CHAPTER 2: SOUTH CAROLINA PRIORITY SPECIES

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

The diversity of animals in South Carolina is vast. Habitats in this state range from the mountains to the ocean and include many different taxonomic animal groups. SCDNR wanted to address as many of those groups as possible for inclusion in the list of priority species for the CWCS; as such, twelve taxonomic groups are included in the Strategy: mammals, birds, reptiles, amphibians, freshwater fishes, diadromous fishes, marine fishes, marine invertebrates, crayfish, freshwater mussels, freshwater snails, and insects (both freshwater and terrestrial). However, taxonomic groups that are excluded from this version of the SC CWCS may be included in future revisions of the Strategy, as additional information and experts specific to those groups are identified.

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

Next, SCDNR developed a list of criteria for consideration in determination of priority species. Eight criteria were developed for this process and are presented in Box 2-1.

The process for determining priority species by each taxa committee is identified herein. After determining which species would be included on South Carolina's Priority Species List, taxa committees categorized species into three groups: Highest, High and Moderate Priority. The species in two taxa groups, marine fishes and marine invertebrates were not categorized into priority groups due to the large number of species and the limited knowledge for those species.

Further, the insect taxa committee did not develop a comprehensive list of priority insects in South Carolina. Because even the number of species of insects in this state is not known, the taxa committee completed their work by developing a table indicating the number of species within each insect order in South Carolina. As such, numbers of insect species are not included in the total number of species on South Carolina's Priority Species List, which is presented in its entirety in Appendix 1.

BOX 2-1: EIGHT CRITERIA USED FOR DETERMINATION OF PRIORITY SPECIES

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

The total number of species included in South Carolina's CWCS is 1,240. Table 2-1 identifies the number of species included in each taxa group. Additionally, Table 2-2 presents the list of species that were prioritized by taxa committees; this list excludes marine fishes, marine invertebrates and insects. Refer to Appendix 1 for lists of marine fishes and marine invertebrates.

TABLE 2-1: NUMBER OF SOUTH CAROLINA PRIORITY SPECIES

Taxa	Number of Species
Mammals (Terrestrial and Marine)	24
Birds	111
Reptiles and Amphibians	52
Freshwater Fishes	56
Diadromous Fishes	6
Crayfish (Freshwater and Terrestrial)	23
Freshwater Mussels	26
Freshwater Snails	4
Marine Fishes	163
Marine Invertebrates	775
Total Number of Species	**1,240**

TABLE 2-2: CATEGORIZED PRIORITY SPECIES

Taxa	Highest Priority	High Priority	Moderate Priority
Mammals	Black Bear Florida Manatee Northern Yellow Bat	Appalachian Cottontail Atlantic Right Whale Bottlenose Dolphin Carolina Red-backed Vole Dwarf Sperm Whale Eastern Small-footed Myotis Hairy-tailed Mole Humpback Whale Masked Shrew Meadow Vole Mink Pygmy Sperm Whale Rafinesque's Big-eared Bat Southeastern Bat Star-nosed Mole Swamp Rabbit	Eastern Fox Squirrel Eastern Spotted Skunk Eastern Woodrat Southern Pygmy Shrew Woodland Jumping Mouse
Birds	American Avocet American Bittern American Coot American Golden Plover American Kestrel American Oystercatcher Bachman's Sparrow Black-crowned Night Heron Black Duck Black Rail Black Skimmer Black-throated Green Warbler Brown-headed Nuthatch Buff-breasted Sandpiper Common Ground-dove Common Loon Dunlin Eastern Brown Pelican Eastern Meadowlark Eastern Wood Peewee Field Sparrow Glossy Ibis Grasshopper Sparrow Gull-billed Tern Henslow's Sparrow Kentucky Warbler King Rail Least Bittern Least Sandpiper Least Tern Lesser Scaup Lesser Yellowlegs Little Blue Heron Loggerhead Shrike Long-billed Curlew Mallard Marbled Godwit Northern Bobwhite Northern Pintail Painted Bunting Pied-billed Grebe	Acadian Flycatcher Bald Eagle Barn Owl Black-bellied Plover Black Scoter Black-throated Blue Warbler Blue-winged Teal Canvasback Forster's Tern Peregrine Falcon Redhead Semipalmated Plover Spotted Sandpiper White-winged Scoter	American Woodcock Bewick's Wren Chestnut-sided Warbler Common Loon Common Raven Dark-eyed Junco Golden-crowned Kinglet Gray Kingbird Great Blue Heron Great Egret Greater Scaup Greater Yellowlegs Green Heron Horned Grebe Long-billed Dowitcher Louisiana Waterthrush Mottled Duck Pectoral Sandpiper Purple Sandpiper Red-breasted Nuthatch Red Crossbill Ringneck Ruffed Grouse Scarlet Tanager Tundra Swan White-rumped Sandpiper Wood Duck

Taxa	Highest Priority	High Priority	Moderate Priority
Birds (continued)	Prairie Warbler Purple Gallinule Red-cockaded Woodpecker Red Knot Royal Tern Rusty Blackbird Sanderling Sandwich Tern Seaside Sparrow Semipalmated Sandpiper Short-billed Dowitcher Snowy Egret Solitary Sandpiper Stilt Sandpiper Swaison's Warbler Swallow-tailed Kite Tricolor Heron Western Sandpiper Whimbrel White Ibis Willet Wilson's Plover Wilson's Snipe Wood Stork Wood Thrush Worm-eating Warbler Upland Sandpiper Yellow-crowned Night Heron Yellow Rail		
Reptiles and Amphibians	Bog Turtle Broad-striped Dwarf Siren Carolina Gopher Frog Chamberlain's Dwarf Salamander Coal Skink Coral Snake Eastern Milk Snake Flatwoods Salamander Florida Green Watersnake Florida Pine Snake Green Salamander Green Turtle Gopher Tortoise Hawksbill Turtle Island Glass Lizard Kemp's Ridley Turtle Leatherback Turtle Loggerhead Turtle Pine Barrens Treefrog Shovel-nosed Salamander Southern Hognose Snake Tiger Salamander Timber Rattlesnake Webster's Salamander	Black Swamp Snake Canebreak Rattlesnake Chicken Turtle Diamondback Terrapin Eastern Diamondback Rattlesnake Florida Cooter Florida Softshell Turtle Four-toed Salamander Gulf Coast Mud Salamander Hellbender Mimic Glass Lizard Pickerel Frog Pine Snake Pine Woods Snake River Cooter Seepage Salamander Spiny Softshell Turtle Striped Mud Turtle Upland Chorus Frog Wood Frog Yellowbelly Turtle	American Alligator Bird-voiced Treefrog Common Snapping Turtle Northern Cricket Frog Slender Glass Lizard Southern Dusky Salamander Spotted Turtle
Freshwater and Diadromous Fishes	American Eel American Shad Atlantic Sturgeon Blueback Herring Bluebarred Pygmy Sunfish Bridle Shiner	Bannerfin Shiner Blackbanded Sunfish Carolina Darter Carolina Fantail Darter "Carolina" Redhorse Greenhead Shiner	Banded Darter Banded Killifish Blacknose Dace Bluefin Killifish Central Stoneroller Comely Shiner

Taxa	Highest Priority	High Priority	Moderate Priority
Freshwater and Diadromous Fishes (continued)	"Broadtail" Madtom Carolina Pygmy Sunfish Christmas Darter Hickory Shad Highfin Carpsucker Redeye Bass Robust Redhorse Saluda Darter Sandhills Chub Savannah Darter Shortnose Sturgeon "Thinlip" Chub	Piedmont Darter Pinewoods Darter Quillback Santee Chub Seagreen Darter Smoky Sculpin Turquoise Darter	Eastern Brook Trout Fireyblack Shiner Flat Bullhead Florida Gar Greenfin Shiner Highback Chub Longnose Dace Lowland Shiner Mirror Shiner Mud Sunfish Notchlip Redhorse Pugnose Minnow Redlip Shiner River Chub Rosyface Chub Satinfin Shiner Snail Bullhead Striped Bass Tennessee Shiner Thicklip Chub V-lip Redhorse Warpaint Shiner White Catfish Whitemouth Shiner Whitetail Shiner
Crayfish	Mimic Crayfish Oconee Stream Crayfish *Cambarus reflexus* *Cambarus* sp. "B" *Distocambarus hunteri* *Distocambarus youngineri* *Procambarus echinatus* Red Burrowing Crayfish	Broad River Spiny Crayfish *Distocambarus crockeri* Pee Dee Lotic Crayfish Sandhills Crayfish Waccamaw Crayfish	Ditch Fencing Crayfish Edisto Crayfish *Procambarus barbatus* *Procambarus chacei* *Procambarus enoplosternum* *Procambarus hirsutus* *Procambarus lunzi* *Procambarus pubescens* Rocky River Stream Crayfish Santee Crayfish
Freshwater Mussels	Atlantic Pigtoe Barrel Floater Brook Floater Brother Spike Carolina Creekshell Carolina Heelsplitter Creeper Notched Rainbow Savannah Lilliput Southern Rainbow Triangle Floater Waccamaw Spike Yellow Lampmussel	Alewife Floater Eastern Pondmussel Northern Lance Pod Lance Rayed Pink Fatmucket/ Eastern Lampshell Roanoke Slabshell Tidewater Mucket	Atlantic Spike Carolina Lance Carolina Slabshell Eastern Creekshell Eastern Elliptio Variable Spike
Freshwater Snails	*Somatogyrus* spp.	Buffalo Pebblesnail Ridged Lioplax	*Physa* sp. nov "A"

Once the lists were complete, species, group or guild accounts were prepared for each animal on South Carolina's Priority Species List, with the exception of marine animals and insects. Specific accounts were not prepared for every animal on the marine fishes and invertebrate and insect lists due to the large number of species and the limited knowledge for those species. Reports were prepared for marine and insect species with known threats and/or for species that are considered indicators of challenges in a specific habitat.

In each account, authors described the species, their status, population and abundance, habitat needs, challenges, conservation accomplishments and conservation actions. This approach allows for identification of both general conservation strategies for wildlife and habitats in South Carolina, as well as development of species-based conservation strategies. The latter allows for management of particular species within a given habitat. A separate volume, Supplemental Volume: Species and Habitat Accounts, contains these reports in their entirety.

This chapter contains an introduction to each taxonomic group considered in the Strategy. The species selection process used by each committee is also included. 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 CWCS.

Mammals

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 four 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 Strategy, 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.

Species Selection Process

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 Strategy 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 Strategy 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.

Because South Carolina started the prioritization process after the same process was well underway in North Carolina and Georgia, we were able to benefit from the information those states had accumulated and shared.

Reviewers were asked to rank each species using the eight criteria for consideration in species prioritization. Species or subspecies were added or dropped from the list if two or more reviewers suggested the addition/deletion. If one reviewer clearly stated we 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. The intent of the conservation planning process is to periodically revisit the priority list and adjust it as more is learned about each species.

TABLE 2-3: MAMMAL TAXONOMIC COMMITTEE

Name	Affiliation
Craig Allen	SC Cooperative Fish and Wildlife Res. Unit
Mary Bunch	South Carolina Department of Natural Resources
John Cely	South Carolina Department of Natural Resources
David Cupka	South Carolina Department of Natural Resources
Rudy Mancke	University of South Carolina
Alex Menzel	US Fish and Wildlife Service
Sally Murphy	South Carolina Department of Natural Resources
Tom Murphy	South Carolina Department of Natural Resources
Jim Ozier	Georgia Department of Natural Resources
Toni Piaggio	University of Colorado, Boulder
Perry Shatley	US Forest Service
Oscar Stewart	US Forest Service
Johnny Stowe	South Carolina Department of Natural Resources
Heather Thomas	Auburn University

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 loss 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.

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 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.

Two diseases, raccoon roundworm and Sudden Oak Death (SOD) can adversely affect mammals in South Carolina. Raccoon roundworm can infect other mammals, resulting in death. SOD attacks and destroys oak trees; these trees produce mast used as food sources for several mammals on South Carolina's Priority Species List.

Introduced and non-native species can adversely affect South Carolina's mammals. Predation by domestic or feral cats and dogs can reduce population numbers. Feral hogs can destroy habitat for many species, particularly those found in wetland habitats. Gypsy moths, like SOD can eliminate food sources for mammals.

Several species of mammals are regarded by humans as "pests;" this view can lead to persecution of these species.

One of the greatest challenges to marine mammals and manatees is boat strikes. An additional threat to these animals is entrapment in fishing devices, including hook and line and trawls.

Birds

As of 2001, 390 species of birds have been documented in South Carolina of which 179 are classified as breeders (Cely 2003). 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). Ultimately, 111 bird species were chosen for inclusion on South Carolina's Priority Species List.

Three different bird conservation regions (BCRs) transect South Carolina: 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). 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 else where 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 Appalachian mountain BCR is not as important for waterfowl and shorebirds as coastal regions but it does contain the headwaters of several major river systems (US NABCI 2000).

The Piedmont BCR is geographically part of Southern Appalachia and makes up the transitional area between the mountains and the flat coastal plan 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 short-leaf 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 comprised of 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).

Species Selection Process

The information about birds contained in the Strategy was mostly supplied by the expertise of several biologists who formed our Bird Taxonomic Committee. The members of that committee invested considerable time to the development of the Strategy and are graciously thanked for their efforts; these individuals are listed in Table 2-4. Other sources of information included published literature and unpublished data from a variety of sources.

TABLE 2-4: BIRD TAXONOMIC COMMITTEE

Name	Affiliation
John Cely	South Carolina Department of Natural Resources (retired)
Elizabeth Ciuzio	Kentucky Dept for Natural Resources
Nathan Dias	Cape Romain Bird Observatory
Dennis Forsythe	The Citadel
Lex Glover	South Carolina Department of Natural Resources
Anna Huckabee Smith	North Carolina Department of Environmental and Natural Resources
Chuck Hunter	US Fish and Wildlife Service
Drew Lanham	Clemson University
Steve Lohr	US Forest Service
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
Felicia Sanders	South Carolina Department of Natural Resources
Craig Watson	US Fish and Wildlife Service

Species prioritization for birds relied heavily upon the Partners in Flight prioritization process. Partners in Flight (PIF) was initiated in the early 1990's and drew together many groups and individuals focused on bird conservation, knowledge and people to keep 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 six 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. The PIF scores and conservation tiers for South Carolina's priority bird species are summarized in Appendix 3: Bird Prioritization Table.

Waterbird, shorebird and waterfowl conservation priority selections depended heavily on national and international conservation plans. Birds were chosen based on their continental priorities as well as professional review of South Carolina's ecological role in the continued conservation of these birds. Plans consulted include the North American All 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.

Challenges

One of the major challenges to birds in South Carolina is loss, fragmentation and/or alteration of habitat. Birds in this state depend upon varied habitats from the mountains to the coast; changes to habitats can result in loss of feeding, breeding 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. Conversion of habitat for birds to agricultural purposes 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 plantation 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 or fragmented as a result of urban development.

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. 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.

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.

Chemical contamination threatens many carnivorous birds, particularly those that consume fish. Persistent organo-chlorine pesticides, such as DDT and heavy metals, such as lead and mercury can result in poisoning.

Several diseases and parasites can affect bird populations and/or food sources for birds. These include West Nile virus, Avian Vacuolar Myelinopathy, cholera, botulism, soft tick infestation and hemlock wooly adelgid infestations.

Non-native predators can also decimate bird populations; predation by domestic and feral cats is particularly problematic for songbirds.

Amphibians and Reptiles

Currently, 142 species of amphibians and reptiles are known to occur in South Carolina. Continued controversy over the taxonomic status of certain species or species complexes results in a lack of certainty in a fixed number of species for the state. New species have been recently discovered or described, which results in a dynamic species list.

To emphasize the way in which the species list can change, consider the following recent additions. Just in the past 30 years, the striped mud turtle, bog turtle and seepage salamander have been verified as occurring in South Carolina. In addition, two newly described species, the mimic glass lizard and Chamberlain's dwarf salamander have been added to the state's list of native herpetofauna.

More changes may be in store for South Carolina’s lists of amphibians and reptiles. Several taxonomic issues involving herpetofauna in South Carolina are currently unresolved, including 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 resemble either *Desmognathus apalachicolae* or *Desmognathus fuscus conanti*, neither of which has been documented for coastal South Carolina.

Ultimately, 52 reptile and amphibian species were chosen for inclusion on South Carolina’s Priority Species List.

South Carolina'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. One area of South Carolina's southern coastal plain supports more frog species (25) than any other place in North America (Duellman 1999).

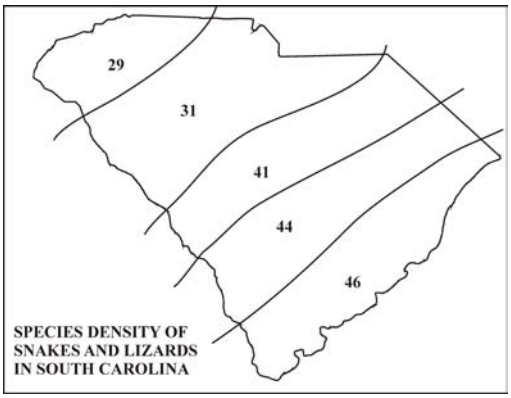

FIGURE 2-1: Species density of snakes and lizards in ecological regions of South Carolina

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 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.

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 142 species of amphibians and reptiles found in the state, 113 occur in the coastal plain and 50 of these are endemic to this province, at least in South Carolina.

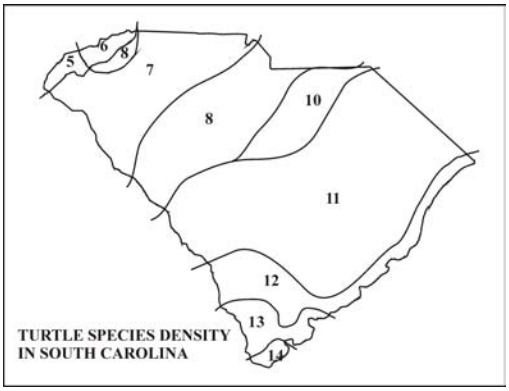

FIGURE 2-2: Species density of turtles in ecological regions of South Carolina

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 sand hills, are home to the pine barrens treefrog.

Species Selection Process

The amphibian and reptile portion of the Strategy has been written in a manner that incorporates a regional as well as a 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 Strategy and are graciously thanked for their efforts; these individuals are listed in Table 2-5.

TABLE 2-5: AMPHIBIAN AND REPTILE TAXONOMIC COMMITTEE

Name	Affiliation
C.L. Abercrombie	Wofford College
Steve Bennett	South Carolina Department of Natural Resources
Eric Billings	
Denise Billings	
Kurt Buhlmann	South Carolina Department of Natural Resources
Jeffrey Camper	Francis Marion University
Heyward Clamp	Edisto Island Serpentarium
John Fauth	Central Florida University
Dr. J.W. Gibbons	Savannah River Ecology Laboratory
Judy Greene	Savannah River Ecology Laboratory
Julian R. Harrison	College of Charleston (ret.)
Joey Holmes	
Jeff Humphries	Clemson University
Kevin Messenger	North Carolina State University
Brian Metts	Savannah River Ecology Laboratory
Tony Mills	Savannah River Ecology Laboratory
Richard Montanucci	Clemson University (ret.)
Zach Orr	
Gene Ott	
Corey Roelke	
David Scott	Savannah River Ecology Laboratory
Keith Taylor	
Tracey Tuberville	Savannah River Ecology Laboratory
Jayme Waldron	Clemson University
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 habitat regions of the state. A number of species did not fit easily into a functional group and are addressed individually in the CWCS. All species, whether addressed individually or in a functional group are related to a specific habitat type or several habitat types.

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 most recently in 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 the Department and Riverbanks Zoo 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 CWCS 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 CWCS. 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 have been identified as priority species, representing 37 percent of the state's species. While these 52 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 plan must take the full spectrum of South Carolina's amphibian and reptile fauna into account, documenting occurrences for all species. There are a number of amphibian and reptiles 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, southern Appalachian salamander, mole kingsnake and glossy crayfish snake are examples of species that are not well known in the state and that may be of future conservation concern.

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.

Challenges

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 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 for these species 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 plantation 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 area can disorient turtles and result in nesting failure. Road mortality is also a significant threat; urban development requires that additional roads be constructed. 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.

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; 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 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, in press). 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. Incidental take of loggerhead turtles from 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). The shark longline fishery, which operates all year long off the south Atlantic, may impact loggerheads in the neritic environment (Lewison et al. 2004).

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 the distributions of approximately 22 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.

The southeastern US is rich in aquatic fauna diversity, but some species are increasingly at risk of extinction. More than two decades ago a fish assessment of the southeastern US identified 85 fishes in jeopardy of imperilment (Deacon et al. 1979). A decade later, Williams et al. (1989)

recognized 109 southeastern fishes as in jeopardy. The most recent assessment of southeastern fishes (Warren et al. 2000) identified 187 taxa as extinct, endangered, threatened or vulnerable, which represents a 125 percent 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 in the latest assessment of southeastern fishes (Warren et al. 2000). An additional 38 fish species were determined to be of conservation concern in South Carolina; a total of 56 freshwater fishes are included on South Carolina's Priority Species List. Although many of those 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.

Species Selection Process

The information about freshwater fishes contained in the Strategy was supplied by the expertise of the biologists who formed our Freshwater Fish Technical Team (FFTT). The members of that team invested considerable time to the development of the Strategy and are graciously thanked for their efforts; these individuals are listed in Table 2-6. Other sources of information included published literature and unpublished SCDNR and Clemson University data.

TABLE 2-6: FRESHWATER FISHES TECHNICAL TEAM

Name	Affiliation
Ron Ahle	South Carolina Department of Natural Resources
Jason Bettinger	South Carolina Department of Natural Resources
Jeff Foltz	Clemson University
Eric Krueger	The Nature Conservancy
Doug Martin	Savannah River National Laboratory
Joe Quattro	University of South Carolina
Fritz Rohde	North Carolina Division of Marine Fisheries
Jeannie Riley	United States Forest Service
Mark Scott	South Carolina Department of Natural Resources
Wayne Starnes	North Carolina State Museum of Natural Sciences
Lora Zimmerman	United States Fish and Wildlife Service

During December 2003, twelve biologists were asked to review a list of South Carolina fish 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 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.

The responses from all reviewers were then summarized to develop a preliminary list of species having the greatest conservation need in South Carolina. The summarization process was as follows. Initial trimming of the list was facilitated by asking reviewers to eliminate species that did not warrant special conservation status in South Carolina or were not primarily restricted to freshwater. A species was eliminated from the list when at least two reviewers suggested elimination and none of the other reviewers provided information for that species. All letter responses (multiple-choice questions) were assigned a numerical value (1 to 3). Within the

knowledge category, higher numbers were assigned to species with the least amount of knowledge (Knowledge of species population status; high (H) = 1, Medium (M) = 2, and Low (L) = 3). Within the conservation category, higher numbers were assigned to the species in greater conservation need (Population status; Increasing (I) = 1, Stable (S) = 2, and Decreasing (D) = 3). Among individual reviewers, the responses were averaged by species for the knowledge category and status category questions. The mean scores in both categories were then ranked by species for each reviewer. Mean ranks were then calculated for each category of questions by species when at least two reviewers provided input for that species.

The initial review by the FFTT resulted in a list of 68 freshwater fish species that warranted further discussion as to their conservation needs and status. FFTT members met on August 11, 2004 in Columbia, South Carolina to review the revised species list, make changes (species additions and deletions) and categorize the conservation needs of each fish species. The FFTT members, by consensus, ultimately identified 56 freshwater fish species of conservation concern in South Carolina and categorized them into three different levels of conservation need (highest, high, and moderate). The 56 species represent roughly 38 percent of the freshwater fishes in the state. While the fish species addressed here are thought to be the most imperiled or likely to become imperiled fish species in the state, it is not an indication that the other species that inhabit the state are stable and secure.

Challenges

One of the major challenges to freshwater fishes in South Carolina is degradation and loss of habitat. As development and urbanization 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 and 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 increased water temperature (Aust and Lea 1991; Perison et al. 1993). Forestry BMPs for bottomland forests are recommendations to landowners in order to conserve site productivity, primarily for silviculture, and are voluntary (South Carolina Forestry Commission 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, 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 1999). 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, which can reduce survival of eggs, larvae or juveniles (Rogers and Weber 1995; NMFS 1998; USFWS 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 fish (ASMFC 1990; NMFS 1998; USFWS 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 nonpoint 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).

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 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 will be addressed in a guilded approach.

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 to the development of the Strategy and are graciously thanked for their efforts; these individuals are listed in Table 2-7. Other sources of information included published literature and unpublished SCDNR data.

TABLE 2-7: DIADROMOUS FISHES TAXONOMIC COMMITTEE

Name	Affiliation
Mel Bell	South Carolina Department of Natural Resources
Jason Bettinger	South Carolina Department of Natural Resources
Mark Collins	South Carolina Department of Natural Resources
Doug Cooke	South Carolina Department of Natural Resources
Billy McCord	South Carolina Department of Natural Resources
Bill Post	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) for which species reports are written are considered to be high 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 ASMFC or the 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 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, 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. 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. 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 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 decade or more has been funded by various federal grants and has 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 sufficiently 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 NMFS recovery plan for shortnose sturgeon (NMFS 1998) and other management plans, make numerous recommendations for data collection needs

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.

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.

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 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

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 3-mile territorial jurisdictional limit of the Atlantic continental shelf.

The information about marine and brackish fishes and marine invertebrates contained in the Strategy was supplied by the expertise of biologists who formed the Marine Taxonomic Committees. The members of these committees invested considerable time to the development of the Strategy and are graciously thanked for their efforts; these individuals are listed in Table 2-8 and Table 2-9. Other sources of information included published literature, and unpublished data from various sources.

TABLE 2-8: MARINE FISHES TAXONOMIC COMMITTEE

Name	Affiliation
William Anderson	College of Charleston
Mel Bell	South Carolina Department of Natural Resources
Jason Bettinger	South Carolina Department of Natural Resources
Mark Collins	South Carolina Department of Natural Resources
Don Hammond	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
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

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. 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 would be facilitated by asking reviewers to eliminate species that did not warrant special conservation concern in South Carolina. A species was to be eliminated from the list if at least two of the reviewers suggested elimination and none of the other reviewers provided information for that species.

TABLE 2-9: MARINE INVERTEBRATES TAXONOMIC COMMITTEE

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
Pam Jutte	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
Jennifer Price	South Carolina Department of Natural Resources
Steve Stancyk	University of South Carolina
Betty Wenner	South Carolina Department of Natural Resources
David Whitaker	South Carolina Department of Natural Resources
Bob Van Dolah	South Carolina Department of Natural Resources

All identified experts were 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. Initially, reviewers were asked to eliminate species that did not warrant special conservation concern in South Carolina. A species was to be 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 changes or as indicators of population health for other species associated with similar habitats. The final list of marine and brackish fishes includes 163 species.

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 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 includes 775 species, or better, types. The classification of some "species" remains in question.

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.

One of the major challenges to marine organisms in South Carolina is degeneration and loss of habitat. As development and urbanization occurs along the coast, beaches and waterbodies 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. Stormwater runoff from developed areas contains sediment, nutrients and contaminants. These substances can substantially degrade water quality. As coastal areas are developed, more contaminants are carried in stormwater. 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 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.

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 damage sustained during harvest or stress related to harvest.

Unregulated harvest threatens some marine species. For example, South Carolina does not currently regulate a commercial cannonball jellyfish fishery. 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.

Crayfish

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 percent 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). South Carolina is the home to a diverse crayfish fauna of at least 36 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.

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, two of the species on our list are in the process of being described.

Commonly thought to inhabit strictly aquatic environments, crayfish can utilize a variety of aquatic, semiaquatic 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 and 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.

The conservation of American crayfishes has received little attention by regulatory agencies. The American Fisheries Society considered 65 species (19.2 percent) of North American crayfish as endangered, 45 (13.3 percent) as threatened and 50 (14.8 percent) as special concern (Taylor et al. 1996). Listing with the American Fisheries Society does not give species any protection. The US Fish and Wildlife service only lists four 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.

Species Selection Process

The information about aquatic and terrestrial crayfish contained in the Strategy was supplied by the expertise of five biologists. These people invested considerable time to the development of the Strategy and are graciously thanked for their efforts; these individuals are listed in Table 2-10. Other sources of information included published literature and museum records.

TABLE 2-10: CRAYFISH TAXONOMIC COMMITTEE

Name	Affiliation
John Cooper	NC Museum of Natural Sciences
Arnold Eversole	Clemson University
Daniel Jones	Clemson University
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 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. 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.

In South Carolina's CWCS, 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 as the challenges these species face may be somewhat different than those to species inhabiting open water.

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.

The arrival of introduced species is probably the greatest challenge to crayfish (Lodge et al. 2000 a,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). 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.

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 as sensitive to water borne pollution than adults; early instars are about three times as 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, particularly genetic research, 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 improve water quality. 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 $foot^2$), removing them from our rivers and streams can have drastic consequences for these ecosystems, particularly in terms of water filtering (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 1800's harvesting mussels for pearls was common. From the 1890's until the 1950's, 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).

Most freshwater mussels are dioecious (separate sexes), although a few species are hermaphroditic. After fertilization and hatching within the female, the larvae, 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 that 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 percent of mussel species were endangered and possibly extinct, 20.6 percent were endangered and extant, 14.5 percent were threatened, 24.2 were of special concern, 4.7 percent had an undetermined status; only 23.6 percent 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.

Records from the mid and early 1800's 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.

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 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. 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 the lack of researchers skilled in mussel identification and taxonomy, especially in South Carolina.

Species Selection Process

The information about freshwater mussels contained in the Strategy was supplied by the expertise of biologists who formed our Freshwater Mussel Taxonomic Expertise Committee. The members of that committee invested considerable time to the development of the Strategy and are graciously thanked for their efforts; these individuals are listed in Table 2-11. Other sources of information included published literature and museum records.

TABLE 2-11: FRESHWATER MUSSEL TAXONOMIC EXPERTISE COMMITTEE

Name	Affiliation
John Alderman	Alderman Environmental Services
Art Bogan	NC Museum of Natural Sciences
Tom Dickinson	The Catena Group
John Fridell	US Fish and Wildlife Service
Eugene Keferl	Coastal Georgia Community College
Eric Krueger	The Nature Conservancy
Tim Savidge	The Catena Group
Jennifer Price	South Carolina Department of Natural Resources
James Williams	US Geological Survey
Lora Zimmerman	US Fish and Wildlife Service

During December 2003, biologists were asked to review a list of 29 mussel 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 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.

The Freshwater Mussel Taxonomic Expertise Committee members met on 6 August 2004 to review the revised species list, 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.

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 inch) 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, 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.

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 byproducts, 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). A recent 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 can also 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. 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 among high densities of *Corbicula*.

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*, but has not yet reached South Carolina. 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.

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 the 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 fish species is known for fewer than half of South Carolina's mussels (Bogan and Alderman 2004). Conservation of specific mussel species by protecting the host fish can only be practiced efficiently if the identity of the host fish is known. Conserving healthy aquatic environments will benefit both fish and mussels.

Freshwater Snails

Mollusks of the class Gastropoda, commonly known as snails and slugs, are found in freshwater, terrestrial and marine habitats. Terrestrial snails are not being included 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 all invertebrate groups, snails and other gastropods are in need of taxonomic and genetic work.

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, South Carolina Department of Natural Resources did not even 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 to the development of the Strategy 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.

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. 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). 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.

Insects

While insects are certainly numerous, broadly represented, and widely encountered in South Carolina, incorporating insects into the Strategy presented many challenges, most of which were unique to insects.

The foremost reason for treating insects differently from other, better-known taxa is the much larger number of insect species currently known. Approximately 1.5 million species of living organisms presently are known in the world, from bacteria to oak trees to blue whales (Hoffman and Frodsham 1993). Animals comprise 1.1 million described species; approximately three-quarters of those animal species (about 825,000) are insects. Not only are insects the single largest component of world biodiversity (Erwin 1982; 1983), they are important in human and environmental health.

Insects are divided into 32 orders, with the largest order, beetles, comprising around 500,000 different species in 125 families. It is estimated that one out of every four known animals is a beetle. Furthermore, scientists estimate that 10 percent of the animal biomass of the world is ants and another 10 percent is termites; therefore, “social insects” may account for an incredible 20 percent of the total animal biomass of our planet.

The most widely used estimate for the total number of living species is roughly three times the number currently described, around 3 to 5 million (Berry 1992). However, extrapolations of local diversity that include world rain forests elevates that figure to somewhere between 30 and 50 million (Erwin 1988, 1997; Odegaard 2000). This estimate is controversial because the larger the estimated number of species, the larger the estimated rate of species loss. It is important to note that Erwin did not present this as a definitive number, but provided his estimate in an effort to spur further research.

Species Selection Process

Ten biologically significant arthropod taxa for which sufficient knowledge exists to build a minimal database were selected, including beetles, (Coleoptera); flies (Diptera); mayflies (Ephemeroptera); true bugs (Hemiptera); wasps, ants, and their relatives (Hymenoptera); butterflies (Lepidoptera); dragonflies and damselflies (Odonata); stoneflies (Plecoptera); caddisflies (Trichoptera); and spiders (Araneae).

The task was to compile a comprehensive, multi-taxa list of South Carolina's insect species of concern, including those currently not having any listing status, those already having a State or Global Natural Heritage Ranking, and those listed as sensitive, threatened and/or endangered. Ideally, the list should include all known species within the state from which only the species of concern would be included in the CWCS. However, the lack of sufficient data to provide a valid ranking system made this master list impossible. Therefore, insect species were only tabulated and summarized, not categorized into the structured hierarchical system used for the other taxa groups. This tabulating was done for only selected taxa. The total number of species in those taxa reported in South Carolina is presented in Table 2-12.

There is a significant lack of data about insect species distribution, habitat requirements and life histories. This data deficiency made development of conservation actions highly problematic, since knowledge of a species' distribution and living requirements are fundamental to those actions. Additionally, serious data deficiency was also encountered at the genus and family levels. Therefore, this necessitated the following working model: insects will be protected whenever they live in habitats being protected for non-insects species. Rather than planning protections for a particular insect species, most of the very few State- or Federally-listed insect species are afforded protections by having their general habitat protected.

The data deficiency is complicated further by the small number of insect experts available for consultation. The members of the Insect Expert Committee invested considerable time to the development of the Strategy and are graciously thanked for their efforts; these individuals are also presented in Table 2-12.

Because of the paucity of data for most insect species, several taxonomic experts were concerned that their estimate of an insect species' rank (likelihood for survival) would be construed as legally binding and considered as "law." The consensus of the Insect Expert Committee was that this ranking would only indicate a working approximation of a species' status and range. The "S" ranking (species status in South Carolina) included in the insect species reports represents a best estimate at an insect species' status and range and has no legal standing. The number of times a species was cited from the literature, known from collection data, or was known by an acknowledged expert to occur in one or more locations would be the working basis for determining an insect's "S" ranking. This method has been used by others in similar endeavors and serves very effectively as a rough guide to the extent and level of knowledge of a species' status and range. While a low number of observations does not imply that a species is "a species of concern," the number does assist in making allocations for future research efforts.

TABLE 2-12: INSECT EXPERT COMMITTEE

Taxa Group	Family	Expert	Affiliation	Reported Species
Odonata	Dragonflies	Wade Worthen Lynn Smith	Furman University Columbia University	155
Plecoptera	Stoneflies	Boris Kondraieff	Colorado State University	84
Hemiptera	Lace Bugs	Al Wheeler	Clemson University	38
Lepidoptera	Butterflies Moths	Brian Scholtens John Snyder	College of Charleston Furman University	158 1,510
Ephemeroptera	Mayflies	Pat McCafferty	Purdue University	76
Trichoptera	Caddisflies	John Morse Bradley Goettle	Clemson University Clemson University	243
Diptera	Mosquitoes Midge Flies Long-legged Flies Fruit Flies Black Flies Horseflies Net-winged Midges	Bill Willis John Epler Harold Robinson Allen Norrbom Peter Adler Bruce Ezell Greg Courtney	Clemson University Private Researcher Smithsonian Institution Smithsonian Institution Clemson University UNC Pembroke Iowa State University	62 392 91 10 54 113 12
Coleoptera	Ground and Tiger Beetles Scarab Beetles Bark Beetles Fireflies	Janet Ciegler Phil Harpootlian Don Bright Jim Lloyd	Private Researcher Private Researcher Agriculture Canada University of Florida	415 746 64 37
Hymenoptera	Sawflies Ants	David Smith Tim Davis	Smithsonian Institution Clemson University	52 103
Araneae	Spiders	Robert Wolff	Private Researcher	432
		Total Number of Reported Species		**4,847**

Due to the large numbers of insect species, fifteen were chosen for which detailed species reports were prepared. Protection of species in other taxa and ultimate protection of ecosystems and habitats is expected to protect insects in South Carolina.

Challenges

Although we know little about most individual species, we do know that insects are incredibly adaptable and have evolved to live successfully in most environments on earth. Insects are by far the most diverse groups of animals and are a significant part of most ecosystems (Samways 1994). Yet insects are insufficiently studied and have received minimal attention from the scientific community. Insect biodiversity is being irreversibly lost through extinction caused by the alteration, degradation and destruction of natural habitats.

Identification of species is only the beginning, a fundamental necessity for all subsequent studies. Discovery of biological characteristics and living requirements of each species is the next step. Data are very scarce for most insect species beyond those observed and provided with their initial discoveries and descriptions. Closing the large data deficiency for insects is a necessary to fully understanding this taxa group.