CHAPTER 9: SWAP IMPLEMENTATION AND ADAPTIVE MANAGEMENT

The primary focus of South Carolina's State Wildlife Action Plan (SWAP) is continued efficient and effective conservation and management of wildlife diversity. In the creation of the 2025 edition of this Plan, South Carolina Department of Natural Resources (SCDNR) staff and conservation partner organization engagement occurred to draft chapters. Agency staff created the list of Species of Greatest Conservation Need (SGCN) with external assistance from other wildlife professionals from across the Southeast and nationally. The public was encouraged to review the draft SWAP and relevant suggestions and edits incorporated into this final version. For a more detailed review of this process, see Chapter 1.

The South Carolina Department of Natural Resources (SCDNR) has been successfully implementing its various SWAPs since the first version in 2005. The 2025 Plan will meet also meet its mandate through the coordination of diverse conservation efforts and forging of effective partnerships. Coordination efforts will bring together expertise and funding sources from various partners and apply them to needs identified in the SWAP. The initial congressional intent for the SWAPs was to identify and focus on the species in greatest conservation need and yet "address the full array of wildlife and wildlife related issues." At this nexus, the SWAP provides focus and guidance for SCDNR priorities when allocating personnel and financial resources for research and management. It has been integrated into agency business practices such as the environmental review process and land acquisitions. The South Carolina SWAP has also grown in popularity and has been cited in multiple other agency and organization planning documents, reinforcing its tenets.

Partnerships already bolstered during the creation of the first SWAP are offering potential resources for meeting the objectives and strategies described in this newest Plan. Many potential partners have also identified the SWAP as an excellent resource to forge additional support for conservation. By compiling state fish and wildlife conservation issues in a single document, it is possible to develop a coordinated approach ranging from individual species' concerns up to regional, habitat-level concerns. This Plan is more than an outline for specific conservation actions; it continues to serve as a framework for expanding partnerships and interdisciplinary collaboration in support of these actions. An important first step will be to identify these additional individuals, land managers, and organizations that can contribute to and use SWAP information in a timely way.

Andrew Grosse (SCDNR)- second from left, Kurt Buhlmann (UGA)- far right, and two wildlife rehabbers from Charlotte, NC, release "Carl", a waif Gopher Tortoise that was found in an electrical substation in Charlotte, NC, onto Aiken Gopher Tortoise Heritage Preserve. Photo by SCDNR.

A major part of the data management related to Species of Greatest Conservation Need (SGCN) listed in the SWAP is the SCDNR Heritage Trust Database for storing element occurrence records. This database is used by SCDNR biologists, permit reviewers, land use planners, conservation easement advocates, landowners, consultants, and other agencies and individuals who are interested in biological data and impacts on land use decisions. South Carolina's Natural Heritage Program (SCNHP) is part of the Heritage Trust and tracts rare species and natural communities across the State, many of which are SGCN or are being monitored for possible future inclusion in the SWAP if populations decline. Currently, SCNHP tracts 1,371 species, of which 230 are globally imperiled, 105 have a federal nexus, and 46 are state protected. Data can be analyzed and models created to best inform management decisions in-state and across the species' ranges.

Habitats preserved for SGCN follow the conservation biology principle of the 3R's—resiliency, redundancy, and representation. Resiliency is the ability of a population to rebound after events that impact the ecosystem in which they are found. Redundancy is making sure there are multiple populations across the landscape so that no single event could impact the species to the extent it cannot recover. Representation is making sure that genetic diversity and habitat diversity are maintained across the landscape and that connectivity is present among populations. All three of these conservation principles combined help buffer a species from catastrophic events and climate change, improving their adaptive capacity. [USFWS 2016]

Funding the Work

Every year, the State of South Carolina receives (through SCDNR) appropriated funds to implement the SWAP through the State Wildlife Grants (SWG) Program. These allotments are based on a formula using the total area of the state and population. Funds flow from the United States Fish and Wildlife Service (USFWS) to each state/territory/commonwealth's wildlife agency which oversees this grant program. Funds can be used for research, surveys, and habitat restoration if it will benefit a species specifically cited in that state's SWAP. There is a 35% match requirement for all implementation grants and a 25% match requirement for planning grants. South Carolina's appropriations over the last 22 years are graphically represented in Figure 9-1. Typically, the funding results in five to eight new projects a year. To date, South Carolina has completed 109 SWG with 18 more in progress.

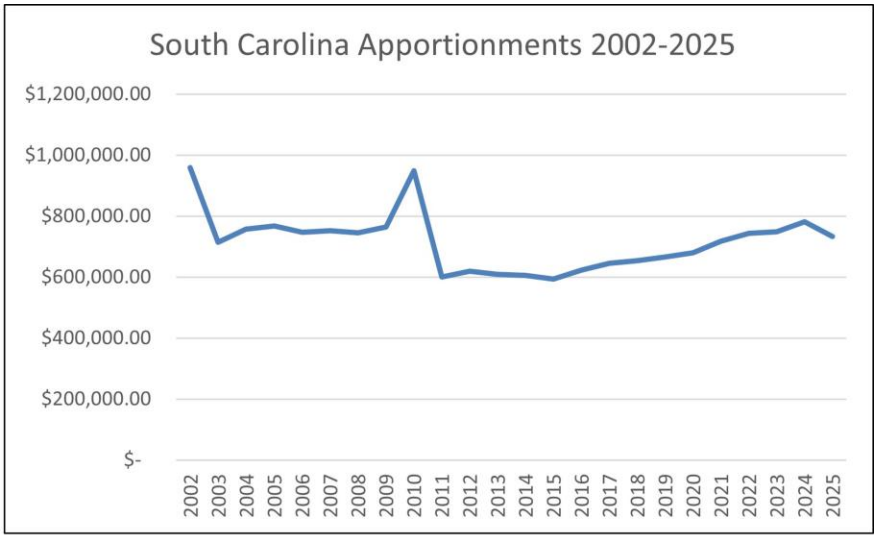


FIGURE 9-1: Federal apportionments directed to South Carolina since inception. Funding is based on a formula that considers the state's size and population.

The companion multi-state program created in 2008, Competitive State Wildlife Grants (C-SWG), has provided funding for 18 projects in which South Carolina has been a partner. Of these, South Carolina was or is currently the lead state for eight.

Depending on when the national budget is approved, states are typically provided their allotments in the spring of the year. The South Carolina SWAP Coordinator position is housed within the Wildlife and Freshwater Fisheries Division of the SCDNR and is funded through State Wildlife Grants matched with state funds. This same coordinator oversees grants related to land acquisition, restoration, research, and survey that serve the interests of SGCN and their habitats, along with providing a robust portfolio of conservation lands overseen by the SCDNR.

In South Carolina, the SWAP Coordinator solicits pre-proposals via an email network. All submitted proposals are reviewed and compiled by the Coordinator in preparation for formal review by the SWG Review Committee. The SWAP Coordinator is the Chair of this committee. Rigorous review and selection procedures ensure that sponsored projects are effective and efficient in meeting the goals and objectives of the SWAP. The SWG Review Committee evaluates all pre-proposals to determine if projects clearly focus on South Carolina priority species, habitats, and their associated mitigation actions recommended within the SWAP. The SWAP must be cited in the proposal. Division leadership is encouraged to meet with Principal Investigators (PIs) and prioritize their projects for consideration so that when the agency divisions and sections convene, it is clear what the most critical needs are for each. The selection process is meant to be fair to all divisions/sections and based on the need and merit of each proposed project. “Pet projects”, programs, and those that do not inform management decisions are not acceptable. The SCDNR seeks to fund innovative, interdisciplinary projects that attempt to address the needs of priority species listed in the SWAP and undertake practical application of SWAP goals. The urgent need to achieve environmental sustainability and protect South Carolina’s ecosystems challenges applicants to develop new ways to engage organizations in problem solving. Therefore, proposals selected should:

- contribute to applied problem-solving for an immediate and specific issue that is directly related to wildlife conservation;
- build capacity for collaborative statewide wildlife conservation; and
- incorporate strategies to apply and communicate outcomes for the improvement of policies and/or management practices.

Standing members of the South Carolina SWG Review Committee include the following or their designee:

- SWAP/SWG Coordinator
- Deputy Director of Wildlife and Freshwater Fisheries Division
- Assistant Deputy Director of Wildlife and Freshwater Fisheries Division
- Chief of Wildlife Management Section
- Assistant Chief of Wildlife Management Section
- Chief of Freshwater Fisheries Section
- Assistant Chief of Freshwater Fisheries Section
- Deputy Director of Marine Resources Division
- Director of the Marine Resources Research Institute (MRRI)

Project Investigators (PIs) whose pre-proposals were selected for funding are informed of the Committee's decision by the SWAP/SWG Coordinator, and a full proposal is requested using a template prepared by the Coordinator. The Coordinator also assists with all state and federally required forms, compliance statements, and uploads to the federal grant system (i.e. Grant Solutions and TRACS). Those not selected for funding receive constructive feedback from the Coordinator.

Since Competitive SWG do not involve allocated dollars and are nationally competitive, proposals are only vetted by the SWG Coordinator for thoroughness and merit, but PIs must have prior project and budget approval from their supervisors, business managers, and grants staff before coordinating with other state agencies, universities, museums, etc.

Adaptive Management, Maintenance, and Communication Plan

Implementation will continue to be a dynamic process through time, involving monitoring process management, performance assessment, adaptation as new information dictates, and refocusing to new tasks and projects as appropriate. As discussed in Chapter 8, a major component of the SWAP's coordination and review will be dependent on successful monitoring of conservation projects and actions: effectiveness monitoring. In the long-term, effective review and revision of the Plan will depend on the effectiveness monitoring protocols and procedures. Conservation actions will have to be evaluated based on their ability to further the goals and objectives of the SWAP. As an agency, SCDNR sets project objectives and identifies measures of success for management actions. Adaptive management comes in the form of updating species lists as well as monitoring and changing course based on trend data and targeted research. As SWAP projects are evaluated, similar indicators of success will be defined at the strategy level.

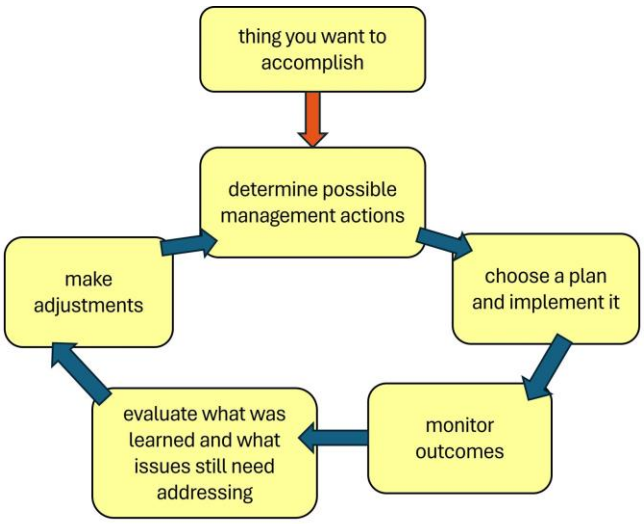


FIGURE 9-2: Adaptive management decision making cycle.

Adaptive management (Figure 9-2) is defined as a structured decision-making process that involves constant monitoring, re-evaluation as new information is learned, and adjusting to reach a desired outcome. It is a method that helps natural resource managers more effectively deal with uncertainties in dynamic ecological systems that are under threat from climate change, invasive species, habitat destruction, and other impacts. Utilizing this approach requires flexibility in management regimes. [Williams and Brown 2012]

Adaptive management requires constant communication between land managers and taxa experts. Likewise, the tool known as the Resist-Accept-Direct (RAD) Framework can guide resource managers in decision-making processes that are a part of adaptive management (CASC 2023). This framework helps land managers determine what desired future condition is needed on the landscape and to be wary of tipping points that may change it to a new steady state. Figure 9-3 defines each level of the framework. Land managers have the option of resisting change and instead returning the current ecosystem to its historic state through species reintroductions or augmentations (through breeding programs or translocations), accepting that changes are occurring and allowing the transformation to progress, or actively directing change to a new state using techniques like assisted migration of animals or planting tree species to establish them in areas that are already transitioning to support such species (Handler et al. 2018).

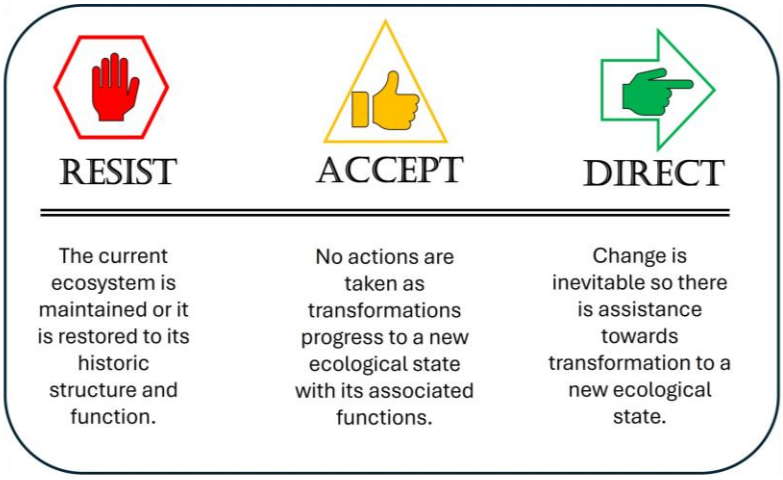


FIGURE 9-3: The Resist-Accept-Direct (RAD) Framework (graphic modeled after USGS).

Red-cockaded Woodpecker translocations can help re-establish colonies within the species' native range. Photos by SCDNR staff.

As a requirement of the USFWS, who oversees the SWG Program, project leaders are required to produce annual (interim) progress reports and final reports for review by the SWAP Coordinator, and these reports are evaluated for insight into adaptive management needs and reassessments of the SWAP. As in years past, final project reports will continue to be made available in an online repository linked to the SWAP website and summaries made available in this chapter of the SWAP. Interim and final reports are uploaded into the federal submission portals. Continued monitoring and evaluation of management actions will create an active implementation of the "living" SWAP document. Project leaders will also be involved in periodic communication efforts focused on increasing public awareness of SWAP implementation. Maintaining these communication links with the public and broader conservation community will be critical to the success of the SWAP.

Old editions of the SWAP will be archived by SCDNR and the newest version posted online and advertised through various social media platforms and through the *South Carolina Wildlife* magazine. Presentations by staff and partners at schools, workshops, conferences, public events, and other venues will introduce the SWAP and encourage citizen scientists and volunteers to contribute to its implementation. Even backyard habitat creation and Adopt-a-Highway programs are beneficial efforts to be encouraged as sustaining healthy ecosystems maintains diversity. Examples of public/partner engagement include:

- a June 2024 presentation at the Sustainable Forestry Initiative (SFI) Conservation Impact Workshop where SCDNR requested that SGCN be considered when determining Forests with Exceptional Conservation Value (FECVs) and harvest impacts;
- a year-long (December 2023 – December 2024) Natural Resources Conservation Service (NRCS) Learning Series where SCDNR experts presented on the major taxa groups in the SWAP so that NRCS staff could recognize them in the field and advise landowners of habitat management; and
- a presentation and nature walk with the Coastal Master Naturalists at Caw Caw Interpretive Center in April 2024 that focused on both native species and non-native invasive plant identification.

Review and Revision of the SWAP

As per Element 6 of the original legislation establishing the SWAP/SWG Program, all states made a commitment to review and revise the SWAP every ten years. The Program in South Carolina will continue to be reviewed on a 10-year cycle to ensure it and the SWAP remain relevant and current with evolving landscapes and developing conservation efforts. This cycle will include the previously described plans for monitoring, maintenance, adaptive management, review, and revision. Within the 10-year period, it is expected that certain matters may trigger a major revision of the SWAP or submission of

Presentations on the SWAP revision were made to conservation partners and input gathered. Photo by Sara Green, SCWF.

addendums or emerging issues letters (minor revisions) to the Plan. The identification of new information on species priorities gained through surveys, research, and monitoring or reprioritization of projects and actions following goal achievement will be recognized as adaptive management efforts requiring Plan reassessment. However, planning improvements such as (1) identification and elimination of flaws in the program or SWAP implementation process, (2) identification of more efficient or valid approaches to internal supporting processes such as species prioritization and threat assessment, and/or (3) expansion of those taxa groups treated only cursorily in this current SWAP document would contribute to the next iteration of the SWAP during a regular revision cycle. Technology is always advancing so that future issues may include new or improved range maps / species distribution models and habitat suitability models. The typical timeline of events for the revision of the SWAP are outlined in Figure 9-4.

TASKS	Two Year Timeline Divided by Quarters							
	Yr1 Q1	Y2 Q2	Y3 Q3	Y4 Q4	Y2 Q1	Y2 Q2	Y2 Q3	Y2 Q4
Letter of intent submitted to USFWS								
SWG planning grant written								
Taxa Teams formed								
Taxa Teams revise SGCN list								
Taxa Teams update species/guild accounts								
SWAP data gathering and chapter editing								
Indigenous Peoples / cultural groups engaged / review period								
Conservation Partners engaged and review period								
General public review								
Final compilation of comments, edits, and internal review								
Submit to USFWS								

FIGURE 9-4: Timeline of events required to complete a SWAP revision over two years.

State Wildlife Grant and Competitive State Wildlife Grant Project Summaries

Table 9-1 lists, in chronological order, SWG projects followed by summaries of each grant. Table 9-2 then follows as well as summaries of C-SWG projects. SWAP/SWG coordination and revision grants are not summarized as they are simply utilized to run the program in South Carolina and revise the SWAP. Pilot projects that evolved into other projects are summarized as noted. Due to personnel turnover, the author of the report may differ from the actual PI of the project for some of the earliest grants. This is noted in the title of each report. Also, there may be more PIs involved but only the lead(s) is/are listed. Grants currently still in progress are listed but not summarized. All final federal reports can be found online as part of SCDNR's SWAP page and go into more depth for each grant, including partners involved and if scientific publications or theses or dissertations resulted from them. It should be noted that many of these projects relied heavily on SCDNR staff but also involvement from partners in academia, conservation organizations, volunteers, and the general public, a testament to the breadth of SWAP implementation by both the professional and public sectors working cooperatively. The subjects of these projects range from research and survey of species or their habitats to habitat protection, enhancement, or restoration.

TABLE 9-1: State Wildlife Grants from 2005-present. T-1, T-3, T-12, T-18, T-22, and T-28 were unassigned numbers.

Federal Grant No.	Duration	Project / Grant Title
T-2-2 ***(see also T-26-R-1 & T-57-R-1)***	2004-2006	Herpetological Research and Survey in SC
T-4 ***(later became a part of T-13-R-2)***	2004-2005?	Swainson's Warbler and Swallow-tailed Kite Movements, Productivity, Survival, and Habitat Use
TT-5-1	2003-2011	Development of original CWCS
T-6 ***(continuation from WCRP R-3 grant)***	2004-2005	Census and Monitoring of Waterbird Nesting in the SC Coastal Plain
T-7-R-1	2006-2008	Conservation of Water and Seabirds in SC
T-8-R-1 ***(later became T-25)***	2005-2007	SC Stream Planning Project
T-9 **F05AF00015**	2004-2013	Robust Redhorse Restoration and Conservation
T-10-P ***(see also T-46)***	2005-2009	Landscape Planning for Priority Species on Agricultural Lands
T-11	2006-2008	Restoration of Longleaf Pine Forest on State Owned Land
T-13-R-2	2006-2009	Conservation of Migratory Landbirds in SC
T-14-T	2005-2009	Development of BMPs for Sustaining Wildlife in the Maritime Zone of SC
T-15-P	2005-2007	SC Reptile and Amphibian Conservation Planning
T-16-R	2005-2009	Upland Habitat Improvements on Lewis Ocean Bay Heritage Preserve
T-17-R	2006-2010	Protection and Management of Seabird Colonies (Monitoring/Breeding Parameters)
T-19-R	2006-2010	Habitat Enhancement on North and South Williman Islands, Beaufort County, SC
T-20	2006-2007	Status and Management Plan Development for Three Rare Burrowing Crayfish, *Distocambarus youngineri, D. hunteri,* and *Cambarus reflexus*
T-21-R	2007-2011	Coordination and Implementation of SC's CWCS (SWAP)
T-23-R-1 **F06AF00025**	2006-2011	Controlling Access to Known and Potential Bat Roosts
T-24	2006-2008	Fish Passage on the Broad River: An Assessment of Benefits of Freshwater Mussels
T-25-R-1 **F06AF00028**	2006-2013	SC Stream Conservation Implementation
T-26-R-1 **F06AF00026** ***(see also T-2-2 & T-57-R-1)***	2006-2011	SC Reptile and Amphibian Conservation
T-27-R-1	2009-2012	Habitat Improvement for Grassland Birds
T-29	2007-2010	Coordination and Implementation of SC's CWCP (SWAP)
T-30-R	2007-2008	Taxonomy, life history, and distribution of the crayfish, *Procambarus echinatus*
T-31-R-1 **F07AF00064**	2007-2012	Assessing Introgressive Hybridization Within and Habitat Requirements of Native SC Redeye Bass
T-32-T-1	2007-2008	Restoring Seabird Nesting on Bird Key Stono Seabird Sanctuary
T-33-R-1 **F07AF00062**	2007-2012	Robust Redhorse Electrofishing and Radio Telemetry Tracking of the Great Pee Dee River, SC
T-34-HM-1 **F07AF00063**	2007-2014	Community Based Habitat Restoration and Large-Scale Resource Enhancement Through SCORE (multiple grant names)
T-35-R	2009-2010	Identification of Diamondback Terrapin Habitats in SC
T-36-HM	2008-2010	A GIS Model to Guide Landscape Scale Restoration at the Woodbury Tract and Hamilton Ridge Properties
T-37-T	2008-2010	Carolina Herp Atlas
T-38-R-1 **F07AF00061**	2007-2012	Mink Restoration and Monitoring Development Project
T-39-M-1 **F08AF00087**	2008-2013	Prescribed Burning Crew for SCDNR Lands
T-40-L	2008-2009	Conservation of Belfast Plantation, Phase I (acquisition)
T-41-R-1 **F08AF00108**	2008-2016	Conservation of Wading Birds, Shorebirds and Seabirds in South Carolina

T-42-R-1	2008-2009	Use of GIS to Assess the Demographic Isolation of RCW Groups in SC
T-43-R F08AF00110	2008-2017	Conservation of Migratory Landbirds in SC
T-44-R-1	2008-2010	Least Tern Reproductive Success on Rooftops
T-45-R-1	2008-2011	American Shad Culture and Stocking in the Edisto River
T-46-1-T F08AF00111 ***(see also T-10)***	2009-2012	Landscape Planning for Priority Wildlife Species on Agricultural Lands
T-47-R-1 F08AF00109	2008-2011	Conservation of Breeding Painted Buntings and Other Songbird Indicators in Early-successional Shrub-scrub Habitat Modified by CP-33 Buffers in SC
T-48-R	2008-2010	Effects of Predation on Seabird Nests in Cape Romain
T-49-R-1 F08AF00107	2008-2015	Sea Turtle Conservation on Botany Bay Plantation WMA
T-50-L	2009-2010	Conservation of Belfast Plantation, Phase II (acquisition)
T-51-R-1 F09AF00159	2009-2011	Ecology and Impacts of Coyotes on Loggerhead Sea Turtles, Least Terns, and Other Wildlife: Implications for Management
T-52-P-1 F10AF00421	2010-2017	Revision of South Carolina's Wildlife Conservation Strategy (SWAP)
T-53-R-1 F10AF00422	2010-2015	Striped Bass Stock Enhancement of Charleston Harbor Estuary/System (multiple grant names)
T-54-R-1 F10AF00443 Part 1	2010-2014	Monitoring Impacts of Yellow Pine Restoration on Avifauna in the SC Mountains
T-54-R-1 F10AF00443 Part 2	2015-2015	Relative abundance (CPUE) and distribution (habitat use) of Lionfish in the Southeast region based on Reef Fish Survey (video) observations
T-55-R-1 F10AF00444	2010-2012	Using Citizen Science in the Study and Conservation of Breeding Painted Buntings
T-56-R-1 F11AF00686	2010-2015	Continued monitoring of recently established crab trap-based oyster reefs to document their values as essential fish habitat for a diverse fauna in South Carolina (multiple grant names)
T-57-R-1 F11AF00666 ***(see also T-2-2 & T-26)***	2011-2016	SC Amphibian and Reptile Conservation
T-58-R-1 F12AF01378 ***(formerly T-45)***	2012-2015	Evaluation of American Shad Stocking in the Edisto River
T-59-R-1 F12AF01381	2012-2015	Composition of American Eels in Freshwater Habitats of SC and Their Infection Status by the Invasive Parasite Species, *Anguillicoloides crassus* (multiple grant names)
T-60-R-1 F12AF01382	2012-2015	Validation of Trammel Netting Monitoring Population Trends for Diamondback Terrapins in the Charleston Harbor Estuary (multiple grant names)
T-61-R-1	2012-2013	Decision Support Tools for Stream Conservation
SC-T-F13AF01180	2013-2015	Mapping and Classifying Tidal Freshwater Wetlands in the ACE Basin
SC-T-F13AF01182	2013-2014	Identification and Distribution of Crayfishes in South Carolina
SC-T-F13AF01183	2013-2016	Evaluation and Monitoring of the Santee River Basin Robust Redhorse Restoration Effort
SC-T-F13AF01185	2013-2015	Assessing the Status of MacGillivray's Seaside Sparrows (*Ammondramus maritimus macgillivraii*) in SC
SC-T-F13AF01207	2013-2015	Enhancement of Upstream Passage for American Eels at the St. Stephen Dam, SC
SC-T-F13AF01208	2013-2016	An Evaluation of Culturing Carolina Diamondback Terrapins for Responsible Stock Enhancement
SC-T-F14AF01233	2014-2020	South Carolina Small River Conservation Planning Project
SC-T-F15AF00727	2015-2018	Distribution, Population Ecology, Genetic Relatedness and Habitat Associations of Eastern Spotted Skunks in South Carolina
SC-T-F15AF00728	2015-2016	Using citizen-science to guide state-wide management of Diamondback Terrapins
SC-T-F15AF00730	2015-2017	Building partnerships on state, federal and private lands to promote conservation of seabirds and shorebirds
SC-T-F15AF00731	2015-2018	Potential Mechanism of Thermal Stress Impairment for Striped Bass Populations
SC-T-F15AF00729	2015-2017	Assessing the status of the Black Rail (*Laterallus jamaicensis)* in South Carolina
SC-T-F15AF00207	2015-2017	Continuation of the Carolina Herp Atlas
SC-T-F16AF00707	2016-2018	Conservation of seabirds, shorebirds, wading birds, and marsh birds in South Carolina (I)

SC-T-F16AF00708	2016-2020	Conservation of South Carolina Coastal Plain Reptiles and Amphibians (I)
SC-T-F16AF00598	2016-2017	Northern Yellow Bat Roost Selection and Fidelity in South Carolina
SC-T-F16AF00713	2016-2021	Optimal nesting microhabitat for Diamondback Terrapins in SC
SC-T-F16AF01121	2016-2019	Documentation of horseshoe crab nesting beaches and egg densities
SC-T-F16AF00714	2016-2017	Investigating the impacts of harvesting on ribbed mussel communities
SC-T-F16AF00720	2016-2018	Abundance and community composition of intertidal macrobenthic invertebrates
SC-T-F17AF00122	2016-2017	Participation by SC in the SEARS Program
SC-T-F17AF01196	2017-2020	Coordination of the SWG Program and Implementation of the SC SWAP
SC-T-F17AF01249	2017-2019	Atlantic Coast Joint Venture - Catalyzing Black Rail Conservation along the Atlantic Coast
SC-T-F17AF01208	2017-2020	Identifying Management Opportunities to Benefit Black Rails Nesting in Coastal South Carolina
SC-T-F17AF01207	2017-2019	Range, life history, and environmental tolerances of the Waccamaw crayfish (*Procambarus braswelli*) and the hummock crayfish (*Procambarus lunzi*) of near-coastal environments
SC-T-F17AF01195	2017-2020	SC Bat Monitoring and Research Project
SC-T-F18AF00026	2017-2019	Survey of Historic Flatwoods Salamander Localities
SC-T-F18AF00961	2018-2020	Conservation of seabirds, shorebirds, wading birds, and marsh birds in South Carolina (II)
SC-T-F18AF00962	2018-2022	Investigating dispersal of the invasive red swamp crayfish (Procambarus clarkii) and its effects on the distribution and status of native crayfish populations
SC-T-F18AF00964	2018-2021	Concentrations of organic contaminants in Carolina and Scalloped Hammerheads: Implications for success and survival in nursery habitats
SC-T-F18AF00965	2018-2020	Addressing crucial American Eel life history questions: Baseline data on the age and sex composition of American Eels in South Carolina, with a comparison of different aging methodologies
SC-T-F18AF00972	2018-2022	NABat monitoring in South Carolina
SC-T-F18AF00973	2018-2022	Green Salamander Population Assessment and Connectivity Across a Gradient of Forest Disturbance
SC-T-F19AF00717	2020-2022	Environmental DNA Determination of the Distribution of the Patch-Nosed Salamander (*Urspelerpes brucei*) in South Carolina
SC-T-F19AF00718	2019-2021	Response of Bachman's sparrow (*Peucaea aestivalis*) to habitat management in a wiregrass-free ecosystem
SC-T-F19AF00719	2020-2022	Effects of forest management on early-successional avian species in Carolina [GWWA, RUGR]
SC-T-F19AF00720	2019-2021	Identification of environmental and biological factors limiting occurrence of the Sandhills Chub (*Semotilus lumbee*) in South Carolina
SC-T-F19AF00722	2019-2020	Upstate Bridge Use by Highest Priority Bat Species
SC-T-F19AF00723	2019-2023	Utilizing trace elements and stable isotope analysis to reconstruct distribution of Scalloped and Carolina Hammerheads
SC-T-F19AF00749	2019-2022	Determining the relative importance of coastal habitat types to horseshoe crab reproduction and migratory shorebird foraging in South Carolina
SC-T-F19AF00750	2019-2020	Ecology of Estuarine Sensitive Infauna Along a Stress Gradient
SC-T-F19AF00779	2019-2022	Integrating crayfish into aquatic assessments from the uplands to the coast
SC-T-F19AF00780	2019-2022	Development, Testing, and Field Validation of an eDNA Tool for Robust Redhorse
F20AF11202-00	2020-2023	Microplastic Exposure for Key Ecological Species in Coastal South Carolina
F20AF11231-00	2020-2022	Conservation of Seabirds, Shorebirds, Wading Birds, and Marsh Birds in South Carolina (III)
F20AF11283-00	2020-2023	Range and Roost Sites of Northern Long-eared Bats in South Carolina
F20AF11556-03	2020-2023	Coordination of the SWG and C-SWG Programs and Implementation of the SC SWAP
F21AF02397-00	2022-2023	Understanding Salt Marsh Loss Through Investigation of Periwinkle Fronts and Other Causes Across Multiple Spatial Scales
F21AF03242-01	2021-present	Conservation of South Carolina Coastal Plain Reptiles and Amphibians (II) Plus Blue Ridge Herps
F21AF03274-00	2021-2022	Determining the Importance of the South Carolina Coast to the Overwintering Survival and Reproductive Output of the Monarch Butterfly (*Danaus plexippus)*
F21AF03426-00	2021-2022	Developing Genetic Sequences for Benthic Prey Resources of Migratory Piping Plover and Red Knot
F21AF03593-03	2021-2024	Occupancy and Distribution of SWAP-listed Freshwater Mussel Species
F21AF03627-02	2021-present	Determining the Effects of Human Disturbance on the Ecology and Conservation Status of Populations of At-Risk Crayfish in the Genus *Distocambarus*
F21AF03715-00	2021-2023	Eastern Brook Trout Restoration in Pig Pen Branch and Lick Log Creek, Oconee County, South Carolina
F22AF03331-00	2022-present	Coastal Maternity Roost Sites of Five High Priority Bat Species

F22AF03386-00	2022-2024	Conservation of Seabirds, Shorebirds, Wading Birds, and Marsh Birds in South Carolina (IV)
F22AF03387-02	2022-2024	Taxonomic Revision of Procambarus Crayfishes in South Carolina
F22AF03590-00	2022-present	High Resolution Acoustic Telemetry Array in the Edisto and Savannah Rivers
F22AF03676-01	2023-present	Edisto River Flow Effects on Summertime Water Temperatures: Are Thermal Tolerances of SWAP Fishes Exceeded at Low Flows?
F22AF03703-01	2023-present	Seasonal Patterns of Horseshoe Crab Spawning and the Relative Importance of Horseshoe Crab Eggs Within the Diets of South Carolina Shorebirds
F22AF03704-02	2023-present	Horizontal Movements of Carolina Hammerheads (*Sphyrna gilberti*) in the Western North Atlantic Ocean
F22AF03776-00	2023	Pilot Project to Document Presence of Sea Turtles in South Carolina Estuarine Waters in an Effort to Reduce Impacts of Watercraft on Endangered and Threatened Sea Turtles
F23AF02951-01	2023-2025	Genetic Characterization of Monarch Butterflies in South Carolina
F23AF03075-00	2023-present	Assessing Occurrence and Habitat Associations of Six Priority Small Mammal Species in High Elevation Appalachian Forests of South Carolina
F23AF03100-01	2023-2025	Planning for the 2025 SWAP Revision and Program Coordination
F23AF03154-01	2023-present	Exploration of Subtidal Oyster Presence in Areas Historically Identified as Supporting Subtidal Populations
F23AF03206-01	2023-present	Using Unmanned Aerial Systems (UAS) Technology to Understand the Relationship of Microhabitat to Estuarine Fish Species
F23AF03212-01	2023-present	Innovative Fish Aging Methods Using Near-infrared Spectroscopy Techniques to Understand Changes in Population Demography: Calibration Model Development for Bonnethead Shark
F24AF02859-01	2024-present	Distribution and Roost sites of Gray Bats in Northwestern South Carolina
F24AF02999-00	2024-present	Conservation of Seabirds, Shorebirds, and Wading Birds in South Carolina (V)
F25AF00610-00	2025-present	Exploration of a New Emerging Threat: Microplastics in Water, Sediment, and SWAP-listed Species in Charleston Harbor
F25AF00262-00	2025	Closing the Loop on the Horseshoe Crab Life Cycle from Eggs to Adults: Surveying Horseshoe Crabs Across Life Stages in Coastal South Carolina
F25AF00609-00	2025-present	South Carolina Horseshoe Crab Genetic Health Reassessment

Regular SWG Project Summaries

Herpetological Research in South Carolina (Federal Grant #: T-2-2 *See T-57-R-1 for summary*)

Swainson's Warbler and Swallow-tailed Kite Movements, Productivity, Survival, and Habitat Use (Federal Grant #: T-4 *See T-13-R-2 for summary*)

Census and Monitoring of Waterbird Nesting in the South Carolina Coastal Plain (Federal Grant #: T-6 continued from grant R-3, Duration: 2004–2005) PI: Laurel Barnhill (formerly SCDNR now USFWS) *This grant is a continuation of South Carolina Grant R-3, which utilized WCRP funds. This grant picks up where Grant R-3 left off, with the exception that the Bald Eagle work initiated under R-3 continues under that grant and is excluded from this grant. To read a review of T-6, please see the online final report.*

Conservation of Waterbirds and Seabirds in South Carolina (Federal Grant #: T-7-R-2, Duration: 2006–2008) PI: Thomas Murphy (SCDNR, retired); Author: Christy Hand (SCDNR)

Grant T-7 funded the monitoring and management of waterbirds nesting on the South Carolina Coastal Plain from October 2006–September 2008. Bald Eagle surveys and ground visits were used to document chick production, estimate mortality rates, and assess population levels. Colonially nesting wading birds were surveyed. More extensive surveys were conducted at Wood Stork colonies to document nest numbers and to estimate productivity. A decline in numbers of colonially nesting wading birds that may be due to loss of habitat and drought

conditions was documented. Movements from natural wetlands to constructed wetlands and an increase in human-bird interactions was observed. Censuses were conducted for 6 species of seabirds, and signs were posted to protect sensitive nesting areas. Least Terns nesting on rooftops were surveyed. American Oystercatchers were surveyed and banded to yield data that will improve regional estimates of survival. Research projects conducted by 3 graduate students at Clemson University were supported and coordinated. Research topics include seabird/human disturbance, techniques to enhance Oystercatcher productivity, and identifying preferred winter foraging habitat for Oystercatchers.

SCDNR staff participated in professional meetings including the annual Wood Stork Working Group, American Oystercatcher Working Group, and gave presentations to educate the public about coastal birds. Technical assistance was provided for a variety of projects including negotiating management zones around eagle nests and enhancing the use of managed impoundments by wading birds and shorebirds.

Robust Redhorse Restoration and Conservation (Federal Grant #: T-9, Duration: 2005-2013)
PI: Ross Self (SCDNR); Author: Scott Lamprecht (SCDNR, retired)

The objective of this project was to establish self-sustaining populations of Robust Redhorse, (*Moxostoma robustum*), suckers in the Santee River Basin using Savannah River brood stock. The first step was to stock the Santee River Basin with cultured Savannah River strain Robust Redhorse (RRH). The Santee Basin was identified as a potential population establishment site because its size, location between two identified population, and evidence of historical RRH occurrence in the drainage. A primary consideration of this effort was to use progeny from 100 pairings to ensure that the new population would be genetically diverse. Brood stock collection was made from a numerically healthy and geographically nearby population of Savannah River RRH. Fish were collected during their natural spawning activities over a mid-channel gravel bar using stationary electro-fishing grids and a mobile electro-fishing boat. Eggs and milt were immediately collected from the actively spawning adults, and fertilization occurred individually between eggs from one female and milt from one male. Depending on the quantity, a female's eggs were divided between 1 and 3 males. Fertilized eggs were transported to the Bayless Hatchery for incubation and hatching. Grow-out was made in production ponds at the Dennis Wildlife Center. Spawning efforts occurred in every spring from 2004-2013.

Of the 45 females spawned over 10 years, 3 females have been used more than once. However, 2 of these incidences occurred in 2010 where production failed. The number of eggs collected from each female varied, and their contribution to subsequent stocks was not monitored. Through the 2009 spring spawning season, we have produced offspring from 98 individual matings. However, production over the last 3 years has been minimal. As a result, we continued spawning efforts through the spring of 2013 in order to reach an introduction goal of 100 genetically distinct matings. Spawning efforts produced 15,000 eggs which resulted in the stocking of 11,000 fry into grow-out ponds. All fish stocked to date have been tagged with either coded wire (CW) tags or pit tags (P).

We also surveyed and monitored the growth, survival, maturation, and spawning success as well as habitat use of stocked RRH in the Santee River Basin and monitored existing populations in

the Savannah and Pee Dee River systems. Monitoring efforts continued into 2013. Building on previous work, observations were collected incidental to anadromous fish monitoring below Wateree Dam, Columbia fish way monitoring on the Congaree River, directed collection effort in the Congaree and Wateree Rivers, and by telemetry studies described below. SCDNR collected 4 specimens in the lower Wateree River during December 2012 and subsequently equipped 2 with sonic transmitters. This collection was made by using transmittered fish to locate aggregations outside of the spawning season. Duke Power picked up 16 specimens during their 2013 spring anadromous fish survey of the Wateree Dam tailrace. The Columbia fishway monitoring was hampered by high flows and turbid water during the spring of 2013. However, when observations were made, RRH were observed moving upstream.

Because of the difficulty in collecting information on juvenile and RRH, a telemetry survey was initiated in 2009 in the Wateree River/Congaree portion of the system. At total of 14 fish have been actively monitored, and the following pattern has been observed during multiple years: all the study fish occupied the Wateree Tailrace during spawning season; all fish used the lower Congaree River after spawning season; 11 of the 14 fish traveled up the Congaree to at least the midway point; 9 of the 14 passed upstream of Rosewood landing; 2 were documented using the Broad River (below the Columbia Dam); 2 fish used the lower Saluda (one in successive years); and 3 fish were detected in the upper Santee River above Lake Marion. The repeated summertime use of the Congaree River is interesting because it is significantly cooler than the Wateree River and may indicate a temperature preference. It is interesting to note that while we observed fish exhibiting spawning behavior in the Wateree Dam tailrace, we observed significant numbers of fish ascending the Columbia Fishway. Long distance movement of these fish can occur relatively quickly; one fished moved downstream 124 km (77 mi.) in 2.6 days and there are numerous instances of fish moving more than 30 km/day (19 mi./day).

The project also gave us the opportunity to inform and educate the public about the relevance of our efforts to reestablish and conserve RRH in South Carolina. During the past year, staff members have included our RRH studies in all appropriate public outreach efforts. Staff often addressed the need for display specimens at the Charleston Aquarium. Staff attended the 2013 annual meeting of the Robust Redhorse Conservation Committee (RRCC) in Georgia, and a plan for brood stock collection, spawning, stocking and research efforts were reviewed. Conservation and recovery were coordinated among the agencies and organizations involved. Staff members were also actively involved in a larval fish toxicology study lead by an NC State researcher.

The development of baseline genetic data for the Savannah population was realized and a foundation for future evaluation of ongoing re-establishment within the Santee River System is being built. Subsequent to development of genetic markers, fin clips from all collected specimens were catalogued in order to determine stock contributions based on individual crossings and to detect evidence of natural recruitment.

Landscape Planning for Priority Wildlife Species on Agricultural Lands (*Combined Summaries* for Federal Grants #: T-10-P and T-46-1-T, Duration: 2005-2009 / 2009-2021) PI: Judy Barnes (SCDNR, retired); Author: Billy Dukes (SCDNR)

The approach utilized in this grant was to employ 3 technical guidance biologists to work with USDA staff to engage in landscape-level planning for priority wildlife species on private agricultural lands. The technical guidance biologists worked to incorporate habitat restoration measures for priority wildlife species into plans written through the Conservation Reserve Program, Environmental Quality Incentives Program, Conservation Security Program, Wetland Reserve Program, Wildlife Habitat Incentives Program, Grassland Reserve Program, and Forest Land Enhancement Program.

Over the course of the grant period, 248 conservation plans potentially affecting 170,359 acres in 23 South Carolina counties were written. Technical guidance biologists also delivered 47 programs for a combined audience of 2,511 people. Nine news releases promoting habitat conservation for priority wildlife species were written and submitted, 6 technical brochures on various aspects of wildlife conservation were developed, and 22 fact sheets on threatened and endangered species were completed. In addition, one biologist provided technical guidance and assistance in the development of a statewide Gopher Tortoise Conservation Plan for South Carolina.

Restoration of Longleaf Pine Forests on State-Owned Lands (Federal Grant #: T-11-1-R, Duration: 2006-2008) PI and Author: Tim Ivey (SCDNR, deceased)

The objective of T-11-1-R was to restore Longleaf Pine forests and associated herbaceous species on a minimum of 1,000 acres of state-owned lands. Accomplishments included herbicide treatment of 45 acres of established longleaf stands to reduce competing hardwood vegetation on three SCDNR-owned heritage preserves. Twenty-five acres of new longleaf plantings (8,000 seedlings) were established on Little Pee Dee River Heritage Preserve and 8500 containerized Longleaf Pine seedlings were interplanted within 42 acres of sparse existing stands of Longleaf Pine on Longleaf Pine Heritage Preserve. Re-establishment and/or improvement of 14 miles of firebreaks and prescribe burning of 1,213 acres of longleaf stands occurred on Woods Bay and Longleaf Pine Heritage Preserves. Aerial herbicide site preparation and planting of 14,000 Longleaf Pine seedlings was conducted to convert 25 acres to Longleaf Pine on Congaree Bluff Heritage Preserve. Site preparation and planting of 25 acres of Longleaf Pine was accomplished at Janet Harrison High Pond Heritage Preserve. Herbicide release of competing vegetation with 40 acres of longleaf was conducted at Longleaf Pine and Lynchburg Savannah Heritage Preserves. Understory brush control was utilized in 140 acres of longleaf stands at Webb Wildlife WMA. The construction of 18 miles of new firelanes at Lewis Ocean Bay Heritage Preserve was also accomplished as well as 162 acres of site prep and Longleaf Pine establishment at Woodbury WMA. McBee WMA underwent 8 acres of longleaf planting while 25 acres of longleaf plantings were done at Hamilton Ridge WMA. Site prep and planting of 831 acres of Longleaf Pine at Manchester State Forest was also accomplished. Mechanical understory control of competing vegetation in 32 acres of Longleaf Pine stands at Lewis Ocean Bay Heritage Preserve and herbicide timber stand improvement of 40 acres at McBee WMA was completed. The total longleaf habitat improvements made equaled 1,510 acres with new Longleaf Pine stands established on 1,135 acres.

Conservation of Migratory Landbirds in South Carolina (Federal Grant #: T-13-R-2, Duration: 2006-2009) PI: Laurel Barnhill (formerly SCDNR now USFWS); Author: Janet Thibault (SCDNR)

Grant T-13-2-R funded prescribed burns at Bonneau Ferry Wildlife Management Area during the growing season of 2008. It also funded research on the habitat requirements and demographics of Swainson's Warblers (*Limnothlypis swainsonii*) and Painted Buntings (*Passerina ciris*) and the development of monitoring protocols for bird species with the greatest conservation need to better manage for these species in coastal South Carolina.

Productivity, survival, habitat use, diet, and movements of Swainson's Warblers were studied at the Woodbury Tract Wildlife Management Area during 2006-2009 and built upon previous research conducted since 1997. Swainson's Warblers were color banded and several were radio tagged and followed with telemetry equipment throughout the nesting season. The site fidelity to Woodbury Tract was high with most birds returning to the same territories year after year. Females appeared to breed after their initial hatch year, while first year males did not. Home ranges often overlapped with other Swainson's Warblers and territory sizes varied. Swainson's Warblers forage in the upper layer of decaying leaves, and hydrology and flooding of the site affects the timing of breeding and foraging opportunities for this species.

The ecology of painted buntings and other early-successional passerines was studied at the Webb Center Wildlife Management Area and The Nemours Wildlife Foundation during the breeding seasons of 2006-2008. The study assessed the suitability of wildlife food plots in these two differently managed landscapes and how the management regimes affected the occurrence of Painted Buntings and other bunting species. Results indicated that buntings were not likely to be present at either of the managed sites due to the frequency of management at these areas. Buntings likely prefer larger areas of old/fallow fields that are interspersed among mid- to late-successional forests.

Development of Best Management Practices for Sustaining Wildlife in the Maritime Zone of South Carolina (Federal Grant #: T-14-T, Duration: 2005-2009) PI and Author: David Whitaker (SCDNR, retired)

The goal of this project was to develop Best Management Practices (BMPs) for anyone building a home or development within an existing maritime forest. These BMPs would have the goal of minimizing ecological impacts to native fauna and flora. Staff conducted an intensive literature review, contacted numerous managers of “low impact” coastal developments to review their development guidelines and regulations, and interviewed various experts. Staff asked for advice from upland mammal biologists, botanists, ornithologists, herpetologists, foresters, and others. A 76-page booklet entitled, “Best Management Practices for Wildlife in Maritime Forest Developments” was published in November 2009. This document reviewed the animal species of the Maritime Forest with emphasis on habitat requirements for each, and special emphasis was given to SWAP priority species. This was followed by detailed descriptions of BMPs at the community, neighborhood, and individual home levels. Immediately after printing, 225 copies were distributed to planners and other officials of coastal communities, Office of Coastal Resources, Coastal Conservation Association, SC Forestry Commission, various SCDNR staff,

SC Sea Grant office, SC Wildlife Federation, Coastal Conservation Association, and a number of private citizens. Additionally, the complete document was made available on the SCDNR website with 1,429 requests for the document being made in the first month after publication.

South Carolina Reptile and Amphibian Conservation Planning (Federal Grant #: T-15-P, Duration: 2005-2007) PI: Steve Bennett (SCDNR, retired); Author: Will Dillman (SCDNR)

This multi-task project included 4 separate jobs for 4 separate priority species: Gopher Tortoise Eastern Diamondback Rattlesnake, Timber Rattlesnake, and seepage slope salamander species. Each job will be addressed in its own section.

Gopher Tortoise Management – The objective of this job was to develop a plan to recover and enhance the Gopher Tortoise population at Aiken Gopher Tortoise Heritage Preserve (AGTHP) in Aiken County to include the re-stocking of tortoises from the surrounding habitat and from other sites in South Carolina. Three 1 ha (2.5 ac.) pens were established on site at the Aiken Gopher Tortoise Heritage Preserve to provide an area to house relocated tortoises. These pens housed groups of tortoises for approximately one year and then were removed to allow the tortoises to become "established" in their new environment. Waif Gopher Tortoises were received from a variety of different places within the Southeastern US, and several federal and state agencies and placed into the pens. Pen 1 housed waif tortoises from the Southeast and a group of hatchling tortoises from Hilda, SC that were contained within the pen under a separate hatchling enclosure. Pen 2 contained tortoises that were trapped on the AGTHP and considered to be the "resident" group. Efforts were made to trap and relocate all known Gopher Tortoises occurring on the site. In addition, aprons of AGTHP tortoises were excavated during the summer of 2007 by Tracey Tuberville (UGA-SREL) and Kurt Buhlmann (SCDNR). One Gopher Tortoise nest containing two eggs was found. One of the eggs hatched, the other was infertile. That hatchling is small and is currently being maintained at SREL with the intention of adding it to the Pen 2 population in the spring of 2008. Pen 3 was used to house a group of Gopher Tortoises from a private property owner near the town of Grays, SC. In addition, two separate introductions of hatchling tortoises were made to Pen 3 during the Project period. Six hatchlings from laboratory-hatched eggs from the Tillman Sand Ridge Heritage Preserve were released into Pen 3 with starter burrows during summer 2007. An additional 6 hatchlings (also form Tillman Sand Ridge HP) were released into Pen 3 but covered under an 8 ft. x 8 ft. wire mesh cage in the autumn of 2007. The intention of the cage was to prevent predation by Coyotes, crows, or Raccoons. To date, the hatchlings seem to be surviving under the cages.

All tortoises have been measured, marked, and had blood samples taken (by Tracey Tuberville) for further genetic analyses. At the conclusion of this project, 56 tortoises were contained in the pens at the AGTHP.

Diamondback Rattlesnake Management – The first objective of this job was to determine the feasibility of managing rattlesnake populations by translocating Eastern Diamondback Rattlesnakes to sites with appropriate habitat within the historic range of the species, and to develop a model for Eastern Diamondback Rattlesnake demography to include population size, survivorship, mortality, growth patterns, age classes, and sex ratio. The second objective was to conduct research and monitoring at the Webb Wildlife Center (continuation of ongoing

monitoring) and at least 3 other public properties in the SC Coastal Plain that support Longleaf Pine habitat. Another task was to determine the potential distribution of Longleaf Pine habitat on public properties in the SC Coastal Plain using a qualitative vector GIS model.

The study was initiated in 2006, encompassing 4 study areas in the South Carolina Coastal Plain: Hoover Plantation (Jasper County), Nemours Wildlife Foundation (Beaufort County), Cheehaw Combahee Plantation (Colleton County), and Donnelly Wildlife Management Area (DWMA; Colleton County). In 2007, we added another study site, Okeetee Plantation (Jasper County), and discontinued efforts to monitor the EDB at DWMA. The study areas comprised varying degrees of upland pine savanna and thus harbored Eastern Diamondback Rattlesnakes. In March 2007, we translocated all of the study animals that were telemetered in 2006 to the Webb Wildlife Center. We captured 4 new rattlesnakes (Nemours, N=1; Cheehaw Combahee Plantation, N=3), and they were translocated in March 2008. All telemetered rattlesnakes were located weekly. We will continue to quantify movement patterns using data collected in 2007 following November ingress. We have begun our analysis comparing pre- and post-translocation movements using the individuals that were captured in 2006.

The long-term monitoring and research on the Eastern Diamondback Rattlesnake population at Webb Wildlife Center continued, and additional surveys were performed at Donnelly Wildlife Management Area, Cheehaw Combahee Plantation, Hoover Plantation, and Nemours Wildlife Foundation. No Diamondbacks were found at Donnelly Wildlife Management Area; however, diamondbacks were found at the other properties surveyed.

Timber Rattlesnake Surveys – The objectives of this job were to (1) determine the distribution of the montane phase and the Coastal Plain phase of this species in the region and to (2) develop a management strategy for the Timber Rattlesnake on public lands in South Carolina. (3) The population size and demography at selected sites had to be determined and included gathering information on population structure, sex ratios, mortality, reproductive success, survivorship, and mortality. (4) The home range size had to be determined as well as habitat use and seasonal activity patterns for both "forms" of this species in this region using radio telemetry.

Between September 2006 and fall 2007, 15 Timber Rattlesnakes were implanted with radio transmitters and tracked. During the course of the study, hibernation, courtship, mating, and birthing were observed. Movements of male snakes appeared to be greater than those of the females, and both sexes showed an affinity for wooded areas. Both the Montane and Coastal Plain phase of the timber rattlesnake were captured, implanted, and tracked. Currently, there appears to be no elevation, habitat, or sex differences in either phase of the upstate timber rattlesnake. Data collected during this study has contributed to the understanding of the biology and habitat requirements of this species in South Carolina.

Seepage Slope Salamander Investigations – The objective of this project was to develop a predictive model for Coastal Plain seepage slope habitat as a means of identifying potential habitat for the Southern Dusky Salamander and Chamberlain's Dwarf Salamander, and to survey potential habitat for presence/absence of the target species. during the study, we collected specimens of the Southern Dusky Salamander, when present, for genetic analysis to determine if there are “cryptic” species of this complex found in South Carolina.

Eight seep sites were monitored with water sampling wells and cover-board transects. Water quality and hydrology sampling was conducted at all seeps quarterly during the reporting period, and cover-boards were sampled three times. We initiated a molecular phylogeny study involving the two focal species of this project *Desmognathus auriculatus* and *Eurycea chamberlainii*. The goal of this study was to resolve the phylogenetic—and eventually the taxonomic status—of these 2 species and their "closest" relatives in South Carolina. Additionally, staff surveyed 26 sites for plethodontid salamanders. Some of these sites were historic locations for *Desmognathus* and others were new sites selected due to their hydrologic and topographic characteristics. Salamander species in the family Plethodontidae were collected at 18 of these sites—*Eurycea chamberlainii* at 2 sites and *Desmognathus auriculatus* at 9 sites. One additional site in the Piedmont was sampled and a *Desmognathus* collected there.

Preliminary results from the molecular phylogeny study indicate that the "focal" species *Desmognathus auriculatus*, Southern Dusky Salamander does not occur in South Carolina. To date, this analysis has identified 4 separate lineages of *Desmognathus* in the Coastal Plain and Piedmont of South Carolina, none of which are closely aligned with *D. auriculatus*.

Upland Habitat Improvements on Lewis Ocean Bay Heritage Preserve (Federal Grant #: T-16-1-R, Duration: 2007-2008) PI and Author: Tim Ivey (SCDNR, deceased)

The objective of the habitat improvement project at Lewis Ocean Bay Heritage Preserve was to restore grassland, pine savannah, and pine woodland habitat sites within the 3-year funding period. Habitat restoration and management included clearing competing vegetation along 13 miles of roads, ditches, and rights-of-ways; 210 acres of competing understory removed from longleaf stands using herbicides and mechanical removal; 20 acres of Longleaf Pine stands underplanted with longleaf seedlings; 533 acres converted from slash pine to Longleaf Pine; and 18 miles of new firebreaks established. In addition, 76 miles of firebreaks were maintained and 2,338 acres prescribe burned.

Protection and Management of Seabird Colonies (Monitoring/Breeding Parameters) (Federal Grant #: T-17-R, Duration: 2006-2010) PI: Laurel Barnhill (formerly SCDNR now USFWS); Author: Janet Thibault (SCDNR)

Seabirds such as Brown Pelicans, Sandwich Terns, Royal Terns, and Black Skimmers nest in large colonies on isolated islands and are susceptible to human disturbance. Over time, effects of disturbance may manifest as reduced reproductive success and increased energy expenditure on the part of adults and young. In 2006, the SCDNR established 3 barrier island seabird sanctuaries in Charleston County: Crab Bank, Bird Key, and Deveaux Bank. New regulations were designed to limit human disturbance and prohibited public access at Crab Bank and Bird Key during the nesting season and limited access to below the high tide line at Deveaux Bank. All 3 of these islands provide nesting habitat and stopover locations for seabirds and shorebirds which require islands that have suitable habitat for nesting and rearing young. The goal of this project was to monitor seabird colonies on these SCDNR protected islands and collect baseline measures of breeding parameters, determine habitat use of seabirds and shorebirds on the islands, and to

better evaluate the health and condition of seabird populations in South Carolina in relation to the new regulations and for future comparisons. Research was conducted from 2006 to 2008.

Overall, the effects of the new seabird conservation regulations resulted in an increase in size of the Black Skimmer colony on Crab Bank, increased productivity of Black Skimmers at Deveaux Bank, and a re-establishment of nesting of Black Skimmers on Bird Key. Colony size and reproductive success of Brown Pelican and tern species at other islands was variable among locations and years. The results of the intertidal surveys indicated that the intertidal area is an essential component of seabird breeding habitat and is used for loafing, feeding, courtship, and chick-rearing by seabirds and shorebirds. The majority of birds were located along the water and on the lower portion of the beach during surveys. Brown Pelicans, Laughing Gulls, Black Skimmers, and Royal, Sandwich, and Gull-billed Terns were most frequently engaged in loafing and maintenance behavior in the intertidal zone of the islands, while shorebirds were most often observed foraging there. The health parameter analyses revealed that age was a significant factor affecting many health parameters of Brown Pelican nestlings. Packed cell volume increased with age when compared to wild adults. Levels of proteins and cholesterol were higher in the older age category, which may be necessary to support physiological development. Collection of baseline data such as that collected in this study provides a means to monitor the health of nesting populations and provides baseline data for comparative and long-term studies. These data are particularly valuable after catastrophic disease outbreaks or environmental contamination events.

Habitat Enhancement on North and South Williman Islands, Beaufort County, SC (Federal Grant #: T-19-R, Duration: 2006-2010) PI and Author: John “Billy” McCord (SCDNR, retired)

This was a large, non-native invasive species eradication project that occurred on North Williman Island and South Williman Island which are located in north Beaufort County, South Carolina. Both islands exceed 1,000 acres in total size, and both are composed of a mosaic of tidal estuarine marshland and interspersed hammocks (small upland islands also called hummocks). These islands are State-owned and are under the management authority of SCDNR.

North Williman Island includes 9 hammocks, ranging from 1.5 to 436.4 acres, while South Williman Island contains 12 hammocks, 0.4 to 688.4 acres in size. Biological inventories of plants and animals were performed by SCDNR on all of the hammocks of North Williman Island and South Williman Island during fall 2003 through winter 2005-2006. These initial SCDNR surveys revealed significant habitat degradation that was presumed to be caused primarily by the impacts of the invasive Chinese Tallowtree (*Triadica sebifera*) and, specifically on several hammocks of North Williman Island, by feral goats (*Capra hircus*).

Habitat enhancement activities for this project were performed primarily on the largest hammocks within both North Williman Island and South Williman Island, hereafter referred to as “Goat Island” (436.4 acres) and “Big South Williman Island” (668.4 acres), respectively. Chinese Tallowtree was particularly abundant and problematic in association with isolated freshwater depression wetlands. Such freshwater wetlands are most abundant on the largest hammocks within both North Williman Island and South Williman Island, and particularly on “Goat Island” and “Big South Williman Island”. Chinese Tallowtree out-competes many native

plants and, as observed in isolated wetlands on both North Williman Island and South Williman Island, may ultimately produce nearly mono-species stands. Fallen leaves of Chinese Tallowtree can alter water chemistry and water quality and may negatively impact populations of some amphibians. Additionally, dense populations of Chinese Tallowtree may limit surface water availability and alter hydrology in isolated wetlands due to high water demand and heightened evapotranspiration during late spring through early fall.

Feral goats were only present on several nearly interconnected hammocks within North Williman Island, and these grazing mammals were typically only observed on "Goat Island". Evidence of over-browsing by feral goats was obvious and widespread, particularly on "Goat Island". Native plant diversity and populations of individual plant species were obviously suppressed relative to the observed status of such made during SCDNR surveys of nearby hammocks of comparable size and habitat diversity and where feral goats were not present.

Habitat restoration and enhancement efforts on North Williman Island were primarily based upon attempts to remedy and/or reduce perceived negative ecological impacts from both feral goats and Chinese Tallowtree. The successful removal of the population of approximately 100 feral goats from "Goat Island" and all of North Williman Island was completed in early 2008. After goats were successfully removed, 423 seedlings of Sweetgrass (*Muhlenbergia sericea*) were planted within 12 colonies on "Goat Island" at scattered sites in the upland transition zone just inland of tidewater influence. Though considered uncommon, this native grass was found to be rather widespread on hammocks within North Williman Island and South Williman Island that were not impacted by feral goats. Sweetgrass and other native grasses provide valuable cover and seeds for wildlife. Only a few damaged specimens of this species were observed on "Goat Island" prior to the successful removal of feral goats. The overall survival rate for planted sweetgrass was nearly 75%, and thriving colonies remained at most planting sites at the completion of this project.

Fourteen trips were made to North Williman Island for herbicide injection of Chinese Tallowtrees from 5 November 2007 through 20 December 2007. Approximately 4,750 such plants were injected with herbicides (50% Habitat® or 50% Clearcast™) over 5 North Williman Island hammocks. The remaining 4 North Williman Island hammocks do not have suitable habitat for Chinese Tallowtree. The total acreage canvassed for Chinese Tallowtree herbicide treatment was ~526.5 acres, requiring 272.5 man/woman-hours. A general evaluation of herbicide injection results was made from spring 2008 through summer 2010 and indicated the successful kill of ~95% of the total Chinese Tallowtree (tree-stage plants) population for the entire North Williman Island hammock group. Isolated, low-salinity wetlands were of highest priority in the attempted eradication of Chinese Tallowtree. The kill rate for tree-stage Chinese Tallowtrees associated with 17 such wetlands likely approached 98%, with nearly 2,500 mature trees killed. Observations through the summer of 2010 revealed a gradual positive response of native plant communities throughout North Williman Island hammocks on which Chinese Tallowtree was eradicated and particularly on hammocks on which feral goats were removed in addition to Chinese Tallowtree eradication.

Primarily due to funding limitations, habitat enhancement on South Williman Island was limited to the placement of Wood Duck (*Aix sponsa*) nesting boxes (one box each) in 7 isolated wetlands

within “Big South Williman Island”. Two Wood Duck nesting boxes were placed in an isolated freshwater wetland on “Goat Island”. Wood Duck had been recorded in winter on both islands during initial SCDNR surveys, but no evidence of nesting was observed prior to these habitat enhancement efforts. All nesting boxes were erected in late winter 2008, and all boxes were inspected for signs of Wood Duck nesting activity during each spring, 2008-2010. One, 2 and 6 boxes were used by nesting wood duck in 2008, 2009, and 2010, respectively. The observed increase in nest box utilization over the 3 years of observations suggests a likely increase in the local Wood Duck population in the vicinity of the Williman Islands, potentially in response to the provision of nesting cavities.

In addition to the aforementioned habitat enhancement activities, complimentary habitat enhancement and restoration activities were achieved on “Goat Island” through a Cooperative Agreement between the United States Department of the Interior, Fish and Wildlife Service and SCDNR from 1 August 2008 through 30 June 2010. The Cooperative Agreement included: (1) the follow-up eradication of Chinese Tallowtree (mostly seedlings); (2) the removal of dead tree-stage Chinese Tallowtree snags (trees killed by herbicide injection in late 2007 and early 2008) from 3 isolated wetlands which previously had particularly dense stands of this invasive plant; and (3) the damming of old historic drainage ditches associated with 5 isolated wetlands. Positive responses of native plants, plant communities and wildlife observed on “Goat Island” through the completion of this project should be attributed to habitat enhancement activities achieved through both this project and the Cooperative Agreement.

“Goat Island” was more severely negatively impacted by the combined impacts of feral goats and Chinese Tallowtree than was any other hammock within either North Williman Island or South Williman Island. Both habitat restoration, as observed through positive responses of native plants and plant communities, and positive responses of wildlife were most obvious on this North Williman Island hammock. Habitat enhancement and restoration activities yielded a nearly immediate positive response in recovery of native plant communities, particularly in and near isolated wetlands and on the periphery or outer upland fringe of hammocks that had been drastically impacted by browsing goats. Wetland plant diversity increased dramatically, as demonstrated by a threefold increase in recorded plant species diversity in one isolated wetland as compared to the recorded diversity prior to habitat enhancement activities. Buttonbush (*Cephalanthus occidentalis*), which is a valuable wetland wildlife plant, responded dramatically to the removal of over-shading Chinese Tallowtrees and to the removal of feral goats. Prior to habitat enhancement activities, buttonbush was fairly widespread and abundant in wetlands on “Goat Island”, but practically all specimens were in poor condition and few, if any, specimens produced blooms or seeds. Following habitat enhancement activities, buttonbush specimens throughout wetlands on “Goat Island” displayed dramatic growth of new stems and foliage and produced abundant flowers and seeds by 2009 and 2010. Plants typical of the upland-tidal marsh ecotone recovered from severe browsing with sprouting of new growth and by recolonization from seedlings. Sweetgrass plantings in peripheral upland areas of “Goat Island” were very successful and supplemented natural colonies of native grasses, including several naturally occurring sweetgrass colonies which slowly recovered and became established after goat removal. The recovery of this forest edge habitat should provide additional breeding and foraging habitat for Painted Bunting (*Passerina ciris*), a species of highest conservation priority in South Carolina and throughout the region. The recovery of forested plant communities and

habitats was more subtle since much of "Goat Island" and other North Williman Island hammocks are covered in closed canopy forest. Subcanopy shrubs, saplings, and herbs slowly responded with resprouting from previously heavily browsed trunks and stems and from rootstock. Also, substantial and diverse germination from the seedbank was observed. Prior to removal of feral goats, seedlings—including those of Chinese Tallowtree—were quickly consumed and were rarely observed. Several decades will likely be required for subcanopy plant communities to recover to a stage similar to such communities on nearby hammocks that have not been impacted by feral goats. With further recovery of shrub thickets and habitat complexity anticipated for "Goat Island" over the next several decades, additional recruitment of breeding birds will likely occur as gradually recovering habitats become suitable as nesting and brood-rearing habitat.

Amphibians and dragonflies were quickly recruited to depression wetlands that displayed enhanced surface water duration following removal of Chinese Tallowtree and damming of drainage ditches. Increased surface water retention in such isolated wetlands on "Goat Island" will likely sponsor an increased distribution of "Lunz's Crayfish"—or Hammock Crayfish—(*Procambarus lunzi*), a species of conservation priority in South Carolina, as well as other aquatic animals as well. Increased surface water retention may also attract American Alligator (*Alligator mississippiensis*) to additional wetlands on "Goat Island", which could result in the creation of dens and pools that may further enhance wetlands for potential colonization by additional aquatic species.

A rookery used by 4 species of wadingbirds was found in the largest wetland on "Goat Island" during SCDNR surveys in spring 2006. The removal of hundreds of large Chinese Tallowtrees from the perimeter of this wetland may have improved the quality of this wetland for wadingbird nesting and foraging habitat. Both White Ibis (*Eudocimus albus*) and the endangered Wood Stork *(Myctera americana*) were observed in higher numbers in association with this wetland after the removal of Chinese Tallowtrees, indicating that access to shallow water foraging sites was improved. Wading bird nests were not observed in Chinese Tallowtrees in spring 2006 or in spring 2007, and all wading bird nests were in either buttonbush or Coastal Plain willow (*Salix caroliniana*). Both of these native wetland plants responded very positively with enhanced growth following the eradication of competing Chinese Tallowtrees. By the spring of 2010, 5 species of wadingbirds, all of which are considered priority conservation species in South Carolina, were recorded within the rookery in this wetland. Also, 2 Great Blue Heron (*Ardea herodias*) nests were constructed in large pines bordering a small, open, isolated wetland on "Goat Island" in spring 2010. No wading bird nesting activity had been observed in association with this wetland prior to the eradication of many large Chinese Tallowtrees that had dominated the perimeter of this and other wetlands.

Habitat restoration and enhancement efforts on North Williman Island—particularly on "Goat Island"—and on "Big South Williman Island" yielded varied positive ecological impacts. The gradual recovery of habitats and plant communities should continue well into the future throughout North Williman Island hammocks on which habitat restoration and enhancement activities were conducted under this and the complementary Cooperative Agreement. Particularly for "Goat Island", where the most intensive habitat enhancement efforts were made and where feral goats had drastically impacted nearly all habitats by over-browsing, native plant

communities and associated wildlife should continue to show positive responses well into the future. However, since seeds of Chinese Tallowtree are very resilient within the seed-bank and can also be transported by birds and by water, future herbicide control of this aggressively invasive plant on hammocks of North Williman Island may be necessary to prevent recolonization by Chinese Tallowtree. Because of the positive results of efforts on hammocks of North Williman Island, serious consideration should be given to the expansion of Chinese Tallowtree eradication throughout the hammocks of South Williman Island, where many isolated freshwater wetlands remained heavily colonized by Chinese Tallowtree at the end of this project in 2010.

Status and Management Plan Development for Three Rare Burrowing Crayfish, *Distocambarus youngineri*, *D. hunteri*, and *Cambarus reflexus* (Federal Grant #: T-20, Duration: 2006-2007) PI: Jennifer Price (formerly SCDNR); Author: Jim Bulak (SCDNR, retired)

The purpose of this study was to create habitat models for 3 species of crayfish of conservation concern in South Carolina - *Distocambarus youngineri, D. hunteri, and Cambarus reflexus.* For the two species of *Distocambarus,* soils data were used to predict occurrence sites. The developed habitat model was a significant predictor of *D. youngineri* occurrence. This species was found in Piedmont prairie habitat. Future management efforts should focus on acquiring property with prairie or savanna-like vegetation structure in the Piedmont. Perhaps due to a severe drought during the collection period, *D. hunteri* was not collected during the study. Future efforts should use genetic techniques to verify collections of *D. hunteri;* its status of "critically imperiled" is appropriate.

Cambarus reflexus habitat was modeled at the Webb Wildlife Center, Palachucola Wildlife Management Area (WMA), and Hamilton Ridge WMA. Model selection indicated that the presence of wiregrass (*Aristida* sp.) was the most important habitat component, indicating *C. reflexus* was associated with high quality, fire-maintained, pine savanna habitats in the Coastal Plain. The species appears to be limited to the Coastal Plain and sensitive to soil surface disturbances. Management should focus on maintaining remnant pine savanna stands with prescribed burns to help maintain this species.

Controlling Access to Known and Potential Bat Roosts (Federal Grant #: T-23-R-1 F06AF00025, Duration: 2006-2011) PI and Author: Mary Bunch (SCDNR, retired)

Human disturbance is a very significant threat to bat colonies. Disturbance can be in the form of recreational caving, mining, or exclusions or disruptions to natural or man-made roosts. This project sought to protect some important bat roosts from human disturbance and to find new bat colonies. When awarded funding in 2006, White-nose Syndrome (WNS), a disease of hibernating bats, had not yet been discovered.

We assessed known roosts for suitability to bat-friendly gating or other measures to reduce disturbance. Sites with priority species from South Carolina's Comprehensive Wildlife Conservation Strategy (CWCS), the Rafinesque's Big-eared Bat (*Corynorhinus rafinesquii*), Southeastern Myotis (*Myotis austroriparius*), and Small-footed Myotis (*Myotis leibii*) were

given highest priority, but other bat species would also benefit from the work. We partnered with the US Forest Service and The Nature Conservancy to erect 6 bat-friendly gates at 5 locations and modified an existing barricade to allow bat passage at another site. We also sought to place a bat-friendly cupola on an open shaft to a tunnel but lacked sufficient funds for such a large project. We planned to erect a fence (site was not suited to gating) around the state's largest southeastern bat colony, but state parks declined the fence because they didn't want to maintain a fence. We mapped 338 potential mine sites and 17 old wells. All of the wells and 54 of the mine sites were evaluated. None of the wells were good bat habitat. Many of the old mine sites had no underground structure but we did locate 8 mine adits with Tri-colored Bats (*Perimyotis subflavus*). Of those, 5 would be suitable for gating.

Concrete bat roosts were built at 4 locations to serve as alternate roosts for Rafinesque's Big-eared Bats where known roosts were imperiled or limited. Other bats will also use the structures. Currently, all of those new roosts are in use by bats. After dramatic WNS related mortality was noted in other colonial hibernating bats typical to our mountains, we provided bat boxes to 3 state parks with known vulnerable colonies (threatened by exclusion), with great success at one of the parks.

Fish Passage on the Broad River: An Assessment of the Benefits to Freshwater Mussels (Federal Grant #: T-24, Duration: 2006-2008) PI: Jennifer Price (formerly SCDNR); Author: Jim Bulak (SCDNR, retired)

The objective of this work was to determine the effects of a newly constructed fish passage facility on the Broad River in Columbia, SC to freshwater mussel populations. Surveys were conducted on the Broad River, upstream of the dam, and on the Broad and Congaree Rivers, downstream of the dam. Nine species of mussels were downstream of the dam and 4 species were observed in upstream areas to Parr Reservoir. The Broad River upstream of Parr Reservoir contained sparse populations of mussels, possibly due to habitat degradation associated with sedimentation. Efforts were made to collect gravid females and determine the seasonality of reproduction of the various mussel species. Peak reproduction and release of glochidia generally occurred in April through June, though this general trend exhibited variability among the various species. Fish host evaluation was conducted for 6 species of mussels - *Ligumia nasuta, Elliptio roanokensis, Lampsilis cariosa, Lampsilis radiata,* and *Elliptio congarea.* Results suggest that the fish lift will benefit mussel populations upstream of the dam (to Parr Reservoir) as increased passage of glochidia-carrying fishes from the more species rich areas downstream of the dam should increase colonization potential. Continued monitoring is recommended.

South Carolina Stream Conservation Planning Project [SC Stream Assessment] (Federal Grant #: T-25-R-1 F06AF00027 *[formerly T-8]*, Duration: 2006-2013) PI and Author: Mark Scott (SCDNR); Map created by Kevin Kubach (SCDNR)

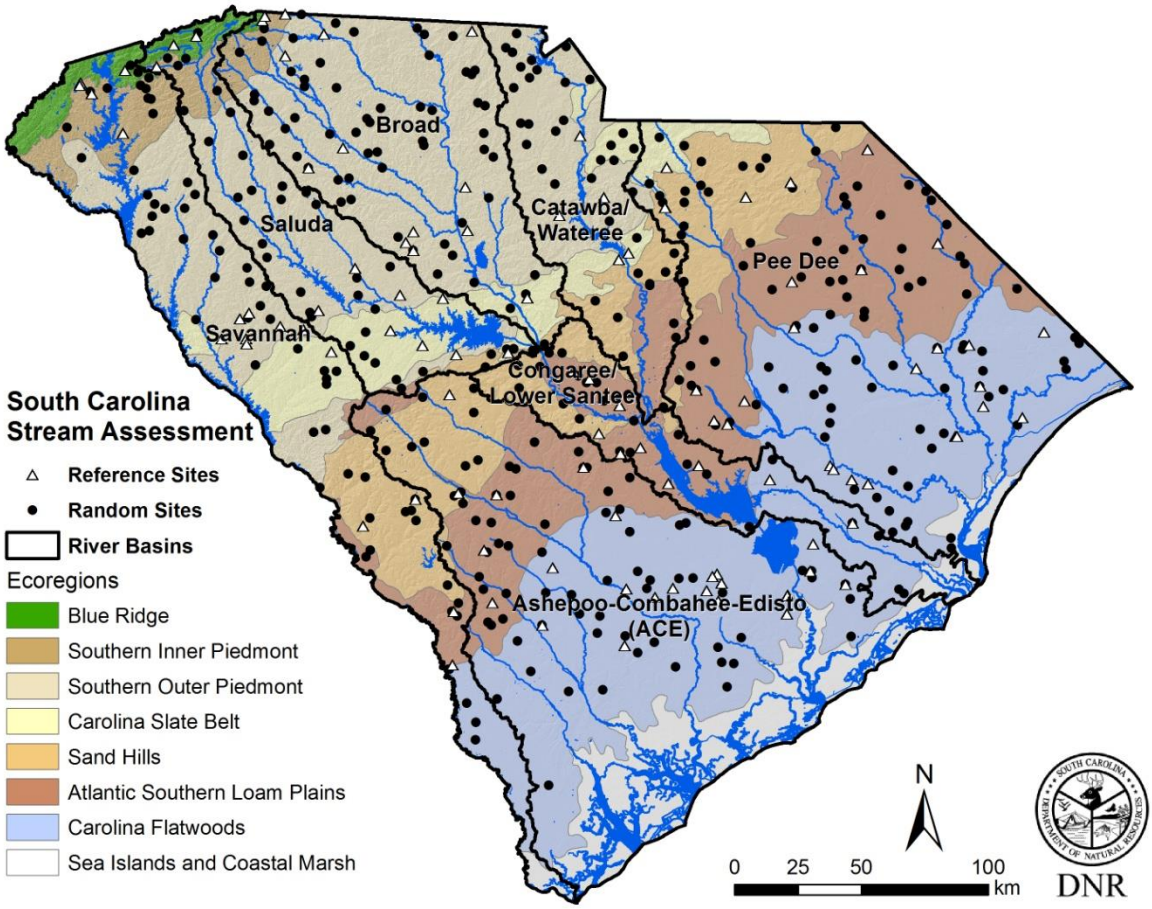
The objective of this project was to conduct an assessment of wadeable streams to gather appropriate data that will allow SCDNR to design effective and efficient management strategies to protect, conserve, and restore the aquatic resources of the State. Freshwater species worldwide face accelerated extinction rates relative to most other wildlife taxa. The Southeastern US, in particular, has been suffering long-term declines in native species of fish and aquatic

invertebrates. SC SWAP species of concern number well over 100 fish, reptiles, amphibians, mussels, crayfish, and snails that are directly dependent on aquatic systems for most or all of their life-stages. Common threats appear in their species accounts, generally associated with pollution from point- and non-point sources. Reversing the decline of native aquatic species requires an understanding of factors that are critical for maintenance of suitable habitat capable of supporting sensitive taxa. It follows that we must also understand the threats that degrade the quality of aquatic habitats to the point where they no longer support vulnerable species. The South Carolina Stream Assessment was designed to provide information to fill these gaps.

Watersheds of appropriate size (4 km^2 to 150 km^2) were sampling units stratified by unique combinations of ecoregion and major river basin in the state, called "ecobasins". Two methods of watershed selection were employed. The first method established long-term annual monitoring of least-impacted, or reference, watersheds, identified by biologists familiar with the region. This method is intended to provide expected resource condition as well as range due to temporal variability. The second method employed random selection of watersheds within ecobasin strata to allow statistically defensible estimates of statewide resource parameters from the sample data. Data collection was identical in both sampling designs, occurring at two spatial scales:

- *Watershed* – Point-sources as measured by NPDES permits; non-point sources as measured by appropriate land use/land cover classes in entire basin and within riparian buffer, hydrological disruption as measured by impounded area or occurrence of dams.
- *Stream Reach* – Selected measures of channel geomorphology and flow characteristics, water quality, and vertebrate and invertebrate community structure.

The Stream Assessment project ran from 2006 to 2013, with the data collection phase completed in 5 years and resulting in nearly 700 samples, each of which has over 200 associated variables that reside in an Oracle database titled StreamWeb. Estimates of stream resource condition have been calculated and mapped, and a number of publications and presentations have been produced to communicate various aspects of these data and results.



South Carolia Reptile and Amphibian Conservation (Federal Grant #: T-26-R-1 *See T-57-R-1 for summary*)

Habitat Improvement for Grassland Birds (Federal Grant #: T-27-R-1, Duration: 2006-2012)
PI: Tim Ivey (SCDNR, deceased); Author: Brett M. Moule (SCDNR, retired)

The goal of this project was to improve grassland bird habitat on Oak Lea Wildlife Management Areas (WMA), Bland Tract WMA, and Tuomey Tract WMA by developing and implementing various management strategies (e.g. burning, mowing, disking; creating fallow buffers and fallow fields; establishing Longleaf Pine and native grasses) and monitoring bird population responses. Over the course of the grant period, 496 acres were winter disked to improve brood rearing and songbird habitat. In order to improve native grass habitat, 1,247 acres were burned while 2,095 acres were disked, fertilized, and planted to enhance forage for dove, quail, and migratory songbirds. Fallow buffer areas totaling 410 acres were maintained. Soft mast seedlings (6,200) and hardwood mast trees (400) were planted.

Fall quail covey counts were conducted on Oak Lea WMA, Bland Tract WMA, and Toumey Tract WMA in either October or November each year. Survey points were established on all 3 tracts, and summer quail and songbird surveys were conducted in July. These call counts were continued annually to monitor the impacts of management activities on quail and grassland birds.

Dove banding was conducted each year as part of the Eastern Management Unit project. Quail banding occurred the first year with walk-in trap sites to monitor impacts of hunting on the population.

Taxonomy, Life History, and Distribution of the Crayfish, *Procambarus echinatus* (Federal Grant #: T-30-R, Duration: 2007-2008) PI: William Poly (formerly SCDNR); Author: Jim Bulak (SCDNR, retired)

The goals of this project were to examine the distribution, abundance, life history, and taxonomic status of the Edisto Crayfish (*Procambarus echinatus*), a crayfish species of conservation concern. Surveys were made in the Salkehatchie, Edisto, Ashepoo, and Coosawhatchie River drainages. Detailed, quantitative sampling was conducted at 3 specific sites within these drainages. Collections indicated that *P.echinatus* was common in the study area, suggesting the perceived rarity of the species was associated with limited sampling for crayfish in these systems. The habitat for this species was undercut banks with root masses and accumulations of leafy debris in areas of good flow. Collections indicated that a new, distinct species, similar to *P. echinatus*, may be found in the South Edisto River and its tributaries as there was a substantial difference in the size of the structure of reproducing adults. This species was found in similar habitat to *P.echinatus.* Some concern exists that continued population expansion in Aiken County could impact the South Fork Edisto River crayfish. Additional monitoring of this perceived new species is recommended.

Assessing Introgressive Hybridization Within and Habitat Requirements of Native South Carolina Redeye Bass (Federal Grant #: T-31-R, Duration: 2007-2012) PI and Author: Jean Leitner (formerly SCDNR)

A survey was conducted to assess genetic impacts of Alabama Bass (*Micropterus henshalli*) introductions to Redeye Bass (*M. coosae*) in the Savannah Basin. Analysis was completed for N=669 Black Bass collected in 2004, and N=632 black bass collected in 2010 from reservoir sites on Lakes Russell, Hartwell, Keowee and Jocassee. Species composition was compared and showed a precipitous decline in Redeye Bass collected from 2004 to 2010. Our 2004 survey indicated redeye bass had been virtually eliminated from Lakes Keowee and Russell, where they comprised 0% and 2% of black bass collected, respectively. Collections in 2010 show little change in Redeye Bass proportions from these two lakes, but a decline is evident in Lakes Hartwell (from 26% to 8%) and Jocassee (from 39% to 14%). Hybrids between the two species were prevalent in collections and ranged across years/reservoirs from 26% to 54% of black bass collected. Proportions of hybrids increased from 2004–2010 on all but Lake Russell.

Genetic analysis of black bass collected from Savannah basin tributaries in 2009 and 2010 confirmed non-natives and/or hybrids from 5 of 9 collection sites, and from at least one tributary associated with each of 3 reservoirs. Three of these collections represent new documentation of Alabama Spotted Bass hybrids, as we collected only native black bass from those sites in 2004. The potential for the spread of Alabama Spotted Bass and their hybrids from the reservoirs to additional tributary populations is indicated. A new incidence of the non-native Smallmouth Bass (*M. dolomieu*) and their hybrids was documented in the Savannah River, as was the

presence of an extant Redeye Bass population throughout the Enoree River in the Santee drainage.

A GIS database was developed that includes all Savannah and Santee basin black bass collections associated with this study (2004–present), all Savannah and Santee Basin South Carolina Department of Natural Resources stream team collections made within the range of Redeye Bass (2008–present), and all historic South Carolina stream database collections that include record of Redeye Bass (1962–2002). The spatial distribution of tributary collections that included hybrids between Alabama Bass and Redeye Bass provides important information with respect to the spread of non-native black bass alleles in the Savannah Basin. Tributary populations where hybrids have been collected were those in closest geographic proximity to the reservoirs, within which non-native alleles are already widespread. Our results indicate that the spread of Alabama Bass alleles into the sampled tributary populations is the result of upstream movement from the reservoirs.

New genetic assays for the mtDNA locus ND2 were successfully developed. ND2 is one of 4 loci used to differentiate the species of black bass found or having genetic influence in South Carolina populations. Previously, sequencing of all loci was necessary to classify individual fish as a particular species or hybrid. Primers were designed for haplotypes specific for Largemouth Bass (*M. salmoides*), Florida Bass (*M. floridanus*), Alabama Bass, Redeye Bass, and Smallmouth Bass. These new assays provide a new tool, less expensive and time consuming than sequencing, for the evaluation of hybridization among black bass in South Carolina.

In an effort to assess the status of Redeye Bass in the Santee drainage as native or introduced, species of minnow were collected from sites within the Santee, Tennessee (French Broad), and Savannah River drainages. Genetic divergence among drainages, and diversity within drainages, was compared to that for Redeye Bass in the Savannah and Santee drainages. The Santee population of Redeye Bass is not genetically differentiated from populations collected throughout the upper Savannah River drainage. In contrast, Saffron and Warpaint Shiner populations collected in the Savannah and Santee drainages are significantly differentiated from each other. Pair-wise comparisons between individuals sampled from these 2 drainages, for 2 loci, were significantly differentiated. Results indicate that the Santee Basin Redeye Bass populations evaluated here are the result of a more recent, and likely human-mediated, introduction of fish originating from the Savannah Basin.

Restoring Seabird Nesting on Bird Key Stono Seabird Sanctuary (Federal Grant #: T-32-T-1, Duration: 2007-2008) PI and Author: Felicia Sanders (SCDNR)

Bird Key Stono Seabird Sanctuary is an estuarine sandbar that provides nesting, roosting, and foraging habitat for a variety of seabirds and shorebirds. From the late 1980s–1994, it was the largest Brown Pelican rookery in North America. Isolated sand islands, such as Bird Key, make ideal nesting habitat due to the lack of mammalian predators such as Raccoons. Bird Key was designated as a Seabird Sanctuary in March 2006 because of its importance as a seabird nesting island and because seabirds were declining probably due to human disturbance. The “sanctuary” status limited human disturbance on the island. This project used social attraction to decoy seabirds to Bird Key in efforts to increase the number of birds nesting on the island. Social

attraction is a combination of decoys and a sound system. The sound system is a solar-powered audio system which continuously plays the calls of nesting seabirds.

Unpainted 122 Royal Tern, 52 Black Skimmer, and 32 Least Tern decoys were purchased and shipped to Huntington State Park. Horry County school children painted the decoys as part of an educational program about seabirds. At the beginning of the nesting season, Least Tern decoys were spaced approximately 1 m apart on Bird Key. Black Skimmer decoys were placed approximately 2 m apart in 2 separate flocks of 26 decoys each. Royal Terns were placed approximately ½ m apart in one colony. The sound system was placed near the Royal Tern decoys. The sound system constantly played Black Skimmer, Least Tern, and Royal Tern calls. Five days after placing decoys on the island, approximately 40 Black Skimmers were roosting with and courting the decoys. Royal Terns and Least Terns were observed roosting with their decoys. The seabirds were mostly unsuccessful due to depredation by a Great Horned Owl although they nested on Bird Key in low numbers. These decoys were used in other projects to attract nesting seabirds and continued to be part of an educational program for school groups.

Robust Redhorse Electrofishing and Radio Telemetry Tracking of the Great Pee Dee River, SC (Federal Grant #: T-33-R-1 F07AF00062, Duration: 2007-2012) PIs: Ross Self (SCDNR) and Elizabeth Osier (formerly SCDNR); Author: Robert Stroud (SCDNR)

In late April and early May of 2008, SCDNR Freshwater Fisheries Region 2 personnel met with NCWRC, Progress Energy, Duke Energy, South Carolina Aquarium, and North Carolina Natural History Museum personnel to sample the Great Pee Dee River in NC by electrofishing for spawning Robust Redhorse. Twenty-three Robust Redhorse were collected between 22 April and 8 May 2008, of which 7 were recaptures from previous years, 2 were within year recaptures, and 14 were newly collected fish. All fish were PIT tagged and 10 had new radio tags surgically implanted. The fish ranged from 576 to 766 mm with a weight range of 2,630 to 8,450 grams. All fish were adult and many were ready to spawn.

In October 2008, boat electrofishing was conducted for two days on the Pee Dee River focusing below the South Carolina state line. One Robust Redhorse was collected. In late April and early May of 2009, the survey was conducted above the South Carolina state line using boat electrofishing. The areas targeted were known Robust Redhorse spawning grounds and locations where radio telemetered fish were detected. Twenty Robust Redhorse were collected between 20 April and 7 May 2009, of which 8 individuals were newly collected fish. All fish were PIT tagged and 10 had new radio tags surgically implanted. The fish ranged from 594 to 740 mm with a weight range of 2,986 to 6,660 grams. All fish were adult and many were ready to spawn.

Spring electrofishing for Robust Redhorse was not conducted in the Pee Dee River during or after October1, 2009. At the September 2009 annual meeting of the Yadkin-Pee Dee Technical Working Group of the Robust Redhorse Conservation Committee, it was decided that spring electrofishing would be suspended for 4 to 5 years until minimum flows are established at the Blewitt Falls Hydroelctric Facility.

SCDNR Freshwater Fisheries personnel participated in radio telemetry tracking of previously tagged Robust Redhorse in the Great Pee Dee River in October, November, and December 2007;

February 2008; March, April, July and August 2010; and March 2011. In 18 days of tracking during the grant period, 6 different fish were located a total of 22 times in the South Carolina portion of the Great Pee Dee River. Habitat ranged from open channel to along the riverbank, and always in association with submerged woody debris. Region 2's participation in tracking was not required from March 2008 through July 2009 due to a NC State graduate student having been funded by Progress Energy for the work. Radio telemetry tracking was not performed during 2012 due to the expected expiration of transmitter battery life.

Community Based Habitat Restoration and Large-Scale Resource Enhancement Through SCORE (Federal Grant #: T-34-HM-1 F07AF00063, Duration: 2007-2014) PIs: Nancy Hadley and David Whitaker (both SCDNR, retired); Author: Nancy Hadley (SCDNR, retired)

The goal of this project was to create intertidal oyster reefs and Spartina saltmarsh to provide essential fish habitat, protect shorelines from erosion, and provide forage for American Oystercatchers and other shorebirds, through a community-based restoration program. During the life of this project, more than 15,000 volunteers including more than 35 K-12 schools, have participated in active stewardship, contributing more than 38,000 hours of volunteer time. A total of 2.23 acres of oyster reefs have been constructed at 52 sites along 200 miles of SC coast, protecting more than 2 miles of shoreline. These reefs were constructed with more than 36,000 bushels of recycled oyster shells weighing approximately 1,000 tons. Approximately 5 acres of adjacent saltmarsh was created and/or protected during the life of the project. Public awareness has been increased through 87 visits to schools and participation in events focused on K-12 education, 29 presentations at community meetings and events, 9 teacher workshops, and local and national press coverage. SCORE was featured in Southern Living Magazine, Spirit Magazine (Southwest Airlines), SC Wildlife Magazine (twice), and Coastal Heritage. The SCORE program continues to engage the public, educate future generations, and create habitat through community involvement with funding from other sources.

Identification of Diamondback Terrapin Habitats in South Carolina (Federal Grant #: T-35, Duration: 2009-2010) PIs: Erin Levesque (SCDNR), David Whitaker (SCDNR, retired), and Elizabeth Broyles (former graduate student, College of Charleston); Author: Elizabeth Broyles (College of Charleston)

Very little is known about the current population number, sex ratio, and distribution of Diamondback Terrapin populations in Charleston, South Carolina estuaries. Terrapins were caught in the Ashley River, and population estimates were calculated using mark and recapture techniques and analyzed using the MARK program. Population size was estimated to be 3060 with a 95 % confidence interval of 1,964-4,156. This gives around 179-378 terrapins per km^2 of marsh habitat. The sex ratio was 1.7:1 male biased ($p < 0.001$). Investigations into changes in land usage were used to reveal reasons for change in terrapin abundance in the watersheds of the Ashley River, the Wando River, and the Charleston Harbor from 1995-2009. The number of terrapins caught at all Wando River sites combined significantly decreased during the study period ($r = 0.83$, $p < 0.001$). There has been approximately 12.9 km^2 (10% of 127.72 km^2) of land use change in the Wando River watershed from 1996-2006. Diamondback Terrapin abundance, estimated via catch per unit effort, has remained constant for most of the Ashley River and Charleston Harbor areas. Land use change has been minimal ($\leq$ 2%) in both of these

watersheds during the same time frame. The Wando River, on the other hand, had a significant decline in terrapin catch per unit of effort (CPUE) and also had a much greater amount (10%) of land use change. Land use can encroach on terrapin habitats and nesting sites as well as impact food and foraging areas. If the declining trend of the terrapin population in the Wando River continues, regulatory intervention may need to be considered. This information on population size, sex ratios, and distribution can be used as a baseline to track long-term changes in terrapin populations. This project produced a Master's thesis entitled, "Diamondback Terrapins (*Malaclemys terrapin*) of Charleston, South Carolina: Population Estimate, Sex Ratios, and Distribution."

A GIS Model to Guide Landscape-scale Restoration at the Woodbury Tract and Hamilton Ridge Properties (Federal Grant #: T-36-HM, Duration: 2008-2010) PI: Steve Bennett (SCDNR, retired); Author: Will Dillman (SCDNR)

The purpose of this investigation was to create a GIS-based model of pre-fire excluded landscape patch dynamics and hydrologic change for the Woodberry Tract and Hamilton Ridge properties. At the time of this project, these two properties were recent acquisitions by the SCDNR. Land use histories varied for both properties but included a variety of industrial forestry practices. In developing a Conservation Plan for these properties, the hopes were to (1) restore important ecological processes to the landscape (e.g. fire), and (2) provide habitat structures needed to maximize conservation benefits while using the species composition of the current industrial forest.

The use of GIS and a selection of historical aerial photography of the sites allowed identification of reference forest conditions, and the ability to identify likely locations where remnant fire-maintained landscapes most recently occurred. We were also able to create a GIS coverage identifying former isolated wetlands and a GIS coverage identifying changes in hydrology related to road construction and ditching at the Woodberry Tract and Hamilton Ridge properties. Indices were created to quantify mechanical degradation to the wetland area, provide measures of ecological integrity, and to measure the restoration potential of each wetland, based on time since degradation and current habitat structure, relative to other isolated wetlands in the study area.

Carolina Herp Atlas (Federal Grant #: T-37-T, Duration: 2008-2010) PI: Steve Bennett (SCDNR, retired) and Mike Dorcas (Davidson College); Author: Will Dillman (SCDNR)

The objective of this project was to develop the Carolina Herp Atlas (CHA) and to provide detailed locality data on the reptiles and amphibians of the Carolinas, in particular those species whose distribution and status are poorly known. The CHA was officially launched in March 2007. Prior to the launch, the Davidson College Herpetology Lab imported approximately 3,900 records, primarily from Mecklenburg, Iredell, and Cabarrus counties in the western Piedmont of North Carolina. From March 2007 through 16 November 2010, the CHA totaled 839 registered users, 91 of which identified South Carolina as their home residence. The CHA received 4,930 reptile and amphibian records from South Carolina. Of the 5,008 records, 912 were accompanied by a voucher photograph and/or given a status of 10. A total of 122 South Carolina reptile and amphibian species have at least one record in the CHA. Thus far, the CHA has collected species-

level distribution data on 151 species of amphibians and reptiles, including the occurrence of 32 anurans, 29 salamanders, 37 snakes, 11 lizards, 14 turtles, and the American alligator.

The CHA has thus far been a highly successful, citizen science-based project to document the distribution of reptiles and amphibians in South Carolina. The collection of 4,930 reptile and amphibian records in South Carolina (and 16,958 total records submitted from both South and North Carolina) during the first 3.5 years suggests that the CHA has the potential to surpass many other citizen science-based herpetological atlas projects. For example, the Georgia Herp Atlas collected a total of 7,452 records during the 5 years of operation. Thus far, the CHA represents a significant step towards the development of a better understanding of the distributions of reptiles and amphibians in the Carolinas. An overriding goal of the CHA is to promote conservation and understanding of reptiles and amphibians in South Carolina. The interactive nature of the CHA appears to appeal to a wide variety of people, including school teachers, professional herpetologists, and those generally interested in wildlife.

Mink Restoration and Monitoring Development Project (Federal Grant #: T-38-R, Duration 2007-2012) PI and Author Jay Butfiloski (SCDNR)

The goal of this project was to develop a monitoring program that would minimize staff time and effort by establishing alternative methods of American Mink survey techniques to be used to monitor the success of mink restoration along the coast of South Carolina. Track boards appeared to have the most promise as the boards could be set out and checked at a later date using one person. However, many of the same issues that previously plagued track board work such as tidal fluctuations, wave action, and other environmental factors hampered track board implementation. Once again, track boards were dismissed as a feasible tool in this instance. Previous mink survey work depended on spotlight surveys that required significant high tides occurring a few times per year. The exact heights of these tides were undetermined as to which would be sufficiently high enough for survey work, often leading to poor surveys and wasted manpower. Thus, emphasis was placed on perfecting spotlight surveys in an effort to evaluate which environmental factors were most significant in surveying mink. The project determined that tide heights 6.05 ft. above Mean Lower Low Water (MLLW) level as measured at the Charleston station and adjusted for local areas was the best predictor for when to use spotlight surveys.

During the course of this study, two family groups of mink (5 total) were relocated into the Hog Inlet portion in the northernmost coastal march in the State. This area was the last remaining significant portion of coastal marsh where mink had not been reintroduced. Moving captured mink to this marsh would be the last location along the coast where mink needed to be reintroduced to complete mink reintroduction that was begun in the late 1990s. However, during the course of this project, mink depredation in the original mink restoration site of Cape Romain National Wildlife Refuge (CRNWR) became a concern for refuge staff. As the reintroduced mink into CRNWR began to thrive, concerns from staff at the refuge centered on the impacts mink may be having on nesting shorebirds. Therefore, much of the emphasis of this project became the assessment of reintroduced mink impacts in the original reintroduction site.

A total of 9 mink were implanted with transmitters to assess impacts their activity may be having with other species. Radioed mink did not venture far from initial capture sites and most of their activity appeared to be tide dependent. In addition, diet analysis from mink taken from the CRNWR in an effort to increase shorebird nesting success found that out of 45 mink stomachs collected, 7.4 % contained avian material of unknown species. A bioenergetics model developed from this estimated that an individual mink would consume 8.5 avian prey items per month based on the sampled diet. It is still undetermined to what extent mink predation is affecting shorebird success at CRNWR, as other predators and mortality factors still plague nesting efforts on the refuge.

Prescribed Burning Crew for SC Department of Natural Resources Lands (Federal Grant #: T-39-M-1 F08AF0008, Duration: 2008-2013) PI and Author: Tim Ivey (SCDNR, deceased)

The objective of this grant was to facilitate and increase prescribed burning on Wildlife Management Areas and Heritage Preserves for wildlife habitat enhancement. SCDNR contracted with the South Carolina Forestry Commission to perform the fire management activities of the grant. During 2009, growing season prescribe burning was conducted on 8 SCDNR properties. A total of 3,830 acres were prescribe burned and 49.25 miles of firelanes were disced. During 2010, dormant and growing season prescribe burning was conducted on 18 SCDNR properties. A total of 10,312 acres were prescribe burned and 81.15 miles of firelanes were disced. During 2011, dormant and growing season prescribe burning was conducted on 23 SCDNR properties. A total of 7,906 acres were prescribe burned and 120.9 miles of firelanes were disced. During 2012, dormant and growing season prescribe burning was conducted on 19 SCDNR properties. A total of 6,322 acres were prescribe burned and 44.65 miles of firelanes were disced.

Conservation of Belfast Plantation, Phase I (Federal Grant #: T-40-L, Duration: 2008-2009) Author: Emily Cope (SCDNR) [*T-50-L is Phase II and is covered by this synopsis.*]

SCDNR utilized $1,188,654 from the USFWS (of which $1,063,654 was Wildlife Restoration funding and $125,000 was State Wildlife Grant funds) to acquire the southern half of the Belfast Tract totaling 2,436 acres (also known as Belfast Phase II). The total land acquisition cost for Phase II was $7,710,440. This completes the Belfast acquisition project by protecting a total of 4,664 acres. The Belfast Tract has long been managed to support a diverse range of wildlife species. The hardwood drains, creeks, and beaver ponds support waterfowl management objectives. In addition, the age-class diversity of the pine stands provides valuable wildlife habitat. The property supports excellent populations of deer and turkey, and the uplands provide excellent habitat for Bobwhite Quail. Improved timber thinning and a more aggressive prescribed burning regime will increase the already existing quail population. This will expand the ongoing efforts on the nearby Sumter National Forest to increase the Piedmont quail population. Mudlick Creek, the beaver ponds, and the man-made pond provide many fishing opportunities for sunfish and bass.

The property provides habitat for many priority bird species such as Acadian Flycatcher, American Woodcock, Great Blue Heron, Kentucky Warbler, Little Blue Heron, Louisiana Waterthrush, Rusty Blackbird, Wood Duck, Wood Thrush, and Yellow-crowned Night Heron. The wetlands associated with the river corridor and its tributaries provide habitat for many

reptiles and amphibians including but not limited to the black swamp snake, common snapping turtle, and yellow-belly turtle. Little River, which traverses the Belfast Tract and is the Southern boundary for Phase I, is comprised of Carolina Slatebelt geology. This specific geology is known to be associated with the federally-endangered mussel, the Carolina heelsplitter. While initial survey work has not detected the heelsplitter on the Belfast Tract, it has been located in the nearby area. Further survey work could find the heelsplitter on the tract or the tract may also serve as a restoration/reintroduction area for the species. In addition, several rare species of burrowing crayfish have been found in nearby areas.

Conservation of Water, Shore and Seabirds in South Carolina (Federal Grant #: T-41-R F08AF00108 Duration: 2008–2016) PI and Author: Felicia Sanders (SCDNR)

Many of the seabird, shorebird, wading bird, and marsh bird species that utilize South Carolina's coastal habitats are of conservation concern due to small and threatened populations. This grant funded efforts to reduce human disturbance at key seabird colonies and to conduct nest counts and population surveys of many waterbird species. These count data were incorporated into national databases to allow the agency to make informed management decisions as well as contribute to regional and global knowledge of the species. Survey, research and management activities were shared on webpages, in press releases, in publications, and at outreach events so that the results were made available to partners.

SCNDR staff coordinated with private, federal, state, and county-owned beach managers to close part of the beach for nesting seabirds and shorebirds at 30 sites during summer months and at 2 during the winter. Educational signs were placed at boat ramps and at beach entrances. Annual seabird nest counts were conducted for Black Skimmer, Brown Pelican, Common Tern, Forster's Tern, Gull-billed Tern, Least Tern, Sandwich Tern, and Royal Tern. Counts consisted of walking transects through the colonies and/or using aerial photographic surveys (starting in 2013) which were primarily conducted from SCDNR Law Enforcement planes. Least Tern nests were monitored at natural beach sites and on artificial sites mostly consisting of pebbled roofs in industrial areas. Peak statewide nest estimates for this project period were: Black Skimmer (2014) 1,110 nests; Brown Pelican (2013) 5,396; Gull-billed Tern (2012) 438; Royal Tern (2009) 13,078; and Sandwich Tern (2015) 3,414. From 2008 to 2016, the mean number of Least Tern nests in South Carolina was 1,139/year; 52% were on flat gravel-covered roofs, and 48% were on ground sites.

All known active Wood Stork colonies were surveyed in 2008 and from 2011 to 2016. We counted 1,839 (2008); 2,031 (2011); 1,827 (2012); 2,050 (2013); 2,501 (2014); 2,496 (2015); and 2,512 (2016) Wood Stork nests. The three- and five-year averages of the number of stork nests counted in South Carolina were 2,503 and 2,277, respectively. This grant period was the first time that either of these averages exceeded 2,000 nests per year since storks were first documented nesting in South Carolina in 1981. A sub-set of the stork nests were monitored in index colonies to determine how successful the storks are at raising young in South Carolina. During 2016, a total of 1,117 stork nests were monitored in 7 colonies, and an average of 1.7 chicks fledged per nest site. An average of 2.3 chicks fledged per successful nest site.

Aerial surveys and ground counts of nests in known wading bird colonies and in aerial transect survey plots were used to monitor the distribution and relative size of wading bird colonies during 2011- 2016. All species of wading birds were included in the surveys. The number of Roseate Spoonbills in South Carolina during the post-breeding season appears to be increasing; however, nesting has not yet been confirmed in the State. No Reddish Egret nests were found during the 2011-2016 surveys. Yellow-crowned Night Herons and Green Herons often nest in small, inconspicuous colonies and were rarely located during surveys.

During the winters of 2014 and 2015, we organized the first statewide winter shorebird surveys conducted in South Carolina. In 2014, although the weather was not ideal, 38,235 shorebirds and 28 species were counted from January 31 – February 7. In 2015 the weather was much improved from the previous year's conditions so that 47,287 shorebirds and 28 species were counted January 22 – January 31, 2015; Dunlin (27,087) were over half the total shorebirds. In both years, the high count was on the Intracoastal Waterway shell rakes in The Cape Romain Region (Cape Romain National Wildlife Refuge to Dewees Island) where in 2015 8,895 or 19% of the total shorebirds were counted.

Use of GIS to Assess the Demographic Isolation of Red-Cockaded Woodpecker Groups in SC (Federal Grant # T-42-R-1, Duration: 2008-2009) PI: Jason Brett Craig (former graduate student, Clemson University) and J. Drew Lanham (Clemson University); Author: Derrell Shipes (SCDNR, retired)

This project was sub-contracted to Clemson University. Jason B. Craig (graduate student) and Dr. J. Drew Lanham were the Principal Investigators and Ralph Costa and Dr. Robert Baldwin were collaborators. Eight km (5 mi.) and 25 km (15.5 mi.) radius circles were drawn around known active and inactive Red-Cockaded Woodpecker (RCW) cluster locations in SC in an effort to determine the occurrence of Demographically Isolated Groups (DIGs). These analyses concluded that there are 20 isolated clusters using 8 km (6 active, 14 inactive) and 3 isolated clusters using 25 km (1 active, 2 inactive). Habitat evaluation associated with isolated and non-isolated clusters was conducted. The concept of "isolation" and the location of isolated clusters are essential to the future management of this endangered species. It may be necessary to relocate isolated birds to larger populations in order for the relocated birds to reproduce and contribute genetically. There is a tendency for isolated clusters with small numbers of birds to "blink out".

Conservation of Migratory Land Birds in South Carolina (Federal Grant ID#: T-43 F08AF0010; Duration: 2008-2017), PI and Author: Amy Tegeler (SCDNR)

Many land bird populations are in decline. Some of the threats land birds face include climate change, unsustainable agriculture and forestry, poorly planned urban growth, and a general widespread decline in habitat quantity and quality. Over 240 land bird species occur in South Carolina, of which more than 60 are considered species of conservation concern in the 2015 State Wildlife Action Plan. South Carolina is important to year-round resident land birds as well as Neotropical migrants. As such, conservation of land bird species requires creating and implementing land bird conservation objectives both within the State and at regional scales. The objective of this grant was to coordinate and collaborate with internal and external partners to

implement land bird objectives outlined in the State Wildlife Action Plan at State and regional scales and to provide avian input into the State Wildlife Action Plan update. To meet this objective, collaborations were developed within the agency and with partners to develop, implement, and fund management, monitoring, and research projects to achieve land bird objectives. Collaborations included participating in regional working groups, citizen science projects, projects with non-profit organizations, initiatives with state and federal agencies, and co-advising graduate students. Collaborations were also developed with SCDNR biologists to implement projects on State and private lands to achieve land bird objectives. Examples of projects included songbird use of CP-33 habitat buffers, participation in the South Carolina Quail Technical Committee, breeding season songbird banding and winter Baltimore Oriole monitoring. The SCDNR was also represented at local, state, regional and national meetings to relay information and facilitate implementation and monitoring of South Carolina's State Wildlife Action Plan land bird objectives. In addition, information on land birds in South Carolina was organized and disseminated by writing papers, giving presentations, conducting workshops and field days, developing press releases, and through other means.

Least Tern Reproductive Success on Roof-tops (Federal Grant # T-44-R-1, Duration: 2008-2010) PI: Felicia Sanders (SCDNR); Author: Mary Catherine Martin (SCDNR)

Nesting of Least Terns (*Sternula antillarum*) on flat, gravel-covered roofs was followed at colony sites in Georgetown and Horry Counties in coastal South Carolina. Colony success and failure were documented. Incubation duration was determined at 5 roof colony sites by encasing temperature data loggers in clay eggs. Successful colonies were characterized by incubation temperatures at a constant range except for periods of heavy rainfall, while unsuccessful colonies had incubation temperatures with cooling ranges of 14-20°C (57-68°F) that occurred at night with repeated nest abandonment attributed to possible predators. Movements of fledged Least Terns were tracked by attaching radio transmitters to the legs of the young. Injuries resulted from the transmitter attachments complicating methods of this part of the study. A very limited number of fledged Least Terns were tracked and results were inconclusive. An assessment of fish samples found at colony sites indicated that the more inland the site, the more freshwater fish species present. In addition, observations indicated that adults and fledged young foraged at sites within a 5-10 km (3-6 mi.) radius from the colony site. Inland storm water retention ponds have become a valuable foraging site for Least Terns. Finally, eggs from colony sites were tested for heavy metal contaminants usually found in storm water retention ponds. No contaminants were present in amounts detrimental to hatching or the development of young.

American Shad Culture and Stocking in the Edisto River (Federal Grant #: T-45-R-1, Duration: 2008-2011) PI and Authors: Bill Post (SCDNR) and Chad Holbrook (formerly SCDNR now Santee Cooper)

Historically, the Edisto River in SC had one of the State's larger American Shad fisheries. Overfishing between the 1940s to1980s lead to a dramatic decline in shad landings and decreased abundance over time. These declines lead to added restrictions to the shad fishery beginning in 1998. More recently, in an effort to augment wild production, SCDNR and the USFWS formed a partnership to create a hatchery program. Over a 4-year period (2008-2011), the feasibility of on-river broodfish collections, hatchery production, young-of-year relative

abundance, annual hatchery contribution, movements of adult American Shad, genetic analysis of stock enhancement, and genetic uniqueness were evaluated for the Edisto River population. Collecting broodfish using electro-fishing gear proved to be successful with 347 adult American Shad caught over 3 years of sampling. Of the 347 collected fish, 235 have been used as broodfish; 92 had fin clip samples taken, were implanted with acoustic tags, and returned to the river; and the remaining 20 had fin clip samples taken and were returned to the river.

Collection efficiency of adult American Shad improved each year allowing us to increase the number of broodfish used each year as well as balancing the male/female ratio (2009 N=63; M 51, F 12; 2010 N=75; M 48, F 27; and 2011 N=97; M 57, F 36). Annual egg production has been variable and variability was independent of the number of females collected (2009 – 205,238; 2010 – 600,987; and 2011 – 184,677). From 2009-2011 a total of 39,688 fry were released, ranging from a high in 2010 of 22,209 to a low in 2011 of 4,836. Out-migrating young-of-the-year American Shad were successfully sampled with electrofishing gear in 2010 (601) and 2011 (1,291).

All collected fish were kept to determine hatchery contribution via OTC detection and genetic detection using microsatellite markers. Detection rates for hatchery fish varied between the two methods with OTC indicating a hatchery contribution of 6.8% in 2010 and 0.3% in 2011, while genetic testing indicated a hatchery contribution of 3.6% in 2010 and 0.0% in 2011.

Additionally, this project provided the opportunity to generate baseline genetic data which had not previously been determined for this stock, finding that genetic diversity for the Edisto River American Shad population is high. An initial evaluation of our stocking program detected no difference in genetic composition between the broodstock and field collections in any of our production years ($p>0.692$), indicating the appropriateness of our broodstock collection process in minimizing potential negative impacts of stocking on the wild population. However, significant spatial genetic differentiation was detected between the Santee River and Edisto River ($X^2=\infty$, $p=0.000$). Therefore, broodstock for stock enhancement purposes in the Edisto River should originate only from the Edisto River itself.

Our study was a comprehensive look at the potential of using responsible stock enhancement as an effective management tool. Broodfish collections and hatchery production was a success; however we hope to improve fry/egg ratio with more experience. Telemetry results were somewhat inconclusive; however, it did appear mature shad were congregating in areas near Givhans Ferry State Park around river mile 60. Young-of-the-year collections improved throughout the study and were efficient in 2010 and 2011. Although contribution was relatively low, we were able to detect hatchery individuals in the Edisto River population prior to out-migration. The results of this project, along with future work, will provide valuable information which can be incorporated into management plans to aid in the recovery of this important species in the Edisto River in South Carolina.

Landscape Planning for Priority Wildlife Species on Agricultural Lands (Federal Grant #: T-46-1-T F08AF00111 *See T-10-P summary*)

Conservation of Breeding Painted Buntings and Other Songbird Indicators in Early-Successional Shrub-Scrub Habitat (Federal Grant #: T-47-R-1 F08AF00109, Duration: 2008-2011) PI: Derrell Shipes (SCDNR, retired); Author: Mary Catherine Martin (SCDNR)

Objectives of this study were to determine: (1) abundance of breeding Painted Buntings (*Passerina ciris*) and other indicator songbird species in paired CP-33 and non-CP-33 fields; (2) nest location and success of Painted Buntings in paired CP-33 and non-CP-33 fields; and (3) a landscape/GAP analysis model which tracks seasonal crop rotation and predicts a pattern of habitat occupancy and breeding distribution of Painted Buntings and other early-successional shrub-scrub songbird species. CP-33 is a conservation program established by the Department of Agriculture to provide habitat for upland birds through landowner incentives to plant native grass buffers along row crop field margins.

Eight fields of 4 CP-33 and 4 non-CP-33 were study sites. In each field, habitat types were classified as agriculture, forest, CP-33 border, and cut (recently cut forest area). To determine the abundance of Painted Buntings, 3 survey types were utilized: spot maps, transect counts, and telemetry. The results of each type of survey indicated more Painted Buntings and other species were found in mature (≥ 10 years of growth) forest edges than in any other habitat, and there was no difference in species abundance between CP-33 and non-CP-33 fields. In addition, vegetation data gathered per protocols developed by the Breeding Biology Research and Monitoring Database (BBIRD) in the forested edges of agricultural fields, in the CP-33 strips, and in the crop fields indicated that wheat is preferred forage by Painted Buntings. Second, 3 types of fields (paired CP-33, non-CP-33, and a field managed for doves) were searched for Painted Bunting nests. Twenty-two nest sites were found in forest edge habitat, and none were found in the CP-33 and dove field habitats.

Finally, a landscape/GAP analysis map was created from the data obtained in the spot map, transect count, and radiotelemetry surveys. Results of the landscape/GAP analysis map indicated high priority habitats as: 25 m or less from the edge of mature forest; CP-33 strips, wheat fields, and early growth forests (≤ 10 years of growth) for foraging; and use of CP-33 strips, all agricultural fields, and early growth forests by Painted Buntings was limited to the edges of these habitats. Based on the completion of the study objectives, recommendations for Painted Bunting conservation in central rural South Carolina are: (1) mature forest edge habitat is essential; (2) painted buntings prefer to occupy and nest in the outermost edges of forests and/or thin forest strips (25 m or less from the edge); and (3) a source of food in the form of a wheat field or other grass seed as well as a source of insects when rearing young is necessary.

Effects of Predation on Seabird Nests in Cape Romain (Federal Grant # T-48-R, Duration: 2009-2010) PI and Author: Felicia Sanders (SCDNR)

The goal of this project was to monitor seabird nesting in Cape Romain National Wildlife Refuge to guide management that can benefit seabird species nesting at natural sites. Nesting chronology, reproductive success, and causes of colony abandonment and nest loss were documented for Least Terns and Black Skimmers in 2009-2010. Although species of conservation concern, little is known about the reproductive success of Least Terns and Black Skimmers throughout the Southeastern US.

Nest monitoring occurred at Raccoon Key, Lighthouse Island, Middle White Banks, and Cape Island. Each island was checked every 2-7 days depending upon weather and logistical constraints. Least Tern and Black Skimmer nests were randomly selected across all 4 study sites. Nests were marked by wooden stakes 0.5 m from the nest scrape. Eggs were floated to estimate initiation date. At each visit, researchers recorded the number and condition of eggs or young and when possible, and determined the cause of failure by visual observation. Chick survival was determined at select sites by banding 1-2 day-old chicks with a unique, 2-color leg band combination. Researchers conducted re-sighting surveys every 2-4 days for Least Terns until no fledglings were observed. To determine the minimal survival of Black Skimmer chicks, an island-wide fledgling count was conducted at the end of the season.

Peak nesting for Least Terns occurred from mid-May to mid-June and for Black Skimmers in mid-June. Predation and over-wash were the primary cause of nest failure based on visual cues at or near the nest. Collectively, these ecological stressors attributed to 65% of nest loss for Least Terns and Black Skimmers. Video cameras installed at colonies documented disturbance to colonies by Black Vulture, American mink, and Great Horned Owl. Of the 60 Least Tern chicks monitored, 13 (22%) were re-sighted at ≥ 17 days post hatch. Of the 52 Black Skimmer chicks monitored, 22 (42%) were re-sighted at ≥ 28 days post hatch. Nest success of Least Terns and Black Skimmers within CRNWR was variable among colonies and between years, suggesting that factors at the local level influenced reproductive success. Management techniques within the study area directed toward predator control to decrease nest loss of near-shore seabirds and shorebirds needs to focus on both the avian and mammalian predators identified in this study in order to be effective.

Sea Turtle Conservation on Botany Bay Plantation WMA (Federal Grant #: T-49-R-1 F08AF00107, Duration: 2008-2015) PIs: DuBose Griffin (formerly SCDNR) and Michelle Pate (SCDNR); Author: Michelle Pate, SCDNR

Sea turtles are listed as Threatened or Endangered under the Endangered Species Act. Four marine turtle species utilize South Carolina waters and nest on our beaches. The Loggerhead Sea Turtle (*Caretta caretta*) is the predominant species nesting along the coast, although nests from three other species (Kemp's Ridley, Green, and Leatherback) are observed periodically. Grant funds were used to employ a seasonal field technician to conduct sea turtle management activities on Botany Bay Island and Botany Bay Plantation Wildlife Management Area. This contiguous beach is the highest density nesting beach in South Carolina outside of the federally managed Cape Romain National Wildlife Refuge. The installation of a seasonal technician housed on-site allowed for sea turtle management continuity on the Botany Bay beach. The turtle project is now a standardized, season-long survey conducted seven days a week. The technician was trained and supervised by the SCDNR Marine Turtle Conservation Program and operated under state management guidelines, thus ensuring that scientifically approved methods were used to collect reliable estimates of nest incubation and hatching success. Activities conducted by the technician included nest identification/relocation, nest protection during incubation, genetic sample collection, post-emergence nest inventories to determine nest success, and visitor education. Predator control methods were conducted on an annual basis protecting sea turtle nests from mammalian depredation. This protection during incubation increased nest and

hatchling productivity, essential in threatened and endangered species population recovery efforts. The technician collected standardized data on sea turtles that stranded dead or alive on Botany Bay beach. The technician maintained continuity and quality of data collected from these stranded sea turtles as part of a larger nationwide Sea Turtle Stranding and Salvage Network (STSSN).

Conservation of Belfast Plantation, Phase II (Federal Grant #: T-50-L, Duration: 2009-2010) *See T-40-L summary.*

Ecology and Impacts of Coyotes on Loggerhead Sea Turtles, Least Terns, and Other Wildlife: Implications for Management (Federal Grant #: T-51-R-1 F09AF00159, Duration: 2009-2011) PI and Author: Jamie Dozier (SCDNR)

Control of abundant mammalian predators is a common element of management programs aimed at increasing reproductive and recruitment success of many threatened ground-nesting turtle and bird species. Recent colonization of Coyotes (*Canis latrans*) in South Carolina, however, is changing traditional community dynamics governing and impacting wildlife populations in coastal and barrier island systems. Coyotes have become a major nest predator on Federally Threatened Loggerhead Sea Turtles (*Caretta caretta*) having devastating impacts on nest survival. For example, in 2009 on the Tom Yawkey Wildlife Center Heritage Preserve (TYWCHP) in Georgetown, South Carolina, extensive Coyote depredation on turtle nests was documented with over 50% (21 of 40 nests; 1,208 eggs) of Loggerhead Sea Turtle nests either completely or partially destroyed. The purpose of this project was to attempt to understand Coyote ecology and impacts at the TYWCHP as it relates to Loggerhead Sea Turtle and Least Tern nesting success. A major portion of the study attempted to examine Coyote home range, habitat use, and diet composition on the island complex.

A total of 8 Coyotes were trapped and fitted with radio-transmitters during the study period. Unfortunately, a combination of equipment failure and extreme difficulty in locating collared Coyotes provided a low sample size of locations and data unreliable to support any reasonable estimations of Coyote home range, movements, or habitat use on TYWCHP. Over 400 Coyote scat samples were collected during the study periods on TYWCHP; 370 samples were usable for analysis. A total of 234 scats were collected on Cat Island and 136 on South Island. *Sigmodon* spp. were the most common food item found in Cat Island scats, followed by birds, vegetation, and *Peromyscus* spp. Birds were the most common item found in South Island samples, followed by *Sigmodon* spp., vegetation, and *Neotoma* spp. Cat Island samples comprised a larger percent of scats containing wild hog, lagomorphs, *Diospyros* spp., and soricomporphs, while South Island samples contained more birds, crabs, *Mephitis mephitis* (striped skunk), and mustelids. There was a significant difference between Coyote diet on the two islands ($A = 0.0090$, $p < 0.0001$). Test results yielded significant indicator values for three animal groups and one plant genus (birds, lagomorphs, wild hogs and *Ilex* spp.). Although birds were a component of Coyote diets, samples did not provide enough evidence to determine which species of birds or age class. Observation of Least Tern nesting colonies did not reveal Coyote presence during the study period.

An additional component added to the project was the question of Coyote impacts on mesopredators, in particularly Raccoons, in suppressing depredation/predation on prey items. Three experiments were conducted to examine Coyote-Raccoon interactions: 1) space use of radio-collared Raccoons (10-18) to test avoidance of Coyote urine, 2) avoidance of captured Raccoons (8) in enclosures to Coyote scat, and 3) avoidance of free-ranging Raccoons to monitored feeding sites containing Coyote scat. Summary results of all 3 experiments revealed that Raccoons did not avoid areas where Coyote presence was artificially induced; therefore, this suggested that the threat of Coyotes was not a deterrent in Raccoon use of areas in space and time. From a management perspective, the most significant finding was from a companion study conducted on TYWCHP during the same time period as this study revealing that selective trapping of Coyotes and beach night patrols significantly reduced Coyote depredation of sea turtle nests from 52% in 2009 to 15% in 2010.

Striped Bass Stock Enhancement of Charleston Harbor Estuary System (Federal Grant #: T-53-R-1 F10AF00422, Duration: 2010-2015) PI and Author: Mike Densen (formerly SCDNR now Hollings Marine Laboratory)

This project supported Striped Bass stock enhancement in Charleston Harbor from 2010 to 2014. Project funds were used to evaluate the potential for using stock enhancement as a means to re-establish historic levels of biodiversity and restore a key indicator species to coastal rivers in the Southeast with the ultimate goal of developing a conceptual restoration model for Striped Bass in coastal rivers.

Over the course of the project, Striped Bass (n=164,895) were stocked in the Ashley, Cooper, and Wando rivers of the Charleston Harbor system. Striped Bass from each stocked year class and each river were recaptured during this project. While there were multiple immigrants from the Santee-Cooper lakes captured in the Ashley (n=6), only one Striped Bass released in the Ashley River was recovered from outside of the Ashley River (Cooper). The persistence of multiple year classes within the Ashley River and the limited number of recaptures outside of the system indicate limited emigration of stocked fish out of the Ashley River.

The capture of wild young-of-the-year Striped Bass in 2009 and 2010 may indicate spawning activity is occurring in the Ashley River. It seems unlikely that fish collected at age 0 were spawned in a different system and migrated to the Ashley River at such a young age and small size. Histological examination of ovaries from female Striped Bass collected in the Ashley River revealed that almost 43% of all female Striped Bass captured above the age of 3 had GSI values higher than 5 and all seven females were categorized as either developing or recent spawners. All females aged two years or younger captured in the Ashley River were found to be immature. Of the 5 male Striped Bass examined between the ages of 1-3, all were either developing or sexually mature. The lack of substantial contribution of wild fish to the most recent 2012 and 2013 year classes could be an indication that the system is at capacity or environmental conditions were not favorable for natural recruitment of wild fish.

Metabolic scope experiments suggest that Striped Bass in the Ashley River should be able to manage the energetic costs associated with the extreme high temperatures and low dissolved oxygen concentrations observed in the Ashley River during the summer. These findings confirm

the results of temperature tolerance studies conducted on hatchery reared Striped Bass in previous studies.

The results of this project are encouraging for the future of the Striped Bass restoration effort in the Ashley River. We have determined the best size and age class of fish to stock (Phase II) to successfully increase abundance to a critical mass that might facilitate wild recruitment and have demonstrated survival of Striped Bass grown in both conventional freshwater rearing systems and brackish water pond systems. We have also determined that the environmental conditions within the river are sufficient for survival and that fish are becoming sexually mature and returning to the river to spawn. Continued monitoring over the next 5-10 years will be necessary to determine if the stocking effort was enough to restore this key indicator species to the Ashley River. Further, the methodology and results presented here make production and stocking of Striped Bass in coastal rivers a viable means of reducing the chance of this important species from being listed as a threatened species.

Monitoring Impacts of Yellow Pine Restoration on Avifauna in the SC Mountains (Federal Grant #: T-54-R-1 F10AF00443, Duration: 2010-2013) PIs: Curtis Walker (former graduate student, Clemson University) and J. Drew Lanham (Clemson University); Author: Mark Hall (SCDNR, retired)

Note: The thesis name of this project is *Avian Community Response to Prescribed Fire in Yellow Pine Stands in the Jocassee Gorges Region of South Carolina*.

Comparisons of avian communities were made between the burned treatment sites and reference control sites to examine community and priority species response to prescribed fire in the Jocassee Gorges in the mountains of SC. To assess the impacts of fire disturbance management on the avian community, 10-minute, 50 m radius point counts were conducted in treatment and control plots during the spring breeding seasons of 2011 and 2012. Values of species diversity, richness, and total number of individuals were found to be significantly higher in the burned treatment plots than in the control plots as a result of differences in structural complexity and the distribution of resources. The occurrence of focal species, as well as other species, was found to vary between sites. Species associated with early-successional and more open habitats—such as Eastern Wood-Pewees and Indigo Buntings—were observed more often in burned sites, while species requiring shrubbery and broad-leaved foliage on which to forage—such as Black-throated Green and Hooded Warblers—were observed more often in control sites. Models created using structural vegetation data identified characteristics of vegetation and landform that were found to be useful in predicting the occurrence of 6 of the 7 priority species at Jocassee. Differences in the occurrence of nesting and foraging guilds were related to differences in complexity of habitat structure and composition. This research suggests that fire management can be a useful tool to create wider variation across the landscape, providing increased opportunities for nesting and foraging resources for an array of bird species.

Using Citizen Science in the Study and Conservation of Breeding Painted Buntings (Federal Grant #: T-55-R-1 F10AF00444, Duration: 2010-2012) PIs: John Gerwin (NC Museum of Natural Sciences); Author: Derrell Shipes (SCDNR, retired)

This project was sub-contracted to Dr. John A. Gerwin of the North Carolina Museum of Natural Sciences in Raleigh, North Carolina. Collaborators included Dr. Jamie Rotenberg of the University of North Carolina – Wilmington and Laurel Barnhill formerly of SCDNR, now USFWS.

Painted Buntings (PABU) were banded at 45 sites during 135 banding sessions across NC/SC including 15 in NC, 15 in Coastal SC, and 15 in "interior" SC. Birds were banded with a unique USFWS aluminum band on one leg and a unique combination of 3 plastic color bands on the other leg. Age, sex, and breeding condition was determined and recorded. An internet-based reporting system for reporting of sighted birds was developed, and reporters were recruited using workshops, short newspaper articles, word of mouth and through the website. Volunteers were encouraged to report sightings of birds—banded and un-banded—to the website. A total of 1,379 PABUs (454 females, 395 males, 231 unknown) were captured and banded in South Carolina. Following banding, 34,705 reports of PABUs—banded and un-banded—were received at the website. Researchers found that PABUs appear to survive an average of 5-6 years and appear to exhibit philopatry. They did not find an over-abundance of Brown-headed Cowbirds at the feeder sites or in agricultural areas nearby. Habitat preference, management guidelines, and productivity information is contained in the larger report of the project.

Continued monitoring of recently established crab trap-based oyster reefs to document their values as essential fish habitat for a diverse fauna in South Carolina (Federal Grant #: T-56-R-1 F11AF00686, Duration: 2010-2015) PI and Author: Peter Kingsley-Smith (SCDNR)

This project focused on addressing a major source of marine debris by providing opportunities for the public to report and donate derelict and unwanted crab traps. This project engaged the general public either through a dedicated website (www.dnr.sc.gov/marine/crabtraps), which encourages the public to report derelict traps using either the Marine Debris Tracker smartphone application, created by NOAA's Marine Debris Program (http://marinedebris.noaa.gov/), or through a dedicated email address (crabtraps@dnr.sc.gov). More than 800 crab traps were gathered by this project, either through trap recoveries in the field or from trap donations by recreational and commercial crab fishers. Repurposed traps were deployed as oyster reef-building substrate both in support of this project as well as other grant-funded projects. Crab trap-based reef building efforts targeted areas where traditional restoration approaches using more dense substrates (e.g. bagged shell) are less well suited, primarily in low wave energy, pluff mud environments. Initially (2010-2011) small reefs (6 traps per reef) were created under private docks, with the intention of demonstrating increases in recreational finfish catches through rod-and-line sampling. As the availability of traps increased, however, larger reefs (23 traps per reef arranged in a checkerboard pattern) were constructed in open areas that could be sampled using a monthly drop net sampling technique. This method more effectively and comprehensively sampled the mobile finfish and crustaceans using the reefs as habitat at high tide. These larger (23-trap) reefs were created along intertidal shorelines at the SCDNR Marine Resources Research Institute at Fort Johnson, at the National Fish Hatchery at Bears Bluff on Wadmalaw Island, and in the ACE Basin NERR at Hutchinson Cut in 2012, as well as at 3 public parks in Charleston (Demetre Park, North Bridge Park, and Brittlebank Park) in 2013, with the goal of raising public awareness about both marine debris issues related to derelict crab traps and the ecological significance of oyster reefs as essential fish habitat. During the summer

of 2015, a new oyster reef comprising 100 traps was also created in the Ashley River, along with a new 50-trap reef at the Port Royal Sound Maritime Center. Monthly drop net sampling over several years has supported the premise that oyster reefs constructed using alternative materials support higher abundances and diversity of associated fauna than adjacent non-reef, control areas. During 2014-2015 at the Fort Johnson reef, for example, blue crabs and grass shrimp were collected in significantly greater numbers from the reef plot than from the control plot. Beginning in December 2013, video-based shorebird surveys were also added to the monitoring plans at three of the sites (Fort Johnson, Bear's Bluff, and Hutchinson Cut), although no differences were observed among habitat types, most likely as a result of the generally low numbers of birds observed. Throughout this project, volunteers assisted with drop net sampling and shorebird surveys and were all educated about the importance of oyster restoration in South Carolina in terms of its benefits to priority conservation wildlife species.

Herpetological Research and Survey in South Carolina (*Combined Report* for Federal Grants #: T-2-2, T-26-R-1, and T-57-R-1, Duration: 2004-2006 / 2006-2011 / 2011-2016) PI: Will Dillman (SCDNR); Author: Andrew Grosse (SCDNR)

Gopher Tortoises are state endangered in South Carolina and understanding the life history of this species will lead to more informed management and conservation decisions for this species. In spring 2003, 16 Gopher Tortoises were equipped with radio transmitters: 8 at the Tillman Sand Ridge (TSR) Heritage Preserve and 8 at a Public Service Authority (PSA) property nearby. These two properties are located on the same sand ridge and likely are part of the same population; however, ownership and management are different at the two sites creating two separate groups. In 2006, 11 previously tracked Gopher Tortoises, as well as 14 new Gopher Tortoises, were equipped with new transmitters. Overall, male tortoises had significantly larger home ranges than females. PSA individuals had smaller home ranges, likely due to less suitable habitat and forage because of lack of management. Gopher Tortoises generally selected burrow locations with 30-50% canopy cover, approximately 20% shrub cover, and lower basal area (total, pine, and oak) than in surrounding available habitats. Isotopic analysis made it difficult to determine plant forage species and preferences; however, fecal samples suggested: a) most likely have diverse diets comprised of numerous taxa; b) they may consume less wiregrass relative to herbaceous species and/or broadleaf grasses; and c) they potentially consume less wiregrass than expected based on its availability in the habitat. Clutch sizes were obtained for seven PSA nests and 20 TSR nests. Mean clutch size at PSA was 5.85 eggs (range: 2-9 eggs) and was 5.55 eggs at TSR (range: 2-9 eggs).

At the Aiken Gopher Tortoise Heritage Preserve, waif Gopher Tortoises were translocated and penned to determine the if waifs can be used to recover and enhance the current population. During 2011, 13 released Gopher Tortoises were radio-tracked bi-weekly to determine their site fidelity, movements, and home ranges. These tortoises were all waifs and had been maintained in a 2.5-acre pen on the AGTHP for 2 years prior to their release in 2009. Thus, these tortoises had been radio-tracked for 2 years post-release. All 13 tortoises were alive at the end of the 2011 activity season, and all had remained on the AGTHP property. Nests were found in the apron of burrows in pens with waif tortoises and pens with native South Carolina tortoises.

SCDNR began the "Gopher Tortoise Initiative for South Carolina" in January 2015, to provide population estimates for identified populations and to continue efforts to identify outlying groups and individual tortoises. During our initial efforts, we identified extant populations of tortoises at sandhills associated with the Savannah River (Tillman Sand Ridge area, sandhills associated with the Coosawhatchie River (Jasper, Hampton, Beaufort County), and a population along the South Edisto River in Aiken County. We have collected additional records of individual or small groups of tortoises from Bamberg, Allendale, Colleton, and Dorchester Counties, though most of these records are isolated individuals. The Aiken County population occurs on what is now the Aiken Gopher Tortoise Heritage Preserve and has been the subject of efforts to restore habitat and to restock tortoises to the site using waif tortoises from throughout the range. Two additional populations exist, one at the Savannah River Site that was translocated to the site from Georgia in the early 2000's, and a small group maintained by the Town of Hilda, SC.

Evaluation of American Shad Stocking in the Edisto River (Federal Grant #: T-58-R-1 F12AF01378, Duration: 2012-2015) PI and Author: Tanya Darden (SCDNR) *See also T-45-R-1*

A reduction in catch-per-unit-effort for American Shad in the Edisto River over the past few decades highlighted the need to obtain river-specific information for this system and assess the potential of responsible stocking as an effective management tool. Through a collaborative effort among SCDNR's Wildlife and Freshwater Fisheries Division, SCDNR's Marine Resources Division, and the USFWS (Bear's Bluff National Fish Hatchery), six year classes of American Shad larvae (2009-2014) have been produced/stocked and genetic markers have been optimized to allow for estimates of hatchery contribution using genetic parentage analysis.

Our initial genetic evaluation on juvenile samples collected in 2010-2011 found that even with low stocking levels (< 22,000 larvae), hatchery fry could be detected among the out-migrating juvenile American Shad (up to 3.5%). Using adult samples collected from 2012-2014, we further evaluated the effectiveness of the stock enhancement efforts by determining whether hatchery fish recruit into the adult reproductive pool (i.e. during their return spawning migration). A single hatchery individual from the 2010YC was detected during the 2013 spawning run for a ~1% contribution to the adult American Shad population. We now have documented evidence that stocked larval American Shad can survive to adulthood and return to reproduce, suggesting that stock enhancement does have the potential to be a viable fisheries management tool for American Shad restoration in the Edisto River.

Our initial evaluation of adult samples collected in 2008-2011 (pre-stocking) indicated that the genetic composition of the Edisto spawning run is temporally stable over short time frames, genetic diversity is high and inbreeding is low, and effective population size is relatively large and within the levels recommended to maintain the population's evolutionary potential. Using adult samples collected from 2012-2014 (post-stocking), we investigated any potential influences of hatchery fish on the genetic health of the wild Edisto River American shad population (e.g. reduction of genetic diversity, increase in inbreeding, decrease in effective population size, significant temporal differences between collection years). We found that genetic diversity and inbreeding measures did not change appreciably between collection years, there was no pattern of decline in effective population size between pre- and post-enhancement periods, and there was no significant genetic differentiation between collection years which might indicate changes in

allele frequencies. Therefore, we do not see any evidence that our experimental-scale stocking has had any unintended impacts on the genetic composition of the Edisto River American Shad spawning run, although population genetic parameters should continue to be monitored as other year-classes return to spawn.

Composition of American Eels in Freshwater Habitats of South Carolina and Their Infection Status by the Invasive Parasite Species, *Anguillicoloides crassus* (Federal Grant #: T-59-R-1 F12AF01381, Duration: 2012-2015) PI: Stephen Arnott (formerly SCDNR); Authors: Stephen Arnott (formerly SCDNR) and Isaure de Buron (College of Charleston)

A 2012 benchmark stock assessment of American Eels determined that the U.S. stock was 'depleted'. A South Carolina index of eel abundance was used as part of the assessment. The index, which was derived from a SCDNR electrofishing survey of estuarine waters, showed declining eel numbers in the State since 2002, when the survey began. In response to research recommendations from the stock assessment, the main objectives of this project were: (i) to quantify life history parameters of American Eels in South Carolina; and (ii) to quantify infection rates of a debilitating invasive swim bladder parasite, *Anguillicoloides crassus*.

We examined a total of 1,150 American Eels from 11 South Carolina river drainages, including 677 larger stages (yellow and silver eels) and 473 juvenile stages (glass eels and elvers). After validating our otolith aging methodology, we found that eel ages ranged from 1 to 11 years, with 50% female maturity occurring around 4.5 years and 379 mm total length. Males were generally smaller than females and matured at a smaller and younger (although more variable) size and age. Unlike the females, they were mostly absent from estuarine waters during spring months, but they were caught at other times of the year.

Approximately 65% of the yellow and silver eels were infected by *A. crassus* and ~12% of them had 'severe' swim bladder damage caused by the parasite, as assessed using a previously published evaluation method. This damage likely impairs the eel's ability to migrate to the Sargasso Sea, where spawning occurs. Among the juvenile stages, we found that parasite infection occurred within a few months of glass eels recruiting to coastal habitats from the Atlantic Ocean. For the first time in the American Eel's range, we also identified four species of fish that act as paratenic hosts of *A. crassus*. These hosts provide a mechanism of spreading the parasite between habitats. The host species were Silver Perch, Highfin Goby, Spot and Mummichog. The findings from our study will be provided at the next stock assessment of America Eels with the aim of enhancing the utility of SCDNR's electrofishing dataset within the assessment model.

Validation of Trammel Netting Monitoring Population Trends for Diamondback Terrapins in the Charleston Harbor Estuary (Federal Grant #: T-60-R-1 F12AF01382, Duration: 2012-2015) PI and Author: Mike Arendt (SCDNR)

A three-year study of Diamondback Terrapin distributional patterns in the Ashley River was conducted beginning in 2013. Twenty-six female and 18 male Diamondback Terrapins were tagged with acoustic transmitters, a small subset of the nearly 700 Diamondback Terrapins captured and marked during this research study. In the first two years of the study, telemetry

data emphasis was primarily placed on comparing residence and movement patterns between creek and river habitats and increased emphasis on characterizing along-river movements in the third year of the study. Acoustically-tagged Diamondback Terrapins were detected most frequently between April and June. Individual terrapins were typically (median) detected nine times as frequently in river habitats than in creek habitats, with significantly more river detections during nocturnal periods as well as increased frequency of creek detection during diurnal periods. In contrast to initial assessment in 2013, tidal influence on detection in river vs. creek habitats was not significant.

Given disproportionate time spent in river habitats where commercial crab traps are extensively deployed, the need for improving the probability of implementing bycatch excluder devices (BRDs) as a conservation measure for Diamondback Terrapins in South Carolina was apparent. As such, five BRD designs were systematically developed and tested in 2014 and 2015 in the hopes of identifying a superior alternative to BRD designs that were unsatisfactorily tested with commercial crabbers in South Carolina during 2006–2008. A total of 3,062 crab trap soak hours were recorded during 689 trap sets that were evenly distributed between traps fished without and with BRDs in each year. Trap sets captured 3,184 blue crabs (997 of which were legal-sized, 31%) and 68 Diamondback Terrapins, with greatest capture of legal-sized crabs after August but nearly exclusive capture of Diamondback Terrapins during April and May. BRD designs tested in 2014 captured significantly fewer legal-sized blue crabs than traps fished without BRDs; however, a non-significant difference in catch rates for legal-sized crabs across trap designs was associated with the BRD design tested in 2015. Traps fished with BRDs were associated with a slightly greater frequency of not capturing any legal-sized blue crabs; however, visual observations recorded for a graduate thesis revealed no difference in the physical ability of large (i.e., up to 7.5 in. carapace width) legal-sized blue crabs to traverse through BRDs. Given this observation, and nearly identical size distributions and sex ratios between control traps and all but one BRD design tested in 2014, reduced absolute catch in BRD traps may stem from increased rates of crabs escaping through rigid funnel openings when BRDs are present, and future BRD research should systematically attempt to reduce the occurrence of this behavior.

Decision Support Tools for Stream Conservation (Federal Grant #: T-61 F12AF01417, Duration: 2012-2013) PI and Author: Mark Scott (SCDNR)

Identifying and communicating the relationships between natural gradients, human activities, and aquatic habitat integrity is crucial to aquatic conservation. The SCDNR, in conjunction with Clemson University, has developed a novel, web-based South Carolina Stream Conservation Planning Tool that enables a spatially explicit understanding of how human activities affect the biological condition of wadeable streams. This is intended to support decisions about aquatic conservation actions. The web mapping application communicates findings from the South Carolina Stream Assessment (SCSA) to a broad audience, allowing users to visualize predicted biological conditions based on their status and severity across all South Carolina wadeable stream catchments. Additionally, an interactive catchment management tool allows users to explore and forecast the impacts of customized land management scenarios on aquatic resource indicators at any user-specified location across South Carolina and so engages users in the process of modeling and forecasting stream conditions.

We selected stream condition metrics from over 200 measurements taken at approximately 700 streams locations sampled during the SCSA from 2006 to 2011. Metrics were related to spatial predictor data created under the National Fish Habitat Assessment. We generated prediction models using the Random Forest machine-learning technique from the sample data, and applied the predictions to the entire population of wadeable stream reaches in the State. The mapping application provides users with a browser-based interface to modify predictors at the catchment (local) scale. A web service dynamically generates predictions based on these user inputs, and results are mapped at watershed (network) scales to display cumulative effects of the changes. The dynamic execution of models broadens the utility of the application and opens the forecasting process to a non-technical audience. By providing an accessible means of forecasting the effects of management decisions, the tool encourages a watershed perspective towards aquatic conservation. The application is targeted to stakeholders at the policy making and conservation planning levels. The approach described has been set up for South Carolina but is applicable to assessment programs at the regional and national levels.

Mapping and Classifying Tidal Freshwater Wetlands in the ACE Basin (Federal Grant #: SC-T-F13AF01180, Duration: 2013-2015) PIs: John W. Leffler (SCDNR), Denise Sanger (SCDNR), and Saundra Upchurch (SCDNR); Author: Denise Sanger (SCDNR)

The study area of this project was located in the tidal freshwater zone within the Ashepoo-Combahee-Edisto (ACE) Basin watershed. This area is approximately 284,200 acres, and about 247,000 acres is within Colleton and remaining acreage is in Beaufort and Charleston counties. The three objectives of the project were met. First, the automated mapping tool that applies LiDAR (Light Detection And Ranging) data and remote sensing data to delineate land features was developed. However, only Colleton County was mapped because the LiDAR data for Beaufort and Charleston counties were not made available before projected ended. Secondly, the new high resolution land cover maps were compared to the 1999 SCGAP maps, and areas of change were identified and mapped. We have not attempted to request a change to the 1999 SCGAP maps that are currently housed on the USGS website. Thirdly, instead of conducting training workshops, an instruction manual that walks the user through the steps of the mapping tool was prepared. The manual was designed to be a stand-alone document that guides the user through the mapping process and provides descriptions of the process performed at each step of the tool. Also, two presentations were made at the Marine Resources Division Conference that was held during March 2014 and 2015.

Identification and Distribution of Crayfishes in South Carolina (Federal Grant #: SC-T-F13AF01182, Duration: 2013-2014) PI: Jim Bulak (SCDNR, retired), SCDNR; Author: Arnie Eversole (Clemson University, retired)
Crayfish specimens collected by SCDNR as a by-catch of water and stream sampling programs were identified to lowest possible taxonomic unit, and the number of form I males, form II males, adult females, ovigerous females, juvenile males, juvenile females and unsexed juveniles were recorded for each taxa. Of the 2,883 crayfish specimens in 406 collection jars, adult crayfish comprised 40.5% of the samples of which only 9.5% were form I males. The other adults in the collection were form II males (11.0%) and females (20.0%). A small percentage of the adult females (3.6%) were ovigerous or had attached early instars. Small crayfish classified

as juveniles (59.5%) were frequently too small using existing diagnostic characters to identify beyond genus.

Three genera and 26 species were encountered in the SCDNR collections. Specimens in *Procambarus* (n = 14 species), *Cambarus* (n = 11), and *Fallicambarus* (n = 1) accounted for 52.8%, 47.1% and < 0.1% of the samples, respectively. The most frequently identified species *P. troglodytes* and *P. hirsutus* occurred in 21.8% and 16.9% of the samples, respectively. The exotic *P. clarkii* was encountered in three samples. Two genera and 11 South Carolina crayfish species were not represented in the collections. Crayfish identified to species and geo-located SCDNR collection sites were merged into existing crayfish distribution data (A. Eversole and J. Foltz, unpublished data). These crayfish records added 6.8% to the 4,000 state-wide crayfish museum and collection records. Spatial distribution maps of all 38 described crayfish species in the State are displayed and the conservation status and research needs are discussed in the final report.

Evaluation and Monitoring of the Santee River Basin Robust Redhorse Restoration Effort (Federal Grant #: SC-T-F13AF01183, Duration: 2013-2016) PIs:, SCDNR; Author:

Robust Redhorse (*Moxostoma robustum)* is a large-bodied and long-lived Catastomid with a native range that encompasses the major rivers from the Carolina's Pee Dee River south to the Altamaha River in Georgia, with the notable exception of the Santee River Basin. In an effort to increase the long-term viability of Robust Redhorse within its native range, we began a restoration effort for establishing a self-sustaining population in the Santee River Basin. Broodstock from the Savannah River were used to stock 72,000 juveniles from 9 year classes that involved 101 independent parental crosses during 2004-2013. Fingerlings were stocked in two Broad River segments and one Wateree/Congaree River section. Incidental electrofishing collection of adult fish began two years after stocking began. Males in spawning conditions were first observed in 2008, and the first spawning triad was encountered in 2010. To date, over 70 adults have been collected and adults in spawning condition have been encountered in every stocked segment. Spawning behavior has been documented in two segments. Over 150 mature adult Robust Redhorse have been observed ascending a fish ladder on the Broad River preceding spawning season. Telemetry studies have shown extensive movement and repeated seasonal use of the specific river reaches. Genetic tagging evaluation and population characterization using a suite of 10 microsatellite markers (64 individuals) confirms that stocked fish are surviving in the new population, movement behaviors are similar to native populations, many year classes are present, genetic health metrics are optimistic and similar to the source population, and successful wild-spawned recruitment is occurring. Monitoring of the new Santee River population will continue, but all initial indications are optimistic for the restoration effort.

Assessing the Status of MacGillivray's Seaside Sparrows (*Ammondramus maritimus macgillivraii*) in South Carolina (Federal Grant #: SC-T-F13AF01185, Duration: 2013-2015) PI: Chris Hill (Charleston Southern University); Author: Chris Hill (Charleston Southern University)

Because of the challenges of monitoring populations of marsh-nesting birds, the abundance and demography of MacGillivray's Seaside Sparrow (*Ammodramus maritimus macgillivraii*) along

the Southeast Coast of the United States are relatively poorly known. To update what we know about this subspecies' status, we conducted 5-minute listening surveys at 127 points in tidal marsh habitat across South Carolina in 2014 and 2015. Ninety survey points were in 16 randomly chosen marshes across the State (others were in known historical breeding sites), and we surveyed each point three times over one breeding season. We also conducted an intensive study of nesting MacGillivray's Seaside Sparrows in 2015 at Tom Yawkey Wildlife Center Heritage Preserve, a site known to support a breeding population of these sparrows.

We found that MacGillivray's Seaside Sparrows are very scarce in South Carolina marshes away from a handful of historically known sites. At randomly chosen marshes, an average of only 0.08 sparrows were detected per survey, and when sparrows were detected on one visit to a random point, most often they were not detected on subsequent visits. This indicates either that some "occupied" sites were only visited by transients, or that the occupied marshes had a very low density of nesting birds, lowering detectability. The sparse detections on our statewide survey contrast with both surveys in Georgia and surveys at Tom Yawkey Wildlife Center, where multiple birds were often detected singing on each visit. The intensive study of the breeding population at Tom Yawkey Wildlife Center indicated that nest survival was high (0.92 daily survival rate; 16 of 34 nests with known outcomes fledged young), that predators (likely marsh rice rats, *Oryzomus palustris*), not flooding, were the major cause of nest failure, and that sparrows nested in the greatest density in an impoundment with a mix of smooth cordgrass (*Spartina alterniflora*) and saltgrass (*Distichlis spicata*).

Enhancement of Upstream Passage for American Eels at the St. Stephens Dam, SC (federal Grant #: SC-T-F13AF01207, Duration: 2013-2015) PIs: Allen Hazel (SCDNR) and Bill Post (SCDNR). Author: Bill Post (SCDNR)

American Eel *Anguilla rostrate* are catadromous fish, meaning they live most of their lives in freshwater but spawn in the Atlantic Ocean. Historically, the American Eel was very abundant in East Coast streams, occurring from the estuaries to the headwaters of Coastal Plain streams and at least as far inland as the Fall Line in larger watersheds, including the Savannah, Santee and Pee Dee river basins. Presently, American Eel distribution and population size may be affected by dams and other impediments to migration, although the American Eel is capable of traversing many obstacles that restrict migration and dispersal of other fishes.

The South Carolina SWAP lists American Eel as a species of highest priority, stating that the species performs integral roles in the diverse habitats and ecosystems in which it resides during all portions of its complicated life cycle, and has faced impacts that have caused stock declines in river basins both in South Carolina and across the species' broader range. The Santee River Basin, at 17,000 square miles, is the second largest drainage area in the Eastern United States. The Lower Santee and Cooper rivers are the keystone corridors used by diadromous fish to access habitats in the Santee-Cooper Basin. The first blockages encountered by upriver migrating fish in these systems are the Santee-Cooper project dams (Santee/Wilson Dam on the Santee River, St. Stephen Dam on the Re-diversion Canal, and Pinopolis Dam on the Cooper River). These dams are located on the lower end of the Santee Basin Coastal Plain. As such, adequate passage beyond these dams is essential to diadromous fish restoration throughout the basin. Passage at these dams provides direct access to approximately 160,000 acres of impounded waters in Lakes

Marion and Moultrie and 134 miles of tributary rivers extending to the vicinity of Columbia Dam on the Broad River and to Wateree Dam on the Wateree River.

From 2004-2014, SCDNR operated experimental eel ramps at the St. Stephen Dam and demonstrated that American Eel passage was feasible; however, due to frequent equipment failure from materials exceeding the life span of those used continuously in water, limited water flow, and bird predation, the preexisting experimental ramps needed to be replaced with a more permanent structure. A SWG-funded eel ramp construction project completed in 2015 allowed for the continued capture and passage of elvers at St. Stephen Dam. Manufacturing and installation of the new 6061 marine-grade aluminum eel ramp was completed in September 2014, and the system has operated without malfunction since it was installed. Additionally, the new eel ramp has collected 6,078 elvers and demonstrated a similar effectiveness for collecting elvers as the experimental ramps in place from 2004-2014, thus allowing for continued data collection and long-term abundance analysis.

An Evaluation of Culturing Carolina Diamondback Terrapins for Responsible Stock Enhancement (Federal Grant #: SC-T-F13AF01208, Duration: 2013-2016) PI: Erin Levesque (SCDNR) and Andrew Grosse (SCDNR); Author: Erin Levesque (SCDNR)

During the 2014-2016 mating/nesting season (May through July), viable clutches (1,089 eggs total) from 130 Diamondback Terrapin females captured in trammel nets, and viable clutches from 24 land-captured terrapins were collected and incubated at either male-producing (27ºC) or female producing (31ºC) temperatures. There was no difference in hatching success between these groups ($p>0.05$). There was a positive correlation with larger females producing more eggs per clutch and a greater mean egg size. Growth of hatchlings in Year 1 fed one of three diets (fresh fish, ZooMed pellets, or Mazuri pellets) was assessed from October 2014 through April 2015 to evaluate feed type; both groups fed commercial pelleted diets grew significantly more than those fed fish only. An overwintering study in 2015-2016 season did not provide desired information on preferred habitat due to opportunistic predation on hatchlings by Raccoons. A total of 411 “headstarted” (juveniles raised in a hatchery to accelerate growth) terrapins and 227 hatchlings have been released into the Charleston Harbor Estuarine system since 2014. Seventy-seven individuals have been retained to confirm sex, and 23 remain in a culture pond at the Waddell Mariculture Center for future investigations of accelerated time to maturity of head-started individuals. Results from this study provided information about how to efficiently capture females, harvest eggs, and grow hatchlings/juveniles in order to supplement depleted wild populations. Access to the large number of hatchlings and juveniles that can be cultured in the laboratory also allows investigation of the biology of these naturally cryptic life stages that will allow us to better manage wild populations.

South Carolina Small River Planning Project (Federal Grant #: SC-T-F14AF01233, Duration: 2014-2020) PI and Author: Mark Scott (SCDNR)

Small rivers—those defined as draining watersheds between 150 km² and 2,000 km²—comprise over 3,100 linear km in South Carolina and support a broad diversity of aquatic taxa. The Small River Assessment (SRA) was developed to extend and further the objectives of the South Carolina Stream Assessment (SCSA), which was limited to wadeable streams under 150 km² in

drainage area. The objectives of the SRA were to (1) design a sampling program to define the physical, chemical, and biological conditions in small rivers across South Carolina; and (2) implement a standardized data collection protocol at randomly-selected sites. This study followed the framework of the SCSA in obtaining data necessary to develop models that (1) rank influences on physical, chemical, and biological conditions; (2) identify stressor-response relationships; (3) predict and map population status from sample data; and (4) incorporate the modeled relationships into our decision support tool to allow definition of current and predicted future biological conditions in South Carolina's small rivers, including alternative scenario testing. The SRA represented the first-ever standardized, statewide assessment of small rivers in South Carolina.

One hundred randomly selected small river sites were sampled across South Carolina from 2016-2020, with site selection stratified according to ecobasins (ecoregion x river basin units) and drainage area. Sites were sampled following a standardized sampling protocol for fish assemblage composition, physical habitat, and water quality. Watershed land cover measures for each site were obtained from the 2016 National Land Cover Database in order to facilitate analyses of relationships between biological response measures and watershed factors.

Small rivers were particularly important in supporting freshwater fishes identified in the 2015 South Carolina SWAP as Species of Greatest Conservation Need (SGCN). Altogether, 44 freshwater and diadromous fish SGCN were observed in small rivers, representing 74% of the priority freshwater fish species identified in the SWAP. At least one freshwater fish SGCN was observed at 92% of the randomly selected small river sites, and 84% of sites yielded multiple SGCN. On average, more than four freshwater fish SGCN were observed at each river site, with as many as 11 SGCN observed in a single river site. The occurrence of SGCN was about twice as high in small rivers than wadeable streams, as they represented approximately one in every five fish species observed in small rivers compared with about one of every ten species encountered in wadeable streams. SGCN occurred in all ecobasins of the state; fish SGCN richness was generally higher in the uplands (Piedmont and Blue Ridge) than the Coastal Plain (Southeastern Plains and Middle Atlantic Coastal Plain), largely due to a greater diversity of range-restricted and endemic species in the uplands, many of which are SGCN.

Results of linear modeling suggested both natural and anthropogenic land cover gradients across South Carolina likely influence fish assemblages, including SWAP priority fish species. However, land use/cover appeared to be more important in the uplands. Richness of all native fish species primarily corresponded to elevation and urban land use gradients in the upland sites, whereas in the Coastal Plain native richness was related to gradients in dissolved oxygen (DO) and elevation. SGCN richness in the uplands was also positively related to dissolved oxygen as well as mean flow velocity, whereas in the Coastal Plain SGCN richness was positively related to elevation and DO. In terms of SGCN relative abundance, several predictors ranked high as predictors in the uplands, including water temperature, elevation, turbidity, forest cover, and DO. For the Coastal Plain, site characteristics such as DO, water temperature, and elevation again were more predictive of SGCN relative abundance than watershed variables.

Distribution, Population Ecology, Genetic Relatedness and Habitat Associations of Eastern Spotted Skunks in South Carolina (Federal Grant #: SC-T-F15AF00727, Duration: 2015-

2018) PI: Jay Butfiloski (SCDNR), David Jachowski (Clemson University); Author: from the thesis of Robin Yuet Ying Eng (Clemson University)

Eastern Spotted Skunks are a poorly understood mesocarnivore species that suffered a dramatic range-wide decline in the mid-1900s. Little is known about their current distribution or habitat needs, and in the southern Appalachians, where the Carolinas and Georgia converge, Spotted Skunks have never been studied. We investigated Eastern Spotted Skunk habitat selection to develop an understanding of their habitat and conservation needs in this region.

We used remote-camera surveys and occupancy modelling to evaluate factors hypothesized to influence the probability of Eastern Spotted Skunk detection and occurrence at the landscape scale. We detected Spotted Skunks at 55.6% of our sites and on 18.5% of sampling occasions. Our detection models supported predation risk, camera setup, and scent-based attractants as influential to detection probability but had poor predictive ability overall. Our top occupancy model had moderate predictive power and showed a negative relationship between elevation and occupancy probability. These results suggest Spotted Skunks in the southern Appalachians may be more widely distributed than previously thought but are also highly cryptic and in need of further investigation. In particular, there is a strong need for researchers to identify thresholds of habitat suitability for this species.

To evaluate fine-scale selection of rest site habitat by Eastern Spotted Skunks, we used VHF telemetry and discrete choice modelling. Over two summers we tracked 15 Spotted Skunks and collected habitat data for 233 rest sites and 233 random available sites. Our top model supported positive effects of understory cover and coarse woody debris (CWD), and a negative effect of distance to nearest drainage channel on rest site selection. Previous studies have identified understory cover as important for protection from avian predators; however, ours is the first to identify CWD and drainage channels as important to Spotted Skunk habitat selection. These attributes were hypothesized to be selected based on prey availability, but direct studies of Spotted Skunk diet and foraging strategies are needed. We also recommend further investigation regarding the importance of drainage networks to Eastern Spotted Skunks. Finally, we suggest that preservation of understory vegetation and CWD may benefit Eastern Spotted Skunk conservation in the southern Appalachians.

Using Citizen Science to Guide Statewide Management of Diamondback Terrapins (Federal Grant #: SC-T-F15AF00728, Duration: 2016) PI and Author: Mike Arendt (SCDNR)

A one-year study was initiated to increase awareness of Diamondback Terrapin management efforts in South Carolina. A comprehensive website was launched in mid-April and received over 5,000 unique page visits through December, with the greatest website visits coinciding with a barrage of media releases about terrapins in the fall. An online Diamondback Terrapin reporting form received 137 entries from across the State, but with disproportionately few observations reported north of Charleston County. Both of these deliverables will remain functional in future years and should require only nominal staff time for support and updating. Very few reports of injured or dead terrapins were received; thus, reliance on an existing (albeit sparse) network of authorized reptilian rehabilitation facilities appears to be sufficient for treating the few annual encounters reported by the public. Within-season recapture rates for

Diamondback Terrapins captured by a monthly trammel net survey in the Ashley River were less common in 2016 than during 2008 or 2009; however, overall population structure appears to have remained relatively stable in this system over the past decade. Continued efforts to refine a bycatch reduction device (BRD) show great promise from fishery-independent testing, but public reviews by commercial and recreational crabbers remain mixed. Several very favorable BRD reviews were reported in winter 2016-2017; thus, sustained emphasis on this important aspect of terrapin conservation is encouraged in future funding cycles.

Building Partnerships on State, Federal and Private Lands to Promote Conservation of Seabirds and Shorebirds (Federal Grant #: SC-T-F15AF00730, Duration: 2015-2017) PI and Author: Felicia Sanders (SCDNR)

Many seabird and shorebird populations are in decline. These birds face loss of habitat due to coastal development, sea level rise, armoring of the barrier islands and inlets, and increased recreational pressure along the coast. Nesting birds are especially negatively affected by human disturbance. In order to reverse the declines and stabilize these bird populations, it is necessary to protect nesting colonies and provide sanctuaries where birds can nest, rest, and feed with minimal disturbance. Posting signs and symbolic fencing around nesting areas gives nesting birds a buffer in which pedestrian traffic is restricted. This project built partnerships at 18 sites with managers of properties that have important seabird and shorebird habitat. At most sites, partners were staff or volunteers from the site's management organization. Partners were trained to identify, protect, and monitor beach-nesting birds.

Site visits were the most important activity that taught partners about the need and method to protect seabirds and shorebirds. Workshops and educational material were also used to educate partners. A workshop at Fort Johnson in the MRD auditorium was attended by over 100 participants including naturalists from coastal state parks, USFWS, and private lands. A training at Botany Bay Plantation started a Beach Stewardship program for volunteers. Also, a professional educational sign about shorebirds was purchased and installed at the beach at Botany Bay Plantation to assist beach stewards in educating visitors. A "Best Management Practices (BMPs) for Use of Vehicles" was published and distributed to partners who drive on the beach, especially those staff who also work on sea turtles. A "Breeding Birds of the South Carolina Coast" brochure was developed in partnership with the American Bird Conservancy. This brochure featured images of common coastal nesting shorebirds, seabirds, and wading birds. The brochure also had a conservation message about reducing disturbance to these birds and was distributed to partners.

Potential Mechanism of Thermal Stress Impairment for Striped Bass Populations (Federal Grant #: SC-T-F15AF00731, Duration: 2015-2018) PI and Author: Tanya Darden (SCDNR)
Striped Bass (*Morone saxatilis*) populations have declined throughout their range, and prevailing causal hypotheses are associated with increased summer temperatures. Unlike the northern anadromous populations of Striped Bass that move into coastal estuarine systems in the summer, southern populations tend to move into freshwater habitat for thermal refugia (Scruggs 1957; Combs and Peltz 1982; Bjorgo et al. 2000). Because of the increased temperature associated with global climate change and extreme temperatures of shallow coastal systems, it is possible that coastal populations of Striped Bass are crowded into available temperature refugia (thermal

niche squeeze) with detrimental results likely including direct mortality, decreased fecundity, and increased susceptibility to starvation, harvest, and parasites (Coutant 1985). We hypothesized that in addition to Coutant's (1985) individual-based impacts, thermal stress may result in evolutionary implications for Striped Bass populations, specifically through increased rates of telomere degradation. Telomeres are non-coding DNA regions composed of a conserved repetitive sequence that occur at the ends of linear chromosomes to protect the structural function of chromosomes as well as the DNA coding regions themselves. As the occurrence of organism-wide or critical tissue function loss can result in organismal death, increased net telomere loss rates have the potential to directly influence individual longevity (Barrett et al. 2013). Therefore, if thermal stress in Striped Bass results in higher telomere loss rates that are associated with decreased life spans, shifts in critical population life history traits (i.e. age and size at maturity, fecundity, etc.) would be expected.

Striped Bass remain an important and popular recreational fish species in South Carolina and represent a key indicator species for coastal ecosystems. As such, SCDNR continues to be interested in proactively improving our understanding of the factors currently impacting Striped Bass populations in order to develop management strategies to address potential continued declines. Our mariculture and genetic research teams have leveraged their expertise in both finfish production/husbandry and molecular tool development in conducting manipulative laboratory experiments to determine if thermal stress levels experienced in South Carolina coastal systems are capable of negatively influencing growth and telomere loss rates in Striped Bass. We initially hypothesized that thermal stress may result in evolutionary implications for Striped Bass populations, specifically through increased rates of telomere degradation. While potentially confounding factors in this study resulted in lower confidence in our comparisons of telomere length data between sampling time periods, we have demonstrated the significant effects that high temperatures and limited food have on Striped Bass growth and condition factor. Additionally, it appears Striped Bass may utilize regulation in telomerase activity to assist in reducing or minimizing impacts of potential stress sources that may increase telomere loss rates.

Although our project results have not identified a clear mechanism of thermal stress impacts in Striped Bass, the results are contributing substantially to our understanding of appropriate protocols and tools to evaluate telomere changes, such as incorporation of individual tracking and telomerase quantification with avoidance of short cut qPCR techniques, as well as increasing our knowledge of the complexity of cell replication processes and the influences of environmental factors on those processes. As average annual temperatures within the native Striped Bass range increase, we may expect to see an accelerated decrease in total area of thermal refugia for Striped Bass during the summer months, thereby presenting habitat constraint challenges for the already declining wild populations.

Assessing the status of the Eastern Black Rail in South Carolina (Federal Grant #: SC-T-F15AF00729, Duration: 2015-2017) PI and Author: Christy Hand (SCDNR)

This grant funded 2017 breeding season call-response surveys of Eastern Black Rails (*Laterallus jamaicensis jamaicensis*) at the Bear Island Wildlife Management Area (BIWMA) and the Tom Yawkey Wildlife Center (YWC) and the collection of data using motion-activated cameras (camera traps) during the 2016 breeding and post-breeding seasons. Over 75% of the survey

points where Black Rails were detected during the intensive 2015-2016 coast-wide survey efforts were located on BIWMA and YWC, two coastal wildlife management areas that are owned and managed by SCDNR. Continuing to survey these two properties on an annual basis increases our ability to promptly detect changes in occupancy. Across the two properties, 46 survey points were surveyed three or more times between 15 March and 30 June 2017 by SCDNR and USFWS employees. Black Rails were detected at 13 of the points surveyed (28.3%), including 12 points at the BIWMA and one point at the YWC. Black Rails were also detected at a total of 13 survey points at these two properties during 2016; however, they were detected at over twice as many points (29 points) during 2015. A summary of survey data collected during 2015-2017 is presented in the report. Using camera traps, Black Rail chicks were documented in two wetlands during the 2016 breeding season, allowing us to estimate the timing of incubation and chick rearing activities. Camera trap data collected during the 2016 post-breeding season provide the first documentation of the timing of definitive prebasic molt by Black Rails in Colleton County, South Carolina. During definitive prebasic molt, Black Rails are flightless and are particularly vulnerable to flooding events caused by storms or management activities. Determining the timing of nesting and molt will increase our ability to understand the potential effects of severe storm events and to make informed wetland management decisions.

Continuation of the Carolina Herp Atlas (Federal Grant #: SC-T-F15AF00207, Duration: 2015-2017) PI: Will Dillman (SCDNR) and Mike Dorcas (formerly Davidson College)

This project upgraded the existing Carolina Help Atlas that was first created under SWG grant T-37. The improvements included: optimizing the Atlas for mobile devices, thus allowing users to easily submit data from the field; redesigning the website interface for better compatibility with new web browsers; introducing new features for data accessibility and integration; and increased publicity for new and existing CRA resources.

Conservation of Seabirds, Shorebirds, Wading Birds, and Marsh Birds in South Carolina (I) (Federal Grant #: SC-T-F16AF00707, Duration: 2016-2018) PIs and Authors: Felicia Sanders (SCDNR) and Christy Hand (SCDNR)

Many of the seabird, shorebird, wading bird and marsh bird species that utilize South Carolina's coastal habitats throughout the year are of conservation concern due small and threatened populations. This grant funded efforts to reduce human disturbance at key seabird colonies and to conduct nest counts and population surveys of many waterbird species. These count data are incorporated into a long-term database to allow the agency to make informed management decisions as well as contribute to regional and global knowledge of the species. Also funded was research on two high priority species: Red Knots and Black Rails. Survey, research, and management activities were shared on webpages, in press releases, and at outreach events so results were available to partners.

SCNDR staff coordinated with private, federal, state, and county-owned beach managers to close part of the beach for nesting seabirds and shorebirds at 20 beaches during summer months and at 2 during the winter. Educational signs were placed at boat ramps and at some beach entrances. Annual seabird nest counts were conducted for Black Skimmer, Brown Pelican, Common Tern, Forster's Tern, Gull-billed Tern, Least Tern, Sandwich Tern, and Royal Tern. Counts consisted

of walking transects through the colonies and/or using aerial photographic surveys primarily conducted from SCDNR Law Enforcement planes. In 2018, Unmanned Aerial Vehicles (UAVs or Drones), were also used for surveying colonial seabirds. Least Tern nests were monitored at natural beach sites and also on artificial sites mostly consisting of pebbled roofs in industrial areas.

All known active Wood Stork colonies were surveyed each year. We counted 2,480 and 1,730 Wood Stork nests during 2017 and 2018, respectively. During mid-June, flights were used to determine if storks were successful at raising chicks or if the colonies had failed during the nesting season. A sub-set of the stork nests were monitored in index colonies to determine how successful the storks are at raising young in South Carolina. During 2017, a total of 232 stork nests were monitored in 7 colonies, and an average of 1.7 chicks fledged per nest site. An average of 2.0 chicks fledged per successful nest site. In the 157 stork nest sites that were monitored during 2018, an average of 1.6 chicks fledged (2.2 per successful nest).

Black Rails were under consideration for federal listing at the time; thus, we focused research on this species to better understand monitoring techniques and conservation strategies. We investigated temporal vocalization patterns to develop effective survey techniques for Black Rails in the Southeastern United States. Acoustic recordings collected using autonomous recording units suggested Black Rails were most responsive to call-playback during the sunset and sunrise sampling periods. Camera trap data collected during the breeding season suggested that Black Rails exhibited diurnal/crepuscular activity patterns. We also determined that Black Rails are present in small numbers during the nonbreeding season in breeding habitat.

We continued to capture Red Knots in 2017 and 2018. The purpose of the capture was to retrieve previously placed geolocators and to place nanotags on knots. Location data from nanotagged knots suggest that two-thirds of the knots in State may fly directly to the Arctic after leaving South Carolina beaches in the spring. Additionally a Red Knot with a geolocator was recaptured. It also left directly from South Carolina to nest in the Arctic and wintered in South America.

Conservation of South Carolina Coastal Plain Reptiles and Amphibians (I) (Federal Grant #: SC-T-F16AF00708, Duration: 2016-2020) PI and Author: Will Dillman (SCDNR)

South Carolina is home to 143 species of reptiles and amphibians, making it exceptionally diverse for its size. Excluding the sea turtles, 11 reptile and amphibian species are listed as Threatened or Endangered by the State of South Carolina and 48 are identified in the 2015 revision of the State Wildlife Action Plan. Many of these species are also included as species petitioned for protection under the Endangered Species Act (ESA) or are candidate species.

Surveys were conducted on 22 properties across South Carolina for winter breeding amphibian species, focusing surveys on Gopher Frogs, Tiger Salamanders, Flatwoods Salamanders, and Dwarf Sirens; all of these are species identified in the 2015 State Wildlife Action Plan (SWAP) Supplemental Volume under the Pond Breeding Amphibians Guild. We detected no Flatwoods Salamanders or Dwarf Sirens during all survey activities at any site. We observed Carolina Gopher Frogs (breeding, choruses, and egg masses) at multiple locations on two properties from

2016-2020. Tiger Salamanders were detected on 4 properties, one of which had 14 wetlands occupied during the 2019-2020 breeding season.

Upland snake surveys were conducted on multiple properties across South Carolina, using driving surveys and 14 camera trap fences, focusing on detecting the presence of Pine Snakes and Southern Hognose Snakes, which are included in the Longleaf Pine Reptiles and Amphibian Guild in SCDNR's 2015 SWAP Supplemental Volume. In total we detected 29 Pine Snakes and 10 Southern Hognose Snakes from 2017-2020. Of the 29 Pine Snakes, 16 were detected with camera traps, 6 during driving surveys, and 7 records that were either detected during other survey work or reported to SCDNR. Additionally, camera trap fences documented at least 35 other species of reptiles and amphibians. In conjunction with the camera traps, the long-term snake study on the Webb Wildlife Center, initiated in 1994, was continued from 2016-2019 and documented 19 snake species and 5 turtles species, including the recently petitioned Eastern Diamondback Rattlesnake, which, since the inception of this survey, has been documented a total of 198 times, consisting of 146 individuals.

The Gopher Tortoise is listed as State Endangered in South Carolina and only found in the southern-most portion of the Coastal Plain. Only two populations are on properties owned and managed by the State, including the Aiken Gopher Tortoise Heritage Preserve, which is a population made up almost entirely of "waifs"—tortoises from unknown origins, former captives, etc. We radio-tracked 71 hatchling, one- and two-year headstarted Gopher Tortoises to gain a better understand of the survival and movements of these rarely surveyed and little-known age classes. Preliminary data showed that two-year headstarted gopher tortoises had the highest survivorship of the three age classes and that average distance moved was a significant factor in determining survival.

Northern Yellow Bat Roost Selection and Fidelity in South Carolina (Federal Grant #: SC-T-F16AF00598, Duration: 2016-2017) PI: Mary Bunch (SCDNR, retired) and Mary Socci (Palmetto Bluff Conservancy); Author: Jennifer Kindel (SCDNR)

The primary purpose of this study was to investigate the roost site selection and fidelity of the Northern Yellow Bat by mist-netting and radio-tracking individuals at Palmetto Bluff, as well as completing acoustic surveys, recording bats foraging on the property and initiating a public outreach program to educate the community on the project and the environmental needs of bats. During the 2016-2017 study year, 226 net nights were completed over three seasons, resulting in 118 unique captures representing 8 species. Three Northern Yellow Bats were captured, radio-tagged, and tracked to roost over a period of 18 days per bat, leading to 12 separate roost discoveries including 9 roosts within the dead fronds of Sabal Palmettos and 3 roosts within Spanish Moss on pines or oaks. Roost fidelity was calculated with the Shannon Index and used to quantify the diversity and evenness of roosts utilized, with two bats receiving scores under one, indicating higher roost fidelity, and the remaining bat receiving a score of 1.5, indicating lower roost fidelity. A single Southeastern Bat, a South Carolina species of concern, was also radio-tracked to a Sweetgum roost over 6 days, at which point adverse weather disrupted the remainder of the tracking period. Another South Carolina species of concern as well as Federally Threatened species, the Northern Long-eared Bat was unexpectedly represented during this study which was located outside of their known range. Two individuals were caught separately with

DNA confirmation completed on the first capture via a hair and fecal sample. These captures represent unprecedented extralimital occurrences, suggesting previously unrecognized coastal populations.

Acoustic monitoring was conducted over 27+ nights over three seasons, although several nights were omitted to limit results to the projected 11 nights. Recorded calls were analyzed with Bat Call Identification (BCID), which is currently unable to identify Northern Yellow Bat calls; however, manual vetting suggested that some calls identified as Hoary Bat may have been misidentified Northern Yellow Bat calls. These manually vetted Northern Yellow Bat calls suggest the presence of the species at widely varying locations and habitats across the study area. Acoustic data also supported the unexpected capture of Northern Long-eared Bats with calls identified to the species by BCID on 6 nights. Cumulative data showed seasonal variation in nightly activity patterns including differences in number of calls recorded and temporal concentrations.

Optimal Nesting Microhabitat for Diamondback Terrapins in South Carolina (Federal ID#: SC-T-F16AF00713, Duration: 2016-2021) PI: Erin Levesque (SCDNR) and Andrew Grosse (SCDNR); Author: Erin Levesque (SCDNR)

Nest temperatures and predators were monitored in known areas of Diamondback Terrapin nesting activity in Charleston, SC and at Botany Bay Heritage Preserve, Edisto Island, SC over a five-year period, 2017-2021. Study locations were either defined as natural (limited human activity) or disturbed (increased human activity) to assess differences between these areas and potential differential nest success. Predator identification was largely qualitative; however, predators detected on natural nesting beaches were numerous, potentially because shorebirds and sea turtles used these areas to nest and predators optimized that season to feed on eggs and hatchlings. In 2021, 18 clutches of eggs were buried on the open beach at Botany Bay (natural) and 9 clutches were buried in a landscaped residential neighborhood at Wappoo Creek in Charleston (disturbed). While all of the 9 clutches buried in the disturbed site made it the entire incubation period, 6 of the 18 nests buried on the natural beach on Botany Bay were depredated. Mean hatching success across 21 nests that endured the entire incubation period was 75.6% (Botany Bay 70.8% and Wappoo Creek 82.0%). A 100% hatch rate occurred in nests with mean daily temperatures between 27.3ºC-29.9ºC, a mean maximum no greater than 35.2ºC and a mean daily range no greater than 9.2ºC. Hatching rate decreased significantly with increasing mean maximum daily temperatures and mean daily range in temperatures. The mean, maximum, and range of daily temperatures were significantly higher at the Botany Bay site (unequal variances t-tests, $p<0.0001$), and hatching success was significantly lower there. There were no hatchling mortalities and no differences in growth by nest temperature in the first 83-111 post-hatch. The mean temperatures, mean maximum temperature, and mean temperature ranges recorded over the five-year study period in vegetated/open habitats and natural/disturbed habitat in areas with documented terrapin nests fell within the limits that would produce successful hatching; however, there were some nesting areas that were significantly hotter than the nests that produced highest hatching success. Furthermore, terrapin nests in natural and disturbed areas are each susceptible to predation.

Documentation of Horseshoe Crab Nesting Beaches and Egg Densities (Federal Grant #: SC-T-F16AF01121, Duration: 2016-2019) PIs and Authors: Peter Kingsley-Smith (SCDNR) and Michael Kendrick (SCDNR)

This project provided insight into the spatial variability of American Horseshoe Crab spawning activity and an ability to compare embryonic development between habitat types (i.e., beaches vs. salt marshes). Although salt marshes are widely thought to be sub-optimal for emryonic development of Horseshoe Crabs, eggs were seen to successfully develop to the trilobite stage in this habitat. Spawning and fertilization were successful, but a lower percentage of trilobites was observed in salt marshes compared to beaches. In another component of the study, relationships between shoreline migration characteristics (i.e. erosional vs. accretional) and geographic orientation on levels of the abundances of spawning horseshoe crabs on beaches were investigated. Higher densities of Horseshoe Crabs spawned on north-facing, accretional shorelines compared to south-facing, erosional beaches. The public reported Horseshoe Crabs spawning throughout the State of South Carolina. The continuation of long-term tag-recapture efforts partially supported by this project helped to demonstrate that a small proportion of tagged Horseshoe Crabs made substantial migrations between South Carolina and other states to the south (Florida) and north (Massachusetts and Connecticut).

Investigating the Impacts of Harvesting on Ribbed Mussel Communities (Federal Grant #: SC-T-F16AF00714, Duration: 2016-2017) PI and Author: Peter Kingsley-Smith (SCDNR)

The overall goal of this project was to investigate Ribbed Mussel (*Geukensia demissa*) populations locally in South Carolina and to gain a better understanding of their ecological role in the salt marsh community. Furthermore, this project aimed to determine ecological baselines for this harvested species that could be used in the support of the future management of this emerging commercial fishery. The study monitored the demographics of a local *G. demissa* population at the Folly Beach County Park on a monthly basis over the course of a year in order to gain a better understanding of the size-frequency and size-at-age relationship for this species at sites in South Carolina. This sampling indicated that the population was dominated by larger individuals, that recruitment occurred at low levels over an extended period of the year, and that *G. demissa* is estimated to reach 15 years of age. The demographics of *G. demissa* were also compared between an unharvested and harvested site within the ACE Basin National Estuarine Research Reserve (NERR) to assess the impacts of an emerging commercial fishery on this species. While little difference was observed in the demographics of *G. demissa* at these two sites, the results from a concurrent, year-long manipulative experiment indicate that disruptive harvesting practices may have lasting effects on *Spartina alterniflora* health and the potential for *G. demissa* to recolonize harvested patches; however, these effects may be mitigated by selective harvesting techniques (i.e. size-selective removal of *G. demissa*). Another aspect of this project focused on the habitat characterization of *G. demissa* in relation to elevation and salinity. This involved the development of a model based on presence-absence surveys along a salinity gradient in the Ashley River, SC. The model predicted that *G. demissa* is most likely to occur at an elevation of 0.17m below MHW at intermediate (~18 ppt) salinities. Finally, this project incorporated small-scale drop net sampling to compare the nekton assemblages between areas of the saltmarsh with and without *G. demissa* patches. Based on this sampling, no differences in nekton community composition were observed at the scale of the patches sampled.

Abundance and Community Composition of Intertidal Macrobenthic Invertebrates
(Federal Grant #: SC-T-F16AF00720, Duration: 2016-2018) PI and Author: Andrew Tweel (SCDNR)

This project set out to explore several aspects related to the invertebrate community occupying the intertidal zone of several South Carolina beaches (Intertidal Marine Invertebrates Guild/Intertidal Foraging Habitat Guild for Shorebirds). The objectives were: 1) to determine abundance and factors influencing variability of intertidal macrobenthic communities along a gradient of natural habitat types in South Carolina; 2) to compare macrobenthic organism abundance and composition at pristine and erosional beach habitats to heavily managed beach habitats; and 3) to ultimately inform sustainable management of threatened species such as the Federally Threatened Piping Plover (*Charadrius melodus*) that depend on these invertebrates as prey.

Marine benthic invertebrates provide a method of assessing overall habitat quality and are also a critical food resource for finfish and shorebirds (Intertidal Marine Invertebrates Guild/Intertidal Foraging Habitat Guild for Shorebirds, SC SWAP 2015). In addition to serving as a prey resource, these species play a significant role in the cycling of organic matter and nutrients in coastal systems. Benthic invertebrates are utilized worldwide in assessments of habitat quality because they provide an integrative, reliable, and sensitive means for examining the impact of anthropogenic disturbance on living resources. Reasons for this include limited mobility, ease of sampling, and well-documented responses to a wide array of environmental stressors. The intertidal beach community composition, which typically includes amphipod crustaceans, small bivalves, and large errant polychaetes (Nereididae, Glyceridae), can vary depending on a range of factors including anthropogenic disturbance, water quality, sediment composition, and wave energy.

The benthic community and associated sediment characteristics were sampled in two habitats at each of three South Carolina beaches: Deveaux Bank (SCDNR), Botany Bay (SCDNR), and Harbor Island (private, residential). On Deveaux Bank and Harbor Island, a sheltered mudflat and exposed beach were both sampled, and both sites were being utilized as foraging grounds for Piping Plovers at the time of sampling. Botany Bay served as an example of a highly erosional beach, and two areas were sampled: sandy exposed beach, which was visually comparable to nearby beaches such as Seabrook and Edisto, and relic salt marsh beach habitat exposed by recent storm events. The relic marsh habitat was heavily utilized by a variety of foraging shorebirds but not Piping Plovers. Additionally, as part of other ongoing research, data for impacted sites at Captain Sam's Inlet, Kiawah North End, and Hilton Head Island were also available for 2017.

A total of 3,662 organisms, including 56 unique species, were identified for this study. Overall benthic invertebrate densities varied widely between habitats and locations, with the greatest densities observed in Piping Plover-occupied beach habitats on Harbor Island, and the lowest densities appearing in the adjacent sheltered habitat also used by foraging birds. Reasonably strong associations between habitat type (sheltered/exposed), sediment type, and infaunal community were observed, with amphipods and the Coquina clam *Donax variabilis* occurring in higher densities along sandy, energetic exposed beaches and polychaetes dominating the sheltered habitats characterized by lower wave energy and the accumulation of finer sediments. Furthermore, areas inhabited by foraging Piping Plovers exhibited significantly greater prey

resources than nearby unoccupied areas. This was particularly notable with regard to densities of Haustorid amphipods, a known target prey of Piping Plovers. Similarly, Haustorid amphipods were observed in greater densities at unimpacted beaches as compared to impacted beaches, but further work is needed to better quantify these effects. Although *Donax* clams are also a known prey, density did not correlate with foraging status, suggesting that these may be consumed opportunistically rather than targeted. High densities of the polychaete *Alitta succinea* observed at the Deveaux Bank sheltered mudflat correlate well with the high level of foraging activity observed in that area. Despite these trends, however, some areas foraged by Piping Plovers, such as sheltered habitats on Harbor Island, exhibited relatively low prey densities. These areas are also relatively unimpacted by direct or indirect human disturbance and may indicate that prey resources are one of several aspects of site selection. Overall, the Intertidal Marine Invertebrates Guild (Intertidal Foraging Habitat Guild for Shorebirds, SC SWAP 2015) appears to adequately reflect the variety of prey resources available to foraging shorebirds. Future research should prioritize further refining the prey species list for Piping Plovers and other threatened and endangered species which exploit intertidal marine invertebrates, perhaps by relatively new methods such as DNA barcoding of fecal samples, as well as to better quantify the effects of shoreline modification and sea level rise on prey resources for these sensitive species.

Participation by South Carolina in the SEARS Program (Federal Grant #: SC-T-F17AF00122, Duration: 2016-2017) PI and Author: Anna H. Smith (SCDNR)

This project supported the administration and implementation of the regional Southeastern At-Risk Species (SEARS) Program initiative through the Southeastern Association of Fish and Wildlife Agencies (SEAFWA) including development and implementation of conservation actions at a regional/multi-state level. To accomplish the SEARS Program's objectives, the annual contributions of each participating state's funding and matching funds supported third-party implementation of the SEARS Program through the SEAFWA main office. Cooperating states in the SEAFWA donated funding to a central pot of money in order to fund projects selected for that year's funding cycle. An Request for Proposals (RFP) announced the Program. (Funding for this work is the balance of contributed funding from each state, generally equivalent to 2% of the current fiscal year SWG apportionment for each participant, unless otherwise specified.) The three projects that were chosen for funding included:

1. "Population genetic assessment of MacGillivray's Seaside Sparrow (*Ammodramus maritimus macgillivraii*) as a potentially threatened taxon" [PIs: Dr. Stefan Woltmann, Austin Peay State University in TN; Dr. Christopher E. Hill, Coastal Carolina University in SC]
2. "Distributional surveys, taxonomic investigation, and conservation assessment of crayfishes in the Duck River Watershed of Tennessee and the Santee River Basin in North and South Carolina" [PIs: Dr. Zachary Laughman, West Liberty University in WV; Dr. Bronwyn Williams at the North Carolina Museum of Natural Sciences]
3. "Status Surveys for the Rattlesnake Master Borer Moth (*Papaipema eryngii*) in the Southeast Region" [PI: Dr. James Bess, Northland Environmental Services, LLC in MI]

Atlantic Coast Joint Venture – Catalyzing lack Rail Conservation Along the Atlantic Coast (Federal Grant #: SC-T-F17AF01249, Duration: 2017-2019) PIs: Amy Tegeler (SCDNR) and Christy Hand (SCDNR); Author: Amy Tegeler (SCDNR)

This grant funded the development of a draft Eastern Black Rail Conservation Action Plan. The Atlantic Coast Joint Venture (ACJV) adopted the Eastern Black Rail (*Laterallus jamaicensis jamaicensis)* as one of three flagship priority species, due to precipitous population declines and threats to its high marsh habitat throughout its coastal range. The Black Rail is a highly secretive marsh bird believed by researchers to be one of the most endangered birds along the Atlantic Coast. The Black Rail once occupied coastal areas from Texas north to Massachusetts, but its populations have declined precipitously resulting in a range contraction in the north of more than 450km and catastrophic declines and population collapses within historical population strongholds. Conservative estimates of Black Rail populations suggest that only 455 to 1,315 breeding pairs remain, a range-wide decline of >90% since the 1990s. Reasons for the precipitous declines, and how to address them, are poorly understood as research and conservation efforts are greatly hampered by the highly secretive nature and general inaccessibility of this species. The ACJV identified a critical need to improve the understanding of the factors most impacting Black Rail populations, and to develop a set of coordinated strategies to conserve the species. As such, the ACJV Management Board, representing State, Federal and non-governmental organizations (NGO) partners along the Atlantic Coast, agreed to focus their collective conservation efforts on implementing conservation actions to stabilize or reverse population declines. Atlantic Coast states within the ACJV, including the South Carolina Department of Natural Resources, contributed funds as part of the multi-state effort.

The ACJV coordinated many efforts that contributed to the development of the draft Black Rail Conservation Action Plan. The ACJV and Black Rail Working Group led a Black Rail Conservation Planning Workshop where representatives from State, Federal and Academic backgrounds developed and prioritized draft Black Rail conservation strategies. Several maps and data layers were also developed including a Black Rail conservation opportunity area map, a comprehensive high marsh spatial layer and a coastal impoundment layer for the Atlantic Coast, a derivative map of Black Rail priority areas and an irrigation mapper tool. All of the data layers and spatial mapping were incorporated into the draft Black Rail Conservation Action Plan. Work on the Plan will continue using funds from other sources.

Identifying Management Opportunities to Benefit Black Rails Nesting in Coastal South Carolina (Federal Grant #: SC-T-F17AF01208, Duration: 2017-2020) PIs and Authors: Amy Tegeler (SCDNR) and Christy Hand (SCDNR)

Managed tidal impoundments in coastal South Carolina have been found to host a substantial number of the remaining Eastern Black Rails (*Laterallus jamaicensis jamaicensis*) breeding in Atlantic Coast states and provide an opportunity to actively manage water levels to benefit Black Rails. The primary objective of this project was to develop targeted impoundment management techniques to increase nesting success and survival. Using camera trap arrays and water level loggers, we investigated the relationship between water level fluctuations, occupancy, and breeding success. As a result of this project, targeted management of water levels and vegetation structure focusing on meeting the habitat requirements of Black Rails was initiated or expanded

in 5 impoundments. Rails are also receiving greater consideration in management decisions throughout coastal SCDNR properties. In addition, we provided technical assistance to the ACE Basin National Wildlife Refuge and to the Nemours Wildlife Foundation, partnering with the US Fish and Wildlife Service Coastal Program, as they completed infrastructure improvements and targeted habitat management for Black Rails in impoundments on their properties.

Range, Life History, and Environmental Tolerances of the Waccamaw Crayfish (*Procambarus braswelli*) and the Hammock Crayfish (*Procambarus lunzi*) of Near-coastal Environments (Federal Grant #: SC-T-F17AF01207, Duration: 2017-2019) PI and Author: Michael Kendrick (SCDNR)

This project focused on two species listed in the SC State Wildlife Action Plan (SWAP), the Waccamaw Crayfish (*Procambarus braswelli*) and the Hammock Crayfish (*Procambarus lunzi*), both of which are known to occur in the Coastal Plain physiographic region. These species are of conservation priority, in part, due to their restricted distributions and relatively few known locations in the State. In addition, the geographic range, life history, and life cycle phenology of these crayfish are not well known but are important pieces of information for effectively managing such species. To build on our knowledge of the fundamental biology and ecology of these species, this project addressed two major goals: 1) To define the current range of the Waccamaw Crayfish; and 2) to document life history phenology and habitat characteristics of the Hammock Crayfish. Between October 2017 and March 2019, a total of 46 sites (17 in North Carolina and 29 in South Carolina) were surveyed in the Waccamaw, Great Pee Dee, and Little Pee Dee River drainages. A total of 21 Waccamaw Crayfish were collected across three locations, one in the Waccamaw and two in the Little Pee Dee, including five form 2 males collected on November 28, 2017 and one form 2 collected on January 24, 2018. The two sites in the Little Pee Dee where the Waccamaw Crayfish was found also contained the highly invasive Red Swamp Crayfish, *Procambarus clarkii*. The Red Swamp Crayfish was collected extensively during the sampling for the Waccamaw Crayfish and could be displacing the Waccamaw Crayfish, as well as other native crayfish species.

A study population of the Hammock Crayfish, *Procambarus lunzi*, was first identified in a wetland on a hammock island in Beaufort County. This wetland was surveyed over the course of a year to follow population dynamics and environmental conditions (e.g. water temperature, salinity, and dissolved oxygen). Temperature data demonstrated values and trends typical of seasonal changes, but salinity measurements were unusually high throughout the study and remained above those characteristic of freshwater habitats (> 0.5 psu). Salinity declined steadily over the course of the one-year project from 6 psu to ~1 psu. A total of 137 *P. lunzi* individuals were caught between October 2017 and November 2018. The highest catches of Hammock Crayfish occurred in February 2017 and November 2018. The majority of the individuals caught were juveniles (n = 105). Only one reproductively capable male (form 1) was caught. The overall low abundance of crayfish during each sampling event limited the ability to make accurate conclusions about the life history of this species. Environmental data, specifically the evidence of mesohaline conditions year-round in this wetland, however, coupled with the presence of *P. lunzi* during every sampling event, indicate that this species can tolerate salinities chronically higher than those typically characteristic of freshwater habitats.

South Carolina Bat Monitoring and Research Project (Federal Grant #: SC-T-F17AF01195, Duration: 2017-2020) PI and Author: Jennifer Kindel (SCDNR)

The purpose of this grant was to determine overall bat species richness and opportunistically radio-track Federally Threatened bat species, continue WNS surveillance and outreach, determine roosting requirements and foraging area characteristics of Northern Yellow and Northern Long-eared Bats on the Lower Coastal Plain of South Carolina (SC), initiate a South Carolina Citizen Science Bat Watch program, and to create a SCDNR bat database to efficiently house and share bat data.

The 2017 and 2018 SCDNR mist-netting seasons resulted in a netting effort of 404 net nights deployed over 48 total survey nights over 6 properties making up 5 study sites. A total of 269 bats were captured representing 10 different species. The Santee Coastal Reserve WMA had the highest capture rate per night, highest species richness, and was the only site where Northern Long-eared Bats were represented with 8 individuals captured. The Santee Coastal study site accounted for 83% of all *Myotis* species and 90% of Tricolored Bats captured. Chestnut Ridge HP accounted for the remaining 17% of Myotis species captured and, with Belfast WMA, the remaining 10% of Tricolored Bats captured. Five of the 8 Northern Long-eared Bats captured were radio-tagged and tracked to day roost sites. The adult male roosted in a Sweetgum cavity, and all females (sub-adult and pregnant) roosted under the bark of live, mature Longleaf Pines. We estimate the pup season for this population to be between late April and early May. In both years during summer, WNS swabs testing for *Pseudogymnoascus destructans* (*Pd*), as well as environmental samples and collected guano, were negative. In the winters of 2018 and 2019, a total of 30 hibernacula counts were conducted in caves, mines, rock shelters, and culverts, yielding a bat count of 160 bats. Five Tricolored Bats were observed in Oconee County with signs of WNS, and swabs testing positive for *Pd* were collected in 3 new counties: Cherokee, York, and Spartanburg.

In 2018 and 2019, 6 Northern Yellow, 7 Tricolored, and 2 Northern Long-eared Bats were radio-tagged and tracked to roost trees as part of a project to determine summer roosting requirements for these species. Northern Long-eared Bats were excluded from the results due to small sample size. Tricolored and Northern Yellow Bats were found to switch roosts every 1.3 days on average and used 3.8 and 4.5 trees per bat over the 5-9 day tracking period respectively. Tricolored Bats roosted in foliage while Northern Yellow bats roosted in dead palm fronds; both species roosted in Spanish Moss in hardwood trees. Acoustic surveys were also conducted to determine habitat usage and characteristics for these species.

We created the SCDNR Bat Watch Citizen Science Project to engage the public and collect state-wide data on bat emergence counts of summer maternity sites with the assistance of volunteers. Between 2018 and 2020, a total of 135 emergence counts were submitted from bat boxes, bat condos, buildings, and trees by 14 volunteers at 25 sites across the State for a grand total of 15,621 bats counted. We also held Halloween Bat Counts at Sunrift Adventures Inc. in 2018, 2019, and 2020, with a total of 180 people in attendance and 2,200 total bats counted emerging from boxes on the shop at Sunrift. We also set up an ArcGIS database and data entry forms utilizing Survey123 within our Heritage Trust database. Between 2017 and 2020, a total of 830 bat records were entered into our Heritage Trust database. All hibernacula and maternity

colony bat data was also submitted to the NABat online portal. These tools will allow us to more easily observe species trends such as population changes across the State.

Survey of Historic Flatwoods Salamander Localities (Federal Grant #: SC-T-F18AF00026, Duration: 2017-2019) PI: John Pallis (private researcher); Author: Andrew Grosse (SCDNR)

Frosted Flatwoods Salamanders (*Ambystoma cingulatum*) are known to occur in well-managed Longleaf Pine savannahs and flatwoods ecosystems in three southern states: South Carolina, Georgia, and Florida. This species is listed by South Carolina as a non-game State Endangered species and by the United States Fish and Wildlife Service as Federally Threatened due to loss of habitat and reduction in extant populations. Historically, the Francis Marion National Forest and Santee Coastal Reserve Wildlife Management Area were known to be the only public lands in South Carolina where they occurred. Annual survey efforts by the South Carolina Department of Natural Resources, and others, have failed to document Frosted Flatwoods Salamanders since 2010. Dipnet and minnow trap surveys were conducted in 2019 at 25 wetlands, when suitable breeding conditions occurred. This included all known and suitable historic Frosted Flatwoods Salamander breeding wetlands in both the Francis Marion National Forest and Santee Coastal Reserve Wildlife Management Area. Despite extensive surveys, no Frosted Flatwoods Salamanders were found.

Conservation of Seabirds, Shorebirds, Wading Birds, and Marsh Birds in South Carolina (II) (Federal Grant #: SC-T-F18AF00961, Duration: 2018-2020) PI and Authors: Felicia Sanders (SCDNR) and Christy Hand (SCDNR)

Many of the seabird, shorebird, wading bird and marsh bird species that utilize South Carolina's coastal habitats throughout the year are of conservation concern due to small and threatened populations. This grant funded efforts from October 2018 – September 2020 to reduce human disturbance at key seabird colonies and to conduct nest counts and population surveys of many waterbird species. These count data are incorporated into a long-term data base to allow the agency to make informed management decisions as well as contribute to regional and global knowledge of the species. Survey, research, and management activities were shared on webpages, in press releases, and at outreach events so results are available to partners. Five scientific manuscripts were published.

SCDNR staff coordinated with private, federal, state, and county-owned beach managers to close part of the beach for nesting seabirds and shorebirds at 21 beaches during summer months and at two sites during the winter. Educational signs were placed at boat ramps and on some beach entrances. Annual seabird nest counts were conducted for Black Skimmer, Brown Pelican, Common Tern, Forster's Tern, Gull-billed Tern, Least Tern, Sandwich Tern, and Royal Tern. Counts consisted of on-the-ground estimates or estimates from aerial photographs taken from SCDNR Law Enforcement planes or Unmanned Aerial Vehicles (UAVs or drones). Least Tern nests were monitored at natural beach sites and on artificial sites that mostly consist of pebbled roofs in industrial areas. Peak statewide nest estimates for this project period are: Black Skimmer (2019) 1049, Brown Pelican (2019) 6109, Common Tern (2020) 9, Forster's Tern (2019) 12, Gull-billed Tern (2020) 182, Royal Tern (2019) 12,983, and Sandwich Tern (2019) 3562.

Wood Storks had a very productive nesting season during 2019. The number of nests counted (3,075 nests) far exceeded the previous record high count in South Carolina. During 2020, a statewide stork census could not be completed, but based on ground counts and the review of video footage, the nest numbers were probably within the same range as annual nest counts during the past decade (2,000-3,000 nests). At index colonies, individual stork nests were mapped as they were initiated and were monitored from a distance (using a spotting scope or binoculars) approximately once per week from the time that egg laying began until the chicks reached fledging age. During 2019, a total of 268 stork nests were monitored in 7 colonies. An average of 2.0 chicks fledged per nest site and 2.4 chicks per successful nest site. During 2020, a total of 139 nests were monitored in 4 colonies. An average of 1.6 chicks fledged per nest site and 2.4 chicks per successful nest site.

To determine the timing of arrivals/departures and the seasonal presence of Black Rails, Soras, Virginia Rails, and Yellow Rails in coastal South Carolina, 3 to 12 arrays of 5 camera traps were deployed and maintained throughout October 2018 – August 2020. Black Rails were detected in South Carolina during every month of the year; however, it is unclear if some or all these individual rails are year-round residents or migrants from northern states. Virginia, Sora, and Yellow Rails were also detected by camera traps during the nonbreeding season. Virginia Rails, which previously were not known to breed in South Carolina, were documented breeding in Georgetown County, South Carolina during 2018 and 2019. We captured 29 Ruddy Turnstones in spring 2019 and placed nanotags on them. Most of the turnstones were captured eating Horseshoe Crab eggs at Turtle Island WMA. All Ruddy Turnstones from this capture flew directly to Arctic habitat from South Carolina.

Investigating Dispersal of the Invasive Red Swamp Crayfish (*Procambarus clarkii*) and its Effects on the Distribution and Status of Native Crayfish Populations (Federal Grant #: SC-TF18AF00962, Duration: 2018-2022) PI and Author: Michael Kendrick (SCDNR)

In South Carolina, the introduced Red Swamp Crayfish (*Procambarus clarkii*) has been established since at least the 1970s. The existence of aquaculture ponds in the lower Pee Dee/Winyah watershed (near Georgetown, SC) in the 1970s and 1980s represent important potential sources for the Red Swamp Crayfish that are currently established in natural streams and wetlands in this area. The species is also located in the upper Waccamaw and Little Pee Dee watersheds, but it has been unclear if these Red Swamp Crayfish populations are the result of a series of human-mediated introductions, or if these populations resulted from a single introduction event, followed by subsequent dispersal throughout the watershed. Understanding the relative importance of these dispersal mechanisms is vital for developing effective strategies for mitigating the effects of nuisance species on native taxa. Genetic analyses and field surveys were used to better understand these dispersal patterns and the impacts of this species on native species. Results show a relative lack of population genetic structure in the Little Pee Dee and Waccamaw, as compared with the Winyah region, suggesting that natural dispersal is likely an important factor leading to the recent spread of the Red Swamp Crayfish in the Little Pee Dee and Waccamaw watersheds. Field surveys show that a quarter of all documented Coastal Plain Crayfish (*P. ancylus*) in the study region have been potentially extirpated by the spread of the Red Swamp Crayfish. Similarly, 14% of the Carolina Sandhills Crayfish (*P. pearsei*) and 19% of the Cedar Creek / Waccamaw Crayfish (*P. braswelli* / *P. chacei*) populations within the study

area appear to have been extirpated by the spread of the Red Swamp Crayfish across the upper Waccamaw and Little Pee Dee drainages. The hypothesis that the Red Swamp Crayfish populations are rapidly dispersing is supported by both field surveys and genetic analyses, and their ability to displace native taxa is also highlighted. The spread and impacts of the nuisance Red Swamp Crayfish threatens native organisms, especially those within South Carolina's Coastal Plain.

Concentrations of Organic Contaminants in Carolina (*Sphyrna gilberti*) and Scalloped *(Sphyrna lewini*) Hammerheads: Implications for Success and Survival in Nursery Habitats (Federal Grant #: SC-T-F18AF00964, Duration: 2018-2021) PI and Author: Bryan Frazier (SCDNR)

The main objectives of the study were to quantify a suite of legacy organic contaminant concentrations (83 compounds) in hepatic tissue of young-of-year (YOY) sharks of two hammerhead species, Scalloped Hammerhead (*Sphyrna lewini*) and Carolina Hammerhead (*Sphryna gilberti*). YOYs were sampled from across three states in the Atlantic Southeast, with most samples coming from South Carolina (n = 104), followed by Florida (n = 29) and Georgia (n = 13). As these are cryptic species, samples were genetically assigned post-hoc as either *S. lewini* (n = 56), *S. gilberti* (n = 74), or hybrid (n = 11), and contaminant concentrations and signatures were compared between species (and hybrids when analyses allowed). Samples that could not be genetically confirmed were removed from analyses (n = 5). Organic contaminants were grouped by class (i.e. polychlorinated biphenyls [PCBs], dichlorodiphenyltrichloroethane [DDT] and its metabolites [DDX], and non-DDT pesticides) and the sum of total organic contaminant (Sum OCs) concentrations were quantified for each sample. While overall Sum OCs did not differ between species, significant differences were found for DDXs and PCBs, with *S. gilberti* tending to have higher DDX concentrations and *S. lewini* having higher PCB concentrations. A Random Forest Analysis conducted only on *S. lewini* and *S. gilberti* was able to correctly identify species 85% of the time. Interestingly, when hybrid samples were included, the ability of the model to correctly predict *S. lewini* assignment increased and hybrids were overwhelmingly (81%) assigned as *S. gilberti*, which likely reflects maternal species identity. In general, Sum OCs were highest in the smallest (i.e. youngest) sharks with concentrations decreasing with length for both species, suggesting that growth dilution may account for the decrease in mean concentrations. To test if growth dilution could account for this decrease with length, we created two growth dilution models based on previously published allometry relationships for these species. In general, a larger proportion of *S. gilberti* than *S. lewini* appeared to have contaminant concentrations that exceeded their ability to undergo growth dilution as established by our models. This may possibly be attributed to *S. lewini* having an earlier purported parturition timeframe (i.e. more "growing days") than *S. gilberti*. When these individuals were removed from the data set, the inverse relationship between fork length and Sum OCs was abolished for *S. gilberti* only, possibly suggesting a decrease in fitness and removal from the population. The results of our study suggest that maternal offloading significantly shapes YOY contaminant signatures and may have implications for survival and fitness during the first months of life, the latter of which is yet to be empirically tested.

Addressing Crucial American Eel Life History Questions: Baseline Data on the Age and Sex Composition of American Eels in South Carolina, with a Comparison of Different

Aging Methodologies (Federal Grant #: SC-T-F18AF00965, Duration: 2018-2020) PI and Author: Brock Renkas (formerly SCDNR)

American Eel (*Anguilla rostrata*) are of concern both nationally and locally, being twice petitioned for listing as Federally Threatened or Endangered under the Endangered Species Act by the UU Fish and Wildlife Service and listed as a species of highest priority by the South Carolina State Wildlife Action Plan (SCDNR 2015). The 2015 SC SWAP also identified the need to "determine size, sex, and age structures for each sub-population of American Eels" as a conservation recommendation. Since before 2010, SCDNR has collected American Eel specimens for laboratory analysis of life history parameters, mostly through electrofishing surveys in both freshwater and estuarine habitats. The overall accomplishments of this project were to leverage currently collected histological gonad (n = 1,141) and otolith (n = 1,081) samples to address critical data gaps identified in recent American Eel stock assessments. Life history parameters such as size structure, age structure, sex ratio, size-at-maturity, and age-at-maturity were assessed for South Carolina eels. Additionally, otolith samples were processed via two separate techniques recommended by the Atlantic States Marine Fisheries Commission for American Eel aging, and results were then shared regarding the preferred method. Final metrics showed that the thin sectioned method currently used by SCDNR for aging eel is far more precise with less bias compared to the whole otolith aging method. The final report for this grant provides the most detailed region-specific life history data ever produced for American Eel in South Carolina, and it is therefore valuable at state and federal levels for management of the species.

NABat Acoustic Monitoring in South Carolina (Federal Grant #: SC-T-F18AF00972, Duration: 2018-2022); PIs: Susan Loab (Clemson University/US Forest Service), Dr. David Jachowski (Clemson University), Anna Siegfried (graduate student, Clemson University), and Jennifer Kindel (SCDNR); Author: Jennifer Kindel (SCDNR)

Many of South Carolina's bat species are species of concern and thus, monitoring their population trends and distribution is critical for long term conservation and management. South Carolina was one of the first states to implement the North American Bat Monitoring (NABat) Program. The program has continued each year since its initiation in 2015. The objectives of this project were to continue NABat monitoring across South Carolina and 1) compare models of bat occupancy based on site level characteristics to those based on cell level characteristics to determine the best methods for long-term monitoring and data collection across the State, and 2) determine trends in bat populations across the State and within regions from 2015-2020 based on mobile acoustic transect data. We acoustically surveyed 37 of the 38 established NABat cells across South Carolina in 2019 and 32 of the 38 established cells of priority in 2020. Trend analyses were based on mobile acoustic data we collected in 2019 and 2020 along with those collected from 2015 to 2018. We measured habitat structure at each of the point survey locations and used these data along with landscape level data obtained from various sources to model bat species or species group occupancy at the point and cell levels. We found that the addition of point level data, such as canopy closure and tree density, as well as distance to water and distance to roads, increased our ability to model occupancy for some species. However, cell-level variables were better for other species. This suggests that collecting site level data along with landscape level variables may be valuable for

future modeling efforts. Overall, relative population trends of bats across the State were stable or slightly increasing for most species despite the various threats, such as White-nose Syndrome, that have been impacting South Carolina's bats. However, we were only able to model 6 years of data, and better resolution of population trends will be obtained as more data are obtained.

Green Salamander Population Assessment and Connectivity Across a Gradient of Forest Disturbance (Federal Grant #: SC-T-F18AF00973, Duration: 2018-2022) PI: Will Dillman (SCDNR) and Kyle Barrett (Clemson University); Author: Will Dillman (SCDNR)

The Green Salamander (*Aneides aeneus*) inhabits rock outcrops embedded in mountainous forested landscapes. Green Salamanders are listed as "Near threatened with decreasing populations" by the IUCN Red List and ranked as "Critically Imperiled" in South Carolina by the Department of Natural Resources. This project addressed the objectives of the 2015 State Wildlife Action Plan related to Green Salamanders by 1) identifying suitable habitat features that could be used to derive estimates of occupancy probability of Green Salamanders;(2) estimating population size using a mark-recapture study across 21 sites; and 3) estimating genetic connectivity and inbreeding across 15 sites.

To identify suitable microhabitat features for Green Salamander occupancy, we evaluated features that contribute to microclimate and within-habitat connectivity, including crevice depth (cm), width (cm), length (cm), canopy cover (%), distance from the nearest tree (m), distance from the nearest crevice (cm), and crevice density within a 1 m^2 area. We actively searched for Green Salamanders while assessing these features. We surveyed 424 crevices across 5 sites and found Green Salamanders occupying 116 of the crevices. A global logistic regression model identified crevice width, canopy cover, and crevice density as significant predictors of Green Salamander presence. To estimate population size, we performed capture-mark-recapture methods across 21 sites. Sites were surveyed following the two-tiered procedure of the Pollock's robust design. Population abundances ranged from 3 to 27 individuals (mean = 14.05, SD = 7.33). Green Salamander abundances did not strongly correlate with site elevation or size but did show an increase related to south-facing aspect and the number of crevices present at a site. We assessed genetic connectivity and inbreeding status across 15 sites. We also quantified land cover change from 2001 to 2021 using the National Land Cover Database (NLCD) to compare the genetic connectivity of Green Salamanders to the gradient for land cover type available. Sampling locations showed low levels of genetic diversity and population subdivision. F_{ST} values ranged between 0.002 and 0.267 (mean = 0.07). Sampling locations also showed low levels of F_{IS} values ranging from -0.09 and 0.11 (mean = -0.05), indicating inbreeding is not occurring within sites. Comparative results from the 2001 and 2021 NLCD data showed the area of deciduous, evergreen, and mixed forest land covers decreased by less than 2% in the 20-year time span. Results are consistent with ongoing migration among sampling locations, or historically contiguous population structures.

We recommend rock outcrops with the following features be prioritized for Green Salamander conservation: outcrops with most crevice widths measuring < 3 cm, very high canopy coverage (≥ 99%), and high crevice densities of at least 7 crevices per m^2. Regarding our genetic results, we see no strong population structure across sites and there

is evidence to suggest sufficient gene flow is occurring to maintain similar allelic frequencies across the surveyed populations, and the lack of land cover change may indicate that movement throughout the generations is not hindered by a loss of habitat. Because Green Salamanders prefer rock outcrops with high canopy cover, we recommend preserving the forested land cover between and within known populations.

Environmental DNA Determination of the Distribution of the Patch-Nosed Salamander (*Urspelerpes brucei*) in South Carolina (Federal Grant #: SC-T-F19AF00717, Duration: 2020-2022) PI and Author: Cathy Jachowski (Clemson University)

The Patch-nosed Salamander (*Urspelerpes brucei*) is a small, lungless salamander (family Plethodontidae) that was first discovered in 2007 and was subsequently described as a new genus and species. As of 2020, the species was only known from a handful of headwater streams in a 24 km^2 region spanning a portion of the South Carolina-Georgia boundary and the mainstem Tugaloo River. At the onset of our study, the species was known from only one locality in South Carolina (Oconee County) and listed as a "Highest Priority Species" in South Carolina's 2015 State Wildlife Action Plan. A major challenge to conservation of the species is a lack of knowledge regarding its distribution in the State. In our first objective, we used existing data from occupied and unoccupied localities in Georgia and South Carolina to develop a preliminary predictive model of species occurrence. Our preliminary model suggested Patch-nosed Salamanders were most likely to occur in close-proximity of other known localities and in streams surrounded by relatively steep and rugged terrain. In our second objective, we used our model from Objective 1 to prioritize areas in South Carolina for future surveys. We collected water samples from 85 high priority localities and used a previously validated environmental DNA (eDNA) assay to assess each sample for genetic evidence of the species. We detected Patch-nosed Salamander DNA from only two of 85 samples (0.02%), both clustered near the confluence of a single tributary of the mainstem Tugaloo River, approximately 4.5 km northwest of the only other known locality in the State. In our third objective, we conducted ground-truthing surveys to compare effectiveness of survey methods and compare the distribution of Patch-nosed Salamanders in the two South Carolina localities. In total we detected 32 Patch-nosed Salamanders across both sites. Patch-nosed Salamanders had a low detection probability ($p \leq 0.15$) but were most likely to be detected with unconstrained active searches and aquatic leaf litter bags in spring (March-April). Additionally, the species was more homogenously distributed and about ten-times more common in one locality relative to the other, though the drivers of these patterns remain unclear. We conclude that Patch-nosed Salamanders are uncommon, and patchily distributed both among and within small headwater streams in a single 12-digit hydrologic unit code [HUC 12] (and perhaps bordering catchments) in the State of South Carolina.

Response of Bachman's Sparrow (*Peucaea aestivalis*) to Habitat Management in a Wiregrass-free Ecosystem (Federal Grant #: SC-T-F19AF00718, Duration: 2019-2021) PIs and Authors: Mikayla Thistle (SCDNR), Beth Ross (Clemson University), Mark McAlister (SCDNR), and Jamie Dozier (SCDNR)

Through much of its range, Bachman's Sparrow (*Peucaea aestivalis*) uses the wiregrass (*Aristida spp.*) dominant understory typical of Longleaf Pine (*Pinus palustris*) forest. The central South Carolina Coastal Plain, however, lies within the "wiregrass gap" where Longleaf Pine understories are absent of wiregrass and instead are dominated by bluestem grasses (*Schizachyrium spp.* and *Andropogon spp.*), Bracken Fern (*Pteridium aquilinum*), and shrubs. Habitat use by Bachman's Sparrow in this region has yet to be studied, and declining Bachman's Sparrow populations necessitate a better understanding of habitat selection processes and population dynamics across regional habitat types. The goal of this study was to describe breeding season habitat selection and breeding ecology of Bachman's Sparrow in the unique wiregrass-free Longleaf Pine ecosystem of Tom Yawkey Wildlife Center, Santee Coastal Reserve, and Washo Reserve, South Carolina to inform best management practices for Bachman's Sparrow.

We conducted repeated visit point count surveys at 95 sites and used open *N*-mixture models to estimate the effects of habitat management and forest stand characteristics (e.g. prescribed burns, basal area, stem density, pine species, canopy closure) on Bachman's Sparrow abundance, apparent survival probability, and recruitment rates during the 2020 and 2021 breeding seasons. We also located nests to identify vegetation composition and structure characteristics that Bachman's Sparrows select for nest-sites. To determine if habitat selection in the study population was adaptive, we monitored nests and related nest-site selection to nest survival rates by comparing habitat characteristics related to selection with those related to survival. Across the 9 primary sampling periods, we estimated the abundance of male Bachman's Sparrows within the study area to be between 23 and 49 individuals. Initial abundance and recruitment rates were strongly predicted by the proportion of Longleaf Pine to other pine species within the sample area, with abundance and recruitment rate increasing with Longleaf Pine dominance. Apparent survival probability decreased as the density of stems between 10 and 25 cm DBH increased. Nest site selection in the study population was non-adaptive. Bachman's Sparrows selected nest sites that had intermediate groundcover densities compared to available nest sites; however, nest survival rates decreased at intermediate groundcover densities. The results of this study can be used to inform region-specific management plans and restoration of degraded habitats, which often lack typical understory species like wiregrass, to increase Bachman's Sparrow abundance and reproductive success.

Effects of Forest Management on Early-successional Avian Species in South Carolina
(Federal Grant #: SC-T-F19AF00719, Duration: 2020-2022) PI and Author: Amy Tegeler (SCDNR)

Early-successional habitats are a critical habitat type for Ruffed Grouse (Bonasa umbellus) and Golden-winged Warblers (*Vermivora chrysoptera*). In the Southern Blue Ridge Ecoregion, early-successional habitats have declined over the last 70 years, and the extent of which Ruffed Grouse and Golden-winged Warblers occupy these habitats at the edge of their ranges is unknown. Understanding the factors that drive the presence or absence of these species in this region is critical to inform quality management of early-successional forests. Additionally, increased knowledge of these species will likely benefit other species of conservation concern that rely on early-successional forests, such as the Prairie Warbler (Setophaga discolor), Common Yellowthroat (*Geothlypis trichas*), Field Sparrow (*Spizella pusilla*), and Chestnut-sided Warbler (Setophaga pensylvanica). In this study, we examined multi-scale habitat factors to determine specific drivers of presence or absence of Ruffed Grouse, Golden-winged Warblers, and habitat indicator species. Additionally, we employed both human-observer and autonomous recording unit surveys to determine the efficacy of the two methodologies.

Our first objective was to examine the effects of landscape-scale habitat features on Ruffed Grouse occupancy. Ruffed Grouse in the Southern Blue Ridge Ecoregion seem influenced by habitats not typical of their northern range and occur more frequently in landscapes with higher mixed forest and woody wetland cover. In the absence of early-successional forests, Ruffed Grouse may be seeking habitats that act as structural mimics to early-successional forests. Our second objective was to examine the effects of multi-scale habitat parameters on Golden-winged Warbler, Chestnut-sided Warbler, Prairie Warbler, Common Yellowthroat, and Field Sparrow. As a whole, these species seem to be influenced by landscape and composition, ground cover metrics, vegetation structure, and elevation. Chestnut-sided Warblers may act as the most effective habitat indicator for Golden-winged Warbler habitat, as they exhibit similar preference for habitat features including elevation and vegetative visual obstruction. Our third objective was to examine the efficacy of human-observer surveys and autonomous recording unit surveys to detect Ruffed Grouse, Golden-winged Warbler, and early-successional habitat indicator species. Autonomous recording units performed comparably to human observers and may represent an efficient tool for future monitoring protocols.

This study represents the largest known effort to inventory Ruffed Grouse and Golden-winged Warblers in the State of South Carolina. We found low Ruffed Grouse and Golden-winged Warbler occupancy rates across two seasons (spring and summer 2020 and 2021), indicating the need for both robust monitoring protocols and targeted habitat management for the benefit of these species. Our results indicate unique habitat preferences of Ruffed Grouse in the Southern Blue Ridge Ecoregion. Additionally, our results provide insight into multiple parameters that drive early-successional songbird species occupancy. This project provides information that will aid in both habitat management and conservation of high priority, early-successional avian species. This project also provides context for efficient monitoring protocols.

Identification of Environmental and Biological Factors Limiting Occurrence of the Sandhills Chub (*Semotilus lumbee*) in South Carolina (Federal Grant #: F19AF00720, Duration: 2019-2021) PIs: Derek Crane (Coastal Carolina University) and Mark Scott (SCDNR); Author: Derek Crane (Coastal Carolina University)

The objectives of this project were to assess Sandhills Chub populations in South Carolina, identify environmental and biological features associated with healthy populations and depleted or extirpated populations, and develop a predictive model to guide Sandhills Chub conservation and restoration. The Sandhills Chub is categorized as a Highest Priority species under the SCDNR's 2015 State Wildlife Action Plan because its global distribution is limited to the Sandhills Ecoregion of north-central South Carolina and south-central North Carolina. It has been extirpated from several locations in South Carolina, and quantitative information on habitat use and biological associations are needed to guide conservation and restoration efforts. Habitat and fish data were collected at 115 sites during 2019-2020, and 431 Sandhills Chub were collected at 41 sites, including 26 sites where they had not been previously collected. Co-occurrence analysis and logistic regression were used to identify which biological and habitat features were associated with the presence and absence of Sandhills Chub. Co-occurrence analysis indicated positive relationships between Sandhills Chub and Dollar Sunfish (*Lepomis marginatus*), Creek Chubsucker (*Erimyzon oblongus*), and Margined Madtom (*Notorus insignis*) and negative relationships between Sandhills Chub and Largemouth Bass (*Micropterus*

salmoides), Bluegill (*Lepomis macrochirus*), Creek Chub (*Semotilus atromaculatus*), Eastern Mosquitofish (*Gambusia holbrooki*), and Lined Topminnow (*Fundulus lineolatus*). Sandhills Chub presence was positively associated with dissolved oxygen levels, instream cover, and the percent of substrates that were 6-11 mm. Additionally, when an extreme outlier HUC was removed from the analysis, a negative relationship was observed between Sandhills Chub presence and the number of impoundments within each 12-digit HUC. However, further investigation is required to determine the validity of this relationship. Results from this study will help guide future conservation and restoration efforts for Sandhills Chub.

Upstate Bridge Use by Highest Priority Bat Species (Federal Grant #: SC-T-F19AF00722, Duration: 2019-2020) PI and Author: Jennifer Kindel (SCDNR)

The goal of this project was to select bridges over Lake Hartwell, Lake Keowee, and the Chattooga River thought to be biologically important and/or in the State Transportation Improvement Program (STIP) and use acoustic devices to record bat calls to determine if and how SWAP bat species of highest concern utilize these transportation structures. From the end of May through mid-September, acoustic monitoring was completed for an average of 8 days apiece at 17 total bridge sites and 5 additional sites over open water near bridges. SCDNR staff recorded a grand total of 17,774 calls at 22 sites representing 10 species. Southeastern and Little Brown Bat calls were auto-classified by Kaleidoscope Pro but could not be verified as such when manually vetted. All calls auto-classified as Gray Bats were also manually vetted and were verified at one location: bridge #44. The bridges with the highest number of species recorded were #44, #16 and #27, with 8 species recorded per bridge. These bridges also recorded the highest number of priority species, with 5 species, 4 species, and 4 species recorded, respectively. Open water site #47 also had four high priority species recorded, and its proximity to bridges #44 and #16 supports species confirmation for those sites. The two bridges with the highest average number of calls per night were #13 at 475 calls per night, most of which were Brazilian Free-tailed Bats; and #31 at 384 calls per night, most of which were Tricolored Bats. The top 3 species recorded in the study area were Tricolored (54.3%), Brazilian Free-tailed (24.7%), and the Eastern Red/Seminole Bat complex (6.6%). The acoustic results from this study suggest that the Federally Endangered Gray Bat, which has never been recorded in South Carolina, may be roosting at or around bridge #44 in the Blue Ridge Ecoregion. They also suggest that the State Threatened Eastern Small-footed Bat is likely and could potentially be using expansion joints, corners located between beams, and/or other crevices on some of these surveyed bridges. No bat species were seen roosting on any bridges during this pilot survey.

Utilizing Trace Elements and Stable Isotope Analysis to Reconstruct Distribution of Scalloped and Carolina Hammerheads (Federal Grant #: SC-T-F19AF00723, Duration: 2019-2023) PI and Author: Bryan Frazier (SCDNR)

The main objectives of this study were to determine if spatial segregation of juvenile and adult hammerheads occurs and if there are patterns in life-stage specific habitat use for Carolina and Scalloped Hammerheads. These objectives were investigated using laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) of vertebrae as well as stable isotope analysis (SIA) of eye lenses. Trace element concentrations (Sr, Ba, Mg, Mn, Li and Ca) from the LA-ICP-MS were collected across the whole vertebrae (total transect) and integrated across vertebrae

sections that were designated as life stages (in-utero, young-of-year (YOY) or nursery, early juvenile, late juvenile, and adult) through measurements of the vertebrae associated with age. Layers of eye lenses associated with general life stages were analyzed for $\delta^{15}N$, $\delta^{13}C$, and $\delta^{34}S$ stable isotope analysis. Analyzing life stage signatures from both techniques provided the ability to estimate natal origin of juvenile and adult species, ontogenetic shifts in habitat by maturity or life stage for each species, and the extent of spatial segregation throughout life stages between species.

Nursery trace element signatures of Scalloped Hammerheads were different in Mg concentration between Bulls Bay and Cape Canaveral and between Tolomato River and Bulls Bay, while YOY Carolina Hammerheads significantly differed between Bulls Bay and Cape Canaveral in Sr and Mn. A Random Forest Analysis conducted on Carolina and Scalloped Hammerheads was able to correctly predict natal origin 71.9% of the time. When the model was employed for juvenile and adult individuals, 95% of these older hammerheads were predicted to have originated from Bulls Bay nursery, while only 4.4% and 0.06% likely originated from Tolomato River and Cape Canaveral, respectively. In-utero and YOY trace element signatures differed slightly between species (in Mg, Mn and Li), but there was a more defined species difference in element concentrations (Sr, Mg, Mn and Li) in early juveniles. The overall transect concentrations were assessed by hammerhead maturity stage and generally reflected patterns between vertebrae life stages for both species. Sr:Ca and Sr:Ba ratio concentrations indicate that an ontogenetic habitat shift occurs between YOY and early juvenile sharks for both Carolina and Scalloped Hammerheads, and suggests Carolina Hammerheads migrate to offshore waters at an earlier age and continually inhabit more offshore waters as late juveniles and adults than Scalloped Hammerheads.

Species-specific distinctions in Mn and Li suggest possible dietary differences, which can allude to habitat differences between species throughout their lifespan, though continued research will be needed to assess the extent of any differences. The results of eye lens stable isotope analysis generally confirm these results; that said, eye lens data may suggest Scalloped Hammerheads may have a more open ocean signal than Carolina Hammerheads. Given the disparities, it may be more likely that dietary differences are leading to the observed differences in trace element and stable isotope eye lens data. Unfortunately, Carolina Hammerheads remain rare in catches, and equal sample sizes could not be run during this study. Despite the conclusion of this grant, we will continue to add samples to these analyses, giving us greater ability to tease apart the differences observed in these species. These results allowed the first insights into species-specific trophic ecology of Carolina and Scalloped Hammerheads, data that will be critical to effective management of hammerheads in the United States.

Determining the Relative Importance of Coastal Habitat Types to Horseshoe Crab Reproduction and Migratory Shorebird Foraging in South Carolina (Federal Grant #: SC-T-F19AF00749, Duration: 2019-2022) PIs: Peter Kingsley-Smith (SCDNR) and Michael Kendrick (SCDNR); Author: Michael Kendrick (SCDNR)

The American Horseshoe Crab (*Limulus polyphemus*) is an ecologically- and economically important species found in the United States along the Atlantic and Gulf coasts. Information on locations where Horseshoe Crab spawning occurred was collected from statewide public reports

using an online reporting form, spawning surveys, and egg sampling surveys. Although difficult to discern with certainty based on GPS coordinates and location descriptions, 6 of the 55 reports appear to be of Horseshoe Crabs spawning in marsh habitats. Our spawning surveys in early April 2021 at Coffin Point documented, for the first time during standardized SCDNR spawning surveys, adult Horseshoe Crabs spawning in the salt marsh in South Carolina. In 2021, we found eggs/embryos at 5 out of 50 randomly selected beach sites and at 7 out of 50 randomly selected marsh sites (Fig. 2). There was no significant difference in the likelihood of finding eggs and embryos in either habitat. The likelihood of finding eggs in the entire core sample did not change with time at Otter Island but increased with time at Deveaux Bank. Multiple lines of evidence from this study indicate that Horseshoe Crabs in South Carolina use salt marsh habitats to spawn, potentially at similar densities as they spawn on the beach. These findings are important steps in understanding the role of salt marshes in Horseshoe Crab reproduction in South Carolina.

Ecology of Estuarine Sensitive Infauna Along a Stress Gradient (Federal Grant #: SC-T-F19AF00750, Duration: 2019-2020) PI and Author: Andrew Tweel

Benthic infauna, specifically members of the Estuarine Sensitive Taxa Guild (2015 SC SWAP), serve as a valuable indicator of estuarine habitat quality and environmental stress. Stormwater input is one form of environmental stress that occurs in estuarine systems. As part of an ongoing salinity impact study, this project aimed to quantify benthic infauna along a stormwater-development stress gradient in several tidal creek systems surrounding Charleston, South Carolina. Overall, several taxa were identified that may serve as indicators of degraded conditions, although some of these were observed in low abundances in general. *Mediomastus sp.*, a capitellid polychaete, was the most sensitive of all species observed, although at low abundances throughout, and was significantly inversely correlated to salinity drop, impervious cover percentage, as well as total pesticide concentrations. Annelids, both polychaetes and oligochaetes, generally showed the strongest relationship to development and position within creek (i.e. headwater or downstream), with the lowest abundances occurring at high development and/or headwater sites.

Integrating Crayfish into Aquatic Assessments from the Uplands to the Coast (Federal Grant #: SC-T-F00779, Duration: 2019-2022) PIs: Michael Kendrick (SCDNR) and Mark Scott (SCDNR); Author: Michael Kendrick (SCDNR)

Integrative watershed approaches to water quality have been shown to be effective and efficient ways of maintaining robust and healthy ecosystems across the continuum of aquatic habitats from the mountains to the coast, being used by governments across the world**.** Aquatic resource assessments such the South Carolina Stream Assessment (SCSA), Small River Assessment (SRA), and headwater streams assessments were developed to determine the status of aquatic resources in streams and rivers throughout the State using fish communities to assess resource condition. Crayfish are a representative invertebrate taxon that can be valuable to existing state-wide assessments through their sensitivity to environmental conditions and as priority conservation species in South Carolina.

In order to better assess the distribution and abundance of crayfish in the Savannah River Basin, SCDNR biologists have developed georeferenced locations of 145 potential sampling sites within the South Carolina portion of the Savannah River watershed, selected from previous

SCSA and SRA sampling locations. A subset of 55 sites were selected for sampling by teams of 2-3 biologists from January-March 2021, across all of South Carolina's physiographic regions. Field-assessed canopy cover was a significant driver of both richness and Shannon diversity. Land cover (National Land Cover Database) was not a significant driver of crayfish richness but was marginally significant for Shannon diversity. Physiographic province was a significant driver of crayfish richness and Shannon diversity with the Coastal Plain having greater crayfish richness compared with the Piedmont and Blue Ridge Ecoregions. For fish surveyed at these same sites, Land cover was also not a significant driver of fish richness or Shannon diversity. Physiographic province was not a significant driver of richness or Shannon diversity. In comparing patterns and drivers of crayfish assemblages in the Savannah basin, it becomes apparent that the underlying physiographic province is a strong predictor of both crayfish richness and diversity in the sampled sites. This contrasts with the richness and diversity of finfish assemblages where physiographic province was not a predictor of these metrics. The site-specific patterns of richness and diversity juxtaposed across fish and crayfish assemblages in this study provide the foundation for synthesizing biodiversity data from multiple taxa groups (e.g. fish, crayfish, mussels, insects) into biological assessments of aquatic resources.

Development, Testing, and Field Validation of an eDNA Tool for Robust Redhorse (Federal Grant #: SC-T-F19AF00780, Duration: 2019-2022) PIs: Dr. Tanya Darden (SCDNR) and Daniel Farrae (SCDNR)

This project has provided a new, powerful environmental DNA (eDNA) tool that will increase our passive detection capabilities for Robust Redhorse, a species that has historically evaded routine field efforts outside of their spawning season. The rigorously designed eDNA assay was tested for species specificity, efficiency, and sensitivity. A laboratory experiment was conducted to evaluate the influence of both fish density and sediment on DNA persistence, and sampling of production ponds allowed us to evaluate DNA accumulation using the new eDNA assay. We also successfully detected Robust Redhorse with the new tool during field validation sampling in two areas with known Robust Redhorse present. Collectively, our project activities provide a solid interpretation foundation for the application of this new eDNA tool for Robust Redhorse in the field. The new eDNA tool will allow for the detection of juveniles and/or adults in habitat reaches that are challenging to sample with traditional gears/methods, increasing our understanding of distribution and habitat use for Robust Redhorse. Improvement of passive detection tools such as the new eDNA assay will provide critical data in making the best management decisions during a critical period for the species' survival and regulatory status.

Microplastic Exposure for Key Ecological Species in Coastal South Carolina (Federal Grant #: F20AF11202-00, Duration: 2020-2023) PI: Tanya Darden (SCDNR) and Joey Ballenger (SCDNR); Author: Claire Benson (SCDNR)

While a range of anthropogenic activities threaten estuaries and tidal marshes, an emerging threat in these systems is the impact of microplastics. Field studies document microplastic presence and prevalence in fishes all over the world. However, major data gaps exist in many coastal areas of the globe with most studies focusing on urbanized estuaries. Herein, we conducted a study of microplastic occurrence in the guts of five estuarine fish species within the ACE Basin, SC, a non-urbanized, minimally-developed estuary neighboring the highly studied Charleston Harbor, SC, system. Species were chosen to represent different feeding ecologies: the planktivore

Atlantic Menhaden, the piscivore Southern Flounder, the detritivore/benthivore Striped Mullet, and the benthic omnivores Spot and Mummichog. Microplastics (MP) were present in 75% of fishes collected with an average of 17 MP $fish^{-1}$ and 1 MP g^{-1} of fish, although exposure varied among species. Mummichog possessed significantly more MP g^{-1} fish weight than other species, suggesting the benthic omnivore feeding ecology was particularly vulnerable to microplastic ingestion within the estuary. Among all species, foams had the highest selectivity of all microplastics present. However, fibers had the highest frequency of occurrence within most species. Overall, both the presence and prevalence of microplastics in finfish of the ACE Basin were reduced relative to the urbanized Charleston Harbor estuary, suggestive of decreased point sources in the ACE Basin region.

Conservation of Seabirds, Shorebirds, Wading Birds, and Marsh Birds in South Carolina (III) (Federal Grant #: F20AF11231-00, Duration: 2020-2022) PIs and Authors: Felicia Sanders (SCDNR) and Christy Hand (SCDNR)

Many of the seabird, shorebird, wading bird, and marsh bird species that utilize South Carolina's coastal habitats throughout the year are of conservation concern due small and threatened populations. This grant funded efforts to reduce human disturbance at key seabird colonies and to conduct nest counts and population surveys of many waterbird species. These count data are incorporated into long-term databases to allow the agency to make informed management decisions as well as contribute to regional and global knowledge of the species. Additionally, research on the federally listed Black Rail was funded. Survey, research, and management activities were shared on webpages, in press releases and at outreach events so results are available to partners.

SCDNR staff coordinated with private, federal, state, and county-owned beach managers to close part of the beach for nesting seabirds and shorebirds at 27 beaches during summer months and at 2 during the winter. Educational signs were placed at boat ramps and on some beach entrances. Annual seabird nest counts were conducted (in 2021 and 2022) for Black Skimmer (789; 560), Brown Pelican (5978; 5332), Common Tern (6; 9), Forster's Tern (2; 15), Gull-billed Tern (216; 278), Least Tern (965; 1052), Sandwich Tern (2775; 2651), and Royal Tern (7163; 6260). To minimize disturbance to nesting birds, staff used binoculars or spotting scopes to count the number of adults sitting in incubation postures as a proxy for nest counts or used aerial photographic surveys primarily conducted from SCDNR Law Enforcement planes. Least Tern nests were monitored at natural beach sites and on artificial sites mostly consisting of pebbled roofs in industrial areas.

All known active Wood Stork colonies were surveyed each year. We counted 3,493 and 3,928 Wood Stork nests during 2021 and 2022, respectively, setting a record high number of stork nests for the State. A sub-set of the stork nests were monitored in index colonies to determine how successful the storks are at raising young in South Carolina. During 2021, a total of 191 stork nests were monitored. An average of 1.8 chicks fledged per nest site and 2.3 chicks per successful nest site. During 2022, a total of 346 nests were monitored. An average of 2.2 chicks fledged per nest site and 2.4 chicks per successful nest site.

We attempted to determine if Black Rails are present in substantial numbers in coastal South Carolina during the nonbreeding season and the timing of arrival and departure of wintering rail species. Nonbreeding season call-response surveys for Black Rails were completed during September – October 2022, and Black Rails were detected at 4 of the points. Between 1 October 2020 – 1 March 2021, SCDNR deployed 10 or more camera traps. Black Rail detections sharply declined during November – January (days with detections: October = 16; November = 4; December = 0; January = 4).

Range and Roost Sites of Northern Long-eared Bats in South Carolina (Federal Grant #: F20AF11283-00, Duration: 2020-2023) PI and Author: Jennifer Kindel (SCDNR)

The purpose of this grant was to provide more information on the range and roost sites of the Northern Long-eared Bat in South Carolina through hibernacula counts, mist netting, radio-tagging, and acoustic bat call recording using our established South Carolina NABat acoustic project framework. Strengthening our volunteer base was an additional goal to enhance public engagement and facilitate statewide bat monitoring including winter culvert surveys. With the wide variety of these survey types, we were also able to obtain important information on South Carolina's bat species of "highest" concern as defined in South Carolina's 2015 State Wildlife Action Plan.

During the winters of 2020/21 and 2021/22, a total of 79 culvert surveys were completed across 16 different counties in all ecoregions (Blue Ridge, Piedmont, Upper and Lower Coastal Plain). In 17 culverts across 9 counties, a total of 51 hibernating bats of 5 different species were counted. During the summers of 2021 and 2022, the total mist-netting effort totaled 137 net nights deployed over 80 survey nights at 8 properties across the lower Piedmont and Southeastern Plains Ecoregions, resulting in 302 bats captured representing 10 different species. Of the 8 properties, Santee Coastal Reserve WMA had the highest capture rate per night, highest species richness, and was the only property where Northern Long-eared Bats were captured, leading to the discovery of the first known Northern Long-eared Bat Coastal Plain maternity colony record in the State of South Carolina. Of the 4 Northern Long-eared Bats captured at Santee Coastal Reserve WMA, 3 were radio-tagged and tracked to 10 unique roost trees including 8 live Longleaf Pines and 1 dead Longleaf Pine snag which was established as a maternity colony via emergence count. Eight additional bats of 2 South Carolina species of "highest" conservation concern were also radio-tagged and tracked to their roost locations at 3 other properties.

To keep our long-term, statewide South Carolina NABat acoustic program running, 37 cells were surveyed from late May through mid-July in 2021; 13 cells were surveyed with both mobile and stationary surveys, 13 with mobile only, and 11 with stationary only. A total of 11,216 bat calls identifiable to species were recorded and auto-classified using KPro software, representing 13 species. In 2022, we were able to obtain WNS Grants to States (FY21) funding for a technician to work with statewide volunteers to run South Carolina NABat acoustic surveys instead of only relying on volunteers. Thus, results from the NABat data collected by that grant can be found in the White-nose Syndrome Grants to States and Tribes, SC-E-F21AP03494 report entitled "South Carolina White-nose Syndrome State Support FY21." However, the focus of this objective was to continue to run and strengthen South Carolina's NABat project and volunteer network by

recruiting partners and volunteers, providing reports to landowners in a timely manner, creating partner hubs, and replacing the Anabat SD2 devices with newer, more efficient Anabat Swift devices while providing an updated protocol and training video to continue running NABat into the future. All these tasks were completed through this grant by 2022.

Understanding Salt Marsh Loss Through Investigation of Periwinkle Fronts and Other Causes Across Multiple Spatial Scales (Federal Grant #: F21AF02397-00, Duration: 2022-2023) PI and Author: Andrew Tweel (SCDNR)

Salt marshes are one of the dominant features of the coastal landscape in South Carolina. As a habitat, salt marshes directly support 40 SWAP-listed fish and invertebrate species, and many more indirectly through their role in maintaining water quality and the production of organic material as part of the overall estuarine ecosystem. Coastal marsh loss (also referred to as die-off, dieback, submergence, or collapse) has been reported worldwide, including in South Carolina, and the identified or presumed causes, as well as spatial scales, vary widely. Periwinkle Snails, *Littoraria irrorata*, a listed 2015 SWAP species, have been identified as a potential mechanism for top-down control, and determinations of its role in vegetation cycling and die-off are stated Conservation Recommendations in its SWAP profile (SCDNR 2015).

The study consisted of a series of field experiments to assess the potential for top-down control via a series of field manipulations (snail additions/exclusions/marsh transplanting) in already-impacted areas as well as new areas. Secondly, a remote-sensing analysis addressed the landscape-level extent of marsh loss in certain areas, timing, and trajectory of these changes. In year one of the study, two site types within the experimental marsh were selected: a die-off area with a snail front and non-die-off ("normal" marsh) area without a snail front. Within each site type, three replicate paired 1-m^2 plots were installed—one control plot marked with PVC at the corners and one experimental plot enclosed in an open-topped cage constructed from galvanized wire mesh 24-in high with 0.5-in openings. At snail front sites, cages acted as exclosures and snails were removed from the plot. At non-snail front sites, cages served as enclosures and snails were added to reach densities similar to those seen in the high-density areas to mimic a snail front.

Stem densities were significantly higher in low snail concentration plots than high snail concentration plots, ignoring site type. At the site level, normal marsh plots had significantly higher stem densities in the low snail concentration plots than the high concentration plots. Plants transplanted into areas with Periwinkle Snails had a 44% failure rate after one month, while plants inside cages had a 100% success rate. These results suggest that snail density can play a significant role in regulating primary producers in the marsh, but the extent to which this occurs at a larger scale was not determined here. There appears to be different responses in already stressed marshes versus seemingly healthy marshes which may suggest an environmental trigger or other factor not investigated here.

Conservation of South Carolina Coastal Plain Reptiles and Amphibians (II) Plus Blue Ridge Herps (Federal Grant #: F21AF03242-01, Duration: 2021-2026) PI and Author: Andrew Grosse (SCDNR)

In progress.

Determining the Importance of the South Carolina Coast to the Overwintering Survival and Reproductive Output of the Monarch Butterfly (*Danaus plexippus*) (Federal Grant #: F21AF03274-00, Duration: 2021-2022) PI and Author: Michael Kendrick (SCDNR)

Monarch Butterflies (*Danaus plexippus*) are native to the western hemisphere and are well-known for their long-distance migrations but have experienced significant population declines in recent decades. Here we use a 5-year capture-mark-recapture dataset to compare Monarch distributions, mating activity, and larval host plant use between two Coastal Plain habitats in South Carolina, USA. We observed seasonally specific habitat use, with maritime habitats serving as overwintering areas while nearby inland swamps support significant breeding in spring, summer, and fall seasons due to an abundance of Aquatic Milkweed (*Asclepias perennis*). We also observed mating activity by fall migrating Monarchs and their use of Swallow-wort (*Pattalias palustre*) in the spring as an important larval host plant in maritime habitats. This phenology and habitat use of Monarchs diverges from established paradigms and suggest that a distinct population segment of Monarchs may exist, with significance for understanding the conservation status of Monarch Butterflies and associated habitats in eastern North America.

Developing Genetic Sequences for Benthic Prey Resources of Migratory Piping Plover and Red Knot (Federal Grant #: F21AF03426-00, Duration: 2021-2022) PIs: Denise Sanger (SCDNR), Andrea Bowman (SCDNR), and Andrew Tweel (SCDNR); Author: Andrew Tweel (SCDNR)

Shorebirds depend on a variety of marine invertebrates while overwintering or migrating through coastal South Carolina. Understanding which prey species are important to diet and which habitats are occupied by those species is a key part of management of shorebirds. In order to quantify these relationships, shorebird diet must be better understood. A variety of genetic tools are available to inform this process, but these are dependent on global reference databases, such as GenBank. Existing infaunal species were explored in GenBank to identify which species were not well represented. A targeted effort was made to sequence these species for addition to this database. A total of 56 organisms were sequenced, representing 33 unique haplotypes. These results greatly aid management efforts both here and in other areas important to migratory Piping Plover and Red Knot, among others.

Occupancy and Distribution of SWAP-listed Freshwater Mussel Species (Federal Grant #: F21AF03593-03, Duration: 2021-2024) PI: Morgan Kern (formerly SCDNR) and Ericah Beason (SCDNR); Author: Ericah Beason (SCDNR)

Freshwater mussels from the order Unionida are unique organisms that live discreetly in the substrate of rivers and lakes and serve as a crucial trophic link between the water column and the benthos (Vaughn and Hakenkamp 2001). Unfortunately, freshwater mussels throughout North America have continued to decline in diversity, abundance, and range. The causes of these declines are complex, but anthropogenic at their source. In 2022, South Carolina was home to 26 SWAP listed mussel species, 13 of which were “highest priority” species of greatest conservation need (SGCN). As such, there is a need for the South Carolina Department of Natural Resources to effectively manage and conserve freshwater mussel populations to continue

to meet the expectations of the public as well as maintain the viability of the freshwater mussels within the State. The purpose of this project was to provide updated distribution data on SWAP listed species to update the Natural Heritage Database and inform management decisions. This project was accomplished, in part, by completing 45 catch per unit effort (CPUE) field survey sites for freshwater mussels. Individual mussels were collected through visual and tactile searches. All data was recorded and submitted to the Natural Heritage Database for statewide management. Surveying efforts across 45 field sites yielded a total of 5,667 individual mussels representing 15 different species across 8 different basins. Only 10 individuals with a "highest priority" SCGN ranking were collected, with 8 being collected from the Savannah River Basin sites. A total of 22 sites had 0 mussels found with most sites being in the Broad River Basin. Observations at sites across the State show habitat degradation due to urbanization and agriculture. Streams in these areas are incised, dominated by loose sand substrate, and have steep banks. Additionally, several streams were noted as having no riparian buffer and allowing livestock to enter streams. Completion of this project allowed researchers to visit 25 historical occupancy survey sites and 20 survey sites that were selected from the South Carolina Stream Assessment project across the State of South Carolina. Although only 10 individuals of "highest priority" SGCN were collected, we were able to collect updated general habitat condition parameters and occupancy data that can be used to aid in conservation and management efforts of freshwater mussels across the State.

Determining the Effects of Human Disturbance on the Ecology and Conservation Status of Populations of At-Risk Crayfish in the Genus *Distocambarus* (Federal Grant #: F21AF03627-02, Duration: 2021-2025) PI and Author: Michael Kendrick (SCDNR)

In progress.

Eastern Brook Trout Restoration in Pig Pen Branch and Lick Log Creek, Oconee County, South Carolina (Federal Grant #: F21AF03715-00, Duration: 2021-2023) PI: Dan Rankin (SCDNR); Author: Hailey Goyette (SCDNR)

The Eastern Brook Trout restoration project on Pig Pen Branch and Lick Log Creek began in 2021 and finished in December of 2023. Pig Pen Branch and Lick Log Creek held a large population of Creek Chub, *Semotilus atromaculatus*, that were displacing the native Eastern Brook Trout, *Salvelinus fontinalis*. SCDNR's goal was to restore a reproducing Eastern Brook Trout population in approximately 5.8 kilometers of stream by removing Creek Chub using a piscicide called Antimycin.

The USFWS and United States Forest Service (USFS) removed Burrell's Pond Dam in March of 2022. Logs and stumps removed from the preexisting dam were strategically placed along the stream banks to reduce erosion downstream. Dr. Jeremy Pike, with Clemson University, conducted aquatic community collections, habitat assessments, and in situ water quality measurements over 6 sites. Surveys were conducted at each station on September 5, 2023, October 5, 2023, and September 5, 2024. SCDNR performed longitudinal fish sampling using backpack electro-fishers over the entire reach of Pig Pen Branch and Lick Log Creek (5.8 km) to determine treatment areas. SCDNR collected 75 Eastern Brook Trout from Pig Pen Branch

through electrofishing. Fish were transported to Walhalla State Fish Hatchery to be held during Antimycin treatment.

Twelve Antimycin stations were established based off fish presence and had no more than 75 feet of elevation separating one station from the next. Flow measurements were taken prior to Antimycin treatment and used to calculate amounts of chemical needed at each station. Antimycin treatment was conducted on Pig Pen Branch and Lick Log Creek in the fall of 2023. In total, over the 9 days of treatment, 19.4 units of Antimycin were used to treat Pig Pen Branch and Lick Log Creek. A detox station running Potassium Permanganate was set up downstream at the Chattooga River to neutralize the Antimycin from Pig Pen Branch and Lick Log Creek to prevent impacts to non-target fish and insects.

Fifty Eastern Brook Trout were reintroduced into Pig Pen Branch after treatment on November 7, 2023. SCDNR and the Center for Aquatic Technology Transfer (CATT) crew conducted in-stream habitat census for the entire length of Pig Pen Branch and Lick Log Creek using the Basin Visual Estimation Technique (BVET). BVET surveys indicated Pig Pen Branch and Lick Log Creek lack both large woody debris (LWD) and pool habitat. USFS and SCDNR are awaiting Eastern Brook Trout establishment in Pig Pen Branch and Lick Log Creek before any habitat enhancement efforts are made.

Coastal Maternity Roost Sites of Five High Priority Bat Species (Federal Grant #: F22AF03331-01, Duration: 2022-2025) PI and Author: Jennifer Kindel (SCDNR)

In progress.

Conservation of Seabirds, Shorebirds, Wading Birds, and Marsh Birds in South Carolina (IV) (Federal Grant #: F22AF03386-00, Duration: 2022-2024) PIs and Authors: Felicia Sanders (SCDNR), Christy Hand (SCDNR), Janet Thibault (SCDNR), and Mary Catherine Martin (SCDNR)

Many of the seabird, shorebird, and wading bird species that utilize South Carolina's coastal habitats throughout the year are of conservation concern due to small and threatened populations. This grant funded efforts from October 2022 – September 2024 to reduce human disturbance at key seabird colonies and to conduct nest counts and population surveys of many waterbird species. These count data are incorporated into a long-term database to allow the agency to make informed management decisions as well as contribute to regional and global knowledge of the species. Survey, research, and management activities were shared on webpages, in press releases, and at outreach events so results were made available to partners. Four scientific manuscripts were published.

SCNDR staff coordinated with private, federal, state, and county-owned beach managers to close part of the beach for nesting seabirds and shorebirds at 29 beaches during summer months and at 2 sites during the winter. Educational signs were placed at boat ramps and on some beach entrances. Annual seabird nest counts were conducted for Black Skimmer, Brown Pelican, Common Tern, Forster's Tern, Gull-billed Tern, Least Tern, Sandwich Tern, and Royal Tern. Counts consisted of on-the-ground estimates or estimates from aerial photographs taken from

SCDNR Law Enforcement planes or Unmanned Aerial Vehicles (UAVs or drones). Least Tern nests were monitored at natural beach sites and on artificial sites that mostly consist of pebbled roofs in industrial areas. Peak statewide nest estimates for this project period were: Black Skimmer (2023) 767, Brown Pelican (2024) 4,285, Common Tern (2024) 9, Forster's Tern (2024) 26, Gull-billed Tern (2024) 244, Royal Tern (2024) 7,354, Sandwich Tern (2024) 2,325, and Least Tern (2023) 989.

Wading birds—including egrets, herons, ibis, and storks—were surveyed and monitored in colonies throughout the Coastal Plain. Wood Storks had a very productive nesting season during 2023. The number of nests counted (3,935 nests at 28 active colonies) far exceeded the previous record high count in the State. During 2024, approximately 1,000 fewer nests (2,915 nests in 29 colonies) were counted compared to the record highs set in 2022 and 2023, but numbers were still relatively high compared to pre-2020 surveys. At index colonies, individual stork nests were mapped as they were initiated and were monitored from a distance (using a spotting scope or binoculars) approximately once per week from the time that egg laying began until the chicks reached fledging age. During 2023, a total of 266 stork nests were monitored in five colonies. An average of 1.1 chicks fledged per nest site. During 2024, a total of 92 nests were monitored in two colonies. An average of 2.2 chicks fledged per nest site, exceeding the recovery criteria of 1.5 fledglings per nest.

Taonomic Revision of Procambarus Crayfishes in South Carolina (Federal Grant #: F22AF03387-02, Duration: 2022-2024) PI and Author: Michael Kendrick (SCDNR)

The Southeastern United States (US) is a global hotspot for crayfish diversity, with the majority of the >350 species known in the US occurring here. Crayfishes in the genus *Procambarus* are common in lower gradient lotic and lentic systems of the Southeast, but from both a taxonomic and systematic perspective, this genus is largely neglected in comparison to other crayfish genera. The aim of this study is to clarify the taxonomic status of two conservation priority crayfishes from the Southeastern US by testing the hypothesis that *Procambarus braswelli* (Cooper 1998) and *Procambarus chacei* (Hobbs 1958) are distinct species. We conducted a geometric morphometric analysis of these species, including 17 morphological metrics across 51 specimens throughout the ranges of these species in North Carolina and South Carolina. We then isolated, extracted, and sequenced a fragment of the COI gene and used maximum likelihood phylogenetic analysis to determine genetic distinctness. Results of multivariate analyses show overlapping morphologies between species and genetic structure that does not co-vary with original species determinations. Together, the available morphological and genetic information indicates that *P. chacei* and *P. braswelli* be synonymized. Additional taxonomic, life history, and ecological work is sorely needed for *Procambarus* crayfishes of the species-rich Southeastern US.

High Resolution Acoustic Telemetry Array in the Edisto and Savannah Rivers (Federal Grant #: F22AF03590-00, Duration: 2022-2023) PIs and Authors: Bill Post (SCDNR) and Ellen Waldrop (SCDNR)

A multi-year telemetry study funded by the National Marine Fisheries Service focused solely on sturgeon movements in coastal rivers in North Carolina, South Carolina, and Georgia and

reinforced findings from previous sturgeon studies. It also discovered two previously undocumented behaviors—Atlantic Sturgeon making inland movements indicative of spawning behavior in the fall, and Shortnose Sturgeon using the Atlantic Ocean to migrate between river basins. Additionally, many sturgeon transmitted by other researchers coastwide continued to be detected. Because active transmitters remained in many sturgeon, SCDNR decided to maintain South Carolina's ~300 receiver array through alternative funding sources. This would allow for continued collection of long-term detection data for any transmitted animals. Locations were concentrated in two main areas within the existing array that no longer received funding or support: the ACE Basin (specifically the Edisto River), and the Savannah River (specifically upriver of Interstate Hwy 95).

This project had two main objectives, 1) replace and maintain up to 13 missing receivers in the Edisto River (54% coverage of the original array); and 2) replace and maintain up to 22 missing receivers in the Savannah River (40% coverage of the original array). Both objectives of the study were met. All receivers were purchased and distributed as necessary to fill any gaps within the Edisto River and Savannah River arrays. Several receivers were not deployed and held as replacements to cover future loss in these areas. Each deployed receiver was tethered in the mid-water column and attached to a stainless steel cable, high tensile rope, or chain which was anchored to the bottom using proven techniques. Researchers maintained any downloaded detection in telemetry databases and using Innovasea's VUE and Fathom software to keep track of receivers, transmitted sturgeon, and movement data. All downloaded data was maintained by SCDNR and was shared with both cooperative tagging networks (FACT and ACT [Atlantic Cooperative Telemetry]). Species detected as of the date of this submission were Atlantic Sturgeon (*Acipenser oxyrinchus*) and Shortnose Sturgeon (*Acipenser brevirostrum*), both South Carolina 2015 SWAP species of "highest" concern. Future detection data will be distributed to cooperative tagging networks and participating researchers.

Edisto River Flow Effects on Summertime Water Temperatures: Are Thermal Tolerances of SWAP Fishes Exceeded at Low Flows? (Federal Grant #: F22AF03676-01, Duration: 2023-2025) PIs: Jason Bettinger (SCDNR), Troy Farmer (Clemson University), Luke Bower (Clemson University)

In progress.

Seasonal Patterns of Horseshoe Crab Spawning and the Relative Importance of Horseshoe Crab Eggs Within the Diets of South Carolina Shorebirds (Federal Grant #: F22AF03703-01, Duration: 2023-2025) PI and Author: Daniel Sasson (SCDNR)

In progress.

Horizontal Movements of Carolina Hammerheads (*Sphyrna gilberti*) in the Western North Atlantic Ocean (Federal Grant #: F22AF03703-01, Duration: 2023-2025) PI and Author: Bryan Frazier (SCDNR)

In progress.

Pilot Project to Document Presence of Sea Turtles in South Carolina Estuarine Waters in and Effort to Reduce Impacts of Watercraft on Endangered and Threatened Sea Turtles (Federal Grant #: F22AF03776-00, Duration: 2023) PI and Author: Michelle Pate (SCDNR)

SCDNR initiated a pilot project to document the presence of sea turtles in South Carolina estuarine waters and improve outreach efforts to reduce negative impacts of watercraft interaction with endangered and threatened sea turtles. No direct, formal estuarine survey exists for determining the full extent of sea turtles inhabiting our waters, but rather opportunistic data collection relies on bycatch from SCDNR fishery-independent monitoring, stranded turtle counts from the South Carolina portion of the federally established Sea Turtle Stranding and Salvage Network (STSSN) managed by the Marine Turtle Conservation Program (MTCP), and anecdotal observations reported by biologists and the public. There is a need to expand our knowledge of the presence of sea turtles in interior estuarine areas and establish partnerships with businesses such as marinas and docks as well as ecotour operators who operate within the inshore estuarine environment. Through collection of additional data on healthy live sea turtles, we can enhance management of waterways with greater knowledge of the habitats they occupy. To accomplish this, signage was created to raise awareness about the presence of threatened and endangered sea turtle species inhabiting South Carolina's tidal waters. Signage also provided easy access, by way of a QR Code, to an updated MTCP sea turtle reporting form that utilized the ArcGIS Survey123 program. Signage was distributed among coastal stakeholder groups and via selected placement at high-traffic, popular coastal marinas and boat landings. Signs were printed in various formats to accommodate availability of space at facilities and distributed to 24 locations throughout coastal South Carolina. Results of this project include improved reporting of sea turtles occupying coastal and estuarine water through expansion of outreach efforts, along with building awareness in South Carolina of sea turtle conservation and providing guidance about conservation needs.

Genetic Characterization of Monarch Butterflies in Coastal South Carolina (Federal Grant #: F23AF02951-01, Duration: 2023-2025) PI and Author: Michael Kendrick (SCDNR)

In progress.

Assessing the Occurrence and Habitat Associations of Six Priority Small Mammal Species in High Elevation Appalachia Forests in South Carolina (Federal Grant #: 2023-2026, Duration: 2023-2026) PI: David Jachowski (Clemson University)

In progress.

Exploration of Subtidal Oyster Presence in Areas Historically Identified as Supporting Subtidal Populations (Federal Grant #: F23AF03154-01, Duration: 2023-2025) PI and Author: Andrew Tweel (SCDNR)

In progress.

Using Unmanned Aerial Systems (UAS) Technology to Understand the Relationship of Microhabitat to Estuarine Fish Species (Federal Grant #: F23AF03206-01, Duration: 2023-2026) PI and Author: Joseph Ballenger (SCDNR)

In progress.

Innovative Fish Aging Methods Using Near-infrared Spectroscopy Techniques to Understand Changes in Population Demography: Calibration Model Development for Bonnethead Shark (Federal Grant #: F23AF03212-01, Duration: 2023-2025) PI and Author: Joseph Ballenger (SCDNR)

In progress.

Distribution and Roost Sites of Gray Bats in Northwestern South Carolina (Federal Grant #: F24AF02859-01, Duration: 2024-2026) PI and Author: Jennifer Kindel (SCDNR)

In progress.

Conservation of Seabirds, Shorebirds, and Wading Birds in South Carolina (V) (Federal Grant #: F24AF02999, Duration: 2024-2026) PIs: Felicia Sanders (SCDNR) and Christy Hand (SCDNR)

In progress.

Exploration of a New Emerging Threat: Microplastics in Water, Sediment, and SWAP-listed Species in Charleston Harbor (Federal Grant #: F25AF00610, Duration: 2025-2026) PI and Author: Jimmy Kilfoil (SCDNR)

In progress.

Closing the Loop on the Horseshoe Crab Life Cycle for Eggs to Adults: Surveying Horseshoe Crabs Across Life Stages in Coastal South Carolina (Federal Grant #: F25AF00262, Duration: 2025) PI and Author: Daniel Sasson (SCDNR)

In progress.

South Carolina Horseshoe Crab Genetic Health Reassessment (Federal Grant #: F25AF00609, Duration: 2025-2026) PIs: Richard Harrington (SCDNR), Tanya Darden (SCDNR), Daniel Sasson (SCDNR), Lengzog Yong (SCDNR)

In progress.

TABLE 9-2: Competitive State Wildlife Grants from 2005-present. The lead state is designated in **bold**.

Federal Grant No.	Duration	Project / Grant Title
SC-U2-F14AP00958	2014-2017	Carolinas Acoustic Bat Survey [NC, **SC**]
SC-U2-F15AP00050	2014-2019	Relative Abundance and Trophic Ecology of Two Sympatrically Distributed Sphyrnids, the Scalloped Hammerhead (*Sphyrna lewini*) and the Recently Discovered Carolina Hammerhead (*Sphyrna gilberti*) Within Known Nurseries off the East Coast of the United States [FL, GA, **SC**]
SC-U2-F14AP00997	2014-2019	Development and Implementation of an Environmental DNA (eDNA) Monitoring Tool for Blackbanded Sunfish (*Enneacanthus chaetodon*) [GA, **SC**]
SC-U2-F15AP01096 ***(See also SC-U2-F15AP00051)***	2015-2019	Multistate Sandhills / Upland Longleaf Ecological Restoration Project (Phase 3): Alabama, Florida, Georgia, Louisiana, Mississippi, and South Carolina [AL, **GA**, FL, MS, LA, SC] [Note: SC was involved in U2-1-HM-1 / F09AP00301 from 2009-2012 (Phase I) but the project failed. SC was not involved in Phase II either.]
SC-U2-F16AP00113	2015-2019	Cooperative Conservation of the Green Salamander in the Southeast United States [GA, MS, NC, SC, TN, **VA**]
SC-U2-F16AP00581	2017-2021	Increasing the Probability of Persistence for Robust Redhorse Through Improved Management and Monitoring [**GA**, NC, SC]
SC-U2-F19AP00051 ***(See also SC-U2-F15AP01096)***	2018-2021	Multistate Sandhills / Upland Longleaf Ecological Restoration Project (Phase 4): Alabama, Georgia, Louisiana, and South Carolina [AL, **GA**, LA, SC]
SC-U2-F20AP00258	2019-2023	Multistate Habitat and Population Restoration of Gopher Frogs in Alabama, Georgia, and South Carolina [AL, **GA**, NC, SC]
SC-U2-F20AP00291-02	2020-2024	Basin-wide Planning for "Bartram's" Redeye Bass in the Savannah River [GA, **SC**]
SC-U2-F20AP00255-02	2020-2024	Identification and Optimization of a Disomic Microsatellite Panel for Use in Population Genetics of Shortnose Sturgeon [**SC**]
F21AP00690-03	2020-2024	The Suitability of Alternative Nesting Habitats for the American Horseshoe Crab, *Limulus polyphemus* [**SC**]
F22AP00563-00	2022-present	Black Rail Habitat Creation and Restoration – Designing Management Techniques to Expand the Black Rail Population Along the Atlantic Coast [**FL**, NC, SC, VA]
F22AP00564-01	2022-present	Advanced Conservation and Restoration of Brook Floater and Associated Freshwater Mussels [**MA**, NJ, SC, VA]
F22AP00568-01	2022-present	Conservation Planning for Geographically Restricted Headwater Species, the Sandhills Chub [**NC**, SC]
F23AP00075-01	2023-present	Adaptively Managing for Robust Redhorse: A Range-wide Collaboration to Address Data Gaps and Implement Conservation Actions [**GA**, NC, SC]
F23AP03502-00	2024-present	Developing a Proactive Conservation Planning Tool for Stream Fishes of Greatest Conservation Need in the Carolinas [NC, **SC**]
F24AP00198-00	2024-present	Advancing Conservation and Management of the Spotted Turtle (*Clemmys guttata*) in the Southeastern United States: Addressing Data Gaps, Refining Approaches, and Building Capacity [**GA**, SC, VA, WV]
F25AP00566-01	2025-psresent	An Integrative Conservation Assessment of SGCN Crayfishes in North Carolina, South Carolina, and Georgia to Fill Critical Needs for Conservation Planning [GA, **NC**, SC]
F25AP00567-00	2025-present	Characterizing the Suitability of Salt Marsh Habitat for Spawning Horseshoe Crabs, *Limulus polyphemus*, and Foraging Shorebirds, Including the Rufa Red Knot, *Calidris canutus rufa* [DE, **SC**]

C-SWG Project Summaries

Carolinas Acoustic Bat Survey (Federal Grant #: SC-U2-F14AP00958, Duration: 2014-2017)
PI: Mary Bunch (SCDNR, retired); Author: Jennifer Kindel (SCDNR)

SCDNR staff ran the NABat program in North and South Carolina in 2015 and 2016, sampling a total of 95 grid cells. In South Carolina in 2015 and 2016, we established surveys in 38 grid cells: mobile transect surveys were established in 30 cells, and stationary point surveys were established in 25 cells. In the stationary cells, a total of 44 unique locations were created. In 2015, 35 total cells were surveyed; 15 with mobile transects only, 6 with stationary points only, and 14 with both methods. During this time, stationary points were surveyed on 147 occasions.

In 2016, 38 total cells were surveyed; 13 with mobile transects only, 8 with stationary points only, and 17 with both methods. During this time, stationary points were surveyed on 200 occasions. Using acoustic data collected from these efforts, over 400 calls were identified through bat call software and manual vetting, resulting in ten species and three species groups identified. Four species were found outside their known range (including the Federally Threatened Northern Long-eared Bat), with only one species known to occur in South Carolina not detected during our surveys. Detection probabilities were also determined for both survey methods, with stationary surveys showing higher detection probability than mobile surveys. Lastly, calls identified through Echoclass 3.1 and Kaleidoscope 3.1.5 programs were compared to manual vetting, and false-positive and false-negative errors were shown to exist in both programs, varying depending on species identification, survey duration, and survey method. Thus, manual vetting of call identifications must be done regardless of the program used for call classifications.

In North Carolina in 2015 and 2016, we visited 57 highly ranked NABat grid cells and developed mobile transect surveys for 41 grid cells and stationary point surveys for 40 grid cells. Through over 300,000 acoustic files, we generated NABat grid cell-specific presence/no detection information. Fourteen species of bats were detected, and both mobile and stationary surveys revealed similar general patterns of bat distributions in North Carolina. We also generated species-specific activity density maps via ArcGIS mapping. For federally listed species, Indiana Bats were concentrated mainly in the Cherokee National Forest near the North Carolina/Tennessee border; Gray Bats were mainly distributed along the Appalachian Mountains between Asheville and Boone; and more Northern Long-eared Bats were found in the Coastal Plain Ecoregion than the rest of North Carolina. We suggest that the future implementation of NABat should involve multiple partners with a centralized coordinator to facilitate participation and integrate data. We also have issues of concern that need to be addressed in the future.

Relative Abundance and Trophic Ecology of Two Sympatrically Distributed Sphyrnids, the Scalloped Hammerhead (*Sphyrna lewini*) and the Recently Discovered Carolina Hammerhead (*Sphyrna gilberti*) Within Known Nurseries off the East Coast of the United States (Federal Grant #: SC-U2-F15AP00050, Duration: 2014-2019) PI and Author: Bryan Frazier (SCDNR)

We created a diagnostic panel of single nucleotide polymorphisms to readily identify Scalloped (*Sphyrna lewini*) and Carolina (*S. gilberti*) Hammerheads. We characterized the relative abundance, relatedness, stock structure, genetic diversity, effective number of breeders, diet, and trophic ecology for young-of-the-year (YOY) of both species. Carolina Hammerheads were found to be most abundant in Bulls Bay, SC, although they were found throughout the Southeastern US, with the exception of the Tolomato River, FL, where only Scalloped Hammerheads were identified. Temporal differences in parturition may occur between the two species, and Scalloped Hammerheads are born, on average, 50 mm larger than Carolina Hammerheads. Environmental variables (salinity, and dissolved oxygen) had no effect on abundance of YOY Scalloped Hammerheads but may influence abundance of Carolina Hammerheads. There was significant overlap in the diet of YOY Scalloped and Carolina Hammerheads, indicating no partitioning of food resources in nursery areas. Results from analysis of stable isotopes that reflect maternal diet in YOY hammerheads indicate that adult

female Carolina Hammerheads likely reside further offshore, and feed at higher trophic levels than adult female Scalloped Hammerheads. An unexpected result was the finding of hybridization and backcrossing between the two species. Hybridization appears to be unidirectional, and when documented, female Carolina Hammerheads had produced offspring sired by male Scalloped Hammerheads. Overall, the results of this study found that the nursery area in Bulls Bay, SC is critically important to Carolina Hammerheads, although other nurseries contribute to the population. In the Southeastern US, Carolina Hammerheads have lower genetic diversity, and half the effective number of breeders as Scalloped Hammerheads. While this study focused on YOY hammerheads, our results give some insights into potential spatial and/or resource partitioning between adults of the two species. Our results, coupled with documented unidirectional hybridization, indicate that the Carolina Hammerheads population is relatively small compared to Scalloped Hammerheads, and could be much more susceptible to overfishing or habitat degradation of nursery areas. Future research will be needed to determine aspects of habitat utilization and life history information for juvenile and adult Carolina Hammerheads. Based on the results of this research, Carolina Hammerheads should be added to the Species of Greatest Conservation Need (SGCN) lists in North Carolina, South Carolina, Georgia and Florida.

Development and Implementation of an Environmental DNA (eDNA) Monitoring Tool for Blackbanded Sunfish (*Enneacanthus chaetodon*) (Federal Grant #: SC-U2-F14AP00997, Duration: 2014-2019) PI and Author: Tanya Darden (SCDNR)

The fragmented nature of Blackbanded Sunfish (*Enneacanthus chaetodon*) distribution and its apparent population decline are of conservation concern, particularly in the southern portion of its range. Accordingly, the species is designated as a Species of Greatest Conservation Need in both the South Carolina and Georgia State Wildlife Action Plans (2015). Our completed project represents a rigorous assessment of the current distribution, relative abundance, and population health of *E. chaetodon* throughout the southern portion of its range, providing critical baseline data for this species. The developed eDNA tool provides a time and cost-effective means for *E. chaetodon* monitoring in the remainder of its range as well as future monitoring in South Carolina and Georgia. Although project results provide justification for continued concern for populations in Georgia, South Carolina appears to represent a regional stronghold for *E. chaetodon,* suggesting the Carolina region is perhaps the most robust of the four historic population centers for this species. Overall, project results have provided substantially improved distribution and relative abundance data necessary for managers to protect *E. chaetodon* populations and their habitats. Additionally, genetic characterization of current populations throughout the range of *E. chaetodon* provides excellent baseline metrics of their genetic health as well as important information about population connectivity for guiding conservation priorities and actions.

The data collected during our project has provided guidance for the development of recommendations for additional conservation measures for *E. chaetodon* at both state and site-specific levels. We also updated *E. chaetodon* accounts for each state's SWAP, updated online resources with *E. chaetodon* data, and produced an information brochure for private landowners to promote conservation of *E. chaetodon* and their habitats. Data obtained will lead to better informed adaptive management of *E. chaetodon* and will be useful in monitoring current and

future population impacts. While application of the direct project products will be restricted to management within the Southeastern US, results of the research will also be relevant to management agencies in the northern portion of *E. chaetodon*'s range. Additionally, due to the frequent impacting of freshwater wetland habitats, *E. chaetodon* represents a valuable indicator species for these habitats; increased knowledge of distribution, connectivity, and population health of *E. chaetodon* within these systems is a valuable resource for effective conservation for these ecosystems.

Multistate Sandhills / Upland Longleaf Ecological Restoration Project (Phase 3): Alabama, Florida, Georgia, Louisiana, Mississippi, and South Carolina (Federal Grant #: SC-U2-F15AP01096, Duration: 2015-2019) PI: Will Dillman (SCDNR); Author: Andrew Grosse (SCDNR)

See SC-U2-F19AP00051 for summary of all years.

Cooperative Conservation of the Green Salamander in the Southeast United States (Federal Grant #: SC-U2-F16AP00113, Duration: 2015-2019) SEAFWA; PIs: Andrew Grosse (SCDNR) and Kyle Barrett (Clemson University); Author: Abstract from Dr. Kyle Barrett's manuscript: *A resurvey of historical green salamander locations in South Carolina*

Green Salamanders, *Aneides aeneus*, are habitat specialists found in narrow crevices of rock outcrops and under flaky bark of trees. The species is of high conservation priority throughout its range and has been negatively affected by habitat loss, climate change, disease, and over-collection. Many historical locations for this species have not been visited since the 1980s or earlier in portions of the Blue Ridge Escarpment population. Across three counties in South Carolina, we conducted visual encounter surveys of rock outcrops and used binoculars to conduct arboreal surveys. We detected Green Salamanders at 30 of the 61 sites surveyed (49.2%). We collected a variety of habitat variables and compared a suite of N-mixture models using an AIC framework. Detection probability was positively influenced by time of day. A model of abundance that included aspect, habitat size, and elevation had the most support. Specifically, Green Salamanders were more abundant at larger sites with lower elevations and south-facing slopes. We conducted a follow up survey on a subset of sites in the fall of 2018 to better understand the influence of season and season-related variables on detection probability. Detections for Green Salamanders were marginally higher during the fall surveys. Knowledge of factors that influence population abundance and survey success will help guide future efforts to protect the species in the southern portion of its range.

Increasing the Probability of Persistence for Robust Redhorse Through Improved Management and Monitoring (Federal Grant #: SC-U2-F16AP00581, Duration: 2017-2021) PI and Author: Tanya Darden (SCDNR)

Successful monitoring is critical for determining population status, the effectiveness of management actions, and ultimately whether or not Robust Redhorse populations will persist into the foreseeable future. The comparative approach to Robust Redhorse surveys allowed us to evaluate the limitations and benefits of each method as well as their potential applicability to specific river systems. Our research efforts suggest quantitative visual surveying of adult

spawning populations is a viable, non-invasive method of providing meaningful information about reproductive population size, recruitment, and spawning window. However, this methodology is only applicable in rivers like the Savannah, where base-flow turbidity is low enough to observe spawning activity and distinguish between individuals. Electrofishing surveys were conducted in the Altamaha, Ogeechee, Broad (GA), Santee, and Pee Dee systems during the project, resulting in captures in all systems except the Ogeechee and Broad rivers. We also implemented acoustic tagging with passive and active tracking within the Savannah River population to provide new information on seasonal movement patterns. Although the most invasive method (transmitter implants), acoustic telemetry could be implemented in multiple rivers with established acoustic arrays. Updates on spawning site activity in all systems was reported.

Over the course of this project, a total of 300 Robust Redhorse contemporary field-collected tissue samples were archived, genotyped and analyzed as part of our genetic monitoring of Robust Redhorse. Sixty previously collected samples (2001-2007) from the Oconee River were genotyped for the purpose of identifying the genetic origin of the contemporary samples collected in the Ocmulgee River. Additionally, 200 tissue samples from the Pee Dee River hatchery program were analyzed to determine parental contribution and to genotype before release. A total of 500 historic tissue samples from a variety of collections (1998-2007) were transferred to SCDNR for long-term storage.

Our project team attempted to implement an adaptive management framework to provide quantitative guidance for future Robust Redhorse conservation efforts. However, given the assumptions and lack of quantitative data to inform the modeling, the Robust Redhorse Conservation Committee (RRCC) membership concluded that in its current form, it is not a useful decision-making tool and further work is needed when new data becomes available.

The propagation and stocking of Robust Redhorse into the Pee Dee River has been a huge success. From 2017 to 2021, four different year classes of Robust Redhorse were produced and stocked, totaling 13,280 individuals. The catch per unit effort (CPUE) has increased substantially since augmenting the population with hatchery-reared fish. Since 2016, we have consistently collected and observed more fish on the spawning grounds. To date, we have seen very little recruitment, but hopefully this should improve over the next several years as progeny from the hatchery-stocked fish reach maturity and begin utilizing the spawning shoals.

Extensive partnership and outreach efforts were allocated toward the issue of fish passage at Juliette Dam as well as the development of a new Candidate Conservation Agreement with Assurances (CCAA) for Georgia Power. Although these avenues were not completed during the project period, substantial progress was achieved and worth noting here, and there are plans to continue both activities into the future.

Multistate Sandhills / Upland Longleaf Ecological Restoration Project (Phase 4): Alabama, Georgia, Louisiana, and South Carolina (Federal Grant #: SC-U2-F19AP00051, Duration: 2018-2021) PI and Author: Andrew Grosse (SCDNR) *See also SC-U2- F15AP01096*

Competitive State Wildlife Grants (C-SWG) funds were awarded in four phases to six southeastern states within the range of the Gopher Tortoise (*Gopherus polyphemus*)—Alabama, Florida, Georgia, Louisiana, South Carolina, and Mississippi—to restore habitat and increase populations of Gopher Tortoise and other longleaf/sandhill wildlife. The conservation and restoration of these habitats has been identified as a critical component of the long-term persistence of the Gopher Tortoise and other associated species. Many of these areas have been degraded due to lack of management practices and become unsuitable for many sandhill and Longleaf Pine-associated species of conservation concern.

The objectives were to enhance or restore current Gopher Tortoise habitat at the SCDNR's Tillman Sand Ridge Heritage Preserve (TSRHP). The TSRHP is home to the largest protected population of tortoises in South Carolina and represents one of the most robust populations at the northern edge of the species' range. Additionally, TSRHP represents the highest quality habitat in a greater sand ridge complex, mostly in private ownership, and may serve as a refuge for tortoises in the area as land uses and timber management fluctuates. The SCDNR conducted a Line Transect Distance Sampling survey of the TSRHP in Fall 2015, and analysis of that data indicates this is a population that meets Minimum Viable Population criteria and has the highest tortoise density known in South Carolina (N=232 (95%CI: 169-320) and has a tortoise density of 1.43tortoise/hectare. This site represents a stronghold for tortoises in South Carolina and at the northern edge of the species' range. Any activities that may increase the carrying capacity of the site may serve to buffer this species from extirpation. Additionally, providing more high-quality habitat on the greater Tillman Sand Ridge increases the ability for this site to receive tortoises displaced from adjacent lands.

Some portions of the TSRHP have not been subject to the same management practices as the major interior upland portions of the site and have experienced fire suppression. This has led to high basal areas, shading, and habitat that is not utilized by sandhill species although soils are suitable. We focused restoration activities on these areas of the property and, over the course of five years (2016-2021), achieved the following restoration goals:

Year 1 (October 1, 2015 – September 30, 2016) Accomplishments

- We identified the area and scope of restoration activities at Tillman Sand Ridge Heritage Preserve.
- We worked with preserve managers and the SCDNR forester to identify areas that could be improved with restoration effort to produce an increase in available habitat at TSRHP.
- We performed Line Transect Distance Sampling (LTDS) of the tortoise population at TSHP as part of a different project. The tortoise population is estimated at N=232 (95%CI: 169-320) and a tortoise density of 1.43 tortoise/hectare, making this the highest density site known in SC. This population nearly meets MVP status and is an excellent candidate for habitat restoration to increase the population on site.
- We delineated approximately 184 acres for timber sale to reduce basal areas and or remove hardwoods. Several different approaches have been selected from thinning a longleaf plantation, fuel chipping hardwoods and potential invasives, to intensive cuts with leave-trees marked to drastically reduce basal area and promote herbaceous understory.
- The timber sale was packaged for public notice.

Year 2 (October 1, 2016 – September 30, 2017) Accomplishments

- The timber sale was successfully bid on 2/15/17.
- Logging began on June 2017 and was mostly complete by the end of September 2017.
- All logging operations (including log deck clean-up via tub grinding) concluded Winter/Spring 2018.
- 43.5 acres were treated with herbicide on 10/6/17 to control hardwood resprouts in the initial longleaf planting area.
- 319 acres were prescribed burned 5/17/17.
- An additional parcel (65 acres) was selected for thinning to improve habitat quality (harvesting was scheduled for Winter 2017-18).
- A custom blend of sandhills ecotype seed (6 native grasses and 23 native forbs) for ground cover restoration was purchased.

Year 3 (October 1, 2017 – September 30, 2018) Accomplishments

- All logging operations were completed as of March 2018, including the additional winter cut encompassing 65.3 acres and tub grinding of log deck debris.
- We planted approximately 100 lbs. of native ground cover seed mix on roughly 1/3 of 31 acres in a planted Longleaf Pine stand in May 2018.
- We installed a plot for monitoring germination of seed mix in May 2018.
- A site prep burn of 31 acres before planting the seed mix occurred in May 2018.
- We planted 12,000 Longleaf Pine seedlings on 43.5 acres of restoration cut area in March 2018.
- We planted 200 wiregrass plugs on 43.5 acres of the restoration cut area in March 2018.
- We applied herbicide to 43.5 acres to control woody vegetation in the restoration cut area.
- We added two desired future reference plots to capture more variety of existing tortoise habitat to include one swale/wetland plot and one fire shadow plot.
- 14 known “pioneer” tortoises have already moved into the restoration area.
- We developed plot data signage for our reference pictures.
- We took quarterly photos of each reference plot.

Year 4 (December 1, 2018 – December 31, 2019) Accomplishments

- 305 acres were contract-burned by the South Carolina Forestry Commission (SCFC) within existing interior Gopher Tortoise habitat May 2019 adjacent to the restoration area.
- Wiregrass plugs and Longleaf Pine seedlings were purchased for Spring 2020 planting.
- A Xeric Sandhills Seed Mixture was purchased for Spring 2020 planting.
- We conducted a backpack herbicide release on 138.9 acres.
- Quarterly photos were taken of each reference plot.
- We monitored germination of the xeric seed mixture in the 31-acre planted Longleaf Pine stand.
- “Pioneer” tortoises continued to colonize the restored habitat.

- Burn plans were developed for all new restoration areas ahead of dormant season site prep burns.

Year 5 (January 1, 2020 – December 31, 2020) Accomplishments

- 117.5 acres of restoration habitat was burned by SCDNR staff in March 2020.
- 94.5 acres of wiregrass plugs were planted in the restoration areas.
- 87.8 acres of Longleaf Pine seedlings were planted in the restoration areas.
- Quarterly photos were taken of each reference plot.
- 15 "pioneer" tortoises were observed colonizing the restored habitat.

Year 6 (January 1, 2021 – December 31, 2021) Accomplishments

- 279 acres were contract-burned by the SCFC within existing interior Gopher Tortoise habitat in May 2021 adjacent to the restoration area.
- Native Wiregrass Seeds order was purchased for dispersal in the restoration areas.
- Quarterly photos were taken of each reference plot.
- 20 "pioneer" tortoises were observed colonizing the restored habitat.
- 6 lbs. of native wiregrass seeds were dispersed across the restoration areas.

Basin-wide Planning for "Bartram's" Redeye Bass in the Savannah River (Federal Grant #: SC-U2-F20AP00291-02, Duration: 2020-2024) PIs and Authors: Mark Scott (SCDNR) and Tanya Darden (SCDNR)

The endemic riverine black basses of the Southeastern US are among the most important 'umbrella species' for rallying public support for whole-ecosystems and the biological diversity they support. "Bartram's Bass" and "Altamaha Bass", two closely related and provisionally recognized species historically known as Redeye Bass, are range-restricted to Atlantic Slope river systems in South Carolina and Georgia. These species' native rivers were impounded in the latter 20th century, and invasive Alabama Bass were subsequently introduced into the reservoirs. Over the ensuing decades, Alabama Bass rapidly displaced the endemics through introgressive hybridization and direct competition. In fact, evidence to date suggests endemics have been entirely extirpated from reservoirs, and the few remaining 'pure' populations are now restricted to only a handful of disconnected tributary systems. Accordingly, Bartram's Bass in SC, and both species in GA, are considered of greatest conservation need, as addressed in their respective State Wildlife Action Plans. Both states recognize the imminent threats of extirpation posed by invasive species and habitat change.

To answer key knowledge gaps needed for conservation of Bartram's Bass and Altamaha Bass, for this grant we conducted six investigations under the TRACS objective of Research, Survey, Data Collection and Analysis. First, we completed the taxonomic description of these two provisional species to provide impetus for continued conservation programs for these recognized species. Second, we identified spatial distributions of the strongholds of genetically pure endemic bass throughout their Atlantic Slope range, and focusing on the Savannah Basin, developed predictive models of these refugia for Bartram's Bass. Third, we quantified spread rates in a Savannah tributary undergoing invasion to understand how dispersal processes set the context for effects of habitat quality on hybridization that may be occurring in these streams.

Fourth, we quantified dispersal rates based on observation of actual fish movement to understand invasion dynamics, particularly from downstream reservoirs, as well as basic life-history of Bartram's Bass. Fifth, we used information from Investigations 2-4 to develop a conservation planning map for prioritizing restoration efforts that will benefit all aquatic species. Finally, because genetic diversity is a crucial factor affecting the long-term sustainability of a population, we quantified the basin-wide genetic structure of Bartram's Bass, including population differentiation, inbreeding rates, and effective population sizes. Additional objectives met under this grant include training and education, outreach and communication, stakeholder involvement, and technical assistance.

Identification and Optimization of a Disomic Microsatellite Panel for Use in Population Genetics of Shortnose Sturgeon (Federal Grant #: SC-U2-F20AP00255-02, Duration: 2020-2024) PI and Authors: Tanya Darden (SCDNR) and Daniel Farrare (SCDNR)

The Federally Endangered Shortnose Sturgeon (*Acipenser brevirostrum*) was an initial member of the Endangered Species Act in 1973 largely due to overharvest for caviar, a shrinking population range, range-wide habitat degradation, and limited access to historic gravel bed spawning grounds due to the construction of dams. The use of genetic data to interpret patterns of population structure would vastly improve our ability to manage for population-specific threats and guide recovery efforts for the species. Currently, the only published genetic markers for Shortnose Sturgeon are mitochondrial markers and a set of polysomic microsatellites. The presumed hexaploid nature of Shortnose Sturgeon has made the development of standard disomic microsatellite markers challenging. Microsatellites remain the most affordable and tested method for analyzing genetic health and estimating population structure across a species' range. We utilized genomic sequencing from the Sterlet Sturgeon and Shortnose Sturgeon to identify a high number of microsatellites, which we screened to identify functionally disomic loci. A total of 693,511 conserved microsatellites were identified across both sturgeon genomes. The project team screened 664 of these microsatellites using Shortnose Sturgeon samples from across their range, with a total of 16 markers identified as putatively functionally disomic. Following further testing in two South Carolina data sets, the final multiplexed marker suite includes 13 microsatellites as well as the recently published sex identification marker. Project results suggest that our panel should be useful for genetically characterizing populations of Shortnose Sturgeon, although more research is needed to clarify underlying causes of observed deviations from Hardy-Weinberg Equilibrium (HWE) and potential presence of null alleles prior to interpretation of genetic data for management and conservation purposes. These observations would be expected in populations that experienced a severe historic bottleneck, which is consistent with our observed patterns in long-term N_e, contemporary N_{eb}, and Garza-Williamson Index (G-W) estimates. We did not detect genetic differences between the Winyah Bay and Savannah River data sets with the new marker panel; additional investigation into potential influences of movement patterns and collection biases are needed. From a genetic health perspective, project results would be consistent with a population of Shortnose Sturgeon that underwent a severe bottleneck historically and are slowly recovering. Supporting evidence includes contemporary N_{eb} estimates showing an increasing trend over long-term N_e estimates, a moderate level of retained genetic diversity, no indication of inbreeding, and low levels of outbreeding. Although further marker validation is needed, we are highly optimistic that the new genetic tool will provide important information for future conservation and monitoring of

Shortnose Sturgeon throughout their range. Our work has addressed specific goals and recommendations outlined in the National Marine Fisheries Service (NMFS) Recovery Plan for Shortnose Sturgeon and the South Carolina SWAP by providing improved tools for Shortnose Sturgeon conservation and recovery.

Multistate Habitat and Population Restoration of Gopher Frogs in Alabama, Georgia, and South Carolina (Federal Grant #: F20AP00258, Duration: 2019-2023) PI and Author: Andrew Grosse (SCDNR)

The objectives of this Competitive State Wildlife Grant (C-SWG) were to expand and integrate conservation management projects for the Gopher Frog and other amphibian Species of Greatest Conservation Need (SGCN) across four of the five states that encompass the Gopher Frog species' range: Alabama (AL), Georgia (GA), North Carolina (NC), and South Carolina (SC). Specifically, this C-SWG focuses predominantly on implementing and evaluating two actions – wetland restoration and population augmentation/reintroductions. In South Carolina, three isolated, ephemeral wetlands, encompassing 12 acres, and their surrounding uplands were restored to historical conditions. Canopy and midstory hardwoods and pines were removed from the wetland basin using a combination of either heavy equipment or hand tools and treated with herbicide and/or prescribed fire. Additionally, over 300 headstarted gopher frog metamorphs were released in wetlands and surrounding uplands once restoration was complete. Post-restoration, all wetlands showed a shift to more herbaceous, graminoid and other ground cover vegetation, as well as an increase in anuran species diversity.

The Suitability of Alternative Nesting Habitats for the American Horseshoe Crab, *Limulus polyphemus* (Federal Grant #: F21AP00690-03, Duration: 2020-2024) PIs: Daniel Sasson (SCDNR) and Michael Kendrick (SCDNR); Author: Daniel Sasson (SCDNR)

The American Horseshoe Crab, *Limulus polyphemus*, was long believed to use beaches as their primary spawning habitat, in large part because the environmental conditions in sediments of other habitats, such as salt marshes, was considered inhospitable for embryonic development. This project used adult spawning surveys, egg surveys, reciprocal transplants, and assays of embryonic development to compare the use of beaches and salt marshes as spawning habitat in three states – South Carolina, Connecticut, and New Hampshire – with genetically distinct populations of Horseshoe Crabs. It was found that Horseshoe Crabs spawned in similar densities in both habitats, but eggs were more likely to be found in marsh habitats than beach habitats. Furthermore, eggs laid in salt marsh habitats developed relatively well, contrary to assumptions that these eggs would be inviable. These findings indicate that salt marshes may be critical habitat for Horseshoe Crab recruitment should be considered in the management and conservation of this species. *Note: At the time of this writing (June 2025), the transcriptomics portion of this study are still being analyzed.*

Black Rail Habitat Creation and Restoration – Designing Management Techniques to Expand the Black Rail Population Along the Atlantic Coast (Federal Grant #: F22AP00563-00, Duration: 2022-present) PI and Authur: Christy Hand (SCDNR)

In progress.

Advanced Conservation and Restoration of Brook Floater and Associated Freshwater Mussels (Federal Grant #: F22AP00564-01, Duration: 2022-present) PI and Author: Ericah Beason (SCDNR)

In progress.

Conservation Planning for Geographically Restricted Headwater Species, the Sandhills Chub (Federal Grant #: F22AP00568-01, Duration: 2022-present) PI and Author: Derek Crane (Coastal Carolina University)

In progress.

Adaptively Managing for Robust Redhorse: A Range-wide Collaboration to Address Data Gaps and Implement Conservation Actions (Federal Grant #: F23AP00075-01, Duration: 2023-present) PI and Author: Tanya Darden (SCDNR0

In progress.

Developing a Proactive Conservation Planning Tool for Stream Fishes of Greatest Conservation Need in the Carolinas (Federal Grant #: F23AP03502-00, Duration: 2024-present) PI and Author: Mark Scott (SCDNR)

In progress.

Advancing Conservation and Management of the Spotted Turtle (*Clemmys guttata*) in the Southeastern United States: Addressing Data Gaps, Refining Approaches, and Building Capacity (Federal Grant #: F24AP00198-00, Duration: 2024-present) PI and Author: Andrew Grosse (SCDNR)

In progress.

An Integrative Conservation Assessment of SGCN Crayfishes in North Carolina, South Carolina, and Georgia to Fill Critical Needs for Conservation Planning (Federal Grant #: F25AP00566-01, Duration: 2025-present) PI and Author: Michael Kendrick (SCDNR)

In progress.

Characterizing the Suitability of Salt Marsh Habitat for Spawning Horseshoe Crabs, *Limulus polyphemus*, and Foraging Shorebirds, Including the Rufa Red Knot, *Calidris canutus rufa* (Federal Grant #: F25AP00567-00, Duration: 2025-present) PI and Author: Daniel Sasson (SCDNR)

In progress.

Literature Cited

Bjorgo, K., J. Isely and C. Thomason. 2000. Seasonal movement and habitat use by Striped Bass in the Combahee River, South Carolina. Transactions of the American Fisheries Society 29: 1281–1287.

Barrett, E., A. Burke, M. Hammers, J. Komdeur, and D. Richardson. 2013. Telomere length and dynamics predict mortality in a wild longitudinal study. Molecular Ecology 22: 249-259.

Climate Adaptation Science Centers (CACS). 2023. *The Resist-Accept-Direct (RAD) Framework*. United States Geological Survey. https://www.usgs.gov/programs/climate-adaptation-science-centers/science/resist-accept-direct-rad-framework

Combs, K. and L. Peltz. 1982. Seasonal distribution of Striped Bass in Keystone Reservoir, Oklahoma. North American Journal of Fisheries Management 2: 66-73.

Coutant, C. 1985. Striped Bass, temperature, and dissolved oxygen: a speculative hypothesis for environmental risk. Transactions of the American Fisheries Society 113: 666-671.

Handler, S.; Pike, C.; St. Clair, B.; 2018. Assisted Migration. USDA Forest Service Climate Change Resource Center. https://www.fs.usda.gov/ccrc/topics/assisted-migration

Scruggs, G. 1957. Reproduction of resident Striped Bass in Santee-Cooper reservoir, South Carolina. Transactions of the American Fisheries Society 85: 144-159.

South Carolina Department of Natural Resources (SCDNR). 2015. South Carolina State Wildlife Action Plan and Supplemental Volume.

United States Fish and Wildlife Service (USFWS). 2016. *Species Status Assessment Framework, Version 3.4*. https://www.fws.gov/sites/default/files/documents/species-status-assesment-framework-2016-08-10.pdf

Vaughn, Caryn & Hakenkamp, Christine. (2001). The Functional Role of Burrowing Bivalves in Freshwater Ecosystems. Freshwater Biology. 46. 1431-1446. 10.1046/j.1365-2427.2001.00771.x.

Williams, B. K., and E. D. Brown. 2012. Adaptive Management: The U.S. Department of the Interior Applications Guide. Adaptive Management Working Group, U.S. Department of the Interior, Washington, DC. https://www.doi.gov/sites/doi.gov/files/uploads/DOI-Adaptive-Management-Applications-Guide-WebOptimized.pdf