests vulnerable to mammalian predators, especially when aquatic vegetation becomes established. Unusually high water levels, as seen during floods, can result in prey being dispersed. Heavy rainfall during the chick-rearing period is an issue for tactile foragers such as the Wood Stork, who require concentrated prey in shallow water to feed efficiently. Coastal areas, where both tidal and nontidal foraging areas can be utilized, will become increasingly important to wading birds if prey availability becomes diminished or unpredictable farther inland. Managing impounded wetlands near wood stork colonies to concentrate prey at critical times during the nesting season can counteract some of the negative effects of droughts and floods on prey availability and improve the survival rates of nestlings.

Herpetofauna: Amphibians and Reptiles

Currently, 144 species of amphibians and reptiles are known to occur in South Carolina. The State's rich herpetofaunal diversity is likely due to the diversity of habitat in our state. Though small in land area, South Carolina comprises portions of three major physiographic provinces: the Blue Ridge, Piedmont and Coastal Plain. Within each of these provinces, numerous sub-provinces or distinct ecological regions occur. A variety of unusual or rare habitats are found within these regions, and many support populations of unusual or rare amphibians and reptiles.

South Carolina is particularly important with regards to amphibian diversity. Salamander diversity in our state is very high in the Blue Ridge and Coastal Plain provinces. In fact, the Jocassee Gorges area in the Upstate contains the highest number of salamanders found anywhere on Earth. South Carolina' State Amphibian is the spotted salamander. One area of South Carolina's southern Coastal Plain supports more frog species (25) than any other place in North America (Duellman ed. 1999). See Figures 3-3 and 3-4.

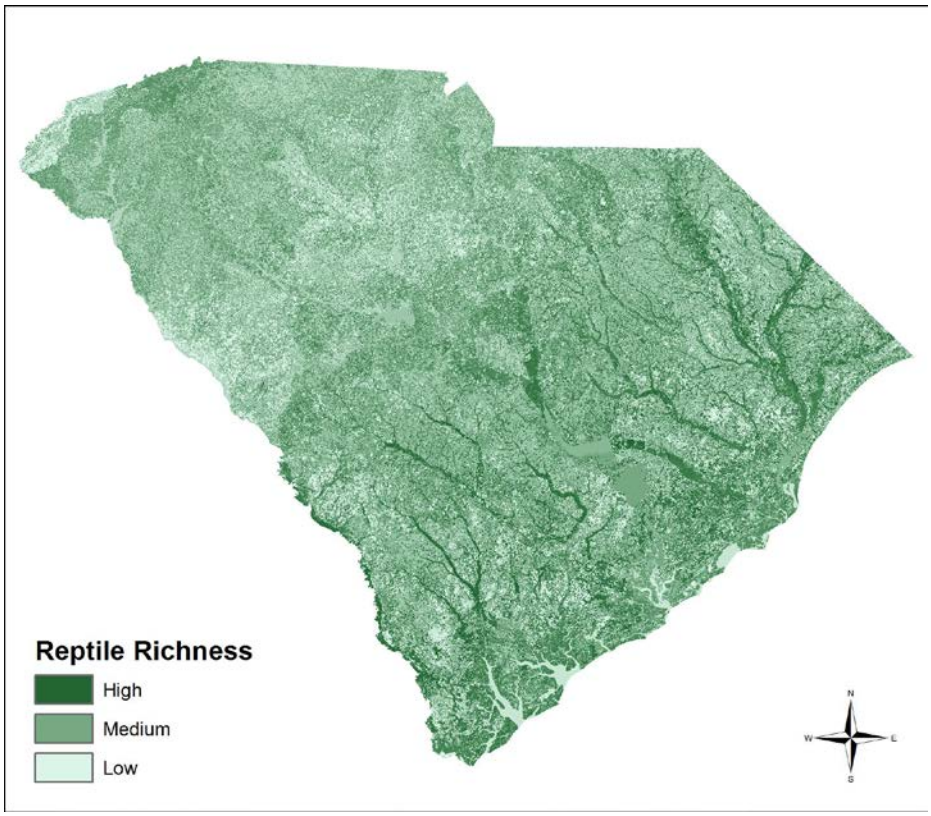


FIGURE 3-3: Reptile species richness in South Carolina

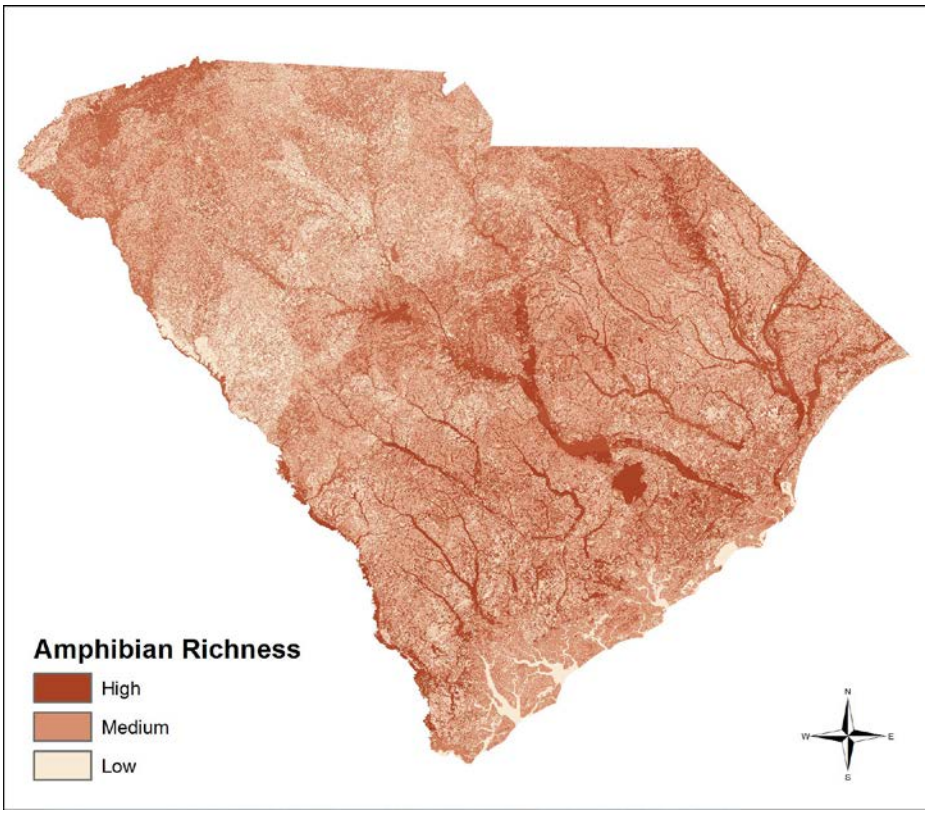
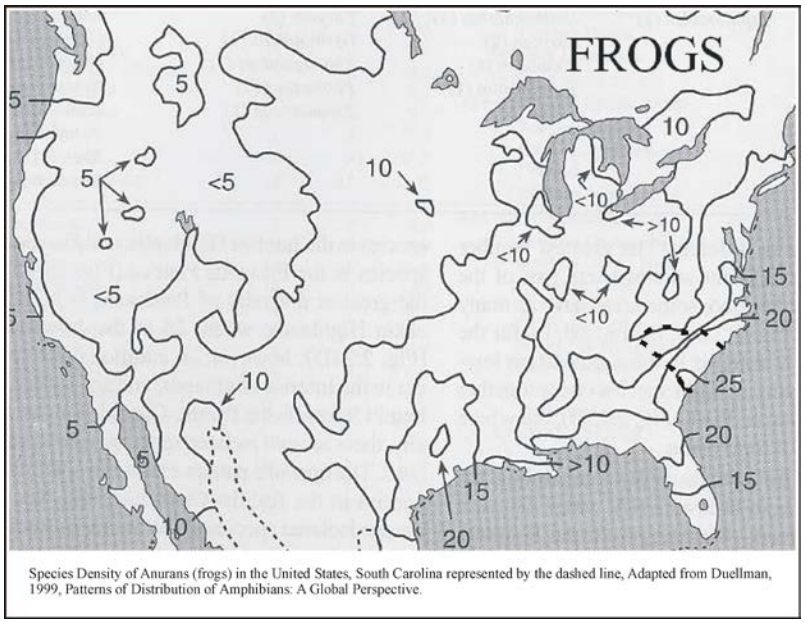
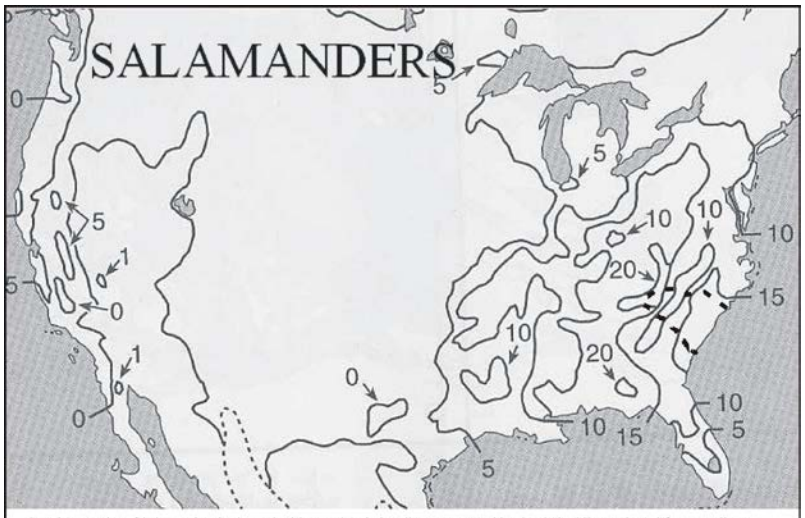


FIGURE 3-4: Amphibian species richness in South Carolina

The Blue Ridge, Upper Piedmont (referred to colloquially as the Foothills) and Coastal Plain are collectively rich in herpetofauna. Rock outcrops in the Blue Ridge and Upper Piedmont provide habitat for Jordan's salamander, the green salamander, and the timber rattlesnake. Bogs in this same region may provide habitat for the bog turtle**.** Several species of amphibians and reptiles found in South Carolina's Blue Ridge are peripheral to our state as the core of their geographic range is farther north.



Species Density of Anurans (frogs) in the United States, South Carolina represented by the dashed line, Adapted from Duellman, 1999, Patterns of Distribution of Amphibians: A Global Perspective.



Species Density of Salamanders in the United States, South Carolina represented by the dashed line, Adapted from Duellman, 1999,Patterns of Distribution of Amphibians: A Global Perspective.

FIGURE 3-5: Maps of frog and salamander densities in the contiguous US.

The Piedmont of South Carolina is not as rich in herpetofauna as the other physiographic provinces, but there are areas of this province that are important. The Savannah River Valley, for instance, is home to the Webster's salamander, a rare species endemic to this region (at least in South Carolina). Numerous species that are found primarily in the Coastal Plain intrude into the Piedmont along the Savannah River. See Figures 3-6 and 3-7.

The Coastal Plain is a very important region overall for herpetofauna in South Carolina, with high species diversity, habitat diversity, and several rare, threatened and endangered species. Of the approximately 144 species of amphibians and reptiles found in the State, 112 occur in the Coastal Plain and 49 of these are endemic, or nearly endemic to this province (at least in South Carolina). See Table 2-5.

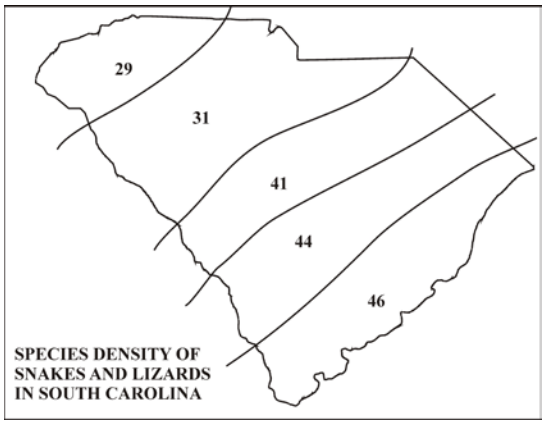


FIGURE 3-6: Species density of snakes and lizards in ecological regions of South Carolina

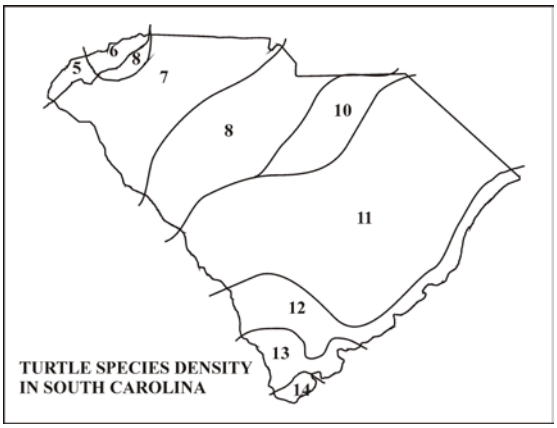


FIGURE 3-7: Species density of turtles in ecological regions of South Carolina

The diversity of reptiles in South Carolina is significantly higher in the Coastal Plain than in other areas of the State. Within this province, longleaf pine habitat plays a vital role in the life history of many species, including such rarities as the pine snake, southern hognose snake, and the gopher tortoise. Isolated, temporary wetlands such as Carolina bays, flatwoods, ponds, and limesinks provide breeding habitat for numerous amphibians, including the flatwoods salamander, tiger salamander, and gopher frog. Seeps and shrub bogs, embedded in xeric longleaf pine habitat in the Fall Line/Sandhills, are home to the pine barrens treefrog. Table 3-3 lists amphibians and reptiles that are endemic or nearly endemic to the South Carolina Coastal Plain.

TABLE 3-3: Herpetofauna endemic or nearly endemic to South Carolina's Coastal Plain

American alligator	Flatwoods salamander	Ornate chorus frog
Banded water snake	Florida cooter	Pig frog
Barking treefrog	Florida green water snake	Pine barrens treefrog
Bird-voiced treefrog	Florida softshell turtle	Pine woods snake
Black swamp snake	Glossy crayfish snake	Pine woods treefrog
Brimley's chorus frog	Gopher tortoise	Rainbow snake
Broad-striped dwarf siren	Greater siren	River frog
Carolina gopher frog	Green treefrog	Southern chorus frog
Carpenter frog	Island glass lizard	Southern cricket frog
Chicken turtle	Lesser siren	Southern hognose snake
Cottonmouth	Little grass frog	Southern toad
Diamondback terrapin	Mabee's salamander	Spotted turtle
Dwarf waterdog	Many-lined salamander	Squirrel treefrog
Eastern coral snake	Mimic glass lizard	Striped mud turtle
Eastern diamondback rattlesnake	Mole salamander	Two-toed amphiuma
Eastern glass lizard	Mud snake	
Eastern tiger salamander	Oak toad	

Species Selection Process

The amphibian and reptile portion of the SWAP has been written in a manner that incorporates a regional as well as species-specific and/or guild-specific approach. These priority species were identified by herpetological experts in the State. The members of that committee invested considerable time to the development of the SWAP and are graciously thanked for their efforts; these individuals are listed in Table 3-4.

TABLE 3-4: AMPHIBIAN AND REPTILE TAXONOMIC COMMITTEE
(Committee members – 2005 only; *2015 only*; **2005 & 2015**)

Name	Affiliation
C.L. Abercrombie	Wofford College
Ken Alfieri	Alligator Adventure
Kimberly Andrews	Savannah River Ecology Laboratory
Rob Baldwin	Clemson University
Dave Beamer	Nash Community College, NC
Jeff Beane	North Carolina Museum of Natural History
Steve Bennett	South Carolina Department of Natural Resources
Eric & Denise Billings	Charleston Turtle and Tortoise Society
Rick Blob	Clemson University
Alvin Braswell	North Carolina Museum of Natural History
Kurt Buhlmann	Savannah River Ecology Laboratory
Carlos Camp	Piedmont College, GA
Jeffrey Camper	Francis Marion University
Joshua Castleberry	University of South Carolina, Sumter
Heyward Clamp	Edisto Island Serpentarium
Mark Danaher	United States Forest Service
Mike Dorcas	Davidson College, NC
Mary Lang Edwards	Erskine College
Eric Fann	South Carolina Aquarium
John Fauth	Central Florida University
Roark Ferguson	Roark's Reptile Safari
Steve Fields	Cultural and History Museum
Barbara Foster	Greenville Zoo
Dr. J.W. Gibbons	Savannah River Ecology Laboratory
Julian R. Harrison	College of Charleston (ret.)
Hugh Hanlin	University of South Carolina, Aiken
Joey Holmes	Private consultant
Deborah Hutchinson	Coastal Carolina University
Jeff Humphries	North Carolina Wildlife Resources Commission
Austin Jenkins	University of South Carolina, Sumter
John Jenson	Georgia Department of Natural Resources
Wade Kalinowsky	South Carolina Department of Natural Resources
Eran Kilpatrick	University of South Carolina, Salkehatchie
Peter King	Francis Marion University
Sally Krebs	University of South Carolina, Beaufort
Mike Martin	University of South Carolina, Columbia
Kevin Messinger	North Carolina State University
Brian Metts	Savannah River Ecology Laboratory
Judy Greene	Savannah River Ecology Laboratory
Tony Mills	Spring Island Trust
Richard Montanucci	Clemson University (ret.)
Jeff Mohr	Macon State College, GA
Zach Orr	Randolf Rattlesnake Refuge and Research Center
Edwin Ott	South Carolina Department of Natural Resources
Gene Ott	South Carolina Amphibians and Reptiles webmaster
Scott Pfaff	Riverbanks Zoo

Melissa Pilgrim	University of South Carolina, Upstate
Corey Roelke	University of South Carolina graduate school
David Scott	Savannah River Ecology Laboratory
Sam Seashole	Alligator Adventure
Chuck Smith	Wofford University
Keith Taylor	Private consultant (dec.)
Tracey Tuberville	Savannah River Ecology Laboratory
Austin Trousdale	Lander College
Jayme Waldron	University of South Carolina, Columbia
Allison Welch	College of Charleston
John D. Willson	Savannah River Ecology Laboratory
Chris Winne	Savannah River Ecology Laboratory

These experts grouped many of the species into guilds (functional groupings) to indicate common habitat requirements, management needs, life history traits, threats, and/or other characteristics. Many of these groups align with provinces (e.g. Blue Ridge) or habitat regions (e.g. the historic distribution of longleaf pine) of the State. A number of species did not fit easily into a functional group and are addressed individually in the SWAP. All species, whether addressed individually or in a functional group, are related (within the SWAP) to a specific habitat type or several habitat types. Species/guild accounts can be found in the Supplemental Volume and habitat associations in Appendices 1-A (terrestrial), and 1-B (freshwater).

The species reports detail the amphibian and reptile priority species and provide information on their life history, status, threats they are facing, and detailed recommendations for conservation actions. Priority species are associated with key habitats, as well as specific descriptions of those habitats. The conservation needs of the species or functional groups are identified for the regions of the State and habitats in which the actions need to take place.

The first gathering of the herpetofauna taxa committee in 2005 began the selection process by compiling all available data and lists for herpetofauna in the State. The initial list of amphibians and reptiles designated as endangered, threatened, or species of concern was developed at the First South Carolina Endangered Species Symposium, held in 1976. As a result of this symposium 16 species of amphibians and 20 species of reptiles were proposed for listing under an appropriate category. Species recommended for endangered or threatened statuses were incorporated into the official list promulgated under South Carolina Regulation. The designation Threatened was changed to Species in Need of Management under the Act. A justification for listing was given for each species in the symposium volume.

The list of amphibian and reptile species that resulted from the 1976 symposium was also used to develop a list of "elements of concern" for the SCDNR's Heritage Trust Program. Listed species are "tracked" by this program through a computer database, developed initially by The Nature Conservancy. Occurrence records for these species are stored in this database. Archived data is very similar to that of a museum collection record and includes location, date, collector/observer, as well as other pertinent data.

The Heritage Trust Program, as part of its routine operation, established taxa review committees to periodically review the species lists and make recommendations for changes. The Amphibian and Reptile Taxa Review Committee met initially in 1983. Subsequent meetings of this group occurred in 1987, 1996, and 2004. A number of additions have been made to the original list as a

result of these meetings and several changes in nomenclature or taxonomy have occurred since the initial list was developed.

On January 30, 2004, SCDNR and Riverbanks Zoo in Columbia, SC sponsored the first annual South Carolina Herpetology Conference. The conference was open to both professional and amateur herpetologists with approximately 130 attendees. One presentation at the conference concerned the SWAP (or CWCS as it was referred to at that time) as it pertained to amphibians and reptiles. At the close of the meeting, SCDNR personnel distributed a packet of questionnaires concerning the status of amphibians and reptiles in South Carolina that was based on the matrix developed for the Strategy/Plan. Attendees who volunteered to fill out the questionnaires were asked to evaluate all of the amphibian and reptile species currently listed as either endangered, in need of management, or species of concern. In addition they were asked to evaluate 16 additional species that were selected based on suggestions from knowledgeable individuals, unknown status, or because the species were representative of habitats that are believed to be rare, uncommon, or potentially threatened. A total of 52 species of amphibians and reptiles in South Carolina were ultimately identified as priority species, representing 37% of the State's species. With the first listing, some mistakes were made and these were subsequently addressed in the 2015 revision of the SWAP.

During the second meeting of the taxa committee for the 2015 iteration of the SWAP, a total of 54 species of amphibians and reptiles in South Carolina were identified as priority species, representing approximately 35% of the State's species. While these 54 species have been identified as requiring immediate conservation attention, this is by no means an indication that the remaining species are stable and secure. All inventory projects originating as the result of this SWAP must take the full spectrum of South Carolina's amphibian and reptile fauna into account, documenting occurrences for all species.

Several changes to the 2015 priority herpetofauna list included upgrades to a higher priority listing or downgrades to a lower listing due to more available data on the species. There were also removals and deletions. The canebreak rattlesnake was removed from the list as it was not supposed to be included as a separate species of the timber rattlesnake in the 2005 edition. Painted turtle was added to the priority list as it had been inadvertently left off the first time while the Eastern box turtle was added due to concerns with losses to the pet trade. New species that were recently discovered included the patch-nosed salamander and dwarf black-bellied salamander, both of which earned a place on the list.

A recent project, funded by the State Wildlife Grants program, focused on the molecular phylogeny of salamanders in the genus Desmognathus, in particular the southern dusky salamander (*Desmognathus auriculatus*), which was identified as a conservation candidate under the 2005 iteration of the SWAP (CWCS). Results of this project indicate that this species does not occur in SC. Five Desmognathine lineages have been identified in SC, one of which is the currently recognized species, the spotted dusky salamander (*Desmognathus conanti*), which is the predominant species in the western portion of the State. The other 4 lineages are aligned with the northern dusky salamander (*Desmognathus fuscus*). Some of these lineages may warrant elevation to species level, but that is a work in progress. With the exception of one lineage, which only occurs in a small portion of SC, the other "*fuscus*" lineages are widespread and can

be relatively common to abundant. Based on this research, the southern dusky salamander has been removed from the SC list of Species in Need of Conservation as identified through the SWAP process.

The Hellbender (*Cryptobranchus alleganiensis*) has been removed from the original list of Species in Need of Conservation due to the lack of data supporting a self-sustaining population in South Carolina. There are two records for this species from the State, both from the area of Lake Tugaloo. Both animals were adults caught by fishermen, and it's been 30+ years since the last record. The hellbender does not occur "naturally" in Atlantic slope drainages, except for a small area in the extreme north of its range, in Massachusetts. Other than that small area this species is restricted to Gulf drainage streams. Surveys conducted by SCDNR staff and conservation partners have not resulted in any additional observations of this species in the State. It is likely that the two historic specimens taken in SC were introduced, escaped, or were from the bait trade and don't represent an established breeding population of hellbenders.

Eight species of freshwater turtles were identified as Species in Need of Conservation under the first version of the SWAP (the CWCS), based on concerns about their harvest for the Asian turtle (food) market. In 2009 South Carolina enacted a law prohibiting the removal of large numbers of these 8 species plus the Eastern box turtle, from the State for any purpose. The law created a permit for owners of private ponds such that they could harvest yellow-bellied and common snapping turtles. To date no one has applied for one of these permits. As such we are changing the status of the following species from high to moderate: spiny softshell turtle, painted turtle, chicken turtle, river cooter, and yellow-bellied turtle. No status change is recommended for the Florida softshell turtle as it is peripheral in SC and relatively uncommon. It is recommended that SCDNR continue to monitor the international trade in turtles and any impact that may have on our native turtle fauna.

The Eastern box turtle is being added to the list of Species in Need of Conservation in South Carolina. This species is relatively common in the State, but has become a target for the "wild-caught" pet trade. It was included in the list of turtles protected under the "turtle law" due to the concerns of researchers who have worked with the species for years. It is common for wild caught box turtles from South Carolina to show up frequently at reptile shows and on reptile websites. This species occurs in 30 states; it is listed as Endangered in one state, Maine, and has some type of regulatory protection in 13 states, including South Carolina. In addition, 18 states have identified it as a Species in Need of Conservation while 16 states allow take/harvest for personal use. Only one state, South Carolina, allows take for commercial purposes, though the number which can be removed from the State is limited under the new turtle law. The Eastern box turtle is being added to the list with a moderate priority with the sale of wild-caught box turtles as the primary conservation issue.

Challenges

As is the case with most wildlife species, amphibian and reptile populations are affected by habitat loss. In particular, the loss of rare, uncommon or vulnerable habitats, such as isolated freshwater wetlands, longleaf pine communities, and freshwater seepage wetlands is taking its toll on herpetofauna.

One of the major challenges to amphibians and reptiles in South Carolina is loss of habitat. Wetland habitats, which are important to many members of this taxa group, have been destroyed by draining and filling throughout the State. Even small alterations to wetlands can make the habitat inhospitable for reptiles and amphibians. Pond breeding amphibians are known to require adequate upland habitat around breeding ponds. Populations of amphibians may be extirpated by the elimination of adequate upland habitat despite the protection of the breeding pond. Conversely, the drainage or alteration of ponds in an otherwise unaltered forest may result in the extirpation of local amphibian populations. Many wetlands that still exist are now unsuitable for breeding because they have been left isolated in the landscape as a result of farming or timber operations.

Conversion of habitat to agricultural purposes represents a significant challenge to reptiles and amphibians. For example, longleaf pine habitat has been greatly reduced both in extent and in quality subsequent to European settlement of the southeast (Noss 1989). Vast acreages of longleaf pine have been converted to agriculture and/or loblolly pine plantations in South Carolina. The loss or degradation of longleaf pine habitat results in the loss of key components necessary for success of the animals that live in that habitat.

Habitat can also be lost to urban development. Nesting habitat for marine turtles is lost as coastal development expands. Even if a suitable sandy beach is available, nesting can be aborted because of beach furniture and equipment blocking access to nest sites. Further, lighting in coastal areas can disorient turtles and result in nesting failure. Road mortality is also a significant threat as urban development requires that additional roadways. These roads are frequently constructed through amphibian and reptile habitat. Mortality occurs as animals attempt to migrate across roadways.

Fire suppression contributes to habitat loss for many amphibian and reptile species. Many species in this taxa group require an understory that contains a diverse herbaceous plant layer that is maintained by routine burning. However, in recent years, use of adequate fire management has decreased in the State, which has resulted in successional changes that render the habitat unsuitable for some animal species.

Emerging diseases can lead to severe population crashes or even extinctions. Chytridiomycosis is a fungal disease caused by *Batrachochytrium dendrobatidis* that affects the skin of amphibians, compromising water and electrolyte uptake. Because amphibians rely on their skin like we do our lungs, the hyperkeratosis caused by the fungus can also impact respiration. Another emerging disease we are watching in South Carolina is Ranavirus which causes hemorrhaging and ulcers.

A new threat that may begin to affect South Carolina's native snakes is Snake Fungal Disease (*Ophidiomyces ophiodiicola*) that causes swelling, scabs, and lesions. Copperheads, cottonmouths, water snakes, garter snakes, ribbon snakes, milk snakes, corn snakes, indigo snakes, and ring-necked snakes can be affected. In October 2013, an infected copperhead was found in Spartanburg County, SC, making it the first confirmed case in the State. Additional possible cases in kingsnakes from the same area are under investigation. The SCDNR will be watching this disease closely for its potential impact on both priority and currently secure species.

Another significant challenge to amphibians and reptiles is unregulated harvest. Currently, collection and/or harvest are regulated for only a few reptiles and amphibians in South Carolina. Collection of salamanders for the bait industry is a threat to some salamander species as collectors do not discriminate among species. Further, the salamander bait trade is unregulated. Generally, all salamander species collected are lumped together and referred to as "spring lizards." Several species of snakes in the State are collected for the pet trade; such collection is also unregulated.

Freshwater turtles can be adversely affected by many factors including habitat destruction and poor water quality. An additional challenge to these animals comes from unregulated harvest. Continuing unregulated harvest in South Carolina could result in drastic population declines for these turtles, which are currently common to abundant.

Introduced species, both plant and animal, can adversely affect South Carolina's reptiles. Beach vitex, an exotic introduced plant, has recently taken over areas in northern Georgetown and Horry Counties. Its aggressive growth and impenetrable roots quickly cover the dunes, making them unsuitable for turtle nesting (R. Westbrooks pers. com.). The Beach Vitex Task Force was established to combat this invasive species, and as of 2011, over 220 sites have been detected and cleaned. This amounts to 99% of the known populations of vitex.

The presence of nonnative fire ants throughout the Southeastern United States has been implicated as a potential reason for the apparent decline of the southern hognose snake (Tuberville and Jensen 2008). Fire ants may also be adversely affecting populations of other fossorial and egg-laying snakes. Further, fire ants are suspected to affect the probability of turtle hatchling survival.

Red-eared sliders (*Trachemys scripta elegans*) impact the population stability of yellowbelly turtles through hybridization. This nonnative species has been released in South Carolina resulting in concerns about the genetic integrity of the yellowbelly turtle as established red-eared sliders interbreed with this species, shifting the genetics of local populations.

Entrapment in fishing devices, including hook and line, trawls, and crab pots represents a significant challenge to turtle species throughout the State. Florida softshell and spiny softshell turtles are often captured incidentally on hook and line and are either killed to retrieve the tackle, or later die due to complications from the ingested hook. Major challenges to the diamondback terrapin in the marine environment include recreational, commercial and abandoned/ghost crab pots. Efforts have been made to educate crab fishermen about the importance of removing old pots and using turtle excluders over the openings. Incidental take of loggerhead turtles from boat strikes and commercial fishing operations also constitutes a major challenge to this species. In a 1990 study, the National Academy of Sciences estimated that between 5,000 and 50,000 loggerheads were killed annually by the shrimping fleet in the southeastern Atlantic and Gulf of Mexico (National Research Council 1990). In 1988, South Carolina was the first to enact Turtle Exclusion Devices (TEDs) on shrimp trawls to reduce incidental take of sea turtles. By 1991, TEDs were required everywhere by the National Marine Fisheries Service. The size of TEDs was adjusted in 2003 to accommodate leatherback sea turtles. The shark longline fishery, which operates all year long off the south Atlantic, may still impact loggerheads in the neritic

environment (Lewison et al. 2004). Turtles are still at risk from entanglement in longlines, float lines, and other ropes and cables (NMFS & USFWS 1991). In addition, sea turtles may mistake floating plastic for jellyfish and ingest it, causing gut obstructions or the absorption of toxic chemicals (NMFS & USFWS 1991).

A silent threat to some herpetofauna is the lack of knowledge about the species and thus the uncertainty of their status. There are a number of amphibian and reptils species in South Carolina for which adequate data on their status is lacking, but there is no immediate indication that they are threatened. Species such as the many-lined salamander (*Stereochilus marginatus*), southern Appalachian salamander (*Plethodon oconaluftee* [*teyahalee*]), mole kingsnake (*Lampropeltis calligaster*), and glossy crayfish snake (*Regina rigida*) are examples of species that are not well known in the State and that may be of future conservation concern.

Several groups of ecologically or taxonomically related species have been identified by SCDNR staff, colleagues and reviewers of the SWAP as problematic, and potentially in need of conservation in the future. These include glass lizards; small, fossorial snakes; and semi-aquatic snakes.

Of the four species of glass lizards found in SC only one, the Eastern glass lizard, appears to be common, even occurring in suburban and urban "habitat". The three remaining species were identified as priority species under the 2005 version of the SWAP. The slender glass lizard is uncommon while the island and mimic glass lizards are rare to extremely rare. Detection is a problem with these species and, to date no sampling or collection technique, such as coverboards or drift fences, has proven effective for them. Identification can be problematic; there are good diagrams in several guides, but there is also some degree of variability within species which may be ontogenetic.

One species, the pine woods snake, was identified as a priority species under the first version of the SWAP, but this may bear further thought as detection is obviously an issue with this species. Some species, such as the ring-necked snake, brown snake, and worm snake are common to abundant and these species also seem to be habitat generalists. Other species, such as the earth snakes and the Southeastern crowned snake may be uncommon and more habitat-restricted than the other species but also simply difficult to detect. All of these small snakes, especially those in the Coastal Plain, may be susceptible to impacts from imported red fire ants.

One species of semi-aquatic snake, the black swamp snake, was identified as a priority species under the first version of the SWAP, and two other species—the glossy crayfish snake and the rainbow snake—are reportedly uncommon in South Carolina. Detection is an issue with these species and any survey efforts aimed at them must use techniques that target them such as aquatic minnow traps or small hoop traps and coverboards at the edges of wetlands.

Continued controversy over the taxonomic status of certain species, or species complexes, results in a lack of certainty in giving a truly fixed number of species for the State. New species have been recently discovered or described, which results in a dynamic species list. Other taxonomic issues include the slimy salamander complex, the southern Appalachian salamander, and the milk snake/scarlet kingsnake relationship. An unidentified species of the genera *Desmognathus*

has been found in Jasper County, within the range of *Desmognathus auriculatus*, that more closely resembles either *Desmognathus apalachicolae* or *Desmognathus fuscus conanti*, neither of which has been documented for coastal South Carolina.

To emphasize the way in which the species list can change, consider the following recent additions. Within the past 30 years, the striped mud turtle (*Kinosternon baurii*), bog turtle (*Glyptemys muhlenbergii*), and seepage salamander (*Desmognathus aeneus*) have been verified as occurring in South Carolina. In addition, two newly described species, the mimic glass lizard (*Ophisaurus mimicus*) and Chamberlain's dwarf salamander (*Eurycea chamberlainii*), were added to the State's list of native herpetofauna in the past decade. Additionally, two more species, the patch-nosed salamander (*Urspelerpes brucei*) and the dwarf black-bellied salamander (*Desmognathus folkertsi*) were added as the SWAP was being revised.

Freshwater Fishes

South Carolina has an abundant and diverse aquatic community. There are 146 fish species that are known to inhabit the freshwaters of South Carolina or are seasonally dependent on freshwater habitats to complete their life cycle, such as shad and sturgeons. Several other fish taxa have not been scientifically described but may warrant species status review and would increase the number of species native to South Carolina. South Carolina's diverse fish fauna is largely due to the myriad of aquatic habitats that can be found throughout the State. Small, high-gradient Blue Ridge streams; large, fertile Piedmont rivers; and the "blackwater" streams and bays of the Coastal Plain are just a few of the aquatic habitats that contain numerous and diverse fish communities. South Carolina's freshwater fish fauna also boasts a relatively high degree of endemism with distributions of approximately 32 species, including the Carolina darter and the Sandhills chub, that are restricted to South Carolina, or more often, restricted to a few drainages that South Carolina shares with one or more of its neighboring states (Table 3-5).

TABLE 3-5: Freshwater fishes endemic to South Carolina and neighboring states in the South Atlantic region with indication of current conservation status.

Scientific Name	Common Name	Priority 2010-2015
Cottus sp. cf. *bairdii*	"Smoky" Sculpin	YES
Cyprinella chloristia	Greenfin Shiner	YES
Cyprinella labrosa	Thicklip Chub	YES
Cyprinella leedsi	Bannerfin Shiner	YES
Cyprinella pyrrhomelas	Fieryblack Shiner	YES
Cyprinella sp. cf. *zanema*	"Thinlip" Chub	YES
Cyprinella zanema	Santee Chub	YES
Elassoma boehlkei	Carolina Pygmy Sunfish	YES
Elassoma okatie	Bluebarred Pygmy Sunfish	YES
Etheostoma brevispinum	Carolina Fantail Darter	YES
Etheostoma collis	Carolina Darter	YES
Etheostoma fricksium	Savannah Darter	YES

Etheostoma hopkinsi	Christmas Darter	YES
Etheostoma inscriptum	Turquoise Darter	YES
Etheostoma mariae	Pinewoods Darter	YES
Etheostoma thalassinum	Seagreen Darter	YES
Hybopsis hypsinotus	Highback Chub	YES
Hybopsis rubrifrons	Rosyface Chub	YES
Micropterus sp. cf. *coosae*	"Bartram's" Bass	YES
Moxostoma pappillosum	V-lip Redhorse	YES
Moxostoma robustum	Robust Redhorse	YES
Moxostoma sp. cf. *erythrurum*	"Carolina" Redhorse	YES
Notropis alborus	Whitemouth Shiner	YES
Notropis chiliticus	Redlip Shiner	YES
Notropis chlorocephalus	Greenhead Shiner	NO
Notropis scepticus	Sandbar Shiner	YES
Noturus sp. cf. *leptacanthus*	"Broadtail" Madtom	YES
Percina crassa	Piedmont Darter	YES
Salvelinus fontinalis	S. Appalachian Brook Trout	YES
Scartomyzon rupiscartes	Striped Jumprock	NO
Scartomyzon sp.cf. *lachneri*	"Brassy" Jumprock	NO
Semotilus lumbee	Sandhills Chub	YES

Despite the Southeast's aquatic faunal diversity, some species are increasingly at risk of extinction. More than two decades ago, a fish assessment of the Southeastern US identified 85 fishes in peril (Deacon et al. 1979). A decade later, Williams et al. (1989) recognized 109 Southeastern fishes as in jeopardy. A published assessment focusing exclusively on Southeastern fishes (Warren et al. 2000) identified 187 taxa as extinct, endangered, threatened or vulnerable, which represents a 125% increase in imperiled fish taxa in only 21 years. Eighteen fish species that inhabit South Carolina were identified as endangered, threatened, or vulnerable to imperilment by Warren et al. (2000). An additional 38 fish species were determined to be of conservation concern in South Carolina in the first version of the SWAP (formerly the CWCS) (Kohlsaat et al. 2005). The third and latest published assessment of North American freshwater fishes reported that approximately 39% of described fish species on the continent are imperiled (Jelks et al. 2008). Compared to the 1989 assessment of Williams et al. (1989), Jelks et al. (2008) found that most taxa were the same or worse in conservation status; only 11% of those imperiled in 1989 had improved or been delisted. Our assessment currently places 57 freshwater fishes on South Carolina's Conservation Priority List. Although many of these species may not be in jeopardy globally, they warrant conservation concern if the goal is to maintain South Carolina's rich and diverse fish fauna. Future extinction rates of freshwater fish species in North America may approach 53 to 86 species by 2050; we have already lost 57 taxa since 1898 (Burkhead 2012).

Species Selection Process

The information about freshwater fishes contained in the SWAP was supplied by the expertise of the biologists who formed our Freshwater Fish Technical Team (FFTT). The members of that team invested considerable time in the development of the SWAP and are graciously thanked for their efforts; these individuals are listed in Table 3-6. Other sources of information included published literature and unpublished SCDNR and Clemson University data.

TABLE 3-6: FRESHWATER FISHES TECHNICAL TEAM
(Committee members – 2005 only; *2015 only*; **2005 & 2015**)

Name	Affiliation
Ron Ahle	South Carolina Department of Natural Resources
Tanya Darden	South Carolina Department of Natural Resources
Jeff Foltz	Furman University
Kevin Kubach	South Carolina Department of Natural Resources
Cathy Marion	South Carolina Department of Natural Resources
Joe Quattro	University of South Carolina
Fritz Rohde	North Carolina Division of Marine Fisheries
Mark Scott	South Carolina Department of Natural Resources
Dustin Smith	North American Native Fishes Association
Wayne Starnes	North Carolina State Museum of Natural Sciences
David Wilkins	South Carolina Aquarium

For the 2015 revision, the methods for determining priority ranking were based on a State Wildlife Grant-funded field survey of statewide streams, which marks the first objective, data-driven ranking of conservation need among South Carolina's diverse assemblage of freshwater fishes. The South Carolina Stream Assessment (SCSA) was initiated in 2006 and completed in 2011, data from which provided population density estimates of the State's freshwater fishes. We developed a quantitative and objective method using these data to rank conservation need among species. While the previous conservation priority designations for South Carolina freshwater fishes provided a useful framework for conservation planning and implementation, those rankings were based largely on qualitative observations such as expert-opinion that are useful in the absence of a robust data set. The availability of the SCSA data now allows us to objectively assess conservation need among species at the statewide scale. A quantitative index for assigning conservation priority for South Carolina stream fishes was created based on multiple attributes related to risk of imperilment including abundance, frequency of occurrence, range size and existing range-wide conservation status. The caveat to this treatment is that species whose preferred habitats are not wadeable streams are not well represented in the ranking, so other accommodations had to be incorporated.

Three hundred ninety-seven (397) randomly selected sites were sampled from 2006 - 2011 following SCSA Standard Operating Procedures for wadeable streams (Scott et al. 2009). Priority score was determined for each species by summing the three values for abundance, frequency of occurrence, and range size. Thus, a lower total score represented a higher conservation priority based on the rationale that species exhibiting low abundance, infrequent occurrence and/or a narrow overall distribution were most likely to decline due to anthropogenic alteration of habitats and ecosystems.

Regardless of status in South Carolina, species known to be declining or at high risk of decline in other portions of their ranges warranted concern. To account for existing conservation status,

scores were adjusted for species recognized as imperiled on a range-wide basis in a recent comprehensive assessment of North American fishes (Jelks et al. 2008). Scores for species listed in Jelks et al. (2008) were reduced by a percentage concordant with imperilment status: Endangered = 75% reduction; Threatened = 50%; Vulnerable = 25%. For the current conservation priority revision, any fish recognized as imperiled in Jelks et al. (2008) was assigned Priority status regardless of its priority index score. (For a complete discussion of the mathematical process, see the Assessment itself.)

The SCSA focused on wadeable freshwater streams draining watersheds between 2 to 58 mi.^{2} (4-150 km^2). Although wadeable streams by length comprise about 90% of all stream and river habitats in South Carolina, they do not represent the primary habitat for certain species and therefore we excluded from the rankings species considered to occur principally outside of wadeable streams or otherwise beyond the scope of the SCSA. Species in the following categories were excluded from the rankings: (1) diadromous species except *Anguilla rostrata* (American Eel); (2) primarily estuarine species not collected in the SCSA; (3) non-native species not collected in the SCSA. Two species in this latter category, Banded Sunfish (*Etheostoma zonatum*) and Bluefin Killifish (*Lucania goodie*) were included in the previous SWAP but removed from consideration in this iteration. One additional species listed in the 2005 plan is omitted here: Saluda Darter (*Etheostoma saludae*) is considered conspecific with Carolina Darter (*Etheostoma collis*) (Rohde et al. 2009). South Carolina's form of what was formerly the Sailfin Shiner is now recognized as the Lowland Shiner (*Pteronotropis stonei*). The Lowland Shiner was a priority species in 2005 and remains one in the 2015 version of this Action Plan.

Prior to assigning final priority status, additional consideration was given to species known to occur primarily outside of wadeable streams, based on best available data and expertise of the Freshwater Fishes Technical Committee. Species falling within the priority range of the rankings yet known to be secure and stable in habitats other than wadeable streams were evaluated on a case-by-case basis by the FFTC. Examples included species occurring primarily in: (1) large (non-wadeable) streams and rivers, (2) lakes, and (3) swamps and wetlands.

Final rankings were computed for 130 fish species occurring in fresh waters of South Carolina. Conservation priority scores ranged from 0.50 ("Carolina" Redhorse, *Moxostoma sp. cf. erythrurum*,) to 156.77 (Redbreast Sunfish, *Lepomis auritus*) and the median score was 30.19, excluding the ubiquitous Eastern Mosquitofish (*Gambusia holbrooki*) at 609.45.

Based on the threshold in score distribution at 22.0 and consideration of status for species on either side of this score, we established a score of 22.0 as the cutoff for priority status (i.e. priority status if score $\leq$ 22.0). Fifty-four species exhibited scores less than 22.0 and were proposed for priority status. Of these, 43 species (80%) were previously designated as priority species in the SWAP (Kohlsaat et al. 2005).

Two additional species whose scores were outside of priority range were automatically assigned priority status due to range-wide imperilment recognition by Jelks et al. (2008): Ironcolor Shiner (*Notropis chalybaeus*) and Lowland Shiner (*Pteronotropis stonei*). All 54 species below the priority score cutoff value of 22.0 were evaluated by the FFTC prior to final assignment. Three proposed priority species were not added due to their secure status in habitats other than

wadeable streams: Brassy Jumprock (*Scartomyzon sp.*, abundant in larger rivers including the Broad River), Whitefin Shiner (*Cyprinella nivea*, abundant in larger rivers), and Lined Topminnow (*Fundulus lineolatus*, abundant in swamps and wetlands).

Nine species were assigned priority status for the first time, including *N. chalybaeus*. Ten previous priority freshwater species, from the 2005 Action Plan, scored beyond the priority cutoff and were proposed for removal from priority status. However, three of these species—White Catfish (*Ameiurus catus*), Highfin Carpsucker (*Carpiodes velifer*), and Quillback (*Carpiodes cyprinus*)—primarily occur in larger riverine habitats, and therefore this stream assessment did not provide sufficient grounds to remove priority status for these species. Five previously assigned priority species were removed from the list based on the ranks: Mud Sunfish, Pugnose Minnow, Longnose Dace, River Chub, and Greenhead Shiner. The above considerations resulted in the total of 57 species of freshwater fish listed in this revised Plan. Species/guild accounts can be found in the Supplemental Volume and habitat association in Appendix 1-B.

Challenges

One of the major challenges to freshwater fishes in South Carolina is degradation and loss of habitat. As urbanization through development occurs, waterbodies are altered in ways that change both the topography and hydrology of streams, rivers, wetlands, lakes and ponds. Removing riparian vegetation can result in siltation, increases in nutrient and pollutant loading, increases in velocity of flow both into and within the waterbody, and temperature increases.

Erosion from agriculture and silviculture (logging) can significantly lower water quality and cause drastic adverse reactions in aquatic life (Butler 1968). Runoff carries silt, chemicals and nutrients into wetlands that, acting alone or in combination, can be lethal to aquatic life, and particularly to larval forms (Matthews et al. 1980; Aust et al. 1997). Runoff can cause sedimentation while nutrients can encourage algal blooms, both leading to eutrophication and possible dissolved oxygen (DO) depletion (Matthews et al. 1980; Lockaby et al. 1997). Siltation can also cause an increase in water temperature (Aust and Lea 1991; Perison et al. 1993). Forestry Best Management Practices (BMPs) for bottomland forests are recommendations to landowners in order to conserve site productivity—primarily for silviculture—and are voluntary (SCFC 1998). When BMPs are not used, braided streams may be obstructed by plant material and disturbed soils; excessive ruts may channel eroded sediments into streams. Additionally, partially stagnated waters may become nutrient-rich and promote algal growth that can die under extended periods of cloud-cover (J.W. McCord, SCDNR, pers. obs.). These factors contribute to increased water temperature and reduced DO.

Rapid development in some parts of South Carolina also contributes to siltation in many ways. Impervious surfaces such as roads, buildings and parking lots increase erosion in adjacent areas and contribute to flooding. Clearing riparian vegetation also destabilizes stream and riverbanks allowing excessive siltation. Clear cutting in a substantial part of a watershed can also contribute to siltation even if a riparian buffer is maintained. In a study of several watersheds in the Georgia piedmont, streams in urban and agricultural watersheds had much higher nutrient and suspended sediment concentrations than watersheds that remained mostly forested. Suburban

watersheds had intermediate levels of nutrients and suspended sediments when compared with watersheds dominated by forested or urban and agricultural land use (Meyer and Couch 2000). The use of motor vehicles in streams and along banks can also degrade the stability of banks, stir up benthic sediments, and increase siltation. Factors that contribute to siltation can also change the topography of the stream or river by changing the slope of the bank and eliminating heterogeneity in the channel.

Siltation from agricultural, silvicultural and other land use practices can also reduce spawning success by causing mortality of eggs or by coating substrates needed for attachment of adhesive eggs (NMFS 1998). Pollution, runoff and siltation input contaminants and pollutants into sturgeon habitat that can cause lowered pH or lowered DO. This, in turn, can reduce survival of eggs, larvae or juveniles (Rogers and Weber 1995; NMFS 1998). Bioaccumulation of contaminants may reduce productivity or increase susceptibility to diseases or stress (Cooper 1989; Sindermann 1994; Varanasi 1992; NMFS 1998).

Hydrologic alterations to waterbodies can be detrimental to freshwater fishes. Dams prevent upstream migration of fish (ASMFC 1990; NMFS 1998; USFWS et al. 2001). Dams can block spawning migrations and severely restrict the availability of spawning and nursery habitat. In the event of a catastrophic event along a stream section, such as the diesel spill on a portion of the Reedy River in 1996, dams can make it very difficult for fishes and other aquatic animals to recolonize areas devastated by the catastrophe. Dewatering streams and rivers for anthropogenic purposes can result in reduced flows, elimination of critical habitats, and reduced water quality by concentrating non-point source pollution and increasing water temperature.

Nonnative fish species, particularly the nonnative Flathead Catfish (*Pylodictis olivaris*) and the Blue Catfish (*Ictalurus furcatus*), can severely impact native fish populations through competition for resources and predation. Flathead Catfish are voracious predators that have decimated ictalurid and other fish populations throughout the Southeastern United States (Guire et al. 1984; Jenkins and Burkhead 1994; Bart et al. 1994).

Climate is a primary force driving ecosystem dynamics, and aquatic systems are particularly susceptible to alterations in the hydrologic cycle. Our ability to predict the consequences of climate change is limited by uncertainty in climate predictions compounded by complexity in ecological system behavior. Climate will interact with a host of other ongoing system alterations—such as land use change—with which organisms must cope. Changes in precipitation timing and amount will affect water quantity and quality and timing of flows**.** Some of the unique characteristics of aquatic ecosystems in South Carolina that must be considered when planning for climate change impacts include:

- a high level of aquatic organism diversity and endemism.
- if migration of fishes is limited to within drainage networks, preventing natural migration across watershed boundaries.
- if barriers to connectivity within drainages are widespread, limiting natural migration upstream and downstream.

Data collected during the South Carolina Stream Assessment are being used to model potential consequences of climate change for streams in the State.

Diadromous Fishes

Diadromous fishes are species with complicated life histories, including partial growth and development in fresh and brackish and/or marine waters. These species are dependent on access to a wide diversity of habitats, particularly relative to water salinity or salt content, to most successfully complete their life cycle (McDowall 1988). There are several basic life history patterns within this group.

Anadromous fishes spawn in freshwater, but typically spend much of their developmental life in marine waters (McDowall 1988). In the Southeast, the classic anadromous life history is exemplified in the three alosine herrings or alosines (all members of the genus *Alosa* and the family Clupeidae): American Shad, Hickory Shad and Blueback Herring. The alosines are highly migratory species that occur along much of the Atlantic coast of North America and spawn in freshwater during late winter and spring. Genetically distinct populations occur in most coastal, freshwater drainage basins throughout the range of these species, including those in South Carolina (ASMFC 1985; ASMFC 1999). Because of similarities in life history, the alosines face similar threats and are often included in single, comprehensive management plans. These species are addressed in a guilded approach in the Supplemental Volume. Habitat associations can be found in Appendix 1-B.

Atlantic Sturgeon is the largest species of fish found in freshwaters of Eastern North America (Robins and Ray 1986). The Atlantic Sturgeon is also anadromous, but both juveniles and non-sexually-mature adults may move between fresh, brackish, and marine habitats during much of their lifespan (ASMFC 1990; McCord 2003). Atlantic Sturgeon may not occur in genetically segregated stocks to the extent as do alosines, but sturgeon are genetically dissimilar by Atlantic coastal region (North Atlantic, Mid-Atlantic and South Atlantic) (Wirgin et al. 2000). The extent of genetic mixing between drainage basin-specific populations or stocks is unknown.

The Shortnose Sturgeon displays a variant anadromous life cycle in southern populations (Dudley et al. 1977; Kynard 1997; McDowall 1988; NMFS 1998). Shortnose Sturgeons move into Atlantic Ocean coastal waters, though with much less frequency than do Atlantic sturgeons (NMFS 1998). Both species generally move between waters over a broad salinity range within particular drainage basins, and occasionally move into high salinity estuarine or nearshore marine waters (McDowall 1988; NMFS 1998). This semi-anadromous life cycle has been termed "freshwater amphidromous" (Kynard 1977; NMFS 1998). Such species typically occur in relatively unique genetic populations or population segments since there is limited opportunity for mixing between riverine populations (NMFS 1998). Genetic mixing between populations is likely rather limited. A potentially dam-locked population of Shortnose Sturgeon occurs in the Santee-Cooper lakes (Collins et al. 2003). Evidence to date indicates that this population is stressed, possibly because of lack of access to habitats with more appropriate food resources (Collins et al. 2003).

The Striped Bass is anadromous in basins along the North Atlantic and most of the Mid-Atlantic Coast, but is marginally anadromous, or freshwater amphidromous, in much of the Southeast (Dudley et al. 1977).

Catadromous fishes have a life history opposite that of anadromous fishes (McDowall 1988). This unusual life history strategy occurs in American eel (McDowall 1988; ASMFC 2000). The American Eel is distributed along much of the Atlantic Coast from Canada to South America in a single population (ASMFC 2000). Adults spawn in the Sargasso Sea, a region of the central North Atlantic, south of Bermuda and east of the Bahamas. Adults die after spawning; juveniles migrate across the Atlantic continental shelf and populate many estuarine and freshwater habitats where they remain until sexually mature (ASMFC 2000).

Ultimately, all seven diadromous fish species described here are included on South Carolina's Priority Species List. However, the Striped Bass is included on the list of freshwater fishes because the populations for which there is concern are located inland.

Since most diadromous species are highly migratory and use, or even require, a vast diversity of habitats, management of such species is much more problematic than for more habitat-specific species. Management is particularly complicated for species such as alosines and sturgeons that occur as individual populations (genetic races) by river basin, or even by major tributary within a basin (as has been indicated for American Shad). Most diadromous species are potentially impacted by threats both within and outside of a particular state's jurisdiction; for example, American Shad from South Carolina rivers occur in coastal bays of Canada during part of each year (Neves and Depres 1979). All portions of the life cycle are equally important for long-term sustainability of stocks. Accordingly, diadromous species generally require management through interstate or interjurisdictional plans.

Species Selection Process

The information about diadromous fishes contained in the Strategy was supplied by the expertise of biologists who formed our Diadromous Fishes Taxonomic Committee. The members of that committee invested considerable time in the development of the SWAP and are graciously thanked for their efforts; these individuals are listed in Table 3-7. Other sources of information included published literature and unpublished SCDNR data.

TABLE 3-7: DIADROMOUS FISHES TAXONOMIC COMMITTEE
(Committee members – 2005 only; *2015 only*; **2005 & 2015**)

Name	Affiliation
Mel Bell	South Carolina Department of Natural Resources
Jason Bettinger	South Carolina Department of Natural Resources
Julia Byrd	South Carolina Department of Natural Resources
Mark Collins	South Carolina Department of Natural Resources
Doug Cooke	South Carolina Department of Natural Resources
Jarrett Gibbons	South Carolina Department of Natural Resources
Allan Hazel	South Carolina Department of Natural Resources
Billy McCord	South Carolina Department of Natural Resources
Elizabeth Miller	South Carolina Department of Natural Resources
Corbett Norwood	South Carolina Department of Natural Resources

Bill Post	South Carolina Department of Natural Resources
Brock Renkas	South Carolina Department of Natural Resources
David Whitaker	South Carolina Department of Natural Resources

The six diadromous species (American Shad, Hickory Shad, Blueback Herring, Atlantic Sturgeon, Shortnose Sturgeon, and American Eel) are considered to be highest priority species. All perform integral roles in the diverse habitats and ecosystems in which they reside during all portions of their complicated life cycles, and all have faced impacts that have caused stock declines, sometimes dramatic, in at least some river basins, both in South Carolina and across their broader ranges (ASMFC 1985; ASMFC 1990; ASMFC 1999; ASMFC 2000; NMFS 1998). The ecological functions of these species are described in detail within the species profiles. These species are all currently covered by dynamic management plans developed through the Atlantic States Marine Fisheries Commission (ASMFC) or the Natioanl Marine Fisheries Service (NMFS). Such management plans are primarily guidance documents that require action and cooperation by individual states. Several plans include mandates to the states that require specific monitoring or management actions. Unfortunately, funding associated with such plans and mandates has been insufficient to support actions necessary to collect information essential to assess and protect most basin-specific populations.

The Shortnose Sturgeon is a Federally Endangered species under the Endangered Species Act (ESA). However, individual basin-specific stocks of other anadromous species may be more imperiled than are many Shortnose Sturgeon stocks. All of the State's priority diadromous species are currently, or have been, targeted by commercial and/or recreational fisheries. Management of these species has generally been limited to control of fisheries. This is oftentimes based on limited data, perceived population levels, and regulatory actions presumed to produce desired positive effects. Currently, all take of Shortnose Sturgeon is prohibited because of its Endangered status. The Atlantic sturgeon is also under a fishery moratorium that began in 1985 and is to remain in effect for an undetermined period based on the ASMFC plan. In addition, the Atlantic Sturgeon are now listed as Federal and State Endangered. State law has closed commercial gear fisheries for alosines in several rivers and has limited such fisheries, as well as recreational creel limits, in other areas within the past decade. The Blueback Herring and American Eel have also been petitioned for listing under the Endangered Species Act by the National Marine Fisheries Service and the United States Fish and Wildlife Service, so further protection of these species may be on the horizon. However, prudent, effective, and responsive management of all of these species is dependent upon surveys and monitoring that can establish current distribution and stock status for all six priority diadromous species.

Challenges

There is a paucity of information on all species, particularly in regard to current population trends or distribution. For most of the priority diadromous species, information concerning presence or absence of these fishes is lacking for many state river basins. Also, the known or perceived status of individual populations for which there are data is variable, ranging from "secure" to "apparently depleted".

Dams that block or limit access of migratory fishes to historical habitats and prevent free movement both up- and downstream, have been indicated as major contributors to stock declines

for all diadromous species (ASMFC 1985; ASMFC 1990; ASMFC 1999; ASMFC 2000; NMFS 1998). Information on current distribution and stock status of all six high priority species is highly applicable to Federal Energy Regulatory Commission (FERC) relicensing considerations for dams and other water diversion facilities. Many dams on drainage basins within South Carolina are currently, or soon will be, undergoing the FERC-relicensing process. Both the NMFS and the USFWS have primary authority over fish passage and diadromous fish restoration issues related to FERC-relicensing (ASMFC 1985; ASMFC 1990; ASMFC 1999; ASMFC 2000; NMFS 1998). However, state natural resource agencies generally participate in such activities as well.

Because of the broad diversity of life history characteristics and habitat utilization displayed by diadromous species, and because of their complicated life cycles, survey and monitoring techniques must be diverse and performed for a decade or more to establish meaningful trends indicative of stock status. Most survey and monitoring to gather information on stock status of diadromous species in South Carolina over the past two decades or more has been funded by various federal grants. These studies have been primarily performed in response to mandates in ASMFC management plans. Funds have not been sufficient to allow for either comprehensive studies of all populations in South Carolina or for the accumulation of sufficient long-term data to provide for conclusive indications of stock status for even any single population.

Furthermore, mandated data collection is most extensive for American Shad, and such data collection is not required for all populations since participants in the ASMFC management plan development process understood (and currently understand) funding limitations. Generally, small rivers are not covered by mandates within the ASMFC plan for alosines (ASMFC 1999; ASMFC 2002). ASMFC management plans for the Atlantic sturgeon and the American eel include few mandates, but like all ASMFC plans, the National Marine Fisheries Services recovery plan for Shortnose Sturgeon (NMFS 1998) and other management plans, make numerous recommendations for data collection needs. These studies will help to establish population status and conservation actions needed to restore or enhance individual populations or population segments.

In many South Carolina river basins, basic surveys must be conducted to determine either presence or absence of these species. Population surveys in some rivers may be useful as indicators of probable stock trends in similar basins. Perhaps among the highest priorities should be the continuation or expansion of existing surveys (i.e. a survey of sturgeons in the Edisto River initiated in 1996) for sufficient duration to allow for characterization of stock status.

Modification of existing habitat poses a threat to all diadromous fishes. Changing the river's profile by deepening of the river channel or closing off existing corridors, can lead to lost habitat, differences in hydrologic features, and changes in water quality (i.e. salinity, dissolved oxygen, temperature, and pH). In addition, deforestation without proper buffers can lead to sedimentation and shoaling. These modifications to spawning habitat not only make once deep river reaches shallow, but affect areas upriver, causing siltation which makes it impossible for eggs to survive.

Climate change also has the potential to affect all diadromous fishes in one way or another. Long-term observations confirm that the climate is changing at a rapid rate. Over the 20th

century, the average annual US air temperature has risen by almost 0.6°C (1°F) and precipitation has increased nationally by 5%-10%, mostly due to an increase in heavy downpours (NAST 2000). These trends have been most apparent over the past few decades. Climate model projections exhibit a wide range of plausible scenarios for both temperature and precipitation over the next century. Both of the principal climate models used by the National Assessment Synthesis Team (NAST) project the Southeast to warm by the 2090s but at different rates (NAST 2000). Some of the major impacts to diadromous fishes will include loss of nursery habitat, loss of spawning habitat, and reduced flows. Expected consequences would be a decrease in the amount of dissolved oxygen in surface waters and an increase in the concentration of nutrients and toxic chemicals due to reduced flushing rate (Murdoch et al. 2000).

Because many rivers are already under a great deal of stress due to excessive water withdrawal or land development—and this stress may be exacerbated by changes in climate—anticipating and planning adaptive strategies may be critical (Hulme 2005). A warmer-wetter climate could ameliorate poor water quality conditions in places where human-caused concentrations of nutrients and pollutants currently degrade water quality (Murdoch et al. 2000). A global analysis of the potential effects of climate change on river basins indicates that due to changes in discharge and water stress, the area of large river basins in need of reactive or proactive management interventions in response to climate change will be much higher for basins impacted by dams than for basins with free-flowing rivers (Palmer et al. 2008). Consistently low stream flow can limit available spawning, thermal refugia, and foraging habitat.

Sea-level rise (SLR) is one of the more certain consequences of climate change; it has already had significant impacts on coastal areas, and these impacts are likely to increase. Since 1852 when the first topographic maps of the southeast region were prepared, high tidal flood elevations have increased approximately 30 cm (12 in.). During the 20th century, global sea level has increased between 15 and 20 cm (6 and 8 in.) (NAST 2000). Analyses attribute the coastal forest decline in the Southeast to salt water intrusion associated with sea level rise. Coastal forest losses will be even more severe if sea-level rise accelerates as is expected as a result of global warming. It is difficult to ascertain which impacts will occur and over what time period, but there is little doubt these impacts will affect diadromous fishes.

Other important issues in diadromous fish management include the determination of the extent of genetic isolation of populations or population segments using tributaries within larger drainage basins. For example, detailed and expensive genetics studies may be required to determine the relationships of alosines spawning within various tributaries of the greater Waccamaw-Pee Dee Basin. Similar relationships may exist for alosines in the ACE Basin rivers. Genetic relationships and the extent of genetic isolation of Atlantic sturgeon in riverine spawning populations are also poorly understood. Genetic implications are also very important with regard to the development of some fish passage and fish restoration programs when the integrity of genetically distinct populations may be negatively affected. For effective management of the Atlantic Coast American Eel population, it is of utmost importance to better understand the contribution of various riverine or regional sub-populations or population segments to the current and long-term productivity of the entire continental population.

Lastly, non-native, invasive species can impact populations of diadromous species. Blue Catfish and Flathead Catfish both are presumed to act as both competitors and predators to sturgeon, for example (NMFS 1998).

Crayfishes and Freshwater Shrimp

Crayfish are freshwater decapod crustaceans of the superfamily Astacoidea. Representatives of two of the three families, Astacidae and Cambaridae are found in North America. About 75% of the total known species of crayfish are endemic to North America (Lodge et al. 2000a). The Southeastern United States exhibits by far the greatest species diversity of any region (Taylor et al. 1996, 2007). South Carolina is the home to a diverse crayfish fauna of at least 38 native species. Nine of the known species appear to be endemic to the State; many others are found only in South Carolina and an adjacent state. Of the five species of the burrowing genus *Distocambarus*, four are South Carolina endemics. South Carolina freshwater shrimps belong to the family Palaemonidae (Caridea, Atyoidea), some of which live in both fresh and brackish water habitats.

Crayfish play several important ecological roles in aquatic habitats. These animals make up a large portion of the invertebrate biomass and the diet of several game fish species in some water bodies (Probst et al. 1984; Rabeni 1992; Roell and Orth 1993). Some South Carolina snakes also rely heavily on crayfish for food. Crayfish also have a drastic effect upon the biomass and species composition of aquatic macrophytes and snails (Lodge et al. 1994). Despite their abundance and importance in many North American freshwater habitats, both the taxonomy and natural history of many species of crayfish are poorly understood. New species are frequently being discovered and existing species are often reclassified. In fact, one of the species on our list is in the process of being described.

Commonly thought to inhabit strictly aquatic environments, crayfish can utilize a variety of aquatic, semi-aquatic, and terrestrial habitats. All species rely on water for reproduction, but many burrowers are terrestrial and either access the water table by digging deep enough or by constructing the burrow with compact soil around the walls, allowing it to retain moisture from rainfall and runoff. Some crayfish are obligate burrowers and rely on habitat such as farm fields, prairies and forests. Others inhabit streams, small lakes, or temporary ponds but may dig terrestrial burrows during dry periods. Still other species are restricted to aquatic habitats. The habitat requirements of many species, particularly primary burrowers, are not well understood.

Hobbs (1981) distinguished freshwater crayfish as primary, secondary, or tertiary burrowers. Primary burrowers spend almost their entire lives in the burrow. Secondary burrowers spend much of their lives in a burrow, but may move to open waters during rainy periods. Tertiary burrowers live primarily in open water but may move into a burrow to escape frost or drought and when brooding eggs.

Historically, the conservation of American crayfishes has received little attention by regulatory agencies; however, there has been some progress over the past decade. In 1996, the American Fisheries Society considered 65 species (19.2%) of North American crayfish as endangered, 45 (13.3%) as threatened, and 50 (14.8%) as special concern (Taylor et al. 1996). In 2007, updates

to the previous assessment resulted in nearly the same composition with 66 species (18.2%) of North American crayfish as endangered, 52 (14.3%) as threatened, and 54 (14.9%) as special concern (Taylor et al. 2007). Listing with the American Fisheries Society does not give species any protection. The US Fish and Wildlife service only lists 4 species as Federally Endangered, none of which are in South Carolina. No crayfish species are currently listed as Threatened by the US Fish and Wildlife Service. In 2011, however, 4 crayfish species that occur in South Carolina were proposed as candidates for listing as Federally Threatened or Endangered species (USFWS 2011).

Since the conservation plan for crayfishes of South Carolina was drafted, efforts have been made to survey crayfishes by the South Carolina Department of Natural Resources and contractors from universities. Additional distribution records across the State have accumulated as a result of these surveys. During the South Carolina Stream Assessment (2006–2011), crayfishes and shrimps were recorded at 364 of 397 random stream sites in 29 ecobasins across the State and at additional stream sites. These specimens are being identified as part of a State Wildlife Grant in progress.

Species Selection Process

The information about aquatic and terrestrial crayfish contained in the initial 2005 Plan was supplied by the expertise of 5 biologists (Kohlsaat et al., 2005). These people invested considerable time in the development of the Plan and are graciously thanked for their efforts; these individuals are listed in Table 3-8. Other sources of information included published literature, museum records, and reports.

TABLE 3-8: CRAYFISH & FRESHWATER SHRIMP TAXONOMIC COMMITTEE
(Committee members – 2005 only; *2015 only*; **2005 & 2015**)

Name	Affiliation
John Cooper	North Carolina Museum of Natural Sciences
Arnold Eversole	Clemson University
Daniel Jones	Clemson University
William Poly	South Carolina Department of Natural Resources
Jennifer Price	South Carolina Department of Natural Resources
Shane Welch	Clemson University

During December 2003, biologists were asked to review a list of 42 crayfish species and comment on the conservation status, conservation needs, and knowledge deficiencies of each species. Each reviewer was given an Excel data sheet with 18 questions accompanied by a set of criteria and instructions for conducting their review. Nine of the questions were multiple-choice and 9 were designed for comments. There were 2 categories of multiple-choice questions: those dealing with the current knowledge of a given species and those dealing with the species' conservation status. There were several species for which no one could provide any information. These species were retained on the conservation concern list due to lack of status information; data on these species was provided through museum records and publications. Ultimately, 23 crayfish species were included on South Carolina's Priority Species List for 2005. In 2011, updates to the status of each species was assessed using the previous assessment along with

recent SCDNR collection records, museum records, research reports, correspondence, and published literature.

In South Carolina's SWAP, crayfish are addressed in two groups. One is entitled "Primarily Aquatic Species Group;" in this group, all aquatic species are treated together, including secondary and tertiary burrowers, based upon our best knowledge. The second group is entitled "Terrestrial Burrowing Crayfish Group;" primary burrowers are addressed in this group since the challenges these species face may be somewhat different than those species inhabiting open water.

Changes to SC's SWAP crayfish list included the addition of 2 new species: the Carolina needlenose crayfish, an endemic, and *Cambarus* sp. "B" The latter species has yet to be described and fully understood so it is ranked as "highest priority" due to the lack of knowledge of the species. The Oconee stream crayfish was renamed the Chauga crayfish. Additionally, 10 other species received common names in this iteration of the SWAP. The latest stream surveys also indicated that the Pee Dee lotic crayfish and Carolina Sandhills crayfish (formerly simply called the Sandhills crayfish) were more abundant than first realized and were thus demoted to the "moderate priority" category. The Ohio River shrimp, first discussed in the 2005 version of the SWAP in the marine invertebrates section, was moved to the freshwater section because of its association with rivers. Species/guild accounts can be found in the Supplemental Volume while habitat associations are in Appendix 1-B.

Challenges

There are a number of potential challenges to crayfish. However, it is difficult to assess the degree to which each species is vulnerable to particular threats until the habitat associations, population trends, and distributions are better understood for each species. Genetic and taxonomic work is also very important where there are questions regarding classification because misidentification, or the lumping of species complexes, may obscure the presence of rare species in need of conservation. The case of *Cambarus* species "B," which was mistaken for an introduced species, is an excellent example. As of January 2012, this species remains undescribed, and most recently it has been treated as an introduced population of *C. longirostris* in South Carolina (McLaughlin et al. 2005; Taylor et al. 2007).

The arrival of introduced species is probably the greatest challenge to crayfish (Lodge et al. 2000a,b). The ranges and abundances of many native crayfish may have been reduced by invasive crayfish, both in the United States and in Europe (Lodge et al. 2000a; Hobbs et al. 1989). In Europe, crayfish introduced from North America appear to be responsible for the spread of diseases to native species (Lodge et al. 2000a). Other potential mechanisms for the deleterious effects of invasive crayfish include predation upon natives, competition, and genetic hybridization with native species (Lodge et al. 2000a).

The red swamp crawfish, *Procambarus clarkii*, has been introduced from the Mississippi drainage into South Carolina (Hobbs et al. 1989). While few studies have documented the effects of the red swamp crawfish on native species, potential negative effects of its introduction include the spread of fungal diseases to other crayfish and the spread of human helminth parasites, for

which this species is an intermediate host (Hobbs et al. 1989). In South Carolina, *P. clarkii* has been collected at sites at which native crayfishes were present in some cases and absent in others (Poly 2007). The latter sites were channelized so lack of native crayfish species could be due either to habitat modification and/or presence of the non-native *P. clarkii*. Several sites in North Carolina that once had native species of crayfishes now have only *P. clarkii* (Cooper and Armstrong 2007), suggesting that *P. clarkii* has possibly displaced them.

Outside of its presumed native range that includes portions of Ohio, Indiana, and Kentucky, the rusty crayfish (*Orconectes rusticus*) has been widely introduced in the United States (Hobbs et al. 1989), although some records had been misidentifications (Wetzel et al. 2004). It is considered an non-native invasive species that usually becomes established where bait buckets have been dumped (A. Eversole, pers. comm.). The Rusty Crayfish has been reported from the upper Broad River drainage in North Carolina (Cooper and Armstrong 2007) and possibly could spread downstream into South Carolina. As of 2012 it has not been found in South Carolina, and the population in North Carolina doesn't appear to be spreading and might even have declined (Steve Fraley NCDENR pers. comm.). Several shipments of crayfishes to South Carolina schools for educational use have contained rusty crayfish (W. Poly pers. obs.).

Prevention of future introductions is most likely the only effective way to deal with the challenges caused by non-native crayfish. No methods for eliminating invasive species without also harming native species are currently available. Even if effective biological control methods are developed, preventing introductions will still be much easier than eradicating an established species. Lodge et al. (2000b) proposed federal legislation that, if enacted and enforced, would drastically reduce the risk of future introductions. They include banning the use of live crayfishes as bait and adopting a "white list" approach for the sale of all crayfish in the aquarium, garden pond, and educational trade. Other non-native crayfishes and shrimps have also been introduced into South Carolina. *Cherax quadricarinatus* and *Macrobrachium rosenbergii* were introduced to South Carolina for aquaculture (Smith et al. 1978, Brummett and Alon 1994) but do not appear to have become established in the wild.

Additionally, the "white list" approach should govern the species allowed for use in aquaculture. This approach restricts the sale of crayfish to only those species that have been extensively researched and demonstrated to pose minimal risk as potential invaders. We may not always be able to predict whether a species is likely to become invasive; even those thought to pose minimal risks should not be released.

Physical alteration of habitat also represents a challenge to the survival of crayfish. Some aquatic crayfishes are quite adaptable and can live in ponds, impoundments, and roadside ditches, while others are more sensitive to habitat alteration. Some crayfishes are oxygen regulators and are able to increase ventilation rates in response to reduced oxygen conditions, while others, the oxygen conformers, are unable to do this (Hobbs 1991). Therefore, some species are better equipped to survive when the flow of water slows and oxygen levels decline. Some species, such as *Cambarus* species "B", have been eliminated from parts of their range as a result of damming activities associated with reservoir construction. Channelization and dredging can also be very detrimental to aquatic crayfish that require rocks, crevices or tree roots along undercut banks as hiding places (Hobbs and Hall 1994). In general, crayfish are not as sensitive to siltation as some

aquatic invertebrates such as mussels, but severe siltation has caused declines in or the extirpation of many populations of crayfish (Hobbs and Hall 1974).

The most serious known challenge to terrestrial burrowing crayfish is the alteration of soil hydrology. These species appear to be able to coexist with some agriculture and timber harvest practices, although they may not survive frequent tilling of soil. In some areas, fire suppression or the lack of fire management may be a threat, since some species appear to prefer Piedmont prairies, savannahs, and other open canopy habitats to densely wooded areas.

Crayfish are fairly sensitive to pH (Hobbs and Hall 1974; Hobbs 1991). It appears that stream-dwelling species tend to have a lower tolerance for low pH than those from shallow lentic habitats (Hobbs and Hall 1974). Observations of diverse crayfish fauna at neutral pH (7.0) and the absence of crayfish at a high pH (11.4) in otherwise similar streams in Georgia suggest that crayfish may also be sensitive to high pH (Hobbs and Hall 1974).

Pollution has been known to eliminate crayfish from streams. Ortmann (1909) noted the extirpation of crayfish from some sections of streams and rivers due to mining and oil refineries. Crayfish are harmed by a variety of insecticides, herbicides, and industrial chemicals (Eversole et al. 1996). Juvenile crayfish are generally about four times more sensitive to water-borne pollution than adults; early instars are about three times more sensitive as juveniles (Eversole and Sellers 1996). There is little knowledge of the differences in sensitivity to toxins among species. Nutrient enrichment is less likely to harm crayfish than other aquatic life because they are omnivorous and can act as scavengers as well as primary and secondary consumers. Hobbs and Hall (1974) noted several casual observations in which crayfish were actually more abundant downstream of areas with large amounts of garbage or animal remains. Enrichment may be harmful to crayfish, however, when it results in oxygen depletion (Hobbs and Hall 1974). Pollution of groundwater may impact terrestrial burrowers, because they inhabit water trapped in their burrows.

Freshwater Mussels

Freshwater mussels native to the United States are bivalve mollusks, belonging to the order Unionoida and superfamily Unionoidea. There are two families within Unionoidea: Unionidae and Margaritiferidae. All of South Carolina's species belong to the family Uniondiae. The Southeastern portion of the United States is the most diverse region in the world for freshwater mussels (Lydeard and Mayden 1995). The taxonomic identification of mussels to species can be difficult. More work is necessary to determine if species designations currently in use are correct.

The conservation of North American freshwater mussels has many broad implications beyond the survival of individual mussel species. As filter-feeders, mussels clean the water of suspended particles and can increase water clarity. They are also important food sources for fish, waterfowl, turtles, muskrats, raccoons, and river otters. Other invertebrates use mussels as hosts; two fish species are known to use mussels as brooding sites (Bogan 2001). Since mussels are sometimes found at densities as high as 200 to 400 per m^2 (19 to 37 per $ft.^2$), removing them from our rivers and streams can have drastic consequences for these ecosystems, particularly in terms of water filtration (Bogan 2001). The tolerance for pollution may differ somewhat between species, and

we have little information on reactions to specific pollutants by species, since most evidence is anecdotal. Laboratory toxicology studies have been conducted on a few species. In general, mussels are quite sensitive to pollutants and are recognized as indicator species; they are often the first to decline when streams and rivers become polluted. Protection and restoration of freshwater ecosystems to support a diverse mussel fauna will also result in improving the health of these ecosystems to the benefit of other aquatic organisms and humans.

Historically, mussels have been used for a variety of commercial purposes. In the mid- to late-1800s, harvesting mussels for pearls was common. From the 1890s until the 1950s, there were large commercial operations to harvest mussels for their shells which were used to make buttons. Today, there is still some demand for mussel shells for use in the cultured pearl industry and large-scale commercial harvesting still occurs in the US. However, no large-scale commercial harvesting currently occurs in South Carolina.

As a group, freshwater mussels are found in a variety of environments throughout South Carolina. A few species are widespread and found throughout the East Coast, but many are endemic to one or a few river drainages. Many species are endemic to only North and South Carolina or only to South Carolina and Georgia (Bogan and Alderman 2004, 2008).

Most freshwater mussels are dioecious (separate sexes), although a few species are hermaphroditic. After fertilization and hatching within the female, the larva—called glochidia—are expelled and must attach themselves to the skin, gills, or fins of a fish host, or in a few cases a salamander, in order to complete development. Some species will only parasitize a single host species, while others can develop within any of several species. Therefore, the presence of the required fish or salamander host at the appropriate time of the year represents an additional habitat requirement for most species. A few species, such as *Strophitus undulatus*, are able to complete larval development without the assistance of a host fish.

Freshwater mussels are among the most threatened groups of organisms in North America. There are nearly 300 recognized species and subspecies in the United States, and 189 of them are currently on the IUCN Red List (Lydeard et al. 2004). At least 30 species are presumed extinct. Many more may be functionally extinct; some long-lived individuals have survived, but their populations are not reproducing (Bogan 1997). In 1993, the American Fisheries Society evaluated the conservation status of freshwater mussels in the United States and Canada (Williams et al. 1993). They determined that 7.1% of mussel species were endangered and possibly extinct, 20.6% were endangered and extant, 14.5% were threatened, 24.2% were of special concern, and 4.7% had an undetermined status; only 23.6% of mussel species were determined to be stable. A panel of experts from the Southeast concluded that only three of 33 native mussel species in South Carolina are stable and abundant enough not to be included as conservation priority species. The earliest effort to establish a list of species of conservation concern in South Carolina was that of Fuller (1979).

Records from the mid- and early 1800s indicate that mussels were once plentiful in most North American rivers and streams (Parmalee and Bogan 1998). Mussels have completely disappeared from many bodies of water and rarely reach densities approaching those from historic times. Qualitative records of the decline of mussels are abundant, but there is little detailed quantitative

information to document the rate of decline of these species (Keferl 1993). While the Broad River mainstem in South Carolina continues to support a variety of mussel species (Price and Eads 2011), many of the tributary streams and rivers do not have any native mussels present (Keferl 1993; Scott et al. 2009).

Difficulty in identifying mussels has added to challenges quantifying their decline. Historic species identifications are often questioned, and the extent of a species' historic range is usually uncertain. Museum specimens are also especially lacking in South Carolina because there is no state natural history museum and collections are not in a centralized location. However, there are several natural history museums in the Eastern United States that contain mussel specimens from South Carolina. In addition, mussel specimens collected during the South Carolina Stream Assessment (2006–2011) were deposited in the North Carolina Museum of Natural Sciences for long-term storage and for use by mussel specialists. Temporal gaps in data exist because surveys have not been conducted at regular intervals. While there seems to be a growing interest in freshwater mussel conservation, conducting surveys is difficult due to (1) the lack of researchers skilled in mussel identification and taxonomy and (2) lack of funding to support surveys and other research, especially in South Carolina. Unresolved taxonomy of mussel species contributes further to the difficulty in making identifications. Taxonomic and systematic studies continue to be done on mussels in South Carolina, and over the next decade or two, additional species diversity likely will be known from the State as a result of these efforts.

Since the conservation plan for freshwater mussels of South Carolina was drafted over seven years ago, substantial efforts have been made to survey mussels in the State by a variety of organizations including The Nature Conservancy, the US Fish and Wildlife Service, the South Carolina Department of Natural Resources, and private consulting groups. Also, the Atlantic Slope Mussel Meetings and Workshops that have been held over the past 5 years have allowed mussel biologists and taxonomists to discuss their recent surveys and research projects. Many significant distribution records across the State have accumulated as a result of these surveys. During the South Carolina Stream Assessment (2006–2011), freshwater mussels were recorded at 77 of 397 random stream sites in 17 ecobasins across the State and at more than 50 additional stream sites. Although these records do not reflect the actual presence and abundances accurately because of the limited sampling for mussels, they do provide useful distribution information and museum specimens that will be used by mussel specialists to reassess the taxonomy and conservation status of various species.

Species Selection Process

The information about freshwater mussels contained in the SWAP was supplied by the expertise of biologists who formed our Freshwater Mussel Taxonomic Expertise Committee. The members of that committee invested considerable time in the development of the SWAP and are graciously thanked for their efforts; these individuals are listed in Table 3-9. Other sources of information included published literature and museum records.

TABLE 3-9: FRESHWATER MUSSELS TAXONOMIC COMMITTEE
(Committee members – 2005 only; *2015 only*; **2005 & 2015**)

Name	Affiliation
John Alderman	Alderman Environmental Services
Joseph Alderman	Alderman Environmental Services
Arthur E. Bogan	North Carolina Museum of Natural Sciences
Tom Dickinson	The Catena Group
David Eargle	South Carolina Department of Health and Environmental Control
John Fridell	United States Fish and Wildlife Service
Eugene Keferl	Coastal Georgia Community College
Eric Krueger	The Nature Conservancy
William Poly	South Carolina Department of Natural Resources
Jennifer Price	South Carolina Department of Natural Resources
Tim Savidge	The Catena Group
James Williams	United States Geological Survey
Morgan Wolf	United States Fish and Wildlife Service
Laura Zimmerman	United States Fish and Wildlife Service

The Freshwater Mussel Taxonomic Expertise Committee members met in August 2004 to review a list of potential priority species, make changes, and categorize the distribution and conservation needs of each mussel species. The committee reached consensus that 26 out of 29 of the species known to occur in South Carolina were rare and/or declining and in need of some conservation action (Kohlsaat et al. 2005). Each reviewer was given an Excel data sheet with 18 questions accompanied by a set of criteria and instructions for conducting their review. Nine of the questions were multiple-choice, and nine were designed for comments. There were two categories of multiple-choice questions: those dealing with the current knowledge of a given species and those dealing with the species' conservation status.

In 2011, biologists were asked to review a revised list of 36 mussel species and comment on the conservation status, conservation needs, and knowledge deficiencies of each species. Changes included the renaming of the Carolina Slabshell (*Elliptio canagarea*) as Carolina Elephantear. The reason for the change was due to the fact that the shell was not shaped like other typical slabshells. Likewise, the Southern Rainbow (*Villosa vibex*) was renamed the Eastern Rainbow (*V. modioliformis*). The Atlantic Spike moved up in priority ranking from "moderate" to "high" due to new information available on the status and distribution of the species. A new species this iteration is the Altamaha Arcmussel (*Alasmidonta arcula*). Eastern Lampmussel (formerly mislabeled in the text as Eastern Lampshell) and the Rayed Pink Fatmucket have been broken out into separate species, *Lampsilis radiata* and *L. splendita*, respectively. In 2011, 4 mussel species that occur in South Carolina were proposed as candidates for listing as Federally Threatened or Endangered species (USFWS 2011). All priority species are discussed in the Supplemental Volume, and habitat associations are provided in Appendix 1-B.

Challenges

Siltation appears to inhibit the reproduction of many mussels and the survival of juveniles (Ellis 1931). Siltation is usually considered the biggest challenge to the survival of freshwater mussels. Ellis (1936) found that silt accumulation on the substrate at a depth of 6 mm to 25 mm (0.25 to 1 in.) over several months caused mortality in several species of mussels in the laboratory, possibly

by reducing oxygen levels near the substrate and by silt build-up in the mantle cavity and gill chambers. Sediments suspended in the water column also harmed mussels by reducing the amount of time that they remained open for feeding (Ellis 1936).

Historically, siltation results from clearing land for farming, from mining operations, and by the construction of dams. Farming continues to be a challenge when too much bare soil is exposed, when sufficient riparian buffers are not maintained, and when cattle are allowed to enter streams. Feral pigs contribute to siltation by digging along streambanks and channels and uprooting vegetation in search of food. Rapid development in some parts of South Carolina also contributes to siltation in many ways. Impervious surfaces such as roads, buildings, and parking lots increase erosion in adjacent areas and contribute to flooding. Clearing riparian vegetation also destabilizes stream and riverbanks allowing excessive siltation. Clear-cutting in a substantial part of a watershed can also contribute to siltation, even if a riparian buffer is maintained. The use of motor vehicles in streams and along banks can also degrade the stability of banks, stir up benthic sediments, and increase siltation. Factors that contribute to siltation can also change the topography of the stream or river by changing the slope of the bank and eliminating heterogeneity in the channel. Eliminating structural heterogeneity may also slow the flow of water and reduce its oxygen content, therefore harming species that require highly oxygenated water. The rapid release of large amounts of sediment that has accumulated behind dams has no doubt had at least localized impacts on mussels occurring below dams.

Freshwater mussels have long been recognized as sensitive species that respond more quickly to pollution and siltation than other aquatic fauna. Ortmann (1909) recognized the rapid disappearance of mussels from streams polluted by coal mining, sewage, oil wells, oil refineries, and dam construction. Acidification appears to have drastic effects upon the survival and shell structure of mussels (Fuller 1974). Point source pollution from paper mills, dye factories, gasoline by-products, and chlorinated hydrocarbon pesticides are extremely toxic to mussels (Fuller 1974). Mercury appears to have significant negative effects on mussel growth (Beckvar et al. 2000). One review paper discussing the effects of ammonia concentration on ten species of mussels indicated that current EPA criteria maximum guidance concentrations for ammonia may be too high to offer protection to many mussels, particularly juveniles and glochidia (Augspurger et al. 2003).

Dam construction has caused the decline of mussels in many locations. Dams can slow the speed of water, thereby reducing the oxygen content and allowing the buildup of additional fine sediment. Dams may interfere with the reproduction of mussels by restricting the travel of host fish or by preventing the travel of sperm through the water to reach female mussels. Impoundments also result in habitat fragmentation and isolation of populations by preventing up- and downstream recruitment, making populations more vulnerable to extirpation from other environmental impacts.

Hydroelectric power plants also can harm mussels by causing sudden variation in water volumes which could leave shallow water mussels stranded. Peak flows can physically dislodge mussels which may later become stranded when flows suddenly recede. Rapid changes in water temperature may also occur and can cause additional stress on mussels. Some mussel species are

fairly tolerant of damming; mussel diversity may be reduced downstream of dams when a few tolerant species replace a previously diverse community of mussels.

Interbasin water transfer can also cause the degradation of streams and rivers and can be harmful to mussels. Such transfers can cause changes in the variability of flow, the speed of water through the channel, and the composition of the substrate. The effects of interbasin transfers on mussels are similar to those caused by dams and siltation.

The Asian clam (*Corbicula fluminea*) has been introduced and has spread throughout the United States. While it often co-occurs in large numbers with native mussels, it may sometimes contribute to their decline. During the South Carolina Stream Assessment (2006–2011), *Corbicula fluminea* was recorded at 68 of 397 random stream sites in 21 ecobasins and was distributed widely in all river basins of the State. In the St. John's River basin, Belanger et al. (1990) found that the density of *Corbicula* was inversely correlated with the density of native mussels. Further, mussels of the genus *Elliptio* experienced slower growth rates when they were among high densities of *Corbicula*. Unfortunately, there seems to be no pre-invasion data to assess impacts on native populations in systems such as Lake Marion where *Corbicula* overwhelmingly dominates the benthos (B. Taylor, pers. comm.).

The zebra mussel (*Dreissena polymorpha*) was introduced into the United States and has become well established in the Northeast and in the Great Lakes area. This is a much more problematic bivalve than *Corbicula*. The zebra mussel can cause the decline of native mussels by competing for food or by overcrowding. Overgrowth by zebra mussels may interfere with the feeding or locomotion of native mussels. It has invaded nearby parts of Tennessee and may eventually spread into South Carolina, although the risk of them becoming established has been assessed as low due to unsuitable water chemistry (de Kozlowski et al. 2002). As of 2012, zebra mussels have not been discovered in South Carolina or in any river drainages that flow into the State.

Feral hogs (*Sus scrofa*) have been roaming the Southeastern United States and have gradually become widespread throughout the Southeastern and South-Central United States and California. The species has become the most abundant free-ranging introduced ungulate in the United States (Sweeney et al. 2003). They are primarily found on floodplains along rivers, but occasionally populations will become established in other areas due to their capture and release for hunting purposes. In addition to contributing to siltation by uprooting streambank vegetation, feral hogs also directly consume mussels.

The identity of the host fishes for more than half of South Carolina's mussels is now known (Bogan and Alderman 2004, 2008), and research on suitable host fishes continues (Eads et al. 2010). Conservation of specific mussel species by protecting the host fishes can only be practiced efficiently if the identity of the host fishes is known. Conserving healthy aquatic environments will benefit both fishes and mussels.

Freshwater Snails

Mollusks of the class Gastropoda—commonly known as snails, slugs and limpets—are found in freshwater, terrestrial, and marine habitats. Terrestrial snails are not being included in the SWAP

at this time because little is known about the distribution and status of these organisms. Further, we have been unable to identify any regional experts who can provide substantial information about South Carolina's land snails. As with other invertebrate groups, the taxonomy of snails requires much additional research to sort out more precisely the species that occur in South Carolina and adjacent areas.

Since the conservation plan for freshwater mussels of South Carolina was drafted over seven years ago, efforts have been made to survey and identify snails in the State by Robert T. Dillon, Jr. (College of Charleston) and colleagues, private consulting groups, and the South Carolina Department of Natural Resources.

Surveys for snails in South Carolina were conducted in the 1980s-1990s (Dillon and Keferl 2000). Recently, the taxonomy of freshwater snails in South Carolina has received attention, resulting in the description of a new species, *Physa carolinae*, which occurs in Georgia, South Carolina, North Carolina, and Virginia (Wethington et al. 2009). Also a web-based Freshwater Gastropods of North America currently includes coverage for five states: Virginia, North Carolina, South Carolina, Georgia, and Tennessee. The South Carolina website includes a species gallery with color photographs of the shells of all species, a dichotomous key to species, and species accounts that discuss the distribution (with maps), biology, and taxonomy of each species (Dillon and Stewart 2010).

During the South Carolina Stream Assessment (2006–2011), freshwater gastropods were recorded at 50 of 397 stream sites in 11 ecobasins across the State. In addition, more collections were made as part of other research projects. Identifications were made possible with the kind assistance of Rob Dillon. *Campeloma decisum* was the snail collected most often and in greatest abundance. Although these records do not reflect the actual presence and abundances accurately because of the limited sampling for gastropods, they do provide useful distribution information and museum specimens that can be used for taxonomic or biological studies. All of the SCDNR snail records were provided to Robert Dillon for inclusion in the aforementioned web-based, Freshwater Gastropods of North America. Gastropod specimens from the South Carolina Stream Assessment were deposited in the North Carolina State Museum of Natural Sciences for long-term documentation and so that the specimens can be used for morphological and genetic research that will contribute a better understanding of the diversity of gastropods in South Carolina.

Species Selection Process

Robert Dillon of the College of Charleston and Paul Johnson of the Tennessee Aquarium were contacted regarding the species status of South Carolina's freshwater snails in November of 2003. At that time, the South Carolina Department of Natural Resources did not have a working list of the freshwater snails that occurred in South Carolina. A tentative list was provided by Paul Johnson and edited by Robert Dillon. Both biologists invested considerable time in the development of the 2005 Plan and are graciously thanked for their efforts. Other sources of information included published and unpublished literature. Ultimately, four freshwater snails were included on South Carolina's Priority Species List for the 2005 edition of the Plan (Kohlsaat et al. 2005). For the 2012 formal review process, Robert Dillon and Arthur E. Bogan

were asked to participate in a revision of the gastropods of conservation concern because of their active work on species in South Carolina and nearby states. See Table 3-10 which details all the experts consulted for freshwater snails.

TABLE 3-10: FRESHWATER SNAILS TAXONOMIC COMMITTEE
(Committee members – 2005 only; *2015 only*; **2005 & 2015**)

Name	Affiliation
Arthur E. Bogan	North Carolina Museum of Natural Sciences
Jennifer Price	South Carolina Department of Natural Resources
Paul Johnson	Tennessee Aquarium
Robert Dillon	College of Charleston
William Poly	South Carolina Department of Natural Resources

Depending on the source, either 32 or 36 species of snails are present in South Carolina as of 2012 (Dillon and Stewart 2010, Johnson et al. in press). Only 3 species are considered to warrant conservation concern at this time (*Gillia altilis, Somatogyrus virginicus / S. spp.*, and *Lioplax subcarinata*). There will no doubt continue to be changes in the knowledge of the gastropod fauna of South Carolina, including new records of both native species and non-native species, along with information on their life histories. A few changes were made in the snail listings from 2005 to 2015. *Somatogyrus sp.* (a pebblesnail) was given a formal name, panhandle pebblesnail, and downgraded to "high priority" due to better knowledge of population estimates. The "*Physa* species A" mentioned in the previous (2005) version of the SWAP was formally described as *Physa carolinae* by Wethington, Wise, and Dillon in 2009. *Physa carolinae* is actually rather common, and does not merit any special conservation concern (R. Dillon, pers. comm.). Freshwater snails of greatest conservation need are discussed in the account found in the Supplemental Volume. Habitat associations are listed in Appendix 1-B.

Challenges

The lack of knowledge and information about life histories and habitat requirements for freshwater snails represents the most significant challenge to these species.

Siltation of streams and rivers through agricultural runoff and erosion of unstable streambanks appears to be the main threat to freshwater snails (Dillon and Keferl 2000). Historically, siltation has occurred due to land clearing for farming, residential development, forestry practices, mining operations, and construction of dams. Absence of sufficient riparian buffers significantly contributes to siltation (Moglen 2000). Clear-cutting a substantial part of a watershed can also contribute to siltation, even if a riparian buffer is maintained. Livestock and feral pigs degrade stream banks and bottoms as they drink and search for food. Impervious surfaces, such as roads, buildings, and parking lots increase erosion in adjacent areas and contribute to flooding (NCWRC 2002). The use of motor vehicles in streams and along banks can also disturb stream flow and increase siltation. All of these factors that contribute to siltation can also alter the topography of streams and rivers by changing the slope of the bank and eliminating heterogeneity in the channel.

Climate change will be a force that may affect mussels in the future. Since some mussels, such as the ridged lioplax, are at the southern edge of the species' presumed range, increasing temperatures may render current locations uninhabitable.

Freshwater, Marine, and Terrestrial Leeches

Leeches (Annelida: Hirudinida) occur in freshwater, marine, and terrestrial habitats. Some leeches are free-living predators on other invertebrates or on eggs, whereas others are primarily parasitic on vertebrate hosts. Some are parasitic, yet can be found off their hosts at times (Davies 1991, Hoffman 1999; Moser et al. 2005; Govedich et al. 2010). The leech fauna of South Carolina is relatively well known from past research on the group by Roy T. Sawyer and colleagues (Sawyer 1972; Sawyer and Pass 1972; Sawyer et al. 1975; Sawyer and Shelley 1976; Sawyer 1979). Leeches often go unnoticed until they become a problem to humans, such as when they attach to swimmers (Sawyer 1973).

Recent Biological and Conservation Efforts

Sawyer and Shelley (1976) surveyed for leeches and described several new species and subspecies occurring in North and South Carolina. Their list for South Carolina included 23 species of leeches, including 1 terrestrial, 19 freshwater, and 3 marine leeches. Since then, little work has been done; however, several recent reports have added species to the South Carolina fauna or corrected erroneous taxonomy (Light et al. 2005; Moser et al. 2011; Poly 2011). During the South Carolina Stream Assessment (2006–2011), freshwater leeches were collected at only a small number of stream sites across the State because this was not a group that was targeted. The most recently discovered species in South Carolina is *Macrobdella sestertia* (Poly 2011), which previously has been found infrequently in Massachusetts and Maine (Smith 1977, Smith and Hanlon 1997). With recent additions of taxa and taxonomic recommendations, the total number of leech species known from South Carolina is 25, including 1 terrestrial, 21 freshwater, and 3 marine.

Species Selection Process

Leeches were not included in the first edition of South Carolina's Priority Species List in 2005. Due to available literature on the group in South Carolina and invertebrate experience, a list of leech species occurring in South Carolina was able to be compiled by William Poly (SCDNR) for the 2015 revision. Sawyer's (1979) previous work on leeches of concern in South Carolina was a major source of information used to decide on the conservation status of leech species in the State. Based on Sawyer's (1979) earlier assessment, data from published literature, and recent collections, 4 species were considered to be species of conservation concern, including 1 terrestrial, 2 freshwater, and 1 marine species. The species of concern all have limited distributions within South Carolina and elsewhere, occurring in only 2 to 4 states, and are not distributed widely within those states. All priority leech species are discussed in the Supplemental Volume under a single guild while habitat associations are found in Appendices 1-A, 1-B, and 1-C.

Challenges

Any alteration of natural habitats can impact the aquatic and terrestrial fauna. Threats to the host animals of parasitic taxa will likewise threaten the existence of the leeches. Life history information is lacking for 2 of the species of conservation concern but is available for the other 2 (Shelley et al. 1979; Moser et al. 2005). Leech identifications can be challenging, and proper fixation and preservation of leeches is time consuming but important (Klemm 1982, 1995).

Marine Fishes and Invertebrates

Most marine fishes and invertebrate species have rather broad geographical distributions that extend outside of South Carolina's jurisdictional boundaries to the north or south and/or offshore, outside of the 3-mile (4.8 km) state territorial limit. Many species—particularly marine and diadromous fishes—are highly migratory, and some occur in state marine waters only during portions of the calendar year or during portions of their life cycle. Efficient and effective management of migratory species and species with complicated life cycles is dependent upon management plans that have coverage outside of any individual state's jurisdiction.

Many marine fish species and some invertebrate species—particularly those of recreational and commercial fishery importance—are currently addressed by state and/or federal or regional plans, laws and/or regulations. However, the population status of most species remains poorly understood. For most species, the genetic relationships of stocks or sub-populations throughout their distribution are also poorly understood. Understanding such relationships is of utmost importance in the identification of individual management units. In general, existing management does not identify individual management units, but attempts to establish a framework for managing commercial and recreational harvest as a surrogate to population management to prevent excessive directed fishing mortality over a broad geographic range. Many management plans identify potential threats and conservation actions to mitigate such threats, but plans do not include sufficient links to funding needed to provide comprehensive population-based management by specific stocks or management units.

The numbers of marine species, both fishes and invertebrates that can be found in the boundaries and/or jurisdiction of South Carolina, is vast. Prior to the beginning the process of preparing South Carolina's Strategy, lists for these taxonomic groups did not exist. Development of completed species lists for these taxa represent a major accomplishment for the SCDNR.

Species Selection Process

In 2005, the initial species selected for review included all marine fishes and invertebrates identified on computer code species lists that are maintained by SCDNR's Marine Resources Division (MRD). A total of 1,059 species were included in the initial list: 256 fishes and 803 invertebrates. The first step was to remove species that had not been recorded in cumulative surveys conducted within South Carolina's marine waters from tidal, brackish river reaches to the 4.8 km. (3 mi.) territorial jurisdictional limit of the Atlantic continental shelf.

The information about marine and brackish fishes and marine invertebrates contained in the SWAP was supplied by the expertise of biologists who formed the Marine Taxonomic Committees. The members of these committees invested considerable time in the development of the SWAP and are graciously thanked for their efforts. These individuals are listed in Table 3-11 and Table 3-12. Other sources of information included published literature and unpublished data from various sources.

TABLE 3-11: MARINE FISH TAXONOMIC COMMITTEE
(Committee members – 2005 only; *2015 only*; **2005 & 2015**)

Name	Affiliation
William Anderson	College of Charleston
Steve Arnott	South Carolina Department of Natural Resources
Joey Ballenger	South Carolina Department of Natural Resources
Mel Bell	South Carolina Department of Natural Resources
Mark Collins	South Carolina Department of Natural Resources
Tanya Darden	South Carolina Department of Natural Resources
Mike Denson	South Carolina Department of Natural Resources
Don Hammond	South Carolina Department of Natural Resources
Erin Levesque	South Carolina Department of Natural Resources
Phil Maier	South Carolina Department of Natural Resources
Bob Martore	South Carolina Department of Natural Resources
Billy McCord	South Carolina Department of Natural Resources
John McGovern	National Oceanic and Atmospheric Administration
Charles Moore	South Carolina Department of Natural Resources
Marcel Reichert	South Carolina Department of Natural Resources
Fred Rohde	NC Division of Marine Fisheries
Bill Roumillat	South Carolina Department of Natural Resources
George Sedberry	South Carolina Department of Natural Resources
Dustin Smith	Native fish enthusiast
Glenn Ulrich	South Carolina Department of Natural Resources
Pearse Webster	South Carolina Department of Natural Resources
David Whitaker	South Carolina Department of Natural Resources

TABLE 3-12: MARINE INVERTEBRATES TAXONOMIC COMMITTEE
(Committee members – 2005 only; *2015 only*; **2005 & 2015**)

Name	Affiliation
Dennis Allen	University of South Carolina – Baurch Institute
Bill Anderson	South Carolina Department of Natural Resources
Loren Coen	South Carolina Department of Natural Resources
Stacie Crowe	South Carolina Department of Natural Resources
Larry Delancey	South Carolina Department of Natural Resources
Arnie Eversole	Clemson University
Nancy Hadley	South Carolina Department of Natural Resources
Pam Jutte	South Carolina Department of Natural Resources
Peter Kingsley-Smith	South Carolina Department of Natural Resources
David Knott	South Carolina Department of Natural Resources
Marty Levisen	South Carolina Department of Natural Resources
Billy McCord	South Carolina Department of Natural Resources
Steve Stancyk	University of South Carolina
Elizabeth Wenner	South Carolina Department of Natural Resources
David Whitaker	South Carolina Department of Natural Resources
Bob Van Dolah	South Carolina Department of Natural Resources

It was clear early in this process that data and knowledge available for most marine species in South Carolina were largely qualitative or of limited scope. In 2005, MRD staff suggested that most reviewers would have difficulty supplying input related to stock or population status for most species of fish and certainly for most invertebrates. Regardless, all identified experts were to be contacted for their input via an Excel data sheet or matrix with 18 questions. Nine of the questions were multiple-choice and nine questions were designed for comments. There were two categories of multiple-choice questions: questions dealing with knowledge of a given species and questions dealing with the species' conservation status. Initial trimming of the lists was facilitated by asking reviewers to eliminate species that did not warrant special conservation concern in South Carolina. A species was eliminated from the list if at least two of the reviewers suggested elimination and none of the other reviewers provided information for that species.

Experts suggested that marine fishes would be best protected by managing essential habitats for species or species groupings as the marine fishes group was a poor fit for the matrix treatment. Accordingly, all core (non-peripheral) marine fish species found in South Carolina marine and brackish water were retained on South Carolina's Priority Species List. Many of these species may be monitored as indicators of habitat health or as indicators of population health for other species associated with similar habitats. The final list of marine and brackish fishes included 163 species for the 2005 version of the SWAP.

The marine invertebrate grouping was more problematic, as there is generally very limited information available relative to population status of practically all species in South Carolina. The 2005 invertebrate list was revised by MRD staff using similar methodologies as were used for developing a marine fish 'list of concern.' Input was solicited via email from several identified marine invertebrate experts. The final list of marine and brackish invertebrates for the 2005 SWAP included 775 species, or better, types. The classification of some "species" remained in question.

In 2013, the marine fish taxa team reconvened to review the old list and make any necessary revisions. A matrix was designed whereby reviewers could place notations in columns that corresponded to factors that would help them determine if various species fit the criteria to be included on the list. Because the first taxa committee (2005) decided to err on the side of caution and list species or types that had no data on them, the list of priority species grew too big to be useful. This time around, the team was able to utilize new data and risk assessments to reduce the number of species on the list to 37 marine fish and 54 marine invertebrates. Many of the species removed from the list were determined to have stable populations or were so understudied that a guess as to their true status could not be determined at this time. If, at any time, any of the "culled" species are found to be in need of priority status, they will be relisted. The taxa committee went a step further and ranked the remaining species into priority categories of highest, high, moderate, or not ranked. All species are highlighted in a species or guild account in the Supplemental Volume while habitat associations are listed in Appendix 1-C.

Challenges

There are a number of potential challenges to marine fishes and invertebrates. However, it is difficult to assess the degree to which each species is vulnerable until habitat associations,

population trends, and distributions are better understood for each species. In some cases, regional management organizations (South Atlantic Fisheries Management Council, Atlantic States Marine Fisheries Commission) are currently conducting stock assessments to determine the health of the populations.

One of the major challenges to marine organisms in South Carolina is the degeneration and loss of habitat. As development and urbanization occurs along the coast, beaches and water bodies are altered in ways that change both topography and hydrology of coastal systems. Removing riparian vegetation can result in siltation and increases in nutrient and pollutant loading.

Habitat loss can affect all life stages of marine organisms. Salt marsh is an extremely productive habitat and is often used by larval forms of both fishes and invertebrates. Degradation of this habitat would be especially detrimental to marine organisms. Coastal development continues to encroach upon salt marshes in South Carolina.

Habitat alterations in marine waters also include damage resulting from trawling, dredging and dredge disposal. These types of habitat alterations are particularly detrimental to benthic fishes and invertebrates.

All marine organisms are affected to some degree by water quality. Industrial and municipal sewage discharge along with runoff from agriculture, golf courses, and suburban developments negatively affect Tarpon and other estuarine fishes. Stormwater runoff from developed areas contains sediment, nutrients and contaminants. These substances can substantially degrade water quality. Sedimentation can impair the ability of many marine organisms to feed. Nutrification can result in harmful algal blooms that substantially reduce dissolved oxygen in the water. Chemical pollution (PCBs, mercury, etc.) can be detrimental to all species; but can be particularly detrimental to benthic species, even in small amounts. Some species, such as fiddler crabs have been shown to bioaccumulate contaminants; bioaccumulation can result in contamination being passed up the food chain. Another species also affected by benthic contaminants is the Southern Flounder, a bottom-dweller.

Several marine fishes may be adversely affected by fishing pressure. Many marine fishes are not managed as either commercial or recreational species, but are targeted by recreational fishermen. If unchecked, such fishing pressure can reduce populations. Also, many species, both fish and invertebrate, are harvested as by-catch in commercial fishing operations. Even if alive when discovered and released, many animals can die due to stress or physical damage sustained during harvest. Some of South Carolina's priority species, such as the Atlantic Spadefish and Sheepshead, are often caught as by-catch.

Unregulated harvest threatens some marine species. For example, South Carolina does not currently regulate a commercial cannonball jellyfish fishery. This species is a major component of endangered sea turtles' diets. However, this fishery does exist in other portions of the cannonball's range. Asian countries are developing fisheries management plans to conserve jellyfish because populations are unstable or declining due to pollution, overfishing, or climate change. Consequently, dealers are looking for new sources of jellyfish (Hsieh et al. 2001). Interest in cannonball jellyfish from the United States increased recently because of high

consumer demand in Asia (Hsieh et al. 2001). Rising demand in Japan and Southeast Asia may create an international market for cannonball jellyfish from South Carolina coastal waters. Likewise, some marine species are collected for the aquarium trade; many of these collections are also unregulated.

Non-native invasive species also have the potential to negatively affect native populations of marine finfish and invertebrates either directly (through predation or the transmission of disease), or indirectly (through competition for resources, such as food and space). On an ecosystem level, the introduction of non-native species is one of the major causes of decreased biodiversity (e.g. Molnar et al. 2008). Examples of introduced marine organisms include the Indo-Pacific Lionfish, Eastern Pacific barnacle, and spiny hands crab (SC Aquatic Invasive Species Task Force and SCDNR 2008).

As the climate changes and becomes warmer, oceans may also warm and become more acidic. Stressed by these environmental conditions, marine fish and invertebrates may experience decreases in reproductive success. Additionally, parasite loads on fish may increase.

Insects

The crafters of the first edition of this document noted many unique challenges to incorporating insects into a conservations strategy. Over a half-decade later, these challenges remain and likely will always be present. As noted previously, one of the greatest challenges is that insects and their kin are species rich and relatively poorly known compared to many other groups. Their small size often renders them inconspicuous and generally unremarkable to the casual observer. Yet their presence on this planet has a profound influence on all other life forms. Additionally, their complex life cycles and seemingly endless diversity have afforded lifetimes of study for many naturalists.

The actual number of insect species is unknown. Of the current 1.5 million named species, approximately 1 million are insects (Foottit and Adler 2009). Other remarkable statistics are that "social insects"—such as ants and termites—could make up 20% of the total animal biomass on the planet. Erwin (1983), through work conducted in tropical forests, estimated that at any one time there are approximately 10 quadrillion (10,000,000,000,000,000) individual insects alive. A recent analysis of taxonomic data estimated there are 8.74 million species of all life forms on Earth (Mora et al. 2011). However, some other estimates suggest between 30 and 50 million species of insects alone could occupy the planet (Erwin 1988, 1997; Odegaard 2000). There are debates about what estimate is correct, but most experts agree that insects are the single largest component of world biodiversity and biomass.

Species Selection Process

With these many challenges, the group of taxonomic insect specialists took to the task of selecting species from the Palmetto State that conformed to the spirit and intent of the SWAP's 8 Required Elements. The size and diversity of the taxonomic group necessitated a large committee, mostly composed of individuals who have devoted many years to their area of expertise. Ten biologically distinct groups were selected for the first edition of this document and

these were here retained. Some experts have retired or no longer could participate and so the taxa presented in the 2005 edition were carried forward while expanding on others. Those who participated then and now have devoted much time to this endeavor and their efforts are acknowledge and greatly appreciated.

The insect taxa committee did not develop a comprehensive list of priority insects in South Carolina because the number of species of insects in this state is not known. As a starting point, the taxa committee completed their work by developing a table indicating the number of species within each insect order in South Carolina.

Table 3-13 presents a summary of the groups that were analyzed, along with specialists who contributed to this project. With some notable exceptions, the paucity of knowledge concerning life histories and insect diversity has not changed significantly since the first edition of the SWAP in 2005. There have been additions to state species records along with new species descriptions, and this will likely continue as more research occurs. It is important to note that this table is far from comprehensive and major groups have not been included. Because of the relative lack of knowledge of numerous species and their distribution, the experts chose again not to include "S" rankings for all groups. However, where knowledge was sufficient, based on the opinions of the various experts, this was included for certain groups. Nevertheless, even for these better-known taxa, this ranking should be considered a rough approximation. Another point of change from the original effort was the inclusion of more species than the 15 selected in the first edition. This again was based on efforts and opinions of various taxonomic experts who served on the committee. The number of priority insects for the State totaled 32. In addition, a list of South Carolina's 158 species of dragonflies and damselflies (order Odonata) are listed in a table in the Insects section of the Supplemental Volume. Taxa team members have made an attempt to assign S-ranks to them for the first time. This exercise may one day result in some of them being included in a future iteration of the SWAP. None of the insects in this Plan can be ranked into categories of "highest", "high", or "moderate" at this time. Select species/guild accounts for the 32 priority species can be found in the Supplemental Volume. The total known insect species reported to occur in South Carolina stands at 6,511 and covers approximately 23 families/groups.

TABLE 3-13: INSECT TAXONOMIC COMMITTEE
(Committee members – 2005 only; *2015 only*; **2005 & 2015**)

Taxa Group	Family Or Groups	Expert	Affiliation	Reported Species 2012
Odonata	Dragonflies	*Chris Hill* Wade Worthen	Coastal Carolina University Furman University	157
		Lynn Smith	Columbia University	
Plecoptera	Stoneflies	**Boris Kondraieff**	Colorado State University	85
Hemiptera	Lace Bugs	Al Wheeler	Clemson University	38
Lepidoptera	Butterflies	**Brian Scholtens**	College of Charleston	158
	Moths	**John Snyder**	Furman University	1,927
Ephemeroptera	Mayflies	*Luke Jacobus* Pat McCafferty	Indiana University Purdue University Columbus Purdue University	185
Trichoptera	Caddisflies	**John Morse** *James Glover* Bradley Goettle	Clemson University SCDHEC Clemson University	270
Diptera	Mosquitoes	*Chris Evans* Bill Willis	SCDHEC Clemson University	62
	Midge Flies	**John Epler**	Private Researcher	392
	Long-legged Flies	Harold Robinson	Smithsonian Institution	91
	Fruit Flies	**Allen Norrbom**	Smithsonian Institution	16
	Black Flies	**Peter Adler**	Clemson University	54
	Horseflies	**Bruce Ezell**	UNC Pembroke	113
	Net-winged Midges	**Greg Courtney**	Iowa State University	12
Coleoptera	Ground and Tiger Beetles	**Janet Ciegler**	Private Researcher	415
	Scarab Beetles	**Phil Harpootlian**	Private Researcher	290
	Bark Beetles	Don Bright	Agriculture Canada	64
	Fireflies Aquatic Beetles Leaf Beetles Tenebrionoid Weevils	Jim Lloyd *Janet Ciegler* *Janet Ciegler* *Janet Ciegler* *Janet Ciegler*	University of Florida Private Researcher Private Researcher Private Researcher Private researcher	37 331 441 339 447
Hymenoptera	Sawflies	David Smith	Smithsonian Institution	52
	Ants	Tim Davis	Clemson University	103
Araneae	Spiders	Robert Wolff	Private Researcher	432
			Total Number of Reported Species	**6,511**

Challenges

Some of the challenges for insect conservation are the same faced by many species of plants and animals. Landuse changes, exotic and invasive species introductions, urban sprawl, and hydrologic modification such as dredging and dam construction can be catastrophic to many species of animals. If predictions of global climate change are correct, all biota, including insects, will be negatively affected in ways impossible to predict. However, one way in which

insect conservation differs from conservation of vertebrates and some marine invertebrates is that direct "take" by humans generally has no measurable effect on populations. While there are rare exceptions, such as tropical butterflies where commercial harvest may be profitable, these practices do not exist in South Carolina. The increased scientific collection of insects will almost certainly benefit the conservation of this diverse but understudied group of animals.

Possibly one of the greatest challenges is that the professional entomologist is also becoming rare and endangered. Robert May (2010) noted that while invertebrates comprise at least 90% of named species, only one-third of professional taxonomists specialize in invertebrates. Thus, the fundamental task of describing and naming insect species, or even being able to identify them, is lacking and probably will be for the foreseeable future. May (2010) noted that funding agencies around the world view basic systematics and taxonomy simplistically, and because much of the work does not conform to the commonly limited notion of falsifiable hypothesis testing, proper funding is not made available. This is a trend not unique to the study of insects. It is hoped that documents such as the SWAP can provide incentive for academic institutions and funding agencies to support high quality training for individuals who devote their careers to describing and naming species, exploring their evolutionary relationships, and studying their life histories. The awareness of the concepts of biodiversity and conservation is likely greater now than in recent memory. However, unless there is a resolve to train the next generation of professional taxonomists, future editions of the SWAP will be comprehensive in name only.

Finally, there have been some very positive trends in recent years that allow for a better understanding of insect diversity. The advancement of computer technology now enables the cataloguing and sharing of data with much greater efficiency. Even if global species richness is closer to 10 million as suggested by Mora et al. (2011) than the 50 million or more proposed by Erwin (1982), the ability to store and share this volume of data would have been unthinkable in the recent past. Numerous agencies have made use of this technology and have attempted to store and make public biotic data from regional and state data.

Geographic Information Systems (GIS) are now sufficiently mature that even user-friendly interactive maps and queries can be built from large datasets and viewed from a desktop computer anywhere in the world. Another advancement is the ability to diagnose species identities using their genetic material (Hebert et al. 2003) with initiatives underway to catalogue the genetic "bar-code" of the world's biota. This initiative has begun to attract interests from various agencies including those within applied fields (Pilgrim et al. 2011). While this tool will likely give rise to a better understanding of insect diversity and a clearer picture of the truly rare and endangered animals that exist within South Carolina, it will do so only with the aid of experienced taxonomists who have the training and years of experience necessary to identify the voucher specimens from which the genes are sequenced. These experts seldom are the ones physically doing the barcoding, but are generally volunteers who are more or less donating their time and effort. Without them, the barcoding would be valuable only for recognizing diversity of haplotype clusters. There is something much more intimate about a recognizable name—or list of names—than indices of haplotype cluster diversity that helps us to understand and comprehend the magnificence of the natural world around us.

Plants

South Carolina, a state with a temperate climate, boasts 2,795 native vascular plant species and perhaps several hundred lichens, algae, mosses, and liverworts (USDA/NRCS 2013). Of the vascular plants known to exist in South Carolina, about 15% are considered at risk (USDA/NRCS 2013). In fact, over half of all federally listed species (i.e. those listed under the US Endangered Species Act of 1973, as amended) nationwide are plants. Currently, the federal guidelines for the State Wildlife Grants Program exclude plants from funding. This is most likely due to the fact that plants are harder to protect on private lands because laws protect plants only if they occur on federal property or if a federal activity on private lands would harm them. There is also the precedent set forth during colonial days that suggests that animals fall under the jurisdiction of the Crown and plants belong to the people (Stein and Gravuer 2008). However, 31 states have created Acts or state ESA requirements that do cover plants along with animals (Stein and Gravuer 2008).

The SCDNR recognizes that plants are an important component of the landscape and therefore is being proactive in the discussion of plant species of concern in this iteration of the SWAP. It has been suggested that the recovery costs for plants may be less than those for vertebrates so perhaps it is time to start considering their inclusion. [Stein and Gravuer 2008]

In addition, some of SC's SWAP priority insects depend upon some of the State's plants of conservation concern for some part of their life cycle. For example, the Argos Skipper utilizes Pine Barrens Reed Grass (*Calamovilfa brevipilis*) while the Two Spotted Skipper uses Tussock Sedge (*Carex stricta*). There are many more plant species that are not in peril themselves but should be maintained for the sake of the insects and other animals that rely on them for survival. For example, monarchs and other migratory butterflies are highly dependent on *Baccharis halimifolia* as a nectar plant (B. McCord, pers. obs.). Maintaining associations such as this is just one more way to ward off population declines and the need for listing species.

Species Selection Process

In October 2004, plant experts convened to revise the South Carolina Heritage Trust database. Reviewers were asked to consider the same types of criteria (e.g. endemism, distribution, population size and trends, threats, knowledge of the species, existing state rank and protection status) as the faunal taxa groups when determining what species to include on their list. The current list of plants tracked by the Heritage Trust Program is divided into priority rankings of highest (those that are federally listed), high (global ranks of G1-G3), and moderate (state ranked S1-S3). This list was further refined to only include G1-G3 and S1 species. These were then split into thirds to derive at the final "highest", "high", and "moderate" SWAP categories.

In ArcMap 10.1, an intersect with the county boundaries layer and ecoregions layer was run, and the resulting table was imported into the University of South Carolina's A. C. Moore Herbarium (USCH) Specify6 database. The list of target species was also imported into the herbarium's database. With these two tables, a query was run against all herbarium specimens matching target species, and details were displayed for habitat information along with their corresponding ecoregion based on the county in which the specimens were collected.

The members of the plant taxonomic committee invested considerable time in the development of the list and are graciously thanked for their efforts; these individuals are listed in Table 3-14. No species/guild accounts have been written for the 333 priority plant species listed in the SWAP. However, habitat associations are listed in Appendix 1-D.

TABLE 3-14: PLANT TAXONOMIC COMMITTEE

(Committee members – 2005 only; *2015 only*; **2005 & 2015**)

Name	Affiliation
Albert B. Pittman, Ph.D.	South Carolina Department of Natural Resources
Katherine Boyle	South Carolina Department of Natural Resources
Julie Holling	South Carolina Department of Natural Resources
Herrick Brown	South Carolina Department of Natural Resources / University of SC

Challenges

Plant species constitute the base of the food chain and are one of the defining characteristics of habitat. From a human perspective, plants are essential for shelter, food, fiber, medicine, filtering runoff to protect water quality, controlling erosion, and providing carbon sequestration services. In addition, many plants are aesthetically pleasing with their foliage colors, patterns, growth habits, and floral components. There are even what some refer to as "game species" in the botanical world—those wild specimens harvested for human use such as American ginseng and black cohosh. [Stein and Gravuer 2008]

Unfortunately, it is some of these highly sought-after properties that have put certain plant species at risk from overharvesting and poaching (Stein and Gravuer 2008). Other threats, potentially even more serious, include habitat destruction or alteration and climate shifts. Long life-spans and lack of mobility mean plants may be affected by climate change earlier and initially more profoundly than animal species. Management can alleviate some of these effects, but management tools often benefit some species at the expense of others. For instance, dormant versus growing season burns in pine forests have markedly different outcomes in regard to understory composition (Roth and Franklin 2009).

Other challenges to plant management include staffing and funding limitations; the difficulties of plant species identification, and the demands of protecting highly localized populations, dependent on specific soils and microclimate (Stein and Gravuer 2008). With a majority of the State in private ownership, long-term land protection is lacking. SCDNR has acquired title to 268,516 acres and protected an additional 22,906 acres with conservation easements. These figures do not include federal lands or NGO holdings. Despite these impressive numbers, many more critical areas are still left to protect across South Carolina's 32,000 mi.^{2}.

In the foreseeable future, climate change will alter the plant communities of South Carolina in ways regarded by many as both positive and negative. As the climate continues to warm while the amount of atmospheric carbon dioxide (CO_2) increases, forests will expand and trees will grow more in a given year due to an extended growing season (SCFC 2010). The increased atmospheric CO_2 will benefit some plant species but not others due to the way it is absorbed (C3

versus C4 plants). Palatability and nutritional content of crops and native plants will decline as a result of the increased CO_2 uptake (SCFC 2010).

Looking further into the future, drought and increased heat will take its toll, turning forests into open savannahs or grasslands. With increases in temperature (and therefore milder winters) come the threat of invasion of more non-native exotic plants, timber and crop pests, and emerging diseases (SCFC 2010). Together with increased drought, these stresses are likely to accelerate tree death. As dead and dying trees contribute to a buildup of the litter layer, this material will act as mulch to help retain ground moisture but also serve as potential fuel and thus increase the risk of wildfire.

One Southern pine species that is being called the "wonder tree" due to its ability to take the heat is longleaf pine. Not only is it a prime candidate in the Southeast for carbon sequestration efforts, but it is more tolerant to drought, overly wet conditions, fire, beetle infestations, forest pathogens, and hurricane-force winds.

CHAPTER 4: SOUTH CAROLINA'S LANDSCAPE

Introduction

Atop Sassafras Mountain, the highest peak in the State of South Carolina, a visitor can catch a glimpse of the splendid vistas of this state from above 914 m (3,000 ft.). From the mountains to the sea, South Carolina has a wide diversity of habitats, environmentally important areas, and scenic resources within the boundaries of its 8 million ha (19.9 million ac.) of land and water (USDA 2000). It is the diversity of the lands and waters of South Carolina that create the myriad environments for the State's varied fish and wildlife which help provide $54 billion to the annual natural resources economy (SCDNR news release, 2013).

Demographics and Economics

In 1790, South Carolina's total resident population numbered 249,073 people. According to data collected in 2010, the US Census Bureau estimated the population density of South Carolina to be 153.9 people per square mile (or roughly 4.2 million people). Of the over 19 million acres of land in the State, approximately 12% is publicly owned while 88% is privately owned (SCFC 2010). The vast majority of the State is characterized as nonfederal rural lands ('nonfederal' referring to all lands in private, municipal, state or tribal ownership). Land use on nonfederal lands in the State, which total 18,115,500 acres, is primarily forestland. South Carolina saw an increase in urbanized areas from 1 million acres in 1968 to 2.5 million in 2006 (SCFC 2010).

According to results of the most recent forest resource assessment, 13 million acres of land in South Carolina are forested. This represents 67% of the land area of the State. The remaining 6.3 million acres is mostly relegated to agriculture and urban centers. Non-industrial private owners, including individual and corporate timberland owners not associated with the forest products industry, own 77 % of these lands. Timberland ownership under corporate control has increased in recent years to 18 %. The percentage of forests managed by the forest products industry has decreased from 16% in 2001 to 11% in 2006 due to large land liquidations by timber companies. Public land ownership increased to 7%. These relationships are illustrated in Figure 4-1.

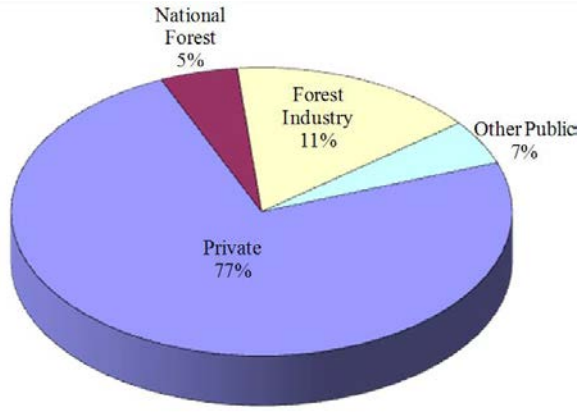


FIGURE 4-1: Distribution of forested land by ownership class in South Carolina (USFC 2010).

Of the 13 million acres of forest land in South Carolina, 6.8 million is in hardwoods and 5.9 million is in softwoods. Of these softwoods, 3.1 million is planted pine. The most common covertype in the softwood group is loblolly-shortleaf pine which accounts for 5.3 million acres in the State. Forestry employees approximately 45,000 workers and contributes $17.4 billion to South Carolina's annual economy. [SCFC 2010]

With an increase in the human population comes an increase in wildfires in the State. There are approximately 3,000 wildfires each year in South Carolina. Prescribed burns are conducted on about 525,000 acres each year, but it is estimated that twice this amount is needed to adequately provide a fire regime to manage fuel loads, maintain fire-dependent flora, and provide habitat enhancement for wildlife. The problems faced by prescribed fire managers include liability concerns, smoke management issues, and forest fragmentation so that there are fewer large tracts to burn. [SCFC 2010]

From 1968 to 2006, agriculture has declined in South Carolina by 60% or approximately 2 million acres. Some has been converted to timber production while most tracts have become developed (SCFC 2010). South Carolina had approximately 12,200 acres under agricultural production in 1950, but by 2011, it had dwindled to 4,900 acres (USDA-ERS 2013). At the same time and over the same period, the number of farms in South Carolina has decreased from 147,000 to 26,000 (USDA-ERS 2013). The market value (total cash receipts) of agricultural products sold in 2011 totaled over $2.5 billion with highest rankings occurring in the following top 10 outputs: (1) poultry (broilers), (2) turkeys, (3) greenhouse/nursery production, (4) cotton, (5) cattle/calves, (6) corn, (7) chicken eggs, (8) soybeans, (9) wheat, and (10) peaches (USDA 2012). Counties in South Carolina with consistently high agricultural yields are Kershaw, York, Dillon, and Orangeburg. Livestock production is typically high in Anderson, Newberry, Kershaw, Lexington, Oconee, Aiken, Saluda, and Orangeburg counties (USDA 2012). As of January 2013, there were approximately 28 USDA certified organic farms registered by the National Organic Program (NOP) in South Carolina (USDA-AMS 2013).

South Carolina is rich in non-fuel raw minerals with a total of over $789 million produced in 2007. The most common minerals produced in South Carolina are, in descending order, cement, crushed stone, construction sand and gravel, industrial sand and gravel, kaolin, crude vermiculite, and common clays. Of all 50 states, South Carolina was ranked 26th in 2007 in total non-fuel mineral production value. Portland and masonry cement still leads South Carolina's mineral commodities. [US Department of the Interior 2007]

Climate

South Carolina has a humid, subtropical climate. The average annual precipitation is about 125 cm (49 in.) per year with the coast receiving approximately127 cm (50 in.) and the Blue Ridge receiving up to 203 cm (80 in.) per year. Average January temperatures range from 10ºC (50 ºF) near the coast to 3ºC (38ºF) in the mountains; July temperatures average 27ºC (81ºF) near the coast and 22ºC (71ºF) in the mountains. The growing season ranges from 200 to 290 days. During the winter months, the State is typically under a continental air mass that is cold and dry, while during summer, the Bermuda high-pressure cell in the Atlantic drives much of the weather. Heat and humidity prevail when clockwise circulation around the Bermuda High brings a

southerly flow of air from the Gulf of Mexico, a pattern that becomes rather stable as the mountains in the northwestern part of the State block any cool fronts which might arrive from the North. Our climate is expected to continue to warm over the coming years and bring with it changes in precipitation patterns and tropical storm intensities (Perry et al. 2012). The SCDNR will be monitoring climate change and how it affects our natural resources.

Aquatic Resources

South Carolina possesses over 17,703 km (11,000 mi.) of permanently flowing rivers (Beasley et al. 1988) and 48,280 km (30,000 mi.) of streams (SCDNR data). All of the streams and rivers that drain a region are collectively called a drainage basin. The precipitation that falls in the state is drained by four major river systems or basins. These include the Savannah, Santee, Pee Dee, and Ashepoo/Combahee/Edisto (ACE). Sometimes these are re-divided into 7 drainage basins (Figure 4-2) in the State: the Pee Dee, ACE, Savannah, Broad, Congaree/Lower Santee, Catawba/Wateree, and Saluda. These, in turn, are made up of 39 sub-basins or HUCs. Except for the ACE Basin, each of these basins originate in the Blue Ridge Ecoregion and pass through the Piedmont, Sandhills, Coastal Plain, and Coastal Zone. Part of the ACE Basin, the Edisto River is the third longest undeveloped free-flowing river in the Southeastern United States. Twenty of South Carolina's rivers connect directly with the State's coastal estuaries. There are 11 major lakes in South Carolina; all are man-made. The SCDNR's State Lakes Program stocks and manages 17 small lakes and ponds across the State, a majority of which are in the Piedmont. South Carolina's major water bodies, rivers, and bays are illustrated in Figure 4-3.

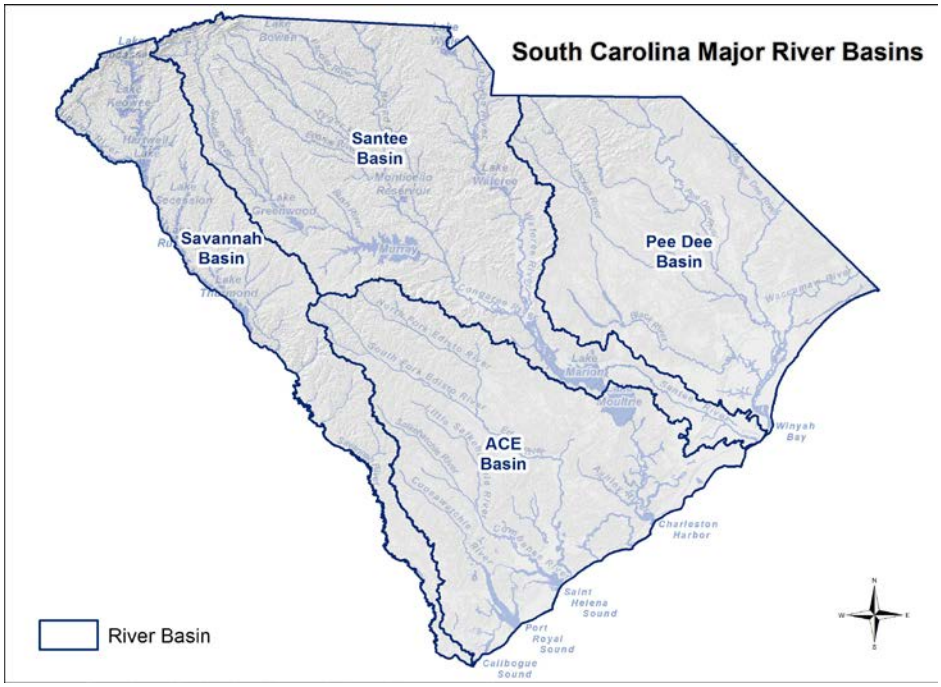


FIGURE 4-2: South Carolina's main river basins

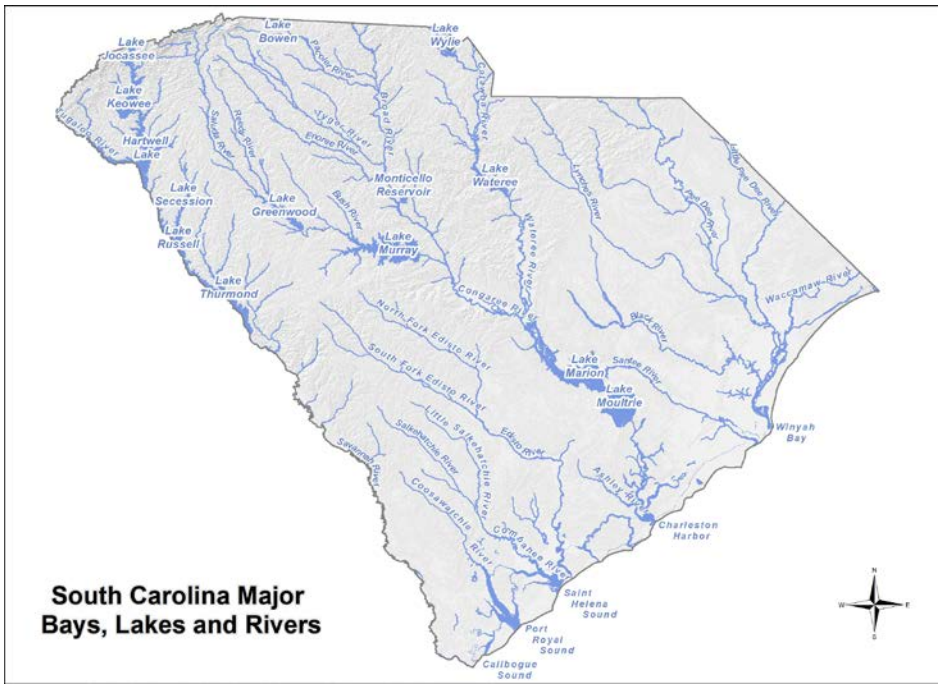


FIGURE 4-3: South Carolina's major bays, lakes, and rivers

Soils

Of the 15,000 and 20,000 soils in the United States, South Carolina has 265. South Carolina soils typically have an organic matter content of less than 5% (closer to 1% or less). Some wetland soils, however, may have greater than 50%. [Scharf 2010]

The majority of soils in the Coastal Plain are sandy or loamy sand in texture. They generally have minimal organic matter, a low cation exchange capacity and water holding capacity, and are infertile. Water rapidly percolates through the soils and can potentially carry contaminates to the shallow water tables and hydrologically connected surface waters. Closer to the coast, depressions and low-lying areas have more poorly drained soils with greater organic matter content and a finer textured subsoil.

Soil texture becomes finer the further west and northward into the State. The "Sandhills", named after very old dune remnants, have surface soils that range from a fine sand to loam in texture. As with the Coastal Plain soils, Sandhills soils have minimal organic matter, yet because of the mineral portion, they have a greater cation exchange capacity and water holding capacity. They are among the most fertile in the State. Many have a finer textured subsoil (clay hardpan) that can limit deep rooting, and result in horizontal movement of rapidly percolating waters above the hard pan to receiving water bodies.

Soils of the Piedmont and Blue Ridge Ecoregions are commonly termed "Piedmont soils". The soils are predominately loamy clay to clay in texture. The majority are deep soils except for soils on deep slopes and tops of mountains. In these two situations, the soils are shallow with the parent material close to the surface. These heavier textured soils have minimal organic matter but high cation exchange capacity and water holding capacity. Water infiltrates slowly, so rapid

rainfall can result in surface water runoff and minimal infiltration. [Dara Park, Clemson Univ., email correspondence July 26, 2013]

General Ecoregion Descriptions

Many habitat types in South Carolina are strongly associated with certain geographic areas or physiographic regions within the state. Habitats in this strategy have been grouped according to five widely recognized regions, called "ecoregions" (Figure 4-4). The primary source of information on the ecoregions of South Carolina and surrounding states is the map and accompanying definitions from Griffith et al. (2002), with supplementary information for South Carolina taken from Myers et al. (1986). This chapter provides a summary of the general landscape and current condition of the 5 ecoregions of South Carolina. In some of the species accounts in the Supplemental Volume, these ecoregions are further divided into the Blue Ridge, Upper Piedmont, Middle Piedmont, Lower Piedmont, Slate Belt, Sandhills, Inner Coastal Plain, Upper Coastal Plain, Outer Coastal Plain, and the Lower Coastal Plain.

Blue Ridge Ecoregion – A narrow belt forming the Southeastern terminus of the Blue Ridge Physiographic Province, ranging from about 366-975 m (1,200-3,200 ft.) in elevation, characterized by steep slopes on Paleozoic crystalline rocks, narrow river valleys, and high-gradient streams; predominantly vegetated by extensive hardwood and hardwood-conifer forests.

Piedmont Ecoregion – A portion of the Piedmont Physiographic Province characterized by rolling hills with highly weathered soils, often severely eroded, overlying mostly Paleozoic crystalline rock substrates, with low-gradient streams on narrow floodplains; vegetation consists mostly of pine and pine-hardwood forests interspersed with agricultural land.

Sandhills Ecoregion – A nearly continuous belt of broad, rolling hills along the Fall Line, generally having sandy soils derived from coarse Cretaceous and Tertiary marine sediments; predominantly vegetated by pine forests interspersed with agricultural land, with hardwood forests on narrow floodplains along medium-gradient streams.

Coastal Plain Ecoregion – A series of broad belts derived from a variety of marine sediments, all oriented more or less parallel to the coastline, the innermost consisting of rolling hills and the outermost consisting of flat terraces. The vegetation consists of pine-dominated forests interspersed with agricultural land on better-drained sites, hardwood forests occupying broad floodplains along low-gradient streams, and extensive pine forests on less well-drained terraces.

Coastal Zone/Marine Ecoregion –This zone comprises the seaward extension of the Coastal Plain Ecoregion, extending from the inland boundary of saltwater influence, seaward to the artificial three-mile offshore limit. Habitat types range from forested variants of Coastal Plain types at inland sites, seaward to sand flats and pine-hardwood forests on unstable emergent coastal sediments, and finally to emergent marshes and submerged bottoms in association with open water.

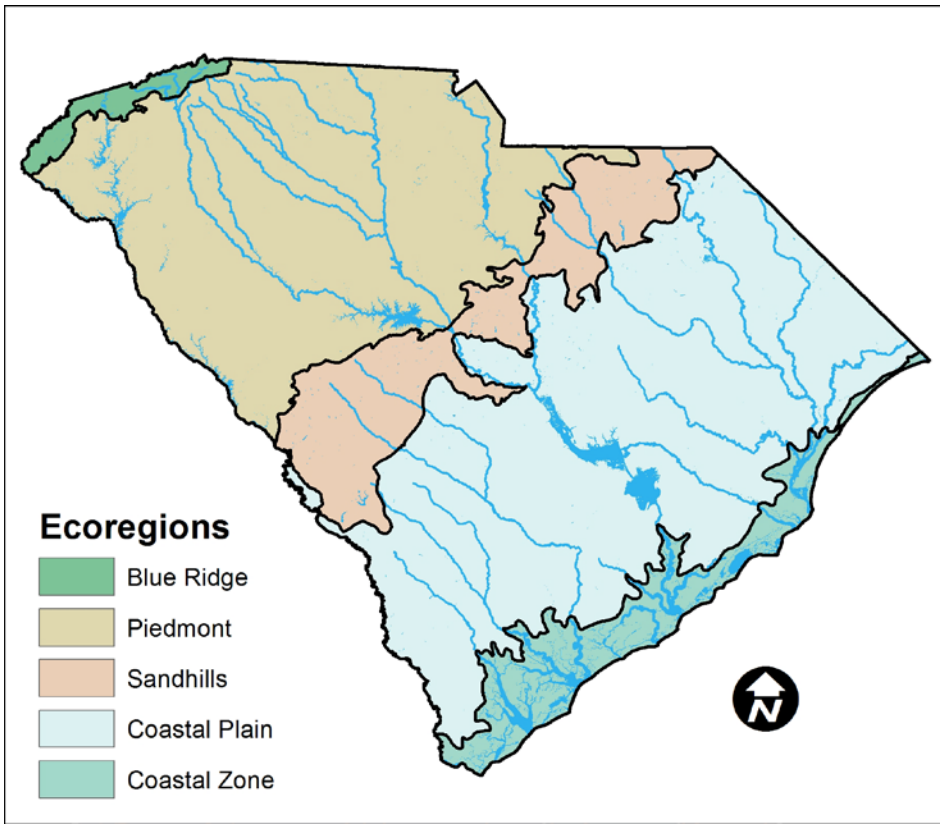


FIGURE 4-4: The 5 ecoregions of South Carolina. Source: Modified from Griffith et al. (2002). The Coastal Plain-Coastal Zone boundary is modified to conform to the legal delineation of the boundary between freshwater and saltwater zones for fisheries management purposes.

The SCDNR and its partners have done a tremendous job of conserving valuable habitat in each ecoregion of the State. The following tables illustrate that fact; Table 4-1 summarizes the percentage of each ecoregion protected in South Carolina while Table 4-2 shows the statewide acreages in conservation status by ownership.

Table 4-1: Ecoregion Acreages

	Ecoregion Area (Acres)	Ecoregion Area (Hectares)	Conservation Areas (Acres)	Conservation Area (Hectares)	Percentage in Conservation Status
Blue Ridge	303,193	122,698	167,479	67,776	55.2%
Piedmont	6,895,523	2,790,519	427,232	172,895	6.2%
Sandhills	2,345,771	949,300	333,154	134,823	14.2%
Coastal Plain	8,927,070	3,612,657	854,352	345,744	9.6%
Coastal Zone	1,508,820	610,598	457,311	185,067	30.3%
Total	**19,980,377**	**8,085,772**	**2,239,528**	**906,305**	**11.3%**

Table 4-2: Statewide Acreages In Conservation Status		
Type	**Acres**	**Hectares**
Federal	1,009,889	408,687
State	462,297	187,085
Private	674,351	272,900
Military	106,371	43,047
Total	**2,252,908**	**911,720**

Invasive Plant Species in Terrestrial and Aquatic Habitats

Throughout all of South Carolina's ecoregions, non-native invasive invasive plant species threaten to disrupt the community composition, structure and function of a variety of habitats and may also have adverse impacts on agriculture. While many non-native species are benign, invasive exotic plants are characterized by their ability to spread rapidly through the environment and may alter entire landscapes within the span of one to three growing seasons. Serious infestations generally result in a significant loss of biodiversity in impacted areas. According to the South Carolina Exotic Pest Plant Council (2004), approximately 100 million acres in the United States already bear some environmental degradation due to invasive plant species. Recognizing potential threats and generating public awareness and support is the first step in preventing further spread of invasive plants. Management to recapture sites already affected presents an enormous on-going effort. Roughly 90 exotic pest plant species have been identified as posing potential to severe threats to South Carolina's terrestrial habitats. Aquatic habitats are also affected by noxious weeds, with tremendous removal and control efforts provided by SCDNR, Clemson University, and others. In a combined effort, through the South Carolina Aquatic Invasive Species Task Force (2008), a list of noxious weeds for aquatic and wetland habitats has been developed. Terrestrial and aquatic invasive plants are listed in Appendices 5 and 6.

Land Covertype Classification System

A major component of this revision includes updates to the current landscape chapter that provide a more comprehensive way of describing and mapping priority habitats within the State. For the initial SWAP preparation (previously referred to as the CWCS), the principal source of information for terrestrial habitat definitions was Nelson's (1986) classification of South Carolina's natural communities. In the previous edition, no GIS supporting maps were included in the Plan. Habitats within the chapter were described in narrative form and were not mapped within the ecoregions. Given the utility that GIS support maps provide, we felt that their addition was an appropriate measure to update our plan that would also echo neighboring states' efforts. A Priority Habitats Technical Team was assembled in 2011 to guide the revision process.

As GAP data has been criticized for its low accuracy rate, it was proposed to use it as a support system for land covertypes, which were loosely based on Nelson's *Natural Communities of South Carolina*, and not as the sole basis for classifications. Utilizing our Technology Development Program staff, SC GAP data were isolated by ecoregion and then re-classified to "fit" into the original habitat classes creating the crosswalk table found in Appendix 4. SC GAP

habitat class descriptions—found in the 2001 final report entitled, *"A GAP Analysis of South Carolina"*—and expertise from the Heritage Trust staff were used to justify merging of the GAP map units into their respective CWCS original habitats. SC GAP data actually identified more land covertypes within the ecoregions, therefore, providing a more comprehensive overview of the actual habitats present.

By merging the SC GAP data into the CWCS habitat types (which thus became the new 2015 SWAP classification), land covertypes can now be supported with GIS data, with the intent to "clip" out each ecoregion, and provide a map illustrating those covertypes that fall within the area discussed.

Some land covertypes rarely provide quality habitat for a majority of wildlife but are nonetheless a part of the landscape. Cultivated land and pasture, recently disturbed land, and urban areas are three such types mapped by GAP but not discussed in terms of habitat qualities, only habitat possibilities if their current condition were to be enhanced for wildlife. They are discussed here in lieu of under each ecoregion.

The cultivated land and pasture land covertype can include current agricultural fields, old field sites, hay meadows, residential lawns, golf courses, and livestock pastures. It may also include low density housing in rural / small farm settings and associated outbuildings and pastures (GAP 2001). Although it has a relatively low habitat value in its current state, cultivated land and pasture is a crucial land covertype to consider for conversion to native vegetation on private lands. Farm Bill programs have been instrumental in funding conservation practices on these lands. Pollinator habitat can be enhanced in agricultural fields by leaving natural areas out of production and protecting hedgerows, abandoned fields, bare soil or sand, and snags (Heinz Center 2013). Several species of pollinating insects are included in South Carolina's SWAP and would benefit from these efforts.

Recently disturbed land is transitional land characterized by sandy, bare soil and/or recently cleared forest. Because of the limitations of GAP data, including the time period and maps used to create GAP, the current state of this covertype is relatively unknown. Therefore, the potential of these areas to proceed through successional stages is there, along with the variety of new habitats this would provide wildlife and plants along the way. However, these same sites are often "recently disturbed" because they are in the process of being developed into housing developments and the like.

Two types of residential development are associated with urban areas; high and low. High density residential development occurs near cities; forest and other green areas are interspersed with urban areas in low-density residential developments (GAP 2001). The sprawling, unplanned development that has accompanied South Carolina's rapid growth in recent decades is accelerating the conversion and fragmentation of the State's landscape. Some portions of the State are building on or paving over the land at a rate five to six times that of their associated population growth. The resulting loss of green spaces affects not only the quality of life in urban areas; it also denies residents ready exposure to the underlying natural values present in undeveloped lands. If people cannot experience nature close to home, they are less likely to value it wherever they encounter it. As human populations continue to increase and sprawl,

urban areas will play an ever-changing role in habitat loss, fragmentation, and species distributions.

Important elements in the urban environment are those remnants of the original natural landscape, or farm and forest lands within an urban setting that retain some natural character. These areas support wildlife habitat, recreational opportunities, green space, and limited ecosystem functions. They can enhance the quality of life within urban settings, and may provide important linkages with other natural landscapes. Urban green spaces offer residents and visitors outdoor opportunities for exercise, relaxation, and appreciation of nature, especially for those who are unable to afford alternatives. Parks, squares, gardens, and greenways help maintain higher property values, and attract workers in the new economy who can choose to live where the quality of life is high. Beautiful green spaces are an essential part of the shared civic spaces which create our sense of place and community.

Despite their comparatively low habitat value relative to wilderness areas, well-managed urban settings can provide important ecological functions and benefits. Urban trees, shrubs, and grasses provide habitat for many of the more common species of birds, mammals, reptiles, and amphibians. This vegetation also filters air pollution, cools air temperatures, absorbs noise, reduces soil erosion, removes water pollution, controls runoff volume and velocity, and increases groundwater infiltration. High-rise office buildings can provide nesting ledges for Peregrine Falcons and Least Terns while the buildings themselves can be built to LEED certification standards (such as using bird-safe exterior glass) to avoid some of the detrimental impacts of the buildings' footprints on the landscape. Nighttime lighting adjustments and encouraging pet owners to keep their cats indoors also help protect native wildlife in the urban environment. In addition, conservation-minded zoning recommendations can be made to maintain travel corridors and a mosaic of appropriate habitat interspersed with urban or suburban areas.

The Gray Kingbird, one of South Carolina's priority species, appears to be well-adapted to living in developed habitats, as it is a common visitor to farms and suburbs which provide foraging opportunities on agricultural pests and insects (Smith and Jackson 2002; Wetmore 1916). It is less sensitive to human disturbance than other species. Several other bird species that have adapted to urban and suburban landscapes include hawks, hummingbirds, orioles, woodpeckers, Purple Martins, Barn Swallows, and Chimney Swifts. In all, over 100 native bird species utilize these areas for breeding or stop-over habitat during migration (NBCI 2013). Eastern glass lizards, relatives of the two priority glass lizards in the SWAP—island and mimic—also can be quite common in urban and suburban sites.

Residential neighborhoods can still provide for wildlife when homeowners landscape with native plants, provide nesting sites, and provide alternative food and water sources. The National Wildlife Federation (NWF) has a program for certifying landscapes as "backyard habitat." In 2013, the South Carolina Chapter of the NWF reported that the State of South Carolina was number one in the country in the number of certified wildlife habitats per capita.

Priority Habitats and Focus Areas

All habitats are important to maintain as each contributes to the diversity of the State of South Carolina; therefore any habitat can arguably be a priority. However, for the purposes of this Action Plan, priority habitats are defined as any habitat type that is optimally suited for one or more priority species. In the 2005 version of the SWAP, priority species were listed within the various habitat narratives. As this did not prove to be a user-friendly format, the priority species habitat associations have instead been compiled in Appendices 1 A-D as a table in which X's designate what habitat(s) the species can be found in by region of the State. These habitat associations were determined by consulting the scientific literature, taxa team members, and experts on particular species. The Land Manager's Guide series by The Nature Conservancy (those of Wilson 1995, Hamel 1992, and Trani et al. 2007) was consulted as well. Marine species have their own table whereas freshwater aquatics and terrestrial species have their own which are sorted by ecobasin and by ecoregion, respectively.

The following ecoregion sections contain descriptions of habitats typical of that ecoregion as well as the priority species that may utilize that habitat if all required conditions are met. Embedded within these main habitats are microhabitats which may be crucial to the continued existence of many priority plants and animals as well as more common species. The SCDNR has further defined some general "conservation opportunity areas" (focus areas) that encompass terrestrial and aquatic habitats, some with known element of occurrence records of priority species, and created a map (Fig. 4-5) to guide its conservation efforts. South Carolina's SWAP and State Forest Action Plan were reviewed simultaneously for common priorities so that the maps that appear in each document express shared values. The boundaries of these focus areas are generalized and dynamic; they can change as new information becomes available. In terms of funding under the State Wildlife Grants (SWG) Program, geographic location of a project will not be the sole determining factor in whether or not projects are considered.

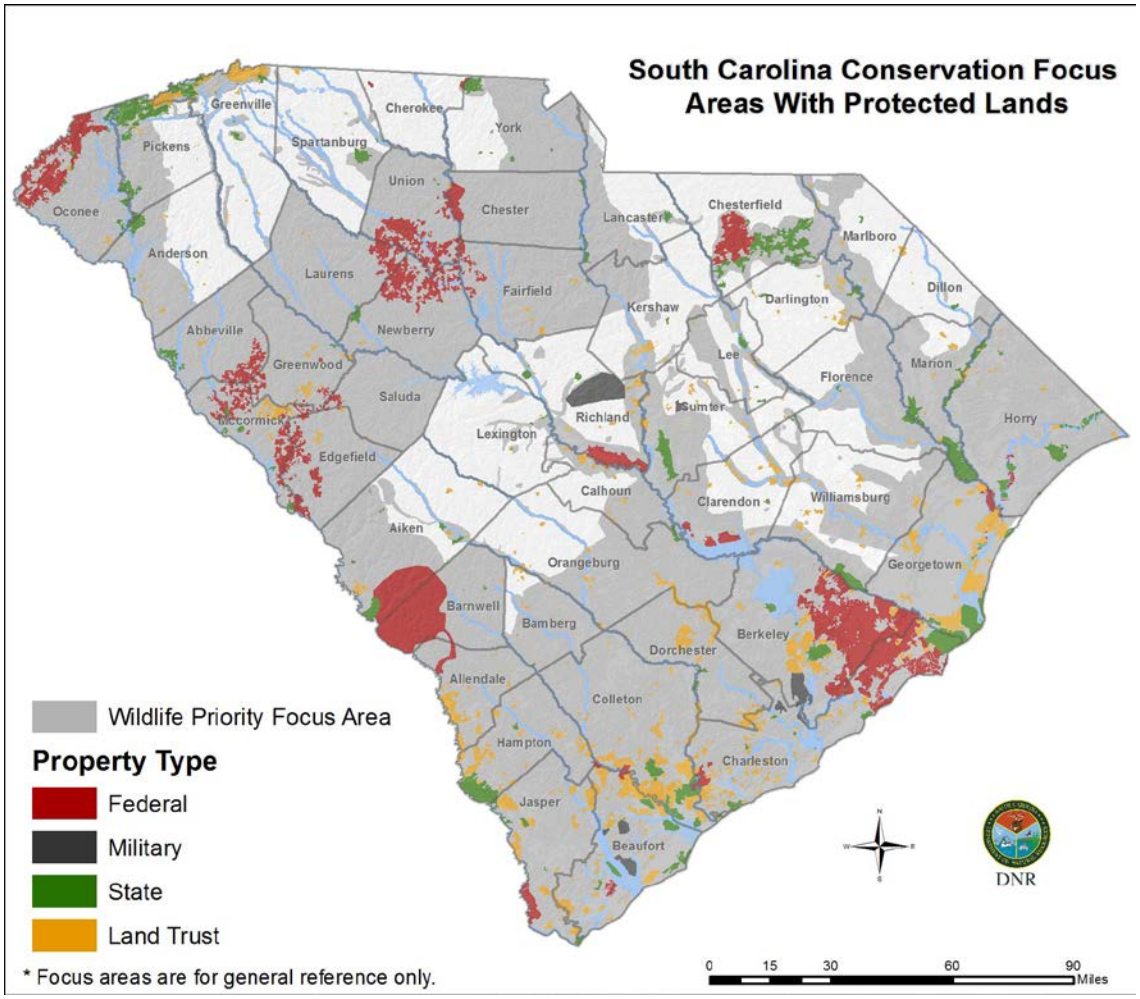


FIGURE 4-5: SWAP Conservation Opportunity Areas in gray and currently protected lands in SC (colored). Map derived from considering the 2013 Northern Bobwhite Habitat Restoration Plan for SC, SC Forest Action Plan, the 2005 SC Comprehensive Wildlife Conservation Plan, Conservation Blueprint 1.0, ACJV bird data, Heritage Trust records, and many other focus area maps used by SCDNR and its conservation partners.

Blue Ridge Ecoregion

General Overview

South Carolina's mountains are part of a multi-state region within the Southern Appalachians known as the Southern Blue Ridge Escarpment. The Escarpment forms an abrupt transition between higher mountains in adjoining states and the Piedmont. High-gradient streams fed by high annual rainfalls carve the mountain landscape (Griffith et al. 2002). In fact, the Jocassee Gorges area of the State receives the second highest rainfall in the continental US. It also boasts one of the highest concentrations of waterfalls in the Eastern US. A portion of the mountain region's northern boundary in South Carolina is formed by the Eastern Continental Divide, which provides resource managers with the rare opportunity of working with ecological and jurisdictional boundaries.

Although the Blue Ridge in South Carolina constitutes a small portion of the State's land area (328,500 acres or 1.69% of the total area), it supports the most extensive upland hardwood forest complex in the State. The region is rich in floral diversity, best expressed in the mixed mesophytic forest vegetation community (Braun 1950), and described as moist broad-leaved forests that can harbor over 30 different tree species and many more types of fungi and ferns. Other biological resources unique to the region include a viable black bear (*Ursus americanus*) population extending across the North Carolina, Georgia, and South Carolina state lines; sustained nesting of Peregrine Falcons (*Falco peregrinus*) following reintroduction in the 1980s; and self-sustaining populations of native Eastern Brook Trout (*Salvelinus fontinalis*). The Jocassee Gorges area of the State was named one of "50 of the World's Last Great Places—Destinations of a Lifetime" by the National Geographic Society in 2012. The 124 km (77 mi.) long Foothills Trail winds through scenic vistas along the Blue Ridge Escarpment and connects to the 684 km (425 mi.) Palmetto Trail leading to the coast.

Overstory, understory, shrub and herbaceous plant communities of the Blue Ridge are generally related to topography, elevation, slope, soil type, and other particular aspects of a site (Abella 2002). A few specialized habitat types, such as bogs or rock faces, are present due to unique geological formations. Rare plants—approximately 60 in all—abound in the Jocassee Gorges area, including 90% of the global population of the rare Oconee bells (*Shortia galacifolia*). Habitat types in the region generally blend from one type to the next with the rare abrupt transition. Because of these intergradations of communities, very few animal species are strictly associated with any single habitat type.

At higher elevations, the current landscape consists of large tracts of unbroken forest. The overall condition is best described as trending toward mid-successional, relatively lacking in both the early-successional stages resulting from disturbances and the late-successional or "old growth" stages characterized by canopy openings and other complexity-providing structures. Major biological changes to forest community composition within historic times include the pathogenic destruction of the American chestnut (*Castanea dentata*) as the dominant canopy tree species, the removal of the Eastern cougar (*Felis concolor*) and red wolf *(Canis rufus)* as the top predators, and the extinction of both the Carolina parakeet (*Conuropsis carolinensis*) and elk (*Cervus canadensis).*

Eighteenth century European settlers cleared flatter sites at all elevations for agricultural settlements and utilized wood from surrounding forests for a variety of purposes (SCDNR, 1998). Beginning in the late 19th and early 20th centuries, industrial development in the upper Piedmont led to a period of extensive timber extraction. Early logging operations focused on removing oaks and tulip poplar from cove and mid-slope forests for construction timbers (SCDNR 1998; Abella 2002). Later, logging operations utilized a network of temporary roads that penetrated the entire region. Therefore, between the early intensive logging at lower elevations and more recent logging roads accessing higher elevation sites, almost all sites in the region have been subjected to timber extraction in some form.

Beginning in the mid-20th century, a series of land consolidations began, which shifted ownership toward public and quasi-public purposes. In 1963, the Jocassee Gorges property was purchased by the Duke Power Company for hydropower development, a transfer that set the

stage for the property's ultimate acquisition by the SCDNR in 1998. Other significant transfers in modern times include Sumter National Forest in Pickens and Oconee Counties; Poinsett and Table Rock Reservoirs in Greenville County; Table Rock, Jones Gap, and Caesars Head State Parks; and several other acquisitions by the SCDNR.

Forest condition and age on public lands varies with ownership. Although the Sumter National Forest is managed under a multiple-use approach, recent legal challenges have significantly curtailed forestry operations. Current composition on Sumter National Forest is primarily a mixture of mid-successional, pine-hardwood stands and managed pine-dominated stands of various ages. The SCDNR-owned Jocassee Gorges tract was heavily logged before acquisition by the SCDNR and US Forest Service, while the Greenville Watershed and State Park lands have a long history of passive management.

Fire management practices also vary across the region, ranging from the regular use of prescribed fire on the Sumter National Forest to total fire exclusion on Greenville Watershed and State Park lands. Current burning practices are contradictory to historic descriptions of widespread wildfires that created relatively open stands with sparse woody understory vegetation (Brose et al. 2001).

Habitats at lower elevations in the Blue Ridge Ecoregion are ecologically similar to those of the adjoining Piedmont Ecoregion. Settlement and land use patterns at these elevations are also similar to those of the Piedmont; most land is in private ownership and, as such, land uses have become highly fragmented with agriculture, managed woodlands, and residential uses separating tracts of natural forests. Furthermore, many historic farming communities are undergoing rapid development as land values rapidly increase. Amenities such as scenic Highway 11, which runs along the base of the escarpment, and SC Department of Parks, Recreation and Tourism properties as well as Lakes Keowee and Jocassee contribute to the Blue Ridge Ecoregion's popularity for recreation and development.

Land Covertypes

Habitat definitions primarily follow the Landscape Ecological Classification of Abella (2002), which is based on a multivariate analysis of geomorphology and vegetation on late-successional sites (more than 70 years since timber harvest) in the Jocassee Gorges. To give a broader picture of habitat types across the region, the work of Patterson (1994) for the Ellicott's Rock area in the extreme Northwestern corner of the region is incorporated, as are a number of classifications based on vegetation composition and structure, notably Nelson (1986). Variation of habitat characteristics within the region has not been systematically quantified, although white pine-dominated types are more prevalent in the western portion of the region. Some qualitative differences in vegetation composition between the Ellicott Rock and Jocassee Gorges areas have also been observed (Camp 2004). Figure 4-6 defines the covertypes associated with the Blue Ridge Ecoregion. Species-habitat associations are presented in Appendices 1 A-D while the faunal makeup of the habitats are described in more detail within this chapter (4).

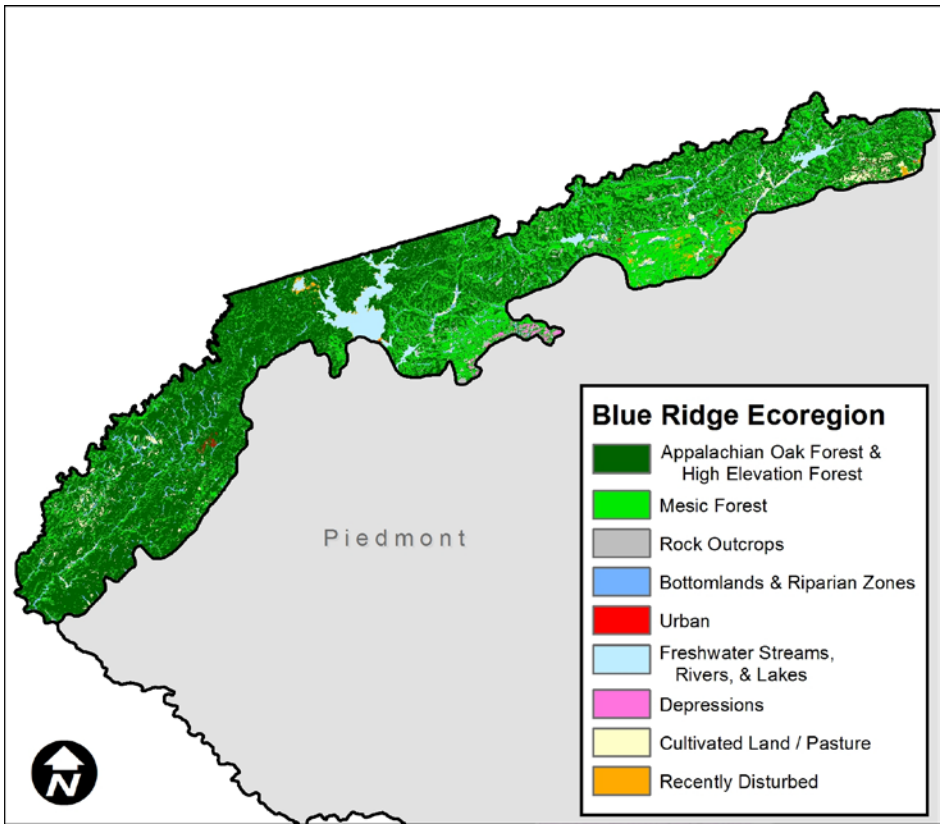


FIGURE 4-6: Land covertypes of the Blue Ridge Ecoregion.

Appalachian Oak Forest *(within Appalachian Oak & High Elevation Forest layer)*	Oak and oak-pine forests compose the predominant vegetation type throughout the Blue Ridge Ecoregion. Vegetation composition and structure is highly variable, depending primarily on exposure and position on slope and, secondarily, on soil moisture. Ridgetops and exposed upper slopes support an open canopy forest of oak species such as scarlet, black, and chestnut oak and/or mixed pine-oaks. The understory is open and groundcover is sparse; blueberry is a characteristic groundcover. Upper portions of hill slopes and exposed nose slopes typically support a canopy dominated by chestnut oak, with numerous hardwood co-dominants, and a shrub layer dominated on some sites by dense stands of mountain laurel. More mesic lower slopes—particularly north-facing slopes at intermediate and low elevations—and sites along small streams and ravines, support diverse hardwood species, typically including white oak, tulip poplar, Fraser magnolia, and red maple. Diverse shrub and herbaceous species are also present, along with widely spaced clumps of mountain laurel. Early-successional sites dominated by grasses, shrubs, and seedlings or saplings of numerous tree species are included in the definition of this habitat type. This covertype may also contain sporadic patches of planted pine for timber production.
High Elevation Forest	In South Carolina, this land covertype is limited to the highest peaks.

(within Appalachian Oak & High Elevation Forest layer)	Occurring at scattered sites at over 900 m elevation, South Carolina represents the southern limit of this habitat (Braun 1950). Several canopy trees, other plant species, and a few priority wildlife species are also at their southern range limits. Canopies consist of red maple, chestnut oak, northern red oak, black oak, hickory, and tulip poplar. Herbaceous species diversity is high, but less than that occurring in mesic hardwood/bloodroot or cove forests. High-elevation forest is distinguished from other forests by the lack of calciphilic species and the dominance of red maple and chestnut oak. On steep to very steep upper to middle slopes with northerly aspects, vegetation is dominated by northern red oak with or without lesser amounts of chestnut oak and red maple. Rosebay rhododendron or great laurel (*Rhododendron maximum*) forms a dense continuous subcanopy, and on more exposed sites, Piedmont or small-leaf rhododendron (*Rhododendron minus)* becomes more dominant.
Low Elevation Basic Mesic Forest *(within Mesic Forest layer)*	Low elevation mesic forest occupies relatively sheltered, well-drained sites on concave landforms and lower slopes. It is a rare type within the ecoregion, occurring only on sites exhibiting unusually deep soils. It corresponds to the mixed mesophytic forest of Braun (1950), which is recognized for its rich floristic composition. Tulip poplar typically dominates the overstory, and Carolina silverbell is a characteristic species in the mid-story or understory. The shrub layer is typically sparse or absent. Herb species richness and cover are highest in this type and characteristic ground flora species include bloodroot, foamflower, silverbell, partridge berry, cane and ginseng. Mixed mesophytic forests are recognized generally as habitats within the Southern Appalachians that support high densities and/or provide optimal habitat for many species of breeding birds and also have high salamander species diversity (Hunter et al. 1999).
Low Elevation Acidic Mesic Forest *(within Mesic Forest layer)*	Low elevation acidic mesic forest occurs on well-drained, relatively sheltered sites in stream bottoms, along ravines of small streams, or on hill slopes. This land covertype is more prevalent on North-facing slopes or lower positions on other slopes. Eastern hemlock is the characteristic tree, occurring either as the dominant overstory or understory tree, while rhododendron dominates the shrub layer, occurring in thickets or solitary clumps. Tulip poplar, white pine, hickories, sweet birch, beech, and basswood are common associates. White pine becomes much more dominant along with hemlock in the Ellicott Rock /Chattooga River basin in the western portion of the Blue Ridge. This land covertype provides critical habitat for wildlife species associated with riparian habitats.

Rock Outcrops	Rock outcrops of widely varying sizes and slopes occur throughout the region. Slopes range from nearly horizontal to nearly vertical. The more extensive and exposed outcrops have their own characteristic vegetation and habitat features. Vegetation ranges from none, (bare rock) to a mosaic of herbaceous plant, shrub, and tree-dominated communities. Successional trees, such as eastern red cedar (*Juniperus virginiana*) and Virginia pine (*Pinus virginiana*) are common at these sites. Crevices and ledges can only provide habitats for larger plants once sufficient soil has accumulated. Vegetative communities are relatively unstable. A cliff or dome may also have a significant area of wet seepage zones.
Bottomlands and Riparian Zones	This land covertype forms the riparian vegetation zone on streams and rivers—typically along wadeable or navigable streams that are wide enough to prevent canopy closure—at scattered locations with a suitable substrate of seasonally flooded rocky or alluvial soils. It exhibits variation in size and persistence. At the base of the escarpment, this habitat also occupies broad floodplains, where it grades into the floodplain forest types of the upper Piedmont (Barry 1980). Alder (*Alnus* spp.) is a characteristic species that occurs at a relatively high abundance along with mixed canopy species. Common shrubs are yellow root (*Xanthorhiza simplicissima*), Virginia willow (*Itea virginica*), azalea (*Rhododendron* spp.) and occasionally black willow (*Salix nigra*) and sweet pepperbush (*Clethra alnifolia*).
Depressions	At high elevations, this land covertype tends to be small in area with a seasonally variable water table. When bedrock is close to the soil surface, such as in the case of exposed granitic domes, perched water tables may form acidic, ombrotrophic bogs, while stream-fed depressions tend to be higher in mineral content. In either type, dense mats of peaty soils are dominated by *Sphagnum* spp. and a variety of grasses, sedges, and low shrubs. The overall community structure may even follow the course of stream channels over slopes forming cataract bogs.
Moist or Wet Types Due to Unique Landform *(specialized habitat not mapped at this scale)*	Highly variable landforms within the Southern Blue Ridge Ecoregion include numerous wet places that increase local and regional habitat diversity. Open seeps of variable size occur on granitic cliffs and domes. Spray cliffs occur in spray and splash zones at the edges and bases of waterfalls. Upland bogs form in poorly drained wet seepage areas at the heads of small streams, which are nearly always saturated. Upland bogs are characterized by sphagnum (*Sphagnum* spp.) and other bog species such as orchids and sedges. Vegetation in upland bogs is apparently fire-controlled. Without burning, succession leads to a wetland community dominated by woody

	vegetation.
Grassland and Early-Successional Habitats *(specialized habitat not mapped at this scale)*	Early-successional habitats are found throughout the state but reach their greatest extent in the Coastal Plain Ecoregion. These habitats are generally characterized by tree canopy coverage that is sparse or absent and herbaceous groundcover comprised of annual forbs, perennial bunchgrasses, and variable coverage of shrubs and small trees. A variety of open land covertypes represents this category and can include native prairies, savannas, old field sites, open canopy gaps, shrub-scrub thickets, recently-cleared forests, field borders, grassed waterways, and filter strips. Lawns, golf courses, pastures, hay fields, crop fields, airports and various urban open spaces are sometimes included in this habitat type but lack the floristic and structural diversity to be considered high quality, early-successional habitat (see Cultivated Land and Pasture). Minor modifications to agricultural land use, such as replacing introduced grasses with native grasses, using native grasses in filter strips and grassed waterways, and implementing no-till or strip-till in crop fields can result in dramatic improvements to quality of early-successional habitat. Maintenance of early-successional habitat requires periodic repeated disturbance or disruption of the existing vegetative community. Purposeful management of early-successional habitat is usually accomplished through the use of timber harvest, prescribed burning, disking, or mowing. Target species for management will determine disturbance intervals, with shorter intervals (1-2 years) favoring those species dependent on herbaceous vegetation and longer intervals (3-5 years) favoring those species dependent on shrub cover. Optimal multi-species management often dictates concurrent maintenance of variety of successional—or seral—stages. Early-successional habitat types have declined dramatically over the past 70 years primarily due to changing agricultural practices, forest succession, fire suppression, and urban / suburban encroachment. A large portion of existing early-successional habitat occurs on privately owned lands. One of the greatest challenges to maintaining priority species associated with this particular land cover is private land outreach and technical assistance.

Freshwater Streams, Rivers, and Lakes

Although the Blue Ridge is the smallest ecoregion in South Carolina, encompassing only 1,204 km^2 (465 $mi.^2$), it harbors a diverse and unique aquatic community. The Blue Ridge Ecoregion cuts across the top of two major South Carolina drainages, the Savannah and the Santee, forming two ecobasins: the Savannah-Blue Ridge and the Santee-Blue Ridge (Fig. 4-7).

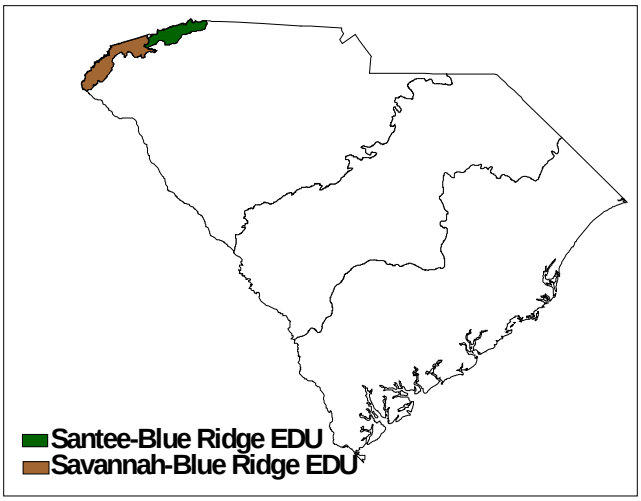


FIGURE 4-7: Drainages of the Blue Ridge Ecoregion

The Blue Ridge Ecoregion is the least developed ecoregion in the State and is primarily forested. Nearly 50% of the land in the Blue Ridge is protected to some degree. Three large tracts account for most of the protected land. These are the Sumter National Forest, the Jocassee Gorges Recreation Area, and the Greenville Watershed Easement.

Wadeable streams are the dominant aquatic classification in the Blue Ridge Ecoregion, and overall water quality is good. Wadeable streams are defined as streams with Strahler stream orders of 0 to 3 that generally can be waded comfortably throughout most of the year. Wadeable streams in the Blue Ridge are typically high gradient with clear water and a mixture of bedrock, gravel, coble, and sand substrates. These streams contain a variety of habitats including riffles, runs, pools, glides, and cascades. At higher elevations, many of these streams contain cascades and waterfalls.

Navigable streams are less common in the Blue Ridge Ecoregion with only about 32 km (20 mi.) of free-flowing stream within South Carolina. These streams are generally defined as being large enough to operate watercraft, if only a canoe, and are generally

too deep to be waded throughout most of the year. The Chauga and Chattooga Rivers are examples of navigable streams in the Blue Ridge. Navigable streams in the Blue Ridge contain a myriad of aquatic habitats including riffles, shoals, pools, runs, and glides in various combinations. These streams are somewhat more productive then the wadeable streams, despite being generally swift flowing and clear. Substrate in these habitats is primarily bedrock, gravel, cobble and sand. Lakes of the area are man-made, with artificial species management; they are not really pertinent habitat for the conservation of native species.

Challenges to conservation of aquatic fauna in these two ecobasins are similar to other ecobasins in the State and primarily include impacts associated with impoundments, non-point source pollution, and the introduction of non-native species. Point source pollution is not a significant problem in the Blue Ridge Ecoregion at this time. Sedimentation is the primary form of non-point source pollution in the Blue Ridge Ecoregion as it is throughout the State. Erosion from residential and commercial development as well as transportation and utility construction projects is the primary source of sedimentation in streams. Poor agricultural and silvicultural practices also contribute significantly to stream sedimentation.

Introductions of non-native species also threaten native fauna in the Blue Ridge Ecoregion. Introduced Rainbow Trout and Brown Trout displace the native Eastern Brook Trout and may prey on native nongame fishes as well. Introductions of Spotted Bass to Lakes Jocassee and Keowee have displaced the native "Bartram's" Redeye Bass and further threaten the fish through hybridization.

Cold and cool water species, particularly our only native trout the Eastern Brook Trout, face an uncertain future with a changing climate. Many of these species are at the southern extent of their ranges, and increases in water temperature may affect their ability to persist in South Carolina. Our ability to predict the consequences of climate change is limited by uncertainty in climate predictions compounded by complexity in ecological system behavior. However, data collected during the South Carolina Stream Assessment are being used to attempt to model potential consequences of climate change for streams in the State.

Santee-Blue Ridge EDU

The Blue Ridge portion of the Santee drainage originates in South Carolina as the headwaters of the Saluda River, which flows southeast and is a major tributary to the Santee River. The ecobasin encompasses approximately 453 km^2 (175 $mi.^2$). Most of the land is privately owned; however, a significant portion is protected by state, municipal and private entities. The ecobasin encompasses approximately 394 km (245 mi.) of lotic habitat. There are 409 km (254 mi.) of wadeable streams in the Santee-Blue Ridge Ecobasin. The largest two impoundments, North Saluda Reservoir and Table Rock Reservoir, total only 615 ha (1,519 ac.).

Sampling by SCDHEC (1998a) found that only 1 of 13 sites (8%) was designated as impaired; that impairment was based on the absence of aquatic fauna.

In the Santee-Blue Ridge Ecobasin, 20 km (12.5 mi.) of stream habitat have been lost to impoundments, including North Saluda Reservoir and Table Rock Reservoir. Impoundments

affect native aquatic fauna through direct loss of habitat as lotic habitat is converted to lentic habitat, which favors competitive and often predacious species such as Largemouth Bass and other centrarchids. In addition, impoundments often negatively impact unimpounded stream reaches downstream due to altered hydrologic and thermal regimes (Cushman 1985), modified stream channel morphology, and increased erosion and sedimentation (Waters 1995), ultimately reducing suitable habitat for native aquatic fauna (Helfrich et al. 1999; Tiemann et al. 2004).

Savannah-Blue Ridge EDU

The Blue Ridge portion of the Savannah drainage originates in the mountains of South Carolina, North Carolina and Georgia. Major tributaries in the ecobasin include the Chauga, Chattooga and Toxaway rivers. The ecobasin encompasses approximately 733 km^2 (283 $mi.^2$). Most of the land is publicly owned with a significant portion protected by federal and state entities including the Sumter National Forest Wild and Scenic River Corridor along the Chattooga River. The ecobasin encompasses approximately 599 km^2 (372 mi.) of lotic habitat and 3,358 ha (8,298 ac.) of impoundments. Most of the impounded area is a result of Lake Jocassee 2,979 ha (7,362 ac.) and the headwaters of Lake Keowee 221 ha (547 ac.). There are 586 km (364 mi.) of wadeable streams in the Savannah-Blue Ridge Ecobasin.

In the Savannah-Blue Ridge Ecobasin, 5 of 27 sites (19%) sampled by the South Carolina Department of Health and Environmental Control were designated as impaired, primarily due to mercury or total phosphorous contamination (SCDHEC 2003a). Fish consumption advisories have been issued for Lake Jocassee and the Seneca River arm of Lake Hartwell (SCDHEC 2003a).

Impoundments in the Savannah-Blue Ridge ecobasin have negatively affected a significant portion of habitat for native aquatic species. Nearly 64 km (40 mi.) of historically free-flowing streams within the ecobasin have been impounded; most of the stream habitat lost (40 km or 25 mi.) was due to the impoundment of the Toxaway River to form Lake Jocassee.

Region-wide Challenges

Most forests in the region are in mid-successional stages; therefore the forest structure is not optimal for many priority bird species (Hunter et al. 1999) and possibly species in other taxa. As forests mature, an optimal age structure is expected to develop; however, management practices that favor a faster transition or provide some of the characteristics of mature forest would benefit many priority species.

The hemlock wooly adelgid (*Adelges tsugae*) threatens to eliminate eastern and Carolina hemlocks from the region's forest over time. Originally confined to the New England states (McClure 1987), this exotic insect pest first appeared in the Southern Appalachians around 2002. Other potentially destructive insects, parasites, and diseases that have been reported from other locations near the Blue Ridge Ecoregion include the Emerald ash borer (*Agrilus planipennis*), gypsy moth (*Lymantria dispar*), dogwood anthracnose disease, and sudden oak death (SOD).

Fire exclusion, which has been the practice since the early 1900s, may be leading to landscape-level changes in forested lands. These changes include the gradual replacement of oak species by less fire-tolerant species in the overstory and the increased dominance of ericaceous plants in the shrub cover (Abella 2002). Concurrently, several studies indicate that early-successional habitat, which provides obligate or optimal habitat for some priority species, may be lacking (Abella 2002; Camp 2004).

At lower elevations and at scattered locations at higher elevations, the region is experiencing a boom in development. This activity is spurred in part by the attraction of nearby mountain scenery which is enhanced by the large public land base protecting the views. If present trends continue, the predominant mix of agricultural lands and woodland existing at lower elevations will be further supplanted by residential and recreational developments. As a consequence of this region-wide shift in land use, the suitability of private land for priority species will change. As the mountains become accessible to more people, recreation pressure will increase, a trend already in progress. Increasing human populations can be expected to lead to increasing numbers of human-wildlife conflicts.

Based on data and analyses of air quality sources within the Southern Appalachian region, concentrations of potentially damaging air pollutants are relatively low along the Blue Ridge, and susceptibility of streams and vegetation to impacts from atmospheric pollution in this region is also relatively low (SAMAB 1996). However, impacts have been reported from other portions of the Southern Appalachians, so this situation should continue to be monitored.

Major recreation resources such as the Foothills Trail and popular state parks such as Table Rock, Mountain Bridge, and Jones Gap, as well as the Jocassee Gorges acquisitions have stimulated demand for recreational access to public lands within the Blue Ridge Escarpment. A new observation tower on Sassafras Mountain is being constructed to encourage visitors to experience the highest point in South Carolina. Although accounts of visitation trends are currently anecdotal, visitation and demand for services is increasing dramatically. The second regional trail to traverse the escarpment, the Palmetto Trail, is also nearing completion and is expected to draw additional interest and traffic to the region. Managing agencies face competing demands for access by users whose interests are not always compatible. Impacts of recreational uses on the resource base vary by intensity and type, posing challenges to meeting resource-based management objectives.

Piedmont Ecoregion

General Overview

The Piedmont Ecoregion occupies a 161 km-wide (100 mile-wide) area between the Southern Blue Ridge Escarpment and the Sandhills Ecoregion. The northwestern boundary is generally considered to be the base of the Blue Ridge Escarpment; the division between the crystalline rocks of the Piedmont and the sedimentary rocks of the Sandhills represents the southeastern boundary of this ecoregion. The Piedmont-Sandhill contact zone is marked in many river channels by shoals and rock ledges that collectively form the "fall line" (as the Piedmont "falls away" into the flatter Coastal Plain). Gently rolling hills with many stream-cut valleys

characterize the region with only a few level floodplains. In the lower Piedmont, there are relatively few sharp breaks in topography except along major river valleys.

To a greater degree than in other regions, the vegetation in the Piedmont has been altered by human activity. Cotton agriculture changed much of the original hardwood and shortleaf pine (*Pinus echinata*) forests into fields. Fields eroded, often losing all topsoil. By the 1930s various factors, including the Great Depression and boll weevil outbreaks, as well as severe erosion led to widespread farmland abandonment in the Piedmont.

Loblolly pine (*Pinus taeda*) was introduced to the Piedmont during the 19th century as a cash lumber crop; this pine now dominates much of the region. According to a US Forest Service survey, loblolly-dominated pine forests occupy over 2 million acres in South Carolina's Piedmont (Conner and Sheffield 2000). Pine plantations are generally poor wildlife habitat, however, lacking in both the food and cover needed by native wildlife.

Although loblolly pine plantations are found throughout the region, they are much more prevalent in some areas, in particular the southwestern Piedmont. By contrast, habitat in the vicinity of York County retains substantial, if fragmented, acreage of hardwood forest. Kings Mountain State Park features a good example of Piedmont upland hardwood forest.

By definition, early-successional habitats have a limited longevity without repeated disturbance. The habitat structure and vegetative composition changes as succession progresses; many wildlife and plant species are adapted to different stages within the early-successional continuum from bare earth through mature forestland. Managing for species dependent upon early-successional habitats presents several management challenges, including the need to identify which successional stage is most appropriate for the species or assemblage of interest, and the need for repeated management actions to maintain suitable habitat.

The extent and quality of early-successional habitats has been greatly dependent upon human land use patterns. While there is some uncertainty as to the extent of early-successional habitats prior to European settlement, it is likely that many early-successional species' populations peaked in the early 1900s with extensive forest clearing and low-intensity agricultural operations. In the second half of the 20th century, the quantity and quality of early-successional habitats diminished due to fire reduction, increasing development, encroachment of exotic vegetation, changing agricultural and forestry practices, and fragmentation of habitat patches into small, isolated units (Cobb et al. 2002; Johnson and Igl 2001; Thompson and DeGraaf 2001; Warner 1994). Populations of many species that depend on these habitats have also declined during this time period (Hunter et al. 2001).

Historically, the Piedmont in York County contained some prairie-type habitats (Barden 1997) with high plant and insect diversity. Around the time of colonization, these Piedmont prairies were maintained through fire and herbivore grazing. Today, remnant tracts of prairie are found primarily along powerline right-of-ways and sites managed specifically for prairie restoration and maintenance.

A considerably smaller portion of forestland is in public ownership in the Piedmont than in the Blue Ridge Ecoregion. The US Forest Service is the primary agent of land protection in the Piedmont with two large Ranger Districts of the Sumter National Forest, the Long Cane and the Enoree, which are located within the region. Actual public ownership within the authorized National Forest boundaries is, however, extremely fragmented. Most of the land in the Piedmont is held by corporate or other private ownerships not associated with the forest product industry (Conner and Sheffield 2000).

Severe soil erosion during the 19th and early 20th centuries has had lasting effects beyond the obvious changes to Piedmont uplands. When large quantities of soil were carried from cotton fields and denuded forests, a portion of the soil was deposited onto Piedmont floodplains (Fox 2000). Today, there is an average of 1.2 m (4 ft.) of surficial sediments, not present prior to European colonization, in the floodplains of most Piedmont streams. Streams typically continue to flow at the original level; therefore, many modern streams are deeply entrenched with one or both banks rising abruptly to about 1.2 m (4 ft.) above the streambed.

Even though agricultural land use practices improved and farming declined during the 20th century, floodplain sediments persisted, overlying former Piedmont wetlands. These wetlands probably featured numerous depressions of swamp tupelo (*Nyssa biflora)* and willow oak (*Quercus phellos)* that served as natural green-tree reservoirs for ducks and other wildlife (Ron Ahle, SCDNR, pers. comm.). Over time, floodplain sediments will be transported downstream as meandering streams erode and re-deposit sediments, but this is a slow process and is hampered, in some cases, by stream channelization.

Land Covertypes

The rolling uplands of the Piedmont landscape are predominantly a mosaic of agricultural land and managed woodland with a history of clearing and economic use that dates back to the earliest times of European settlement. Hardwood-dominated forests occupy relatively narrow floodplains and scattered upland sites, while pine and pine-hardwood forests occupy the majority of forested upland sites. The resulting landscape does not constitute suitable habitat for many area-sensitive wildlife species or for species associated with either early or late-successional conditions. Most of the priority species considered in the SWAP that occur in the Piedmont fall into one or more of these categories. Figure 4-8 defines the covertypes associated with the Piedmont Ecoregion. Species-habitat associations are presented in Appendices 1 A-D while the faunal makeup of the habitats are described in more detail within this chapter (4).

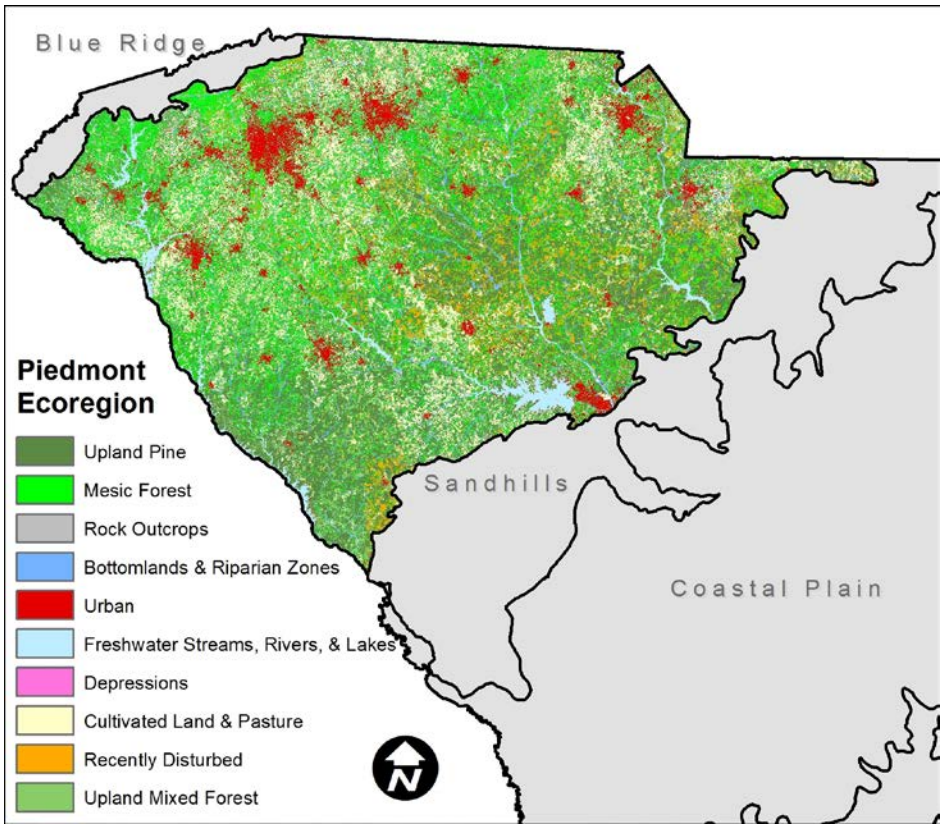


FIGURE 4-8: Land covertypes of the Piedmont Ecoregion.

Upland Pine	Many upland pine forest communities in the Piedmont Ecoregion are artifacts of past or current silvacultural practices. Such monocultural stands of loblolly (*Pinus taeda*) or Virginia pine (*P. virginiana*) are typically characterized by dense, closed canopy forests with little to no understory and low diversity in the herbaceous layer. In contrast, naturally occurring upland pine communities may consist of open, mixed-species stands of loblolly (*P. taeda*), Virginia (*P. virginiana*) and shortleaf pine (*P. echinata*). A sparse canopy layer permits enough light penetration to sustain occasional shrub thickets composed of Blueberries (*Vaccinium*), hawthorns (*Crataegus*) and other woody perennials. Open grassy savannas dominated by big bluestem (*Andropogon*) and little bluestem (*Schizachyrium*) sprawl throughout this landscape and may carry the occasional wild fire.
Mesic Forest	Mesic forests are typically associated with water bodies and natural levies where overflow accumulates during periods of high rainfall. This habitat type may have been more common in the Ecoregion prior to sedimentation from erosion processes during the 'dust bowl' era. This habitat is typically characterized by closed canopy hardwood forests with *Nyssa biflora*, *Acer rubrum*, *Liquidambar styraciflua*, and *Liriodendron tulipifera*. The understory may be dense to sparse but typically composed of smaller tree species and

	infrequently shrubs. Where understory is sparse to absent, a rich herbaceous layer may be found with numerous springtime ephemerals such as *Trillium spp.* and *Arisaema spp.*
Rock Outcrops	Rock outcrops of widely varying sizes and slopes occur throughout the region. Slopes range from nearly horizontal to nearly vertical. The more extensive and exposed outcrops have their own characteristic vegetation and habitat features. Vegetation ranges from none, (bare rock) to a mosaic of herbaceous plant, shrub and tree-dominated communities. Successional trees, such as eastern red cedar (*Juniperus virginiana*) and Virginia pine (*Pinus virginiana*) are common on these sites. Crevices and ledges can only provide habitats for larger plants once sufficient soil has accumulated. Vegetative communities are relatively unstable. A cliff or dome may also have a significant area of wet seepage zones.
River Bottoms *(within Bottomlands & Riparian Zones layer)*	River bottoms or "bottomland forests" consist of hardwood-dominated woodlands with moist soils that are usually associated with major river floodplains. Characteristic tree species include sweetgum (*Liquidambar styraciflua*), loblolly pine (*Pinus taeda*), water oak (*Quercus nigra*), willow oak (*Quercus phellos*), laurel oak (*Quercus laurifolia*), cherrybark oak (*Quercus pagoda*), and American holly (*Ilex opaca*). A subtype dominated by bald cypress (*Taxodium distichium*) and water tupelo (*Nyssa aquatica*) occurs on lower elevation sites, but is not as prevalent as in the broader floodplains of the coastal plain. Compared to the coastal plain, the floodplains of major rivers in the Piedmont are confined by topography to relatively narrow corridors.
Piedmont Small Stream Forest *(within Bottomlands & Riparian Zones layer)*	Piedmont small stream forests are distinguished from forest communities on larger floodplains because of differences between the scales of the ecosystems. In smaller floodplains, the levees, sloughs, and ridges are largely absent or poorly developed. Flooding regime is also more variable between small watersheds than larger ones. Soils are various alluvial types that are seasonally or intermittently flooded. The forest has an open to dense understory or shrub layer and a sparse to dense herb layer. The canopy has a mixture of bottomland and mesophytic trees including river birch (*Betula nigra*), sycamore (*Platanus occidentalis*), sweetgum (*Liquidambar styraciflua*), tulip poplar (*Liriodendron tulipifera*), American elm (*Ulmus americana*), hackberry (*Celtis laevigata*), green ash (*Fraxinus pennsylvanica*), and red maple (*Acer rubrum*).
Cove Forest *(within Bottomlands &*	Cove forests are botanically diverse, well-developed hardwood forests occurring on scattered rich, and generally small, sites (less than 81 ha or 200 ac.). These forests usually occur on protected bluffs

Riparian Zones layer)	in association with small stream forests or river bottoms. No single species tends to dominate. Shrub species are usually numerous and the herbaceous flora is fairly rich, with many spring ephemerals. The canopy and understory are composed of hardwoods including beech (*Fagus grandifolia*), tulip poplar (*Liriodendron tulipifera*), black gum (*Nyssa sylvatica*), sourwood (*Oxydendrum arboreum*), white oak (*Quercus alba*), northern red oak (*Q. rubra*), black oak (*Q. velutina*), sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), southern sugar maple (*A. saccharum*), basswood (*Tilia heterophylla*), ironwood (*Carpinus caroliniana*), flowering dogwood (*Cornus florida*), American holly (*Ilex opaca),* witch-hazel (*Hamamelis virginiana)* and hop-hornbeam (*Ostrya virginiana*).
Depressions	While Piedmont depressions, or high ponds, may occasionally be referred to as Carolina bays, they do not necessarily share the same geological history and may play host to an entirely different vegetative community. Often characterized by perched water tables over clay basins, high ponds are usually dependent on rainfall and may be associated with an out-flowing stream channel during periods of heavy precipitation. Frequently converted for agricultural purposes, these fishless waters play an important role in the reproductive cycle of many pond breeding amphibians. Their relative isolation also tends to coincide with specialized emergent plant communities which may include uncommon herbaceous species such as Harperella (*Ptilimnium nodosum*) and *Coreopsis rosea*.
Upland Mixed Forest	Occurring throughout the State but most characteristic of rolling uplands in the Piedmont, oak-hickory forest is a widely distributed community that varies from site to site. Occurring in highly fragmented stands, later successional stages tend to be made up of a diverse assemblage of hardwoods, primarily oaks and hickories, as co-dominants in combination with pines. Understory, shrub and herbaceous layers are present in varying degrees, represented by diverse woody and non-woody species. Vegetation on most sites consists of early- to mid-successional managed stands of pine and pine-hardwood forest. The understory in pure pine stands is often open, but in mixed or older stands, it is dominated by the hardwoods characteristic of the site. Common pine species of the Piedmont include shortleaf (*Pinus echinata*) and loblolly (*P. taeda*), with the former better adapted to dry, fine textured upland soils and loblolly achieving maximum growth on deep soils with good moisture and drainage.
Grassland and Early-Successional Habitats	As in other ecoregions, a variety of grassland and early-successional habitats are present, either as transitional vegetation following forest disturbances or as managed areas. Early-successional habitats are

(specialized habitat not mapped at this scale)	generally characterized by tree canopy coverage that is sparse or absent and herbaceous groundcover comprised of annual forbs, perennial bunchgrasses, and variable coverage of shrubs and small trees. A variety of open land covertypes represents this category and can include native prairies, savannas, old field sites, open canopy gaps, shrub-scrub thickets, recently-cleared forests, field borders, grassed waterways, and filter strips. Lawns, golf courses, pastures, hay fields, crop fields, airports and various urban open spaces are sometimes included in this habitat type but lack the floristic and structural diversity to be considered high quality, early-successional habitat (see Cultivated Land and Pasture). Minor modifications to agricultural land use, such as replacing introduced grasses with native grasses, using native grasses in filter strips and grassed waterways, and implementing no-till or strip-till in crop fields can result in dramatic improvements to quality of early-successional habitat. Maintenance of early-successional habitat requires periodic repeated disturbance or disruption of the existing vegetative community. Purposeful management of early-successional habitat is usually accomplished through the use of timber harvest, prescribed burning, disking, or mowing. Target species for management will determine disturbance intervals, with shorter intervals (1-2 years) favoring those species dependent on herbaceous vegetation and longer intervals (3-5 years) favoring those species dependent on shrub cover. Optimal multi-species management often dictates concurrent maintenance of variety of successional, or seral, stages. Early-successional habitat types have declined dramatically over the past 70 years primarily due to changing agricultural practices, forest succession, fire suppression, and urban / suburban encroachment. A large portion of existing early-successional habitat occurs on privately owned lands. One of the greatest challenges to maintaining priority species associated with this particular land cover is private land outreach and technical assistance.

Freshwater Streams, Lakes, and Ponds

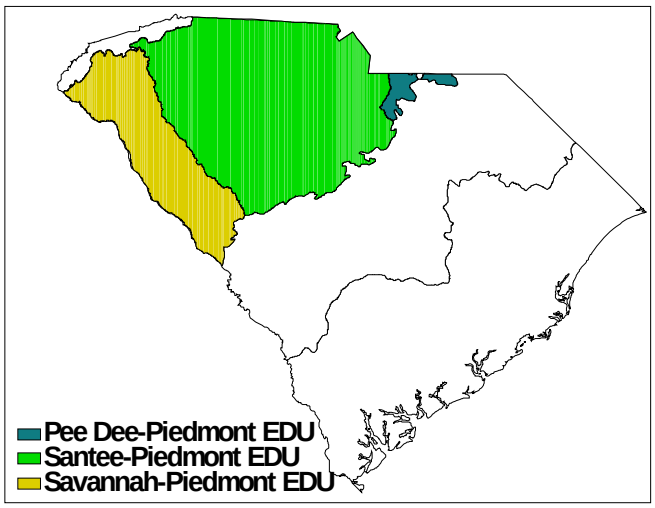


FIGURE 4-9: Drainages of the Piedmont Ecoregion

The Piedmont Ecoregion extends south of the Blue Ridge to the Fall Line near Columbia, South Carolina and from the Savannah River east to the Pee Dee River. Encompassing 24 counties and 27,941 km^2 (10,788 $mi.^2$), the Piedmont is the largest physiographic province in South Carolina. The Piedmont is an area with gently rolling hills dissected by narrow stream and river valleys. Forests, farms and orchards dominate most of the land. Elevations range from 114 to 305 m (375 to 1,000 ft.). Freshwaters in the Piedmont Ecoregion total approximately km 17,703 km (11,000 mi.) of streams and rivers with over 777 km^2 (300 $mi.^2$) of major impoundments. By length, first- through fourth-order (wadeable) streams comprise the primary aquatic habitat type. At higher elevations, Piedmont streams may exhibit moderate gradient with coarse substrates including cobble, gravel, and bedrock. Lower elevation Piedmont streams generally have less gradient with substrates primarily consisting of sand, gravel, and silt. Piedmont streams are typified by long runs of intermediate depth separated by shallow riffles and deeper pools. The Piedmont Ecoregion cuts across the top of 3 major South Carolina drainages, the Savannah, the Santee, and the Pee Dee, forming 3 ecobasins: the Savannah-Piedmont, Santee-Piedmont and Pee Dee-Piedmont.

In the not too distant past, forests and farms dominated the land cover in the Piedmont Ecoregion. However, the vast majority of Piedmont forests were cleared at some point during the last two centuries to develop crop and pasture lands. Most Piedmont streams are now heavily silted due to the agricultural development of the Piedmont's modest slopes and highly erodible soils.

Wadeable streams are the dominant habitat in the Piedmont and are defined as those with Strahler stream orders of 0 to 3; they are generally comfortably wadeable throughout most of the year. Wadeable streams in the Piedmont posses different characteristics based chiefly on their gradient. Streams in the Inner Piedmont (just below the Blue Ridge) typically have moderate gradients with clear to moderately turbid water. Substrates in those streams are generally sand, gravel, and coble with boulders and exposed bedrock occurring less frequently. These streams contain a variety of habitats including frequent long stretches of riffles and runs separated by short sections of pools and glides. As one moves south and east through the Outer Piedmont toward the Fall Line, wadeable streams have less gradient; runs and riffles become less frequent and shorter in length, while slow-flowing pools comprise the majority of habitat. Outer Piedmont streams are generally turbid, carrying a heavy sediment load from both historic and current conversion of forested land to agriculture and silviculture. These streams have substrates of mostly sand, silt, clay, and detritus.

Navigable streams are common in the Piedmont Ecoregion and include large rivers like the Savannah River, Saluda River, Broad River, and Catawba River, as well as smaller rivers like the

Reedy River, Enoree River, and Fishing Creek. These streams are generally defined as being large enough to operate watercraft, if only a canoe, and are generally too deep to be waded throughout most of the year. These larger streams are more productive than their smaller counterparts and typically carry a heavy sediment burden. Substrates are typically sand, clay, and detritus, although the high gradient areas produce shoals and riffles that contain gravel, cobble and, occasionally, exposed bedrock and boulders. All of the large rivers (Savannah, Saluda, Broad, and Catawba) and many of the smaller rivers (Reedy, Enoree, and Tyger) have been impounded somewhere along their course. These impoundments have forever altered the natural hydrographs of these rivers and the habitats they contain.

Savannah-Piedmont Ecobasin

The Savannah River drainage originates in the mountains of North Carolina and Georgia. The Savannah River flows southeast along the border of South Carolina and Georgia through the Piedmont for approximately 211 km (131 mi.) on its way to the Atlantic Ocean. Major tributaries to the Savannah River in the South Carolina portion of this ecobasin include the Tugaloo River, Seneca River, Chauga River, Rocky River, Little River and Stevens Creek.

The ecobasin encompasses 36 watersheds and approximately 7,457 km^2 (2,879 $mi.^2$). The ecobasin contains 5,356 km (3,328 mi.) of lotic habitat with 370 km^2 (143 $mi.^2$) of impoundments. Most of the impounded water occurs in 4 large reservoirs: Lake Keowee (6,884 ha or 17,010 ac.), and the South Carolina portions of Lake Hartwell (35,187 ha or 35,187 ac.), Lake Russell (6,154 ha or 15,207 ac.), and Thurmond Reservoir (8,619 ha or 21,297 ac.).

Primary conservation targets within the ecobasin include the Stevens Creek watershed in Greenwood and McCormick Counties, the Turkey Creek watershed in Edgefield County and the main stem Savannah River in Edgefield and Aiken Counties (Smith et al. 2002). The Stevens Creek and Turkey Creek watersheds are home to several mussels on South Carolina's Priority Species List including the brook floater, yellow lampmussel, creeper and the federally endangered Carolina heelsplitter. At least 13 priority fish species are also found in this ecobasin, including the Christmas darter, Savannah darter and turquoise darter. The main stem of the Savannah River in Edgefield and Aiken Counties is home to the Robust Redhorse and federally endangered Shortnose Sturgeon as well as several other priority fish species. Several priority mussel species (barrel floater, pod lance, Roanoke slabshell, yellow lampmussel, rayed pink fatmucket, and Savannah lilliput) are also found in the main stem Savannah River.

Water quality in this ecobasin was designated as impaired at 65 of 138 sites (47%) sampled by SCDHEC in 2003. Recreational uses were not supported at 30 sites due to the presence of fecal coliform bacteria. Aquatic life uses were not supported at 28 sites due to copper contamination, paucity of aquatic fauna, low dissolved oxygen concentrations, or abnormal pH values. Fish consumption advisories have been listed for 7 sites including Lake Hartwell, Lake Jocassee, Lake Russell, and the Chauga River (SCDHEC 2003a). Fish consumption advisories are due to mercury and PCB contamination.

Approximately 735 km (457 mi.) of streams within the Savannah-Piedmont Ecobasin have been impounded. Seven dams have been erected on navigable streams to form large impoundments,

and 210 smaller dams have impounded smaller streams (small reservoirs and farm ponds). Approximately 177 km (110 mi.) of the 211 km (131 mi.) of the Savannah River that occur within the ecobasin have been impounded by main stem reservoirs including Lake Hartwell, Lake Russell, and Thurmond Reservoir. The Stevens Creek hydroelectric dam on the Savannah River represents an impediment to diadromous fish movement within the Basin. Notable species affected include Striped Bass, American Shad, Blueback Herring, and American Eels. Passage is needed to accommodate both upstream migration of adults and outmigration of adult and juvenile fishes. Priority mussel species will also benefit from fish passage, as fish are a dispersal mechanism for mussels.

Excessive inputs of nutrients and other chemicals also degrade water quality. There are 128 active discharges permitted by SCDHEC within the ecobasin (SCDHEC 2003a). Of those, the majority (70 discharges) are industrial, while the remainder are from municipal (31 discharges) and community sources (27 discharges). CAFOs also add non-point source pollution. There are 120 agricultural facilities permitted by SCDHEC within the ecobasin, the majority of which are poultry operations (8 small farms, 54 medium farms, and 27 large farms). The remaining facilities include dairy farms (16 small and 1 medium operation), and 8 small swine farms. On a statewide basis the amount of agricultural activity within the ecobasin is moderate (just over 4agricultural operations per 259 km^2 (100 $mi.^2$) which probably doesn't significantly threaten water quality throughout the ecobasin. However, within the Tugaloo River/Lake Hartwell watershed there are many agricultural facilities (55, or approximately 41 per 259 km^2 or 100 square miles). These are primarily poultry operations that may significantly impact water quality within the watershed. Other agricultural operations such as row crops (corn and wheat) and pastureland also contribute to non-point source pollution of sediments and nutrients.

Poorly planned industrial, residential, and commercial development has resulted in significant negative impacts to aquatic resources within the ecobasin. Overall, a moderate amount of industrial, residential, and commercial growth can be expected for the ecobasin (SCDHEC 2003). Moderate to high levels of growth are expected in the upper third of the ecobasin along the I-85 corridor. Areas likely to experience high growth include Clemson, Easley, and Anderson. Growth in the lower portion of the ecobasin will be slower because the Sumter National Forest encompasses much of the land, limiting development opportunities.

The Stevens Creek watershed in Edgefield, McCormick, and Greenwood Counties is known to be a unique aquatic resource. Priority fish species such as the Christmas darter and imperiled mussels such as the Carolina heelsplitter reside in streams of this watershed. Tributaries such as Hard Labor Creek drain the region around metropolitan Greenwood, South Carolina. This is an area of rapid urban growth and increased human population. Impacts to the watershed from point and non-point sources can have a degrading effect on the aquatic community downstream.

Santee-Piedmont Ecobasin

The upper Santee River drainage originates mostly in the south central Piedmont of North Carolina, but receives some input from the mountains of South Carolina and North Carolina through the Saluda and Catawba River systems, respectively. The Broad River and Catawba-Wateree Rivers are the dominant rivers in this ecobasin. The Broad River flows nearly directly

south from North Carolina to Columbia, South Carolina where it merges with the Saluda River at the fall line to form the Congaree River. As the Broad River flows south, it picks up inputs from the Pacolet River, Tyger River, and Enoree River along the western portion of the drainage and Kings Creek, Turkey Creek, Sandy River, and Cedar Creek from the eastern portion of the drainage. The Catawba River originates on the eastern slope of the Blue Ridge in North Carolina and flows through the Inner Piedmont and Charlotte, North Carolina before entering South Carolina. The Catawba flows south through South Carolina until it is impounded to form Lake Wateree and thereafter is known as the Wateree River. The Wateree River continues to flow south through the Southeastern Plains until it merges with the Congaree River to from the Santee River.

The Santee-Piedmont Ecobasin is the largest in the State, containing part or all of 84 watersheds and encompassing 19,694 km^2 (7,604 $mi.^2$). The ecobasin contains approximately 18,547 km^2 (7,161 mi.) of stream habitat and nearly 414 km^2 (160 $mi.^2$) of impoundments. Most of the impounded area (329 km^2 or 127 $mi.^2$) is the result of five large reservoirs, including Lake Greenwood (4,029 ha or 9,957ac.) and Lake Murray (19,594 ha or 48,417 ac.) on the Saluda River, Monticello Reservoir (2,689 ha or 6,644 ac.) on the Broad River, and Lake Wylie (2,051 ha or 5,067 ac.) and Wateree Lake (4,608 ha or 11,386 ac.) on the Catawba-Wateree River.

The Santee-Piedmont Ecobasin contains several areas of conservation priority (Smith et al. 2002). Conservation targets that contain rare, threatened, and endemic species include: the Saluda River headwaters, which encompass the North Saluda River, South Saluda River and Oolenoy River watersheds located in the Inner Piedmont of Greenville and Pickens Counties; the Clouds Creek watershed in the Slate Belt Ecoregion in Saluda County; the main stem of the Broad River from the North Carolina line to Parr Shoals Reservoir in South Carolina; the Kings Creek watershed and the Clarks Fork system in the Bullocks Creek watershed located primarily in the Kings Mountain area in Cherokee and York Counties; the Six Mile Creek and Waxhaw Creek systems in the Twelve Mile Creek watershed in Lancaster County; the Gills Creek system in the Camp Creek watershed in Lancaster County; and the Wateree Creek watershed in Richland County. The Saluda River headwaters contain populations of priority fish species including turquoise darter and Carolina fantail darter. The Clouds Creek watershed contains populations of the priority fish species the Carolina darter (formerly Saluda darter) as well as at least one priority mussel species, the Savannah lilliput. The main stem of the Broad River contains priority fish species including several catostomids (Notchlip Redhorse, V-lip Redhorse, Quillback, and Highfin Carpsucker) and percids (Seagreen Darter, Carolina Fantail Darter, and Piedmont Darter). The Kings Creek watershed and Clarks Fork system contain several priority fish species including the Carolina Fantail Darter, the Seagreen Darter, and the Piedmont Darter. The Six Mile Creek and Waxhaw Creek systems contain several priority mussel species including the notched rainbow, Carolina creekshell and the federally endangered Carolina heelsplitter. The Gills Creek system also contains Carolina creekshell and Carolina heelsplitter. The Wateree Creek watershed contains several priority fish species including the Carolina Darter, the Piedmont Darter, and the Seagreen Darter.

Water quality was impaired at 279 of 468 locations (59%) sampled by SCDHEC (SCDHEC 1998a; SCDHEC 1999a; SCDHEC 2001). Recreational uses were not supported at 151 sites due to the presence of high concentrations of fecal coliform bacteria. Aquatic life uses were not

supported at 125 sites primarily due to a lack of invertebrate fauna, low pH, low dissolved oxygen concentrations, or copper contamination. Fish consumption advisories due to mercury contamination have been issued for the Wateree River below Wateree Dam to its confluence with the Congaree River, and the Saluda River from Pelzer to the Congaree River in Columbia. Only approximately 18 km or 11 river miles have been designated as Outstanding Resource Waters by SCDHEC.

Nearly 805 km (500 mi.) of streams within this ecobasin have been impounded. Roughly 50 dams have been constructed on navigable streams during the last two centuries, and nearly 700 smaller impoundments (small reservoirs and farm ponds) pepper the landscape, disrupting and fragmenting smaller streams. The Lake Murray Dam, which impounds the Saluda River to form Lake Murray, has degraded aquatic habitat in the Saluda River below the dam.

Excessive nutrient and other chemical inputs also degrade water quality within the ecobasin. There are 454 point source contributors permitted by SCDHEC within the ecobasin (SCDHEC 1998a; SCDHEC 1999a; SCDHEC 2001). Of those, 261 are associated with industry, 119 are associated with municipalities, and the remainder are associated with community discharges. Saluda River studies conducted by Hayes and Penny (2002) implicated the Ware Shoals Waste Treatment Plant (WTP) as having a depressing effect on the downstream fish community. The study indicated that species richness and abundance were reduced in the stretch of river between Ware Shoals and Lake Greenwood. CAFOs are abundant in the ecobasin as well, with 245 facilities permitted by SCDHEC (SCDHEC 1998a; SCDHEC 1999a; SCDHEC 2001). Agricultural facilities throughout the ecobasin are relatively sparse in most areas, and on a statewide basis there is only a moderate amount of agricultural activity with approximately 3 facilities per 259 km^2 (100 $mi.^2$). However, in the upper Lake Murray area, including the Clouds Creek, Little Saluda River and Bush River watersheds, there is significant agricultural activity (86 sites) with nearly 14 agricultural facilities per 259 km^2 (100 $mi.^2$).

The Saluda River Basin drains much of the Greenville-Spartanburg metropolitan area. The rapidly increasing population and accompanying development have led to significant urban sprawl and resulted in associated aquatic impacts such as stormwater runoff, non-point source chemical inputs, and stream channel alterations. Although improvements in municipal waste treatment have occurred in this area, point source pollutants add unnatural coloration and increase nutrient levels that sometimes lead to noxious algal blooms downstream in Lake Greenwood (SCDNR, unpublished data).

The I-85 corridor from Anderson, South Carolina to Charlotte, North Carolina is one of the most rapidly developing areas of the State. Impacts of road construction, residential and commercial development, and general urban sprawl have been felt in most of the major river systems (Saluda, Reed, Pacolet, Enoree, Tyger, and Broad Rivers) in this area. Water quality degradation and stream channel alteration are probably the most obvious impacts to these aquatic systems.

Pee Dee-Piedmont Ecobasin

The South Carolina Piedmont portion of the Pee Dee drainage originates just across the state line in North Carolina. The Pee Dee–Piedmont Ecobasin is the second smallest ecobasin in the state,

encompassing only 715 km^2 (276 $mi.^2$). Tributaries to the Pee Dee River included in the ecobasin are Lynches River and Thompson Creek. There are approximately 753 km (468 mi.) of stream habitat within the ecobasin and only 136 ha (337 ac.) of impounded water.

The majority of the ecobasin is a primary conservation target, including the Lynches River, Flat Creek, and Little Lynches River systems in the upper Lynches River basin located in Lancaster and Chesterfield Counties. Also, the Thompson Creek system in the upper Pee Dee basin in Chesterfield County is a high priority. Several priority fish species occur in the upper Lynches River basin, including the "Thinlip" Chub, Sandhills Chub, and "Broadtail" Madtom. In addition to those fish species, several priority mussel species populate the basin including, the brook floater, creeper, notched rainbow, and the Federally Endangered Carolina heelsplitter. The Thompson Creek system contains several priority fish species—"Thinlip"Chub, Sandhills Chub, Fantail Darter, and Piedmont Darter—as well as several species whose populations in South Carolina are entirely restricted to that system such as the Satinfin Shiner, Redlip Shiner, and Comely Shiner.

SCDHEC sampled the ecobasin in 2000 and found that water quality was impaired at 15 of 25 sites (60%), representing one of the highest ratios of impairment within the State. Recreational uses were not supported at 6 sites due to the presence of high concentrations of fecal coliform bacteria. Aquatic life uses were not supported at 9 additional sites due to lack of aquatic invertebrate diversity, low dissolved oxygen, copper contamination, or high turbidity (SCDHEC 2000).

Impoundments do not currently pose a great threat to aquatic fauna in the Pee Dee-Piedmont ecobasin. There are only 15 dams permitted by SCDHEC within the ecobasin and only 10 km (6 mi.) of impounded streams, none of which are navigable.

As with most ecobasins, especially in the Piedmont Ecoregion, erosion and sedimentation have substantially degraded aquatic habitat. Ground disturbance from development activities, agriculture and silviculture are primary sources of erosion that lead to sedimentation in Piedmont streams. In the Pee Dee-Piedmont ecobasin, more than 25% of the land within the ecobasin is agricultural, which may contribute significantly to stream sedimentation.

Excessive nutrient and other chemical inputs may degrade water quality within the ecobasin. There are 9 active point source discharges permitted by SCDHEC (2000) within the ecoregion including, 2 industrial and 4 municipal (e.g. waste water treatment plant) discharges. With 35 CAFOs, the ecobasin has the highest density of CAFOs in the State at nearly 13 per 259 km^2 (100 $mi.^2$). Most of the CAFOs are turkey (22) and poultry (12) farms. In addition to the CAFOs, other agricultural operations (row crops and pastureland) may significantly impact water quality within the ecobasin.

There is low to moderate potential for growth within the ecobasin (SCDHEC 2000). The greatest potential for development occurs in the northwestern portion of the ecobasin which is part of the Charlotte Metroplex. Future development will pose new threats to aquatic habitats and biota, particularly if those developments are not carefully planned.

Region-wide Challenges

The primary factor influencing habitat quality and quantity in the Piedmont is urban sprawl. Since World War II, population growth in the Piedmont has been rapid, outpacing growth in the United States as a whole. Migration from other regions of the United States as well as international immigration has fueled this growth. Both population growth and the land use patterns that have accompanied it have contributed to sprawl (Rusk 2003). Table 4-3 compares urbanization patterns in some of the Piedmont's major cities.

Table 4-3: A comparison of urban sprawl in the Piedmont Ecoregion

Urbanized Area	**Urbanized Acreage Per New Resident**
USA (396 areas)	0.18
Spartanburg	0.88
Greenville	0.93
Anderson	0.99
Rock Hill	1.01

Low-density development contributes to habitat fragmentation which impacts many fish and wildlife species. In the Piedmont, development has been particularly rapid in association with the interstate highway system. Habitat fragmentation also hinders the use of prescribed fire. Therefore, most of the priority species associated with fire-dependent communities decline as development encroaches. While most birds can rapidly find and colonize early-successional habitat patches, some bird species—grassland birds in particular—are area sensitive and will not use small patches of habitat surrounded by forest or developed areas. The Northern Bobwhite may require large areas of contiguous habitat (greater than 2,023 ha or 5,000 ac.) for long-term population viability (Guthery et al. 2000). The isolation of suitable early-successional habitats may be most problematic for mammals, reptiles, and amphibians that have limited dispersal ability and may suffer high mortality when traveling through unsuitable habitats.

Concerns about liability, air quality, social acceptance, and smoke management, as well as the lack of landowners with experience and equipment to conduct prescribed burns, has limited the use of fire on private lands. Similar to the coastal regions, fire was once an important natural feature of the Piedmont (Frost 1998). Pre-settlement oak-hickory forests experienced surface fires that were frequent, of low intensity, and that were sustained by fine grass, pine needles and hardwood litter. An absence of fire leads to forest stands dominated by fire-intolerant species such as maple, beech, and sweet gum. The pre-settlement mean fire return interval was 4 to 6 years in many parts of the Piedmont, while in certain places, fires burned almost every year. Early European explorers described small, open prairies on the upper Piedmont maintained by annual fall burns conducted by Native Americans.

Piedmont prairies contain highly diverse and specialized plant and insect communities, and only small remnant tracts remain in South Carolina. Fire and/or other low-intensity soil disturbances, such as light disking at the proper time of year, are necessary for the maintenance of prairie communities. Current restoration efforts are focused on plant

conservation and have been implemented on small acreages that have limited value for area-sensitive grassland species such as the Grasshopper Sparrow and the Eastern Meadowlark.

Challenges to conservation of aquatic fauna in these three ecobasins are similar to other ecobasins in the State and primarily include impacts associated with impoundments, non-point source pollution, point source pollution, poorly planned development, and introductions of non-native species.

Impacts from hydropower development have substantially altered and degraded a significant portion of habitat for most native aquatic species. Nearly 1,561 km (970 mi.) of streams within the ecoregion have been impounded. Roughly 57 dams have been constructed on navigable streams during the last two centuries, and more than 900 smaller impoundments, including farm ponds, pepper the landscape, disrupting and fragmenting smaller streams. Dams result in a loss of connectivity and negatively affect aquatic biota both above and below the impoundment (Doeg and Koehn 1994; Kanehl et al. 1997; Tiemann et al. 2004) through direct loss of habitat as lotic habitat is converted to lentic habitat. This favors competitive, and often predacious, species including Largemouth Bass and other centrarchids. In addition to direct loss of habitat, impoundments often impact the unimpounded stream reaches downstream through altered hydrologic and thermal regimes (Cushman 1985), modified stream channel morphology, and increased erosion and sedimentation (Watters 1996); all of which ultimately reduce suitable habitat for native aquatic fauna (Helfrich et al. 1999; Tiemann et al. 2004). Impoundments on the Savannah River, Saluda River, Broad River and Catawba-Wateree River have disrupted the historic migrations of anadromous species (American Shad and Striped Bass) that once represented culturally and economically important fisheries. Fish passage is also critical in allowing the dispersal of mussels, since larval mussels are parasitic on the gills of host fishes and are dispersed by the fish prior to settlement.

Although a large portion of the ecoregion is currently forested, most of the forests were cleared at some point during the last two centuries to develop crop and pasture lands. Forest and tilling of the Piedmont's highly erodible soils has resulted in streams that are still heavily silted. Modern soil conservation practices, such as the creation of Streamside Management Zones (SMZs), have reduced those impacts, but sedimentation from non-point and point sources remains a significant detriment to Piedmont streams today. Farmers that have neglected to implement soil conservation practices further compound sedimentation problems in Piedmont streams. Ground disturbance from development activities, agriculture, and silviculture are primary sources of erosion that lead to sedimentation in Piedmont streams. Corporate and private timber managers that fail to follow Best Management Practices (BMPs) further contribute significant siltation and other non-point source pollution within the ecoregion. Streambank erosion due to loss of riparian areas, livestock grazing, and altered hydrology also contribute to sedimentation in Piedmont streams.

Excessive nutrients and other chemical contamination also negatively affect water quality in the ecoregion. Point source discharges from industrial, municipal, and community sources add nutrients and other pollutants to the receiving streams, rivers and lakes. In addition to those sources of pollution, agricultural operations also impact water quality. Nationwide, pollution

from agricultural sources is the greatest impairment to streams and lakes (SCDHEC 2003a). The Piedmont has the highest density of permitted discharges within the State and the second highest density of concentrated animal feeding operations (CAFOs) with nearly 5 agricultural operations per 259 km^2 (100 $mi.^2$). Water quality in the Piedmont was impaired at 57% of the sites sampled by the SCDHEC (1998a, 199a, 2000, 2001, 2003a), which is the second highest impairment rate among the four aquatic ecoregions in the State. Recreational uses were impaired at nearly 30% of the sites sampled due to the presence of high concentrations of fecal coliform bacteria. Fecal coliform bacteria are present in the digestive tract of warm-blooded animals; although fecal coliform bacteria are not generally harmful to humans, they do indicate that surface waters may contain disease-causing pathogens (SCDHEC 1998a, 1999a, 2000, 2001, 2003a). More than one quarter of the streams sampled by SCDHEC within the ecoregion did not support aquatic life uses. Those stream sites do not possess sufficient water quality to maintain a balanced aquatic community of plants and animals.

Introductions of non-native fish species may threaten native aquatic fauna in the Piedmont. Smallmouth Bass, Spotted Bass, Muskellunge, Flathead Catfish, and Blue Catfish are established in portions of the ecoregion. The effects of these introduced species on native game and nongame species is not currently well known. Flathead Catfish introductions into the Savannah River, Saluda River, and Catawba River Basins as well as Blue Catfish introductions into the Savannah River, Broad River, and Catawba River Basins likely pose the greatest risks to native fauna. Flathead Catfish have been shown to prey on bullheads, darters, shad, suckers, and sunfish. Severe declines in native species, particularly bullheads and sunfish, have been observed after the introductions of Flathead Catfish (Guire et al. 1984; Jenkins and Burkhead 1993; Bart et al. 1994). The introduced Spotted Bass and Smallmouth Bass in the Savannah River and its tributaries threaten the native Redeye Bass through competition and hybridization.

Introduction of nonnative invertebrates also pose a threat to the native fauna. The Asian clam, *Corbicula fluminea*, has been introduced and has spread throughout the United States, including into South Carolina. The effects of *Corbicula* on native species are not well understood. A review of the literature on the interactions between *Corbicula* and native mussels (Dillon 2000) indicated that most field studies failed to find any significant negative effects on native species, although a few detected reductions in growth of mussels. The red swamp crayfish has been introduced to South Carolina as well and has been observed at several locations in the Coastal Plain, but has yet to be identified in the Piedmont. However, there have been very few crayfish inventories conducted, none of which have been initiated on a statewide basis. In North Carolina, the red swamp crayfish has become established in all drainages of the Coastal Plain and Eastern Piedmont Plateau and appears to have extirpated all the native crayfish at one location (Cooper 2003). Introduced crayfish are believed to be the biggest threat to native crayfish species (Lodge et al. 2000 a,b), and the risk to our native species is great if further introductions or if extensive spread of nonnative crayfish occurs.

Rapid development in the Piedmont, especially in the Upstate, has included substantial highway construction. The requirement for sand in road construction has resulted in sand mining operations in the main stem or riparian areas of many Piedmont rivers and streams. Sand mining not only causes bank stability problems and loss of riparian areas at the mining site but instream impacts as well. Mining operations affect physical and chemical habitat and can negatively affect

biological communities (Nelson 1993) and recreational uses (Hartfield 1993). Physical impacts on instream habitat include increasing bedload materials and turbidity, changing substrate type and stability, and altering stream morphology (Nelson 1993). Physical habitat alterations associated with sand mining can adversely affect the biological community by decreasing reproduction and survival of fishes (Stuart 1953; Newport and Moyer 1974) and distribution and composition of other aquatic organisms (Buck 1956; Trautman 1957; Newport and Moyer 1974).

Sandhills Ecoregion

General Overview

The Sandhills Ecoregion is the inland portion of the Coastal Plain that borders the Fall Line. This ecoregion is frequently recognized as a physiographic province distinct from the Coastal Plain, although some researchers incorporate the Sandhills within a broader area known as the "Inner Coastal Plain." The Sandhills form a discontinuous belt of varying width of deep sands across the middle of the State (Porcher and Rayner 2001).

Pliocene and Pleistocene sands deposited up to 10 million years ago by strong southwest prevailing winds form the top layer of the Sandhills (Murray 1995). These sands are a very pure and high quality source of silica; they are mined throughout the Sandhills, especially in Lexington County (Murray 1995). These deep sands have created a xeric environment that supports a distinctive type of vegetation dominated by longleaf pines (*Pinus palustris*) and turkey oaks (*Quercus laevis*). This fire-adapted community burns with a frequency interval of 5 to 10 years and may be one of the oldest communities of this type in the Southeastern United States (Wharton 1978).

Compared to the adjoining Piedmont Ecoregion and Upper Coastal Plain, upland forest cover in the Sandhills Ecoregion is relatively unbroken. However, numerous cycles of pine removals and exclusion of fire have left a vast, rather monotonous forest cover over much of the landscape, consisting of small longleaf pines, turkey oak, and other scrub oak species. Forest in this condition is not suitable habitat for South Carolina's priority species. Indeed, the prevalence of forest in this condition is a primary source of concern for many of these priority species.

Considerable effort is being made by the forestry community and other conservation groups to encourage the production of saw timber-size longleaf pines and a more liberal application of fire. Historically, slash pine was planted approximately 161 m (100 mi.) north of its natural range on many thousands of acres in the Sandhills region but over the last few decades, public and private landowners have been replacing it with longleaf pine. Much of our knowledge base concerning longleaf pine planting is from the SC Forestry Commission based on methods utilized on Sandhills State Forest. This knowledge has greatly impacted longleaf pine restoration across all of its range. Longleaf pine seedlings and technical guidance for establishing longleaf stands are also becoming increasingly available.

Significant public land holdings in the Sandhills Ecoregion include: the US Army installation at Fort Jackson and the Army National Guard Leesburg Training Site; the Sandhills National Wildlife Refuge; Sandhills State Forest; major portions of the Savannah River Site; and

Hitchcock Woods (operated by a private foundation). Although the impetus for conservation-oriented management on many of these facilities stems from the listing status of the Red-cockaded Woodpecker (RCW), the intended future condition of many forested tracts on these lands is a longleaf pine-wiregrass community, with a significant portion of longleaf pine stands reaching older age classes.

Impoundments have been constructed in Sandhills streams for many centuries. In the 18th and 19th centuries, these were built to provide power and water for gristmills, and indeed most of these old mill ponds are still in existence. As agriculture continued to expand in the Sandhills Ecoregion, farm ponds were constructed to provide irrigation for agricultural fields. The number of small impoundments in blackwater streams increased dramatically during the 1960s and 1970s (Melven pers. comm.), and this trend continued through to the end of the century. There were approximately 1,100 farm ponds in Lexington County as of 1970 (Lawrence 1976) and there are now more than 4,000 (Deaderick pers. comm.). In a study of the Edisto River Basin, most of the wetland alterations documented in the North and South Forks of the Edisto River were found to have occurred in the headwater streams where the relatively steep and narrow valleys in the Sandhills represent favorable farm pond sites. Very few headwater streams in the Edisto Basin were found without impoundments (Marshall 1993).

Land Covertypes

Although xeric sandy soils predominate, the rolling terrain and variations in soil and subsoil composition provide significant local variation in habitat composition. The principal habitat of this ecoregion is Sandhills pine woodland, with local structure and composition influenced mainly by fire history. Fire is a dominant factor in the ecology of this region. Sandhills pine forests are a fire climax community; as such, these forests are dependent on frequent ground fires to reduce hardwood competition and to perpetuate pines and grasses.

Deep sand ridges ranging from 91 to over 183 m (300-600 ft.) above mean sea level are one of the most striking and dominant features of the Sandhills Ecoregion. Ridge tops of pure Lakeland and Kershaw Sands, some up to 9 m (30 ft.) in depth (Wharton 1978), support the most extreme xeric scrub communities of longleaf pine and turkey oaks. The sandy soils on the ridges, excessively drained with low available water capacity, are low in fertility due to rapid leaching and possess little to no leaf litter (Lawrence 1976). The drier sand ridges are suitable for agriculture only when managed through fertilization and irrigation. These ridges can support timber production, particularly of longleaf pine, which is well adapted to deep, dry sandy soils.

Sand ridges that have more clay and silt mixed with sand support subxeric Sandhill scrub vegetation and mesic pine flatwoods. Increased plant diversity in such areas is a result of the more moderate growing conditions. Due to the increase in leaf litter, fire is an important factor in the maintenance of the subxeric scrub forest and woodlands. These subxeric to mesic communities can grade into oak-hickory forests or, in the absence of fire, they may succeed to oak-hickory forests.

Rainwater rapidly percolates through the sand ridges until it reaches hardpan, at which point it moves laterally until emerging at the surface on side slopes or near the base of sand ridges. These natural seepage areas result in distinctive wetland habitats embedded within the xeric

forests and woodlands. The community type that develops is determined by the amount of water, the position on the slope, and—especially—by fire. In the absence of fire, this wetland habitat can be forested with longleaf or pond pines (*Pinus serotina*) growing over a dense evergreen pocosin-like shrub layer or, with frequent fire, it can be an open hillside herb bog. Seepage accumulating at the base of the sand ridges results in a saturated zone that supports a streamside pocosin forest. Figure 4-6 illustrates the distribution of land covertypes in the Sandhills Ecoregion. Species-habitat associations are presented in Appendices 1 A-D while the faunal makeup of the habitats are described in more detail within this chapter (4).

Major brownwater rivers that cut their way through the Sandhills on their way from the Mountains and Piedmont to the sea include the Lynches, Wateree, Congaree, and Savannah Rivers. The North and South Forks of the Edisto River are the only major rivers that originate in the Sandhills.

Figure 4-10 defines the covertypes associated with the Piedmont Ecoregion, and the habitat types are summarized in text format. Species-habitat associations are presented in Appendices 1 A-D while the faunal makeup of the habitats are described in more detail within this chapter (4).

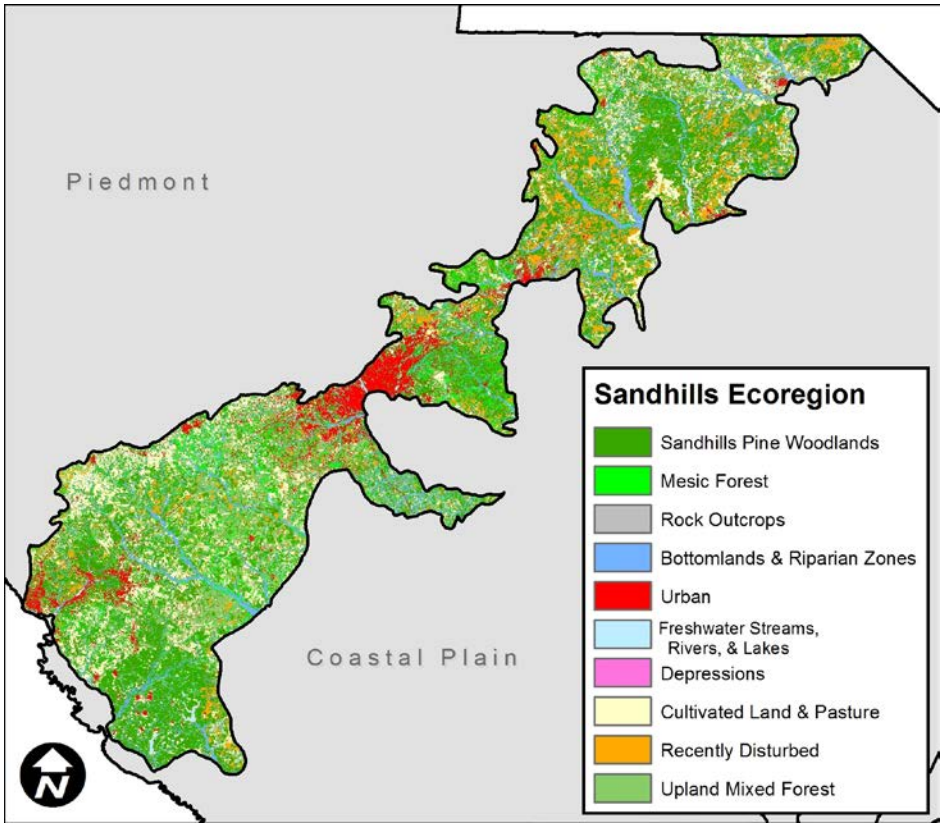


FIGURE 4-10: Land covertypes of the Sandhills Ecoregion.

Sandhills Pine Woodlands	Pine woodland is the characteristic vegetation on the sandy soils that define the region. On deep, well-drained sands, a longleaf pine (*Pinus palustris*) canopy with a subcanopy of turkey oak and other scrub oak species prevails. On lower or middle slopes, or on sites with relatively high amounts of organic matter, other pine species may share dominance with longleaf and a more diverse understory and herbaceous layer is present. On lower slopes sufficiently protected from fire, succession can proceed to oak-hickory forests similar to those of the Piedmont Ecoregion. Several priority species favor the longleaf pine-wiregrass community: a canopy composed of longleaf pine, an open understory, and a diverse herbaceous layer with extensive wiregrass *(Aristida* spp.) cover. The longleaf pine-wiregrass subtype is dependent on fire for maintenance. Wiregrass and leaf litter generally carry fire well and longleaf pine is well adapted to fire dependent communities. Where fire is excluded, turkey oak and other scrub oak species increase in abundance.
Mesic Forest	Usually associated with water bodies and natural levies, these forest communities may vary from closed canopy hardwood stands with little to no shrub layer to dense pocosin-like thickets with numerous ericaceous evergreen shrubs dotted with Pine species. At the interface with the Piedmont, hardwood dominants typically include *Taxodium distichum*, *Nyssa biflora*, *Acer rubrum*, *Liquidambar styraciflua*, *Liriodendron tulipifera*. Habitats closer to the Coastal Plain may include a sparse to dense shrub layer with *Pinus serotina* and *Pinus palustris* in the overstory. *Vaccinium* spp. may be present in the shrub layer.
Rock Outcrops	Confined to the inland-most portions of the Sandhills Ecoregion, at the boundary with the Piedmont, this habitat type roughly follows the geological fall line. Characterized by open, glady habitats with highly alkaline soils, there is little to no canopy layer and a dominant herbaceous layer. Numerous dry-adapted wild flowers and grasses predominate. While this habitat type is a minor component of the Sandhills Ecoregion, it may provide significant resources for wildlife cover and foraging at the periphery of surrounding forested lands.

Blackwater Stream Systems *(within Bottomlands & Riparian Zones layer)*	Tributary streams rising in the Sandhills and Coastal Plain are commonly known as "blackwater streams" for the color of tannins that leach from decaying vegetation. Forests on the narrow floodplains formed by these streams typically have a canopy dominated by swamp tupelo *(Nyssa biflora)* and red maple *(Acer rubrum)*. On broader sites, bald cypress *(Taxodium distichum)* can become an important canopy species. Tulip poplar *(Liriodendron tulipifera)*, sweet gum *(Liquidambar styraciflua)*, pond pine *(Pinus serotina)*, loblolly pine *(Pinus taeda)* and laurel oak *(Quercus laurifolia)* are important associates. The shrub layer is open in areas subjected to the most flooding, or it can be fairly dense and pocosin-like in areas subject to infrequent flooding. Headwaters and wet flats immediately above the floodplain can support dense, pocosin-like shrub thickets or, under suitable fire conditions, pure stands of Atlantic white cedar (*Chamaecyperus thyoides*).
River Bottoms *(within Bottomlands & Riparian Zones layer)*	The State's major rivers transect the Sandhills, forming broad floodplains similar to those in the Coastal Plain. Steep bluffs occur where rivers have cut into Sandhill formations with an erosion-resistant iron-bearing sandstone layer. Hardwood-dominated woodlands form the characteristic vegetation. As in the Coastal Plain, characteristic trees include sweetgum (*Liquidambar styraciflua*), loblolly pine (*Pinus taeda)*, water oak (*Quercus nigra*), willow oak (*Quercus phellos*), laurel oak *(Quercus laurifolia)*, cherrybark oak (*Quercus pagoda*) and American holly (*Ilex opaca*). The Cypress-tupelo swamp subtype occurs on lower elevation sites as seasonally flooded swamps. Dominant trees are bald cypress *(Taxodium distichum)*, water tupelo (*Nyssa aquatica)*, water-elm (*Planera aquatic)* and red maple *(Acer rubrum)*.
Depressions	Clay lenses and other confining layers support a variety of permanently and semi-permanently flooded isolated freshwater wetlands throughout the Sandhills Ecoregion. Landforms include natural and artificial ponds dominated by cypress and/or swamp tupelo. Varying amounts of peat accumulation and fire frequencies produce shrub-dominated pocosins or grass-sedge-herb-dominated depression meadows. Upslope from these lowland habitats, the transition to well-drained uplands supporting Sandhills pine woodland is often abrupt.
Seepage Slopes *(specialized habitat not mapped at this scale)*	Seepage slopes occur on sites having a hard clay moisture-confining layer underlying the sandy soil, such as iron-bearing sandstone or kaolin deposits. Water percolating downhill is forced to the surface, which results in seasonally or permanently saturated soils. Vegetation is variable, depending

	on position on the slope, the amount of peat accumulation, and fire history. Dense shrubland composed of several fire-tolerant species, with an open canopy of pond pine *(Pinus serotina)* is typical. The shrubland community intergrades with open grass-sedge vegetation on wetter seeps that are regularly burned or maintained in an open condition by mechanical clearing or herbicide application. Steeper slopes support a mixture of pine species, including longleaf pine and Virginia pine and a characteristic shrub layer of titi *(Cyrilla racemiflora)*, sand myrtle *(Leiophyllum buxifolium)*, mountain laurel *(Kalmia latifolia)*, and inkberry *(Ilex glabra)*.

Upland Mixed Forest	Oak-hickory forest is a widely distributed community that varies from site to site. Occurring in highly fragmented stands, later successional stages tend to be made up of a diverse assemblage of hardwoods, primarily oaks and hickories, as co-dominants in combination with pines. Understory, shrub and herbaceous layers are present in varying degrees, represented by diverse woody and non-woody species. Vegetation on most sites consists of early- to mid-successional managed stands of pine and pine-hardwood forest. The understory in pure pine stands is often open, but in mixed or older stands, it is dominated by the hardwoods characteristic of the site. Common pine species of the Sandhills include shortleaf (*Pinus echinata*) and loblolly (*P. taeda*), with the former better adapted to dry, fine textured upland soils and loblolly achieving maximum growth on deep soils with good moisture and drainage.
Grassland and Early-Successional Habitats *(specialized habitat not mapped at this scale)*	As in other ecoregions, a variety of grassland and early-successional habitats are present here, either as transitional vegetation following forest disturbances or as managed areas. Early-successional habitats are generally characterized by tree canopy coverage that is sparse or absent and herbaceous groundcover comprised of annual forbs, perennial bunchgrasses, and variable coverage of shrubs and small trees. A variety of open land covertypes represents this category and can include native prairies, savannas, old field sites, open canopy gaps, shrub-scrub thickets, recently-cleared forests, field borders, grassed waterways, and filter strips. Lawns, golf courses, pastures, hay fields, crop fields, airports and various urban open spaces are sometimes included in this habitat type but lack the floristic and structural diversity to be considered high quality, early-successional habitat (see Cultivated Land and Pasture). Minor modifications to agricultural land use, such as replacing introduced grasses with native grasses, using native grasses in filter strips and grassed waterways, and implementing no-till or strip-till in crop fields can result in dramatic improvements to quality of early-successional habitat. Maintenance of early-successional habitat requires periodic repeated disturbance or disruption of the existing vegetative community. Purposeful management of early-successional habitat is usually accomplished through the use of timber harvest, prescribed burning, disking, or mowing. Target species for management will determine disturbance intervals, with shorter intervals (1-2 years) favoring those species dependent on herbaceous vegetation and longer intervals (3-5

	years) favoring those species dependent on shrub cover. Optimal multi-species management often dictates concurrent maintenance of variety of successional, or seral, stages. Early-successional habitat types have declined dramatically over the past 70 years primarily due to changing agricultural practices, forest succession, fire suppression, and urban / suburban encroachment. A large portion of existing early-successional habitat occurs on privately owned lands. One of the greatest challenges to maintaining priority species associated with this particular land cover is private land outreach and technical assistance.

Freshwater Streams, Rivers and Lakes

[A large proportion of the freshwater streams, rivers, and swamps in the Sandhills Ecoregion were mapped within the Bottomlands and Riparian Zones covertype. Also, the aquatic habitats discussed in this ecoregion are discussed in the framework of the larger Southeastern Plains instead of just the Sandhills.]

Streams and rivers originating in the Sandhills Ecoregion are generally low to moderate gradient and often possess tannin-stained waters imparted by the surrounding vegetation. The classic Sandhills stream exhibits steady, moderate flow over a predominantly sand substrate with patches of rooted aquatic vegetation and scattered woody debris. Streams in this region may also transition into swamps and wetlands in areas of lower gradient. First- through fourth-order streams make up the majority of freshwater habitats on the landscape.

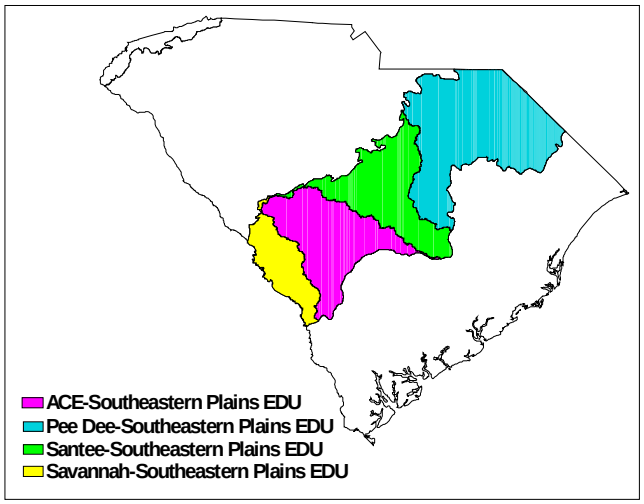


FIGURE 4-11: Drainages of the Sandhills/Southern Plains.

Portions of all of South Carolina's major river basins occur in the Sandhills Ecoregion (Fig. 4-11).

The region denoted the Southeastern Plains encompasses the Sandhills and Upper Coastal Plain and is sandwiched between the Piedmont to the north and the Lower Coastal Plain to the south. (This follows the Griffith et al. 2002 ecoregion map before its modification for Fig. 4-4.) It extends northwest from the Savannah River to the Pee Dee River. The Southeastern Plains encompasses portions of 24 counties and 23,584 km^2 (9,106 $mi.^2$). Just below the Fall Line, the region is dominated by sandy soils with scrub vegetation on moderate sloping lands. This portion is known as the Sandhills and varies in elevation from 76-137 m (250-450 ft.) above mean sea

level. Moving toward the coast, the topography is reduced to gentle sloping and then to nearly level lands with elevations of 130-137m (25-450 ft.).

Wadeable streams are the dominant aquatic habitat in the Southeastern Plains Ecoregion and provide most of the habitat for aquatic animals on South Carolina's Priority Species List. Wadeable streams are those with Strahler stream orders of 0 to 3; generally, these are streams that can be waded comfortably throughout most of the year. These streams are often bordered with pond-like backwaters and swamps. Wadeable streams in the Southeastern Plains are mostly low gradient, although some near the Fall Line have swifter flows. In moderate flowing areas, the substrate is chiefly clean shifting sand; with the absence of rocks in most streams, logs and debris jams provide habitat for aquatic fauna. In slow flowing areas, substrate is comprised of finer materials such as mud, clay, silt, and fine detritus. Most Southeastern Plains streams that receive ample sunlight are well vegetated with aquatic macrophytes. The streams that flow through the ecoregion are often termed "blackwater" due to their tannin-stained waters.

Navigable streams are less common in the Southeastern Plains, but provide habitat for many priority species. These streams are generally defined as large enough to operate watercraft, if only a canoe and are usually too deep to be waded throughout most of the year. The Pee Dee River, Lynches River and Edisto River are examples of navigable streams in the Southeastern Plains. These lazy meandering streams have substrates of mostly shifting sand in the flowing areas while finer materials (silt, clay and detritus) are deposited in the pools. As with the smaller streams in the ecobasin, the navigable streams are also "blackwater," stained by the decomposition of organic materials.

The lower portion of the Southeastern Plains, known as the Atlantic Southern Loam Plains, contains the highest concentration of Carolina bays in the State. Carolina Bays are shallow, elliptical depressions of unknown origin, many of which contain water throughout the year. The waters in Carolina bays are highly acidic, which limits the number of fish species. However, some sunfish and minnow species populate these depressions. Carolina bays may be important habitat for some rare crayfish species, as several have been observed in these formations. However, data on the crayfishes associated with Carolina bays is particularly lacking; more surveys are needed in order to determine the importance of these depressions as crayfish habitat.

Savannah–Southeastern Plains Ecobasin

The Savannah-Southeastern Plains Ecobasin extends from the southern portions of Edgefield County south to the southern portion of Allendale County. It includes about 137 km (85 mi.) of the Savannah River as it meanders toward the Coastal Plain and ultimately the Atlantic Ocean. Major South Carolina tributaries to the Savannah River in the ecobasin include Horse Creek, Hollow Creek, Upper Three Runs Creek, and Lower Three Runs Creek. The ecobasin encompasses most of 6 watersheds and parts of 10 others in its 2,538 km^2 (980 $mi.^2$). The ecobasin contains 1,576 km (979 mi.) of lotic habitat and 2,600 ha (6,425 ac.) of lentic habitat, primarily impoundments. A small portion of the lentic habitat is comprised of Carolina bays. The largest impoundment in the ecobasin is Par Pond 1,195 ha (or 2,953 ac.) on the Savannah River Site property. The next largest reservoir is Langley Pond (122 ha or 301 ac.) near Langley, South Carolina. Other impoundments in the ecobasin total less than 61 ha (150 ac.).

Primary conservation targets in the ecobasin include the main stem Savannah River in Aiken and Allendale Counties, Upper Three Runs Creek and its tributaries in Aiken and Barnwell Counties, and the Brier Creek system in Allendale County (Smith et al. 2002). The main stem of the Savannah River within the ecobasin contains several aquatic animals on South Carolina's Priority Species List including Shortnose Sturgeon and Robust Redhorse, as well as several mussel species (pod lance and Savannah lilliput). Priority fish species in Upper Three Runs Creek and its tributaries include the Savannah Darter and Turquoise Darter. The Savannah Darter and Bluebarred Pygmy Sunfish inhabit the Brier Creek system.

Water quality was impaired at 17 of 40 sites (43%) sampled by the South Carolina Department of Health and Environmental Control (SCDHEC 2003a). Aquatic life uses were not supported at 2 sites due to a lack of invertebrate diversity or abnormal pH. Recreational uses were not supported at 8 sites due to the presence of high fecal coliform bacteria concentration. Fish consumption advisories were listed for several areas due to mercury contamination, including Flat Rock Pond, Langley Pond, Vaucluse Pond, and the Savannah River. No streams within the ecobasin are considered outstanding resource waters by SCDHEC.

Approximately 87 km (54 mi.) of streams have been impounded in the ecobasin. Nearly 90 dams are present in the ecobasin, 10 of which impound navigable streams, forming small reservoirs. Most of the dams occur in the Horse Creek (34 dams) and Hollow Creek (26) watersheds.

There is comparatively little agricultural activity within the ecobasin, with only 6 active permitted agricultural operations. However, point source discharges are abundant. The ecobasin has the highest density of point source discharges in the State with more than 6 per 259 km^2 (100 $mi.^2$). Most of those discharges (5.5 per 259 km^2 or 100 $mi.^2$) are from industrial sources, giving the ecobasin the highest density of industrial discharges in the State.

There is moderate growth potential in the ecobasin. Residential and commercial growth in the vicinity of North Augusta and Aiken is expected and will have negative effects on aquatic environments if those developments are not carefully planned.

ACE–Southeastern Plains Ecobasin

The ACE–Southeastern Plains Ecobasin is the only ecobasin in the State to originate entirely in

the Southeastern Plains Ecoregion. The headwaters of the North and South Forks of the Edisto River originate in the extreme southern portion of Edgefield and Lexington Counties. The headwaters of the Salkehatchie River originate in Barnwell County. Major tributaries to the North Fork Edisto River in the ecobasin include Black Creek, Bull Swamp Creek, and Caw Caw Swamp. Major tributaries to the South Fork Edisto River include Shaw Creek, Dean Swamp Creek, Little River, and Roberts Swamp. The ecobasin includes portions of 27 watersheds and covers 5,747 km^2 (2,219 $mi.^2$). The ecobasin contains approximately 2,239 km (2,117 mi.) of lotic habitat and 9,047 acres of lentic habitats. There are no major reservoirs within in the ecobasin, and largest lentic areas (more than 730 ha or 5 ac.) are primarily Carolina bays.

Primary conservation targets in the ecobasin include the upper portion of the South Fork Edisto River in Aiken, Barnwell, and Orangeburg Counties; the main stem of the lower North Fork Edisto River in Orangeburg County; and Black Creek, a tributary to the North Fork Edisto River in Lexington County (Smith et al. 2002). Priority fish species in the upper South Fork Edisto River include the "Broadtail" Madtom, Savannah Darter, Turquoise Darter, and Blackbanded Sunfish. The lower North Fork Edisto River and its tributaries provide habitat for the "Broadtail" Madtom, Bluebarred Pygmy Sunfish and Savannah Darter as well as the Federally Endangered Shortnose Sturgeon.

Water quality was impaired at 33 of 77 sites (33%) sampled by SCDHEC (SCDHEC 1998b; SCDHEC 2003b). Aquatic life uses were not supported at 13 sites due to lack of invertebrate diversity (7 sites), low dissolved oxygen concentrations (4 sites) and abnormal pH values (2 sites). Recreational uses were not supported at 15 sites due the presence of high fecal coliform bacteria concentrations. Fish consumption advisories were listed for the Salkehatchie River below US 301, the South Fork Edisto River below Aiken State Park, and the Orangeburg County portion of the North Fork Edisto River. No streams within the ecobasin are considered outstanding resource waters by the SCDHEC. Many dams (368) impound approximately 175 km (109 mi.) streams within the ecobasin, but none of them impound navigable streams.

On a statewide basis, the ecobasin contains a moderate number of point source discharges. There are 57 active discharges permitted by SCDHEC within the ecobasin, 28 of which are from industrial sources, 19 from municipal sources, and 10 from community sources. The ecobasin has the second highest density of agricultural operations in the state with nearly 11 operations per 259 km^2 (100 $mi.^2$). There are 244 permitted active agricultural operations within the ecobasin, most of which are poultry farms (42 large, 129 medium, and 32 small). Other significant agricultural operations include swine farms (17), dairy farms (13), and peach orchards (6). The highest concentration of agricultural operations occurs in the upper portion of the North Fork Edisto River drainage where 113 permitted farms are located in the Chinquapin Creek/Lightwood Knot Creek and Black Creek watersheds.

Development throughout most of the ecobasin is not a major concern. There is low potential for growth in most areas. The Caw Caw Swamp watershed and North Fork Edisto River watershed may be negatively affected by development in the vicinity of Orangeburg. There is high potential for commercial development in the Shaw Creek watershed northeast of Aiken, near the intersection of I-20 and US 1.

Santee–Southeastern Plains Ecobasin

The upper extent of the Santee-Southeastern Plains Ecobasin is the Fall Line, which runs through central Lexington, Richland, and Kershaw Counties. The ecobasin extends southeasterly to the upper portion of Berkeley County and includes 3 major rivers. The Congaree and Wateree merge to form the Santee River southeast of Columbia. Major tributaries to the Congaree River include Congaree Creek, Gills Creek, and Cedar Creek. Major tributaries to the Wateree River include Five and Twenty Mile Creek, Big Pine Tree Creek, Colonel's Creek, and Beech Creek. The ecobasin contains all of 17 watersheds and portions of 30 others, and covers 5,346 km^2 (2,064 $mi.^2$). The ecobasin contains approximately 3,589 km (2,230 mi.) of lotic habitat and 379 km^2 (146 $mi.^2$) of lentic habitat, most of which is contained in Lake Marion (352 km^2 or 136 $mi.^2$). Big Pine Tree Creek near Camden South Carolina is a primary conservation target in the ecobasin as it holds one of very few known Carolina Pygmy Sunfish populations.

Water quality was impaired at 50 of 127 sites (39%) sampled by SCDHEC (SCDHEC 1998a; SCDHEC 1999a; SCDHEC 1999b). Aquatic life uses were not supported at 14 sites primarily due to a lack of invertebrate diversity (4 sites) and low dissolved oxygen (5 sites). One site was contaminated with tin. Recreational uses were not supported at 24 sites due the presence of high concentrations of fecal coliform bacteria. Fish consumptions advisories were listed for 12 sites, primarily due to the presence of mercury (11 sites). Fish consumption advisories have been listed for the Congaree River from Columbia to the Santee River, the Wateree River along its entire length within the ecobasin, Lake Marion, Cary's Lake, Windsor Lake, and Sesquicentennial State Park.

There are 378 km (235 mi.) of impounded streams in the ecobasin, most of which (238 km or 148 mi.) results from the impoundment of the Santee River to form Lake Marion. There are 295 dams permitted by SCDHEC within the ecobasin. Hydroelectric peaking operations on rivers (Saluda, Broad, and Wateree) located in the Piedmont have had significant negative impacts on the integrity of the Congaree and Wateree rivers in the Southeastern Plains. Rapidly fluctuating flows associated with hydroelectric peaking have lead to decreased bank stability, allowing the banks to slough-off into the rivers, increasing sedimentation.

Excessive nutrients and other chemical inputs from both point and non-point sources are a serious threat to water quality within the ecobasin. The ecobasin has the second highest density of active discharges permitted by SCDHEC with more than 6 discharges per 259 km^2 (100 $mi.^2$). There are 128 active discharges permitted by SCDHEC within the ecobasin; 80 of which are from industrial sources, 33 from community sources and 14 from municipal sources. There are 114 active agricultural operations within the ecobasin; most are poultry and turkey farms (14 large, 45 medium, and 4 small). Other significant agricultural operations include 33 manure brokers and nine swine farms (2 medium-sized and 7 small).

Residential, industrial, and commercial development in the northern portion of the ecobasin poses a significant threat to aquatic habitats. Significant growth is occurring in the Lexington, West Columbia, Columbia, and northeast Columbia areas, threatening water quality and aquatic habitats in the Congaree River, Congaree Creek, and Gills Creek watersheds. Development pressure is also great in the Wateree River watersheds near Camden and Lugoff. The Spears Creek watershed can also expect moderate to high residential, commercial, and industrial

growth.

Pee Dee–Southeastern Plains Ecobasin

The Pee Dee-Southeastern Plains Ecobasin is located in the northeast corner of the State, originating in Chesterfield, Marlboro, and Dillon Counties and flowing through parts or all of Kershaw, Darlington, Florence, Lee, Marion, Sumter, and Clarendon Counties. The ecobasin contains 3 major rivers including the Lynches, Pee Dee, and Little Pee Dee as well as the headwaters of the Black River. The Lynches River originates just north of South Carolina in the Piedmont of North Carolina. It flows about 34 km 114 km (21 mi.) through the South Carolina Piedmont before entering the Pee Dee-Southeastern Plains Ecobasin, then flows another 114 km (71 mi.) until it enters the Coastal Plain, picking up inputs from 2 major tributaries, Buffalo Creek and the Little Lynches River, along the way. The Pee Dee River originates in the southern portion of the North Carolina Piedmont and Southeastern Plains. Within the Pee Dee-Southeastern Plains Ecobasin, the Pee Dee River flows about 148 km (92 mi.) before entering the Coastal Plain. Major tributaries to the Pee Dee River include Thompson Creek, Crooked Creek, Black Creek and Jefferies Creek. The Little Pee Dee River originates in the Southeastern Plains of North Carolina and flows approximately 119 km (74 mi.) through the Pee Dee-Southeastern Plains Ecobasin before entering the Coastal Plain of South Carolina. The primary tributary is Buck Swamp. Pocataligo River and Black River Swamp are the main tributaries of the Black River. Both originate within the ecobasin and flow southeast before entering the Coastal Plain and merging to form the Black River. The ecobasin contains all of 11 watersheds and parts of 46 others, and covers 9,920 km^2 (3,830 $mi.^2$). There are about 7,388 km (4,591 mi.) of lotic habitat and 96 km^2 (37 $mi.^2$) of lentic habitat. There are no major reservoirs within the ecobasin. The largest lentic areas are Big Bay (1,002 ha or 2,476 ac.), a Carolina bay, and Lake Robinson (833 ha or 2,058 ac.), an impoundment on Black Creek.

Areas of primary conservation concern include the upper Lynches River and its Sandhills tributaries in Chesterfield, Kershaw, Lee, and Darlington Counties; the upper Pee Dee River between Marlboro and Chesterfield Counties; and Sandhills tributaries to the Little Pee Dee River along the border of South Carolina and North Carolina in Marlboro and Dillon Counties (Smith et al. 2002). The upper Lynches River is home to several aquatic priority species including fish (Sandhills Chub, "Thinlip" Chub, and "Broadtail" Madtom) and mussels (brook floater, creeper, notched rainbow, and the Federally Endangered Carolina heelsplitter). The main stem of the upper Pee Dee River contains several fish ("Carolina" Redhorse, Robust Redhorse, and the Federally Endangered Shortnose Sturgeon) and mussel (yellow lampmussel and Roanoke slabshell) priority species. Sandhills tributaries to the Little Pee Dee River contain Sandhills chub and once harbored populations of pinewoods darter that may now be extirpated from the State.

Water quality was impaired at 57 of 134 sites (43%) sampled by SCDHEC (SCDHEC 2000). Aquatic life uses were not supported at 28 sites due to low dissolved oxygen concentrations (17 sites), copper contamination (4 sites), abnormal pH values (4 sites), and lack of invertebrate diversity (3 sites). Recreational uses were not supported at 19 sites due to the presence of high concentrations of fecal coliform bacteria. Fish consumption advisories were listed for 10 sites due to mercury contamination including every major river within the ecobasin (Pocotaligo River, Lynches River, Great Pee Dee River, and Little Pee Dee River) and 2 small impoundments: Louthers Lake and Lake Robinson.

The 291 dams located in the ecobasin impound 241 km (150 mi.) of streams; 16 of those dams impound navigable streams.

There are 128 active discharges permitted by SCDHEC within the ecobasin, including 76 industrial discharges, 40 municipal discharges, and 12 community discharges. The highest concentration of those discharges (28) occurs in the Pocotaligo River watershed near Shaw Air Force Base and the town of Sumter. There are 226 agricultural facilities permitted by SCDHEC within the ecobasin, primarily poultry and turkey farms (15 small, 126 medium, and 18 large) and swine farms (22 small, 19 medium, and 19 large).

The construction of a proposed new interstate highway (I-73) running from Michigan to Myrtle Beach has the potential to result in significant impacts to the aquatic resources of this ecobasin. The final route for the highway has not been established so it is unknown which resources will be impacted.

Development pressure is expected to be high in the Black Creek and Jeffries Creek watersheds. Those watersheds encompass Hartsville, Darlington, and Florence. Major industrial expansion is expected beyond the several large industrial parks that are already located along the western side of Florence. Increased water withdrawals and point source discharges that accompany development could potentially have severe impacts on aquatic habitats in the main stem of the Pee Dee River.

Region-wide Challenges

The rate of urbanization has increased in the Sandhills Ecoregion over the past two decades, primarily in the Aiken, Columbia, Camden, and North Augusta areas. Tracts of land with existing ponds are especially sought after for residential development which tend, therefore, to be concentrated around the ponds and where there is often very little buffer of natural vegetation remaining between the home sites, roads, and ponds.

Although land management practices that favor restoration of the longleaf pine ecosystem are gaining widespread acceptance, significant alterations continue to affect transition areas between uplands and wetlands. These alterations typically occur when access roads or firebreaks are placed at the upland-wetland boundary, which effectively excludes fire from the wetlands. The result is a closed canopy forest, rather than a complex of dense shrub (pocosin) and grass-sedge successional stages that would occur under a more natural fire regime.

The longleaf pine ecosystem, the dominant natural vegetation type in the Sandhills Ecoregion, is one of the most imperiled ecosystems in the country with only 3% of its original extent considered to be in a relatively natural condition (Frost 1993). Even in areas where longleaf pine remains, fire suppression has severely impacted the ecosystem. Fire suppression in the Southeastern United States began to be institutionalized between 1910 and 1930 (Frost 1993; Ware et al.1993). This practice severely affected the remaining patches of the longleaf pine ecosystem, resulting in a change in species composition and forest structure. In recent years, some areas have been restored or are in the process of being restored with the use of prescribed

fire. This practice has been limited, however, because of the costs associated with prescribed fire and because of other risks associated with prescribed burning, including problems with smoke management.

Economic considerations have also affected timber management practices. Conversion of areas to tree species not usually associated with the Sandhills region have also contributed to the decline of the longleaf pine ecosystem. Many land managers have planted pine species other than longleaf because they were less expensive to plant and produced a superior mid-term return on investment.

Challenges to the conservation of aquatic fauna in the Southeastern Plains Ecoregion are similar to other ecobasins in the State and primarily include impacts associated with impoundments, non-point source pollution, point source pollution, poorly planned development, and the introduction of non-native species.

There is only one major impoundment (Lake Marion) in the Southeastern Plains; however, dams still have a significant impact on aquatic resources within the ecoregion. With more than 1,000 dams impounding 550 miles of streams, there are more dams in the Southeastern Plains Ecoregion than any other; the density of dams within the ecoregion is second only to the Blue Ridge. Dams result in a loss of connectivity and negatively affect aquatic biota both above and below the impoundment (Doeg and Koehn 1994; Kanehl et al. 1997; Tiemann et al. 2004). Impoundments affect native aquatic fauna through direct loss of habitat as lotic habitat is converted to lentic habitat; the latter favors competitive and often predacious species like Largemouth Bass and other centrarchids. In addition, impoundments often negatively affect unimpounded downstream reaches by altering hydrologic and thermal regimes (Cushman 1985), modifying stream channel morphology, increasing erosion and sedimentation (Waters 1995), and ultimately reducing suitable habitat for native aquatic fauna (Helfrich et al. 1999; Tiemann et al. 2004). Dams also prevent migrations of native anadromous fish (shad species, Striped Bass, and sturgeon) to their historic spawning grounds.

Forest clearing, soil tilling, and channelization in the vicinity of Southeastern Plains streams have resulted in streams that are heavily silted. Modern soil conservation practices and lower potential for channelization have reduced those impacts, but sedimentation from non-point and point sources remains a significant detriment to streams. Development activities, agriculture, and silviculture are primary sources of erosion that lead to sedimentation in streams. Corporate and private timber managers that fail to follow Best Management Practices (BMPs) contribute to siltation and other non-point source pollution within the ecoregion. 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 Southeastern Plains were channelized to improve drainage of croplands. Channelized streams lead to increased erosion of cropland and increased sedimentation of the receiving streams (Etnier and Starnes 1993). The result of channelization was changing many streams into straight, shallow ditches with severely depressed populations of aquatic fauna.

Excessive contamination by nutrients and other chemicals also negatively affect water quality within the ecoregion. Point source discharges from industrial, municipal, and commercial

sources add a variety of chemical pollutants to the receiving streams, rivers, and lakes. In addition, non-point source discharges from agricultural operations negatively affect water quality. Nationwide, pollution from agricultural sources is the greatest cause of impairment to streams and lakes (SCDHEC 2003). The Southeastern Plains has the second highest density of permitted discharges within the State and the highest density of Concentrated Animal Feeding Operations (CAFOs) with approximately 6.5 operations per 259 km^2 (100 $mi.^2$).

Water quantity is also a problem in Southeastern Plain streams. Water withdrawal for irrigation is a common practice in the ecoregion. During summer months, some streams are completely dewatered due to uncontrolled irrigation of croplands. Furthermore, many pond-owners will close their drain structures during dry periods in an attempt to maintain aesthetic water levels, thereby dewatering the stream below.

Introductions of non-native species have had a significant impact on native aquatic fauna in the Southeastern Plains Ecoregion. Buffalo (fish), Common Carp, Flathead Catfish, and Blue Catfish are established in several drainages. Flathead Catfish and blue catfish introductions probably pose the greatest direct risks to native fauna. Flathead Catfish have been shown to prey on bullheads, darters, shad, suckers, and sunfish. Severe declines in native species, particularly bullheads and sunfish, have been observed after the introductions of Flathead Catfish (Guire et al. 1984; Jenkins and Burkhead 1993; Bart et al. 1994). It is not well known what effects buffalo have on the native community, but it has been suggested that they may be a factor in the decline of some catostomids in the Pee Dee River (Wayne Starnes, pers. comm.). Common Carp occur in every South Carolina drainage and are considered a pest; however, their impact on native fauna is not well known. Common Carp disrupt aquatic habitats by rooting around in the substrate where they uproot aquatic plants and increase turbidity and siltation. Common Carp have also been shown to prey on the eggs of other fish species.

The Asian clam, *Corbicula fluminea*, has been introduced and has spread widely throughout the United States, including into South Carolina. The effects of *Corbicula* on native species are not particularly well understood. According to a review of the literature on interactions between *Corbicula* and native mussels (Dillon 2000), most field studies failed to find any significant negative effects on native mussels, although a few detected reductions in growth. Three invasive snail species (*Viviparus georgianus*, *V. purpureus*, and *Bellamya/Cipangopaludina japonica)* are present in Lakes Marion and Lake Moultrie, but their impact on native fauna is not known.

The red swamp crayfish has been introduced to South Carolina and has been observed at several locations in the Southeastern Plains and other portions of the Lower 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 one of the native species have made it particularly difficult to determine the extent of its introduced range. In North Carolina, it has become established in all drainages in the Coastal Plain and Eastern Piedmont Plateau and appears to have extirpated all the native crayfish at one location (Cooper 2003). Introduced crayfish are thought to be the biggest threat to native crayfish species (Lodge et al. 2000 a,b); the risk to our native species is great if further introductions or extensive spread of the red swamp crayfish occur.

Sand mining operations have been initiated or are ongoing in the main stem or riparian areas of many Southeastern Plains rivers. Instream sand mining is a significant threat to aquatic resources within the ecoregion. Sand mining not only causes bank stability problems and loss of riparian areas at the mining site, but within the stream, this activity adversely affects physical and chemical habitat and can negatively affect biological communities (Nelson 1993) and recreational uses (Hartfield 1993). Physical impacts on instream habitat include increasing bedload materials and turbidity, changing substrate type and stability, and altering stream morphology (Nelson 1993). Physical habitat alterations associated with sand mining can adversely affect the biological community by decreasing reproduction and survival of fishes (Stuart 1953; Newport and Moyer 1974) and distribution, composition, and reproduction of other aquatic organisms (Buck 1956; Trautman 1957; Newport and Moyer 1974).

Coastal Plain Ecoregion

General Overview

The Coastal Plain is the largest ecoregion in South Carolina. Land elevation in this ecoregion begins at 82-91 m (270-300 ft.) at the inland boundary with the Sandhills Ecoregion and reaches nearly to sea level at the Coastal Zone boundary. Although the Sandhills Ecoregion shares some of the geological history and physical features and is included in some definitions of the Coastal Plain, wildlife habitats in the two regions differ in some important respects. Therefore, the Coastal Plain and Sandhills are treated as separate regions in the SWAP.

From a land use standpoint, the Coastal Plain consists of two significantly different landscapes. An inner belt is predominantly composed of cropland, with forest limited to small patches and hardwood "stringers" along creeks. An outer belt, sometimes called the "flatwoods", is primarily pine-dominated forest. Bisecting both belts are major floodplains which are largely forested. Most public lands in the region have a strong wildlife management focus, including an emphasis on threatened and endangered species and other species of concern; for planning purposes, the lands are considered "protected."

The Coastal Plain has been predominantly used for agricultural purposes since settlement by Europeans in the 18th century. Uplands, and the better-drained terraces, were cleared to create fields for agriculture concurrently with the clearing of extensive areas of longleaf pine and swamp hardwood forest on mesic and wet sites to supply timber. Several cycles of short-rotation pine forest were favored, along with agricultural practices that often provided substantial edge habitat for game species such as quail, as well as deep woods or swamp habitat for deer, turkey and waterfowl. By the late 20th century, economic conditions began to favor the consolidation of land into larger holdings, the practice of clean field agriculture, and shorter rotations of both upland and lowland timber. Extensive holdings in the Flatwoods Belt were also used as recreational hunting reserves, and as such, were managed primarily for the production of game species with timber production generating income to offset management expenses.

Grasslands or early-successional fields include those with cover provided by grasses and/or weeds with few, if any, trees. These sites also include managed open areas such as meadows, pastures, and golf courses, with or without damp depressions. These fields occur throughout the region, but are more extensively in the inner "agriculture belt." Pine woodlands include all pine-

dominated forests throughout the ecoregion and include tracts that occupy a variety of soil moisture characteristics excluding floodplains. The canopy is dominated by one or several species of pine: generally loblolly (*Pinus taeda*) or longleaf (*Pinus palustris*), depending on elevation, soil type and silvicultural history. Dense shrub thickets of hollies (*Ilex* spp.) and wax myrtle (*Morella cerifera*) may be found within these stands as well.

Finally, the river bottoms of the Coastal Plain include a variety of hardwood and hardwood-pine communities that occupy the floodplains of small streams and infrequently flooded flats that are associated with streams or rivers. These flats are often characterized by the presence of American beech (*Fagus grandifolia*) and occur in scattered locations on sheltered sites with moist soils, particularly on North-facing river bluffs and on the slopes of drains and creeks.

The rivers and streams that occur in South Carolina's Coastal Plain are often called blackwater systems. These soft tannin stained waters are acidic and drain oxygen-poor floodplain swamps. This naturally occurring condition of low pH and low oxygen make the low-gradient Coastal Plain rivers and streams a place where elemental mercury can be methylated and mobilized into the food chain. Bio-magnification of methyl-mercury loads occurs in these systems resulting in the promulgation of consumption advisories for piscivorous fish and other animals.

Wadeable streams, as with the other ecoregions, are the dominant aquatic habitat in the Coastal Plain and provide a large portion of the habitat for aquatic animals on the priority species list. Wadeable streams are those with Strahler stream orders of 0 to 3 that are generally comfortably wadeable throughout most of the year. These streams are often bordered with pond-like backwaters and swamps. Wadeable streams in the Coastal Plain are low-gradient with sluggish flows. Although some of the larger streams may have moderate currents, they lack whitewater. In the moderate flowing areas, the substrate is chiefly clean shifting sand.With the absence of rocks in most streams, logs and debris jams provide habitat for aquatic fauna. In slow-flowing areas, substrate is comprised of finer materials such as mud, clay, silt and fine detritus. Most Coastal Plain streams that receive ample sunlight are well-vegetated with aquatic macrophytes. Coastal plain streams can contain turbid or clear water (whether stained or not). Generally those streams that originate in the Piedmont and flow through the Coastal Plain are turbid due to the heavy sediment load they carry and are termed "brownwater." Streams that originate in the Southeastern Plains and/or Coastal Plain and are not turbid as a result of anthropogenic impacts are termed "blackwater" due to their tannin-stained waters.

Navigable streams are less common in the Coastal Plain, but provide habitat for many species on the priority list. These streams are generally defined as large enough to operate watercraft, if only a canoe, and are usually too deep to be waded throughout most of the year. The Pee Dee River, Lynches River and Edisto River are examples of navigable streams in the Coastal Plain. These lazy meandering streams have substrates of mostly shifting sand in the flowing areas while finer materials (silt, clay and detritus) are deposited in the pools. As with the smaller streams in the ecobasin, the navigable streams that originate in the southeastern plains and/or coastal plain are also "blackwater," stained by the decomposition of organic materials.

Carolina bays are common in the Coastal Plain. These shallow, elliptical depressions are of unknown origin, and many of which contain water throughout the year. The waters contained in

Carolina bays are highly acidic which limits the number of fish species. However, some sunfish, minnow, killifish, and livebearer species may populate Carolina bays. These depressions may be important habitat for some rare crayfish species, as several have been observed in these formations. However, data on the crayfishes of Carolina bays is particularly lacking, and more surveys are needed in order to determine the importance of these depressions as crayfish habitat.

Land Covertypes

The predominant land covertypes that most casual observers associate with the Coastal Plain are 1) grassland and early-successional habitats, 2) pine woodland and 3) river bottoms. Although the remaining types are less extensive, they provide habitat diversity that is important to a number of animals, especially wetland species. Figure 4-12 defines the various habitat types found in this ecoregion. Species-habitat associations are presented in Appendices 1 A-D while the faunal makeup of the habitats is described in more detail within this chapter (4).

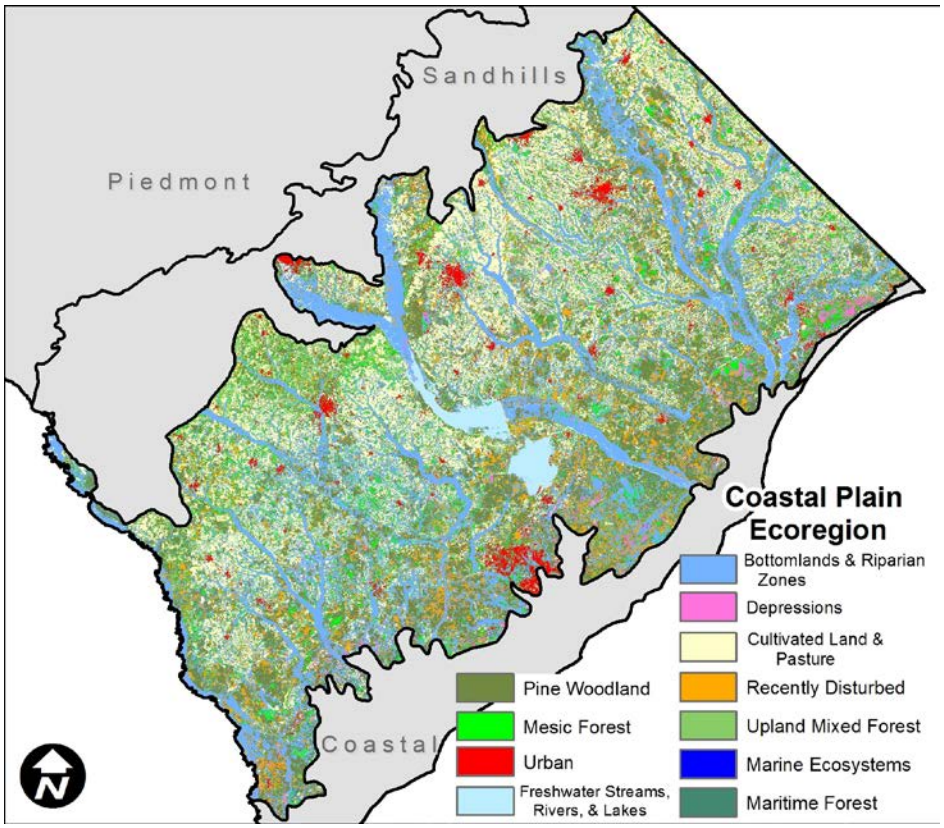


FIGURE 4-12: Land covertypes of the Coastal Plain Ecoregion.

Pine Woodland	This land covertype is assigned to all pine-dominated forests throughout the region, including those occupying a variety of soil moisture characteristics with the exception of floodplains. The canopy is dominated by one or several species of pine, generally loblolly (*Pinus taeda*), or longleaf (*Pinus palustris*), depending on elevation,

	soil type and silvicultural history. Dense shrub thickets of hollies (*Ilex* spp.) and wax myrtle (*Morella cerifera*) may be present. Higher elevation pine woodlands have abundant grasses and herbaceous cover, particularly when burning is frequent. Optimal habitat for priority species consists of open stands of longleaf pine, a sparse understory and shrub layers, and a ground cover of wiregrass (*Aristida* spp.) and diverse herbaceous species.
Sandhill Pine Woodland *(within the Pine Woodland layer)*	Sandhill pine woodland is a variation of pine woodland composed of species adapted to xeric, sandy soils. This land covertype occurs principally in the Sandhills but also on sand ridges in the Coastal Plain. It is characterized by an absence of frequent fire, a canopy of longleaf pine, and a subcanopy of turkey oak interspersed with scrub oak species and scrub-shrub cover. Frequent burning leads to the development of longleaf pine-wiregrass communities.
Mesic Forest	Pine savanna, also known as open savanna, is an important variant of pine woodland. Wet prairie, grass-sedge bog, herb bog or pitcher plant bog, are typically found in the Outer Coastal Plain on flat sites with a high water table and soil that is saturated for at least part of the year. Vegetation consists of a thin canopy of pines—almost always longleaf (*Pinus palustris*—although loblolly (*P. taeda*) and pond pine (*P. serotina*) may also be present. The understory is essentially absent or very scattered. Herbaceous flora is quite rich, consisting of many grasses and sedges. Pine flatwoods intergrade with pine savanna; like pine savanna, it is pine woodland situated on essentially flat or rolling terrain with sandy soil and a high water table. Unlike pine savanna, pine flatwoods feature a well-developed subcanopy of several tall shrub species. Pine flatwoods is the principal forest type for much of the Outer Coastal Plain. Occasional hardwood stands may line the downslopes of pine savannas and form the ecotone between these and bottomland habitats. Sweet gum (*Liquidambar styraciflua*) is an important early-successional species in these environments, but shares these habitats with several oak species such as water oak (*Quercus nigra*), laurel oak (*Q. laurifolia*), and pin oak (*Q. phellos*). Other hardwoods may include tulip poplar (*Liriodendron tulipifera*) and river birch (*Betula nigra*).

Hardwood Slopes and Stream Bottoms *(within the Bottomlands & Riparian Zones layer)*	A complex of hardwood and hardwood-pine communities occupies the floodplains of small streams, mesic bluffs and infrequently flooded flats in association with streams or rivers. Fire is infrequent, due either to the sheltered locations of these communities on bluffs or their isolation within a floodplain. Several mixed mesophytic subtypes characterized by the presence of American beech *(Fagus grandifolia)* occur in sheltered sites with moist soils, particularly on North-facing river bluffs and on slopes of drains and creeks. On upland flats within floodplains (hammocks), southern magnolia *(Magnolia grandiflora)* is frequently co-dominant with American beech. The calcareous cliff and marl forest subtype occurs on circumneutral soils derived from limestone or unconsolidated calcareous substrates such as marl. Forest structure of all subtypes is diverse, with understory, shrub and herbaceous species varying according to soil moisture and chemistry. All subtypes intergrade with blackwater stream forest or river bottom forest on lowland sides and with upland forest on upland sides.
Blackwater Stream Systems *(within the Bottomlands & Riparian Zones layer)*	Tributary streams arising in the Sandhills and Coastal Plain are commonly known as "blackwater streams" attributable to the color of tannins leaching from decaying vegetation. Forests on the narrow floodplains formed by these streams typically have a canopy dominated by swamp tupelo *(Nyssa biflora)* and red maple *(Acer rubrum)*. At broader sites, bald cypress *(Taxodium distichum)* can become an important canopy species. Tulip poplar *(Liriodendron tulipifera)*, sweet gum *(Liquidambar styraciflua)*, pond pine *(Pinus serotina)*, loblolly pine *(Pinus taeda*) and laurel oak *(Quercus laurifolia)* are important associated species. The shrub layer is open in areas subjected to the most flooding, or may be fairly dense and pocosin-like in areas subject to infrequent flooding. Headwaters and wet flats immediately above the floodplain can support dense, pocosin-like shrub thickets or, under suitable fire conditions, pure stands of Atlantic white cedar (*Chamaecyperus thyoides*).
River Bottoms *(within the Bottomlands & Riparian Zones layer)*	River bottoms, or "bottomland forests" consist of hardwood-dominated woodlands with moist soils that are usually associated with the broad floodplains of major rivers rising in the Piedmont or Blue Ridge Ecoregion. Locally, the floodplains of major Coastal Plain rivers are significant components of the landscape. Characteristic tree species include the sweetgum (*Liquidambar styraciflua*), loblolly pine (*Pinus taeda*), water oak (*Quercus nigra*), willow oak (*Quercus phellos*), laurel oak (*Quercus laurifolia*), cherrybark oak (*Quercus pagoda*) and American holly (*Ilex opaca*). A habitat subtype dominated by bald cypress (*Taxodium distichium*) and water tupelo (*Nyssa aquatica*) occurs on lower elevation sites that is interspersed and intergrades with oak-dominated woodlands.

	Dominant trees here include the bald cypress (*Taxodium distichium*) and water tupelo (*Nyssa aquatica*), swamp gum (*Nyssa biflora*), Carolina ash (*Fraxinus caroliniana*), water elm (*Planera aquatica*) and red maple (*Acer rubrum*).
Depressions	Depression wetlands of some type occur in every ecoregion in South Carolina. These habitats are known by a number of names including vernal pool, high pond, flatwoods pond, limesink, wet weather pond, Carolina bay and several other colloquial names. Depression wetlands in the Sandhills, Coastal Plain and Coastal Zone typically formed due to the collapse of a friable subterranean layer such as limestone or sandstone forming a "slump" in the landscape. These habitats may also have formed due to natural concavities, bowls or slumps on the surface topography. These depressions will hold water given the presence of an impermeable soil layer such as clay, rock, or humate-impregnated sand. Depression wetlands are often referred to as "perched" water tables because they hold water perched above the normal sub-surface water table. They are also referred to as isolated, temporary wetlands due to the general lack of connection to surface streams and the pulsed nature of their hydrology, typically filling and drying with rainfall cycles. Some of these wetlands display unique geomorphologies, such as Carolina bays and limesinks. Carolina bays are a class of depression wetland that display both a unique shape and orientation. Carolina bays are all either oval or elliptical in shape with the long axis of the ellipse, or oval lying along a northwest to southeast alignment. There are a number of hypotheses about the origin of these features, but no conclusive data supports any one of them to date. Limesinks are typically circular on the surface with steep sides that are conical in form. Depression wetlands in the Coastal Plain can support a variety of vegetative community types ranging from pond cypress or black gum ponds, to pond cypress savannas and wet meadow communities, to pocosin and pond pine woodlands. Open water ponds, hardwood ponds, and sedge-dominated ponds may occur in other parts of the state as well. Despite the differences in origin, geomorphology, and vegetative structure, these habitats are similar in ecological function. With a few notable exceptions, these habitats are primarily linked to rainfall cycles, relying on rain to fill their basins and subsequently drying out during periods of low rainfall. The frequency of inundation may vary both in time and in location, such that most of these wetlands do not fill and dry on an annual basis.

	Depression wetland habitats are detritus-based systems. When they dry, herbaceous plants and grasses die back and desiccate, forming a detrital layer. When the basins are inundated again this detritus forms the base of a food web that can support a variety of invertebrate and vertebrate species. A number of native plant and animal species, including numerous rare species, rely on depression wetlands as a primary habitat or for some life history stage such as breeding habitat. Because these habitats fill and dry cyclically, they typically do not support large predatory fish populations. Numerous amphibian species in South Carolina breed preferentially or exclusively in depression wetland habitats. Avoidance of larval predators, such as fish, is a critical adaptive mechanism for amphibians, and one solution is to breed in fish-free habitats such as depression wetlands. As such, depression wetlands are critically important habitats for a number of amphibian species in South Carolina.
Upland Mixed Forest	The composition of the vegetation in the upland forest land covertype is similar to that of oak-hickory forest in the Piedmont, where it is a major vegetation type. In contrast, upland forest is rare in the Coastal Plain, typically occurring on fire-suppressed upland slopes near river floodplains or between rivers and tributaries, intergrading with river slope communities. Representative canopy trees include white oak (*Quercus alba*), black oak (*Quercus velutina*), post oak (*Quercus stellata*), mockernut hickory (*Carya tomentosa*), pignut hickory (*Carya glabra*), loblolly pine (*Pinus taeda*), flowering dogwood (*Cornus florida*) and black gum (*Nyssa sylvatica*). Understory, shrub and herbaceous layers are present in varying degrees, represented by diverse woody and non-woody species. Vegetation on most sites consists of early- to mid-successional managed stands of pine and pine-hardwood forest. The understory in pure pine stands is often open, but in mixed or older stands, it is dominated by the hardwoods characteristic of the site.
Maritime Forest	This land covertype is most dominant in the Coastal Zone, but a small portion is detectable with GAP mapping procedures in this ecoregion. It is most likely composed of live oak (*Quercus virginiana*) suffusely decked with Spanish moss (*Tillandsia usneoides*) and resurrection fern (*Pleopeltis polypodioides*), Southern magnolia (*Magnolia grandiflora*), cabbage palmetto (*Sabal palmetto*), laurel oak (*Quercus laurifolia*), and the occasionally loblolly pine (*Pinus taeda*). These are usually closed canopy forests in protected inner dune zones with deep sands with an understory characterized by medium-dense to sparse shrub layer that may include southern red cedar *(Juniperus silicicola)*, cabbage palm *(Sabal palmetto)*, American holly *(Ilex opaca)*, red bay *(Persea borbonia)*, wax myrtle *(Morella cerifera)*, and yaupon holly *(Ilex vomitoria)*.

	Maritime forests exhibit much greater species and structural diversity away from the direct effects of salt spray where deciduous trees are more common and include southern red oak *(Quercus falcata)*, water oak *(Quercus nigra)*, sugarberry *(Celtis laevigata)* and pignut hickory *(Carya glabra)*. Dogwood *(Cornus florida)*, American olive *(Osmanthus americana)*, and Carolina laurel cherry *(Prunus caroliniana)* are also common in the understory. Under fragmented canopy conditions, shrubs, including beauty-berry *(Callicarpa americana)* and red buckeye *(Aesculus pavia)* become more common, and saw palmetto *(Serenoa repens)* which reaches its northern extent of its range on Kiawah Island in Charleston County. A variant maritime forest resembling xeric pine woodland of the Coastal Plain occurs on relict dune ridges inland from the barrier island forests. This habitat has an open super-canopy of longleaf pine *(Pinus palustris)* with an understory composed of live oak *(Quercus virginiana)*, laurel oak *(Quercus hemisphaerica)*, sand live oak *(Quercus geminata)* and turkey oak *(Quercus laevis)*. Unlike typical maritime forests, maritime Sandhill forests are open and characterized by patches of bare sand and lichens, such as reindeer lichens *(Cladonia* spp.).
Grassland and Early Successional Habitat *(specialized habitat not mapped at this scale)*	As in other ecoregions, a variety of grassland and early-successional habitats are present, either as transitional vegetation following forest disturbances or as managed areas. Early-successional habitats reach their greatest extent in the Coastal Plain Ecoregion. These habitats are generally characterized by tree canopy coverage that is sparse or absent and herbaceous groundcover comprised of annual forbs, perennial bunchgrasses, and variable coverage of shrubs and small trees. A variety of open land covertypes represents this category and can include native prairies, savannas, old field sites, open canopy gaps, shrub-scrub thickets, recently-cleared forests, field borders, grassed waterways, and filter strips. Lawns, golf courses, pastures, hay fields, crop fields, airports and various urban open spaces are sometimes included in this habitat type but lack the floristic and structural diversity to be considered high quality, early-successional habitat (see Cultivated Land and Pasture). Minor modifications to agricultural land use, such as replacing introduced grasses with native grasses, using native grasses in filter strips and grassed waterways, and implementing no-till or strip-till in crop fields can result in dramatic improvements to quality of early-successional habitat. Maintenance of early-successional habitat requires periodic repeated disturbance or disruption of the existing vegetative community. Purposeful management of early-successional habitat is usually

	accomplished through the use of timber harvest, prescribed burning, disking, or mowing. Target species for management will determine disturbance intervals, with shorter intervals (1-2 years) favoring those species dependent on herbaceous vegetation and longer intervals (3-5 years) favoring those species dependent on shrub cover. Optimal multi-species management often dictates concurrent maintenance of variety of successional, or seral, stages. Early-successional habitat types have declined dramatically over the past 70 years primarily due to changing agricultural practices, forest succession, fire suppression, and urban / suburban encroachment. A large portion of existing early-successional habitat occurs on privately owned lands. One of the greatest challenges to maintaining priority species associated with this particular land cover is private land outreach and technical assistance.

Freshwater Streams, Rivers and Lakes

[A large proportion of the freshwater streams, rivers, and swamps in the Coastal Plain Ecoregion were mapped within the Bottomlands and Riparian Zones covertype.]

Freshwater habitats in the Coastal Plain exhibit a wide range of characteristics depending on elevation and gradient, with first- through fourth-order streams comprising the majority of aquatic habitats by length. Streams at higher elevations in this ecoregion may possess moderate flow and primarily sand substrate with patchy aquatic vegetation, often slowing and widening into densely vegetated swamps in areas of lower gradient. In the lower elevations of the region, streams generally are sluggish, strongly meandering blackwater channels with primarily organic substrates including detritus and woody debris. Streams in the Coastal Plain are often strongly associated with adjacent floodplain swamps and wetlands in which the exchange of water, nutrients, and biota is critical to ecosystem function. The Coastal Plain contains portions of all of South Carolina's major river basins.

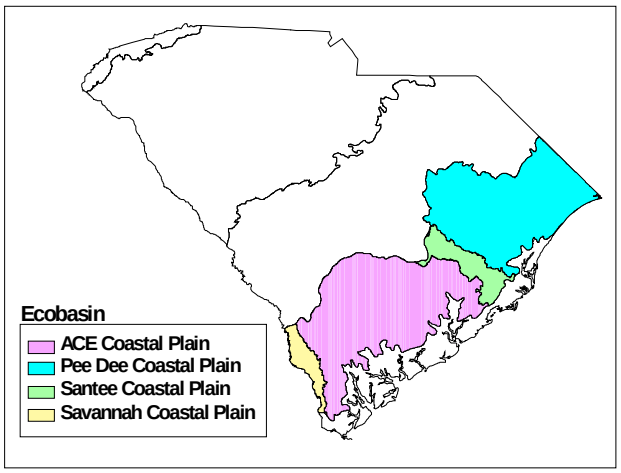


FIGURE 4-13: Ecobasins in the lower portion of the Coastal Plain Ecoregion

The Lower Coastal Plain is situated directly below the Southeastern Plains and terminates at the Coastal Zone marsh. In South Carolina, it extends northwest from the Savannah River to the North Carolina State line. The Lower Coastal Plain intersects 19 counties and covers approximately 22,157 km^2 (8,555 $mi.^2$). The Coastal Plain is nearly level with elevations ranging from 8-38 m (25-125 ft.). The major aquatic habitats within the

ecoregion include lazy meandering streams, swamps, marshes, and estuaries. Pocosins and Carolina Bays are abundant in some areas. These unique aquatic habitats are discussed in more detail in the Coastal Zone Ecoregion.

Savannah–Coastal Plain Ecobasin

The Savannah-Coastal Plain Ecobasin is located in the extreme southwest corner of the State extending from southern Allendale County through Hampton and Jasper Counties before terminating at the Coastal Zone marsh. The ecobasin includes 72 km (45 mi.) of the Savannah River as it meanders toward the coast. Primary tributaries to the Savannah River in this ecobasin include Brier Creek and Boggy Branch. The ecobasin intersects 10 watersheds and covers 906 km^2 (350 $mi.^2$). The ecobasin contains approximately 446 km (277 mi.) of lotic habitat and 251 ha (620 ac.) of lentic habitat. There are no major reservoirs within the ecobasin; the largest lentic habitat is only 26 ha (62 ac.).

Primary conservation targets within the ecobasin include the main stem of the Savannah River throughout the ecobasin and the Brier Creek/Boggy Gut Creek system in Allendale County (Smith et al. 2002). The main stem of the Savannah River contains several aquatic animals that are on South Carolina's Priority Species List including fish (Shortnose Sturgeon and Robust Redhorse) and mussels (pod lance and Savannah lilliput). The Brier Creek/Boggy Gut Creek system is home to one of the few known populations of Bluebarred Pygmy Sunfish.

Water quality was impaired at 7 of 10 sites sampled by the SCDHEC (2003a). Aquatic life uses were not supported at two sites due to a lack of invertebrate diversity and low dissolved oxygen levels. Fish consumption advisories were listed for 5 sites due to mercury contamination. Fish consumption advisories have been issued for the Savannah River and Cypress Creek. Point source pollution from within the ecobasin is not currently a major threat as there are only two active discharges permitted by SCDHEC: one municipal and one industrial. There are no active agricultural operations permitted by SCDHEC within the ecobasin. None of the streams within the ecobasin is considered an outstanding resource water by SCDHEC.

Approximately km 58 km (36 mi.) of stream within the ecobasin have been impounded. There are 15 dams permitted by SCDHEC within the ecobasin, none of which impound navigable streams. Numerous other dams not permitted by SCDHEC also occur in the ecobasin.

There is little expected growth throughout the majority of the ecobasin. One area that may experience moderate growth is the area near the town of Hardeeville.

ACE–Coastal Plain Ecobasin

The northern extreme of the ACE-Coastal Plain Ecobasin is situated in central Bamberg and Orangeburg Counties. The ecobasin encompasses parts of Allendale, Hampton, Colleton, Dorchester, Jasper, Beaufort, Berkeley and Charleston Counties before terminating at the Coastal Zone marsh. Coastal rivers in the ecobasin include the Coosawhatchie, Salkehatchie, Combahee, Ashepoo, Ashley, Edisto, and Cooper.

The Coosawhatchie River originates just north (10 km or 6 mi.) of the Coastal Plain in the Southeastern Plains and flows for about 76 km (47 mi.) through the Coastal Plain before merging with Tulifiny River to form the Broad River, which ultimately is deposited into the Atlantic Ocean at Port Royal Sound. The Salkehatchie River originates in the Southeastern Plains and flows for about 43 km (27 mi.) through the Coastal Plain before merging with the Little

Salkehatchie River to form the Combahee River, which flows for 82 km (51 mi.) through the Coastal Plain before terminating in the Atlantic Ocean at St. Helena Sound. The Ashepoo River originates in the Coastal Plain and flows for about 92 km (57 mi.), picking up inputs from Horseshoe Creek and Deer Creek before terminating at the Atlantic Ocean in St. Helena Sound. The Edisto River is formed at the confluence of the North Fork Edisto River and South Fork Edisto River. Each fork originates in the Southeastern Plains and flows for about 31 km (19 mi.) through the Coastal Plain before merging and forming the Edisto River. The Edisto River flows for about 196 km (122 mi.) through the Coastal Plain before entering St. Helena Sound and the Atlantic Ocean. As the Edisto flows through the Coastal Plain, it picks up inputs from Field Swamp, Four Hole Swamp, and Penny Creek. The Ashley River originates entirely in the Coastal Plain. Its headwater, Great Cypress Swamp, flows for about 40 km (25 mi.) until it merges with Captains Creek to form the Ashley River. The Ashley River flows for about 64 km (40 mi.) through the Coastal Plain until terminating at Charleston Harbor and the Atlantic Ocean. The Cooper River is formed at the confluence of the East Branch and West Branch Cooper River. Once a self-contained drainage, the Cooper River now receives inputs from the Santee River via a diversion canal that diverts water from Lake Marion to Lake Moultrie. The West Branch Cooper River originates at the tailrace of Lake Moultrie and flows through the Coastal Plain for about 29 km (18 mi.) before merging with the East Branch Cooper River to form the Cooper River. The Cooper River flows through the Coastal Plain for about 48 km (30 mi.), picking up inputs from the Back River, Goose Creek, and Filbin Creek along its western shore; further, Flag Creek and Yellow House Creek are picked up along its eastern shore before being deposited in Charleston Harbor and the Atlantic Ocean.

The ecobasin intersects 72 watersheds and encompasses 10,601 km^2 (4,093 $mi.^2$). There are approximately 5,919 km (3,678 mi.) of lotic habitat and 280 km^2 (108 $mi.^2$) of lentic habitat within the ecobasin. The majority (231 km^2 or 89 $mi.^2$) of lentic habitat is represented by Lakes Moultrie and Marion, the only major reservoirs in the Coastal Plain.

Primary areas of conservation concern in the ACE-Coastal Plain Ecobasin include the Jasper County wetlands in Jasper County; the Cypress/Beaver Dam Creek systems in Jasper and Hampton Counties; the Sandy Run system in Colleton County; the lower North Fork Edisto and main stem Edisto Rivers throughout the ecobasin; and the Cooper River in Berkeley and Charleston Counties. The Jasper County wetlands, Cypress/Beaver Dam Creek, and the Sandy Run systems all contain populations of Bluebarred Pygmy Sunfish and other fishes that are on South Carolina's Priority Species List. The North Fork and main stem Edisto River contain several fish species on the priority species list ("Broadtail" Madtom, Shortnose Sturgeon, Bannerfin Shiner, and Striped Bass). The Cooper River and its backwaters contain populations of Bluefin Killifish, Striped Bass and the Federally Endangered Shortnose Sturgeon.

Water quality was impaired at 72 of 115 sites (62%) sampled by SCDHEC. Aquatic life uses were not supported at 30 sites due to a lack of invertebrate diversity (13 sites), low dissolved oxygen concentrations (7 sites), zinc excursions (5 sites), abnormal pH values (3 sites), high turbidity (1 site), and chromium excursions (1 site). Recreational uses were not supported at 23 sites primarily due to high concentrations of fecal coliform bacteria. Mercury excursions were found in the tissue of fish at 19 sites. Fish consumption advisories have been issued for nearly every major water body in the ecobasin including the North Fork Edisto River, South Fork

Edisto River, main stem Edisto River, Cooper River, East Fork Cooper River, Ashepoo River, Salkehatchie River, Little Salkehatchie River, Combahee River, Coosawhatchie River, New River, Black River, Ashley River, Four Hole Swamp, Wadboo Creek, Chessie Creek, Horseshoe Creek, Lake Moultrie and Goose Creek Reservoir.

Water quantity will likely be a future challenge to the aquatic habitats of the ACE-Coastal Plain Ecobasin. Currently, an interbasin water transfer exists on the Edisto River where water is removed via the water treatment plant to support the town of Hannah and the large industries along the Cooper River.

There is a moderate amount of industrial and agricultural activity within this ecobasin. Increased industrial growth along the Cooper River, the expected large scale residential growth in the town of Hannah, and growth in North Charleston will exacerbate water quantity issues.There are 98 active discharges permitted by SCDHEC; of those active discharges 60 are industrial discharges, 26 are municipal discharges, and 12 are community discharges. There are 87 CAFOs permitted by SCDHEC; the majority of those facilities are poultry farms (17 small, 21 medium, and 10 large). Swine farms also contribute significantly to the total number of agricultural facilities with 21 sites (11 small, 9 medium, and 1 large). CAFOs are not a major threat to aquatic habitats overall, but may pose a significant threat to portions of the ecobasin. The vast majority (70 operations) of the agricultural facilities are located in the north-central portion of the ecobasin in the Edisto River Basin, primarily in the Cattle Creek, Indian Field Swamp, and Cowcastle Creek watersheds. CAFOs likely pose a significant threat in those watersheds.

There is little expected commercial, residential, or industrial development throughout most of the northern portion of the ecobasin, although, a moderate amount of commercial and residential growth can be expected along the I-95 corridor and Lake Moultrie. In the middle and southern portion of this ecobasin, uncontrolled residential, commercial, and (potentially) industrial growth is a serious threat to aquatic habitats. Many areas are experiencing high levels of commercial and residential development as spillover from Charleston. The area between Cottageville and Charleston along the US 17 corridor is one of the fastest growing areas in the State. Other areas where large-scale residential and commercial development is expected include the towns of Ridgeland and Bluffton.

Approximately 117km (73 mi.) of stream in the ecobasin have been impounded. There are 77 dams permitted by SCDHEC within the ecobasin. The majority of the impounded area is a result of Pinopolis Dam on the Cooper River that forms Lake Moultrie. The Pinopolis Dam has had a significant negative impact on the Cooper River below the dam. Currently, there is no continuous minimum flow for the Pinopolis Dam tailrace, and aquatic habitats are frequently dewatered during low flows.

Santee–Coastal Plain Ecobasin

The Santee-Coastal Plain Ecobasin originates in southeastern Clarendon County and encompasses portions of Williamsburg, Berkeley, Georgetown and Charleston Counties before terminating at the coast. The only major river within the ecobasin is the Santee River. The headwaters of the Santee originate in the Blue Ridge and Piedmont Ecoregions. The Santee River flows for approximately 130 km (81 mi.) through the Coastal Plain, receiving inputs from Echaw Creek and Wambaw Creek, until terminating at the Atlantic Ocean. The ecobasin intersects 19 watersheds and encompasses 1,606 km^2 (620 $mi.^2$). There are 921 km (572 mi.) of lotic habitat and 11 km^2 (4.4 $mi.^2$) of lentic habitats. There are no large impoundments within the ecobasin.

Ten of 16 sites (62.5%) sampled by SCDHEC (1999b) within the ecobasin were impaired. Aquatic life uses were not supported at 2 sites due to a lack of invertebrate diversity. Recreational uses were impaired at 2 sites due to the presence of high fecal coliform concentrations. Fish consumption advisories due to mercury contamination have been issued for the Diversion and Rediversion Canals, Santee River, South Santee River, North Santee River, Wambaw Creek and Wadmacon Creek.

There are 19 active discharges permitted by SCDHEC within this ecobasin. Of those active discharges, 16 are from industrial sources and 3 are from municipal sources. There is only one active agricultural operation, a medium-sized poultry farm, within the ecobasin.

Development in this ecobasin is not a major concern, but moderate growth is expected on the south side of Lake Marion and in the vicinity of the town of St. Stephen.While much of the Santee River flood plain is public land, a substantial amount is privately held; removal of tree canopy poses a threat to aquatic habitats. The increasing trend towards conversion of upland agrarian land use to smaller home sites has the potential to negatively change hydrology, nutrient loading, and sedimentation. A growing beaver population is also likely to affect streams in this ecobasin, changing habitat that favors warm lentic-adapted species over those that favor cooler lotic habitats.

There are no large impoundments in this ecobasin; roughly 11 km (6.8 mi.) of stream are impounded. There are 11 dams permitted by SCDHEC within the ecobasin, although numerous unpermitted dams also occur in the ecobasin. Aquatic habitat in the Santee River is negatively influenced by the operation of the Santee Dam upstream.

Pee Dee–Coastal Plain Ecobasin

The Pee Dee-Coastal Plain ecobasin is located in the northeast corner of the State and encompasses portions of Dillon, Lee, Horry, Florence, Marion, Sumter, Clarendon, Williamsburg, and Georgetown Counties. Several coastal rivers are located within the ecobasin, including the Black River, Lynches River, Pee Dee River, Little Pee Dee River, and Waccamaw River. The headwaters of the Black River originate in the Southeastern Plains. The Black River flows unimpounded through approximately 198 km (123 mi.) of the Coastal Plain before merging with the Pee Dee River at the coast. As the Black River flows through the Coastal Plain it picks up inputs from several major tributaries including Black Mingo Creek, Peters Creek,

Cottage Creek, Lanes Creek and Six-mile Creek. The headwaters of the Lynches River originate in the Piedmont of South Carolina and North Carolina. The Lynches flows unimpounded through approximately 124 km (77 mi.) of the Coastal Plain before merging with the Pee Dee River near Gilbert Crossroads, SC. Major tributaries to the Lynches River in the Coastal Plain include Sparrow Swamp and Lake Swamp. The Pee Dee River originates in the southern portion of the North Carolina Piedmont and Southeastern Plains and flows through about 143 km (89 mi.) of South Carolina's Coastal Plain before terminating at Winyah Bay. As the Pee Dee flows through the Coastal Plain, it picks up inputs from several significant tributaries, including Catfish Creek, Lynches River, Little Pee Dee River, Conch Creek and the Black River. The Little Pee Dee River originates in the Southeastern Plains of North Carolina and flows through approximately 119 km (74 mi.) of the South Carolina's Southeastern Plains before entering the Coastal Plain. Within the Coastal Plain, the Little Pee Dee River flows for about 105 km (65 mi.), receiving input from the Lumber River before merging with the Pee Dee River. The Waccamaw River originates in the Coastal Plain of North Carolina and flows through approximately 167 km (104 mi.) of South Carolina's Coastal Plain before terminating at Winyah Bay. Within the ecobasin, the Waccamaw River picks up significant inputs from Buck Creek, Simpson Creek, and Kingston Swamp.

The ecobasin intersects 50 watersheds and encompasses 9,044 km^2 (3,492 $mi.^2$). Within the ecobasin, there are approximately 6,027 km (3,745 mi.) of lotic habitat and 47.4 km^2 (18.3 $mi.^2$) of lentic habitats. There are no major impoundments (lakes) within the ecobasin. Approximately 58.7 km (36.5 mi.) of streams are impounded within this ecobasin. There are 73 dams permitted by SCDHEC, most of which occur on small tributary streams.

Areas of primary conservation concern in the Pee Dee-Coastal Plain Ecobasin include the Lynches River and its tributaries in Lee, Florence and Sumter Counties; the Pee Dee River from its confluence with the Lynches River to Winyah Bay; and the upper Waccamaw River in Horry County. The Lynches River contains populations of "broadtail" madtom as well as several mussel species on South Carolina's Priority Species List (brook floater, creeper and notched rainbow). The Pee Dee River and its backwaters contain several fishes on the priority list including the "Broadtail" Madtom, Robust Redhorse, Carolina Pygmy Sunfish and the Federally Endangered Shortnose Sturgeon. Several mussel species on the priority list are in the Pee Dee River, including the Waccamaw spike, yellow lampmussel, Roanoke slabshell, and rayed pink fatmucket. The upper Waccamaw contains populations of Carolina Pygmy Sunfish and "Broadtail" Madtom as well as mussel species (Waccamaw spike and yellow lampmussel).

Water quality was impaired at 70 of 110 sites (64%) sampled by SCDHEC. Aquatic life uses were not supported at 23 sites due to low dissolved oxygen levels (11 sites), abnormal pH values (5 sites), copper contamination (3 sites), lack of invertebrate diversity (3 sites), and zinc contamination (1 site). Recreational uses were not supported at 3 sites due to the presence of high concentrations of fecal coliform bacteria. Due to high levels of mercury in fish tissue, SCDHEC has issued a fish consumption advisory for the entire length of every major river (Pocotaligo River, Black River, Black Mingo Creek, Lynches River, Pee Dee River, Little Pee Dee River, Lumber River, and Waccamaw River) in the ecobasin.

There are a moderate number of point source discharges within the ecobasin with 76 active

discharges permitted by SCDHEC. Of those active discharges, 38 are from municipal sources, 31 are from industrial sources, and 7 are from community sources. There are 71 active agricultural facilities within the ecobasin, the majority (48) of which are swine farms (27 small farms, 14 medium farms, and 7 large farms). Poultry and turkey farms are also prevalent within the ecobasin, accounting for 20 operations (2 small farms, 15 medium farms, and 3 large farms).

Increased population growth accompanied by unplanned and uncontrolled industrial, residential, and commercial development is a serious threat to aquatic resources in the Pee Dee-Coastal Plain Ecobasin. The majority of the growth and the greatest threat to aquatic resources is expected to occur along the eastern portion of the ecobasin near the coast. Increased commercial and residential growth is expected along several highway corridors: US 52 connecting Florence to Charleston, US 378, and US Hwy 501 connecting I-95 to Myrtle Beach. The construction of a proposed new interstate highway (I-73) running from Michigan to Myrtle Beach, South Carolina has the potential of significantly impact the aquatic resources of this ecobasin. The final route for I-73 has not been established; therefore, the exact location for impacts is unknown. Residential and resort communities along the "Grand Strand" will strain the already significantly degraded aquatic habitats. When developed, the largest tract of currently undeveloped land (Buist Tract) in Horry County is expected to accommodate 10,000 new residents and 11 new golf courses.

Marine Ecosystems

This land covertype occurs primarily in the Coastal Zone, although according to the SC GAP data, a small portion was mapped within this ecoregion. It included any brackish or salt waters, associated with estuaries or the Atlantic Ocean coast and was supported by the National Wetland Inventory salt water class (GAP 2001). See a more comprehensive definition for Marine Ecosystems within the Coastal Zone Ecoregion.

Region-wide Challenges

Although overall urban growth rates in the Coastal Plain are not as high as those in the Piedmont and Coastal Zone Ecoregions, there are some local exceptions. The Myrtle Beach area, at the eastern-most boundary of the region, is one of the fastest growing areas in the country. Two other cities qualify as Metropolitan Statistical Areas: Florence and Sumter. Three cities in the state recently received a new designation from the Census Bureau and are known as Micropolitan Statistical Areas: Bennettsville, Dillon and Walterboro. This designation recognizes that, although these areas are small in comparison to the larger Metropolitan Statistical Areas, they nevertheless have many of the same characteristics as larger urban areas and are experiencing typical urban growth dynamics. Rural portions of two counties, Jasper and Beaufort, are also exposed to the leading edges of expansion from rapidly growing coastal cities, namely Beaufort, South Carolina and Savannah, Georgia.

Pine woodland is likely the most fire-adapted forest in North America. Historically, frequent low-intensity fires were ignited by both Native Americans and lightning. Pre-colonial fire frequencies in the southeastern Coastal Plain region have been estimated at 1-3 years. As European settlement expanded, features such as roads and plowed fields created incidental

firebreaks. By the early 20th century, fire had come to be viewed as an agent of destruction and was actively and effectively suppressed. Reduction in fire frequency to intervals greater than 5 years leads to elimination of the herb layer in pine woodlands (Frost 1990) and eliminates much of the habitat value of early-successional stages.

The benefits of prescribed burns, especially those conducted during spring and summer months, are now more widely appreciated; however, burning is increasingly hampered by liability concerns. Expanding urban areas and proliferating highways are such that the smoke from a prescribed fire often creates extremely dangerous conditions. Keeping smoke away from roads is further complicated by the highly variable nature of the weather during the spring and summer months.

Few, if any alternative treatments have, however, been developed that can compete with fire from the standpoint of effectiveness and cost. Currently, the cost per acre for a controlled burn is $15-30 while a chemical treatment is typically $65-80 per acre, or about 2-3 times as much per acre as prescribed fire. Mechanical treatments such as disking, chopping, or raking are even more expensive. However, a combination of a chemical application to "burn down" the vegetation, followed by a controlled burn, can be a very effective management regime in some cases. The competing hardwoods are controlled better, and the follow-up cool season burn cleans up the duff layer to promote the growth of native grasses and forbs for wildlife.

Challenges to conservation of aquatic fauna in the Coastal Plan Ecoregion are similar to other ecobasins in the State and primarily include impacts associated with impoundments, non-point source pollution, point source pollution, poorly planned development, and introductions of non-native species. Increased population growth and the accompanying uncontrolled residential, commercial, and industrial growth may be the greatest challenge to species and their habitats in this ecoregion, especially near the coast.

There is only one major impoundment (Lake Moultrie) in the Coastal Plain; however, dams still have a significant impact on aquatic resources within the ecoregion. There are roughly 176 dams permitted by SCDHEC, although numerous other unpermitted dams, such as those associated with farm ponds, also exist and impound 245 km (152 mi.) of stream. The presence of dams results in a loss of connectivity and negatively affects aquatic biota both above and below the impoundment (Doeg and Koehn 1994; Kanehl et al. 1997; Tiemann et al. 2004). Impoundments negatively affect native aquatic fauna by direct 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. In addition, impoundments often negatively impact unimpounded reaches downstream by altering hydrologic and thermal regimes (Cushman 1985), modifying stream channel morphology, increasing erosion and sedimentation (Waters 1995), and ultimately reducing suitable habitat for native aquatic fauna (Helfrich et al. 1999; Tiemann et al. 2004). Dams in the Coastal Plain like Pinopolis Dam also hinder the migrations of native anadromous fish including shad, Striped Bass, and sturgeon to their historic spawning grounds in the Piedmont.

Siltation resulting from clearing forests, tilling soils, and the channelization of Coastal Plain streams has altered stream morphology. Modern soil conservation practices and reduced

channelization have lessened those impacts, but sedimentation from non-point 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. When timber managers fail to follow Best Management Practices (BMPs), significant siltation occurs. 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. Channelized streams lead to increased erosion of cropland and increased sedimentation of the receiving streams (Etnier and Starnes 1993). The result of channelization changed many streams into straight, shallow ditches with severely depressed populations of aquatic fauna.

Clearing hardwoods from bottomland and cypress swamps also threatens aquatic habitat in the Coastal Plain. In addition to increasing sedimentation and erosion, the loss of canopy results in increased water temperatures that will limit the amount of available habitat for some species like Striped Bass. Timber companies, which have been proven to be good stewards of the land, are selling off large tracts of land, making floodplain timber more vulnerable to harvest by other owners.

Excessive contamination from nutrients and chemicals also negatively affect water quality within the ecoregion. Point source discharges from industrial, municipal, and commercial sources add a variety of pollutants to receiving streams, rivers and lakes. In addition, contamination from non-point sources also negatively impacts water quality. Nationwide, pollution from agricultural sources is the greatest cause of impairment to streams and lakes (SCDHEC 2003). Statewide, the Coastal Plain has a modest amount of permitted discharges and concentrated animal feeding operations (CAFOs), 2.3 and 1.9 per 259 km^2 (100 $mi.^2$), respectively. However, those discharges and CAFOs are a significant threat to aquatic habitats. Water quality in the coastal plain was impaired at 63% of the sites sampled by the SCDHEC, which is the highest impairment rate of the 4 ecoregions in the state. Recreational uses were impaired at nearly 11% of the sites sampled due to the presence of high concentrations of fecal coliform bacteria. Fecal coliform bacteria are present in the digestive tract of warm-blooded animals. Although the bacteria themselves are not generally harmful to humans, they do indicate that surface waters may contain disease-causing pathogens (SCDHEC). Of the streams sampled by SCDHEC (2003?) within the ecoregion, 23% 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 is 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. Nearly 30% of the sites sampled by SCDHEC were impaired due to mercury contamination in fish tissue, which is the highest impairment rate in the State.

Water quantity is also a problem in Coastal Plain streams. Water withdrawal for irrigation is a common practice in the ecoregion. During summer months, some streams are completely dewatered due to uncontrolled irrigation of croplands. Furthermore, many pond owners will close their drain structures during dry periods in an attempt to maintain esthetic water levels, thereby dewatering the stream below. With rapidly increasing human 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.

Introductions of non-native species have had a significant impact on native aquatic fauna in the Coastal Plain Ecoregion. Buffalo (fish), Common Carp, Flathead Catfish, and Blue Catfish are established in several drainages. Flathead Catfish and blue catfish introductions probably pose the greatest direct risks to native fauna. Flathead Catfish have been shown to prey on bullheads, darters, shad, suckers, and sunfish. Severe declines in native species, particularly bullheads and sunfish, have been observed after the introductions of Flathead Catfish (Guire et al. 1984; Jenkins and Burkhead 1993; Bart et al. 1994). It is not well known what effects buffalo have on the native community, but it has been suggested that they may be a factor in the decline of some catostomids in the Pee Dee River (Wayne Starnes, pers. comm.). 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.

The Asian clam, *Corbicula fluminea*, has been introduced and has spread widely throughout the United States, including into South Carolina. The effects of *Corbicula* on native species are not particularly well understood. According to a review of the literature on interactions between *Corbicula* and native mussels (Dillon 2000), most field studies failed to find any significant negative effects on native mussels, although a few detected reductions in growth. Three invasive snail species (*Viviparus georgianus*, *V. purpureus*, and *Bellamya/Cipangopaludina japonica*) are present in Lakes Marion and Lake Moultrie; however, their impact on native fauna is not known.

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 native catfish have made it particularly difficult to determine the extent of its introduced range. In North Carolina, it has become established in all drainages in the Coastal Plain and Eastern Piedmont Plateau and appears to have extirpated all the native crayfish at one location (Cooper 2003). Introduced crayfish are thought to be the biggest threat to native crayfish species (Lodge et al. 2000 a,b); the risk to our native species is great if further introductions or extensive spread on non-indigenous crayfish occurs.

Sand mining operations have been initiated, or are ongoing, in the main stem or riparian areas of many Coastal Plain rivers. Instream sand mining is a significant threat to aquatic resources within the ecoregion. Sand mining not only causes bank instability and loss of riparian habitat at the mining site, but also causes instream impacts by changing the physical and chemical habitat. Such impacts can negatively affect biological communities (Nelson 1993) and recreational uses (Hartfield 1993). Physical impacts on instream habitat include increasing bedload materials and turbidity, changing substrate type and stability, and altering stream morphology (Nelson 1993). Physical habitat alterations associated with sand mining can adversely affect the biological community by impacting the reproduction and survival of fishes (Stuart 1953; Newport and Moyer 1974) and the distribution, composition, and reproduction of other aquatic organisms (Buck 1956; Trautman 1957; Newport and Moyer 1974).

Coastal Zone Ecoregion

The Coastal Zone is the portion of the Lower Coastal Plain that lies seaward of US Highway 17. This region includes a small portion of the mainland but is primarily comprised of tidal marshlands and associated uplands. Large sea islands that are greater in size than 1,000 ac. (404.69 ha) are included. These extend eastward to include barrier islands, Atlantic Ocean beaches, and the Atlantic Ocean shallow continental shelf offshore to South Carolina's 4.8 km (3 mi.) jurisdictional boundary. The lower approximately 32-48 km (20-30 mi.) of all of the State's coastal rivers are included in the Coastal Zone.

The inland boundary of the Coastal Zone is somewhat arbitrary relative to mainland habitats, but it is particularly relevant to riverine and alluvial habitats since Section 50-5-80 of the Code of Laws of South Carolina establishes boundaries for fresh and 'marine' waters that are generally associated with US Highway 17. These boundaries were established primarily for wildlife law enforcement concerns related to freshwater and marine fishery laws and regulations. The actual point at which riverine waters change from fresh (salinity of < 0.5 ppt) to brackish or 'marine' (salinity > 0.5 ppt) is highly variable, even on a daily basis, depending upon the combined impacts of tides and river discharge (as determined by rainfall) or water releases from dams. South Carolina experiences semi-durnal tides such that two high tides and two low tides occur approximately every 24 hours and can be described as microtidal in terms of their range of 0 to 2 m (0-6 ft.). During each approximately six-hour period from low tide (maximum ebb) to high tide (maximum flood), the point of change from fresh to brackish water—in some places existing as a "salt wedge"—may move several miles upriver, only to return downriver during the next ebb tide period.

The soils or surficial sediments (sands, silts and clays) of the Coastal Zone are derived from the Appalachian Mountains and are organized into coastal, fluvial (riverine) and aeolian (dune) deposits. Most of these deposits were transported seaward during the Quaternary Period, which began approximately 1.8 million years ago. Underlying these surficial sediments is a bedrock stratum of eroded sedimentary rocks dating back to the Tertiary Period and the Mesozoic Era, between 130 and 1.8 million years ago. With the exception of manmade quarries, the bedrock stratum within the Coastal Zone is only exposed on river banks and bottoms, in deep scoured tidal channels, and on near-shore Atlantic Ocean continental shelf bottoms as "hard bottom." The oldest sedimentary rocks are deeply buried sandstones, shales, and siltstones from the Cretaceous period (up to 130 million years old). Limestones ranging in age from 100 to 30 million years overlie these sedimentary rocks (Mathews et al. 1980).

Much of the South Carolina Coastal Zone has been adversely affected by human population growth and associated coastal development. By the early 1990s, approximately 50% of the total US human population lived in coastal areas (Moore et al. 1995), and an annual increase of 7.3% is still occurring (Appalachian State University 2008). The trend of concentrated population growth along coasts is expected to continue into the next century (Cullitan et al. 1990; SCFC 2010). In the 1990s, approximately 142 km (88 mi.) or 48.6% of South Carolina beachfront was affected by development (Kana 1988), but this number has since increased.

The rapid rate of human population growth and associated development in the Coastal Zone has fragmented forests and negatively impacted other valuable habitats, such as shrub thickets and isolated wetlands. The vast majority of protected Coastal Zone holdings are located within two regions: the ACE Basin and the Cape Romain National Wildlife Refuge.

Land Covertypes

The Coastal Zone contains the most diverse amount of habitats of any of the South Carolina ecoregions. Within this ecoregion, many habitats that are intricately linked to priority wildlife species are completely dependent upon the influence of salt water and direct management actions, such as the creation of coastal impoundments.

Diverse forest types are distributed throughout the extreme eastern portion of the Lower Coastal Plain mainland that is adjacent to estuaries and tidal river basins. Due to this proximity, large Coastal Zone islands, including barrier islands, sea islands, and many hammock islands also support forested habitats that are very similar to those found in the Lower Coastal Plain. Forested habitats distributed within both the Coastal Zone and Coastal Plain include: bottomland hardwood, pine woodland, oak-hickory or hardwood-dominated, mixed mesic hardwood and bald cypress/tupelo gum swamp. Larger landmasses within the Coastal Zone also contain grassland, early-successional habitats, and wet flatwoods. Ponds and depressions, or wetlands isolated from tidal waterways also occur in the Coastal Zone. Inter-dune ponds that are restricted to dune systems along the Atlantic Ocean beaches are also included. Figure 4-14 illustrates these Coastal Zone covertypes. Species-habitat associations are presented in Appendices 1 A-D while the faunal makeup of the habitats are described in more detail within this chapter (4).

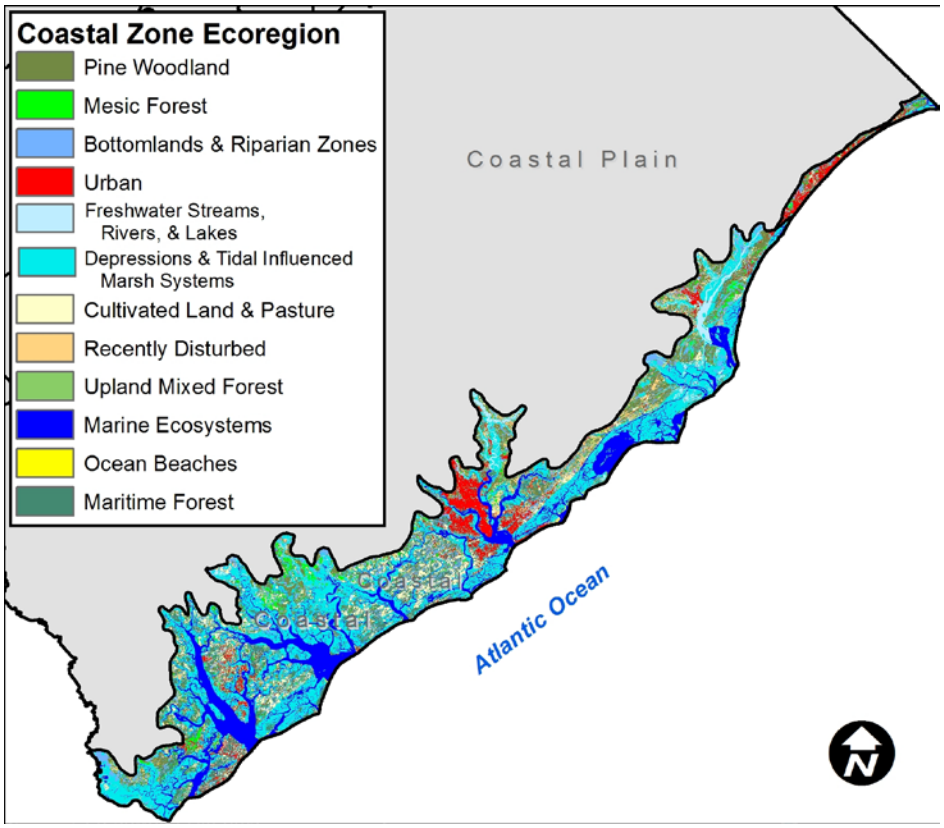


FIGURE 4-14: Land covertypes of the Coastal Zone Ecoregion.

Pine Woodland	This habitat is used to describe all pine-dominated forests throughout the region, including those occupying a variety of soil moisture characteristics except floodplains. The canopy is dominated by one or several species of pine, generally loblolly (*Pinus taeda*) or longleaf (*Pinus palustris*), depending on elevation, soil type and silvicultural history. Dense shrub thickets of hollies (*Ilex* spp.) and wax myrtle (*Morella cerifera*) may be present. Higher elevation pine woodlands have abundant grasses and herbaceous cover, particularly when burning is frequent. Optimal habitat for priority species consists of open stands of longleaf pine, sparse understory and shrub layers, a ground cover of wiregrass (*Aristida* spp.), and diverse herbaceous species. Pine savanna—also known as open savanna—is an important variant of pine woodland. Wet prairie, grass-sedge bog, and herb bog or pitcher plant bog are typically found in the Outer Coastal Plain on flat sites with a high water table and soil that is saturated for at least part of the year. Vegetation consists of a thin canopy of pines, almost always longleaf (*Pinus palustris*), although loblolly (*P. taeda*) and pond pine (*P. serotina*) may also be present. The understory is essentially absent or very scattered. Herbaceous flora is quite rich, consisting of many grasses and sedges. Pine flatwoods intergrade with pine savanna; like pine savanna, it is pine woodland situated on mainly flat or rolling

	terrain with sandy soil and a high water table. Unlike pine savanna, pine flatwoods feature a well-developed subcanopy of several tall shrub species. Pine flatwoods is the principal forest type for much of the Outer Coastal Plain. Sandhill pine woodland is another variation of pine woodland composed of species adapted to xeric, sandy soils. The type occurs principally in the Sandhills but may occur through the Coastal Plain with only limited representation on sand ridges in the Coastal Zone. In the absence of frequent fire, a canopy of longleaf pine, and a subcanopy of turkey oak prevail, interspersed with scrub oak species and scrub-shrub cover. Frequent burning leads to the development of longleaf pine-wiregrass communities.
Mesic Forest	Also found in the outer reaches of the Coastal Plain, these areas may be considered a broad transitional habitat between pine flatwoods and maritime forest. While the sparse canopy typically is dominated by longleaf pine (*Pinus palustris*) and loblolly (*P. taeda*), pond pine (*P. serotina*) may also be present. The understory consists of sporadic tall shrub species like *Ilex* spp. and members of the heath family (Ericaceae), interspersed with characteristic 'bog' species such as *Sphagnum* spp., *Sarracenia* spp., *Rhexia* spp., and grasses and sedges under open canopies. These areas are often closely associated with low-lying maritime forests dominated by live oaks, *Ilex* spp., as well as *Taxodium* and *Nyssa* spp.
Hardwood Slopes and Stream Bottoms *(within Bottomlands & Riparian Zones layer)*	This type is composed of a complex of hardwood and hardwood-pine communities that occupy the floodplains of small streams, mesic bluffs, and infrequently flooded flats in association with streams or rivers. Fire is infrequent, due either to the sheltered locations of these communities on bluffs or their isolation within a floodplain. Several mixed mesophytic subtypes characterized by the presence of American beech *(Fagus grandifolia)* occur in sheltered sites with moist soils, particularly on north-facing river bluffs and on slopes of drains and creeks. On upland flats within floodplains (hammocks), southern magnolia *(Magnolia grandiflora)* frequently shares dominance with American beech. The calcareous cliff and marl forest subtype occurs on circumneutral soils derived from limestone or unconsolidated calcareous substrates such as marl. Forest structure of all subtypes is diverse, with understory, shrub and herbaceous species varying according to soil moisture and chemistry. All subtypes intergrade with blackwater stream forest or river bottom forest on lowland sites and with upland forest on upland sites.
Blackwater Stream Systems	Tributary streams rising in the Sandhills and Coastal Plain are commonly known as "blackwater streams" for the color of tannins

(within Bottomlands & Riparian Zones layer)	leaching from decaying vegetation. Forests on the narrow floodplains formed by these streams typically have a canopy dominated by swamp tupelo *(Nyssa biflora)* and red maple *(Acer rubrum)*. On broader sites, bald cypress *(Taxodium distichum)* can become an important canopy species. Tulip poplar *(Liriodendron tulipifera)*, sweet gum *(Liquidambar styraciflua)*, pond pine *(Pinus serotina)*, loblolly pine *(Pinus taeda*) and laurel oak *(Quercus laurifolia)* are important associates. The shrub layer is open in areas subjected to the most flooding, or it can be fairly dense and pocosin-like in areas subject to infrequent flooding. Headwaters and wet flats immediately above the floodplain can support dense, pocosin-like shrub thickets or, under suitable fire conditions, pure stands of Atlantic white cedar (*Chamaecyperus thyoides*).
River Bottoms *(within Bottomlands & Riparian Zones layer)*	River bottoms, or "bottomland forests" consist of hardwood-dominated woodlands with moist soils that are usually associated with the broad floodplains of major rivers arising in the Piedmont or Blue Ridge. Locally, the floodplains of major coastal plain rivers are significant components of the landscape. Characteristic trees include sweetgum (*Liquidambar styraciflua*), loblolly pine (*Pinus taeda*), water oak (*Quercus nigra*), willow oak (*Quercus phellos*), laurel oak (*Quercus laurifolia*), cherrybark oak (*Quercus pagoda*) and American holly (*Ilex opaca*). A subtype occurs on lower elevation sites interspersed and intergrading with oak-dominated woodlands. Dominant trees are bald cypress (*Taxodium distichium*) and water tupelo (*Nyssa aquatica*), swamp gum (*Nyssa biflora*), Carolina ash (*Fraxinus caroliniana*), water elm (*Planera aquatica*) and red maple (*Acer rubrum*).
Maritime Forest	Maritime forests are the typical forested plant community in the Coastal Zone and are found on barrier islands, salt marsh islands (including hammock islands) and mainland areas that are influenced by salt spray. Maritime forests are typically dominated by live oaks *(Quercus virginiana)*, southern magnolia *(Magnolia grandiflora)* and one or more species of pine. Typical shrubs and small trees include southern red cedar *(Juniperus silicicola)*, cabbage palm *(Sabal palmetto)*, American holly *(Ilex opaca)*, red bay *(Persea borbonia)*, wax myrtle *(Morella cerifera)*, and yaupon holly *(Ilex vomitoria)*. The herbaceous layer is usually fairly sparse due to the dense canopy cover. Maritime forests exhibit much greater species and structural diversity away from the direct effects of salt spray where deciduous trees are more common and include southern red oak *(Quercus falcata)*, water oak *(Quercus nigra)*, sugarberry *(Celtis laevigata)* and pignut hickory *(Carya glabra)*. Dogwood *(Cornus florida)*, American olive

	(Osmanthus americana), and Carolina laurel cherry *(Prunus caroliniana)* are also common in the understory. Under fragmented canopy conditions, shrubs, including beauty-berry *(Callicarpa americana)* and red buckeye *(Aesculus pavia)*, become more common, and saw palmetto *(Serenoa repens)* which reaches its northern extent of its range on Kiawah Island in Charleston County. A variant maritime forest resembling xeric pine woodland of the Coastal Plain occurs on relict dune ridges inland from the barrier island forests. This habitat has an open super-canopy of longleaf pine *(Pinus palustris)* with an understory composed of live oak *(Quercus virginiana)*, laurel oak *(Quercus hemisphaerica)*, sand live oak *(Quercus geminata)* and turkey oak *(Quercus laevis)*. Unlike typical maritime forests, maritime Sandhill forests are open and characterized by patches of bare sand and lichens, such as reindeer lichens *(Cladonia* spp.).
Hammock Island *(specialized habitat not mapped at this scale)*	 Approximately 3,500 hammock (or hummock) islands are distributed throughout the coastal tidelands of South Carolina, located inland of barrier islands. Hammock islands are most abundant (90%) within the expansive estuarine and brackish marshlands and tidal waterways of Charleston, Colleton and Beaufort Counties. Hammock islands range in size from 0.04 to 404.5 ha (0.108-999.9 ac.) and are surrounded by tidal wetlands. Most were naturally formed while some, particularly along the Intracoastal Waterway, were created by the disposal of dredged materials or sediments excavated from post-Civil War era phosphate mining. Many hammocks also occur within the delta portions of coastal river basins. As upland landforms, hammocks provide a diversity of woodland, shrub and wetland habitats. The diversity of habitats, plant communities, and associated fauna generally increase with hammock size. Islands of less than 0.4 ha (1 ac.) may be of uniformly low elevation and may become partially or completely inundated by salt water during extreme high tides. Such hammocks have few, if any, large trees and may be predominantly salt-shrub or grassland. Some very small hammocks with low elevations, precluding inundation except during extreme storm-driven tides, may

	have a few stunted specimens of live oak (*Quercus virginiana*) and/or cabbage palmetto (*Sabal palmetto*), but frequently are composed almost exclusively of stands of southern red cedar (*Juniperus virginiana* var. *silicicola*) with a narrow salt-shrub collar. Most hammock islands that are larger than 0.4 ha (1 ac.) have some cover provided by live oak (*Q. virginiana*) and cabbage palmetto (*S. palmetto*) and in at least these respects share characteristics with typical maritime forest. A narrow band of salt-shrub thicket encircles most hammocks at the marsh and upland interface. A broken band of southern red cedar (*J. virginiana* var. *silicicola*) and shrub thicket dominated by wax myrtle (*Morella cerifera*) frequently occupies the transition zone directly upland of this thicket. Seasonally-flooded depressions and high marsh or salt-shrub incursions or sloughs may extend beneath cabbage palmetto-dominated swales. Frequently, salt-tolerant grasses, sedges and herbs colonize these hydric soils where the shrub layer is absent or sparse. Portions of hammocks abutted by tidal waterways often transition abruptly from mature canopy forest to the high tide zone, with a very thin salt-shrub or high marsh collar if such occurs at all.
Upland Mixed Forest	Vegetation composition of upland forest is similar to that of oak-hickory forest in the Piedmont, where it is a major vegetation type. Upland forest is rare in the Coastal Zone, typically occurring on fire-suppressed upland slopes over calcareous deposits and often associated with shell middens. Representative canopy trees include white oak (*Quercus alba*), nutmeg hickory (*Carya myristiciformis*), sand hickory (*Carya pallida*), loblolly pine (*Pinus taeda*), with chalk maple (*Acer leucoderme*) and ironwood (*Carpinus caroliniana*).
Grassland and Early-Successional Habitat *(specialized habitat not mapped at this scale)*	Typical Coastal Plain upland grasslands or early-successional fields extend into the Coastal Zone, with cover provided by grasses and / or weeds and with few, if any, trees. These habitats are generally characterized by tree canopy coverage that is sparse or absent and herbaceous groundcover comprised of annual forbs, perennial bunchgrasses, and variable coverage of shrubs and small trees. A variety of open land covertypes represents this category and can include native prairies, savannas, old field sites, open canopy gaps, shrub-scrub thickets, recently-cleared forests, field borders, grassed waterways, and filter strips. Lawns, golf courses, pastures, hay fields, crop fields, airports and various urban open spaces with or without damp depressions are sometimes included in this habitat type but lack the floristic and structural diversity to be considered high quality, early-successional habitat (see Cultivated Land and Pasture). Minor modifications to agricultural land use, such as replacing introduced grasses with native grasses, using native grasses in filter strips and

	grassed waterways, and implementing no-till or strip-till in crop fields can result in dramatic improvements to quality of early-successional habitat. Maintenance of early-successional habitat requires periodic repeated disturbance or disruption of the existing vegetative community. Purposeful management of early-successional habitat is usually accomplished through the use of timber harvest, prescribed burning, disking, or mowing. Target species for management will determine disturbance intervals, with shorter intervals (1-2 years) favoring those species dependent on herbaceous vegetation and longer intervals (3-5 years) favoring those species dependent on shrub cover. Optimal multi-species management often dictates concurrent maintenance of variety of successional, or seral, stages. Early-successional habitat types have declined dramatically over the past 70 years primarily due to changing agricultural practices, forest succession, fire suppression, and urban / suburban encroachment. A large portion of existing early-successional habitat occurs on privately owned lands. One of the greatest challenges to maintaining priority species associated with this particular land cover is private land outreach and technical assistance.
Isolated Non-forested Uplands *(specialized habitat not mapped at this scale)*	Numerous small emergent landforms occur within inlets, sounds, bays and river deltas. These are generally sparsely vegetated and are constantly reshaped by the dynamic forces of currents, waves and wind. Such islands lying entirely within sounds and inlets and surrounded by expanses of open, relatively deep water are generally devoid of terrestrial predators, particularly raccoons. Lower-lying islands are vulnerable both to over-washing by storm-induced high tides and to salt spray from strong winds. In more sheltered situations, even though high-profile dunes are absent, vegetation develops in the form of salt tolerant grasses and low shrubs. Sandy beach, intertidal beach, and surf zone habitats may also be present. The extent and type of vegetation likely determines the utilization of such sites by nesting and resting seabirds, shorebirds, and wading birds. Emergent landforms influenced by human activity consist of diked spoil islands and shell rakes. Diked spoil islands are created by the disposal of dredged materials in previously open tidal marshlands or on previously existing uplands. Both dikes and interior areas above normal spoil pooling are usually colonized by early-successional grasses such as broom sedges (*Andropogon* spp.), and shrubs and trees including groundsel tree (*Baccharis halimifolia*), tallowtree (*Triadica sebiferum*) and sugarberry (*Celtis laevigata*). Vegetation cover becomes more dense when spoil deposition is discontinued. Although the value of

	these sites to wildlife is highly variable, spoil islands receiving sediments consisting primarily of sand with a low organic content can be manipulated to maintain an unvegetated condition to facilitate their use by seabirds and shorebirds. Shell rakes are deposits of oyster and other molluscan shells produced by wave action from wind and/or boat wakes that occur along the exposed marsh borders of inlets, sounds, bays and other large waterways. Shell rakes are particularly abundant adjacent to the Intracoastal Waterway and are highly valuable as nesting and roosting sites for American Oystercatchers (*Haematopus palliates*) and other shorebird species. High wakes are especially problematic during the summer when over-washing can destroy oystercatcher nests (T. Murphy, SCDNR, pers. comm. 2004).
Depressions	Depressions, including pools and isolated wetlands, occur throughout the Coastal Zone and may be embedded within larger habitats such as forested habitats, early-successional habitats, hammock islands, maritime forest, and diked spoil islands. Such sites are not generally identified on soil maps. In addition to the isolated wetland subtypes occurring throughout the Coastal Plain, the following subtypes are unique to the Coastal Zone (see Depressions & Tidal Influenced Marsh Systems).

Depressions & Tidal Influenced Marsh Systems	*Man-made Ponds*	These are constructed for recreational, water supply, or stormwater retention, are highly variable with regard to their physical features, water chemistry, and connection to open tidal systems. These factors, as well as land use and other human activities near such wetlands, primarily control both floral and faunal features. Though such habitats are not generally considered high quality wildlife habitat, some provide suitable foraging, nesting, roosting and resting habitat for priority species of wading birds.
	Vernal Pools	These are small, seasonally flooded depressions with

		gradually sloping margins, occur in sandy uplands on barrier islands and within other landforms of recent origin. These pools may be embedded in non-alluvial swamp forests or other forest types within the interior of uplands, or they may lie near the perimeter of uplands and receive occasional input of water of varying salinity on exceptionally high tides. Except where soils are highly saline, many of these habitats have been colonized by the invasive, non-native Chinese tallowtree (*Sapium sebifera*).Vernal pools may be a primary source of low salinity water for birds and mammals and may serve as breeding and/or resident habitat for turtles, amphibians, and crayfish. Since these pools are only seasonally flooded, large predatory fishes are absent. Smaller vernal pools may afford the only wetland habitats on smaller islands.
	Small Depression Ponds	These may intergrade with vernal pools but are permanently flooded, except possibly during severe droughts. Obligate aquatic plants—like fragrant waterlily (*Nymphaea odorata*) or yellow pondlily (*Nuphar lutea*)—may inhabit submerged areas, and a variety of emergent and wetland species, including sedges and grasses, generally colonize shallows and intermittently exposed borders. Small

		depression ponds are generally not affected by tidal activities.
	Interdune Ponds	These are depressions located in swales between beach secondary dunes or ridges that contain permanent or vernal pools. Both vegetation and animal life in pools is largely determined by salinity. Interdune ponds, whether permanently or seasonally watered, may provide at least a short-term supply of low salinity water in areas where it is otherwise generally absent.

Estuarine Systems

Estuaries form one of the predominant landscapes of the Coastal Zone. They consist of interconnected networks of intertidal marshland with tidal channels of various sizes branching throughout, generally interfacing with marine or Atlantic Ocean waters via deep channels through sounds and bays or through smaller inlets. Listed here are the broadly recognized vegetative and geophysical components of estuaries and their inter-relationships:

Salt Marsh	Intertidal marshlands in estuarine (salinity ranges 15 to ~40 ppt) areas that are variously flooded and drained by tidal forces, with influence from lunar cycles, wind, rainfall, and river discharge, particularly within or near river deltas. Smooth cordgrass (*Spartina alterniflora*) is the dominant plant.
Black Needlerush Marsh	The portion of highest elevation salt marsh dominated by black needlerush (*Juncus roemerianus*) which often occurs in dense stands. This habitat is usually near uplands.
Salt Flat	Sparsely vegetated, hypersaline (salinity > 40 ppt), and exposed flats of sand and/or mud. Typical plants include glassworts (*Salicornia* spp.) and saltwort (*Batis maritima*).
Salt-Shrub Thicket	Bands or patches of usually low, dense shrubs that typically interface with high salt marsh and uplands. Characteristic plants include sea ox-eye (*Borrichia frutescens*), marsh elder (*Iva frutescens*), and groundsel tree (*Baccharis*

	halimifolia).
High Marsh Pool	Poorly drained pools in high salt marsh, often near uplands. Salinity is highly variable depending on the frequency and timing of tidal inputs and rainfall. Both soils and water may become hypersaline (salinity > 40 ppt).
Estuarine Intertidal Flat	Mud and sand flats in estuarine systems that have little or no vegetation and are drained on the ebb tide and flooded during high tides. Mud and sand flats may occur between marshlands, channels, and creeks or may be interspersed within marshlands.
Estuarine Intertidal Sandbar	Sandbars in estuarine systems that are partially exposed during part of most tidal cycles (i.e. spring and neap tidal cycles) and river stages but are typically submerged during high tide.
Estuarine Tidal Channels and Creeks	Tidal estuarine waterways of variable depth and with currents generated by riverine and/or tidal flows.
Estuarine Subtidal / Submerged Flat	Mud and sand flats with little or no vegetation that are inundated during all or part of each tidal cycle. Submerged flats include sand and / or mud bottom areas outside of channels and creeks, and usually lie between channel habitats and tidal marshlands.
Oyster Reef	Fringing oyster reefs and extensive reef flats primarily composed of live Eastern oysters (*Crasostrea virginica*). Oyster reefs are predominantly (>95%) intertidal and are often found in close spatial proximity to salt marshes for which they serve as natural breakwaters (fringing reefs). Oyster reefs also occur as flats between tidal channels and salt marsh.
Shell Rakes	Shell rakes are piles of "washed shell" which were at one time on the bottom of a channel, perhaps they were remnants of old subtidal oyster beds. They are so old that their shells are very light weight and over time they get moved by boat wakes, dredging and storms and gradually wash up into the high intertidal zone. They are common along the Intracoastal Waterway but also in many tidal creeks and estuaries. A survey published by the SCDNR in 1979 lists 998 washed shell deposits, 58 % of which are in Beaufort county and 36% in Charleston county. That survey says "Shell

	deposits are formed in estuarine areas where an abundance of submerged oyster shells are exposed to frequent wave action generated by prevailing winds or boat traffic" (Anderson et al. 1979). Shell rakes are favored nesting, roosting, and foraging areas for many shorebirds such as the American Oystercatcher.
Managed Impoundments	The coastal wetland impoundments of South Carolina comprise managed and formerly managed tidal wetlands. Impoundments generally occur from Georgetown County southward, coincident with the state's most extensive tidal marshlands. Salinity regimes range from fresh to brackish, depending on their water sources and management practices. A diverse assemblage of rooted floating aquatics, such as white waterlily *(Nymphaea alba)*, American lotus *(Nelumbo lutea)*, and pondweeds occupies managed freshwater impoundments. Emergent plants such as cattails (*Typha spp.)*, southern wild rice (*Zizania aquatic*) and pickerel weed *(Pontederia spp.)* are common. Submerged and free-floating aquatic plant species also occur and include duckweed *(Lemna minor)* and bladderwort *(Utricularia spp.)*. Managed brackish and intermediate emergent wetlands principally contain widgeongrass *(Ruppia maritima)*, saltmarsh bulrush *(Scirpus robustus)*, and dwarf spikerush *(Eleocharis parvula)*. Emergent tidal marshes are common along the banks of canals of abandoned rice fields and modern-day waterfowl impoundments. Dominant species can include cutgrass (*Zizaniopsis miliacea*) or Jamaica swamp sawgrass (*Cladium jamaicense*). Intermixed among these grasses are various herbaceous plants such as pickerelweed (*Pontederia cordata*), arrowheads (*Sagittaria* spp.), and alligatorweed (*Alternanthera philoxeroides*). Shrubs and trees are present in the more elevated areas of the tidal marsh community.

	Bald cypress-tupelo swamp communities occur on abandoned rice fields and swales inland of modern-day impoundments.

Freshwater Streams, Rivers, and Lakes

Fresh waters in the Coastal Zone are limited and primarily confined to the interior portion of this ecoregion where large volumes of fresh water enter via major rivers. These areas include portions of the Waccamaw, Santee, Cooper, Ashley, Edisto, and Combahee rivers. These habitats usually support a mixture of brackish water species and freshwater species tolerant of higher salinity.

Tidal, Fresh, and Brackish Systems

Tidal fresh and brackish systems consist of a complex of intertidal and subtidal marshlands, sandbars, mud flats and sand flats, and waterways (channels and creeks) that are subject to the mixing of salt and freshwater flows, usually in association with a freshwater source, such as a river delta. Vegetation includes both emergent marsh and submerged forms, and is predominantly comprised of grasses, sedges, and herbs with few trees and with species composition driven largely by salinity.

Marine Ecosystem

South Carolina's coastline is the 11th longest in the nation at 301 km or187 mi. If all convolutions (bays, inlets, etc.) are included, South Carolina ranks 12th with 4,628 km or 2,876 mi. of shoreline. The marine ecosystem occurs along all of South Carolina's Atlantic Ocean coastline and extends offshore to the State 4.8 km (3 mi.) jurisdictional boundary, incorporating a surface area of nearly 140,000 ha (345,946 ac.). Ocean beaches and the associated transition zones are formed primarily from unconsolidated sand and are ubiquitous features on barrier islands or ocean strands that directly front the Atlantic Ocean. Dune habitat includes sand dunes and swales, flats and pools between dunes, and between dunes and other features. Seaward of the dune system, sandy flats may occur in areas where dunes have been eroded. Beaches and associated habitats are influenced by wind-blown salt spray and sand, and may be occasionally flooded, particularly during storms. The following vegetative and aquatic habitats are generally recognized within the beach/marine ecosystem. Interdune Ponds have been discussed previously in Depressions & Tidal Influenced Marsh Systems.

Maritime Grassland	That portion of the Atlantic Ocean beach dune system vegetated by grasses and herbs. This habitat includes sand dunes, swales, and flats between dunes as well as between dunes and other features. Characteristic plants include sea oats (*Uniola paniculata*), bitter panicgrass (*Panicum amarum*), seabeach evening

	primrose (*Oenothera humifusa*), and dune waterpennywort (*Hydrocotyle bonariensis*).
Maritime Shrub Thicket	Thickets of shrubs, vines, and stunted trees often in swales within secondary dunes. Trees and shrubs must be salt tolerant and are "pruned" by wind-blown salt spray and sand. Typical plants are wax myrtle (*Morella cerifera*), red bay (*Persea borbonia*), groundsel tree (*Baccharis halimifolia*), saw greenbrier (*Smilax bona-nox*), and poison ivy (*Toxicodendron radicans*).
Intertidal Beach	The front ocean beach region that is typically inundated on flood tides and drained on ebb tides. Invertebrate fauna in the intertidal beach zone, such as the coquina clam (*Donax variablis*) and the mole crab (*Emerita talpoida*), are an integral part of the food chain for shorebirds and seabirds (e.g. Piping Plover, *Charadrius melodus*; Willet, *Catoptrophorus semipalmatus*; Sanderling, *Calidris alba*; and Red Knot, *Calidris canutus*) that forage on the intertidal beach and at the surf interface.
Surf Zone	The submerged portion of the beach area and extending offshore to a depth of 2 m (6 ft.) at any tidal stage. Marine aquatic species in this zone are heavily influenced by turbulence from wave action. As many as 98 fish and 317 macro-invertebrate species are recognized as at least occasional inhabitants of this zone.
Shallow Shelf *(Soft Bottom, Hard Bottom, Pelagic Zone)*	The portion of the Atlantic Ocean submerged continental shelf offshore to the 4.8 km (3 mi.) state territorial limit. Shallow shelf habitats can be further divided into three important types; soft bottom, hard bottom, and the pelagic zone. Soft bottom is composed of unconsolidated sediments that supply sand to the continental shelf, barrier islands, and beaches; store nutrients in the sediment; and provide critical nursery and feeding habitat to fish and invertebrates. Hard bottom supports a wide variety of invertebrate and fish species, including many species popular with recreational and commercial fishers. Hard bottom habitats are continually being discovered and mapped. The pelagic zone supports many resident nekton (water-column)

	species (i.e. those capable of determining their position in the water column against tide currents, as opposed to planktonic species) but also forms an important migration route or habitat for transient species.

Man-made Structures

Engineered, man-made structures are estimated to cover over 25% of South Carolina's nearly 145 km (90 mi.) of developed coastline. SC Sea Grant estimates that 27% of the State's shoreline is armored. Some of the most familiar of these structures include piers, boardwalks, housing and commercial development, jetties, and groins. Manmade structures can provide hard surfaces, vertical relief, and structural complexity in the water column, all of which promote the attachment of many aquatic, sessile, and sedentary species. These include algae and mosses in low salinity waters, and algae and invertebrates (e.g. hydroids, bryozoans, sponges, barnacles, oysters, and mussels) in estuarine and near-shore marine waters.

Rock seawalls and jetties provide hard substrate for the attachment of organisms in intertidal and subtidal zones, while exposed rock may be used as resting and foraging habitat for shorebirds and seabirds—most notably the Purple Sandpiper (*Calidris maritima*), which prefers rocky coast habitats that are generally rare in the Southeast. Submerged rock also provides refuge habitat for many fishes and invertebrates.

Intertidal reefs, commonly constructed of shell, refurbished crab traps, or concrete blocks, serve the same purpose as naturally occurring oyster reefs. The hard surfaces and structures are substrate for attachment of oysters and other invertebrates and the resulting communities are refuge habitat for many fish and invertebrates as well as foraging habitat for larger fish and shorebirds such as American Oystercatchers. These reefs are often used to stabilize eroding shorelines along tidal creeks and have proved effective at encouraging saltmarsh expansion.

Subtidal reefs in nearshore and offshore waters comprised of manmade structures account for a relatively small percentage of the EEZ off of South Carolina. The State's ten nearshore reef sites are generally about 30 acres (0.05 square miles) in size while the 32 offshore sites are typically 160 acres (0.25 square miles). Each site is made up of numerous individual steel or concrete structures ranging from small, prefabricated concrete modules to large steel-hulled vessels hundreds of feet in length. Each structure provides surface area for the attachment of sessile organisms including algae, barnacles, corals, sponges, hydroids, and bryozoans which become the foundation of the reef community. Once colonized by invertebrates, other marine animals such as crabs, shrimps, urchins, amphipods, and mollusks take up residence as well. Studies have documented nearly 300 invertebrate species attached to or residing on artificial reef structures. The ultimate goal of creating manmade reefs is the creation of finfish habitat for the enhancement of fisheries resources. Over 50 species of fishes have been observed on the State's artificial reefs, including both recreational and commercially important species, and in densities usually higher than in natural areas. In addition, nesting and spawning activities on these reefs attest to their use as permanent fish habitat. Artificial reefs off South Carolina have been

declared Essential Fish Habitat (EFH) by the South Atlantic Fishery Management Council (SAFMC).

Hardened structures designed for shoreline and channel protection also disrupt the natural processes of sand movement along beaches and can therefore contribute significantly to beach erosion. Seawalls and bulkheads in inland waterways can protect the immediate shoreline while potentially exacerbating erosion of the nearby, unprotected shoreline. Such structures also interfere with the nesting of sea turtles either by totally displacing nesting sites or by rendering them more susceptible to flooding.

Region-wide Challenges

Non-native plants colonize both terrestrial and wetland habitats. Such species can dominate or displace native vegetation and can occur in nearly single-species stands that present a lowered structural diversity and less desirable wildlife habitat. Both tidal low-salinity marshes and wetlands and littoral (shallow water) areas in ponds and impoundments can be densely covered in waterthyme (*Hydrilla verticillata*) or common reed (*Phragmites communis*). Dense colonies of these plants may restrict hydrological flows and capture sediment, thereby increasing the rate of eutrophication and contributing to low dissolved oxygen (DO) (McCann et al. 1996; Aulbach-Smith and deKozlowski 1996). Forested wetlands and coastal forests with damp (hydric or mesic) soils may be heavily populated with Chinese tallowtree (*Triadica sebiferum*), which quickly becomes established and out-competes more desirable native plants (J.W. McCord, SCDNR, pers. obs.). Feral non-native mammals, such as goats (*Capra hircus*) and pigs (*Sus scrofa*), inhabit Coastal Zone islands and marshlands. Goats can heavily browse vegetation, thereby reducing plant diversity, cover, and soil stability, while feral pigs can damage soils, marshes and impoundment dikes (J.W. McCord, SCDNR, pers. obs.). Non-native fishes like the Common Carp (*Cyprinus carpio*), the Flathead Catfish (*Pylodictis olivaris*), and the Blue Catfish (*Ictalurus furcatus*), may not directly impact habitats, but can alter ecosystem health through predation on or competition with native species. From marine and estuarine habitats, non-native species that are of concern as documented as invasive species (or have the potential to be) would include the Indo-Pacific Lionfish (*Pterois volitans/miles*), the swimbladder parasite of the American Eel (*Anguillicoloides crassus*), the Asian tiger shrimp (*Penaeus monodon*), and the green mussel (*Perna viridis*). Some examples of invasive freshwater invertebrates include the island apple snail and Florida apple snail (*Pomacea insularum* and *P. paludosa*, respectively), as well as the Asian clam (*Corbicula fluminea*).

Coastal development along the Grand Strand (Horry County) and barrier island beaches has reduced unique Coastal Zone habitats. A high percentage of the State's maritime forests, maritime grasslands, maritime shrub thickets, beach flats, and intertidal beaches have been negatively affected. Terrestrial habitats are physically removed to accommodate housing and other structures and natural and dynamic beach processes of erosion and accretion of sands have been altered to protect human structures and recreational interests. Hardened structures such as rocks, groins, and jetties prevent natural sand movements. Beach renourishment from sand pumped from offshore or estuarine sites is frequently therefore required to restore dune systems and beach flats. However, this often smothers marine invertebrates on the beaches, thus negatively impacting the system and its inhabitants in the short term (Peterson et al. 2000) and the long term (Jutte et al. 1999).

Beachfront habitats in South Carolina have likely been more negatively affected by anthropogenic activities than any other ecosystem. Furthermore, many priority species either presently rely, or once relied upon, such habitats. Human population growth and associated anthropogenic impacts are greater in or near the Coastal Zone than in any other ecoregion in the state.

According to the US Census Bureau, the human population within the seven counties (Horry, Georgetown, Charleston, Berkeley, Colleton, Beaufort and Jasper) that include or border portions of the Coastal Zone increased by 41.1% from 1980 to 2000; this area is predicted to undergo an additional 28.1% increase in human population from 2000 to 2020. Over the past decade, there has been a substantial increase in the proportion of the population that lives within watersheds that drain into South Carolina estuaries (Cofer-Shabica et al. 1999).

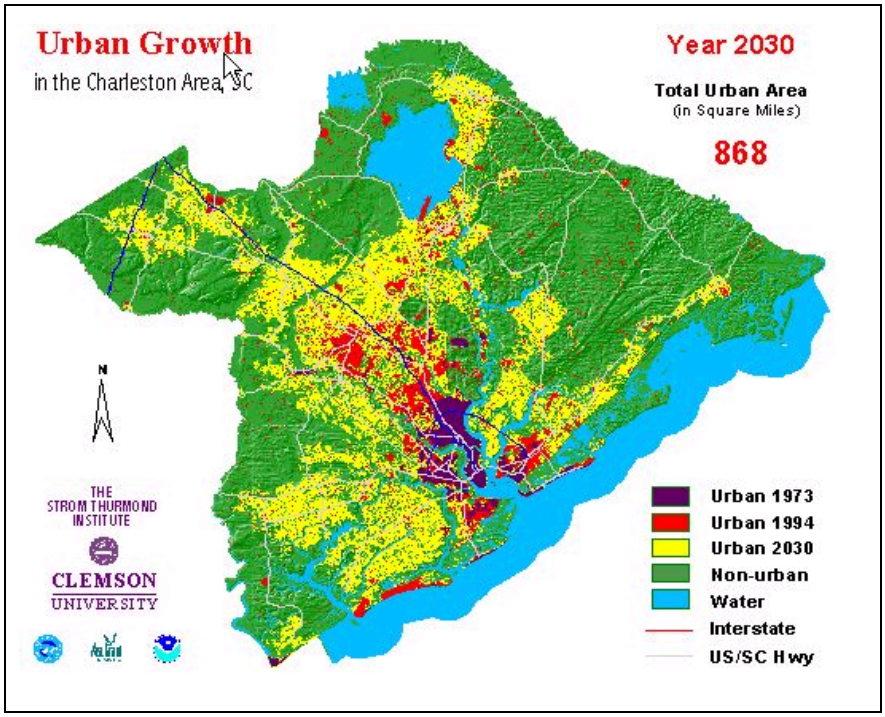


FIGURE 4-15: Projected urban land area changes for the Charleston area to the year 2030 (Allen and Lu 2000).

The urbanized area of Charleston increased by more than 400% from 1973 to 1994 and is expected to increase at a similar rate over the next several decades (Allen and Lu 2000). Figure 4-15 illustrates this scenario. Obvious impacts have been, and will continue to be, increased deforestation and forest fragmentation caused by increased residential, commercial and industrial development as well as expanded highway and other transportation corridors to support the increased population.

Both general point source and non-point source pollution also increase with population growth. Consumptive pressures relative to recreational uses of fishery resources will also accompany population growth, as will non-point source pollution specifically from watercraft and

disturbance of wildlife from increased human activity. The ultimate result is increased stress on natural habitats and natural resources within the Coastal Zone, as well as increased vulnerability of people, habitats, and fish and wildlife populations, to catastrophic events such as major hurricanes. Such predicted human population growth, and the associated impacts on wildlife and habitat, is added incentive to proactively plan for wildlife habitat conservation in the State's Coastal Zone.

CHAPTER 6: SOUTH CAROLINA'S COMPREHENSIVE MONITORING PROGRAM

Purpose and Justification for Monitoring

Throughout most of the history of natural resource conservation, single species management has been the focus. Threatened and endangered species, especially, have been the subject of intensive management. However, the literature provides testament to the effects of missed indices and unanticipated events on successful conservation. Although sometimes individual species need targeted management approaches, the majority of species would benefit from a broader strategy aimed at their shared ecosystems. The animals included on South Carolina's Priority Species List each have individual ecological roles connected in myriad ways to others. From this perspective, multi-species and systems approaches to conservation become the clearer path to accomplishing the many goals and strategies that the SCDNR has identified in the SWAP.

It seems apparent that this view of management will require constant and consistent adaptation to change. Single alterations in community function—such as the loss of a keystone species—can produce ripple effects that confound the most complete systems model. Despite imperfect knowledge, however, management must still move forward if conservation is to succeed. Likewise, as the system evolves, so does the method of management. Adaptive management cannot proceed without vigilant attention to these changes. Monitoring and evaluation then become the essential tools for detecting, measuring, and interpreting these changes over time.

Assessing changes in populations and habitats over time, especially in response to applied conservation actions, requires monitoring at multiple levels (species, guilds, natural communities, and implementation activities) and across multiple scales (local, statewide, regional, and national). Through varying styles of monitoring, SCDNR can detect species-specific trends from estimates of population size, relative abundance, or distributional shifts. Similarly, by measuring species associations such as longleaf pine-associated reptiles, we can assess habitat-level responses. Monitoring of habitats leads to identification of challenges or impacts of management activities or landscape alterations. Finally, monitoring simply helps us understand the effects, intended or otherwise, of any management approach.

During the initial planning stages before 2005, SWAP project leaders received guidance from partners—including USFWS, USGS, NPS and USFS—aimed at identifying essential elements in the design of effective monitoring programs to support the SWAP and its subsequent implementation. South Carolina's team attended meetings to discuss collaborative efforts and structural design of SWAP monitoring programs. Paul Dressler from the USGS presented a list of the basic elements of a monitoring program. Representatives of USFS and NPS provided descriptions of current monitoring programs instituted at varied scales by their agencies. This information has proved invaluable in considering the framework and strategies the SCDNR will employ through implementation of the SWAP to create a more effective and efficient statewide monitoring program.

Cooperative efforts remain essential to accomplishing the goals of these programs. SCDNR works first to ensure that existing programs remain effective where they meet the needs of conservation strategies within the SWAP. Monitoring continues to be a necessary component of most SCDNR efforts outside of the SWAP as well. The structure of the South Carolina Monitoring Program builds on existing SCDNR monitoring efforts and, where appropriate, partners' monitoring programs. Additional partnerships and support will continue to be researched during the development of the monitoring program.

Current Monitoring Programs in South Carolina

Monitoring programs are not a novel approach in successful conservation. International and domestic efforts to monitor migratory bird species provide excellent resources for developing species-level monitoring programs. The North American Breeding Bird Survey (BBS) is a well-known, long-term, continental sentinel monitoring program. The Christmas Bird Count similarly provides documentation of winter distribution and abundance for bird species. Such efforts set precedents in data collection and distribution which other taxa monitoring programs might find beneficial to emulate. Other bird surveys established in South Carolina include the International Migratory Bird Day and Backyard Feeder Watch. Of important note is the consistent, effective use of volunteers, or "citizen scientists," to conduct these assessments.

In South Carolina, current monitoring projects for both SWAP priority species and others include the following:

- The US Army Corps of Engineers and South Carolina Ocean and Coastal Resource Management (OCRM) provide essential monitoring efforts for marine invertebrates.
- SCDHEC monitors water quality while surveying for some freshwater invertebrate species.
- SCDNR assesses commercial fishery stocks and State Shellfish Grounds on an annual basis to evaluate shellfish population status.
- SCDNR estuarine trammel net sampling efforts have sampled SC estuaries since 1990, with over 20,000 net sets that intercept 151 species of fish.
- SCDNR's electrofish sampling program evaluates species abundance in the critical oligohaline stretches of SC rivers.
- SCDNR longline surveys monitor inshore waters for a number of species of concern, especially sharks.
- SCDNR monitors juvenile American Shad abundance and timing of outmigration in the Pee Dee, Edisto, and Savannah Rivers, as well as the Santee Cooper Lakes and tributaries.
- SCDNR monitors the movements and critical habitat use of adult Shortnose and Atlantic Sturgeon along the East Coast as part of a multi-state collaboration between SC, GA, and NC.
- SCDNR monitors Shortnose Sturgeon habitat use in the Santee Cooper Basin as part of the Santee Accord.
- SCDNR monitors young-of-the-year American Eel in the Rediversion Canal and Goose Creek Reservoir.

- SCDNR monitors the adult American Shad and Blueback Herring spawning migration in coastal rivers. Additionally, the SCDNR monitors fish passage of American Shad and Blueback Herring at the St. Stephen Fish Lift.
- The South Carolina Estuarine and Coastal Assessment Program (SCECAP) monitors habitat quality of estuarine waters statewide and identifies specific sites with degraded water or sediment quality.
- The SCDNR-SEAMAP program currently monitors the abundance of fish and decapod crustaceans using a trawl survey of coastal waters (4 to 10 m; 13 to 33 ft.) from North Carolina to Florida.
- South Carolina participates in the Harvest Information Program (HIP) that has been fully implemented nationwide, allowing for comparisons of migratory game bird numbers and harvest levels in South Carolina.
- Comprehensive hunter harvest surveys have been conducted for all species in South Carolina periodically since 1963. Fifteen surveys have been completed spanning 44 years. (1963–64; 1966–67; 1975–76; 1978–79; 1981–82; 1984–85; 1991–92; 1993–94; 1999–2000; 2002–03; 2004–05; 2006-07; 2008-09; 2010-11; 2012-13).
- The South Atlantic Fishery Management Council (SAFMC) assesses stock status of many species.
- Reproductive effort and fledging success of South Carolina nesting Bald Eagles has been documented (mid-winter surveys) on an annual basis since 1986.
- SCDNR monitors the reproductive effort and success of Wood Storks nesting in South Carolina.
- A spring Whistling Call Count Survey for Northern Bobwhite has been conducted annually since 1979.
- South Carolina has participated in Mourning Dove Call Count Surveys since 1966. Annual banding also occurs across the State.
- Annual summer Wild Turkey Brood Surveys have been conducted since 1982 to monitor reproductive success.
- Over 1,250 Furbearer Scent (Tracking) Station Survey routes have been run annually since 1984, while Black Bear Bait Stations have been monitored every other year since 1993 for the mountain population.
- Fox Squirrel Sighting Surveys were initiated in 1989 and began being conducted on even number years starting in 1994.

This list only briefly describes some of the monitoring efforts SCDNR undertakes in current management programs. An extensive list of monitoring efforts currently employed across the State and region is included in Appendix 7.

Additionally, the Freshwater Fisheries section of the Wildlife and Freshwater Fisheries Division of the SCDNR has run continued surveys of user preferences and user impact on the fisheries of the State. The following are those programs completed within the last 25 years.

- 1990 - Freshwater fishing study
- 1998 - South Carolina fishing license holders opinions and attitudes toward fisheries management and the South Carolina Department of Natural Resources, results of Largemouth Bass and Smallmouth Bass anglers

- 1998 - South Carolina fishing license holders opinions and attitudes toward fisheries management and the South Carolina Department of Natural Resources
- 1999 - Youth and fishing in South Carolina
- 1991, 1996 and 2001 - The 2001 Economic Benefits of Freshwater Fishing in SC
- 2000 - Striped Bass anglers' attitudes toward fisheries management on Lake Murray
- 2000 to present - Annual Cooper River Tailrace Canal American Shad Fishermen Survey
- 2001 - South Carolina youth aquatic survey
- 2003 - South Carolina residents' attitudes and behaviors toward aquatic resources
- 2003 - South Carolina and Georgia anglers' attitudes on fishing regulations on Lake Russell
- 2004 - South Carolina fishing license holders opinions and attitudes toward fisheries management and the South Carolina Department of Natural Resources

Authors of the SWAP species accounts identified monitoring, survey, and research needs for priority species. Recommendations for individual species can be located in the separate volume, Supplemental Volume: Priority Species Accounts. Several needs are currently being addressed to varying degrees while others still need to be done. Some of the general needs for monitoring efforts are described here.

Many freshwater species—especially invertebrates such as crayfish, snails, and mussels—lack distribution and survey information for baseline data upon which a monitoring program could be built. Similarly, many of the marine fish and marine invertebrates on South Carolina's Priority Species List have only recently received initial survey attention and will require further study to create effective tracking programs. Where baseline data is available for freshwater aquatic species, there is a strong need to improve long-term monitoring across species groups. SCDNR fisheries biologists have recently developed a system for stream habitat monitoring and assessment (Decision Support Tools for Stream Conservation), made possible through State Wildlife Grants. Otherwise, monitoring is needed to assess specific management actions such as buffer establishment and species restoration projects. Impacts of introduced or exotic species on priority species remain a concern for many freshwater systems.

A pressing issue for monitoring terrestrial species is the establishment of taxa-relevant monitoring protocols such as those already established for birds. Efforts to expand monitoring on public lands and initiate monitoring on key private lands, where possible, should be addressed. A monitoring protocol for small mammals and bats should be developed. Survey and data needs are most pressing for all species of bats on South Carolina's Priority Species List. Therefore, it may be most important to survey and institute long-term monitoring programs at roosting locations. A pilot project on conducting bat acoustic surveys statewide is currently being developed.

Ongoing monitoring coordination and support of recommendations of national and regional planning bodies (such as PIF, SAMBI, NABCI, NAWMP and others) should be continued. Primary landbird species identified for specific monitoring programs include Swainson's Warbler, Henslow's Sparrow, Bachman's Sparrow, Wayne's Black-throated Green Warbler, Loggerhead Shrikes and Painted Buntings. Baseline studies are currently being conducted on Black Rail and MacGillivray's Seaside Sparrow which will help with their future monitoring. Key habitats of concern include pine savannah and pine woodland, early-successional types,

grasslands, and forested wetlands. Efforts to continue the monitoring of migratory and resident waterbirds and waterfowl are also recommended.

Development of monitoring protocols for amphibians and reptiles is of primary importance. SE PARC has published an Inventory and Monitoring Guide for the US and has developed protocols for some species. SCDNR's continued involvement in this process is important for both the continued development and refinement of reptile and amphibian monitoring guidelines.

Strategies for South Carolina's Comprehensive Monitoring Program

The following are specific strategies outlined for the advancement of South Carolina's Comprehensive Natural Resources Monitoring Program (South Carolina Monitoring Program). These strategies were developed during the initial iteration of the SWAP in 2005. Continuing to address these strategies should be considered a priority for future implementation goals. Where progress has been made, successes are discussed in italics under each strategy.

Strategy 1: Initiate a comprehensive monitoring program to coordinate monitoring efforts, including establishment of a collaborative working group staffed with agents both from the SCDNR and partner agencies. Data sharing in regards to common monitoring efforts should be a priority.

- Coordinate monitoring efforts across scales and jurisdictions through partnerships, defining scope as a function of the monitoring subject.
- Provide a means to share information, provide advice, and coordinate state monitoring efforts to be nationally and internationally compatible.
- Develop an ecologically-based framework considering the incorporation of an ecosystem-based approach to allow for regional compatibility.
- Use monitoring results to prepare future iterations of the SWAP.
- Build on existing state monitoring systems; utilize existing protocols where applicable.
- Support local planning initiatives, regional planning teams, and existing cooperative agreements where appropriate (See Appendix 3 for a list of existing partnerships).
- Develop a monitoring process that is easily understood, sustainable, cost-effective and relevant to all parties involved, and paced appropriately.
- Include assessments of cumulative impacts and, where possible, an interdisciplinary approach (geologic, genetic, ecologic, climatic).
- Maintain participation in monitoring networks as established between states during the national SWAP planning efforts.

Strategy 2: Create a South Carolina Comprehensive Natural Resources Data Initiative. Currently, there are various means of storing data in use by the agency. Unfortunately, many of these data layers are housed within separate divisions and are not compatible across operating systems at this time. A goal would be to standardize data gathering and prepare a repository for housing it. This data could then be retrieved in-house or shared, as appropriate, with partners or the public. Specifics of this initiative may include the following:

- Develop a standard system to facilitate species, habitat, and monitoring data collection for storage and dissemination across the agency and partnerships.
- Create a SWAP project monitoring system to link tracking of conservation actions with recommendations and appropriate species of concern.
- Establish standard operating procedures for project reporting and provide access to templates for web-based data input that will support research and monitoring efforts.
- Provide public and partner access to information collected and maintained to increase ownership and collaborative efforts. This collaborative data interface should allow for input directly from the field.
- Examine the ability to link previous databases with new information through consistent species and habitat codes.
- Collaborate with neighboring and regional states to create standardized platforms, enabling information exchange at broader scales.
- Spatially relate all database information, where appropriate, to provide summarizations through geographic information systems (GIS) software capabilities.
- Regularly update the conservation status (S-ranks; state listings) of species in South Carolina.
- Track distribution and status of all priority species with the intent to expand the database for tracking non-priority species as well.
- Use element of occurrence points to create more accurate range maps for species.
- Design the database with the intent to facilitate future reporting and revisions of the SWAP.

Strategy 3: Translate species-level goals and objectives to habitat and landscape scales for implementation and monitoring.

The Freshwater Fisheries division has created a Decision Support Tools application for online modeling of watershed impacts relative to deforestation, urbanization, road building, and other disturbance scenarios. Element of Occurrence Records (EORs) for freshwater fish species are overlaid to represent species that may be affected by habitat alterations. These new EORs were made possible by the Stream Assessment Survey (2006-2011) funded by State Wildlife Grants. Further needs include:

- Accomplish long-term objectives of monitoring key habitats using existing and new GIS programs.
- Continue to update and analyze the existing GAP databases and crosswalk this information with a statewide habitat characterization as provided in the SWAP.
- Design and implement an aquatic GAP initiative to support aquatic monitoring.
- Complete periodic updates of land use and land cover in the State to help translate threats from species to a habitat scale.
- Elevation models of the State, especially the coastal counties, should be updated and at a finer scale so that potential sea level rise due to climate change can be more accurately predicted and charted over time.
- Evaluate the existing SWAP species' goals for feasibility and applicability at broadening scales.

- Utilize landscape-level remote sensing and other mapping techniques, which are of particular value given the proportion of key habitats and priority species that are located on private lands.
- Monitor partnerships and public involvement such as conservation easements, stewardship agreements, and volunteer efforts at the habitat scale.

Strategy 4: Augment monitoring group efforts by developing or expanding citizen science partnerships, where appropriate. The SCDNR already relies on volunteers and citizen scientists to assist with surveys and DNA collection for research, especially in freshwater and marine fisheries. A page has recently been created on SCDNR's website dedicated to citizen science links. Further suggestions include:

- Consider the efficacy of developing and training citizen science groups to expand data gathering capability across the State.
- Build public understanding of ecological issues and meet the varied educational and public outreach recommendations for priority species by involving increasing numbers of citizens and institutions in basic status and trends monitoring efforts.
- Encourage partnerships with secondary and higher education institutions to provide students with opportunities to integrate classroom learning with practical experiences.
- Increase the use of graduate training programs in creating and implementing response monitoring, an excellent opportunity for standard graduate level research.

While presented last, it is important to consider the potential benefits of citizen-based programs (AFWA 2012). The Breeding Bird Survey and Christmas Bird Counts are citizen initiatives. These programs provide some of the most complete data on bird distributions. Already, South Carolina citizens utilize online reporting systems for monarch butterfly counts, green darner migration counts, firefly sightings, Purple Martin scout sightings, and Swallow-tailed Kite sighting reports. Support for continued conservation efforts can only benefit from a sense of ownership and collaboration among partners and the public. For more information regarding public input and partnership development, see Chapter 7.

Monitoring Program Defined

As the SCDNR proceeds with the refinement of the South Carolina Monitoring Program in support of the SWAP, several elements of design must be considered; these are outlined in Box 6-1 and are adapted from guidance provided to the States by federal partners.

BOX 6-1: BASIC ELEMENTS OF A MONITORING PROJECT AND PROGRAM

- Identification of monitoring goals and objectives
  - What is the question and why; identify existing information; conceptual model
- Identification of targets to monitor
  - Selection based on above results and availability of resources (fiscal/human)
- Establishing monitoring protocol (peer reviewed)
  - All elements documented (question; sampling design; methodology; anticipated analysis/analytic tools; data management and reporting strategy; schedule)
- Quality assurance and quality control
  - Assuring and controlling quality; training and potential certification of users
- Data management and archiving
  - Scheme to ensure data are documented, maintained, archived, and accessible
- Data analysis and assessment
  - Anticipated analysis including estimates of confidence
- Reporting
  - Reporting formats and schedule (useable, understandable, responsive) to user
- Periodic review and evaluation
  - Ensure project is responsive to the need and reflects the best available science

Monitoring targets will be dictated during the program implementation and adaptive management process; this process is more thoroughly described in Chapter 8: Implementation and Adaptive Management. In most cases, one or more of the following types of programs will be developed:

1) **Targeted species or habitat status and trends.** This type of monitoring tracks the status and trends of selected species, habitats, and communities and how they respond to management.
2) **Multi-species context or habitat condition.** Context or condition monitoring for either species or habitats allows us to track change at the ecosystem level to understand patterns of change.
3) **Cause and effect or response.** Cause and effect or response monitoring, in reality, mimics traditional research on the underlying explanation of observed events.
4) **Management action effectiveness.** Effectiveness monitoring relates directly to adaptive management as it assesses how well management actions undertaken achieve desired results.

Effective monitoring must integrate trend data with cause and effects for successful adaptive measures to be taken. Likewise, it must integrate habitat description with species measures. Viewing either as a surrogate for the other is inappropriate. Habitat-species relationships are not

always well understood; often, quality habitat will lack presence of expected species. Species trends, conversely, cannot provide direct insight into changes in habitat composition.

Targeted Monitoring

Targeted species status and trends monitoring might assess species presence/absence, population density, productivity (number of offspring), breeding success, offspring and adult survival, and/or the use of treated areas. In general, this form of monitoring is very similar to existing efforts to monitor harvested species. Targeted monitoring focuses on species or primary habitats selected due to risk, concern, or interest. Strengths of this facet of monitoring are first, the ability to narrow perspective to those elements likely to change, and second, to tie monitoring efforts to management actions. However, a drawback of such a focused effort is the very assumption that a relationship truly exists between the target and the attributed management action or threat. It is necessary, then, to conduct targeted monitoring within a contextual frame produced in the second division of monitoring efforts: condition and context monitoring.

For comparatively well-studied species, targeted monitoring protocols have been described—often in great detail—in recovery plans, conservation plans, published literature, and gray literature; SCDNR will use these if available. If no established protocol exists, SCDNR will adapt protocols from similar species or develop its own protocols based on what is known about the species. In developing protocols, we will follow Oakley et al. (2003). For species deemed important to target but with disparate information, inventories must first be conducted. When presence data are assembled, distributions of the species, along with population conditions can be mapped and used to direct future efforts.

Context and Condition Monitoring

Context monitoring is not restricted to particular species or system elements. Rather it provides status and trend information on a wide range of related facets of an ecosystem. With context monitoring, managers may detect unanticipated effects on a system that would have been lost in a targeted approach. It is a necessary link between targeted and response monitoring. In contextual monitoring, data may be collected for species not identified in specific targeted studies as described above. Additionally, monitoring of communities can provide context documentation against which targeted trends can be evaluated. Context-based monitoring extends to the habitat or landscape level when possible to further explain trend relationships between populations and habitats. When appropriate, context and condition monitoring will rely heavily on the identification of indicators. For example, with their large home range, Swallow-tailed Kites can serve as umbrella species for other area-sensitive wetland wildlife including Neotropical migrants, Barred Owls, Red-shouldered Hawks, Pileated Woodpeckers, river otters and black bears. The selection of appropriate indicators is challenging. The SCDNR will rely on the guidance provided by Schoonmaker and Luscombe (2005) (see Box 6-2 for additional definitions and discussions of indicators). It is important to stress that context and condition monitoring is not intended to follow every component of a system but rather provide a picture of the system from a broader perspective.

BOX 6-2: DEFINITION AND SELECTION OF INDICATORS

Categories for Indicator Evaluation:

- Relevance – the degree to which the indicator measures the issue of concern
- Practicality – the feasibility of measuring the indicator
- Scientific merit – the extent to which the indicator is supported by science
- Ecological breadth – the number of ecological components the indicator includes
- Usability – the ability of decision makers to make decisions using the indicator

Qualities of Valid Indicators

- Intended use is clear
- Simplifies status of a complex system
- Sensitive to known stressors
- Able to distinguish between anthropogenic stressors and natural variation
- Provide early warning of change
- Not greatly sensitive to sample size
- Low variability in response
- Easy and inexpensive to measure
- Easy to understand and translate into decision making
- Represents cause and effect relationships

Pressure-State-Impact-Response Indicator Framework

- **Pressure indicators** represent the level of a pressure or stressor that affect a natural resource
- **State (or condition) indicators** describe the current state or condition of a natural resource
- **Impact indicators** indicate the change in a natural resource as a result of a pressure
- **Response indicators** indicate the level of human action taken to reduce the pressure on a value of interest

Response Monitoring

Response monitoring or cause and effect monitoring (Holthausen et al. 2005) dovetails tightly with the objectives of targeted and condition/context monitoring and is the monitoring of species responses to management changes at the project (or several projects) level. It can be further described as the collection and assessment of observations to evaluate changes in condition in relationship to actions (Elzinga et al. 2001). Response monitoring of relationships between targets and conditions integrates monitoring with research. For this reason, efficiency may be increased where researchers and managers work closely to identify objectives for management. With proper choice of management goals and well-identified expectations that are defensibly quantifiable, response monitoring lends itself easily to the collaborative development of research efforts.

Effectiveness Monitoring

A final necessary division of monitoring includes efforts to quantify the effects of management actions in relation to management goals, rather than the effectiveness of an action taken. Effectiveness monitoring will be essential to adaptive management and future revisions of the SWAP. It involves not only looking at outcomes but at processes. This type of monitoring can determine whether the treatments were applied as they were conceptualized and prescribed. In order to adapt management efforts effectively, managers must be able to evaluate why an action is successful or unsuccessful and be able to gain a clear understanding of actions implemented so that future assessments are based on actual occurrences.

Proposed quantifiable criteria of management actions include net increases in partner and public involvements, removal of threats to priority species, or successful completion of conservation actions. Additional qualitative measures will be important as well (see Chapter 8: Implementation and Adaptive Management, for further descriptions of implementation and review). Of course, the long-term measure of effectiveness would be a reduction in the number of species of conservation need.

The balance between these four forms of monitoring is an important consideration in the design of conservation actions and projects at all scales. Additional attention will be given to the appropriate use of each facet of monitoring to most effectively meet the goals of the SWAP.

Experimental Design for Monitoring Programs

As successful research is typically built on detailed experimental design, so shall design efforts benefit the SWAP monitoring process. Attention to statistical design will improve the applicability of most monitoring outputs. While not all facets of the program need to be rigorously treated, an understanding of traditional scientific reasoning may increase the effectiveness of the program as a whole. Additionally, response monitoring endeavors would likely rely on sound analytical design due to their relationship to research.

Analyzing monitoring data most effectively will require the use of several techniques including traditional hypothesis testing, as well as less traditional techniques such as information theoretics methods (Burnham and Anderson 2001) and meta-analysis (Franklin and Shenk 1995). The object will be to determine whether actions do or do not produce their intended effect. Model comparisons and comparisons of treatments across differing areas and scales may require extended analysis of non-traditional statistical testing and inference.

Setting Monitoring Objectives

The proposed South Carolina Monitoring Program working group will establish measurable monitoring objectives through the planning of the monitoring program and selection of individual projects. These objectives will be closely tied to priorities for conservation actions as provided in Chapter 5: Statewide Conservation Strategies. Statistically defensible design will be employed, if applicable, to the measurements made. Attention in these decisions should also be given to the provision of opportunities for local and community involvement as well as cooperation among agencies and stakeholders. Similarly, a primary directive for selection of

objectives within the outlined framework should be the ability to acquire and use information for adaptive management.

CHAPTER 7: SEEKING PUBLIC INPUT AND MAINTAINING PARTNERSHIPS

The Initial Stages: Focus Groups and Public Meetings (2005)

From the beginning of the SWAP effort, the South Carolina Department of Natural Resources (SCDNR) and the planning team sought to realize successful partnerships and public involvement in the development of the Action Plan. It is understood that successful conservation is furthered by the existence of a strong collaborative involvement between all resource stakeholders, private or public, governmental or non-governmental. In July 2003, a Neighboring States meeting was held in association with our regional Federal Assistance coordinators to discuss issues common to all as well as to develop an outline and format for our Action Plans. Participating states included Virginia, North Carolina, South Carolina, Georgia and Alabama. The model created was one of two used by the US Fish and Wildlife Service as an example for the rest of the nation to emulate.

The SCDNR retained the Clemson Institute for Economic and Community Development (CIECD) to manage and conduct the Public Participation Process with planning beginning in January 2004. The team used a parallel participation process (focus groups and public meetings) to ensure that both the professional and general public concerns and comments were separately heard and acknowledged.

For the very first iteration of the SWAP (the 2005 CWCS), the team identified the issues of most prominent concern for wildlife conservation from both the perspective of agency staff and that of individuals and groups outside of the SCDNR. First, focus groups were developed in order to determine the wildlife conservation priorities of the SDCNR's partners. Representatives from partner groups were invited to share their ideas with the planning team. These partner organizations included federal and state agencies such as the US Fish and Wildlife Service, the US Forest Service, Clemson University, and the SC Forestry Commission. Likewise, non-governmental organizations like The Nature Conservancy, Katawba Valley Land Trust, SC Sporting Protection League, SC Native Plant Society, and Safari Club International were also involved. To ensure that SCDNR received input from partners with more diverse interests in wildlife conservation, other non-governmental organizations also participated in the focus groups including developers, local and county planners, professional foresters, and representatives from the agricultural community.

Five focus group meetings were held across the State in 2004 and were facilitated by our partners at Clemson Extension. Participants were invited via email and phone calls. The goal of these meetings was to identify general actions that would protect priority species in South Carolina. After discussing current wildlife conservation methods in the State and the factors contributing to wildlife and habitat decline, the participants determined that three broad general actions should be considered high priority by the SCDNR in conserving priority species; these three actions are:

- Public education
- Land use planning

- Habitat acquisition and protection

In addition, the following four actions were given slightly less priority but were mentioned at all focus group meetings:

- Greater research and monitoring - (population and species monitoring; exotic/invasive species management; investigating and verifying the decline of species)
- Water quality - (better water quality management programs; wetland protection)
- Agency collaboration - (inter- and intra-agency collaboration; public-private cooperation; collaborating with neighboring states; enforcing existing regulations)
- Landowner incentives - (landowner incentives improved; ecological restoration on private lands; cost-sharing programs)

After the focus group meetings, the SCDNR conducted four public meetings throughout South Carolina in order to allow all segments of the population to provide their opinions on priorities for wildlife conservation in the State. Announcements for the meetings were advertised in newspapers, mentioned on local television news reports, and an interview with the SWAP (CWCS) Coordinator was conducted by ETV radio. The information obtained through the focus groups allowed the SCDNR to be better prepared to answer questions that might arise during these public meetings. Public meetings were attended by representatives of groups similar to those present at the focus group meetings as well as members of the general public. The public meetings brought together a wider array of people and concerns. However, the dominant actions were similar to those stated in the focus groups: public education, land use planning, and habitat acquisition and protection.

A complete list of partners established throughout the 2005 planning process, and continued into the present (with additions), is included in Appendix 3.

Native American Tribes (2005, 2013)

Late in the 2005 planning process, a representative of the Catawba Indian Nation was briefed on the SWAP (then CWCS) to explore partnership opportunities. The Catawbas, located in York County near Rock Hill, SC, are the only federally recognized tribe in South Carolina. According to the SC Commission for Minority Affairs, state recognized tribes in South Carolina include the Beaver Creek Indians, Edisto Natchez-Kusso Tribe, Pee Dee Indian Nation of Upper SC, Pee Dee Indian Tribe of SC, Santee Indian Organization, Waccamaw Indian People, and the Wassamasaw Tribe of Varnertown Indians. There are five other state-recognized groups and 15 non-recognized entities.

Potential actions identified for future discussion with the Catawba Nation are based on four broad goals. (1) Support for aquatic resource conservation, education, and recreation activities where the Catawba reservation borders the Catawba River could be broadened through financial and technical assistance from the SCDNR. (2) Similarly, the SCDNR could help Reservation land managers develop biological resource inventories and site-specific management plans for priority species. (3) The Catawba Nation could also support expanding outreach to other Native American bands and groups. (4) In return, the SCDNR could assist in developing new and

existing cooperative conservation projects with neighboring landowners where objectives cross the Reservation boundaries. These ideas are still being considered.

In 2013, a list of priority species that would be in the revised SWAP was mailed to Catawba Nation representatives. This list only contained those species relevant to the Nation's land holdings—those that were known or suspected to occur on site. Updated lists will be sent as needed.

Adding to Our Knowledge Base: Climate Change Workshops (2012)

Since 2005, discussions about climate change have increased, leading the Agency to once again gain public input into a topic that greatly affects priority species in SC. As suggested by the Association of Fish and Wildlife Agencies' Best Practices for State Wildlife Action Plans (2012), the number and types of public participants solicited was at a scale that would make efficient use of agency resources and glean the type of information we desired.

The South Carolina State Climatology Office produced "The Climate Connection Workshop Series: Climate Variability and Impacts to South Carolina's Natural Resources" which was held three times in three different locations across the State and attracted 151 total participants representing federal, state, and local governments; scientists; land and water resource managers; utility representatives; NGOs; the media; private companies; and other interested stakeholders. The purpose of these workshops was to increase awareness and utilization of climate knowledge to improve natural resource management. There exists a genuine need for new approaches and partnerships to cope more effectively with climate variability. The series was advertised to the general public on the State Climatology Office's website, but also invitations were sent to ~350 select individuals / organizations that had attended like conferences and workshops in the past.

As with the 2005 focus groups and public meetings, workshops were strategically located across the State. The first climate workshop was held in Charleston, SC in September 2012 and was attended by 68 people. The second workshop was held in Columbia, SC in October 2012 with an attendance of 48. The final workshop was held in Greenville, SC in December 2012 and was attended by 35 people.

The workshops began with a series of presentations on climate science and impacts to natural resources. Over 26 speakers participated. A PowerPoint presentation on the State Wildlife Grants program and SC's State Wildlife Action Plan (SWAP) was presented at each workshop. An interactive session came next in which Turning Technology (a polling process) was utilized to elicit responses from all members of the audience for guaranteed feedback on topics presented. Twelve questions regarding climate issues, impacts, actions, and perceived needs and challenges were asked and responses were gathered and displayed anonymously. In addition to the SWAP, other discussions included: SC climate trends for the past 109 years; an analysis of 60 years of water temperature data; aquifer water level trends; how climate affects estuarine fauna, shrimp abundance, and other wildlife and plant species; climate variability and forest health; fire regimes; urban growth's impacts during changing times; salinity intrusion into freshwater areas; the National Integrated Drought Information System; and partnership needs in data gathering and

analysis. Responses were graphed and analyzed for the final report which can be viewed at http://www.dnr.sc.gov/ccworkshops/reports.html.

All participants selected drought as the primary climate-related issue affecting the State, probably since South Carolina has had frequent drought episodes within the last 15 years. Other concerns included sea level rise (especially among coastal participants), temperature extremes, and severe weather. Water quantity was likewise a concern for its impact on natural resources. Ecosystem integrity, water quality, and shoreline change were also important. The responses revealed that research, survey, education, and outreach are the main actions perceived being undertaken to address climate-related issues. Needs and challenges identified regarding climate-related work included tracking local data on effects and impacts, creating a centralized information area to store it, and obtaining monetary and staff resources to improve management related to climate variability. Other tools suggested included the need for predictive impact modeling, legislation, standardized climate modeling, and standardized data and methods. These needs then translated into action items that are listed in Chapter 5: Statewide Conservation Strategies. The workshop website can be accessed at http://www.dnr.sc.gov/ccworkshops/.

Building Consensus on the Issues

Partnerships and collaborations were essential to the development of the first Action Plan and this iteration. Not only were partners identified and sought for technical advice in creating the extensive compilation of species and habitat background accounts, but also further connections were built in the process of defining threats to SCDNR's priority species and developing conservation recommendations and strategies for abating these threats. The implementation of the SWAP has brought in new partners and volunteers to help with research, survey, and habitat enhancement work.

The development of the South Carolina Priority Species List, as well as the accounts for listed species, was a broad, collaborative effort that involved partners from all over the Southeastern United States and from every facet of natural history background. The taxa teams responsible for creating the species lists were selected by agency staff as well as individuals from State universities and other agencies. Taxa leaders often sought input from taxa experts from all over the country. Lists were also reviewed extensively both inside the agency and out. For example, in 2005, over 100 individuals were contacted in the creation and review of the bird priority list alone. The varying approaches to taxa priority list creations reflected the varying degree of expertise available and the efforts necessary to employ their help.

The habitat characterization of the State helped to identify potential partners well beyond the doors of research institutions. Concerned individuals from myriad groups were also given opportunities to provide input for defining the key habitats, threats to their continued health, and potential conservation actions. Additionally, technical assistance was pursued to create a proper vegetative classification and develop mapping capabilities.

Conservation recommendations provided by species account contributors and taxa groups were refined by a process of identifying concrete strategies, plausible actions to carry out those strategies, and potential partners for proposed measures. As conservation strategies were

developed for each species, it became evident that they could be separated into eight categories, which we have designated as Conservation Action Areas (CAAs). A ninth—climate change—was added in 2013. These CAAs and their associated specific implementation strategies are presented in Chapter 5 and repeated here in Box 7-1.

BOX 7-1: NINE CONSERVATION ACTION AREAS

- Education and Outreach
- Habitat Protection
- Invasive and Non-native Species
- Private Land Cooperation
- Public Land Management
- Regulatory Actions
- Survey and Research Needs
- Urban and Developing Lands
- Climate Change [NEW]

Additionally, the SCDNR recognized that there are overarching conservation strategies that are likely to assist in protecting wildlife and habitats statewide. Therefore, the SCDNR determined that formation of Conservation Action Committees around each of the CAAs identified would assist in determining these overarching strategies. Conservation Action Committees would provide an excellent opportunity to work with partners to develop comprehensive statewide strategies for South Carolina that were not tied specifically to a single species or habitat. The strong partnerships between the SCDNR and other state and federal agencies, organizations, academic institutions, and industries within the State demonstrate dedication to overcoming challenges inherent in implementing conservation strategies. Two Conservation Action Committees, those for Education and Outreach and Urban and Developing Lands, were convened prior to completion of the 2005 SWAP (then CWCS); additional committee meetings will be held as needed for the remaining CAAs as the SWAP continues to be implemented. Resulting conservation strategies will be included in future revisions of the South Carolina SWAP.

The two Conservation Action Committees that were convened in 2005 were facilitated by planning team members, but attendees were otherwise allowed to discuss the technical process and elaborate as a group. Typical information derived from these working groups included not only specific identification of interested parties and stakeholders, but also histories of related actions and leads for further partnering efforts. Perhaps most exciting were the instances where working groups reached consensus on issues and began brainstorming innovative solutions. Additional discussion of the fruits of the working groups efforts is included within each CAA discussion in Chapter 5.

Public Review and Comment (2014)

As the time approached to review and revise the Plan, the public was kept informed of the process and encouraged to participate. Articles in *South Carolina Wildlife* magazine and other publications described the process. Completed species lists were sent to conservation partners in-state and in neighboring states for peer review and comment. Social media has become a highly effective way to distribute timely information to the public. A Pew Research (2013) report shows that over 64% of American adults use Facebook and half of these use it as a source of news. From 2007 to 2014, the SCDNR's website has seen an increase in requests for specific pages by 57% (P. Epley, pers. comm.) Therefore, when it was time for the draft of the 2015 SWAP to

undergo public review, it was posted online at the SCDNR website for 35 days during the summer of 2014. An announcement was sent in an email blast to all partners, staff, and other interested individuals with a request to forward. In addition, posts were made on SCDNR's Facebook page and Twitter account. Comments were compiled and archived by the State Wildlife Grants Coordinator and relevant comments incorporated into appropriate chapters of the Plan. Suggestions given were in regards to education/outreach opportunities, measures of success for programs implemented, and grammatical/typographical error corrections. A direct result of a request for more citizen science opportunities using a web-based approach was a new page on the SWAP website with links to participation opportunities by species, habitat, or miscellaneous data gathering needs. The public did not suggest the addition of any species for inclusion on the SWAP priority species list but did question the inclusion of game species since they are regularly hunted. Therefore, an explanation was added in Chapter 2: SC's Priority Species.

Bringing the Message to Partners and the Public

With the collaborative foundations built during the initial stakeholder input and the planning stages of the project, the focus now turns to the future and the potential to continue these efforts. As the newest revision of the SWAP drives the implementation stage, partnering will become even more important in reaching successful outcomes. Financially, the ability to collaborate can only improve the efficiency of all partner efforts.

As implementation continues and planning for future revisions is on the horizon, the State Wildlife Grants (SWG) Coordinator will be tasked with maintaining the network of partnerships. Web-based contacts and media, presentations, and popular publications will continue to be utilized in this endeavor. *South Carolina Wildlife*, the SCDNR magazine publication, will continue to release updates on the SWAP and related SWG-funded research. The magazine has over 52,000 subscribers with research indicating that each issue is read by three to four individuals. In 2005, SCDNR planned to create a Wildlife Initiative Newsletter so that partners and the public could follow the successes of the SWAP. Instead, the magazine plans to include a section highlighting one or two species of need in each issue. Challenges and successes will be discussed, and a section on how the public can help support conservation efforts will be a key component. The vast readership of the magazine makes this route a better alternative to the previously proposed newsletter and cuts down on printing and distribution costs.

In addition, a SWAP display was created for use at various workshops, educational facilities, and outdoor programs to inform the citizens of South Carolina about our species of greatest conservation need, where they live, and the challenges they face. An accompanying handout provides information on simple actions people can take to be environmentally conscience and help implement the SWAP.

Finally, as the development of data tools to support the SWAP continues, the SWG Coordinator will continue soliciting involvement and interest from partners throughout the State and region, to create a dynamic user interface for collaborative input on projects, species and habitat information, as well as demographics and, ultimately, future SWAP iterations. A novel approach to information collection, the collaborative data interface described in Chapter 6 will allow field biologists access to the SCDNR's information storehouse in an effort to make data updates fluid

and almost instant. This open information gathering, while closely moderated for technical accuracy, will allow planners and managers to actively adapt their land use decisions with the most current knowledge of species needs and threat characterizations.

The SWAP will be placed on the World Wide Web through a SCDNR link on our homepage. Web-enabling the SWAP will make searching it easier, and interactive maps are being considered to accompany the document.

The mission of the SCDNR defines our role as one of stewards of the State's natural resources. Essentially, that role depends on the support and involvement of those groups and individuals with vested interests in the continued health and wealth of South Carolina's natural heritage. Public and partner involvement must—and will—continue to be a focus of the SWAP as the program strives to meet the needs of present and future interests.

CHAPTER 8: IMPLEMENTATION AND ADAPTIVE MANAGEMENT

Implementation of the SWAP

The primary focus of South Carolina's SWAP is continued, efficient, and effective conservation and management of wildlife diversity. Through implementation of the Plan, coordination of diverse conservation efforts, and forging of effective partnerships, the SWAP will meet its mandate. Coordination efforts will bring together expertise and funding sources from various partners and apply them to needs identified in the SWAP. The initial congressional intent for the State Wildlife Grant Action Plans was to identify and focus on the species in greatest conservation need and yet "address the full array of wildlife and wildlife related issues." At this nexus, the SWAP provides focus and guidance for SCDNR priorities when allocating personnel and financial resources for research and management.

Already, partnerships bolstered during the creation of the SWAP are offering potential resources for meeting the objectives and strategies described in this Plan. Many potential SWAP partners have also identified the Action Plan as an excellent resource to forge additional support for conservation. By compiling state fish and wildlife conservation issues in a single document for the first time, it was possible to develop a coordinated approach ranging from individual species' concerns up to regional habitat-level concerns. This Plan is more than an outline for specific conservation actions; it continues to serve as a framework for expanding partnerships and interdisciplinary collaboration in support of these actions. An important first step will be to identify these additional individuals, land managers, and organizations that can contribute to and use SWAP information in a timely way.

Two main concerns were identified in the past in association with implementation planning. The first, identified in the 2005 public input process undertaken in the early stages of initial Plan development, involved the need to communicate with constituents more effectively about the goals and vision of the SCDNR and the SWAP. Such communication, it was deemed, would increase public support, ownership and partnership development. In response, news articles, poster sessions, videos, and other outreach materials have been created highlighting SDNR's role in the SWAP. The second concern dealt with the potential expense of time and funding for the collection, analysis, and reporting of extensive data needs as identified by SCDNR biologists. These needs included those associated with the development of the South Carolina Comprehensive Monitoring Program outlined in Chapter 6. The Monitoring Program is still being refined and the SCDNR will continue to expound upon this concept. These challenges must, and will be, met as the evaluation of this Plan in future revisions depends on public support and effective monitoring for dynamic management.

In 2006, SCDNR drafted an Implementation Plan for the SWAP (then CWCS) which made suggestions for priority research. Many of these suggested topics went on to become State Wildlife Grant proposals that were chosen for funding and have been successfully completed. Those projects that have been completed as of 2013 are summarized in Chapter 9. An additional 17 more are in some phase of completion and will be summarized in subsequent iterations of the Plan.

Request for Proposals and Project Selection within the SWAP

Every year, the State Wildlife Grants Coordinator solicits proposals via an email network. All submitted proposals are reviewed and compiled by the Coordinator in preparation for formal review. Rigorous review and selection procedures ensure that sponsored projects are effective and efficient in meeting the goals and objectives of the SWAP. The SWAP Steering Committee reviews all proposals to determine if projects clearly focus on South Carolina priority species and their associated actions recommended within the SWAP.

Members of the SWAP Steering Committee include the following or their designee:

- State Wildlife Grants Coordinator
- Deputy Director of Wildlife and Freshwater Fisheries
- Assistant Deputy Director of Wildlife and Freshwater Fisheries
- Chief of Wildlife Management
- Assistant Chief of Wildlife Management
- Chief of Freshwater Fisheries
- Assistant Chief of Freshwater Fisheries
- Deputy Director of Land and Water Resources
- Deputy Director of Marine Resources
- Assistant Deputy Director of Marine Resources

The SCDNR seeks to fund innovative, interdisciplinary projects that attempt to address the needs of priority species listed in the SWAP and undertake practical application of SWAP goals. The urgent need to achieve environmental sustainability and protect South Carolina's ecosystems challenges applicants to develop new ways to engage organizations in problem solving. Proposals selected will:

- contribute to applied problem-solving for an immediate and specific issue that is directly related to wildlife conservation;
- build capacity for collaborative statewide wildlife conservation; and
- incorporate strategies to apply and communicate outcomes for the improvement of policies and/or management practices.

Funding is allocated according to budget cycles and request-for-proposal processes associated with State Wildlife Grants and other funding sources. Competitive SWG and Multi-state SWG proposals are reviewed in the same fashion.

Adaptive Management, Maintenance, and Communication Plan

Implementation will continue to be a dynamic process through time, involving monitoring process management, performance assessment, adaptation as new information dictates, and refocusing to new tasks and projects as appropriate. As described in Chapter 6: SC's Comprehensive Monitoring Program, a major component of the SWAP's coordination and review will be dependant on successful monitoring of conservation projects and actions—

effectiveness monitoring. In the long-term, effective review and revision of the Plan will depend on the proposed effectiveness monitoring protocols and procedures. Conservation actions will have to be evaluated based on their ability to further the goals and objectives of the SWAP. As an agency, SCDNR sets project objectives and identifies measures of success for management actions. As SWAP projects are evaluated, similar indicators of success will be defined at the strategy level.

As a requirement of the SWG program, project leaders will be required to produce annual progress reports for review by the Steering Committee. These reports will be evaluated for insight into adaptive management needs and reassessments of the SWAP. Final project reports will be available in an online repository linked to the SWAP website and will be summarized in future revisions of the SWAP. Continued monitoring and evaluation of management actions will create an active implementation of the "living" SWAP document. Project leaders will also be involved in periodic communication efforts focused on increasing public awareness of SWAP implementation. The Catawba Indian Nation will also receive updated lists of priority species that do or may occur on their tribal lands. Maintaining these communication links with the public and broader conservation community will be critical to the success of the SWAP.

Review and Revision: Considering Lessons Learned

As discussed in Chapter 5, the purpose of a monitoring plan is to assess both species and habitats as well as related conservation actions. Also, as it pertains to the SWAP, it is important to evaluate the effectiveness of projects funded through the State Wildlife Grants program. Performance measures should be selected that are realistic goals and easily reportable in the USFWS's Wildlife TRACS online system.

As per Element 6 of the original legislation establishing the SWG program, all states made a commitment to review and revise the SWAP within ten years. The SWAP/SWG program in South Carolina will continue to be reviewed on a 5-year cycle to ensure the program and the SWAP remain relevant and current with evolving landscapes and developing conservation efforts. This cycle will include the previously described plans for monitoring, maintenance, adaptive management, review and revision. Within the 5-year time period, it is expected that certain issues will trigger an early revision of the SWAP or submission of addendums for the Plan. The identification of new information on species priorities gained through surveys, research, and monitoring or reprioritization of projects and actions following goal achievement will be recognized as adaptive management efforts requiring Plan reassessment. However, planning improvements such as (1) identification and elimination of flaws in the program or SWAP implementation process, (2) identification of more efficient or valid approaches to internal supporting processes such as species prioritization and threat assessment, and/or (3) expansion of those taxa groups treated only cursorily in this current SWAP document would be viewed as lessons learned contributing to the next iteration of the SWAP during a regular revision cycle.

CHAPTER 9: SC'S STATE WILDLIFE GRANTS PROJECT SUMMARIES

South Carolina began implementing its Action Plan as soon as it was initially approved back in 2005. Since that time, 35 State Wildlife Grants have been completed and are summarized in this chapter. Table 8-1 lists them in numerical order. Due to personnel turnover, the author of the report may differ from the actual principal investigator (PI) of the project. This is noted in the title of each report. There are an additional 18 regular grants in progress as well as 3 competitive SWG grants, and those will be reviewed in the next revision of the SWAP. All final federal reports can be found online at the State Wildlife Grants website and go into more depth for each grant. The subjects of these projects range from research and survey to habitat enhancement.

TABLE 9-1: CLOSED SWG GRANTS FROM 2005-PRESENT

Federal Grant No.	Duration	Project / Grant Title
T-6	2004-2005	Census and Monitoring of Waterbird Nesting in the South Carolina Coastal Plain *(continued from R-3)*
T-7-R-2	2006-2008	Conservation of Water and Seabirds in South Carolina
T-8	2005-2007	South Carolina Stream Planning Project *(became T-25-R-1)*
T-9	2005-2013	Robust Redhorse Restoration and Conservation
T-10-P	2005-2009	Landscape Planning for Priority Species on Agricultural Lands *(also T-46)*
T-11	2005-2008	Restoration of Longleaf Pine Forest on State-owned Land
T-13-R	2006-2009	Conservation of Migratory Landbirds in South Carolina *(previously T-4)*
T-14-T	2005-2009	Development of BMPs for Sustaining Wildlife in the Maritime Zone of South Carolina
T-15-P	2005-2007	South Carolina Reptile and Amphibian Conservation Planning
T-16-R	2005-2009	Upland Habitat Improvements on Lewis Ocean Bay Heritage Preserve
T-17-R	2006-2010	Protection and Management of Seabird Colonies (Monitoring/Breeding Parameters)
T-19-R	2006-2010	Habitat Enhancement on North and South Williman Islands, Beaufort County, South Carolina
T-20	2006-2007	Status and Management Plan Development for Three Rare Burrowing Crayfish
T-23-R-1	2006-2011	Controlling Access to Known and Potential Bat Roosts
T-24	2006-2008	Fish Passage on the Broad River: An Assessment of Benefits of Freshwater Mussels
T-25-R-1	2006-2013	South Carolina Stream Assessment *(previously T-8)*
T-27-R-1	2009-2012	Habitat Improvement for Grassland Birds
T-30-R	2007-2008	Taxonomy, Life History, and Distribution of the Crayfish, *Procambarus echinatus* (Edisto Crayfish)
T-31-R-1	2007-2012	Assessing Introgressive Hybridization Within and Habitat Requirements of Native South Carolina Redeye Bass
T-32-T-1	2007-2008	Restoring Seabird Nesting on Bird Key Stono Seabird Sanctuary
T-33-R-1	2007-2012	Robust Redhorse Electrofishing and Radio Telemetry Tracking of the Great Pee Dee River, South Carolina
T-35	2009-2010	Identification of Diamondback Terrapin Habitats in South Carolina *(thesis)*
T-36-HM	2008-2010	A GIS Model to Guide Landscape Scale Restoration at the Woodbury Tract and Hamilton Ridge Properties
T-37-T	2008-2010	Carolina Herp Atlas
T-38-R-1	2010-2012	Mink Restoration and Monitoring Development Project *(see 2 theses)*
T-39-M-1	2008-2013	Prescribed Burning Crew for South Carolina DNR Lands
T-40-L	2008-2009	Conservation of Belfast Plantation, Phase I
T-42-R-1	2008-2009	Use of GIS to Assess the Demographic Isolation of RCW Groups in South Carolina
T-44-R	2008-2010	Least Tern Reproductive Success on Rooftops
T-47-R-1	2008-2011	Conservation of Breeding Painted Buntings and Other Songbird Indicators in Early-successional Shrub-scrub Habitat Modified by CP-33 Buffers in South Carolina
T-48-R	2008-2010	Effects of Predation on Seabird Nests in Cape Romain
T-50-L	2009-2010	Conservation of Belfast Phase II
T-51-R-1	2009-2011	Ecology and Impacts of Coyotes on Loggerhead Sea Turtles, Least Terns, and Other Wildlife: Implications for Management
T-54-R-1	2010-2013	Monitoring Impacts of Yellow Pine Restoration of Avifauna in the SC Mountains
T-55-R-1	2010-2012	Using Citizen Science in the Study and Conservation of Breeding Painted Buntings
T-61-R-1	2012-2013	Decision Support Tools for Stream Conservation
U2-1-HM-1	Incomplete	Multistate Sandhills Ecological Restoration Project: Alabama, Florida, Georgia, and South Carolina

Note: T-5, T-21, T-29, and T-52 were CWCS/SWAP revision grants. T-1, T-3, t-12, T-22, and T-28 are unassigned numbers. T-26 is being continued as T-57. T-34, T-41, T-43, T-45, T-49, and T-53 are still active.

Project Summaries

Census and Monitoring of Waterbird Nesting in the South Carolina Coastal Plain (Federal Grant #: T-6 (continued from grant R-3), Duration: 2004–2005) PI: Laurel Barnhill, SCDNR (formerly)
This grant is a continuation of South Carolina Grant R-3, which utilized WCRP funds This grant picks up where Grant R-3 left off, with the exception that the Bald Eagle work initiated under R-3 continues under that grant and is excluded from this grant. To read a review of T-6, please see the online final report.

Conservation of Waterbirds and Seabirds in South Carolina (Federal Grant #: T-7-R-2, Duration: 2006–2008) PI: Thomas Murphy, SCDNR (retired); Author: Christine Hand, SCDNR

Grant T-7 funded the monitoring and management of waterbirds nesting on the South Carolina Coastal Plain from October 2006–September 2008. Bald Eagle surveys and ground visits were used to document chick production, estimate mortality rates, and assess population levels. Colonially nesting wading birds were surveyed. More extensive surveys were conducted at Wood Stork colonies to document nest numbers and to estimate productivity. A decline in numbers of colonially nesting wading birds that may be due to loss of habitat and drought conditions was documented. Movements from natural wetlands to constructed wetlands and an increase in human-bird interactions was observed. Censuses were conducted for 6 species of seabirds, and signs were posted to protect sensitive nesting areas. Least Terns nesting on rooftops were surveyed. American Oystercatchers were surveyed and banded to yield data that will improve regional estimates of survival. Research projects conducted by 3 graduate students at Clemson University were supported and coordinated. Research topics include seabird/human disturbance, techniques to enhance Oystercatcher productivity, and identifying preferred winter foraging habitat for Oystercatchers.

DNR staff participated in professional meetings including the annual Wood Stork Working Group, American Oystercatcher Working Group, and gave presentations to educate the public about coastal birds. Technical assistance was provided for a variety of projects including negotiating management zones around eagle nests and enhancing the use of managed impoundments by wading birds and shorebirds.

Robust Redhorse Restoration and Conservation (Federal Grant #: T-9, Duration: 2005-2013) PI: Ross Self, SCDNR; Author: Scott Lamprecht, SCDNR

The objective of this project was to establish self-sustaining populations of Robust Redhorse, (*Moxostoma robustum*), suckers in the Santee River Basin using Savannah River brood stock. The first step was to stock the Santee River Basin with cultured Savannah River strain Robust Redhorse (RRH). The Santee Basin was identified as a potential population establishment site because its size, location between two identified population, and evidence of historical RRH occurrence in the drainage. A primary consideration of this effort was to use progeny from 100 pairings to ensure that the new population would be genetically diverse. Brood stock collection was made from a numerically healthy and geographically nearby population of Savannah River

RRH. Fish were collected during their natural spawning activities over a mid-channel gravel bar using stationary electro-fishing grids and a mobile electro-fishing boat. Eggs and milt were immediately collected from the actively spawning adults, and fertilization occurred individually between eggs from one female and milt from one male. Depending on the quantity, a female's eggs were divided between 1 and 3 males. Fertilized eggs were transported to the Bayless Hatchery for incubation and hatching. Grow-out was made in production ponds at the Dennis Wildlife Center. Spawning efforts occurred in every spring from 2004-2013.

Of the 45 females spawned over 10 years, 3 females have been used more than once. However, 2 of these incidences occurred in 2010 where production failed. The number of eggs collected from each female varied, and their contribution to subsequent stocks was not monitored. Through the 2009 spring spawning season, we have produced offspring from 98 individual matings. However, production over the last 3 years has been minimal. As a result, we continued spawning efforts through the spring of 2013 in order to reach an introduction goal of 100 genetically distinct matings. Spawning efforts produced 15,000 eggs which resulted in the stocking of 11,000 fry into grow-out ponds. All fish stocked to date have been tagged with either coded wire (CW) tags or pit tags (P).

We also surveyed and monitored the growth, survival, maturation, and spawning success as well as habitat use of stocked RRH in the Santee River Basin and monitored existing populations in the Savannah and Pee Dee River systems. Monitoring efforts continued into 2013. Building on previous work, observations were collected incidental to anadromous fish monitoring below Wateree Dam, Columbia fish way monitoring on the Congaree River, directed collection effort in the Congaree and Wateree Rivers, and by telemetry studies described below. DNR collected 4 specimens in the lower Wateree River during December 2012 and subsequently equipped 2 with sonic transmitters. This collection was made by using transmittered fish to locate aggregations outside of the spawning season. Duke Power picked up 16 specimens during their 2013 spring anadromous fish survey of the Wateree Dam tailrace. The Columbia fishway monitoring was hampered by high flows and turbid water during the spring of 2013. However, when observations were made, RRH were observed moving upstream.

Because of the difficulty in collecting information on juvenile and RRH, a telemetry survey was initiated in 2009 in the Wateree River/Congaree portion of the system. At total of 14 fish have been actively monitored, and the following pattern has been observed during multiple years: all the study fish occupied the Wateree Tailrace during spawning season; all fish used the lower Congaree River after spawning season; 11 of the 14 fish traveled up the Congaree to at least the midway point; 9 of the 14 passed upstream of Rosewood landing; 2 were documented using the Broad River (below the Columbia Dam); 2 fish used the lower Saluda (one in successive years); and 3 fish were detected in the upper Santee River above Lake Marion. The repeated summertime use of the Congaree River is interesting because it is significantly cooler than the Wateree River and may indicate a temperature preference. It is interesting to note that while we observed fish exhibiting spawning behavior in the Wateree Dam tailrace, we observed significant numbers of fish ascending the Columbia Fishway. Long distance movement of these fish can occur relatively quickly; one fished moved downstream 124 km (77 mi.) in 2.6 days and there are numerous instances of fish moving more than 30 km/day (19 mi./day).

The project also gave us the opportunity to inform and educate the public about the relevance of our efforts to reestablish and conserve RRH in South Carolina. During the past year, staff members have included our RRH studies in all appropriate public outreach efforts. Staff often addressed the need for display specimens at the Charleston Aquarium. Staff attended the 2013 annual meeting of the Robust Redhorse Conservation Committee (RRCC) in Georgia, and a plan for brood stock collection, spawning, stocking and research efforts were reviewed. Conservation and recovery were coordinated among the agencies and organizations involved. Staff members were also actively involved in a larval fish toxicology study lead by an NC State researcher.

The development of baseline genetic data for the Savannah population was realized and a foundation for future evaluation of ongoing re-establishment within the Santee River System is being built. Subsequent to development of genetic markers, fin clips from all collected specimens were catalogued in order to determine stock contributions based on individual crossings and to detect evidence of natural recruitment.

Landscape Planning for Priority Wildlife Species on Agricultural Lands (Federal Grant #: T-10-P, Duration: 2005-2009) PI: Judy Barnes, SCDNR (retired); Author: Billy Dukes, SCDNR See also T-46.

The approach utilized in this grant was to employ 3 technical guidance biologists to work with USDA staff to engage in landscape-level planning for priority wildlife species on private agricultural lands. The technical guidance biologists worked to incorporate habitat restoration measures for priority wildlife species into plans written through the Conservation Reserve Program, Environmental Quality Incentives Program, Conservation Security Program, Wetland Reserve Program, Wildlife Habitat Incentives Program, Grassland Reserve Program, and Forest Land Enhancement Program.

Over the course of the grant period, 248 conservation plans potentially affecting 170,359 acres in 23 South Carolina counties were written. Technical guidance biologists also delivered 47 programs for a combined audience of 2,511 people. Nine news releases promoting habitat conservation for priority wildlife species were written and submitted, 6 technical brochures on various aspects of wildlife conservation were developed, and 22 fact sheets on threatened and endangered species were completed. In addition, one biologist provided technical guidance and assistance in the development of a statewide Gopher Tortoise Conservation Plan for South Carolina.

Restoration of Longleaf Pine Forests on State-Owned Lands (Federal Grant #: T-11-1-R, Duration: 2006-2008) PI and Author: Tim Ivey, SCDNR

The objective of T-11-1-R was to restore longleaf pine forests and associated herbaceous species on a minimum of 1,000 acres of state-owned lands. Accomplishments included herbicide treatment of 45 acres of established longleaf stands to reduce competing hardwood vegetation on three SCDNR-owned heritage preserves. Twenty-five acres of new longleaf plantings (8,000 seedlings) were established on Little Pee Dee River Heritage Preserve and 8500 containerized longleaf pine seedlings were interplanted within 42 acres of sparse existing stands of longleaf pine on Longleaf Pine Heritage Preserve. Re-establishment and/or improvement of 14 miles of

firebreaks and prescribe burning of 1,213 acres of longleaf stands occurred on Woods Bay and Longleaf Pine Heritage Preserves. Aerial herbicide site preparation and planting of 14,000 longleaf pine seedlings was conducted to convert 25 acres to longleaf pine on Congaree Bluff Heritage Preserve. Site preparation and planting of 25 acres of longleaf pine was accomplished at Janet Harrison High Pond Heritage Preserve. Herbicide release of competing vegetation with 40 acres of longleaf was conducted at Longleaf Pine and Lynchburg Savannah Heritage Preserves. Understory brush control was utilized in 140 acres of longleaf stands at Webb Wildlife WMA. The construction of 18 miles of new firelanes at Lewis Ocean Bay Heritage Preserve was also accomplished as well as 162 acres of site prep and longleaf pine establishment at Woodbury WMA. McBee WMA underwent 8 acres of longleaf planting while 25 acres of longleaf plantings were done at Hamilton Ridge WMA. Site prep and planting of 831 acres of longleaf pine at Manchester State Forest was also accomplished. Mechanical understory control of competing vegetation in 32 acres of longleaf pine stands at Lewis Ocean Bay Heritage Preserve and herbicide timber stand improvement of 40 acres at McBee WMA was completed. The total longleaf habitat improvements made equaled 1,510 acres with new longleaf pine stands established on 1,135 acres.

Conservation of Migratory Landbirds in South Carolina (Federal Grant #: T-13-R-2, Duration: 2006-2009) PI: Laurel Barnhill (formerly with SCDNR now USFWS); Author: Janet Thibault, SCDNR

Grant T-13-2-R funded prescribed burns at Bonneau Ferry Wildlife Management Area during the growing season of 2008. It also funded research on the habitat requirements and demographics of Swainson's Warblers (*Limnothlypis swainsonii*) and Painted Buntings (*Passerina ciris*) and the development of monitoring protocols for bird species with the greatest conservation need to better manage for these species in coastal South Carolina.

Productivity, survival, habitat use, diet, and movements of Swainson's Warblers were studied at the Woodbury Tract Wildlife Management Area during 2006-2009 and built upon previous research conducted since 1997. Swainson's Warblers were color banded and several were radio tagged and followed with telemetry equipment throughout the nesting season. The site fidelity to Woodbury Tract was high with most birds returning to the same territories year after year. Females appeared to breed after their initial hatch year, while first year males did not. Home ranges often overlapped with other Swainson's Warblers and territory sizes varied. Swainson's Warblers forage in the upper layer of decaying leaves, and hydrology and flooding of the site affects the timing of breeding and foraging opportunities for this species.

The ecology of painted buntings and other early-successional passerines was studied at the Webb Center Wildlife Management Area and The Nemours Wildlife Foundation during the breeding seasons of 2006-2008. The study assessed the suitability of wildlife food plots in these two differently managed landscapes and how the management regimes affected the occurrence of Painted Buntings and other bunting species. Results indicated that buntings were not likely to be present at either of the managed sites due to the frequency of management at these areas. Buntings likely prefer larger areas of old/fallow fields that are interspersed among mid- to late-successional forests.

Development of Best Management Practices for Sustaining Wildlife in the Maritime Zone of South Carolina (Federal Grant #: T-14-T, Duration: 2005-2009) PI and Author: David Whitaker, SCDNR

The goal of this project was to develop Best Management Practices (BMPs) for anyone building a home or development within an existing maritime forest. These BMPs would have the goal of minimizing ecological impacts to native fauna and flora. Staff conducted an intensive literature review, contacted numerous managers of "low impact" coastal developments to review their development guidelines and regulations, and interviewed various experts. Staff asked for advice from upland mammal biologists, botanists, ornithologists, herpetologists, foresters, and others. A 76-page booklet entitled, "Best Management Practices for Wildlife in Maritime Forest Developments" was published in November 2009. This document reviewed the animal species of the Maritime Forest with emphasis on habitat requirements for each, and special emphasis was given to SWAP priority species. This was followed by detailed descriptions of BMPs at the community, neighborhood, and individual home levels. Immediately after printing, 225 copies were distributed to planners and other officials of coastal communities, Office of Coastal Resources, Coastal Conservation Association, SC Forestry Commission, various SCDNR staff, SC Sea Grant office, SC Wildlife Federation, Coastal Conservation Association, and a number of private citizens. Additionally, the complete document was made available on the SCDNR website with 1,429 requests for the document being made in the first month after publication.

SC Reptile and Amphibian Conservation Planning (Federal Grant #: T-15-P, Duration: 2005-2007) PI: Steve Bennett, SCDNR (retired); Author: Will Dillman, SCDNR

This multi-task project included 4 separate jobs for 4 separate priority species: gopher tortoise diamondback rattlesnake, timber rattlesnake, and seepage slope salamanders. Each job will be addressed in its own section.

Gopher Tortoise Management – The objective of this job was to develop a plan to recover and enhance the gopher tortoise population at Aiken Gopher Tortoise Heritage Preserve (AGTHP) in Aiken County to include the re-stocking of tortoises from the surrounding habitat and from other sites in South Carolina. Three 1 ha (2.5 ac.) pens were established on site at the Aiken Gopher Tortoise Heritage Preserve to provide an area to house relocated tortoises. These pens housed groups of tortoises for approximately one year, and then were removed to allow the tortoises to become "established" in their new environment. Waif gopher tortoises were received from a variety of different places within the Southeastern US, and several federal and state agencies and placed into the pens. Pen 1 housed waif tortoises from the Southeast and a group of hatchling tortoises from Hilda, SC that were contained within the pen under a separate hatchling enclosure. Pen 2 contained tortoises that were trapped on the AGTHP and considered to be the "resident" group. Efforts were made to trap and relocate all known Gopher Tortoises occurring on the site. In addition, aprons of AGTHP tortoises were excavated during the summer of 2007 by Tracey Tuberville and Kurt Buhlmann. One gopher tortoise nest containing two eggs was found. One of the eggs hatched, the other was infertile. That hatchling is small and is currently being maintained at SREL with the intention of adding it to the Pen 2 population in the spring of 2008. Pen 3 was used to house a group of gopher tortoises from a private property owner near the town of Grays, SC. In addition, two separate introductions of hatchling tortoises were made to Pen 3

during the Project period. Six hatchlings from laboratory-hatched eggs from the Tillman Sand Ridge Heritage Preserve were released into Pen 3 with starter burrows during summer 2007. An additional 6 hatchlings (also form Tillman Sand Ridge HP) were released into Pen 3 but covered under an 8 ft. x 8 ft. wire mesh cage in the autumn of 2007. The intention of the cage was to prevent predation by coyotes, crows, or raccoons. To date, the hatchlings seem to be surviving under the cages.

All tortoises have been measured, marked, and had blood samples taken (by Tracey Tuberville) for further genetic analyses. At the conclusion of this project, 56 tortoises were contained in the pens at the AGTHP.

Diamondback Rattlesnake Management – The first objective of this job was to determine the feasibility of managing rattlesnake populations by translocating Eastern diamondback rattlesnakes to sites with appropriate habitat within the historic range of the species, and to develop a model for eastern diamondback rattlesnake demography to include population size, survivorship, mortality, growth patterns, age classes, and sex ratio. The second objective was to conduct research and monitoring at the Webb Wildlife Center (continuation of ongoing monitoring) and at least 3 other public properties in the SC Coastal Plain that support longleaf pine habitat. Another task was to determine the potential distribution of longleaf pine habitat on public properties in the SC Coastal Plain using a qualitative vector GIS model.

The study was initiated in 2006, encompassing 4 study areas in the South Carolina Coastal Plain: Hoover Plantation (Jasper County), Nemours Wildlife Foundation (Beaufort County), Cheehaw Combahee Plantation (Colleton County), and Donnelly Wildlife Management Area (DWMA; Colleton County). In 2007, we added another study site, Okeetee Plantation (Jasper County), and discontinued efforts to monitor the EDB at DWMA. The study areas comprised varying degrees of upland pine savanna, and thus harbored Eastern diamondback rattlesnakes. In March 2007, we translocated all of the study animals that were telemetered in 2006 to the Webb Wildlife Center. We captured 4 new rattlesnakes (Nemours, N=1; Cheehaw Combahee Plantation, N = 3), and they were translocated in March 2008. All telemetered rattlesnakes were located weekly. We will continue to quantify movement patterns using data collected in 2007 following November ingress. We have begun our analysis comparing pre- and post-translocation movements using the individuals that were captured in 2006.

The long-term monitoring and research on the diamondback rattlesnake population at Webb Wildlife Center continued, and additional surveys were performed at Donnelly Wildlife Management Area, Cheehaw Combahee Plantation, Hoover Plantation, and Nemours Wildlife Foundation. No Diamondbacks were found at Donnelly Wildlife Management Area; however, diamondbacks were found at the other properties surveyed.

Timber Rattlesnake Surveys – The objectives of this job were to (1) determine the distribution of the montane phase and the Coastal Plain phase of this species in the region and to (2) develop a management strategy for the timber rattlesnake on public lands in South Carolina. (3) The population size and demography at selected sites had to be determined and included gathering information on population structure, sex ratios, mortality, reproductive success, survivorship, and

mortality. (4) The home range size had to be determined as well as habitat use and seasonal activity patterns for both "forms" of this species in this region using radio telemetry.

Between September 2006 and fall 2007, 15 timber rattlesnakes were implanted with radio transmitters and tracked. During the course of the study, hibernation, courtship, mating, and birthing were observed. Movements of male snakes appeared to be greater than those of the females, and both sexes showed an affinity for wooded areas. Both the montane and Coastal Plain phase of the timber rattlesnake were captured, implanted, and tracked. Currently, there appears to be no elevation, habitat, or sex differences in either phase of the Upstate timber rattlesnake. Data collected during this study has contributed to the understanding of the biology and habitat requirements of this species in South Carolina.

Seepage Slope Salamander Investigations – The objective of this project was to develop a predictive model for Coastal Plain seepage slope habitat as a means of identifying potential habitat for the Southern dusky salamander and Chamberlain's dwarf salamander, and to survey potential habitat for presence/absence of the target species. During the study, we collected specimens of the southern dusky salamander, when present, for genetic analysis to determine if there are "cryptic" species of this complex found in South Carolina.

Eight seep sites were monitored with water sampling wells and cover-board transects. Water quality and hydrology sampling was conducted at all seeps quarterly during the reporting period, and cover-boards were sampled three times. We initiated a molecular phylogeny study involving the two focal species of this project *Desmognathus auriculatus* and *Eurycea chamberlainii*. The goal of this study was to resolve the phylogenetic—and eventually the taxonomic status—of these 2 species and their "closest" relatives in South Carolina. Additionally, staff surveyed 26 sites for Plethodontid salamanders. Some of these sites were historic locations for *Desmognathus* and others were new sites selected due to their hydrologic and topographic characteristics. Salamander species in the family Plethodontidae were collected at 18 of these sites—*Eurycea chamberlainii* at 2 sites and *Desmognathus auriculatus* at 9 sites. One additional site in the Piedmont was sampled and a *Desmognathus* was collected there.

Preliminary results from the molecular phylogeny study indicate that the "focal" species *Desmognathus auriculatus,* Southern dusky salamander does not occur in South Carolina. To date, this analysis has identified 4 separate lineages of *Desmognathus* in the Coastal Plain and Piedmont of South Carolina, none of which are closely aligned with *D. auriculatus.*

Upland Habitat Improvements on Lewis Ocean Bay Heritage Preserve (Federal Grant #: T-16-1-R, Duration: 2007-2008) PI and Author: Tim Ivey, SCDNR

The objective of the habitat improvement project at Lewis Ocean Bay Heritage Preserve was to restore grassland, pine savannah, and pine woodland habitat sites within the 3-year funding period. Habitat restoration and management included clearing competing vegetation along 13 miles of roads, ditches, and rights-of-ways; 210 acres of competing understory removed from longleaf stands using herbicides and mechanical removal; 20 acres of longleaf pine stands underplanted with longleaf seedlings; 533 acres converted from slash pine to longleaf pine; and 18 miles of new firebreaks established. In addition, 76 miles of firebreaks were maintained and 2,338 acres prescribe burned.

Protection and Management of Seabird Colonies (Monitoring/Breeding Parameters) (Federal Grant #: T-17-R, Duration: 2006-2010) PI: Laurel Barnhill (formerly with SCDNR and now USFWS); Author: Janet Thibault, SCDNR

Seabirds such as Brown Pelicans, Sandwich Terns, Royal Terns, and Black Skimmers nest in large colonies on isolated islands and are susceptible to human disturbance. Over time, effects of disturbance may manifest as reduced reproductive success and increased energy expenditure on the part of adults and young. In 2006, the South Carolina Department of Natural Resources (DNR) established 3 barrier island seabird sanctuaries in Charleston County: Crab Bank, Bird Key, and Deveaux Bank. New regulations were designed to limit human disturbance and prohibited public access at Crab Bank and Bird Key during the nesting season and limited access to below the high tide line at Deveaux Bank. All 3 of these islands provide nesting habitat and stopover locations for seabirds and shorebirds which require islands that have suitable habitat for nesting and rearing young. The goal of this project was to monitor seabird colonies on these DNR protected islands and collect baseline measures of breeding parameters, determine habitat use of seabirds and shorebirds on the islands, and to better evaluate the health and condition of seabird populations in South Carolina in relation to the new regulations and for future comparisons. Research was conducted from 2006 to 2008.

Overall, the effects of the new seabird conservation regulations resulted in an increase in size of the Black Skimmer colony on Crab Bank, increased productivity of Black Skimmers at Deveaux Bank, and a re-establishment of nesting of Black Skimmers on Bird Key. Colony size and reproductive success of Brown Pelican and tern species at other islands was variable among locations and years. The results of the intertidal surveys indicated that the intertidal area is an essential component of seabird breeding habitat and is used for loafing, feeding, courtship, and chick-rearing by seabirds and shorebirds. The majority of birds were located along the water and on the lower portion of the beach during surveys. Brown Pelicans, Laughing Gulls, Black Skimmers, and Royal, Sandwich, and Gull-billed Terns were most frequently engaged in loafing and maintenance behavior in the intertidal zone of the islands, while shorebirds were most often observed foraging there. The health parameter analyses revealed that age was a significant factor affecting many health parameters of Brown Pelican nestlings. Packed cell volume increased with age when compared to wild adults. Levels of proteins and cholesterol were higher in the older age category, which may be necessary to support physiological development. Collection of baseline data such as that collected in this study provides a means to monitor the health of nesting populations and provides baseline data for comparative and long-term studies. These data are particularly valuable after catastrophic disease outbreaks or environmental contamination events.

Habitat Enhancement on North and South Williman Islands, Beaufort County, SC (Federal Grant #: T-19-R, Duration: 2006-2010) PI and Author: John McCord, SCDNR (retired)

This was a large, non-native invasive species eradication project that occurred on North Williman Island and South Williman Island which are located in north Beaufort County, South Carolina. Both islands exceed 1,000 acres in total size, and both are composed of a mosaic of

tidal estuarine marshland and interspersed hammocks (small upland islands also called hummocks). These islands are State-owned and are under the management authority of SCDNR.

North Williman Island includes 9 hammocks, ranging from 1.5 to 436.4 acres, while South Williman Island contains 12 hammocks, 0.4 to 688.4 acres in size. Biological inventories of plants and animals were performed by SCDNR on all of the hammocks of North Williman Island and South Williman Island during fall 2003 through winter 2005-2006. These initial SCDNR surveys revealed significant habitat degradation that was presumed to be caused primarily by the impacts of the invasive Chinese tallowtree (*Triadica sebifera*) and, specifically on several hammocks of North Williman Island, by feral goats (*Capra hircus*).

Habitat enhancement activities for this project were performed primarily on the largest hammocks within both North Williman Island and South Williman Island, hereafter referred to as "Goat Island" (436.4 acres) and "Big South Williman Island" (668.4 acres), respectively. Chinese tallowtree was particularly abundant and problematic in association with isolated freshwater depression wetlands. Such freshwater wetlands are most abundant on the largest hammocks within both North Williman Island and South Williman Island, and particularly on "Goat Island" and "Big South Williman Island". Chinese tallowtree out-competes many native plants and, as observed in isolated wetlands on both North Williman Island and South Williman Island, may ultimately produce nearly mono-species stands. Fallen leaves of Chinese tallowtree can alter water chemistry and water quality and may negatively impact populations of some amphibians. Additionally, dense populations of Chinese tallowtree may limit surface water availability and alter hydrology in isolated wetlands due to high water demand and heightened evapotranspiration during late spring through early fall.

Feral goats were only present on several nearly interconnected hammocks within North Williman Island, and these grazing mammals were typically only observed on "Goat Island". Evidence of over-browsing by feral goats was obvious and widespread, particularly on "Goat Island". Native plant diversity and populations of individual plant species were obviously suppressed relative to the observed status of such made during SCDNR surveys of nearby hammocks of comparable size and habitat diversity and where feral goats were not present.

Habitat restoration and enhancement efforts on North Williman Island were primarily based upon attempts to remedy and/or reduce perceived negative ecological impacts from both feral goats and Chinese tallowtree. The successful removal of the population of approximately 100 feral goats from "Goat Island" and all of North Williman Island was completed in early 2008. After goats were successfully removed, 423 seedlings of sweetgrass (*Muhlenbergia sericea*) were planted within 12 colonies on "Goat Island" at scattered sites in the upland transition zone just inland of tidewater influence. Though considered uncommon, this native grass was found to be rather widespread on hammocks within North Williman Island and South Williman Island that were not impacted by feral goats. Sweetgrass and other native grasses provide valuable cover and seeds for wildlife. Only a few damaged specimens of this species were observed on "Goat Island" prior to the successful removal of feral goats. The overall survival rate for planted sweetgrass was nearly 75%, and thriving colonies remained at most planting sites at the completion of this project.

Fourteen trips were made to North Williman Island for herbicide injection of Chinese tallowtrees from 5 November 2007 through 20 December 2007. Approximately 4,750 such plants were injected with herbicides (50% Habitat® or 50% Clearcast™) over 5 North Williman Island hammocks. The remaining 4 North Williman Island hammocks do not have suitable habitat for Chinese tallowtree. The total acreage canvassed for Chinese tallowtree herbicide treatment was ~526.5 acres, requiring 272.5 man/woman-hours. A general evaluation of herbicide injection results was made from spring 2008 through summer 2010 and indicated the successful kill of ~95% of the total Chinese tallowtree (tree-stage plants) population for the entire North Williman Island hammock group. Isolated, low-salinity wetlands were of highest priority in the attempted eradication of Chinese tallowtree. The kill rate for tree-stage Chinese tallowtrees associated with 17 such wetlands likely approached 98%, with nearly 2,500 mature trees killed. Observations through the summer of 2010 revealed a gradual positive response of native plant communities throughout North Williman Island hammocks on which Chinese tallowtree was eradicated and particularly on hammocks on which feral goats were removed in addition to Chinese tallowtree eradication.

Primarily due to funding limitations, habitat enhancement on South Williman Island was limited to the placement of Wood Duck (*Aix sponsa*) nesting boxes (one box each) in 7 isolated wetlands within "Big South Williman Island". Two Wood Duck nesting boxes were placed in an isolated freshwater wetland on "Goat Island". Wood Duck had been recorded in winter on both islands during initial SCDNR surveys, but no evidence of nesting was observed prior to these habitat enhancement efforts. All nesting boxes were erected in late winter 2008, and all boxes were inspected for signs of Wood Duck nesting activity during each spring, 2008-2010. One, 2 and 6 boxes were used by nesting wood duck in 2008, 2009, and 2010, respectively. The observed increase in nest box utilization over the 3 years of observations suggests a likely increase in the local Wood Duck population in the vicinity of the Williman Islands, potentially in response to the provision of nesting cavities.

In addition to the aforementioned habitat enhancement activities, complimentary habitat enhancement and restoration activities were achieved on "Goat Island" through a Cooperative Agreement between the United States Department of the Interior, Fish and Wildlife Service and SCDNR from 1 August 2008 through 30 June 2010. The Cooperative Agreement included: (1) the follow-up eradication of Chinese tallowtree (mostly seedlings); (2) the removal of dead tree-stage Chinese tallowtree snags (trees killed by herbicide injection in late 2007 and early 2008) from 3 isolated wetlands which previously had particularly dense stands of this invasive plant; and (3) the damming of old historic drainage ditches associated with 5 isolated wetlands. Positive responses of native plants, plant communities and wildlife observed on "Goat Island" through the completion of this project should be attributed to habitat enhancement activities achieved through both this project and the Cooperative Agreement.

"Goat Island" was more severely negatively impacted by the combined impacts of feral goats and Chinese tallowtree than was any other hammock within either North Williman Island or South Williman Island. Both habitat restoration, as observed through positive responses of native plants and plant communities, and positive responses of wildlife were most obvious on this North Williman Island hammock. Habitat enhancement and restoration activities yielded a nearly immediate positive response in recovery of native plant communities, particularly in and near

isolated wetlands and on the periphery or outer upland fringe of hammocks that had been drastically impacted by browsing goats. Wetland plant diversity increased dramatically, as demonstrated by a threefold increase in recorded plant species diversity in one isolated wetland as compared to the recorded diversity prior to habitat enhancement activities. Buttonbush (*Cephalanthus occidentalis*), which is a valuable wetland wildlife plant, responded dramatically to the removal of over-shading Chinese tallowtrees and to the removal of feral goats. Prior to habitat enhancement activities, buttonbush was fairly widespread and abundant in wetlands on "Goat Island", but practically all specimens were in poor condition and few, if any, specimens produced blooms or seeds. Following habitat enhancement activities, buttonbush specimens throughout wetlands on "Goat Island" displayed dramatic growth of new stems and foliage and produced abundant flowers and seeds by 2009 and 2010. Plants typical of the upland-tidal marsh ecotone recovered from severe browsing with sprouting of new growth and by recolonization from seedlings. Sweetgrass plantings in peripheral upland areas of "Goat Island" were very successful and supplemented natural colonies of native grasses, including several naturally occurring sweetgrass colonies which slowly recovered and became established after goat removal. The recovery of this forest edge habitat should provide additional breeding and foraging habitat for Painted Bunting (*Passerina ciris*), a species of highest conservation priority in South Carolina and throughout the region. The recovery of forested plant communities and habitats was more subtle since much of "Goat Island" and other North Williman Island hammocks are covered in closed canopy forest. Subcanopy shrubs, saplings, and herbs slowly responded with resprouting from previously heavily browsed trunks and stems and from rootstock. Also, substantial and diverse germination from the seed-bank was observed. Prior to removal of feral goats, seedlings—including those of Chinese tallowtree—were quickly consumed and were rarely observed. Several decades will likely be required for subcanopy plant communities to recover to a stage similar to such communities on nearby hammocks that have not been impacted by feral goats. With further recovery of shrub thickets and habitat complexity anticipated for "Goat Island" over the next several decades, additional recruitment of breeding birds will likely occur as gradually recovering habitats become suitable as nesting and brood-rearing habitat.

Amphibians and dragonflies were quickly recruited to depression wetlands that displayed enhanced surface water duration following removal of Chinese tallowtree and damming of drainage ditches. Increased surface water retention in such isolated wetlands on "Goat Island" will likely sponsor an increased distribution of "Lunz's crayfish"—or hammock crayfish—(*Procambarus lunzi*), a species of conservation priority in South Carolina, as well as other aquatic animals as well. Increased surface water retention may also attract American alligator (*Alligator mississippiensis*) to additional wetlands on "Goat Island", which could result in the creation of dens and pools that may further enhance wetlands for potential colonization by additional aquatic species.

A rookery used by 4 species of wadingbirds was found in the largest wetland on "Goat Island" during SCDNR surveys in spring 2006. The removal of hundreds of large Chinese tallowtrees from the perimeter of this wetland may have improved the quality of this wetland for wadingbird nesting and foraging habitat. Both White Ibis (*Eudocimus albus*) and the endangered Wood Stork *(Myctera americana*) were observed in higher numbers in association with this wetland after the removal of Chinese tallowtrees, indicating that access to shallow water foraging sites was

improved. Wading bird nests were not observed in Chinese tallowtrees in spring 2006 or in spring 2007, and all wading bird nests were in either buttonbush or Coastal Plain willow (*Salix caroliniana*). Both of these native wetland plants responded very positively with enhanced growth following the eradication of competing Chinese tallowtrees. By the spring of 2010, 5 species of wadingbirds, all of which are considered priority conservation species in South Carolina, were recorded within the rookery in this wetland. Also, 2 Great Blue Heron (*Ardea herodias*) nests were constructed in large pines bordering a small, open, isolated wetland on "Goat Island" in spring 2010. No wading bird nesting activity had been observed in association with this wetland prior to the eradication of many large Chinese tallowtrees that had dominated the perimeter of this and other wetlands.

Habitat restoration and enhancement efforts on North Williman Island—particularly on "Goat Island"—and on "Big South Williman Island" yielded varied positive ecological impacts. The gradual recovery of habitats and plant communities should continue well into the future throughout North Williman Island hammocks on which habitat restoration and enhancement activities were conducted under this and the complementary Cooperative Agreement. Particularly for "Goat Island", where the most intensive habitat enhancement efforts were made and where feral goats had drastically impacted nearly all habitats by over-browsing, native plant communities and associated wildlife should continue to show positive responses well into the future. However, since seeds of Chinese tallowtree are very resilient within the seed-bank and can also be transported by birds and by water, future herbicide control of this aggressively invasive plant on hammocks of North Williman Island may be necessary to prevent recolonization by Chinese tallowtree. Because of the positive results of efforts on hammocks of North Williman Island, serious consideration should be given to the expansion of Chinese tallowtree eradication throughout the hammocks of South Williman Island, where many isolated freshwater wetlands remained heavily colonized by Chinese tallowtree at the end of this project in 2010.

Status and Management Plan Development for Three Rare Burrowing Crayfish, *Distocambarus youngineri, D. hunteri,* and *Cambarus reflexus* (Federal Grant #: T-20, Duration: 2006-2007) PI: Jennifer Price (formerly SCDNR); Author: Jim Bulak, SCDNR

The purpose of this study was to create habitat models for 3 species of crayfish of conservation concern in South Carolina - *Distocambarus youngineri, D. hunteri, and Cambarus reflexus.* For the two species of *Distocambarus,* soils data were used to predict occurrence sites. The developed habitat model was a significant predictor of *D. youngineri* occurrence. This species was found in Piedmont prairie habitat. Future management efforts should focus on acquiring property with prairie or savanna-like vegetation structure in the Piedmont. Perhaps due to a severe drought during the collection period, *D. hunteri* was not collected during the study. Future efforts should use genetic techniques to verify collections of *D. hunteri;* its status of "critically imperiled" is appropriate.

Cambarus reflexus habitat was modeled at the Webb Wildlife Center, Palachucola Wildlife Management Area (WMA), and Hamilton Ridge WMA. Model selection indicated that the presence of wiregrass (*Aristida* sp.) was the most important habitat component, indicating *C. reflexus* was associated with high quality, fire-maintained, pine savanna habitats in the Coastal

Plain. The species appears to be limited to the Coastal Plain and sensitive to soil surface disturbances. Management should focus on maintaining remnant pine savanna stands with prescribed burns to help maintain this species.

Controlling Access to Known and Potential Bat Roosts (Federal Grant #: T-23-R-1 F06AF00025, Duration: 2006-2011) PI and Author: Mary Bunch, SCDNR

Human disturbance is a very significant threat to bat colonies. Disturbance can be in the form of recreational caving, mining, or exclusions or disruptions to natural or man-made roosts. This project sought to protect some important bat roosts from human disturbance and to find new bat colonies. When awarded funding in 2006, White-nose Syndrome (WNS), a disease of hibernating bats, had not yet been discovered.

We assessed known roosts for suitability to bat-friendly gating or other measures to reduce disturbance. Sites with priority species from South Carolina's Comprehensive Wildlife Conservation Strategy (CWCS), the Rafinesque's big-eared bat (*Corynorhinus rafinesquii*), Southeastern myotis (*Myotis austroriparius*), and small-footed myotis (*Myotis leibii*) were given highest priority, but other bat species would also benefit from the work. We partnered with the US Forest Service and The Nature Conservancy to erect 6 bat-friendly gates at 5 locations, and modified an existing barricade to allow bat passage at another site. We also sought to place a bat-friendly cupola on an open shaft to a tunnel, but lacked sufficient funds for such a large project. We planned to erect a fence (site was not suited to gating) around the state's largest southeastern bat colony, but state parks declined the fence because they didn't want to maintain a fence. We mapped 338 potential mine sites and 17 old wells. All of the wells and 54 of the mine sites were evaluated. None of the wells were good bat habitat. Many of the old mine sites had no underground structure but we did locate 8 mine adits with tri-colored bats (*Perimyotis subflavus*). Of those, 5 would be suitable for gating.

Concrete bat roosts were built at 4 locations to serve as alternate roosts for Rafinesque's big-eared bats where known roosts were imperiled or limited. Other bats will also use the structures. Currently, all of those new roosts are in use by bats. After dramatic WNS related mortality was noted in other colonial hibernating bats typical to our mountains, we provided bat boxes to 3 state parks with known vulnerable colonies (threatened by exclusion), with great success at one of the parks.

Fish Passage on the Broad River: An Assessment of the Benefits to Freshwater Mussels (Federal Grant #: T-24, Duration: 2006-2008) PI: Jennifer Price (formerly SCDNR); Author: Jim Bulak, SCDNR

The objective of this work was to determine the effects of a newly constructed fish passage facility on the Broad River in Columbia, SC to freshwater mussel populations. Surveys were conducted on the Broad River, upstream of the dam, and on the Broad and Congaree Rivers, downstream of the dam. Nine species of mussels were downstream of the dam and 4 species were observed in upstream areas to Parr Reservoir. The Broad River upstream of Parr Reservoir contained sparse populations of mussels, possibly due to habitat degradation associated with sedimentation. Efforts were made to collect gravid females and determine the seasonality of

reproduction of the various mussel species. Peak reproduction and release of glochidia generally occurred in April through June, though this general trend exhibited variability among the various species. Fish host evaluation was conducted for 6 species of mussels - *Ligumia nasuta, Elliptio roanokensis, Lampsilis cariosa, Lampsilis radiata,* and *Elliptio congarea.* Results suggest that the fish lift will benefit mussel populations upstream of the dam (to Parr Reservoir) as increased passage of glochidia-carrying fishes from the more species rich areas downstream of the dam should increase colonization potential. Continued monitoring is recommended.

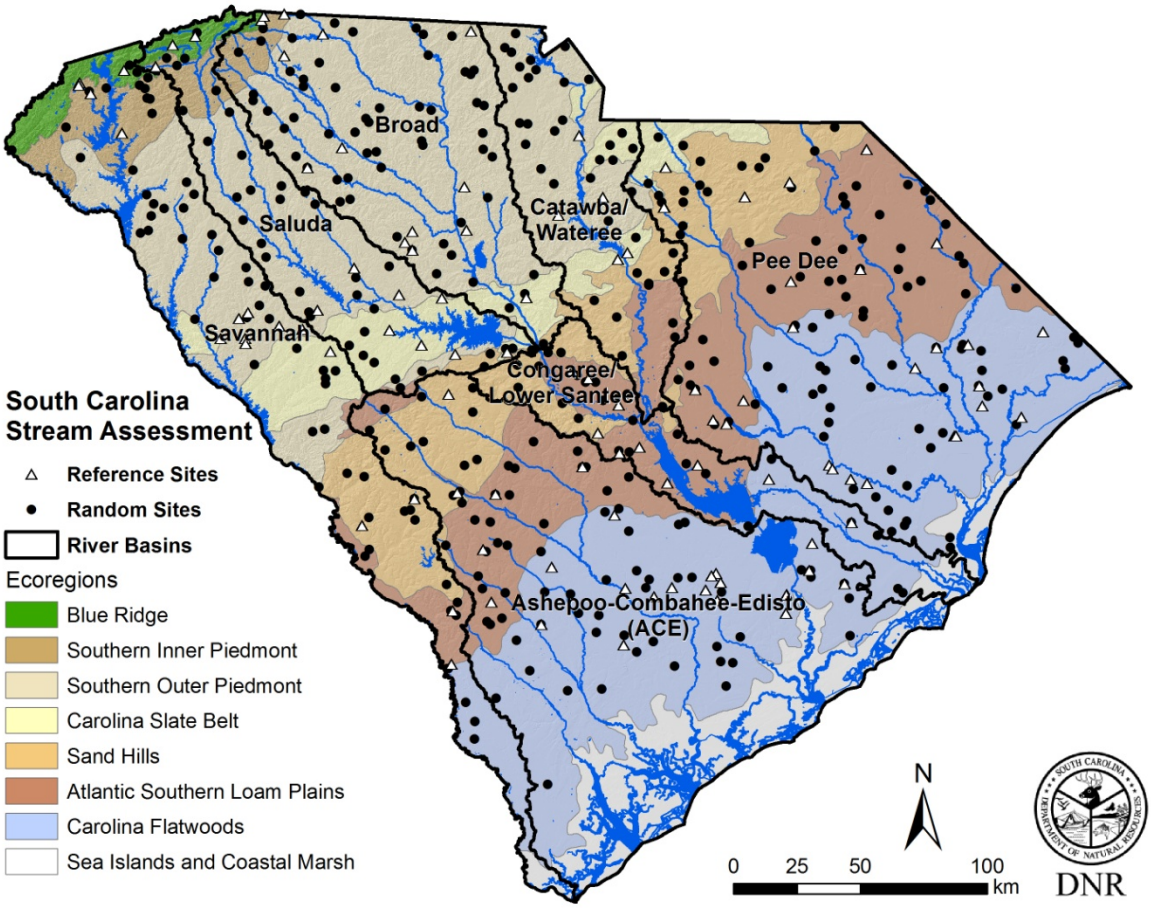
South Carolina Stream Conservation Planning Project [SC Stream Assessment] (Federal Grant #: T-25-R-1 F06AF00027 [formerly T-8], Duration: 2006-2013) PI and Author: Mark Scott, SCDNR; Map created by Kevin Kubach, SCDNR

The objective of this project was to conduct an assessment of wadeable streams to gather appropriate data that will allow SCDNR to design effective and efficient management strategies to protect, conserve, and restore the aquatic resources of the State. Freshwater species worldwide face accelerated extinction rates relative to most other wildlife taxa. The Southeastern US, in particular, has been suffering long-term declines in native species of fish and aquatic invertebrates. SC SWAP species of concern number well over 100 fish, reptiles, amphibians, mussels, crayfish, and snails that are directly dependent on aquatic systems for most or all of their life-stages. Common threats appear in their species accounts, generally associated with pollution from point- and non-point sources. Reversing the decline of native aquatic species requires an understanding of factors that are critical for maintenance of suitable habitat capable of supporting sensitive taxa. It follows that we must also understand the threats that degrade the quality of aquatic habitats to the point where they no longer support vulnerable species. The South Carolina Stream Assessment was designed to provide information to fill these gaps.

Watersheds of appropriate size (4 km^2 to 150 km^2) were sampling units stratified by unique combinations of ecoregion and major river basin in the state, called "ecobasins". Two methods of watershed selection were employed. The first method established long-term annual monitoring of least-impacted, or reference, watersheds, identified by biologists familiar with the region. This method is intended to provide expected resource condition as well as range due to temporal variability. The second method employed random selection of watersheds within ecobasin strata to allow statistically defensible estimates of statewide resource parameters from the sample data. Data collection was identical in both sampling designs, occurring at two spatial scales:

- *Watershed* – Point-sources as measured by NPDES permits; non-point sources as measured by appropriate land use/land cover classes in entire basin and within riparian buffer, hydrological disruption as measured by impounded area or occurrence of dams.
- *Stream Reach* – Selected measures of channel geomorphology and flow characteristics, water quality, and vertebrate and invertebrate community structure.

The Stream Assessment project ran from 2006 to 2013, with the data collection phase completed in 5 years and resulting in nearly 700 samples, each of which has over 200 associated variables that reside in an Oracle database titled StreamWeb. Estimates of stream resource condition have been calculated and mapped, and a number of publications and presentations have been produced to communicate various aspects of these data and results.



Habitat Improvement for Grassland Birds (Federal Grant #: T-27-R-1, Duration: 2006-2012)
PI: Tim Ivey; Author: Brett M. Moule, SCDNR

The goal of this project was to improve grassland bird habitat on Oak Lea Wildlife Management Areas (WMA), Bland Tract WMA, and Tuomey Tract WMA by developing and implementing various management strategies (e.g. burning, mowing, disking; creating fallow buffers and fallow fields; establishing longleaf pine and native grasses) and monitoring bird population responses. Over the course of the grant period, 496 acres were winter disked to improve brood rearing and songbird habitat. In order to improve native grass habitat, 1,247 acres were burned while 2,095 acres were disked, fertilized, and planted to enhance forage for dove, quail, and migratory songbirds. Fallow buffer areas totaling 410 acres were maintained. Soft mast seedlings (6,200) and hardwood mast trees (400) were planted.

Fall quail covey counts were conducted on Oak Lea WMA, Bland Tract WMA, and Toumey Tract WMA in either October or November each year. Survey points were established on all 3 tracts, and summer quail and songbird surveys were conducted in July. These call counts were continued annually to monitor the impacts of management activities on quail and grassland birds. Dove banding was conducted each year as part of the Eastern Management Unit project. Quail

banding occurred the first year with walk-in trap sites to monitor impacts of hunting on the population.

Taxonomy, Life History, and Distribution of the Crayfish, *Procambarus echinatus* (Federal Grant #: T-30-R, Duration: 2007-2008) PI: William Poly (formerly SCDNR); Author: Jim Bulak, SCDNR

The goals of this project were to examine the distribution, abundance, life history, and taxonomic status of the Edisto crayfish (*Procambarus echinatus*), a crayfish species of conservation concern. Surveys were made in the Salkehatchie, Edisto, Ashepoo, and Coosawhatchie River drainages. Detailed, quantitative sampling was conducted at 3 specific sites within these drainages. Collections indicated that *P.echinatus* was common in the study area, suggesting the perceived rarity of the species was associated with limited sampling for crayfish in these systems. The habitat for this species was undercut banks with root masses and accumulations of leafy debris in areas of good flow. Collections indicated that a new, distinct species, similar to *P. echinatus*, may be found in the South Edisto River and its tributaries as there was a substantial difference in the size of the structure of reproducing adults. This species was found in similar habitat to *P.echinatus.* Some concern exists that continued population expansion in Aiken County could impact the South Fork Edisto River crayfish. Additional monitoring of this perceived new species is recommended.

Assessing Introgressive Hybridization Within and Habitat Requirements of Native South Carolina Redeye Bass (Federal Grant #: T-31-R, Duration: 2007-2012) PI and Author: Jean Leitner, SCDNR

A survey was conducted to assess genetic impacts of Alabama Bass (*Micropterus henshalli*) introductions to Redeye Bass (*M. coosae*) in the Savannah Basin. Analysis was completed for N=669 Black Bass collected in 2004, and N=632 black bass collected in 2010 from reservoir sites on Lakes Russell, Hartwell, Keowee and Jocassee. Species composition was compared, and showed a precipitous decline in Redeye Bass collected from 2004 to 2010. Our 2004 survey indicated redeye bass had been virtually eliminated from Lakes Keowee and Russell, where they comprised 0% and 2% of black bass collected, respectively. Collections in 2010 show little change in Redeye Bass proportions from these two lakes, but a decline is evident in Lakes Hartwell (from 26% to 8%) and Jocassee (from 39% to 14%). Hybrids between the two species were prevalent in collections and ranged across years/reservoirs from 26% to 54% of black bass collected. Proportions of hybrids increased from 2004–2010 on all but Lake Russell.

Genetic analysis of black bass collected from Savannah basin tributaries in 2009 and 2010 confirmed non-natives and/or hybrids from 5 of 9 collection sites, and from at least one tributary associated with each of 3 reservoirs. Three of these collections represent new documentation of Alabama Spotted Bass hybrids, as we collected only native black bass from those sites in 2004. The potential for the spread of Alabama Spotted Bass and their hybrids from the reservoirs to additional tributary populations is indicated. A new incidence of the non-native Smallmouth Bass (*M. dolomieu*) and their hybrids was documented in the Savannah River, as was the presence of an extant Redeye Bass population throughout the Enoree River in the Santee drainage.

A GIS database was developed that includes all Savannah and Santee basin black bass collections associated with this study (2004–present), all Savannah and Santee Basin South Carolina DNR stream team collections made within the range of Redeye Bass (2008–present), and all historic South Carolina stream database collections that include record of Redeye Bass (1962–2002). The spatial distribution of tributary collections that included hybrids between Alabama Bass and Redeye Bass provides important information with respect to the spread of non-native black bass alleles in the Savannah Basin. Tributary populations where hybrids have been collected were those in closest geographic proximity to the reservoirs, within which non-native alleles are already widespread. Our results indicate that the spread of Alabama Bass alleles into the sampled tributary populations is the result of upstream movement from the reservoirs.

New genetic assays for the mtDNA locus ND2 were successfully developed. ND2 is one of 4 loci used to differentiate the species of black bass found, or having genetic influence in South Carolina populations. Previously, sequencing of all loci was necessary to classify individual fish as a particular species or hybrid. Primers were designed for haplotypes specific for Largemouth Bass (*M. salmoides*), Florida Bass (*M. floridanus*), Alabama Bass, Redeye Bass, and Smallmouth Bass. These new assays provide a new tool, less expensive and time consuming than sequencing, for the evaluation of hybridization among black bass in South Carolina.

In an effort to assess the status of Redeye Bass in the Santee drainage as native or introduced, species of minnow were collected from sites within the Santee, Tennessee (French Broad), and Savannah River drainages. Genetic divergence among drainages, and diversity within drainages, was compared to that for Redeye bass in the Savannah and Santee drainages. The Santee population of Redeye Bass is not genetically differentiated from populations collected throughout the upper Savannah River drainage. In contrast, Saffron and Warpaint Shiner populations collected in the Savannah and Santee drainages are significantly differentiated from each other. Pair-wise comparisons between individuals sampled from these 2 drainages, for 2 loci, were significantly differentiated. Results indicate that the Santee Basin Redeye Bass populations evaluated here are the result of a more recent, and likely human-mediated, introduction of fish originating from the Savannah Basin.

Restoring Seabird Nesting on Bird Key Stono Seabird Sanctuary (Federal Grant #: T-32-T-1, Duration: 2007-2008) PI and Author: Felicia Sanders, SCDNR

Bird Key Stono Seabird Sanctuary is an estuarine sandbar that provides nesting, roosting, and foraging habitat for a variety of seabirds and shorebirds. From the late 1980s–1994, it was the largest Brown Pelican rookery in North America. Isolated sand islands, such as Bird Key, make ideal nesting habitat due to the lack of mammalian predators such as raccoons. Bird Key was designated as a Seabird Sanctuary in March 2006 because of its importance as a seabird nesting island and because seabirds were declining probably due to human disturbance. The "sanctuary" status limited human disturbance on the island. This project used social attraction to decoy seabirds to Bird Key in efforts to increase the number of birds nesting on the island. Social attraction is a combination of decoys and a sound system. The sound system is a solar-powered audio system which continuously plays the calls of nesting seabirds.

Unpainted 122 Royal Tern, 52 Black Skimmer, and 32 Least Tern decoys were purchased and shipped to Huntington State Park. Horry County school children painted the decoys as part of an educational program about seabirds. At the beginning of the nesting season, Least Tern decoys were spaced approximately 1 m apart on Bird Key. Black Skimmer decoys were placed approximately 2 m apart in 2 separate flocks of 26 decoys each. Royal Terns were placed approximately ½ m apart in one colony. The sound system was placed near the Royal Tern decoys. The sound system constantly played Black Skimmer, Least Tern, and Royal Tern calls. Five days after placing decoys on the island, approximately 40 Black Skimmers were roosting with and courting the decoys. Royal Terns and Least Terns were observed roosting with their decoys. The seabirds were mostly unsuccessful due to depredation by a Great Horned Owl although they nested on Bird Key in low numbers. These decoys were used in other projects to attract nesting seabirds and continued to be part of an educational program for school groups.

Robust Redhorse Electrofishing and Radio Telemetry Tracking of the Great Pee Dee River, SC (Federal Grant #: T-33-R-1 F07AF00062, Duration: 2007-2012) PIs: Ross Self, SCDNR and Elizabeth Osier (formerly with SCDNR); Author: Robert Stroud, SCDNR

In late April and early May of 2008, SCDNR Freshwater Fisheries Region 2 personnel met with NCWRC, Progress Energy, Duke Energy, South Carolina Aquarium, and North Carolina Natural History Museum personnel to sample the Great Pee Dee River in NC by electrofishing for spawning Robust Redhorse. Twenty-three Robust Redhorse were collected between 22 April and 8 May 2008, of which 7 were recaptures from previous years, 2 were within year recaptures, and 14 were newly collected fish. All fish were PIT tagged and 10 had new radio tags surgically implanted. The fish ranged from 576 to 766 mm with a weight range of 2,630 to 8,450 grams. All fish were adult and many were ready to spawn.

In October 2008, boat electrofishing was conducted for two days on the Pee Dee River focusing below the South Carolina state line. One Robust Redhorse was collected. In late April and early May of 2009, the survey was conducted above the South Carolina state line using boat electrofishing. The areas targeted were known Robust Redhorse spawning grounds and locations where radio telemetered fish were detected. Twenty Robust Redhorse were collected between 20 April and 7 May 2009, of which 8 individuals were newly collected fish. All fish were PIT tagged and 10 had new radio tags surgically implanted. The fish ranged from 594 to 740 mm with a weight range of 2,986 to 6,660 grams. All fish were adult and many were ready to spawn.

Spring electrofishing for Robust Redhorse was not conducted in the Pee Dee River during or after October1, 2009. At the September 2009 annual meeting of the Yadkin-Pee Dee Technical Working Group of the Robust Redhorse Conservation Committee, it was decided that spring electrofishing would be suspended for 4 to 5 years until minimum flows are established at the Blewitt Falls Hydroelctric Facility.

SCDNR Freshwater Fisheries personnel participated in radio telemetry tracking of previously tagged Robust Redhorse in the Great Pee Dee River in October, November, and December 2007; February 2008; March, April, July and August 2010; and March 2011. In 18 days of tracking during the grant period, 6 different fish were located a total of 22 times in the SC portion of the Great Pee Dee River. Habitat ranged from open channel to along the riverbank, and always in

association with submerged woody debris. Region 2's participation in tracking was not required from March 2008 through July 2009 due to a NC State graduate student having been funded by Progress Energy for the work. Radio telemetry tracking was not performed during 2012 due to the expected expiration of transmitter battery life.

Identification of Diamondback Terrapin Habitats in South Carolina (Federal Grant #: T-35, Duration: 2009-2010) PIs: Erin Levesque (SCDNR), David Whitaker (SCDNR), and Elizabeth Broyles (CofC graduate student); Author: Elizabeth Broyles, College of Charleston

Very little is known about the current population number, sex ratio, and distribution of diamondback terrapin populations in Charleston, South Carolina estuaries. Terrapins were caught in the Ashley River, and population estimates were calculated using mark and recapture techniques and analyzed using the MARK program. Population size was estimated to be 3060 with a 95 % confidence interval of 1,964-4,156. This gives around 179-378 terrapins per km^2 of marsh habitat. The sex ratio was 1.7:1 male biased ($p < 0.001$). Investigations into changes in land usage were used to reveal reasons for change in terrapin abundance in the watersheds of the Ashley River, the Wando River, and the Charleston Harbor from 1995-2009. The number of terrapins caught at all Wando River sites combined significantly decreased during the study period ($r = 0.83$, $p < 0.001$). There has been approximately 12.9 km^2 (10% of 127.72 km^2) of land use change in the Wando River watershed from 1996-2006. Diamondback terrapin abundance, estimated via catch per unit effort, has remained constant for most of the Ashley River and Charleston Harbor areas. Land use change has been minimal ($\leq$ 2%) in both of these watersheds during the same time frame. The Wando River, on the other hand, had a significant decline in terrapin catch per unit of effort (CPUE) and also had a much greater amount (10%) of land use change. Land use can encroach on terrapin habitats and nesting sites as well as impact food and foraging areas. If the declining trend of the terrapin population in the Wando River continues, regulatory intervention may need to be considered. This information on population size, sex ratios, and distribution can be used as a baseline to track long-term changes in terrapin populations. This project produced a Master's thesis entitled, "Diamondback Terrapins (*Malaclemys terrapin*) of Charleston, South Carolina: Population Estimate, Sex Ratios, and Distribution."

A GIS Model to Guide Landscape-scale Restoration at the Woodbury Tract and Hamilton Ridge Properties (Federal Grant #: T-36-HM, Duration: 2008-2010) PI: Steve Bennett, SCDNR (retired); Author: Will Dillman, SCDNR

The purpose of this investigation was to create a GIS-based model of pre-fire excluded landscape patch dynamics and hydrologic change for the Woodberry Tract and Hamilton Ridge properties. At the time of this project, these two properties were recent acquisitions by the SCDNR. Land use histories varied for both properties but included a variety of industrial forestry practices. In developing a Conservation Plan for these properties, the hopes were to (1) restore important ecological processes to the landscape (e.g. fire), and (2) provide habitat structures needed to maximize conservation benefits while using the species composition of the current industrial forest.

The use of GIS and a selection of historical aerial photography of the sites allowed identification of reference forest conditions, and the ability to identify likely locations where remnant fire-maintained landscapes most recently occurred. We were also able to create a GIS coverage identifying former isolated wetlands and a GIS coverage identifying changes in hydrology related to road construction and ditching at the Woodberry Tract and Hamilton Ridge properties. Indices were created to quantify mechanical degradation to the wetland area, provide measures of ecological integrity, and to measure the restoration potential of each wetland, based on time since degradation and current habitat structure, relative to other isolated wetlands in the study area.

Carolina Herp Atlas (Federal Grant #: T-37-T, Duration: 2008-2010) PI: Steve Bennett, SCDNR (retired); Author: Will Dillman, SCDNR

The objective of this project was to develop the Carolina Herp Atlas (CHA) (www.carolinaherpatlas.org) and to provide detailed locality data on the reptiles and amphibians of the Carolinas, in particular those species whose distribution and status are poorly known. The CHA was officially launched in March 2007. Prior to the launch, the Davidson College Herpetology Lab imported approximately 3,900 records, primarily from Mecklenburg, Iredell, and Cabarrus counties in the western Piedmont of North Carolina. From March 2007 through 16 November 2010, the CHA totaled 839 registered users, 91 of which identified South Carolina as their home residence. The CHA received 4,930 reptile and amphibian records from South Carolina. Of the 5,008 records, 912 were accompanied by a voucher photograph and/or given a status of 10. A total of 122 South Carolina reptile and amphibian species have at least 1 record in the CHA. Thus far, the CHA has collected species-level distribution data on 151 species of amphibians and reptiles, including the occurrence of 32 anurans, 29 salamanders, 37 snakes, 11 lizards, 14 turtles, and the American alligator.

The CHA has thus far been a highly successful, citizen science-based project to document the distribution of reptiles and amphibians in South Carolina. The collection of 4,930 reptile and amphibian records in South Carolina (and 16,958 total records submitted from both South and North Carolina) during the first 3.5 years suggests that the CHA has the potential to surpass many other citizen science-based herpetological atlas projects. For example, the Georgia Herp Atlas collected a total of 7,452 records during the 5 years of operation. Thus far, the CHA represents a significant step towards the development of a better understanding of the distributions of reptiles and amphibians in the Carolinas. An overriding goal of the CHA is to promote conservation and understanding of reptiles and amphibians in South Carolina. The interactive nature of the CHA appears to appeal to a wide variety of people, including school teachers, professional herpetologists, and those generally interested in wildlife.

Mink Restoration and Monitoring Development Project (Federal Grant #: T-38-R, Duration 2007-2012) PI and Author Jay Butfiloski, SCDNR

The goal of this project was to develop a monitoring program that would minimize staff time and effort by establishing alternative methods of mink survey techniques to be used to monitor the success of mink restoration along the coast of South Carolina. Track boards appeared to have the most promise as the boards could be set out and checked at a later date using one person.

However, many of the same issues that previously plagued track board work such as tidal fluctuations, wave action, and other environmental factors hampered track board implementation. Once again, track boards were dismissed as a feasible tool in this instance. Previous mink survey work depended on spotlight surveys that required significant high tides occurring a few times per year. The exact heights of these tides were undetermined as to which would be sufficiently high enough for survey work, often leading to poor surveys and wasted manpower. Thus, emphasis was placed on perfecting spotlight surveys in an effort to evaluate which environmental factors were most significant in surveying mink. The project determined that tide heights 6.05 ft. above Mean Lower Low Water (MLLW) level as measured at the Charleston station and adjusted for local areas was the best predictor for when to use spotlight surveys.

During the course of this study, two family groups of mink (5 total) were relocated into the Hog Inlet portion in the northernmost coastal march in the State. This area was the last remaining significant portion of coastal marsh where mink had not been reintroduced. Moving captured mink to this marsh would be the last location along the coast where mink needed to be reintroduced to complete mink reintroduction that was begun in the late 1990s. However, during the course of this project, mink depredation in the original mink restoration site of Cape Romain National Wildlife Refuge (CRNWR) became a concern for refuge staff. As the reintroduced mink into CRNWR began to thrive, concerns from staff at the refuge centered on the impacts mink may be having on nesting shorebirds. Therefore, much of the emphasis of this project became the assessment of reintroduced mink impacts in the original reintroduction site.

A total of 9 mink were implanted with transmitters to assess impacts their activity may be having with other species. Radioed mink did not venture far from initial capture sites and most of their activity appeared to be tide dependent. In addition, diet analysis from mink taken from the CRNWR in an effort to increase shorebird nesting success found that out of 45 mink stomachs collected, 7.4 % contained avian material of unknown species. A bioenergetics model developed from this estimated that an individual mink would consume 8.5 avian prey items per month based on the sampled diet. It is still undetermined to what extent mink predation is affecting shorebird success at CRNWR, as other predators and mortality factors still plague nesting efforts on the refuge.

Prescribed Burning Crew for SC Department of Natural Resources Lands (Federal Grant #: T-39-M-1 F08AF0008, Duration: 2008-2013) PI and Author: Tim Ivey, SCDNR

The objective of this grant was to facilitate and increase prescribed burning on Wildlife Management Areas and Heritage Preserves for wildlife habitat enhancement. SCDNR contracted with the South Carolina Forestry Commission to perform the fire management activities of the grant. During 2009, growing season prescribe burning was conducted on 8 DNR properties. A total of 3,830 acres were prescribe burned and 49.25 miles of firelanes were disced. During 2010, dormant and growing season prescribe burning was conducted on 18 DNR properties. A total of 10,312 acres were prescribe burned and 81.15 miles of firelanes were disced. During 2011, dormant and growing season prescribe burning was conducted on 23 DNR properties. A total of 7,906 acres were prescribe burned and 120.9 miles of firelanes were disced. During

2012, dormant and growing season prescribe burning was conducted on 19 DNR properties. A total of 6,322 acres were prescribe burned and 44.65 miles of firelanes were disced.

Conservation of Belfast Plantation, Phase I (Federal Grant #: T-40-L, Duration: 2008-2009) Author: Emily Cope [*T-50-L is Phase II and is covered by this synopsis.*]

SCDNR utilized $1,188,654 from the USFWS (of which $1,063,654 was Wildlife Restoration funding and $125,000 was State Wildlife Grant funds) to acquire the southern half of the Belfast Tract totaling 2,436 acres (also known as Belfast Phase II). The total land acquisition cost for Phase II was $7,710,440. This completes the Belfast acquisition project by protecting a total of 4,664 acres. The Belfast Tract has long been managed to support a diverse range of wildlife species. The hardwood drains, creeks, and beaver ponds support waterfowl management objectives. In addition, the age-class diversity of the pine stands provides valuable wildlife habitat. The property supports excellent populations of deer and turkey, and the uplands provide excellent habitat for Bobwhite Quail. Improved timber thinning and a more aggressive prescribed burning regime will increase the already existing quail population. This will expand the ongoing efforts on the nearby Sumter National Forest to increase the Piedmont quail population. Mudlick Creek, the beaver ponds, and the man-made pond provide many fishing opportunities for sunfish and bass.

The property provides habitat for many priority bird species such as Acadian Flycatcher, American Woodcock, Great Blue Heron, Kentucky Warbler, Little Blue Heron, Louisiana Waterthrush, Rusty Blackbird, Wood Duck, Wood Thrush, and Yellow-crowned Night Heron. The wetlands associated with the river corridor and its tributaries provide habitat for many reptiles and amphibians including but not limited to the black swamp snake, common snapping turtle, and yellow-belly turtle. Little River, which traverses the Belfast Tract and is the Southern boundary for Phase I, is comprised of Carolina Slatebelt geology. This specific geology is known to be associated with the federally-endangered mussel, the Carolina heelsplitter. While initial survey work has not detected the heelsplitter on the Belfast Tract, it has been located in the nearby area. Further survey work could find the heelsplitter on the tract or the tract may also serve as a restoration/reintroduction area for the species. In addition, several rare species of burrowing crayfish have been found in nearby areas.

Use of GIS to Assess the Demographic Isolation of Red-Cockaded Woodpecker Groups in SC (Federal Grant # T-42-R-1, Duration: 2008-2009) PI: Jason Craig and Drew Lanham (Clemson University); Author: Derrell Shipes, SCDNR

This project was sub-contracted to Clemson University. Jason B. Craig (graduate student) and Dr. J. Drew Lanham were the Principal Investigators and Ralph Costa and Dr. Robert Baldwin were collaborators. Eight km (5 mi.) and 25 km (15.5 mi.) radius circles were drawn around known active and inactive Red-Cockaded Woodpecker (RCW) cluster locations in SC in an effort to determine the occurrence of Demographically Isolated Groups (DIGs). These analyses concluded that there are 20 isolated clusters using 8 km (6 active, 14 inactive) and 3 isolated clusters using 25 km (1 active, 2 inactive). Habitat evaluation associated with isolated and non-isolated clusters was conducted. The concept of "isolation" and the location of isolated clusters are essential to the future management of this endangered species. It may be necessary to

relocate isolated birds to larger populations in order for the relocated birds to reproduce and contribute genetically. There is a tendency for isolated clusters with small numbers of birds to "blink out".

Least Tern Reproductive Success on Roof-tops (Federal Grant # T-44-R-1, Duration: 2008-2010) PI: Felicia Sanders, SCDNR; Author: Mary Catherine Martin, SCDNR

Nesting of Least Terns (*Sternula antillarum*) on flat, gravel-covered roofs was followed at colony sites in Georgetown and Horry Counties in coastal South Carolina. Colony success and failure were documented. Incubation duration was determined at 5 roof colony sites by encasing temperature data loggers in clay eggs. Successful colonies were characterized by incubation temperatures at a constant range except for periods of heavy rainfall, while unsuccessful colonies had incubation temperatures with cooling ranges of 14-20°C (57-68°F) that occurred at night with repeated nest abandonment attributed to possible predators. Movements of fledged Least Terns were tracked by attaching radio transmitters to the legs of the young. Injuries resulted from the transmitter attachments complicating methods of this part of the study. A very limited number of fledged Least Terns were tracked and results were inconclusive. An assessment of fish samples found at colony sites indicated that the more inland the site, the more freshwater fish species present. In addition, observations indicated that adults and fledged young foraged at sites within a 5-10 km (3-6 mi.) radius from the colony site. Inland storm water retention ponds have become a valuable foraging site for Least Terns. Finally, eggs from colony sites were tested for heavy metal contaminants usually found in storm water retention ponds. No contaminants were present in amounts detrimental to hatching or the development of young.

American Shad Culture and Stocking in the Edisto River (Federal Grant #: T-45-R-1, Duration: 2008-2011) PI and Authors: Bill Post and Chad Holbrook, SCDNR

Historically, the Edisto River in SC had one of the State's larger American Shad fisheries. Overfishing between the 1940s to1980s lead to a dramatic decline in shad landings and decreased abundance over time. These declines lead to added restrictions to the shad fishery beginning in 1998. More recently, in an effort to augment wild production, South Carolina Department of Natural Resources (SCDNR) and the United States Fish and Wildlife Service (USFWS) formed a partnership to create a hatchery program. Over a 4-year period (2008-2011), the feasibility of on-river broodfish collections, hatchery production, young-of-year relative abundance, annual hatchery contribution, movements of adult American Shad, genetic analysis of stock enhancement, and genetic uniqueness were evaluated for the Edisto River population. Collecting broodfish using electro-fishing gear proved to be successful with 347 adult American Shad caught over 3 years of sampling. Of the 347 collected fish, 235 have been used as broodfish; 92 had fin clip samples taken, were implanted with acoustic tags, and returned to the river; and the remaining 20 had fin clip samples taken and were returned to the river.

Collection efficiency of adult American Shad improved each year allowing us to increase the number of broodfish used each year as well as balancing the male/female ratio (2009 N=63; M 51, F 12; 2010 N=75; M 48, F 27; and 2011 N=97; M 57, F 36). Annual egg production has been variable and variability was independent of the number of females collected (2009 – 205,238; 2010 – 600,987; and 2011 – 184,677). From 2009-2011 a total of 39,688 fry were released,

ranging from a high in 2010 of 22,209 to a low in 2011 of 4,836. Out-migrating young-of-the-year American Shad were successfully sampled with electrofishing gear in 2010 (601) and 2011 (1,291).

All collected fish were kept to determine hatchery contribution via OTC detection and genetic detection using microsatellite markers. Detection rates for hatchery fish varied between the two methods with OTC indicating a hatchery contribution of 6.8% in 2010 and 0.3% in 2011, while genetic testing indicated a hatchery contribution of 3.6% in 2010 and 0.0% in 2011.

Additionally, this project provided the opportunity to generate baseline genetic data which had not previously been determined for this stock, finding that genetic diversity for the Edisto River American Shad population is high. An initial evaluation of our stocking program detected no difference in genetic composition between the broodstock and field collections in any of our production years ($p>0.692$), indicating the appropriateness of our broodstock collection process in minimizing potential negative impacts of stocking on the wild population. However, significant spatial genetic differentiation was detected between the Santee River and Edisto River ($X^2=\infty$, $p=0.000$). Therefore, broodstock for stock enhancement purposes in the Edisto River should originate only from the Edisto River itself.

Our study was a comprehensive look at the potential of using responsible stock enhancement as an effective management tool. Broodfish collections and hatchery production was a success; however we hope to improve fry/egg ratio with more experience. Telemetry results were somewhat inconclusive; however, it did appear mature shad were congregating in areas near Givhans Ferry State Park around river mile 60. Young-of-the-year collections improved throughout the study and were efficient in 2010 and 2011. Although contribution was relatively low, we were able to detect hatchery individuals in the Edisto River population prior to out-migration. The results of this project, along with future work, will provide valuable information which can be incorporated into management plans to aid in the recovery of this important species in the Edisto River in South Carolina.

Conservation of Breeding Painted Buntings and Other Songbird Indicators in Early-Successional Shrub-Scrub Habitat (Federal Grant #: T-47-R-1 F08AF00109, Duration: 2008-2011) PI: Derrell Shipes, SCDNR; Author: Mary Catherine Martin, SCDNR

Objectives of this study were to determine: (1) abundance of breeding Painted Buntings (*Passerina ciris*) and other indicator songbird species in paired CP-33 and non-CP-33 fields; (2) nest location and success of Painted Buntings in paired CP-33 and non-CP-33 fields; and (3) a landscape/GAP analysis model which tracks seasonal crop rotation and predicts a pattern of habitat occupancy and breeding distribution of Painted Buntings and other early-successional shrub-scrub songbird species. CP-33 is a conservation program established by the Department of Agriculture to provide habitat for upland birds through landowner incentives to plant native grass buffers along row crop field margins.

Eight fields of 4 CP-33 and 4 non-CP-33 were study sites. In each field, habitat types were classified as agriculture, forest, CP-33 border, and cut (recently cut forest area). To determine the abundance of Painted Buntings, 3 survey types were utilized: spot maps, transect counts, and

telemetry. The results of each type of survey indicated more Painted Buntings and other species were found in mature (≥ 10 years of growth) forest edges than in any other habitat, and there was no difference in species abundance between CP-33 and non-CP-33 fields. In addition, vegetation data gathered per protocols developed by the Breeding Biology Research and Monitoring Database (BBIRD) in the forested edges of agricultural fields, in the CP-33 strips, and in the crop fields indicated that wheat is preferred forage by Painted Buntings. Second, 3 types of fields (paired CP-33, non-CP-33, and a field managed for doves) were searched for Painted Bunting nests. Twenty-two nest sites were found in forest edge habitat, and none were found in the CP-33 and dove field habitats.

Finally, a landscape/GAP analysis map was created from the data obtained in the spot map, transect count, and radiotelemetry surveys. Results of the landscape/GAP analysis map indicated high priority habitats as: 25 m or less from the edge of mature forest; CP-33 strips, wheat fields, and early growth forests (≤ 10 years of growth) for foraging; and use of CP-33 strips, all agricultural fields, and early growth forests by Painted Buntings was limited to the edges of these habitats. Based on the completion of the study objectives, recommendations for Painted Bunting conservation in central rural South Carolina are: (1) mature forest edge habitat is essential; (2) painted buntings prefer to occupy and nest in the outermost edges of forests and/or thin forest strips (25 m or less from the edge); and (3) a source of food in the form of a wheat field or other grass seed as well as a source of insects when rearing young is necessary.

Effects of Predation on Seabird Nests in Cape Romain (Federal Grant # T-48-R, Duration: 2009-2010) PI and Author: Felicia Sanders, SCDNR

The goal of this project was to monitor seabird nesting in Cape Romain National Wildlife Refuge to guide management that can benefit seabird species nesting at natural sites. Nesting chronology, reproductive success, and causes of colony abandonment and nest loss were documented for Least Terns and Black Skimmers in 2009-2010. Although species of conservation concern, little is known about the reproductive success of Least Terns and Black Skimmers throughout the Southeastern US.

Nest monitoring occurred at Raccoon Key, Lighthouse Island, Middle White Banks, and Cape Island. Each island was checked every 2-7 days depending upon weather and logistical constraints. Least Tern and Black Skimmer nests were randomly selected across all 4 study sites. Nests were marked by wooden stakes 0.5 m from the nest scrape. Eggs were floated to estimate initiation date. At each visit, researchers recorded the number and condition of eggs or young and when possible, and determined the cause of failure by visual observation. Chick survival was determined at select sites by banding 1-2 day-old chicks with a unique, 2-color leg band combination. Researchers conducted re-sighting surveys every 2-4 days for Least Terns until no fledglings were observed. To determine the minimal survival of Black Skimmer chicks, an island-wide fledgling count was conducted at the end of the season.

Peak nesting for Least Terns occurred from mid-May to mid-June and for Black Skimmers in mid-June. Predation and over-wash were the primary cause of nest failure based on visual cues at or near the nest. Collectively, these ecological stressors attributed to 65% of nest loss for Least Terns and Black Skimmers. Video cameras installed at colonies documented disturbance to

colonies by Black Vulture, American mink, and Great Horned Owl. Of the 60 Least Tern chicks monitored, 13 (22%) were re-sighted at ≥ 17 days post hatch. Of the 52 Black Skimmer chicks monitored, 22 (42%) were re-sighted at ≥ 28 days post hatch. Nest success of Least Terns and Black Skimmers within CRNWR was variable among colonies and between years, suggesting that factors at the local level influenced reproductive success. Management techniques within the study area directed toward predator control to decrease nest loss of near-shore seabirds and shorebirds needs to focus on both the avian and mammalian predators identified in this study in order to be effective.

Conservation of Belfast Plantation, Phase II (Federal Grant #: T-50-L, Duration: 2009-2010)- *See synopsis under T-40-L.*

Ecology and Impacts of Coyotes on Loggerhead Sea Turtles, Least Terns, and Other Wildlife: Implications for Management (Federal Grant #: T-51-R-1 F09AF00159, Duration: 2009-2011) PI and Author: Jamie Dozier, SCDNR

Control of abundant mammalian predators is a common element of management programs aimed at increasing reproductive and recruitment success of many threatened ground-nesting turtle and bird species. Recent colonization of coyotes (*Canis latrans*) in South Carolina, however, is changing traditional community dynamics governing and impacting wildlife populations in coastal and barrier island systems. Coyotes have become a major nest predator on federally threatened loggerhead sea turtles (*Caretta caretta*) having devastating impacts on nest survival. For example, in 2009 on the Tom Yawkey Wildlife Center Heritage Preserve (TYWCHP) in Georgetown, South Carolina, extensive coyote depredation on turtle nests was documented with over 50% (21 of 40 nests; 1,208 eggs) of loggerhead sea turtle nests either completely or partially destroyed. The purpose of this project was to attempt to understand coyote ecology and impacts at the TYWCHP as it relates to loggerhead sea turtle and least tern nesting success. A major portion of the study attempted to examine coyote home range, habitat use, and diet composition on the island complex.

A total of 8 coyotes were trapped and fitted with radio-transmitters during the study period. Unfortunately, a combination of equipment failure and extreme difficulty in locating collared coyotes provided a low sample size of locations and data unreliable to support any reasonable estimations of coyote home range, movements, or habitat use on TYWCHP. Over 400 coyote scat samples were collected during the study periods on TYWCHP; 370 samples were usable for analysis. A total of 234 scats were collected on Cat Island and 136 on South Island. *Sigmodon* spp. were the most common food item found in Cat Island scats, followed by birds, vegetation, and *Peromyscus* spp. Birds were the most common item found in South Island samples, followed by *Sigmodon* spp., vegetation, and *Neotoma* spp. Cat Island samples comprised a larger percent of scats containing wild hog, lagomorphs, *Diospyros* spp., and soricomporphs, while South Island samples contained more birds, crabs, *Mephitis mephitis* (striped skunk), and mustelids. There was a significant difference between coyote diet on the two islands ($A = 0.0090$, $p < 0.0001$). Test results yielded significant indicator values for three animal groups and one plant genus (birds, lagomorphs, wild hogs and *Ilex* spp.). Although birds were a component of coyote diets, samples did not provide enough evidence to determine which species of birds or age class.

Observation of Least Tern nesting colonies did not reveal coyote presence during the study period.

An additional component added to the project was the question of coyote impacts on mesopredators, in particularly raccoons, in suppressing depredation/predation on prey items. Three experiments were conducted to examine coyote-raccoon interactions: 1) space use of radio-collared raccoons (10-18) to test avoidance of coyote urine, 2) avoidance of captured raccoons (8) in enclosures to coyote scat, and 3) avoidance of free-ranging raccoons to monitored feeding sites containing coyote scat. Summary results of all 3 experiments revealed that raccoons did not avoid areas where coyote presence was artificially induced; therefore, this suggested that the threat of coyotes was not a deterrent in raccoon use of areas in space and time. From a management perspective, the most significant finding was from a companion study conducted on TYWCHP during the same time period as this study revealing that selective trapping of coyotes and beach night patrols significantly reduced coyote depredation of sea turtle nests from 52% in 2009 to 15% in 2010.

Monitoring Impacts of Yellow Pine Restoration on Avifauna in the SC Mountains (Federal Grant #: T-54-R-1 F10AF00443, Duration: 2010-2013) PIs: Curtis Walker, M.S. and J. Drew Lanham, PhD [Clemson University]; Author: Mark Hall, SCDNR

Note: The thesis name of this project is *Avian Community Response to Prescribed Fire in Yellow Pine Stands in the Jocassee Gorges Region of South Carolina*.

Comparisons of avian communities were made between the burned treatment sites and reference control sites to examine community and priority species response to prescribed fire in the Jocassee Gorges in the mountains of SC. To assess the impacts of fire disturbance management on the avian community, 10-minute, 50 m radius point counts were conducted in treatment and control plots during the spring breeding seasons of 2011 and 2012. Values of species diversity, richness, and total number of individuals were found to be significantly higher in the burned treatment plots than in the control plots as a result of differences in structural complexity and the distribution of resources. The occurrence of focal species, as well as other species, was found to vary between sites. Species associated with early-successional and more open habitats—such as Eastern Wood-Pewees and Indigo Buntings—were observed more often in burned sites, while species requiring shrubbery and broad-leaved foliage on which to forage—such as Black-throated Green and Hooded Warblers—were observed more often in control sites. Models created using structural vegetation data identified characteristics of vegetation and landform that were found to be useful in predicting the occurrence of 6 of the 7 priority species at Jocassee. Differences in the occurrence of nesting and foraging guilds were related to differences in complexity of habitat structure and composition. This research suggests that fire management can be a useful tool to create wider variation across the landscape, providing increased opportunities for nesting and foraging resources for an array of bird species.

Using Citizen Science in the Study and Conservation of Breeding Painted Buntings (Federal Grant #: T-55-R-1 F10AF00444, Duration: 2010-2012) PIs: John Gerwin, NCNMS; Author: Derrell Shipes, SCDNR

This project was sub-contracted to Dr. John A. Gerwin of the North Carolina Museum of Natural Sciences in Raleigh, North Carolina. Collaborators included Dr. Jamie Rotenberg of the University of North Carolina – Wilmington and Laurel Barnhill formerly of SCDNR, now USFWS, Athens, Georgia.

Painted Buntings (PABU) were banded at 45 sites during 135 banding sessions across NC/SC including 15 in NC, 15 in Coastal SC, and 15 in "interior" SC. Birds were banded with a unique USFWS aluminum band on one leg and a unique combination of 3 plastic color bands on the other leg. Age, sex, and breeding condition was determined and recorded. An internet-based reporting system for reporting of sighted birds was developed, and reporters were recruited using workshops, short newspaper articles, word of mouth and through the website. Volunteers were encouraged to report sightings of birds—banded and un-banded—to the website. A total of 1,379 PABUs (454 females, 395 males, 231 unknown) were captured and banded in South Carolina. Following banding, 34,705 reports of PABUs—banded and un-banded—were received at the website. Researchers found that PABUs appear to survive an average of 5-6 years and appear to exhibit philopatry. They did not find an over-abundance of Brown-headed Cowbirds at the feeder sites or in agricultural areas nearby. Habitat preference, management guidelines, and productivity information is contained in the larger report of the project.

Decision Support Tools for Stream Conservation (Federal Grant #: T-61 F12AF01417, Duration: 2012-2013) PI and Author: Mark Scott, SCDNR

Identifying and communicating the relationships between natural gradients, human activities, and aquatic habitat integrity is crucial to aquatic conservation. The South Carolina Department of Natural Resources (SCDNR), in conjunction with Clemson University, has developed a novel, web-based South Carolina Stream Conservation Planning Tool that enables a spatially explicit understanding of how human activities affect the biological condition of wadeable streams. This is intended to support decisions about aquatic conservation actions. The web mapping application communicates findings from the South Carolina Stream Assessment (SCSA) to a broad audience, allowing users to visualize predicted biological conditions based on their status and severity across all South Carolina wadeable stream catchments. Additionally, an interactive catchment management tool allows users to explore and forecast the impacts of customized land management scenarios on aquatic resource indicators at any user-specified location across South Carolina, and so engages users in the process of modeling and forecasting stream conditions.

We selected stream condition metrics from over 200 measurements taken at approximately 700 streams locations sampled during the SCSA from 2006 to 2011. Metrics were related to spatial predictor data created under the National Fish Habitat Assessment. We generated prediction models using the Random Forest machine-learning technique from the sample data, and applied the predictions to the entire population of wadeable stream reaches in the State. The mapping application provides users with a browser-based interface to modify predictors at the catchment (local) scale. A web service dynamically generates predictions based on these user inputs, and results are mapped at watershed (network) scales to display cumulative effects of the changes. The dynamic execution of models broadens the utility of the application and opens the forecasting process to a non-technical audience. By providing an accessible means of forecasting the effects of management decisions, the tool encourages a watershed perspective towards

aquatic conservation. The application is targeted to stakeholders at the policy making and conservation planning levels. The approach described has been set up for South Carolina but is applicable to assessment programs at the regional and national levels.