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.

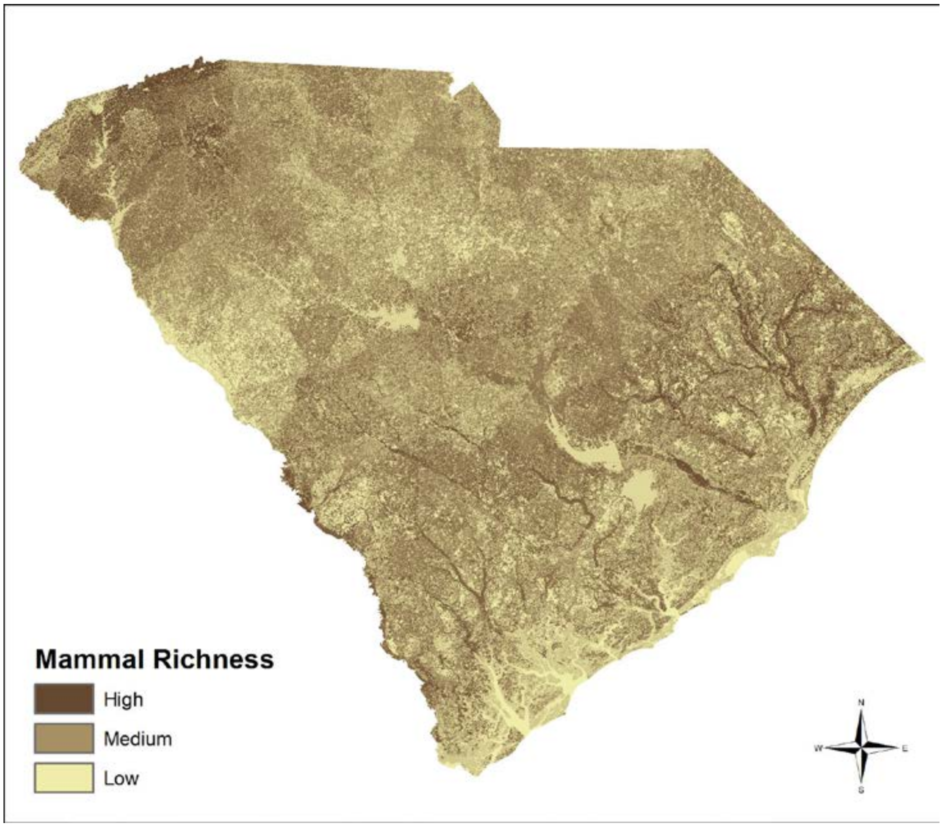


FIGURE 3-1: Mammal richness in South Carolina

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.

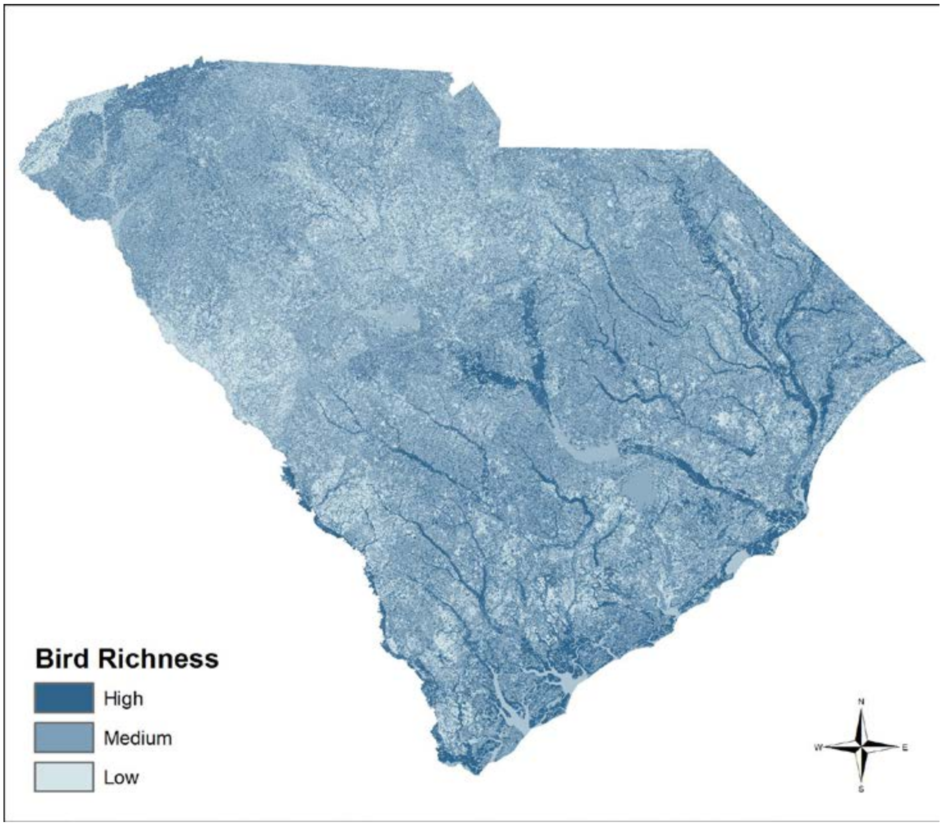


FIGURE 3-2: Bird richness in South Carolina

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.

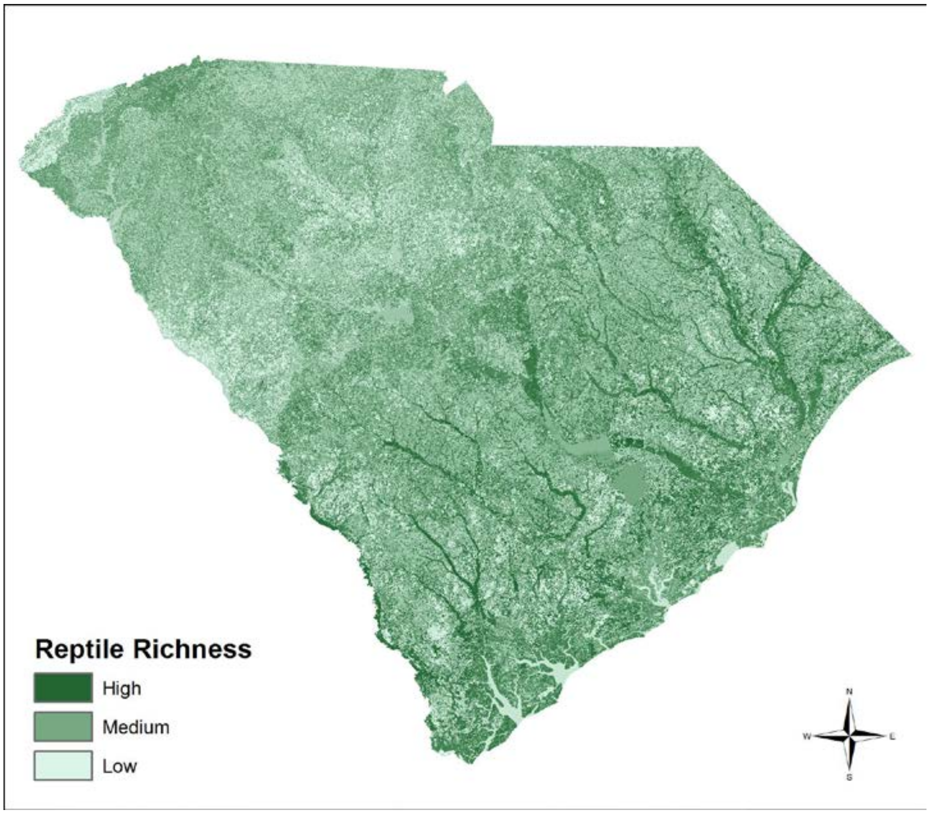


FIGURE 3-3: Reptile species richness in South Carolina

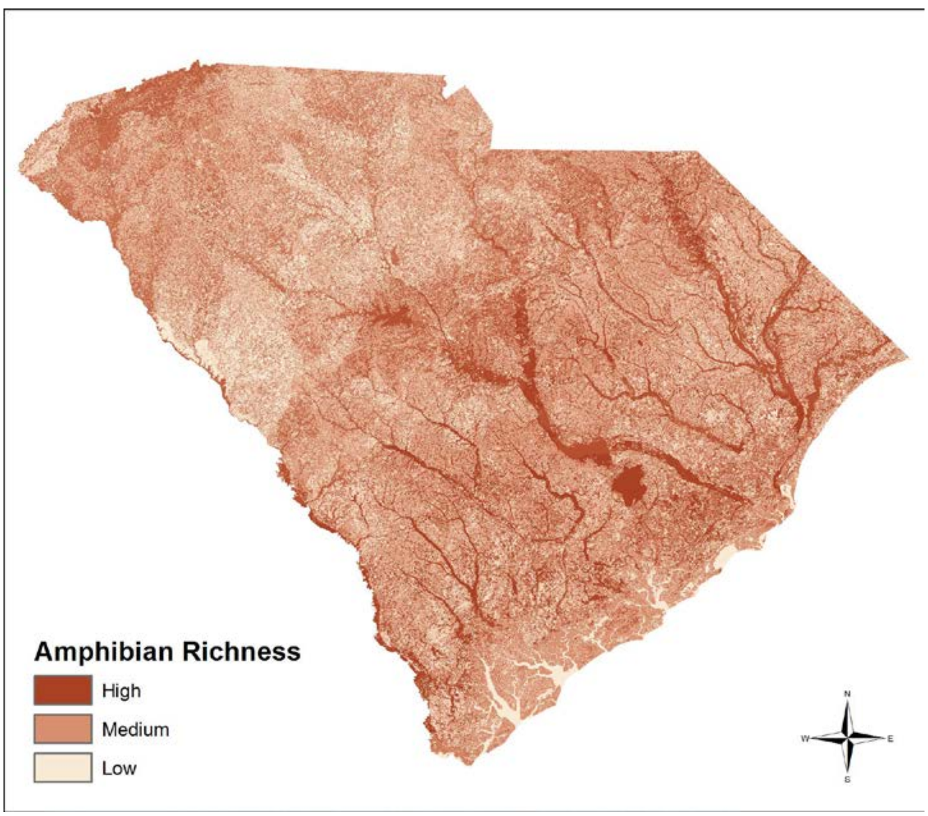
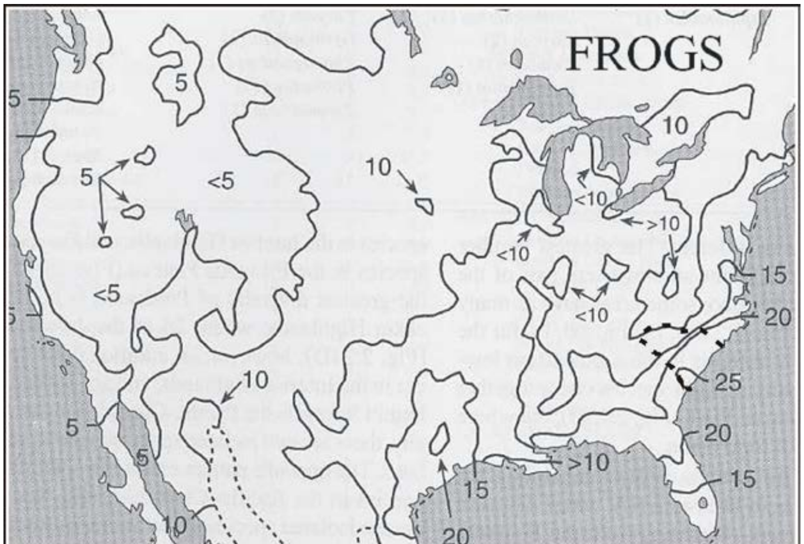


FIGURE 3-4: Amphibian species richness in South Carolina

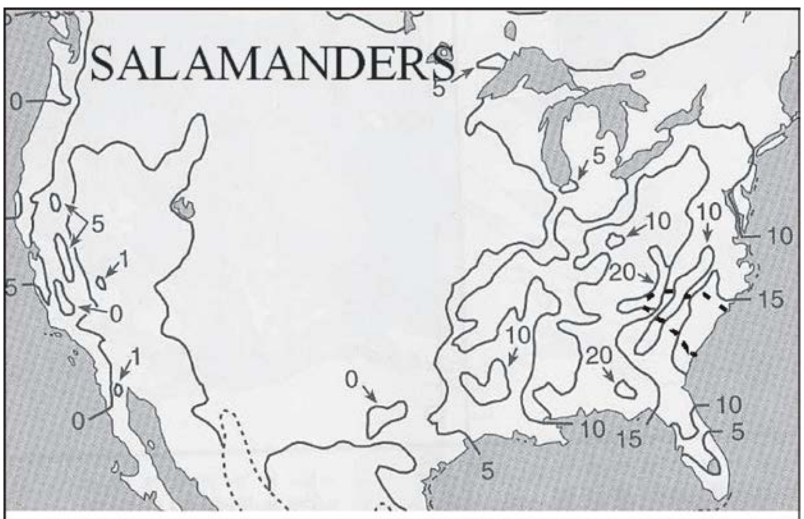
The Blue Ridge, Upper Piedmont (referred to colloquially as the Foothills) and Coastal Plain are collectively rich in herpetofauna. Rock outcrops in the Blue Ridge and Upper Piedmont provide habitat for Jordan's salamander, the green salamander, and the timber rattlesnake. Bogs in this same region may 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.

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.



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.

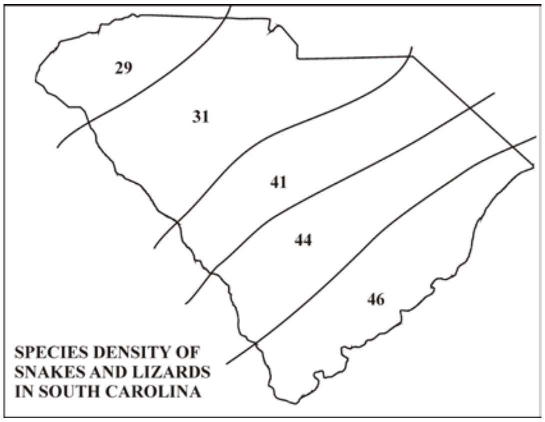


FIGURE 3-6: Species density of snakes and lizards in ecological regions of South Carolina

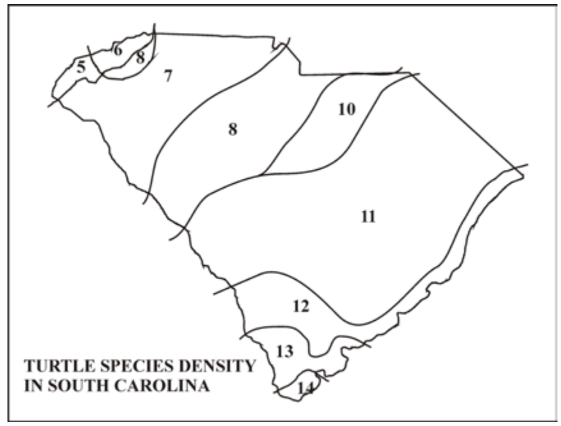


FIGURE 3-7: Species density of turtles in ecological regions of South Carolina

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 ≤ 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.