FINAL PERFORMANCE REPORT
South Carolina State Wildlife Grant SC-T-F08AF00110 (T-43)
South Carolina Department of Natural Resources
October 1, 2008—December 31, 2017

Project Title: Conservation of Migratory Land birds in South Carolina

Principal Investigator

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Objective 1:

Coordinate and collaborate with internal and external partners to implement land bird objectives outlined in the CWCS at state and regional scales. Provide avian input into the CWCS update and implement recommendations.

[NOTE: The Comprehensive Wildlife Conservation Strategy (CWCS) of 2005 was renamed the State Wildlife Action Plan (SWAP) when it was revised in 2015.]

Accomplishments:

I. Work within the agency and with partners to develop, implement and fund management, monitoring and research projects to achieve land bird objectives.

Assessing the Status of Loggerhead Shrike in South Carolina

Participated in the International Loggerhead Shrike Working Group. The goals are to identify limiting factors, quantify genetics of remaining loggerhead shrikes in eastern North America, better understand population demographics, and develop habitat models addressing habitat requirements. To assist with these efforts, developed and funded a graduate project titled "Assessing the status of Loggerhead Shrike in South Carolina" in collaboration with Clemson University. The project evaluated 1) what factors affect loggerhead shrike detectability, 2) how land cover characteristics influence loggerhead shrike occupancy on a landscape and habitat patch scale, and 3) factors influencing loggerhead shrike nest site selection in South Carolina. The report resulting from this work is in Appendix 1.

Innovative Approaches to Monitoring Success of Farm Bill Incentive Programs in Conserving Avian Wildlife on Private Lands

Developed project to evaluate the success of Farm Bill incentive programs to conserve avian wildlife on private lands entitled “Quantifying the effects of Farm Bill cost-share conservation practices on avian species on private lands in South Carolina”. It was a collaboration with Clemson University. The objectives of the project were to 1) investigate the relationship between species abundance, or occupancy, and habitat characteristics relating to National Resource Conservation Service (NRCS)-incentive program management practices, 2) determine which management practices have positive effects on songbird diversity, and 3) evaluate the effectiveness of acoustic recorders on enrolled lands as a tool for species monitoring and assess the transferability of this technology. The project is ongoing, but a progress report is located in Appendix 2.

Army National Guard Clark’s Hill Breeding Bird Counts

Assisted the Army National Guard by conducting point counts on the Clark’s Hill property. The objectives were to create a list of breeding birds on the property, and determine how the bird species change over time.

Army National Guard McCrady Training Center Songbird Banding

Coordinated and ran constant effort mist net stations at the Army National Guard McCrady Training Center. The banding station used the Monitoring Avian Productivity and Survivorship protocol which is a national program to identify and describe temporal and spatial patterns of bird species populations, relationships between these patterns and ecological characteristics, and develop population trends for species. More information on the protocol is available here https://www.birdpop.org/pages/mapsDataForms.php. The banding station at McCrady Training Center was first run in 2004 and will continue.

Army National Guard McCrady Training Center Migratory Bird Counts

Implemented fall banding at the Army National Guard McCrady Training Center to monitor migratory bird species populations using a modified Monitoring Avian Productivity and Survivorship protocol. The fall banding station at McCrady Training Center has run since 2010 with varying levels of effort.

Bald and Golden Eagle Projects

Evaluated bald eagle monitoring requirements, priorities, and funding in South Carolina. Also reviewed the federal eagle EIS and proposed rule to determine if there may be concerns for eagle populations in South Carolina resulting from the proposed regulation changes. Coordinated the annual midwinter eagle survey in collaboration with the Center for Birds of Prey which included recruiting volunteers, entering data and summarizing results. The national survey is an effort to identify winter habitat and develop population trends. Conducted several routes. Additionally, assisted the University of Georgia with a project researching the effects of AVM on bald eagle fledglings from nests located near Lake Thurmond. Golden eagle work was expanded within South Carolina in collaboration with staff from Savannah River Site, who coordinate a winter camera trap study. Conducted field visits and provided technical assistance to assess the status of at least 38 bald eagle nests and assisted South Carolina Department of Natural Resources (SCDNR) law enforcement in collecting and, when necessary, determining the cause of death from bald eagle carcasses.

Swallow-Tailed Kite Conservation Alliance

Participated in the Swallow-Tailed Kite Conservation Alliance with staff from federal and state agencies and non-government organizations. The inter-agency partnership was created to discuss management, research, monitoring, and outreach needs for swallow-tailed kite conservation. Reviewed and contributed to a multi-state grant to fund swallow-tailed kite surveys in South Carolina and obtain a region wide population estimate. The final products including a report and GIS maps are being completed by Ken Meyer at the Avian Research and Conservation Institute.

Painted Bunting Observer Team

Coordinated work in the Painted Bunting Observer Team (PBOT) project where SCDNR was one of three leaders of a citizen science project where homeowners (volunteers) are recruited to make detailed observations of painted buntings using feeders in their yards. Birds were banded to determine mark recapture information. More information on PBOT is available here https://www.birdpop.org/pages/mapsDataForms.php. The final report for work relating to this grant is available on the SCDNR website at http://dnr.sc.gov/swap/grants/T-55-R-1.pdf. In addition, continued conducting statewide banding for PBOT during 2013 and 2014. Trapped and banded 192 painted buntings at 10 locations during those two years. Banding occurred at private homes. These data could be combined with similar data collected at Parris Island and Kiawah Island. Number of birds trapped at each location by year is in Table 1.

Examples of other collaboration and coordination within and outside of the agency to identify and implement projects to achieve land bird objectives:

- Part of a four person team to develop a business plan for National Fish and Wildlife Federation (NFWF) to fund Southeastern grassland bird management.
- Worked with South Carolina Audubon to evaluate Important Bird Areas in South Carolina as part of the Important Bird Area committee.
- Served as chair of the South Carolina Ivory-billed Woodpecker Work Group, a multi-agency partnership focused on coordinating the search effort in the state. Work for the group concluded after hundreds of hours of search time were logged and millions of remote camera images were reviewed.
- Collaborated with a planning team assisting National Oceanic and Atmospheric Association (NOAA) to update the South Carolina Environmental Sensitivity Index. The Index includes information on the distribution, abundance, and seasonality of sensitive bird species that occur along the South Carolina coast. The Index can be used by United States (US) Coast Guard, NOAA, state agencies, and will be available to the public.
- Participated in a multi-state, interagency meeting to discuss double-crested cormorant populations in North Carolina and the Southeast. Provided information to the North Carolina Wildlife Resources Commission regarding the use of double crested cormorant depredation orders.
- Represented SCDNR on the Atlantic Flyway Non-game Technical Committee conducting routine duties, correspondence and meeting preparation to address bird objectives within the Atlantic flyway. Served as secretary for the Committee. Assisted with a human dimensions survey focused on measuring what people most desire out of their waterfowl-related recreational experiences. Also provided information regarding the need for collaborations, developing priorities, and implementing projects for the United States Fish and Wildlife Service (USFWS) Land bird Coordinator position. In addition, reviewed recommendation and scoping letters addressing eagle management and permitting that was sent to the USFWS on behalf of the Atlantic Flyway Council.
- Represented SCDNR as the Nongame Atlantic Coast Joint Venture Technical Committee and handled routine duties, correspondence and meeting preparation to address bird objectives within the Joint Venture region. Served as vice chair for the technical committee and as chair of the Black Rail Working Group. Participated in the development of an eastern black rail population objective with the Atlantic Coast Joint Venture and other species experts.
- Assisted United States Forest Service (USFS) by conducting a number of R8 point counts on the Andrew Pickens Ranger District. Also conducted point counts within the Indian Creek project area and attended a number of the monthly project area meetings.
- Worked as a member of the South Atlantic Conservation Cooperative interim steering committee and detail as coordinator.

- Represented SCDNR in the Partners in Flight working group including routine duties, correspondence, and meeting preparation that addressed bird objectives at state, national, and international levels. Provided a current list of bird conservation projects in South Carolina.
- Served as coordinator for the South Carolina Breeding Bird Survey routes as part of the national Breeding Bird Survey program run by the United States Geological Survey (USGS). The Breeding Bird Survey is a long-term, large-scale, international avian monitoring program to track the status and trends of North American bird populations.
- Assisted a biologist from Shaw Air Force Base on a project run by the National Purple Martin Society studying migration paths of purple martins using geolocators. Surveyed purple martin roosts on Lake Moultrie and Lake Monticello to determine roost population sizes. There was an observed decrease in the number of birds roosting at the Lake Murray roost in 2014.
- Provided comments on bird monitoring projects for the Shaw Air Force Base/Poinsett Integrated National Resource Management Plan.
- Assisted with the NFWF/NatureServe Charleston Harbor and Savannah Coastal Resilience Assessment to analyze the exposure of the human community and fish and wildlife habitat to coastal and inland storms, ultimately to highlight where natural and nature-based conservation and restoration projects may benefit both human communities and fish and wildlife.
- Worked with Parris Island Marine Corps Recruit Depot to develop a monitoring program for the site. Also, conducted some fall migration monitoring on-site.
- Participated in the North American Bird Conservation Initiative Human Dimensions Working Group. Helped create a Bird Conservation Relevance document linking bird conservation to human benefits such as economics and human health.
- Part of a multiagency collaboration to help the USFWS determine data needs for the MacGillivray's seaside sparrow USFWS Species Status Assessment. The Assessment is a USFWS requirement because the species was petitioned for listing under the Endangered Species Act.
- Assisted with the recovery action of translocating 20 pairs of red-cockaded woodpeckers into the ACE Basin. Birds were moved from Francis Marion National Forest to Cheeha-Combahee Plantation.
- Provided guidance to the South Carolina Forestry Commission Upstate Firewise Field Coordinator on potential impacts to birds for a proposed plan to reduce the risk of fire in a residential community along Lake Keowee.
- Assisted Town of Kiawah biologists trap Seaside Sparrows and attach geolocators to collect information on their migration routes.
- Reviewed the United States Department of Agriculture Animal and Plant Health Inspection Service (USDA-AHPIS) Environmental Assessment (pre-decision draft) on Reducing Bird Damage in the State of South Carolina.

- Reviewed the Carolina Sandhills National Wildlife Refuge Comprehensive Conservation Plan and provided comments; previously participated in workshop to develop the Plan. Also provided information to help Carolina Sandhills National Wildlife Refuge complete their Inventory and Monitoring Plan.
- Served on the Carolina Bird Club Records Committee. The Committee verifies observations of rare and unexpected birds in South Carolina.
- Provided information to the UFWS on Kirtland's warbler to help inform the USFWS proposed rule to reclassify Kirtland's Warbler from endangered to threatened status under the Endangered Species Act.
- Provided comments on potential avian impacts for the Columbia, SC Canal Repair Stakeholder Survey as part of the process to repair the breach resulting from the October 2015 flood.
- Provided information to Federal Emergency Management Agency on species occurrence data and state guidelines to avoid disturbance for federally listed bird species in South Carolina for projects in response to the October 2015 flood event.
- Worked with partners to develop management guidelines and swallow-tailed kite population objectives for the Francis Marion National Forest Management Plan.
- Initiated discussion with the International Wood Thrush Conservation Alliance to provide ideas on regional projects and determine priorities for the species in South Carolina.
- Peer-reviewed two manuscripts, one for the Wildlife Society Bulletin evaluating the effectiveness of different survey methods for bird species, the other for the Avian Conservation and Ecology journal evaluating the effectiveness of audio recorders to survey bird species.
- Assisted Congaree National Park with their Monitoring Avian Productivity and Survivorship bird banding station.
- Provided technical assistance to over 2,500 inquiries regarding potential impacts to land bird species related to proposed development, creation of nature trails, window collisions, installing nest cameras, solar farms, etc.
- Submitted at least 32 proposals for funding from state, federal, and nonprofit sources to support conservation needs of State Wildlife Action Plan land bird species. Of these at least 28 were funded, including projects on red-cockaded woodpecker, loggerhead shrike, MacGillivray's seaside sparrow, painted bunting, and several multi-species projects.

II. Work with DNR biologists to implement projects on state and private lands to achieve land bird objectives. Provide on-the-ground assistance when needed.

Conservation of Songbirds using CP-33 Habitat Buffers

Coordinated a project titled "Conservation of Breeding Painted Buntings and Other Songbird Indicators in Early-successional Shrub-scrub Habitat". The objectives were to

1) determine breeding bird abundance in paired CP-33 (treatment) and non-CP-33 (control) fields for painted bunting and other indicator songbird species, 2) determine nest location and success of painted buntings in paired CP-33 and non-CP-33 fields, and 3) develop a landscape/GAP analysis model to track dynamic seasonal crop rotation and predict the pattern of habitat occupancy and breeding distribution of painted buntings as well as associated early-successional shrub-scrub songbird indicator species (i.e. indigo bunting and blue grosbeak). Recommendations for bird conservation from the project include the importance of mature forest edges, and that a source of food in the form of wheat or other grass seed, as well as insects when rearing young is necessary. The final report is available on the SCDNR website at http://dnr.sc.gov/swap/grants/T-47-R-1.pdf.

South Carolina Quail Technical Committee

Collaborated with SCDNR staff and other agencies as part of the South Carolina Quail Technical Committee to discuss the National Bobwhite Conservation Initiative, conservation of quail and other grassland and early successional bird species, and habitat restoration in South Carolina. Represented the SCDNR nongame bird program. Lead the Quail and Other Grassland Bird Habitat and Bird Survey Subcommittee to develop whistling count, covey count and habitat survey protocols for the focal areas. The whistling count survey includes seven addition grassland bird focal species. Trained SCDNR staff for the Quail Initiative whistle count surveys. Survey methods and data collecting were practiced, as well as learning the songs and identification of the seven additional bird species to be surveyed. Conducted four of the whistling count and covey call surveys. The surveys were first run in 2017 and will continue annually. In addition, worked with SCDNR Small Game Program staff to develop a project to determine seasonal calling patterns of Northern Bobwhite quail and other grassland birds in South Carolina using audio recording units. The protocols and survey results are available through the SCDNR Small Game Program.

Improve Grassland Bird Habitat on Oak Lea, Bland, and Tuomey Wildlife Management Areas

Worked with SCDNR staff to improve grassland bird habitat on Oak Lea Wildlife Management Area (WMA), Bland Tract WMA, and Tuomey Tract WMA by developing and implementing various management strategies and monitor bird population responses. Activities included strategies such as winter disking, prescribed burning, and fallow buffers. Grassland bird surveys were conducted in monitor impacts of the management activities. The final report is available on the SCDNR website at http://dnr.sc.gov/swap/grants/T-27-R-1.pdf.

Breeding Bird Survey

Coordinated the USGS Breeding Bird Survey in South Carolina, and organized volunteers for the routes. The Breeding Bird Survey is a program designed to monitor bird populations across North America and inform wildlife managers of significant changes in bird population levels. More information on the Breeding Bird Survey can be found here https://www.pwrc.usgs.gov/bbs/. As coordinator, established new Breeding Bird Survey routes for the state. In addition to conducting up to nine routes annually as part of the national program, set-up and ran modified breeding bird survey routes on Jocassee Gorges, DNR's Jim Timmerman Natural Resources Area, and the Army National Guard McCrady Training Center to better understand bird species using those properties.

James W Webb Wildlife Center and Game Management Area Songbird Banding

Coordinated and ran constant effort mist net stations at James W. Webb Wildlife Center and Game Management Area (Webb WMA). The banding station used the Monitoring Avian Productivity and Survivorship protocol which is a national program to identify and describe temporal and spatial patterns of bird species populations, relationships between these patterns and ecological characteristics, and develop population trends for species. More information on the protocol is available here https://www.birdpop.org/pages/mapsDataForms.php. The banding station was run from 2007-2016. During this grant period, 2,958 birds were trapped encompassing 51 species (Table 2).

Loggerhead Shrike Banding and Genetics

Initiated project to color band and collect feather samples during both breeding and nonbreeding seasons for inclusion in an international project analyzing stable isotope and trace element genetics throughout the loggerhead shrike species' range. The project is coordinated through the Loggerhead Shrike Working Group. Once common throughout much of North America, loggerhead shrike populations have decreased significantly across the species' range. Banding and associated feather sampling will assist in locating wintering areas, thereby facilitating study of threats, wintering ecology, and full-life cycle modeling. Banding began in 2017 and 22 loggerhead shrikes were banded.

Wintering Baltimore Oriole Monitoring

The number of Baltimore orioles over-wintering in South Carolina seems to be increasing over time. Coordinated Baltimore oriole winter population monitoring to get a better idea of where the wintering Baltimore orioles are distributed. The number of birds trapped each year by location is in Table 3. Banding occurred at private homes. The first out-of-state band recovery from the wintering Baltimore oriole banding project was received. A second year male, banded in Myrtle Beach on 8 March 2011, was found in British Columbia in August 2015. Beginning in 2016, banding efforts were supplemented by a citizen science survey of Baltimore orioles observed at bird feeders on a specific date. The surveys were held in conjunction with the Great Backyard Bird Count and followed the same protocol. More information on the protocol is available here http://gbbc.birdcount.org/. Since the SCDNR citizen science survey began, South Carolina has had the largest number of Baltimore orioles tallied in the US during the Great Backyard Bird Count. In South Carolina, orioles were counted from the upstate, across the midlands and along the coast from North Myrtle Beach to Hilton Head. South Carolina had approximately 300 Baltimore orioles tallied each year.

Nightjar Surveys

Completed annual nightjar surveys on Hamilton Ridge WMA, Webb WMA, Palachucola WMA, and Army National Guard McCrady Training Center. A nightjar survey was also conducted on Wateree River Heritage Preserve (HP) during 2017. These surveys were part of the national Nightjar Survey Network organized by the Center of Conservation Biology. Little is known about the basic aspects of nightjar biology, habitat use, and population status due to their cryptically nocturnal lifestyle. In recent years, conservationists believe that populations of nightjars are dramatically declining. This survey program was created to gain a better understanding of population status across the nation that will help determine the magnitude and scale of population changes so a course for conservation may be developed. More information on the program is available here http://www.nightjars.org/.

Christmas Bird Counts

The Christmas Bird Count is a national program hosted by the National Audubon Society. Its purpose is to estimate population trends for bird species wintering in North America, more information is available here http://www.audubon.org/conservation/science/christmas-bird-count. Annually coordinate the volunteers for up to three counts, in addition to participating in seven counts. The counts include federal, state, and private properties.

Examples of other collaboration with SCDNR biologists to implement projects on state and private lands to achieve land bird objectives:

- Worked with staff at Jocassee Gorges WMA to discuss peregrine falcon management needs at the nest site of the second known pair of nesting birds in the State.
- Provided information on State Wildlife Action Plan bird species on properties being considered for acquisition by SCDNR.
- Attended meeting and provided comments to SCDNR staff when discussing the proposed Avian Vacuolar Myelinopathy Plan Draft Environmental Assessment and Draft Finding of No Significant Impact to evaluate the potential impacts of managing hydrilla within J. Strom Thurmond Lake to reduce occurrences of avian vacuolar myelinopathy (AVM) in bald eagles.
- Updated the SCDNR Wildlife Rehabilitator Registry by compiling new information and posting to website. Attended meeting hosted by SCDNR to begin the process of updating wildlife rehabilitator permit requirements in South Carolina.
- Coordinated with SCDNR staff to develop a prescribed burn schedule for Persanti Island that will not negatively impact the nesting bald eagles or the historic red-cockaded woodpecker clusters.
- Initiated collection of site information, historical and current, for a subspecies of black-throated green warbler, commonly referred to as Wayne’s warbler. This subspecies nests in the Coastal Plain.
- Updated the state scientific collection permit to alleviate bird banding concerns.
- Developed SCDNR peregrine falcon take application for fall harvest and administered the peregrine falcon take.
- Established and completed a point count survey (15 counts) on Wateree River HP to collect information on bird species utilizing the property.
- Reviewed and provided guidance on two proposals submitted by a consultant to NFWF to support translocating red-cockaded woodpeckers from Francis Marion National Forest to private properties in South Carolina. The proposal was funded in 2016 and was resubmitted for funding in 2017.
- Provided input on the Little Pee Dee Lumber Focus Area and Cowasee Basin Focus Area plans. The plan objective is to establish a network of partners comprised of private landowners, conservation organizations, land trusts, and government agencies to oversee and maintain a landscape-scale conservation initiative to protect and enhance the important lands, waters, rare and sensitive habitats, cultural sites, and diverse natural resources while maintaining in perpetuity the long-honored traditional uses of hunting, fishing, forest management, and agriculture.
- Assisted SCDNR law enforcement with questions regarding state and federal regulations regarding non-game bird species.

- Assisted regional SCDNR biologists with the Bluebird Nest Box Program by checking bluebird boxes and provided guidance on the placement of Eastern bluebird boxes on Aiken Gopher Tortoise HP.
- Assisted in the development of a bird species checklist for Webb WMA for the public to use while visiting the property.
- Reviewed and provided comments on the SCDNR Nuisance, Injured, and Orphaned Wildlife document.
- Reviewed a research proposal "Comparison of health and behavior of wintering common loons" that was submitted to Earthwatch that will characterize the behavior of wintering loons on Lake Jocassee.
- Provided information on avian species for a Forest Legacy Grant for a property that abuts Chestnut Ridge Heritage Preserve.
- Assisted in the coordination effort for the recovery action of translocating 10 red-cockaded woodpecker pairs onto Donnelley WMA. The first translocation occurred in 2016 and the last will be 2018.
- Captured red-cockaded woodpeckers that naturally dispersed to Aiken Gopher Tortoise HP to determine color band combinations to verify their natal location. Also translocated a pair of red-cockaded woodpecker from an above-baseline cluster on a Safe Harbor Program property to Aiken Gopher Tortoise HP.
- Worked with SCDNR staff at Jocassee Gorges WMA to discuss prescribed fire in the mountains, bird responses, and needed monitoring and research.
- Provided information on avian citizen science projects as part of the South Carolina State Wildlife Action Plan's education and outreach strategy.
- Developed a more efficient way to organize and maintain past and future land bird data sets. Made changes to the relational database, began creating a spreadsheet to more easily import data from different databases, and submitted banding data to the USGS Bird Banding Lab.

III. Represent SCDNR at local, state, regional and national meetings to facilitate implementation and monitoring of South Carolina's CWCS land bird objectives and information transfer.

Local Meetings

Attended the ACE Basin Sea Level Rise scoping meeting hosted by Audubon. The objective was to begin building a working partnership of stakeholders to work toward preserving tidal marsh habitat in the ACE Basin together with its ecosystem services and full assemblage of associated bird species and other wildlife.

Represented SCDNR at a black vulture information sharing meeting hosted by the USFWS, USDA-APHIS Wildlife Services, and SCDNR.

Represented SCDNR at ACE basin task force meeting, prepared to address concerns and provide information on bringing red-cockaded woodpeckers into the ACE Basin.

Attended multi-agency meeting to discuss what is known about ruffed grouse in South Carolina, data needs, and determine interest in conducting ruffed grouse surveys.

Represented SCDNR at Sandhill's-longleaf partnership inaugural meeting; an on-the-ground initiative to restore, manage and protect the longleaf ecosystem in Chesterfield and Lee Counties. Continued efforts by reviewing concept plan for the group.

Attended annual SCDNR and Clemson University research meeting to review past cooperative research efforts, current projects, introduce new faculty and staff, and discuss research interests for future cooperative opportunities.

Attended a data management strategy meeting to identify needs and ways to make data storage better for the SCDNR Wildlife and Freshwater Fisheries Division.

Represented SCDNR at a workshop on bird-friendly recommendations for bottomland forests for bird conservationists, landowners, and foresters hosted by Audubon.

State Meetings

Attended annual South Carolina annual meetings of The Wildlife Society. Provided information on the use of bioacoustics to monitor and study wildlife species. Led bird section of the Bioblast.

Attended annual SCDNR wildlife technicians' meetings.

Attended the annual SCDNR Migratory Game Bird Committee meetings. Presented changes to the South Carolina Falconry Regulations and summaries of the Atlantic Flyway Nongame Technical Committee meeting activities.

Attended multiagency meeting to review the current status of highly pathogenic avian influenza in the US and discuss surveillance in South Carolina.

Participated in annual interagency meetings to discuss the status of red-cockaded woodpecker in South Carolina.

Participated in a meeting with the Longleaf Alliance, private consultants, USFWS, and USFS at Francis Marion National Forest to discuss a NFWF-funded red-cockaded woodpecker translocation project.

Attended South Carolina Prescribed Fire Council meeting.

Attended annual SCDNR and USFWS coordination meetings that provided an update on state and federal activities relating to wildlife management.

Represented SCDNR at Audubon South Carolina Important Bird Area committee meetings to determine what areas in South Carolina should be part of the program.

Attended annual USFS and SCDNR coordination meetings that provided updates on state and federal activities relating to wildlife management.

Participated in a multiday workshop, Longleaf Alliance Academy: Fire and Longleaf 201, hosted by the Longleaf Alliance.

Attended the South Carolina Prescribed Fire Council meeting.

Attended annual SCDNR biologists meetings to discuss current and planned projects.

Hosted the annual business meetings of the South Carolina Bird Records Committee. The Committee addresses by-law changes and bird observation reports in South Carolina that need to be verified.

Regional Meetings

Represented SCDNR in Swallow-tailed Kite Conservation Alliance meetings to discuss management, research, monitoring, and outreach needs for swallow-tailed kite conservation. Also attended several South Carolina Swallow-tailed Kite working group meetings and conference calls.

Represented SCDNR at an At-Risk Species Workshop for Southeast Coastal Plain species hosted by the USFWS to discuss priority species, current species distributions, and known threats.

Attended the annual Southeastern Association of Fish and Wildlife Agencies (SEAFWA) meetings to discuss bird-related issues among different agencies and organizations in the Southeast.

Represented SCDNR at biannual Atlantic Coast Joint Venture Technical Committee meetings. Served as vice-chair and chair of the Committee. Participated in various calls and meetings representing SCDNR at the technical committee and proxy for management board member.

Attended biannual Atlantic Flyway Nongame Migratory Bird Technical Section meetings. Served as secretary for the Technical Committee.

Attended annual meetings of Southeast Partners in Flight and at the Northeast and Southeast Partners in Flight meeting. Participated in workshops on integrating bobwhite quail and other grassland bird initiatives, black rail conservation, and threats to pineland ecosystems. The meetings provided an opportunity for South Carolina to collaborate with regional groups to advance bird conservation priorities.

Represented SCDNR at annual international Loggerhead Shrike Working Group meetings to establish research, monitoring and management objectives for loggerhead shrike throughout their distribution.

Participated in a southeastern interagency meeting to discuss the status of mid-winter bald eagle surveys being conducted in each state.

Participated in the South Atlantic Landscape Conservation Cooperative workshop to review and provide comments on the Conservation Blueprint.

Participated in a Species Status Assessment multiagency meeting hosted by the USFWS to discuss the MacGillivray's seaside sparrow.
Attended and hosted a joint meeting of Southeast Partners in Flight and Southeast Quail Study Group.

National Meetings

Attended The Wildlife Society Meeting, and assisted with the organization of the State Wildlife Action Plan monitoring session.

Participated in a USFWS webinar on the Migratory Bird Treaty Centennial Celebration to discuss proposed activities and opportunities for states to get involved.

Participated in a webinar hosted by the Association of Fish and Wildlife Agencies (AFWA) on ways states can utilize citizen science to meet their State Wildlife Action Plan goals and data collection needs.
Attended the North American Ornithological Conference to discuss bird related issues among representatives of State, Territorial, and Provincial fish and wildlife agencies and organizations. The conference brought together leading ornithologists from all over the western hemisphere.

Participated in Avian Knowledge Network webinar that demonstrated what the Avian Knowledge Network is and the functionality of the program.

Represented SCDNR on various committees at the annual North American Wildlife and Natural Resources Conferences. Presented the Atlantic Flyway Non-game Technical Committee Section summary and recommendation to the Atlantic Flyway Council.

Participated in a webinar hosted by the USFWS presenting a draft framework for management of conflict species.

Participated in a North American Bird Conservation Initiative meeting by conference call.

Participated in USFWS scoping webinar on the Incidental Take Programmatic Environmental Impact Statement and provided comments to SCDNR staff.

Attended the Association of Fish and Wildlife Agencies' annual meetings to discuss bird related issues among representatives of State, Territorial, and Provincial agencies. Attended Bird Conservation, Partners in Flight/Shorebird/Waterbird, and Energy committee meetings.

Attended North American Wetlands Conservation council meeting to review and discuss grant proposals for funding to conserve wetlands and wetland-associated bird species.

IV. Organize and disseminate accomplishments and information by writing papers, giving presentations, conducting workshops and field days, developing press releases, and other means.

Publications

Published and co-authored a journal article “Influence of Atmospheric Properties on Detection of Wood-Warbler Nocturnal Flight Calls” in the peer-reviewed International Journal of Biometeorology.

Published and co-authored a journal article “Individual Flight-calling Behaviour in Wood Warblers” in the peer-reviewed journal Animal Behaviour.

Published and was primary author on a journal article “Surveillance of Avian Influenza in Waterfowl (Family Anatidae) within Erie and Mercer Counties, Pennsylvania” in the peer-reviewed Journal of the Pennsylvania Academy of Sciences.

Part of the US State of the Bird Science Team tasked with developing a report using birds to indicate the nation’s environmental health. Reports were produced in March 2009 and 2010. Also a co-author on a paper presented during the American Ornithologists’ Union session on the State of The Birds. The reports can be found here http://nabci-us.org/how-we-work/state-of-the-birds/.

Part of a regional team that wrote the Southeast Partners in Flight Web Tech field guide.

Presentations

Co-authored poster presentation titled “Loggerhead Shrike Occurrence in South Carolina” given at the American Ornithological Society Annual Conference (Figure 1).

Co-authored poster presentation titled “Occupancy and Detectability of Loggerhead Shrikes in South Carolina” given at The Wildlife Society Annual Conference (Figure 2).

Co-authored poster presentation titled “Quantifying the Effects of Farm Bill Cost-Share Conservation Practices on Avian Species on Private Lands in South Carolina” given at The Wildlife Society Annual Conference (Figure 3).

Presented painted bunting and Baltimore oriole monitoring and research findings to Katawba Valley Land Trust, and on another occasion, to the Jensen’s Garden Club in Murrells Inlet.

Presented information on how to attract birds to urban landscapes and also findings from current land bird projects to two garden clubs.

Presented backyard bird feeding program to Wahalla Lutheran Men’s group.

Presented South Carolina's double crested cormorant control program results to the Atlantic Flyway Nongame Migratory Bird Technical Section.

Presented findings and implications of painted bunting assessment project at annual SCDNR/USFWS cooperative meeting.

Presented an overview of the bird conservation program to the Heritage Trust Advisory Board (HTAB).

Presented Forest Management for Songbirds during an Upstate Forestry Workshop sponsored by the American Tree Farm System, Clemson Extension, Forest Landowner Association, Greenville Forestry and Wildlife Society, South Carolina Forestry Association, and South Carolina Forestry Commission.

Presented painted bunting monitoring and research findings to Charleston County, SC Audubon Society.

Co-authored presentation titled "The relationship between refueling performance, migratory flight calls, weather, and competition at an inland stopover site" given at the North American Ornithological Conference.

Presented information on bird biology to Bookman Elementary School Science day (560 students, 20 adults).

Presented Bluebird Management to the Kershaw County's Seagull Program.

Presented research findings from the McIntyre Bird/Wildlife Aircraft Strike Hazard (BASH) project conducted by Clemson University, SCDNR, and University of South Carolina at the US Department of Defense BASH findings meeting.

Presented the Atlantic Flyway Non-game Technical Committee Section summary and recommendation to the Atlantic Flyway Council.

Presented information on purple martin natural history and population status in South Carolina to a 4-H Camp.

Presented information for a Saluda Trails Middle School project on the effects of climate change on bird populations in South Carolina.

Workshops and Field Days

Coordinated and hosted annual Bird Identification Workshops that provided an opportunity for SCDNR staff to learn how to identify songbirds, increase their knowledge on songbird natural history, and begin to learn how to conduct songbird surveys.

Part of a team that organized the Santee Bird Festival and led two field trips during the Festival.

Led a Bird Identification program for SCDNR Media and Outreach staff as part of their retreat.

Hosted and organized a South Carolina Bird Conservation Workshop to update organizations and agencies that work with birds on management, monitoring and research projects within South Carolina.

Worked as part of an agency team to host the first ever joint meeting between the Southeast Quail Study Group and Southeast Partners in Flight.

Assisted with program organization and presented South Carolina information at a workshop during an annual meeting of The Wildlife Society. The workshop was titled: Converting Plans to Actions – a Workshop on Designing a Wildlife Monitoring Program In Support of State Wildlife Action Plans.

Provided information to the public at the annual Palmetto Sportsman’s Classic at both the SCDNR Wildlife booth and the Kid’s booth.

Led an avian identification field trip for a Carolina Bird Club winter meeting.

Led a bird identification walk as part of the South Carolina meeting of The Wildlife Society Bioblast.

Presented information about SCDNR nongame bird projects and guided hands-on activities to Boy Scouts who attended a Boy Scout event at the Orangeburg Fish Hatchery to help them earn a Bird Study Merit Badge.

Worked with students from Columbia, SC area high schools that were job shadowing SCDNR staff.

Hosted several presentations on the usefulness of trapping and banding birds and demonstrated how to mist-net, band, age and sex birds. Groups included students from the Wildlife Management Program at Central Carolina Technical College and on separate occasions, students from the Clemson University's Student Chapter of The Wildlife Society, the Francis Marion University Vertebrate Zoology class, and Lugoff-Elgin Middle School Science Club.

Participated in the Webb WMA Field Day by providing two bird ID walks and bird banding demonstrations to the public.

Participated in the 75th Anniversary celebration at Wateree River HP. Conducted two bird banding demonstrations for the event.

Press Releases and Other Media

Created six bird press releases related to bird use of snags, holiday cheer for wildlife, steps to help migratory birds, guidance on why and how to clean bird feeders, and to announce and provide a summary of results from the Baltimore oriole winter survey coordinated by SCDNR (example press releases are in Appendix 3). Many of these press releases were released annually.

On three occasions, answered bird-related questions during the hour-long Your Day program on public radio.

Updated the agency web pages for bald eagles to reflect delisting status and to better provide current information on the status of bald eagles in South Carolina. Additionally, more information was added regarding state and federal eagle regulations and ways to avoid disturbance. Also, in 2016 created a digital map that shows the location of all documented bald eagle nests in South Carolina and a digital form the public can use to notify SCDNR of the location of bald eagle nests (Appendix 4). Thirty bald eagle nests were reported using the online form.

Updated information on the SCDNR scientific collection permit and USGS federal bird banding lab webpages.

Completed the development of new non-game bird webpages for the SCDNR website to provide additional information about these species (Appendix 5).

Worked with SCDNR Land, Water and Conservation Division staff to redesign the Heritage Trust section of the SCDNR website.
Provided four interviews to various newspapers. The topics included purple martins at Lake Murray, bald eagles, State of North American Birds report, and ospreys.

Worked with SCDNR outreach staff to develop educational materials on bird species for audiences that communicate in Spanish.

Assisted with developing signs for outreach and education about birds for the Cohen Campbell Fish Hatchery.

Created 10 social media posts that highlighted bird conservation work in South Carolina that were used on SCDNR and USFWS social media pages.

Assisted writing four articles in the South Carolina Wildlife magazine on the following topics: American robins, the Baltimore oriole project, roosting and migratory behaviors of purple martins and other bird species, and palm warbler natural history in South Carolina.

Provided CBS television network with information on the status of bald eagles in South Carolina for a television news story.

Conducted social media interview for SCDNR Facebook Live about the loggerhead shrike banding project. The video is available here https://www.facebook.com/lifesbetteroutdoors/videos/10156196174684095/.

Taped video for two shows on the Coastal Kingdom television program, topics included the loggerhead shrike banding project and wintering Baltimore oriole trapping.

Answered over 13,750 general inquires for bird-related information (letters, phone calls, emails, etc.) related to nuisance animals, strandings and other dead birds, discovery of nestlings and recent fledglings, falconry, and other wildlife issues.

Significant deviations:

The Bird Conservation Coordinator position was vacant from December 2010 to June 2014 and the land bird technician was on leave from March-August 2015. In addition, some travel was not conducted due to state travel restrictions.

Estimated Federal Cost: $210,560.00

Recommendations: Close the grant.

Tables

Table 1. Number of painted bunting trapped as a continuation of the Painted Bunting Observer Team by location each year. Banding occurred at private homes so location names are abbreviated.

LOCATION	2013	2014	TOTAL
LOTT		6	**6**
MATHIAS	3	6	**9**
MORRIS		3	**3**
NOLTE	51	54	**105**
PITTMAN	29	21	**50**
RAPP	1		**1**
RODGERS		5	**5**
SMITH	2	3	**5**
STRANC	2	5	**7**
TOLTON	1		**1**
TOTAL	**89**	**103**	**192**

Table 2. Number of birds trapped during breeding season constant effort mist netting at James W. Webb Wildlife Center and Game Management Area by species and year.

	2009			2010			2011			2012			2013			2014			2015			2016			
SPECIES	N[a]	R[b]	U[c]	N	R	U	N	R	U	N	R	U	N	R	U	N	R	U	N	R	U	N	R	U	TOTAL
Acadian flycatcher				2			2			1		1				2			2			5			15
American goldfinch													2									2			4
American redstart	1						1			1					1	1									5
Bachman's sparrow	1			1			2			5			1	1	1	1									13
Black-and-white warbler							1			1															2
Black-throated blue warbler	1		1				8			7			7		1	6			9						40
Blue grosbeak	1			2			1						1				1								6
Blue jay	13	1		17	4		20			12		1	11	4	1	10	2		11	2	1	7	5		122
Blue-gray gnatcatcher				3			1						2									1			7
Brown thrasher	2						3						3			8	2				3	1			22
Brown-headed cowbird													1												1
Carolina chickadee							1						1									1			3
Carolina wren	12	2	1	15	6		13			13	2		23	7	3	19	13	1	17	5		14	6	3	175
Chipping sparrow	4			2			11		1	6		1	9			3			8			6		1	52
Common yellowthroat	12	3	2	7	1		3			26	1	1	20	9	2	14	4		9	1		11	3		129
Downy woodpecker				2			4						3			1						1			11
Eastern bluebird							4									4			6						14
Eastern kingbird				2			1			2			1						1						7
Eastern screech-owl				1						1															2
Eastern towhee	7	1		23	1		8		1	14			14	7	3	11	5	2	6	6		5	4	2	120
Eastern wood-pewee	3			4	1		3			7			7	6	1	2	2		5	1		3	1		46
Gray catbird	1			3			9			3			4			5			2			4			31
Great crested flycatcher				2						5															7
Hooded warbler	3			2			4			3			4			4	1		2			3			26
Indigo bunting	39	4	1	36	4		58		4	77	3		46	12	2	40	9	1	32	4	1	31	9		413
Kentucky warbler							1						1			1									3
Magnolia warbler													1												1
Northern bobwhite									1																1
Northern cardinal	34	15	2	74	16		44			35	1		26	22	3	48	22	1	48	35	1	34	30		491
Northern mockingbird	2						1						1			4	1		1			1	1		12
Northern parula	1						4				1		5			2			3						16
Orchard oriole	5	2		8	2					8			5	6	1				1			6	1		45
Ovenbird	1									1															2
Painted bunting	37	12	2	24	6		22			31	1		38	18	1	26	13		26	8		25	6	1	297
Pine warbler							2			1															3
Prairie warbler	1						2			5			2			1			3			1			15
Red-bellied woodpecker	5			3	1								2						1			2	1		15
Red-eyed vireo	5			3			2			6			8	1		4			2	1		2			34
Red-headed woodpecker										1			1									2			4
Rudy-throated hummingbird			5						5			14			12			2			5			2	45
Summer tanager	3			5	1		1			2		1	11	6	1	3			6	1		5			46
Swainson's warbler																2									2
Tufted titmouse	1			4			4			3			1			5			5	1		3			27
White-breasted nuthatch							1																		1
White-eyed vireo	35	18	2	27	11		18			23		1	19	36	1	32	25	4	17	19		22	11	2	323
Yellow warbler	30	17		24	7		15	1		44	3		34	30	1	30	12	1	13	6	1	9	4		282
Yellow-billed cuckoo																3			2	1					6
Yellow-breasted chat																						1			1
Yellow-throated vireo				3						1												2			6
Yellow-throated warbler	1												2												3
TOTAL	2270	75	16	2309	61	0	2286	1	12	2357	12	20	2330	165	35	2306	112	12	2253	91	12	2226	82	11	2954

[a] N stands for new, meaning the bird was banded after it was trapped

[b] R stands for recapture, meaning the bird was banded during an earlier trapping session but was trapped again

[c] U stands for unbanded, meaning a band was not put on the bird after it was trapped

Table 3. Number of Baltimore orioles trapped during wintering season by location each year. Banding occurred at private homes so location names are abbreviated.

	2010		2011		2012		2013		2014		2015		2017		
LOCATION	New[a]	Recapture[b]	New	Recapture	New	Recapture	New	Recapture	New	Recapture	New	Recapture	New	Recapture	TOTAL
BEARDSLE													4		**4**
BEATSON			16	2	9	6	14	6	37	20			19	2	**131**
BURNETT			31	3	13		14	8	32	2	31	5			**139**
CHANDLER					4		1	1	2	2					**10**
CLOS			20	1	1	2	4	2	1						**31**
FLOYD									8		7				**15**
HAMILTON							13		2						**15**
HAYES									14		8				**22**
HILL			7												**7**
HOVIS									4	2					**6**
HUX									31		13	1	31	1	**77**
JOHNSON									4		16				**20**
KELLY									1						**1**
KLINKE					8	1	2			2					**13**
KRUCKE							4								**4**
LINDSEY			11	1	13				4	1	1				**31**
MALLARD	62	11	38	12	11	3	15	10							**162**
MCCULLOU									2						**2**
MEDLIN									1						**1**
NARAMORE							7	3	13	3					**26**
OLIN					10				19	1	17	9			**56**
OSBORNE									4						**4**
PHILLIPS			1				6		5						**12**
SHERRILL							3		7						**10**
SMOAK			19	1			6	2	9	2	11	9			**59**
SNEED			37	3	2		14	1	7		11	8			**83**
SPENCE							10		7	1					**18**
STONE									17		36	3			**56**
SWAGERTY							4		2						**6**
SYMS			13				18								**31**
THOMAS									17		10	3			**30**
WEST					26		13		13						**52**
WILSON			31				15		22	5					**73**
TOTAL	**62**	**11**	**224**	**23**	**97**	**12**	**163**	**33**	**285**	**41**	**161**	**38**	**54**	**3**	**1207**

[a] New means the bird was banded after it was trapped

[b] Recapture means the bird was banded during an earlier trapping session but was trapped again

Figures

Figure 1. Presentation titled “Loggerhead Shrike Occurrence in South Carolina” given at the American Ornithological Society Annual Conference.

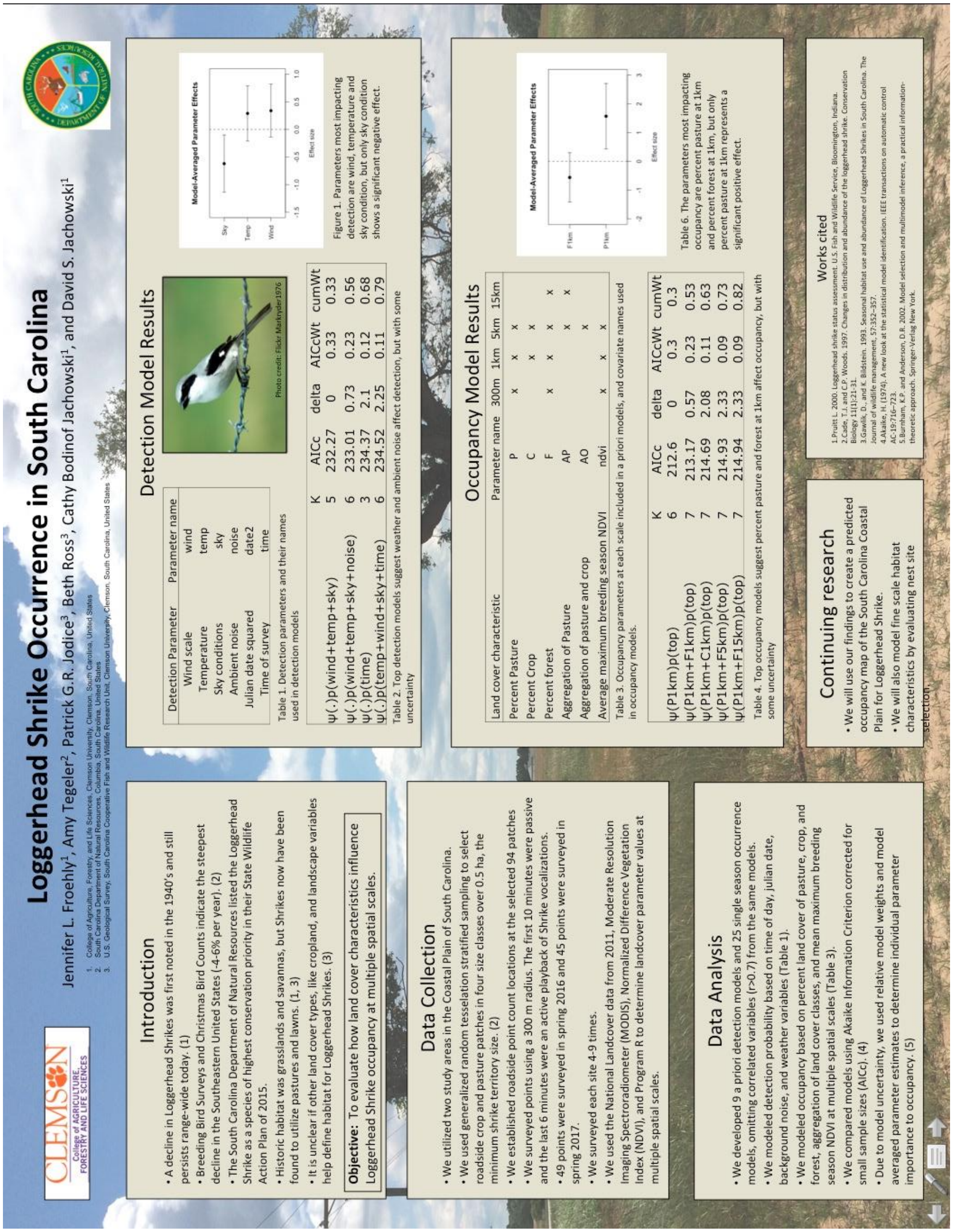


Figure 2. Presentation titled "Occupancy and detectability of Loggerhead Shrikes in South Carolina" given at The Wildlife Society Annual Conference.

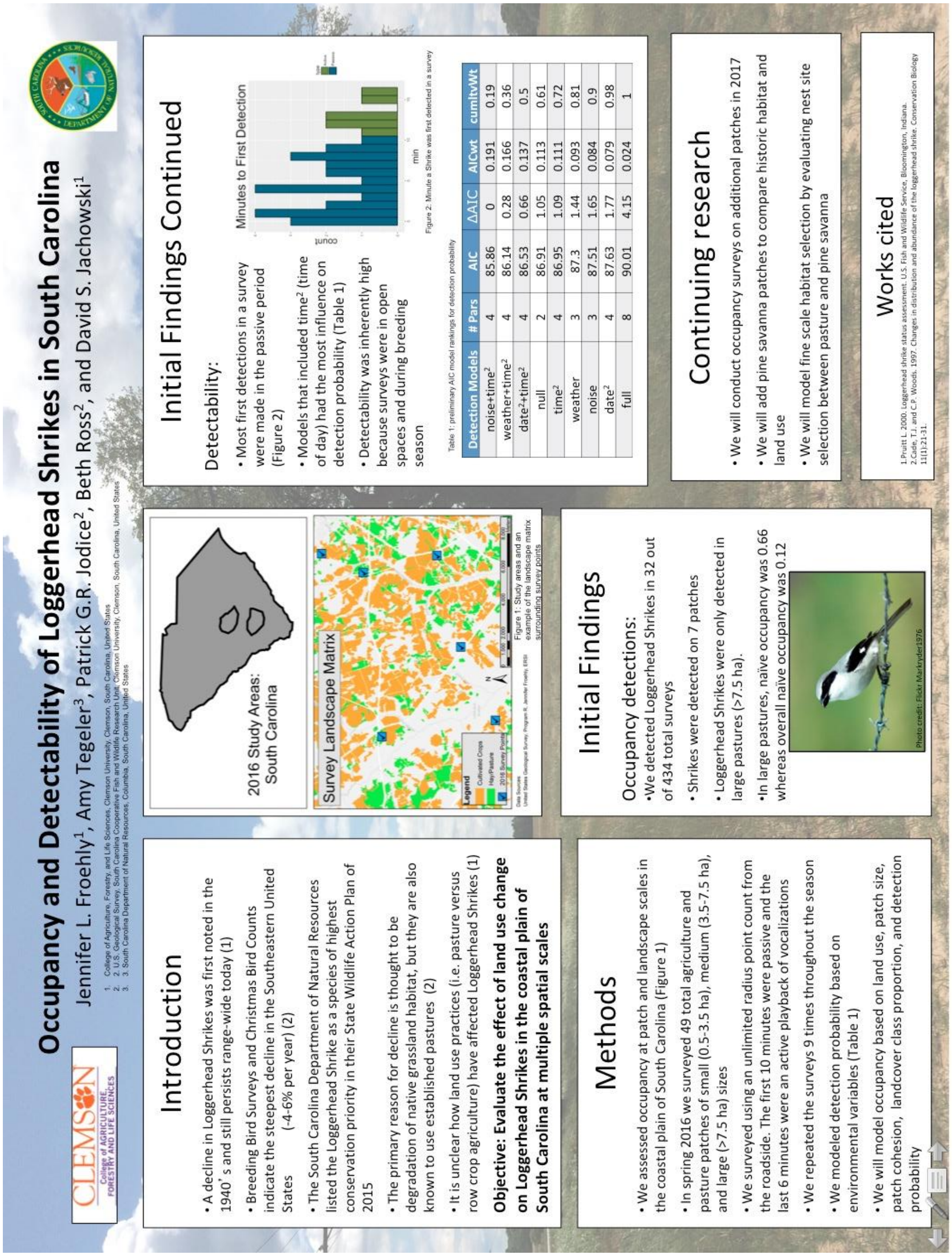
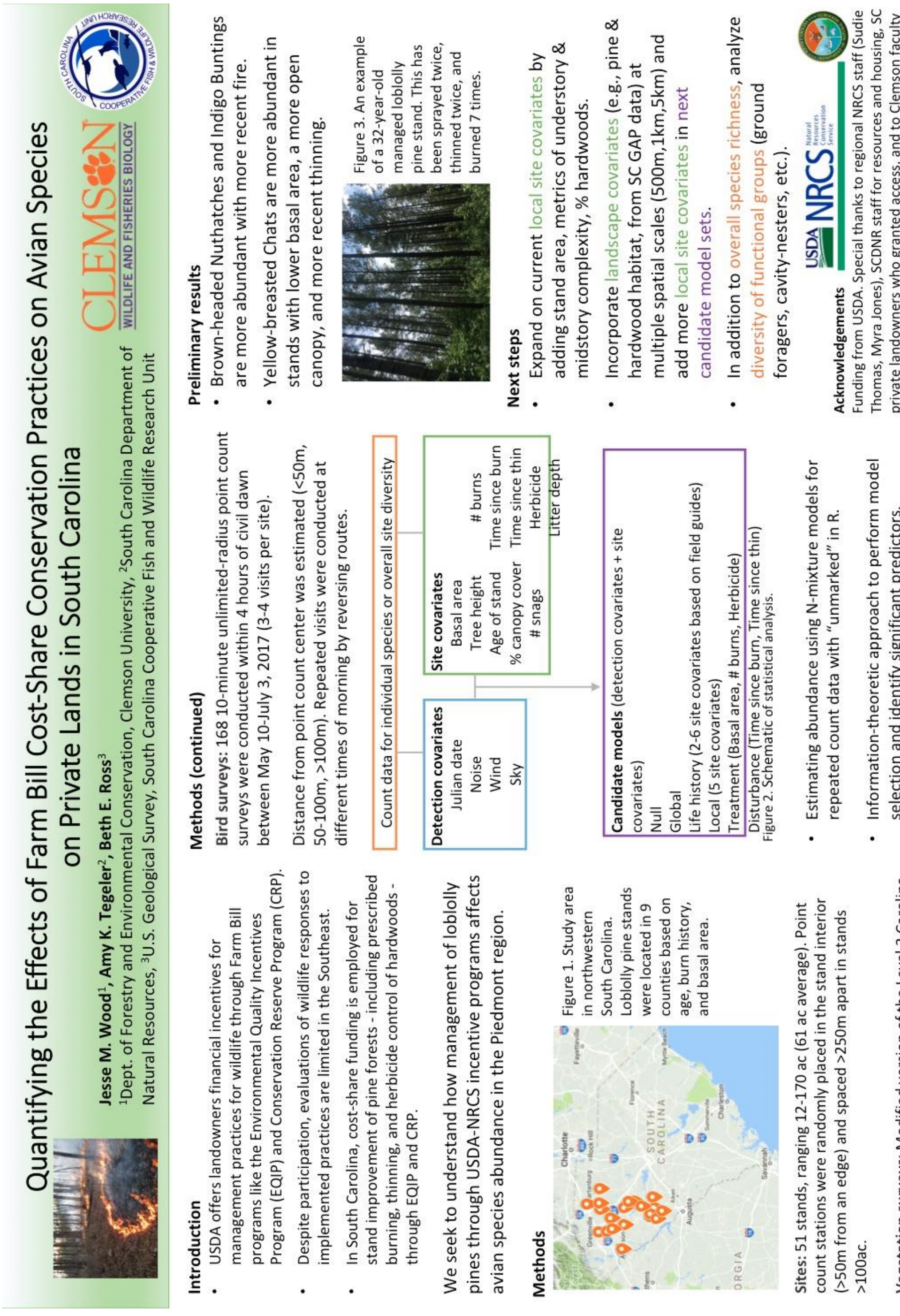


Figure 3. Presentation titled “Quantifying the Effects of Farm Bill Cost-Share Conservation Practices on Avian Species on Private Lands in South Carolina” given at The Wildlife Society Annual Conference.



Appendices

Appendix 1. Report for the project titled "Assessing the Status of Loggerhead Shrike in South Carolinas" in collaboration with Clemson University.

LOGGERHEAD SHRIKE HABITAT SELECTION IN SOUTH CAROLINA

A Thesis
Presented to
the Graduate School of
Clemson University

In Partial Fulfillment
of the Requirements for the Degree
Master of Science
Wildlife and Fisheries Biology

---

by
Jennifer L. Froehly
May 2018

Accepted by:
David Jachowski, Committee Chair
Patrick Jodice
Beth Ross
Cathy Bodinof Jachowski

ABSTRACT

The loggerhead shrike (*Lanius ludovicianus*) is a species of concern throughout its range due to severe population declines over the past seven decades. Grassland habitat loss and fragmentation is widely viewed as contributing to the decline. Habitat associations have primarily been studied up to the territory scale, with few studies assessing shrike habitat selection at landscape scales. In Chapter 1 we conducted roadside passive-active point counts for loggerhead shrikes in the coastal plain of South Carolina to evaluate support for several competing hypotheses of how land use and habitat fragmentation at multiple spatial scales influenced the occupancy of loggerhead shrikes. Detection probability increased with fair weather and temperature, and decreased with noise. High probability of detection ($p=0.49$, SE=0.08) indicated support for the application of passive point counts in future loggerhead shrike monitoring. Occupancy was best predicted by percentage of pasture at 1 km, where predicted occupancy increased from 2%, SE= 0.02 when there was 0% pasture in a 1 km radius, to 98%, SE=0.03 occupancy when there was 43% pasture in a 1 km radius. There was considerable model selection uncertainty, and our model averaged occupancy estimate was low ($\psi=0.17$, SE=0.05). Extrapolation of our averaged model suggested that only 8.7% of the South Carolina coastal plain was occupied by loggerhead shrikes in the 2016 and 2017 breeding seasons. Our results highlight the importance of habitat beyond breeding territories, and highlight the need for higher concentrations of pasture and grassland at a 1 km scale in order to increase the proportion of area in South Carolina occupied by shrikes.

Identification of factors that influence habitat selection of a nest site can also help managers effectively conserve a species. The Loggerhead Shrike could potentially benefit from fine scale management for nesting habitat, especially where fragmentation impedes conservation at the landscape scale. In Chapter 2 we examined how habitat characteristics at the nest tree and territory core scales influenced nest site selection by Loggerhead Shrikes in the coastal plain of South Carolina. We found 41 Loggerhead Shrike nests and measured characteristics at the nest site and at available sites to model selection factors at the tree and territory core scales. At the territory core scale, we found that low vegetation density heterogeneity, high vegetation height heterogeneity, shorter distances to powerlines, and lower shrub density increased selection. Diameter at breast height increased selection at the tree scale. Overall, Loggerhead Shrikes appeared to select for nest site characteristics that enhanced foraging ease and success, and limited predation risk. For the purpose of increasing optimal nesting habitat for Loggerhead Shrikes, we suggest that private landowners in South Carolina increase grassy habitat on their property and retain large trees in suitable nesting locations.

DEDICATION

I dedicate this thesis to Christopher, my husband, and to my Dad for all their love and support through this project. I also dedicate this thesis to Andrew for his encouragement and friendship.

ACKNOWLEDGMENTS

I would like to thank my advisor D. Jachowski for all his help, support, and patience throughout my masters program, and thank you to my committee; C. B. Jachowski, P. Jodice and B. Ross for their help in project design and support through the life of this project. Thank you to A. Tegeler from the South Carolina Department of Natural Resources for the inception of the project and support throughout the project. Thank you to the South Carolina Department of Natural Resources project funding, field housing and field transportation, SCDNR FY2016-010. Also, thank you to the numerous landowners for allowing us access to measure nest site characteristics on their land and thank you to the biologists and researchers on the Loggerhead Shrike Working Group for study design advice and feedback throughout the project.

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CHAPTER ONE

EFFECTS OF SCALE AND LAND COVER ON LOGGERHEAD SHRIKE OCCUPANCY

The loggerhead shrike (*Lanius ludovicianus*), a mid-sized passerine endemic to North America, has exhibited a range-wide decline of at least 74.0% since the 1940's (Cade and Woods 1997, Rosenberg et al. 2016). The Breeding Bird Survey estimated an average annual decline of 3.0% from 1966-2015 (Sauer et al. 2017), although annual population trends in key ecoregions range from −7.3% in the Texan oaks and prairies, to −1.3% in the intermountain west (Rosenberg et al. 2016). The Atlantic Coast has exhibited average annual long-term population declines (−2.9%), but has experienced one of the highest regional total population loss percentages (−89.0%, Rosenberg et al. 2016). In particular, the southeast experienced an average population decline of 6.0% per year prior to 1985 (Luukkonen 1987). Consequently, the loggerhead shrike has become a species of conservation concern and is now listed as a species of conservation priority in numerous State Wildlife Action Plans, including all southeastern and coastal states from Texas to New York.

Despite the extent and longevity of loggerhead shrike declines, the causes are still unknown. One plausible reason for the decline of loggerhead shrike populations is the loss of available habitat (Luukkonen 1987, Smith and Kruse 1992, Gawlik and Bildstein 1993, Prescott and Collister 1993). The loggerhead shrike has been found to have four essential habitat requirements; open grassy areas for foraging, trees or large shrubs for nesting, elevated perches for foraging, and spiky vegetation for prey impalement (Pruitt 2000). These requirements have historically been filled by numerous ecosystems such as sage-steppes, prairies, desert scrubs, pinyon-juniper woodlands, and pine savannas (Pruitt 2000), but these habitats are disappearing. As a result, grasslands, savannas, and barrens represent 55% of all critically endangered ecosystems (identified by having at least a 98% decline in area) in the United States (Noss et al. 1995).

As native grassland habitat has become increasingly rare, researchers have observed shrikes utilizing a variety of human modified habitat, from pasture to croplands (Luukkonen 1987, Esely and Bollinger 2001, Chabot et al. 2001, Walk et al 2006). Indeed, in South Carolina, pasture comprised over half of the area within 100 m of nests (Gawlik and Bildstein 1990). However, it is unclear whether other human modified habitats like row crop agriculture is useful habitat for shrikes. Shrikes have been reported to use fencerows by roads and cropland, and edges of cropland (Stewart 1975, Smith and Kruse 1992), but have also been reported to avoid cropland (DeGeus 1990). Conflicting evidence for selection or avoidance of cropland has even been observed within studies. For example, Gawlik and Bildstein (1990) found no cropland within 100 m of nests, yet they observed shrikes using cropland and pasture equally during the breeding season, and shrike use of cropland increased in the non-breeding season. Additionally, some large grassy areas seemingly ideal for shrikes have remained unoccupied leading some researchers to suggest that habitat is not a limiting factor to shrike populations (Jobin et al. 2005). Collectively, this suggests that researchers still have a poor understanding of what constitutes habitat for shrikes.

The objective of this study was to examine how land use and habitat fragmentation at multiple spatial scales influences the occupancy of loggerhead shrikes in South Carolina. How an individual selects habitat can be an intricate process that occurs on multiple spatial scales (Johnson 1980), yet most shrike studies have only examined habitat selection up to the territory scale (e.g., Luukkonen 1987, Gawlick and Bildsein 1990, Prescott and Collister 1993, Walk et al. 2006). For many avian species, it is increasingly understood that larger scale habitat connectivity is important (Brennan and Kuvlesky 2005), and fragmentation has been shown to negatively affect the occurrence of shrikes in Ontario (A.A.Chabot et al., Queens University, unpublished report). In the southeastern US, landscape composition has become increasingly fragmented, particularly over the past several decades (Griffith et al. 2003). Thus, including landscape scale characteristics in resource selection studies is imperative to building an understanding of how land use change and the patchiness or connectivity of suitable habitat influences shrike populations. To inform future conservation decision-making, our study evaluated support for several competing hypotheses of how land use and habitat fragmentation at multiple spatial scales influenced the occupancy of loggerhead Shrikes.

STUDY AREA

The South Carolina Breeding Bird Atlas (Cely 2003) and ebird records (eBird 2012) suggest that shrikes are most often sighted in the coastal plain and portions of the piedmont regions in South Carolina, with a majority in the coastal plain. Accordingly, we identified two separate study areas in the coastal plain of South Carolina totaling 368,086 ha (Figure 1). Both study areas were selected to maximize our ability to collect enough shrike detections and represented a range of land cover conditions that would be suitable for testing our habitat selection hypotheses relative to pasture and cropland cover. Study area one was located in Calhoun and Orangeburg counties and was composed of 42% forest, 22% crop, 14% shrub/scrub, 10% pasture, and 12% other land cover types as determined by the 2011 National Land Cover Database (NLCD) (Homer et al. 2015). Study area two was located in Colleton county and was composed of 61% forest, 15% shrub/scrub, 6% each of pasture and crop, and 12% other landcover types as determined by 2011 NLCD.

METHODS

Data Collection Methods

We conducted point count surveys to determine loggerhead shrike occupancy of selected survey sites. To select survey sites, we used the 2011 NLCD layer (Homer et al. 2015) to create polygons of pasture and cultivated crop cover types in our study areas. We chose to use a roadside survey methodology because our study areas had high road density allowing 90% of all of the pasture and crop polygons to be considered for survey site selection, and because previous research suggests roadside surveys are not likely to affect grassland bird detection probabilities (Lituma and Buehler 2016). Accordingly, only polygons adjacent to non-major roadways were retained. Polygons smaller than 0.5 ha were also eliminated because they would be too small for a loggerhead shrike territory (Pruitt 2000). To ensure that a range of polygon sizes were equally represented in our study, the remaining polygons were separated into four size classes, small (0.5-3.5 ha), medium (3.5-7.5 ha), large (7.5-11.5 ha), and extra-large (>11.5 ha), with the small size reflecting the minimum territory size of a shrike (Pruitt 2000), the medium and large size classes being representative of different published average shrike territory sizes (Pruitt 2000), and the extra-large size capable of supporting larger than average territories or multiple territories. We then used the Generalized Random Tessellation Stratified (GRTS) sampling design with the spsurvey package (Kincaid and Olsen 2016) in Program R version 3.3.3 (R Core Team 2017) to select the final polygons for establishing survey sites. The GRTS sampling allowed for a spatially balanced, random sampling distribution so that each polygon type (pasture and crop) and size was represented in our survey sites across the study area. When first visiting a GRTS selected polygon, we established a roadside point that allowed the maximum viewing area of the polygon, and which was used as the center point for the survey site.

We used previously reported detection and occupancy probability rates to determine the number of survey sites and replicate visits used in our study. Shrikes occurred at an average of

62% of sites in Big Bend National Park (Gutzwiller and Barrow 2001) with an estimated detection probability of 0.24 (which we derived from their reported occupancy and mean abundance of shrikes detected per count per site (Gutzwiller and Barrow 2001, 2002)). Using these estimates and power analyses (as per MacKenzie et al. 2006), we determined that we needed to survey up to 96 sites, 7-10 times each to be 95% confident that we would detect shrikes during at least one survey if they were present at a site. We surveyed a total of 96 points over two years, where 12 points were surveyed adjacent to each polygon type and size class. In an attempt to ensure independence between sampling sites, we maintained a minimum of 1 km between survey sites based on the diameter of the largest territory size reported (47 ha; A. A. Chabot et al., unpublished report). To maintain closure within the sampling period, all surveys were conducted during the breeding season when shrikes are highly territorial and most likely to remain in one location (Pruitt 2000). In 2016, we surveyed each site 9 times between 24 March-16 June. Based on obtaining relatively higher detection estimates than expected during 2016 (p = 0.50 in 2016 vs. p = 0.24 expected based on literature surveys), we adjusted our survey effort in 2017 to only survey sites 4 times between 24 March - 22 May.

At each survey site we conducted unlimited radius point counts using a combined methodology of a passive point count followed by a call playback period. Before a survey was started, we used a rangefinder to establish visual distance landmarks to ensure accurate distance estimates. Our surveys started with a 10-minute passive point count where all birds seen or heard were recorded, immediately followed by a 6-minute call playback sequence during which we looked and listened for adult loggerhead shrikes. The sequence was as follows: 20 seconds song, 40 seconds silence, 20 seconds begging call, 40 seconds silence, 20 seconds alarm call, 40 seconds silence. This sequence repeated for the second 3 minutes of the callback survey. For shrike and all other avian detections, we recorded distance to the bird and whether the detection was auditory or visual. Detection variables were also recorded at the start of each survey either by a direct measure (temperature, time of day, julian date) or as an index (noise, wind, sky conditions). Noise was indexed from 0 to 4 where zero was no noise, and four was loud noise preventing the detection of any birds beyond 50 m (Huff et al. 2000), wind was indexed using the beaufort wind scale from 0 to 5 where zero was calm, and five was 17-21 mph, and sky conditions were indexed by the following; 0: clear, 1: partly cloudy, 2: overcast, 3: fog, 4: drizzle/light rain, 5: rain. All point count surveys were conducted within four hours after sunrise, and were completed by a single observer who varied the time of day between visits to an individual point.

We utilized the 2011 NLCD to obtain spatial data for landscape characteristics (Homer et al. 2015) and calculated percent cover and aggregation index values using the SDMTools package (VanDerWal et al. 2014) in Program R (R Core Team 2017). We estimated vegetation productivity using Normalized difference vegetation index (NDVI) data obtained through the National Air and Space Administration Moderate Resolution Imaging Radiospectrometer (MODIS) data (Didan 2015) and reformatted to the same spatial scale as the NLCD data (30 m). All covariates were standardized using the scale function in program R prior to analysis.

Analytical methods

We used a two-step occupancy modeling approach (MacKenzie’s et al. 2006) to evaluate habitat selection at multiple spatial scales. In the first step, we examined how weather (temperature, sky conditions, or wind speed), variability in timing (time of day or julian date), and ambient noise levels, affected the probability of detection. We hypothesized that increasing temperature, wind, and worsening sky conditions would hinder detection as strong winds, clouds, and extreme temperatures can all decrease activity level of birds due to energy budgeting (Richards 1981, Robbins 1981b). We hypothesized that unlike most passerine species, shrikes would be more active later in the morning, and therefore, detections would increase with time of day (Robbins 1981a, Chabot 2014). We also hypothesized that more ambient noise would decrease our detection ability due to difficulty of the observer hearing a calling bird, and difficulty of a shrike hearing and reacting to the call-playback. Finally, we hypothesized that detectability of shrikes would peak during the breeding season when most individuals are breeding (Skirvin 1981) and highly territorial (Pruitt 2000). Peak breeding is reported to occur during April and May depending on location (Yosef 1996), so we used a quadratic form ($x + x^2$) of julian date to represent this hypothesized relationship in our survey time period March-June. We developed 8 *a priori* models to evaluate hypothesized effects of individual and combined covariates on detection while holding occupancy constant. We tested for correlations between covariates and did not include correlated covariates ($r > 0.7$) in the same model. We ran all occupancy models using the unmarked package (Fiske and Chandler 2011) in Program R (R Core Team 2017). We compared models using the Akaike Information Criterion corrected for small sample sizes (AIC_c) and by examining model weight (Burnham and Anderson 2002). We considered all models within the 90% cumulative model weight to influence detection, and carried over all covariates within this confidence set to the detection portion of our models in step two.

In step two we examined support for hypothesized habitat and landscape variables at four different scales to predict shrike site occupancy. Our smallest scale was a 300 m radius from the center of the survey site. This was the farthest a shrike was detected from a point count and therefore represented the survey site scale and the scale at which we were able to make occupancy predictions. We also used a 1 km radius scale, which is representative of the maximum distance a shrike would travel in the breeding season (A. A. Chabot et al., unpublished report). Finally, both the 5 km and 15 km scales were analyzed because they were found to be significant in other shrike studies looking at landscape factors (Burton and Whitehead 1990, Chabot 2001, A. A. Chabot et al., unpublished report). We hypothesized that the influence of land cover on occupancy depends on spatial scales (Table 1). For example, because shrikes have been found to utilize pastures (Luukkonen 1987, Gawlik and Bildstein 1990, Esely and Bollinger 2001, Walk et al 2006), we hypothesized that percent pasture at the three smaller scales would have a positive effect on occupancy probability. In addition, because shrike occurrence can decline in more productive grasslands (Shen et al. 2013), we hypothesized that as an index for productivity, increasing average maximum breeding season NDVI at the three smaller scales would have a negative effect on occupancy probability. We hypothesized that percent crop cover at the 1 km and 5 km scales would have a negative effect on occupancy probability due to some evidence of row crop avoidance (DeGeus 1990), and we hypothesized that percent forest at all scales would have a negative effect on occupancy probability because Shrike occurrence has also been found to be negatively associated with forest cover (Johnson et al. 2017). We also hypothesized that the aggregation of pasture at the two largest scales, as a measure of connectivity, would have a positive effect on occupancy probability, and that the aggregation of pasture and cropland combined in one “open” habitat type at the 5 km scale would have a positive effect on occupancy probability (A. A. Chabot et al., unpublished report).

We used our 15 occupancy covariates (Table 1) to formulate 26 *a priori* occupancy models, evaluating hypothesized effects of land cover, aggregation and primary productivity at each selected scale separately, and between scales on occupancy probability. We tested for correlations between covariates to determine if any model contained correlated covariates (r

>0.7). In instances where correlated covariates occurred in the same model, we ran separate occupancy models with each singular covariate, and retained the covariate that produced the lower AIC_c score. We compared our *a priori* models using AIC_c (Burnham and Anderson 2002). We determined that models carrying any portion of the upper 90% AIC_c cumulative weight were important to occupancy rates and fell within our confidence set of models. We calculated model-averaged occupancy, detection, and covariate estimates and their 95% confidence intervals based on all models in our 90% confidence set. We assumed that covariates with 95% confidence intervals not overlapping zero were important predictors of detection or occupancy.

We used a Pearson chi square test with 10,000 bootstrap replications to determine if our averaged model fit our data (MacKenzie and Bailey 2004). To further assess model performance, we conducted a 10-fold cross validation (Boyce et al. 2002) by randomly separating our data by a 75:25 ratio to establish our training: testing datasets, running our averaged model with the training dataset, and then using the resulting averaged beta coefficients to predict occupancy with the testing data set. Differences between predicted and known occupancy of the testing datasets were assessed using a receiving operator characteristic (ROC) and calculating the area under the curve (AUC) (Boyce et al. 2002). Model performance was ultimately determined by the AUC value, which could range from 0.0 (predicts opposite of the truth 100% of the time) to 0.5 (no better than a null model) to 1.0 (predicts truth 100% of the time). If our model performed well (AUC > 0.7 (Morelli et al. 2017)) in the cross validation analysis, we applied it across a grid of the coastal plain of South Carolina with a resolution equal to the size of our sampling unit (530 m^2 resolution) to predict occupancy probabilities. Since occupancy probability is also a measure of proportion area occupied (MacKenzie et al. 2002), we binned the extrapolated occupancy probability values by tenths, multiplied the bin area by the bin mean occupancy probability, and scaled it to the whole South Carolina coastal plain area to determine the hectares and the proportion area occupied by loggerhead shrikes in each probability bin. Finally, all bins were summed together to get total predicted hectares and proportion area occupied by loggerhead shrikes in the whole coastal plain of South Carolina during the 2016 and 2017 breeding seasons.

Additionally, in order to inform future loggerhead shrike monitoring efforts, we used our model confidence set to determine if our detection and occupancy probabilities would change if a playback period were not included. We removed detection data collected during the playback section of our surveys and ran our confidence set with this modified dataset. We then compared 95% confidence intervals of detection and occupancy probability between the original dataset and the modified dataset to determine if estimates changed when the playback survey period was removed. We determined if occupancy and detection probability estimates were similar when confidence intervals overlapped between datasets.

RESULTS

Loggerhead shrikes were detected at 20 of 94 survey sites. Twelve of the occupied sites were in study area one, and 8 were in study area two. Our detection model confidence set from step one included 5 models (Table 2) and included all of our detection covariates. Therefore all of our detection covariates were carried over and used in our second model-fitting step. Five models were retained in our step two model 90% confidence set (Table 2). When covariates were held at their mean value, our model averaged results predicted detection at 0.486, SE=0.082, and occupancy at 0.166, SE=0.0465. Within the confidence set, sky conditions was the only model averaged detection covariate whose 95% confidence interval did not overlap zero, though confidence intervals for temperature and noise indicate moderate support as they just barely overlapped zero (Table 3). Detection estimates increased from 26%, when skies were cloudy, to 63%, when skies were clear, from 4% at our minimum survey temperature (2° C) to 83% at our maximum survey temperature (28° C), and from 41%, when moderate noise was present, to 63%, when there was no background noise (Figure 2). Pasture within 1 km was the only model averaged occupancy covariate with a confidence interval not overlapping zero (Table 3). Predicted occupancy increased from 2% when amount of pasture at a 1 km radius was 0%, to 26% at 15% pasture, and leveled off with 98% occupancy at 43% pasture (Figure 3).

Our final model from our confidence set (ψ(P1km+FOR1km+FOR5km+FOR15km+crop1km)p(wind+temp+sky+noise+start.time+date^2)) fit our data (X^2=191.82, p value=0.5, $\hat{c}$=0.92). The occupancy portion of this final model set performed well in our cross validation with an AUC of 0.74. Extrapolation of our model across the coastal plains of South Carolina indicated few areas with high occupancy probability (Figure 4), and predicted that the total proportion area occupied by Loggerhead Shrikes in the South Carolina coastal plain was 8.5% (Table 4).

The detection portion of our averaged model (p(wind+temp+sky+noise+start.time+date^2)) did not perform very well in our cross validation with an AUC of 0.62, suggesting it does not have a strong predictive ability. The passive survey period was sufficient to determine occupancy at all but three sites where shrikes were only observed during one survey, and only during the active survey period. Indeed, removing data gathered in the active survey period from the model did not affect detection rates (0.44, SE=0.09 without playback, compared to p=0.49, SE=0.08 with playback included), or occupancy rates (0.12, SE=0.04 without playback, compared to ψ=0.17, SE=0.05 with playback).

DISCUSSION

Our finding that occupancy of loggerhead shrikes in the South Carolina Coastal Plain was best predicted by the availability of pasture at a 1 km scale suggests that shrikes are sensitive to habitat at a broader spatial scale than previously thought. Previous shrike research has focused on habitat associations within 100-300 m of nest sites (Luukkonen 1987, Gawlik and Bildstein 1990, Esely and Bollinger 2001, Walk et al 2006), or on breeding territories (Yosef and Grubb 1994) that are smaller (4-13ha (Pruitt 2000)) than our 1 km scale. Our landscape scale findings are consistent with recent findings elsewhere in the southeast that predicted shrike occupancy to decline as percent forest cover increased at the 2.5 km scale (Johnson 2017). Pasture availability at 1 km could be important to shrikes for securing specific resources throughout the year. Shrike territories have been shown to expand due to experimental prey scarcity (Yosef and Deyrup 1998), suggesting that fluctuations in prey availability could explain changes in territory size and selection of more habitat than what is utilized on an average day-to-day basis. Further, territories expand during the post-fledging period (A. A. Chabot et al., unpublished report) suggesting extra buffer habitat around the smaller breeding season territory could provide essential resources during the vulnerable post-fledging period. Thus, to better understand the influence of these moderate scale effects of pasture on site occupancy, further research of shrike space use is likely needed during the fledgling and little-studied non-breeding seasons.

Our lack of support for fragmentation effects on shrike occupancy could be explained by the strength of our percent pasture predictor and by temporal limitations. Simulations testing the importance of habitat variables to extinction thresholds suggest that the abundance of habitat on a landscape has a much larger effect on extinction than does fragmentation (Fahrig 2001), and grassland percentage has been found to be a more consistent predictor of grassland bird abundance than fragmentation (Renfrew and Ribic 2008). Additionally, since fragmentation occurs over time, effects may only appear when analyzing long-term data from when fragmentation occurred. For example, negative effects of large-scale fragmentation on bobolinks (*Dolichonyx oryzivorus*) were found when analyzing data over 25 years, but when data were analyzed in 5-year increments, no effects of fragmentation were found (Either et al. 2017). Our snapshot analysis suggests that fragmentation was not an important predictor of occupancy during our survey period, though low occupancy probabilities and high fragmentation of pastures in our study areas could indicate that loggerhead shrikes in our study could have already suffered from fragmentation.

While our study only identified pasture as a strong land cover predictor of shrike occupancy (Table 4), it is important to remember that National Land Cover Data lumped rural residential areas, hay, old fields, grassy areas, and pasture into the one pasture category. Delineating land cover data into more specific habitats and monitoring shrike occupancy through time could allow researchers to determine more specific habitat preferences, and how shrikes are responding to land cover change. Further, as occupancy only measures presence, not abundance, it is unknown whether fitness varies between different open habitats. For example, by examining population growth rates in different habitats, Arlt et al. were able to determine that northern wheatears *Oenanthe oenanthe* in pastures and farmyards acted as population sources, but those in crop fields and tall grasslands were population sinks, and that population decline was influenced by the decline of source habitats (2008). Further investigation of shrike populations is needed to determine if different types of open habitats act as population sources or sinks.

Our study illustrates the utility of passive point counts in monitoring shrikes during the breeding season, although poor detection model validation results suggests that more research is needed. Our model suggests that surveying in fair weather, higher temperatures, and low noise levels result in higher detection probability, and that a passive point count is sufficient for detecting shrikes in our study system. This effective use of passive-only point counts to monitor shrike population trends could be beneficial to researchers since other species of interest can also be observed at the same time without biasing shrike specific detection. Currently, shrikes are surveyed differently between researchers, and standardization of survey methodology is needed so that comparisons can be made between or within studies (A. Chabot, loggerhead shrike working group coordinator, personal communication). Our results suggest that passive point counts could be used as part of a standardized survey protocol. Further, in areas like South Carolina that are believed to be host to both residents and over wintering migrants, we suggest that surveying in the non-breeding season could be a vital addition to shrike monitoring. Habitat may be more limited in the non-breeding season due to the influx of migrant individuals (Johnson 2017), and migrants may be settling for more marginal habitat since residents get first pick of the best habitat (Lymn and Temple 1991). Thus, pairing breeding and non-breeding surveys could provide an even better understanding of factors limiting shrike occurrence and abundance.

Overall, our exploration into habitat scale relationships for loggerhead shrike confirms that landscape scale habitat conditions influence shrike breeding habitat selection. The scarcity of suitable habitat in our predictive map of the South Carolina Coastal Plain illustrates the importance of maintaining open pasture habitat in higher concentrations on the South Carolina landscape for the recovery of the shrike population. Maintaining high concentrations of pasture habitat is also likely to benefit other grassland bird species of conservation concern, which as a guild, have experienced more severe declines than any other avian guild in North America (Rosenberg et al. 2016). Savanna sparrow (*Passerculus sandwichensis*), grasshopper sparrow

(*Ammodramus savannarum*), and bobolink abundance was found to be best explained by variables including percent forest and percent grassland at the 1.2 km scale (Renfrew and Ribic 2008), and occupancy of 11 out of 19 grassland species was best explained by percent tree cover at the 1.2-1.6 km scales (Cunningham and Johnson 2006). These correlative results suggest that preserving grassland and pasture habitat at a 1 km scale for shrikes could help to protect habitat for numerous grassland bird species. Thus, conservation and restoration of grassland in high densities will contribute to the conservation of loggerhead shrikes as well as many other declining grassland species.

MANAGEMENT IMPLICATIONS

Land-use predictions through 2051 for the southeastern US highlight the susceptibility of open habitats to land use change; predicting a 49.3% loss of pasture and a 24.2% loss of natural rangeland under current land use trends, and 66.7% and 38.6% predicted loss of pasture and rangeland under increased crop demand (Martinuzzi et al. 2015). Our finding of the importance of pasture habitat at moderate spatial scales, and this predicted loss of grassland habitat, highlight the urgency for further research on how grassland conversion will affect shrike habitat in the future. To further understand shrike habitat, future research should focus on the addition of non-breeding season surveys, as well as understanding the long-term effects of land use change on shrike habitat. Finally, based on our high detection rate, we suggest that researchers use passive point counts to allow for standardization of shrike and other grassland bird survey efforts.

FIGURES

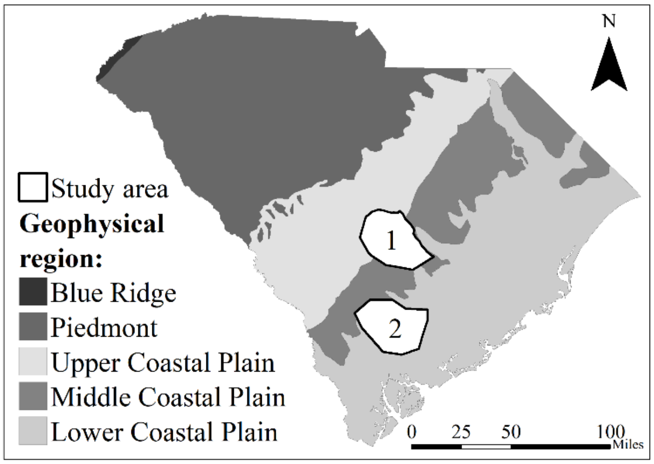

Figure 1.1: Location of study areas for loggerhead shrike point count surveys in relation to South Carolina geophysical regions.

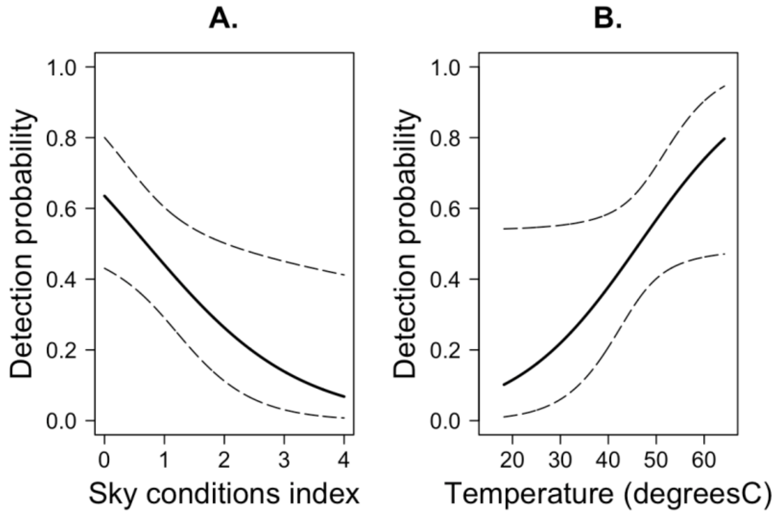

Figure 1.2: Predicted model averaged covariate effects on detection probability of loggerhead shrike. Dashed lines represent 95% confidence interval. **A**. Sky conditions: 0: clear, 1: partly cloudy, 2: overcast, 3: fog, 4: drizzle/light rain **B**. Temperature at time of survey in degrees C. **C**. Ambient noise index: 0: no noise, 1:gentle bubbling brook noise, probably not missing any birds, 2: babbling creek noise, might be missing some distant birds, 3: rushing creek noise, probably detecting only those birds within 50m, 4: roaring creek and river noise, probably detecting only the very loudest calls and songs within 50 m (Huff et al. 2000).

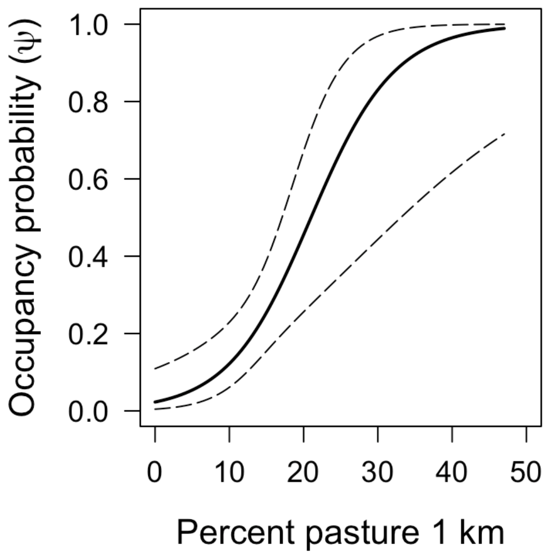

Figure 1.3: Predicted model averaged effect of percent pasture at 1 km on occupancy probability for loggerhead shrike. Dashed lines represent 95% confidence interval.

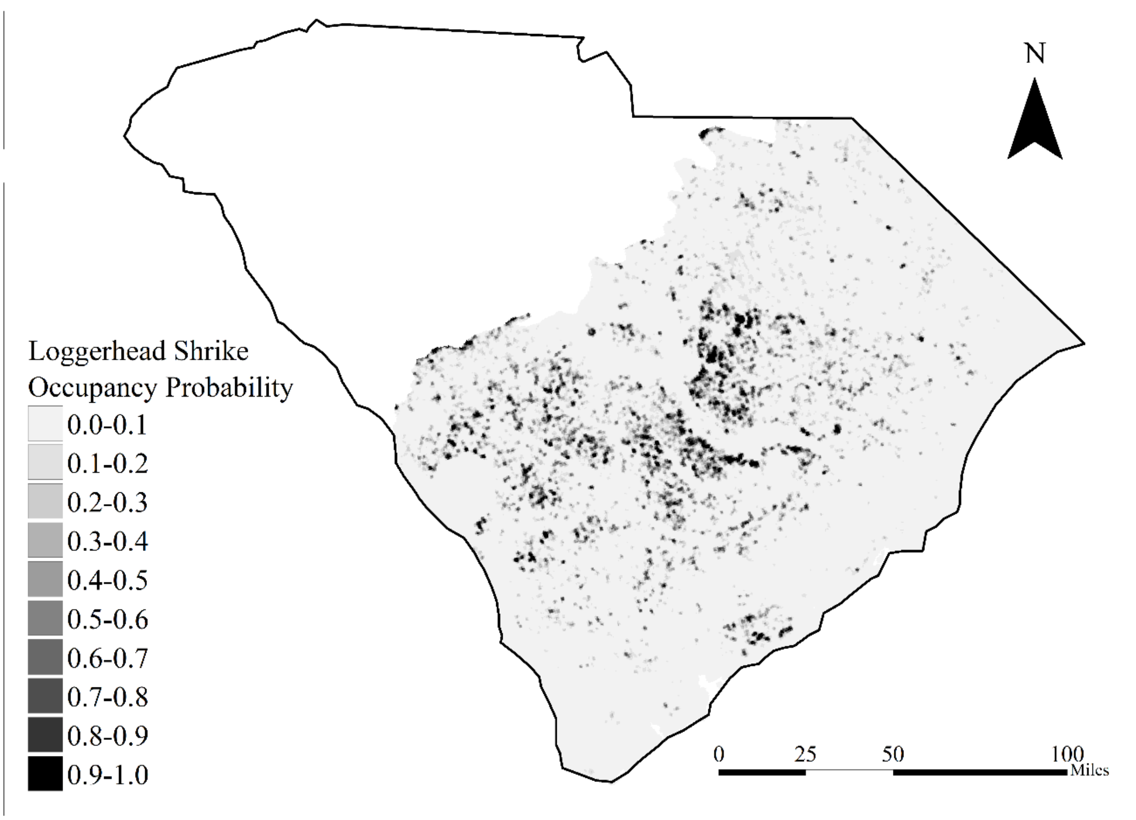

Figure 4: Predicted loggerhead shrike occupancy probability across the South Carolina Coastal Plain using our averaged model:

(ψ(P1km+FOR1km+FOR5km+FOR15km+crop1km)p(wind+temp+sky+noise+start.time+date^2))

TABLES

Table 1.1: Occupancy covariates and their predicted effect on shrike occupancy. X's denote which scales were used in a priori models.

Occupancy Covariate	Covariate name	Predicted effect	Spatial Scales Examined			
			300 m	1 km	5 km	15 km
Percent Pasture	P	(+)	x	x	x	
Percent Crop	C	(-)		x	x	
Percent forest	F	(-)	x	x	x	x
Aggregation of Pasture	AP	(+)			x	x
Aggregation of pasture and crop	AO	(+)			x	
Average maximum breeding season NDVI	ndvi	(-)	x	x	x	

Table 1.2: Model rankings for those retained in the 90% confidence sets for step one and step two.

Model	K[a]	AIC_c[b]	ΔAIC_c	w_i[c]	Log L.
Detection (step 1) confidence set					
ψ(.)p(wind+temp+sky)	5	232.27	0	0.31	-110.80
ψ(.)p(wind+temp+sky+noise)	6	322.01	0.73	0.22	-110.02
ψ(.)p(time)	3	234.37	2.1	0.11	-114.05
ψ(.)p(wind+temp+sky+date^2)	7	234.52	2.14	0.11	-109.56
ψ(.)p(wind+temp+sky+time)	6	235.37	2.25	0.10	-110.78
Ψ(.)p(.)	2	235.57	3.29	0.06	-115.72
Occupancy (step 2) confidence set					
ψ(P1km)p(global)	10	216.54	0	0.33	-96.94
ψ(P1km+F1km)p(global)	11	217.33	0.79	0.22	-96.06
ψ(P1km+C1km)p(global)	11	218.85	2.31	0.11	-96.80
ψ(P1km+F15km)p(global)	11	219.10	2.56	0.09	-96.94
ψ(P1km+F5km)p(global)	11	219.10	2.56	0.09	-96.94

[a] Number parameters in the model

[b] Akaike Information Criterion corrected for small sample sizes

[c] Akaike weight

Table 1.3: Model averaged covariate estimates, standard errors (SE), and 95% confidence intervals (CI) for covariates in the step two 90% confidence model set for loggerhead shrike detection and occupancy in the South Carolina Coastal Plain.

Model	Estimate	SE	CI
Detection covariates			
Sky	-0.62	0.27	-1.16, -0.09
Wind	0.47	0.3	-0.12, 1.06
Temp	0.69	0.36	-0.01, 1.39
Noise	-0.39	0.22	-0.69, 0.04
Time	-0.27	0.36	-0.98, 0.45
$Date^2$	0.22	0.22	-0.20, 0.65
Date	-0.42	0.31	-1.04, 0.19
Occupancy Covariates			
Pasture 1 km	1.63	0.52	0.61, 2.66
Forest 1 km	-0.47	0.36	-1.19, 0.24
Forest 15 km	-0.02	0.32	-0.66, 0.61
Crop 1 km	0.16	0.3	-0.42, 0.74
Forest 5 km	-0.02	0.31	-0.64, 0.59

Table 1.4: Extrapolated area occupied by loggerhead shrike in the South Carolina Coastal Plain determined by occupancy probability predicted by our top model of (ψ(P1km+FOR1km+FOR5km+FOR15km+crop1km)p(wind+temp+sky+noise+start.time+date^2))

Occupancy bin	Total ha in bin	Mean ha occupied	Proportion area occupied in SC plain
0.0-0.1	4266112.6	132249.5	0.025
0.1-0.2	404973.5	57101.3	0.011
0.2-0.3	168006.3	41161.5	0.008
0.3-0.4	99494.8	34624.2	0.007
0.4-0.5	70281.2	31556.2	0.006
0.5-0.6	54073.3	29740.3	0.006
0.6-0.7	43988.9	28592.8	0.005
0.7-0.8	37303.5	27977.6	0.005
0.8-0.9	35899.0	30621.9	0.006
0.9-1.0	44944.0	42966.5	0.008
Total	5225077.1	456591.8	0.087

CHAPTER TWO

NEST SITE SELECTION BY LOGGERHEAD SHRIKES IN A FRAGEMENTED LANDSCAPE

While landscape-scale habitat conditions are increasingly recognized as an important factor impacting the viability of many avian species (Ribic et al. 2009), fine-scale factors are also important for avian conservation. In particular, fine-scale habitat conditions, such as nesting resources, are often not represented by measures assessed at landscape scales (Johnson 1980). An individual is only able to attempt to produce offspring if nesting habitat needs are met (Walters 1991). Therefore, limited nesting habitat could contribute to a decline in population viability. For example, warm and cool season grass plantings enrolled in the conservation reserve program (CRP) in Missouri provided nesting sites and increased populations of Grasshopper Sparrows (*Ammodramus savannarum)*, Eastern Meadowlarks (*Sturnella magna)*, Field Sparrows (*Spizella pusilla)*, and American Goldfinches (*Spinus tristis)* (McCoy et al. 1999). Even in sink populations (i.e., where population growth is negative) of Dickcissel (*Spiza Americana)* and Red-winged Blackbirds (*Agelaius phoeniceus)*, nesting efforts in these CRP fields may reduce the severity of the sink by providing nesting habitat within areas they otherwise would not have nested, increasing the number of individuals that have at least some chance of productivity (McCoy et al. 1999).

Fine-scale management actions can also be easier to implement than at the landscape scale, especially when land ownership is fragmented. For example, in urban areas where natural cavities are limiting, installation of nest boxes can help to increase population numbers of cavity nesting species like the Eastern Bluebird (*Sialia sialis)* (Newton 1994). Planting native tree and shrub species in residential yards has also been shown to support locally higher densities of insectivorous birds due to increased prey (Narango et al. 2017). Thus, fine-scale management actions like these could be instrumental in conserving avian populations in areas that have otherwise undergone rapid habitat degradation and fragmentation at the landscape scale.

The Loggerhead Shrike (*Lanius ludovicianus*), a mid-sized passerine endemic to North America, is one grassland bird that could potentially benefit from fine-scale management for nesting habitat. The Loggerhead Shrike has exhibited a range-wide decline of at least 74% since the 1940's (Cade and Woods 1997, Rosenberg et al. 2016) with the Atlantic coast experiencing one of the highest regional population declines (-89%, Rosenberg et al. 2016). Consequently, the Loggerhead Shrike is a species of conservation concern in many state wildlife action plans. Recent findings predicted that Loggerhead Shrikes in South Carolina were more likely to occur in areas with high pasture percentages within 1 km of the individual (Froehly et al. in review) suggesting that high concentrations of pasture will be important for the conservation of the species. In addition to maintaining relatively large open grassland habitats, Loggerhead Shrikes are also likely selecting for finer scale factors like the number of foraging perches and the availability of nest trees to establish a nest site in the breeding season (Gawlik and Bildstein 1990, Esely and Bollinger 2001, Michaels and Cully 1998, Chabot et al. 2001). Thus, information on how Loggerhead Shrikes select nesting habitat could guide fine scale management actions to promote both occupation and breeding.

The objective of this study was to examine how fine-scale habitat characteristics within the breeding territory influence nest site selection by Loggerhead Shrikes in the coastal plain of South Carolina. We examine selection at the territory core scale to provide insight into the critical resources required during the nesting season and also examine selection at the tree scale to inform managers as to what Loggerhead Shrikes considered a suitable nesting location.

Collectively, our study can provide recommendations for land managers and individual land-owners on how to enhance nesting habitat for Loggerhead Shrikes across the fragmented southeast coastal plain.

METHODS

Study Area

We conducted our study within the South Carolina Coastal Plain where Loggerhead Shrike occupancy is known to be relatively high (see Froehly et al. in review). The South Carolina Coastal Plain is composed of 51% forest, 12% crop, 4% pasture, 8% developed, 24% other (Homer et al. 2015). Land in South Carolina is 90% privately owned (Vincent et al. 2017, South Carolina Department of Administration 2018) though private property sizes range from plantations of thousands of acres, to residential houses on less than an acre of land. We selected 2 study areas in the coastal plain of South Carolina totaling 368,086 ha (Figure 1). One study area one was located in Calhoun and Orangeburg counties, while the other was located in Colleton County. These study areas were chosen so that we were able to maximize shrike detections and because they represented a range of land cover conditions that suitable for testing our fine scale habitat selection hypotheses across the South Carolina Coastal Plain.

Data Collection Methods

In March-June 2016 and 2017 we used three techniques to locate Loggerhead Shrike nests within the South Carolina Coastal Plain. First, we conducted unlimited radius point counts using a 10-minute passive point count followed by a 6-minute call playback period. We selected point count locations from roadside crop and pasture polygons using a Generalized Random Tessellation Stratified (GRTS) sampling design in the *spsurvey* package (Kincaid and Olsen 2016) in Program R version 3.3.3 (R Core Team 2017) so that survey points represented a range of sizes of crop and pasture polygons in our study area as defined by the National Landcover Database (NLCD)(Homer et al. 2015)(see methods in Froehly et al. in review). When a Loggerhead Shrike was observed during a survey, we remained after the survey to make extended visual observations to determine if the individual may be nesting and to locate the nest. Second, we made extended observations where there had been eBird sightings (particularly spring sightings) from the last 10 years since Loggerhead Shrikes are known to reuse territories (Pruitt 2000). Lastly, we made extended observations at locations from expert sightings within the current field season, including sightings by state biologists and our own incidental sightings that were made while driving between point-count survey locations.

Once a Loggerhead Shrike was observed at a location, we obtained landowner permission to further search for and locate the nest. Nests were confirmed by visual observations of an individual building a nest, incubating eggs, or feeding chicks. We collected a GPS location of the nest, then to minimize disturbance to the birds, we returned to the nest after it had failed or fledged to collect data on nest tree and territory core habitat characteristics. Other Loggerhead Shrike studies have analyzed territory characteristics anywhere from 2.5 m to 100 m from the nest (Chabot et al. 2001, St-Louis et al. 2009, Galwik and Bildstein 1990). We defined the territory core as a 40 m radius circle around the nest tree, which is equal to the smallest reported Loggerhead Shrike territory size (Yosef and Grubb 1994). Within the territory core we counted the number of shrubs (woody stems <2 m in height), the number of trees (woody stems >2 m in height), and the number of artificial posts (Table 1). We measured ground cover vegetation structure in two transects radiating out from the nest tree at random directions using a modified "Weins" pole method to quantify vegetation structure (Michaels and Cully 1998, Rotenberry and Wiens 1980). Specifically, we placed a 6 mm diameter rod vertically at 10, 20, 30, 40 meters and recorded the number of times a piece of vegetation hit the rod (separated by type: grass, forb, standing dead), height of the tallest live vegetation, and litter presence and depth. We used these ground cover data to calculate the probability of each grass, forb, standing dead, and litter occurring at the territory core as well as vertical and horizontal heterogeneity (Table 1). We calculated vertical heterogeneity by finding the coefficient of variation of all the maximum live vegetation heights. Likewise, we calculated horizontal heterogeneity by finding the coefficient of variation of all the number of vegetation pole hits. Using a laser rangefinder, we also measured distance from the nest tree to the nearest road, the nearest artificial perch, the nearest tree, the nearest bush, the nearest powerline, the nearest building, and the nearest crop field (Table 1). These distances were not confined to the 40 m radius territory core. We also collected data on characteristics of the nest tree itself. We recorded tree species, nest height, the distance from the nest to the trunk of the tree, height of the tree, height of the lowest branch, diameter at breast height in cm (DBH), and calculated the percent canopy openings from spherical convex densiometer readings at each cardinal direction taken with the observer's back against the trunk of the tree (Table 1).

To compare used nest sites to available nest sites, we also collected the same territory core and nest tree data on two nearby trees that were available for nesting. We chose nearby available trees by following a random compass bearing from the nest tree. We used the first woody structure (tree or shrub) encountered outside of 40 m as the unused available tree to ensure that we were sampling at least partially different territory core areas than the used territory core. We collected all nest tree and territory core data near the end of the breeding season and within a month's time as to minimize the potential confounding effects of vegetation growth throughout the season.

Analytical Methods:

We used a discrete choice modeling framework, where paired choice sets of used and available resources were analyzed to provide the utility, or usefulness, of a location to an individual compared to the resources available to that individual (Cooper and Millspaugh 1999). We developed and evaluated support for 12 *a priori* models representing our hypotheses on territory core selection factors (Table A2.1). These territory core models were subset into three groups of factors we hypothesized to influence ground cover type and structure, tree and shrub structure, and proximity to manmade structures. We hypothesized that ground cover type and structure influenced prey diversity and density, and ease of foraging by Loggerhead Shrikes in grassland systems (Rotenberry and Wiens 1980). We predicted that the occurrence of grass, bare ground, forbs and standing dead vegetation would increase selection while litter and litter depth would decrease selection by Loggerhead Shrikes (Gawlik and Bildstein 1990, Michaels and Cully 1998, Rotenberry and Weins 1980, DeGeus 1990, Chabot et al. 2001). The influence of ground cover structure on Loggerhead Shrike habitat use has differed between studies, as studies occurring mainly in pasture report selection of short, uniform grass (Gawlik and Bildstein 1990, Chabot et al. in prep), but studies occurring in more natural prairie landscapes report selection of high structural diversity (Michaels and Cully 1998, St-Louis et al. 2010, Prescott and Collister 1993, Rotenberry and Wiens 1980). Since there is little natural prairie habitat in South Carolina, we predicted that selection would occur for short, uniform ground vegetation structure.

We hypothesized that tree and shrub structure influences core territory selection through the balance of predator evasion and perch density factors. In Ontario, isolated trees were more often selected as nest trees than non-isolated trees (Chabot et al. in prep), and areas with a higher density of tress, like along fencerows, have led to higher nest predation rates in several

Loggerhead Shrike populations (Gawlik and Bildstein 1990, Yosef 1994, Walk et al. 2006). Thus, we predicted that low tree and shrub density and greater distances to the nearest tree and shrub would increase selection.

We hypothesized that human modified habitat factors including perch availability and human disturbance could influence territory core selection. Shrikes are sit and wait predators and are known to benefit by a high density of perches (Yosef and Grubb 1994), therefore, we predicted that low distance to powerline and nearest post, as well as post density would increase selection as Loggerhead. Shrikes have also been observed nesting in fencerows along roads (Stewart 1975, Smith and Kruse 1992) so we predicted that Loggerhead Shrikes would select for areas near roads due to the foraging opportunity that fencerows and mowed corridors commonly found along roadsides provide. Past research suggests that the influence row crop agriculture on Loggerhead Shrike habitat selection may differ between populations, as Loggerhead Shrikes have been found to both use (Gawlik and Bildstein 1990) and avoid (DeGeus 1990) cropland. Since croplands do not offer any woody vegetation for nesting, we predicted that Loggerhead Shrikes would select for areas to nest away from cropland. Finally, we developed a global model and 6 sub-global *a-priori* models to evaluate how multiple hypothesized factors influenced nest site selection at the territory core scale (Table A2.1).

We developed 5 *a priori* models representing our hypotheses that nest tree selection would be influenced by predation risk (Martin 1993), environmental exposure (Luukkonen 1987, Gawlik and Bildstein 1990), and structural preference (Chabot et al 2001) (Table A2.2). Specifically, we predicted that selection would occur for denser, larger trees with higher bottom branches because they offer more protection from predation and weather, and offer sturdy branches for nest building (Gawlik and Bildstein 1990, Chabot et al. in prep).

We tested for correlations between covariates and did not include correlated covariates (r >0.65) in the same model. In instances where correlated covariates occurred in the same model, we ran separate occupancy models with each singular covariate, and retained the covariate that produced the lower AIC_c score. We fit models in Program R using discrete choice modeling with the *mlogit* package (Croissant 2013). We extracted the Log Likelihood from each model to calculate Akaike Information Criterion for small sample size (AIC_c) values and model weights (Burnham and Anderson 2002). We evaluated nest tree and territory core models separately and considered models within 2 ΔAIC_c units of the highest ranked model to influence selection, and further investigated effects of covariates within these models. We validated each scales' top model(s) using k-fold cross validation (Boyce et al. 2002). For each of 5 validation replications we randomly separated data so that 75% of choice sets (the nest and the two paired available points) made up the training dataset, and the remaining 25% of the choice sets made up the testing dataset. We ran the top models with the training data and used the resulting fitted models to calculate the relative probability of selection within each choice set. In each choice set, the model predicted correctly if the relative probability of the used site was higher than the relative probabilities of the available sites. We determined final model accuracy as the percentage of correctly predicted choice sets out of the 5 testing datasets.

RESULTS

We found 15 nests between 4 April and 26 May 2016 and 30 nests between 17 March and 31 May 2017, and collected habitat measurements on these nests and their paired points between 5 June and 18 June 2016 and between 21 May and 5 June in 2017. Nests were mostly located within the primary study area boundaries, though 2 nests were located just southeast of the northern study area (Figure 1). All nests were located on private property with the exception of 2 nests that occurred in a town park and at a county recycling facility. We found 10 nests in loblolly pine (*Pinus taeda),* 9 nests in live oak (*Quercus Virginiana),* 4 nests in water oak (*Quercus nigra*), 3 nests in laurel oak (*Quercus laurifolia*), 2 nests in each of longleaf pine (*Pinus palustris*), black cherry (*Prunus serotina*), and sweetgum (*Liquidamber styraciflua*), and a nest in each of 9 additional tree, shrub or vine species. Nests were located at an average height of 6.9±4.9 m and 3.8±2.8 m out from the main trunk of the tree or bush.

Our modeling results indicate that Loggerhead Shrike habitat selection at the territory core scale was best explained by the 2 top models (Table 2). The highest ranked model included covariates of shrub and tree density, vegetation density heterogeneity, and vegetation height heterogeneity and held 40% of the model weight (Table 2). Based on this top model, vegetation height heterogeneity, and vegetation density heterogeneity most influenced probability of selection (Table 3). Vegetation density heterogeneity had a negative effect on relative selection probability. As variation increased from 0.0 to 2.0, selection probability decreased from 16% to 0.0% (Figure 2A). In contrast, vegetation height heterogeneity had a positive effect, where predicted selection probability increased from 0.0 to 14% as variation increased from 1 to 3 (Figure 2B). Cross validation resulted in a 43% chance that the model would correctly predict the used territory. The second ranked model included covariates of grass presence, post density, distance to powerline, shrub and tree density, vegetation density heterogeneity, vegetation height heterogeneity, and distance to crop and held 39% of the model weight (Table 2). In this model, effects of vegetation density and vegetation height heterogeneity were similar to the first model, though this model was more complex, and also indicated a slight negative effect of both distance to powerline, and shrub density (Table 3). Relative probability of selection increased as distance to powerline decreased, as there was a only a 1% relative selection probability for a nest being

180m from a powerline, but a 5% probability at 70m, and a maximum 18% probability at zero meters from a powerline (Figure 2C). Additionally, relative probability of selection decreased from 18% to 5% to 0% as shrub density increased from zero to 24 to 72 shrubs in the territory core (Figure 2D). Cross validation resulted in only a 52% chance that this second model would correctly predict the used territory.

Our modeling results indicate that Loggerhead Shrike habitat selection at the tree scale was also explained by 2 top models (Table 2). The top nest tree model included only DBH as a covariate and held 62% of the model weight, while the second ranked model included DBH and canopy openings and held 31% of the model weight, though canopy openings had a standard error larger than the estimate and therefore was likely not influencing selection (Table 3). We found that DBH had a relatively slight, positive influence on selection probability, where trees with a 100 cm DBH had a relative selection probability of 3% and our maximum measured DBH of 165cm had a relative selection probability of 10% (Figure 3). Cross validation resulted in a 40% chance that the 1st ranked model would correctly predict the used tree, and a 32% chance that the second ranked model would predict correctly.

DISCUSSION

As expected, our models included specific habitat characteristics that increased relative probability of selection at both the territory core scale and tree scale, indicating that nest site selection by Loggerhead Shrikes was not random, and involved both scales. Loggerhead Shrikes selected for habitat characteristics that would enhance foraging ease and success, limit predation risk, and ultimately increase survival and fitness.

Similar to previous studies of Loggerhead Shrike nest selection in other portions of their range, ground vegetation structure was an important factor in territory core selection. Studies in South Carolina and Ontario have noted that Loggerhead Shrikes nesting in pasture preferred short, uniform vegetation (Gawlik and Bildstein 1990, Chabot et al. in prep), but Loggerhead Shrikes nesting in native prairie prefer higher diversity in vegetation structure (Michaels and Cully 1998, St-Louis et al. 2010, Prescott and Collister 1993, Rotenberry and Wiens 1980). Our prediction that Loggerhead Shrikes would select for nest sites in short, uniform ground vegetation structure was only partly supported, where individuals preferred to nest where territory cores contained low variation of ground vegetation density, but higher variation in vegetation heights. This result is likely a function of the habitat conditions specific to our study area. First, raw data from all used and available territories indicated that all ground cover was short (average maximum heights=9.03±8.77 cm) and sparse (average hits=1.48±0.99). Therefore, it is likely Loggerhead Shrikes preferred consistently sparse ground vegetation that was also variable in height while still being short. Second, selection for nesting in areas with higher vegetation height diversity was likely a function of Loggerhead Shrikes selecting pasture-lands for nesting rather than manicured lawns. Lastly, higher height diversity may be preferred by Loggerhead Shrikes because it is likely home to a more robust insect population that could provide more prey items for foraging (St-Louis et al. 2010, Chabot et al. 2001). Additionally, Loggerhead Shrikes showed some preference for territory cores with fewer shrubs, likely to maximize the amount of grassy foraging area close to the nest and to minimize predation risk. To provide higher vegetation height diversity and improve nesting conditions for Loggerhead Shrikes, we suggest that residential landowners could wait longer to mow their lawns, rotate mowing different sections of lawn, or establish a “meadow” section that is not mown.

Loggerhead Shrikes also showed some selective preference for territory cores closer to powerlines, which is likely indicative of their propensity to use powerlines as unobstructed perches. In South Carolina, Loggerhead Shrikes were most often observed when perched on utility lines rather than on posts or natural perches (Gawlik and Bildsein 1993). Similarly, Loggerhead Shrikes in Texas preferentially perched on partially dead trees, dead trees, or bare perches, all which like powerlines, offer unobstructed views, over fully foliated trees (Becker et al. 2009). Therefore, our findings suggest that nest trees that are closer to powerlines are preferred because parents are likely able to utilize an ideal perch with an unobstructed view for foraging, but also be close to the nest.

Loggerhead Shrikes occupied a variety of tree species in our study, but overall, trees with larger DBH measurements were selected for. Trees with larger DBH not only likely provide more, higher perches for detecting prey and potential nest predators (DeGeus 1990, Bekoff et al. 1987), but may be preferred by Loggerhead Shrikes because they could offer more defenses against snake predation since it is difficult for snakes to climb large trees (Rudolph et al. 1990). Further, given that Loggerhead Shrikes show high site fidelity and have been known to reoccupy previously used nest sites (Pruitt 2000, Chabot et al. in prep), relatively older, large diameter trees are likely critically important for nesting. In our study, an extreme case of nest site fidelity was observed when one pair decided to nest in a brush pile that contained their previous year's nest bush, even though there were other trees available in their territory (J. Froehly, pers. obs). While a large DBH is not preferred in this example, it does demonstrate to what lengths a shrike will go to maintain a preferred nesting site. Overall, we suggest that landowners retain large trees in grassy habitat. Further, given evidence of high nest site fidelity, landowners should examine trees they are considering cutting down and conserve those that hold nests.

Our results reflect what Loggerhead Shrikes chose for nesting locations, but may not reflect the fitness value of those locations. Selection of nests sites is thought to be adaptive so that preferred sites offer high reproductive success (Martin 1998). However, sometimes seemingly ideal locations can act as ecological traps and decrease fitness (Dwernychuk and Boag 1972). For example, at the Savannah River Site, Indigo Buntings (*Passerina cyanea*) selected winged habitat patches that had 50% more edge than simple rectangular patches, but produced more fledglings from nests in the rectangular patches with less edge, possibly due to increased predation pressure in patches with more edge (Weldon and Haddad 2005). Indeed several researchers have observed a high rate of Loggerhead Shrike car strikes (Pruitt 2000), which could indicate an ecological trap associated with nests near powerlines. Therefore, it is essential for future work to determine how nesting success relates to selected nest sites.

Overall, while Loggerhead Shrike distribution and occupancy may be more strongly influenced by larger scale habitat requirements like the amount of pasture and grassland in an area (Froehly et al. in review), suitable nesting sites are still necessary for population recruitment. Ideally, both large and small scales should be managed so that all habitat requirements are met, but in areas with highly fragmented ownership, like in South Carolina, small-scale actions may be the only management option. Fine scale nesting characteristics are not only more easily managed, but can also have the ability to influence larger scale factors through the cumulative effects of many landowners carrying out the same management actions (Jennings et al. 1999). Many landowners taking action to preserve specific habitat characteristics at small scales can help to increase natural habitat abundance and connectivity, and thereby decrease the severity of fragmentation and habitat loss at even the landscape scale (Marzluff and Ewing 2001). In order to promote nesting and to increase available habitat for Loggerhead

Shrikes in the Southeast coastal plain, we recommend that private landowners maximize the amount of grassy habitat on their property which will provide essential grassland habitat, retain large trees in open habitat to provide nesting substrate, and increase diversity in ground vegetation height to provide more natural and high quality grassland cover.

FIGURES

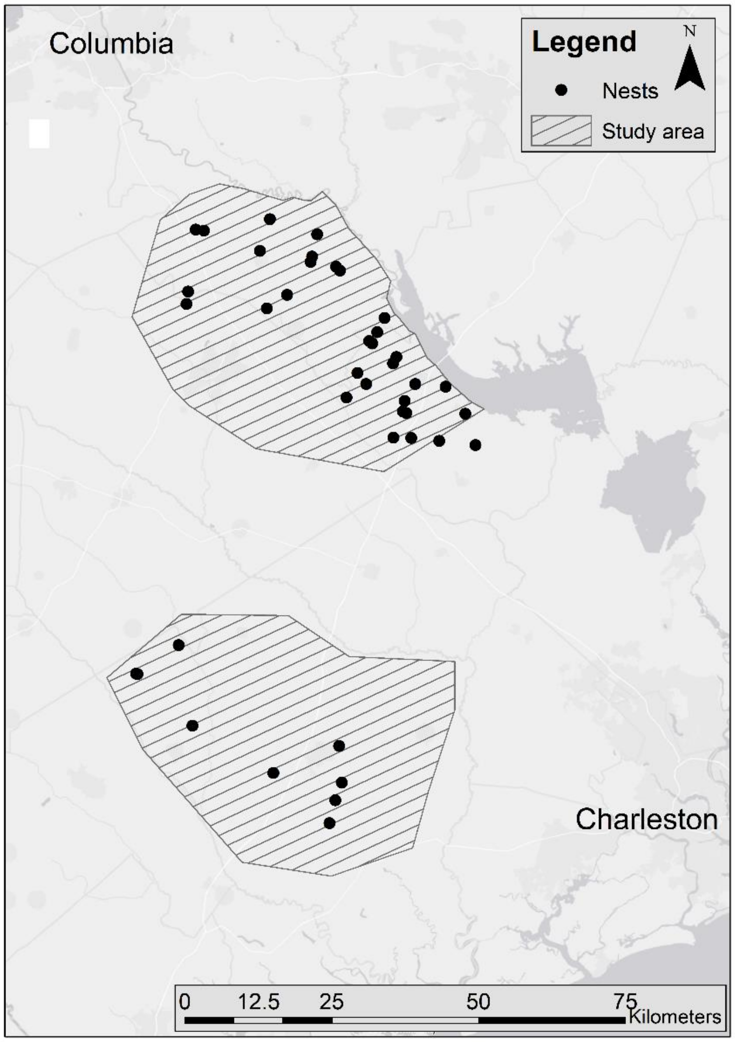

Figure 2.1: Location of study areas for point count surveys and nest searching in South Carolina, and location of nests from the 2016 and 2017 breeding seasons used in analysis.

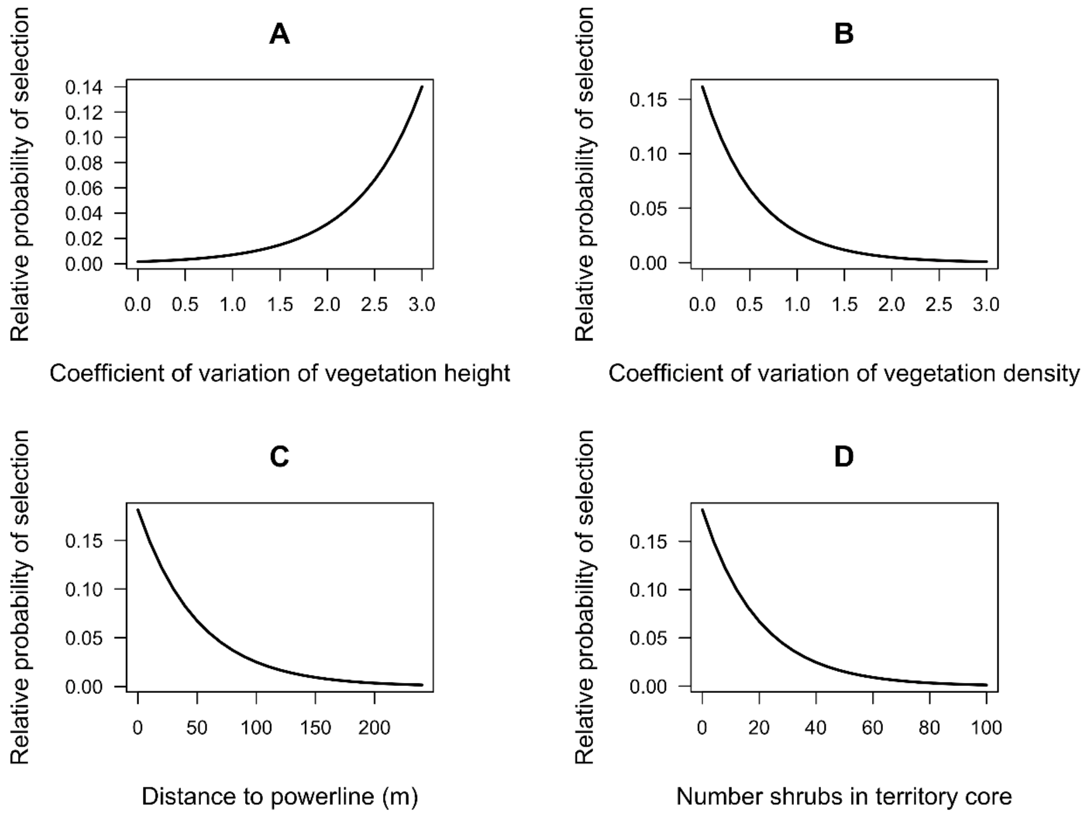

Figure 2: Influence of ground vegetation height variablity (A), territory core ground vegetation density variability (B), nest distance to the nearest powerline (C), and shrub density (D), on the relative probability of selection at the territory core scale by Loggerhead Shrikes in South Carolina during 2016 and 2017.

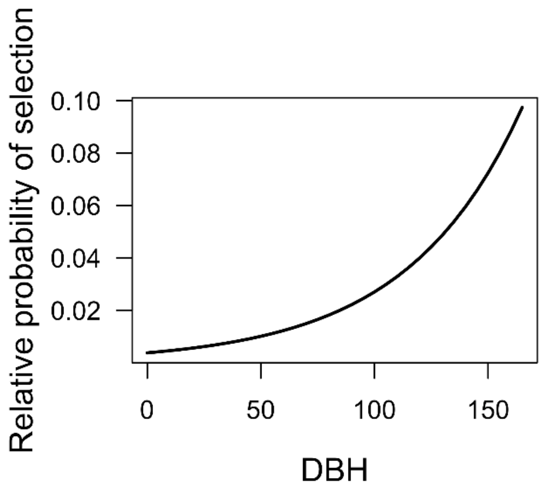

Figure 3. Influence of nest tree diameter at breast height (DBH), on the relative probability of selection at the tree scale by Loggerhead Shrikes in South Carolina during 2016 and 2017.

TABLES

Table 2.1: Loggerhead Shrike tree scale and territory core scale (40m radius) nest selection factors used in *a priori* models:

Tree Scale	
Variable	Description
DBH	Diameter at breast height (cm)
l.branch	Distance from the ground to the lowest branch on the tree (m)
c.open	Average canopy opening percentage from densiometer readings at the trunk in each cardinal direction
Territory Core Scale	
Variable	Description
H.Het	Maximum ground cover height heterogeneity. Coefficient of variation of maximum vegetation heights.
D.Het	Ground cover density heterogeneity. Coefficient of variation of vegetation total hits.
Grass	Probability of grass presence
Forb	Probability of forb presence
Litter	Probability of litter presence
Standing.dead	Probability of standing dead vegetation presence
Litter.depth	Average litter depth
dist.shrub	Distance to the nearest woody stem >2m in height (m)
dist.tree	Distance to the nearest woody stem <2 (m)
Shrubs	Number of woody stems <2m in height within 40m radius
Trees	Number of woody stems >2m in height within 40m radius
Posts	Number posts within 40m radius
dist.post	Distance to the nearest post (m)
dist.powerline	Distance to the nearest utility line (m)
dist.building	Distance to the nearest building (m)
dist.road	Distance to the nearest road (m)
dist.crop	Distance to nearest row crop (m)

Table 2: Discrete choice model ranking for Loggerhead Shrike resource selection at the tree and territory core scales in South Carolina during 2016 and 2017. Models listed are those that contributed to the 90% cumulative model weight. K is the number parameters in the model. ΔAICc is the change in Akaike Information Criterion value corrected for small sample sizes from the top model. *Wi* is the Akaike weight.

Model	K	ΔAICc	*Wi*	Log L.
Territory Core Scale				
1. β(Shrub)+β(Trees)+β(D.Het)+β(H.Het)	4	0.00[a]	0.40	-32.73
2. β(grass)+β(posts)+β(d..poweline)+β(Shrub) +β(Trees) +β(D.Het)+β(H.Het)+β(d.crop)	8	0.03	0.39	-30.33
3. β(Shrub)+β(Trees)+β(grass)	3	3.27	0.08	-34.93
Tree Scale				
1. DBH	1	0.00[b]	0.62	-40.13
2. DBH+c.open	2	1.39	0.31	-39.79

[a] Territory core scale lowest AIC_c value was 68.79
[b] Tree scale lowest AIC_c value was 82.29

Table 3: Top model parameter estimates, standard error (SE) and 95% confidence intervals on Loggerhead Shrikes' relative selection of probability at the territory core and tree scales.

Covariate	Estimate	SE	95% CI
Territory Core Model 1			
Shrub	-0.692	0.46	-1.630, 0.246
Trees	-0.657	0.43	-1.524, 0.211
D.Het	0.892	0.49	-0.100, 1.884
H.Het	-1.085	0.54	-2.175, 0.004
Territory Core Model 2			
d.crop	-2.514	2.16	-6.842, 1.813
grass	0.440	0.40	-0.376, 1.257
posts	-0.307	0.33	-0.984, 0.370
d..poweline	-0.948	0.53	-2.009, 0.112
Shrub	-0.974	0.54	-2.055, 0.107
Trees	-0.193	0.50	-1.192, 0.806
D.Het	0.860	0.49	-0.131, 1.851
H.Het	-0.940	0.56	-2.073, 0.192
Tree Model 1			
DBH	0.62513	0.24	0.140, 1.110
Tree Model 2			
DBH	0.58891	0.25	0.083, 1.094
canopy.opening	0.15732	0.22	-0.284, 0.598

APPENDICES

Appendix A

Chapter 1 Supplemental Materiel

Table A1.1: Detection *a priori* hypotheses from step 1

Hypothesis	Model Formula
1. Detection probability will not be affected by any of these variables.	$\psi(.)p(.)$
2. Time of day will increase detectability	$\psi(.)p(\text{time})$
3. Increasing ambient noise level will decrease detectability	$\psi(.)p(\text{noise})$
4. Detectability will maximize at peak breeding	$\psi(.)p(\text{date}^2)$
5. Increasing wind and temperature, and worsening sky conditions will decrease detectability	$\psi(.)p(\text{wind + temp + sky})$
6. Increasing wind, temperature, and ambient noise, and worsening sky conditions will decrease detectability	$\psi(.)p(\text{wind + temp + sky + noise})$
7. Increasing wind and temperature, and worsening sky conditions will decrease detectability. Detectability will also maximize at peak breeding	$\psi(.)p(\text{wind + temp + sky + date}^2)$
8. Increasing wind and temperature, and worsening sky conditions will decrease detectability. Time of day will increase detectability.	$\psi(.)p(\text{wind + temp + sky + time})$
8. Increasing wind and temperature, and worsening sky conditions will decrease detectability. Time of day will increase detectability. Detectability will also maximize at peak breeding	$\psi(.)p(\text{wind + temp + sky + noise + date}^2\text{ + time})$

Table A2.1: Occupancy *a priori* hypotheses

Hypothesis	Model formula
300 m	
1. Higher proportions of pasture at 300 m will increase occupancy probability	ψ(pasture 300 m)*p*(covariates from step 1)
2. Higher NDVI values at 300 m will decrease occupancy probability	ψ(NDVI 300 m)*p*(covariates from step 1)
3. Higher proportions of pasture at 300 m will increase occupancy probability and higher proportions of forest at 300 m will decrease occupancy probability	ψ(pasture 300 m + forest 300 m)*p*(covariates from step 1)
4. Higher proportions of pasture at 300 m will increase occupancy probability and higher proportions of forest and NDVI values at 300 m will decrease occupancy probability	ψ(pasture 300 m + forest 300 m + NDVI 300 m)*p*(covariates from step 1)
1 km	
5. Higher proportions of pasture at 1 km will increase occupancy probability	ψ(pasture 1 km)*p*(covariates from step 1)
6. Higher NDVI values at 1 km will decrease occupancy probability	ψ(NDVI 1 km)*p*(covariates from step 1)
7. Higher proportions of pasture at 1 km will increase occupancy probability and higher proportions of crop at 1 km will decrease occupancy probability	ψ(pasture 1 km + crop 1 km)*p*(covariates from step 1)
8. Higher proportions of pasture at 1 km will increase occupancy probability and higher proportions of forest at 1 km will decrease occupancy probability	ψ(pasture 1 km + forest 1 km)*p*(covariates from step 1)
8. Higher proportions of pasture at 1 km will increase occupancy probability and higher proportions of forest and crop at 1 km will decrease occupancy probability	ψ(pasture 1 km + crop 1 km + forest 1 km)*p*(covariates from step 1)
5 km	
9. Higher proportions of pasture at 5 km will increase occupancy probability	ψ(Pasture 5 km)*p*(covariates from step 1)
10. Higher NDVI values at 5 km will decrease occupancy probability	ψ(NDVI 5 km)*p*(covariates from step 1)NDVI 5km
11. Higher proportions of pasture and pasture aggregation at 5 km will increase occupancy probability	ψ(pasture 5 km + pasture aggregation 5 km)*p*(covariates from step 1)
11. Higher pasture aggregation at 5 km will increase occupancy probability and higher NDVI values at 5 km will decrease occupancy probability	ψ(pasture aggregation 5 km + NDVI 5 km)*p*(covariates from step 1)
12. Higher proportions of pasture at 5 km will increase occupancy probability and higher NDVI values at 5 km will decrease occupancy probability	ψ(Pasture 5 km + NDVI 5 km)*p*(covariates from step 1)

13. Higher proportions of pasture and pasture aggregation at 5 km will increase occupancy probability and higher NDVI values at 5 km will decrease occupancy probability	ψ(Pasture 5 km + NDVI 5 km + open aggregation 5 km)*p*(covariates from step 1)
14. Higher proportions of pasture and pasture aggregation at 5 km will increase occupancy probability and higher proportion of crop at 5 km will decrease occupancy probability	ψ(pasture 5 km + pasture aggregation 5 km + crop 5 km)*p*(covariates from step 1)
14. Higher proportions of pasture and pasture aggregation at 5 km will increase occupancy probability and higher proportion of crop and higher NDVI values at 5 km will decrease occupancy probability	ψ(pasture 5 km + NDVI 5 km + pasture aggregation 5 km + crop 5 km)*p*(covariates from step 1)
15 km	
15. Higher proportion of forest at 15 km will decrease occupancy probability	ψ(forest 15 km)*p*(covariates from step 1)
16. Higher proportion of forest at 15 km will decrease occupancy probability and higher pasture aggregation at 15 km will increase occupancy probability	ψ(forest 15 km + pasture aggregation 15 km)*p*(covariates from step 1)
multiple scales	
17. Higher proportions of pasture at 300 m will increase occupancy probability and higher NDVI values at 1 km and high proportion of forest at 15 km will decrease occupancy probability	ψ(pasture 300 m + NDVI 1 km + Forest 15 km)*p*(covariates from step 1)
18. Higher proportions of pasture at 300 m will increase occupancy probability and higher proportions of forest at 1 km will decrease occupancy probability	ψ(pasture300 m + forest 1km)*p*(covariates from step 1)
19. Higher proportions of pasture at 1 km will increase occupancy probability and higher NDVI values at 300 m will decrease occupancy probability	ψ(NDVI 300 m + pasture 1 km + forest 15 km)*p*(covariates from step 1)
20. Higher proportions of pasture at 5 km will increase occupancy probability and higher proportions of forest at 15 km will decrease occupancy probability	ψ(pasture 5 km + forest15 km)*p*(covariates from step 1)
21. Higher proportions of pasture at 1 km will increase occupancy probability and higher proportions of forest at 5 km will decrease occupancy probability	ψ(pasture1 km + forest 5 km)*p*(covariates from step 1)
22. Higher proportions of pasture at 1 km and pasture aggregation at 5 km will increase occupancy probability and higher NDVI values at 300 m will decrease occupancy probability	ψ(NDVI 300 m + pasture 1 km + pasture aggregation 5 km+ forest 15 km)*p*(covariates from step 1)
23. Higher proportions of pasture at 1 km will increase occupancy probability and higher proportions of forest at 15 km will decrease occupancy probability	ψ(Pasture 1 km+forest 15 km)*p*(covariates from step 1)

Appendix B

Chapter 2 Supplemental Materiel

Table A2.1: Territory core scale *a priori* hypotheses

Hypothesis	Model Formula
Ground Cover	
1. Negative effect of vegetation density and height heterogeneity, positive effect of grass, forbs, negative effect of litter and litter depth, and positive effect of standing	β(D.Het)+β(H.Het)+β(grass)+β(forb) +β(litter)+β(litter.depth) +β(standing.dead)
2. Positive effect of grass, forbs, negative effect of litter and litter depth, and positive effect of standing dead.	β(grass)+β(forb)+β(litter)+β(litter.depth) +β(standing.dead)
3. Negative effect of vegetation density and height heterogeneity	β(D.Het)+β(H.Het)
4. Positive effect of grass.	β(grass)
Tree and shrub	
5. Negative effect of tree and shrub density, and distance to the nearest tree and shrub	β(d.tree)+β(d.shrub)+β(Trees)+β(Shrub)
6. Negative effect of distance to the nearest tree and shrub	β(d.tree)+β(d.shrub)
7. Negative effect of tree and shrub density	β(Trees)+β(Shrub)
Proximity to manmade	
8. Negative effect of distance to powerlines and nearest post, positive effect of distance to building, road, and crop, and post density	β(d..powerline)+β(d..building) +β(d..road)+β(d.perch)+β(d.crop) +β(posts)
9. Positive effect of post density, negative effect of distance to powerline.	β(posts)+β(d..powerline)
10. Positive effect of post density and distance to buildlings	β(posts)+β(d..building)
11. Positive effect of post density	β(posts)
12. Positive effect of distance to crop	β(d.crop)
Combined	
13.Positive effect of grass, and post density, negative effect of distance to powerlines, tree and shrub density, vegetation density and height heterogeneity, and positive effect of	β(grass)+β(posts)+β(d..poweline) +β(Shrub)+β(Trees)+β(D.Het)+β(H.Het) +β(d.crop)
14.Positive effect of grass, and post density, negative effect of tree and shrub density	β(grass)+β(posts)+β(Trees)+β(Shrub)

15. Negative effect of tree and shrub density, and vegetation density and height heterogeneity	β(Shrub)+β(Trees)+β(D.Het)+β(H.Het)
16. Negative effect of tree and shrub density, positive effect of grass	β(Shrub)+β(Trees)+β(grass)
17. Positive effect of grass and post density	β(grass)+β(posts)
18. Positive effect of grass, forbs, negative effect of litter and litter depth, and positive effect of standing dead, positive effect of post density, negative effect of distance to the nearest tree and shrub, tree and shrub density, distance to powerlines and nearest post, positive effect of distance to building, road, and crop, negative effect of vegetation density and height heterogeneity	β(grass)+β(forb)+β(litter)+β(litter.depth) +β(standing.dead)+β(posts) +β(d..powerline)+β(Shrub)+β(Trees) +β(d.tree)+β(d.shrub)+β(d.building) +β(d.road)+β(d.perch)+β(D.Het) +β(H.Het)+β(d.crop)

Table A2.2: Nest tree scale *a priori* hypotheses

Hypothesis	Model Structure
1. Positive influence of DBH	β_1(DBH)
2. Positive influence of height of the lowest branch	β_1(l.branch)
3. Negative influence of canopy openings	β_1(c.open)
4. Positive influence of height of the lowest branch and negative influence of canopy openings	β_1(l.branch)+β_2(open)
5. Positive effect of DBH and negative influence of canopy openings	β_1(DBH)+β_2(c.open)

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Appendix 2. Progress report for an ongoing project titled “Monitoring Success of Farm Bill Incentive Programs in Conserving Avian Wildlife on Private Lands” in collaboration with Clemson University.

Monitoring Success of Farm Bill Incentive Programs in Conserving Avian Wildlife on Private Lands

Team:

Principal Investigator: Beth E. Ross, Assistant Unit Leader, USGS South Carolina Cooperative Fish and Wildlife Research Unit

State Partner: Amy Tegeler, Bird Conservation Coordinator, South Carolina Department of Natural Resources

Graduate Student Research Assistant: Jesse Wood, Department of Forestry and Environmental Conservation, Clemson University

Project Summary:

A primary focus of Farm Bill conservation incentive programs is to promote habitat conservation of at-risk species. Given that over 77% of land in South Carolina is under private ownership, conservation of the many at-risk bird species in the state requires effective design and implementation of habitat conservation incentive programs on private lands. However, feedback on whether Farm Bill habitat conservation incentive programs such as EQIP have been successful has largely been limited to anecdotal evidence and informal feedback from program participants and partners.

We initiated a research project in the spring of 2017 to assess the conservation impact of Farm Bill programs in SC. The objectives of this project are to 1) evaluate the effectiveness of Farm Bill programs (e.g. EQIP) at conserving habitat and wildlife, and 2) assess the use of audio recorders as a tool for monitoring bird species of conservation concern on private lands. In particular, we are examining prescribed burning, thinning, and herbicide spray practices to understand how forest stand management affects avian species composition in loblolly pine stands enrolled in EQIP programs.

Working with regional NRCS representatives and local landowner organizations, we obtained permission to conduct our bird and vegetation surveys at 51 sites in 9 counties of the Piedmont to Midlands regions of South Carolina (Fig. 1). From May-July 2017, we conducted 168 point count surveys and deployed 8 Wildlife Acoustics recorders which captured 828 GB of audio data from 29 sampling sessions. We also conducted vegetation surveys at each site for habitat conditions. We detected over 75 unique species with point count surveys, including widespread common species and species of conservation concern in the Piedmont region (SCDNR 2015). Statistical analysis of point count data began in the fall of 2017; audio data processing is in progress during the spring of 2018. Findings will not only provide guidance on improved monitoring effectiveness of incentive programs and habitat management, but will also provide unique insights into how such technology can be used to identify areas of future focus.

Presentations:

Wood, J.M., A.K. Tegeler, B.E. Ross. September 2017. Quantifying the effects of Farm Bill cost-share conservation practices on avian species on private lands in South Carolina. 24th Annual Conference of The Wildlife Society. Albuquerque, New Mexico. (Student-in-Progress Research poster)

Project timeline and efforts to date:

- 2016:
    - Graduate student begins project with literature review, coursework, and acoustic analysis workshop at national conference
    - Software obtained for acoustic analysis
- 2017:
    - Potential sites scouted; permission and site management history obtained from private landowners
        - Outreach conducted through USDA NRCS district conservationists, county agricultural commissioners, Clemson Cooperative Extension, and an Upstate forest landowner association
        - Sites with varying management histories stratified by age, size, basal area, and burn/management history
        - 9 counties: Abbeville, Aiken, Anderson, Edgefield, Greenwood, Laurens, Saluda, Spartanburg, Union
    - May-July field work (season 1)
        - 168 passive 10-minute point count surveys conducted on 51 sites
        - 8 Wildlife Acoustic Song Meter 4 recording units deployed at 29 sites for 5 days minimum collected 828 GB audio data
        - Modified Level 3 Carolina Vegetation Survey protocol (Peet et al. 1998) employed in 5 replicate 10x10m plots for all 51 sites to characterize vegetation by site
    - GIS work was conducted to calculate patch area, patch shape metrics, and quantities of different types of land cover at several spatial scales from each study site using 2011 National Land Cover Dataset
    - Abundance analysis initiated for modeling abundance of single species in response to various habitat variables

    - Results generated for Brown-headed Nuthatch, Carolina Wren, Tufted Titmouse, Prairie Warbler, Pine Warbler, Yellow-breasted Chat, Indigo Bunting, Red-bellied Woodpecker to start but no figures to share yet
  - Species richness values generated from season 1 data at each of 51 sites as a metric of site diversity
  - Correlation analysis conducted to understand relationships between habitat variables and remove correlated covariates from analyses
- 2018 Plans:
  - May 2 workshop for NRCS and SCDNR professionals on using acoustic recorders for monitoring wildlife
  - May-July field work (season 2)
  - Abundance analyses repeated and expanded with season 2 data
  - Thesis produced and defended; graduation of Master's student
  - Final report produced for project partners
    - Including written guide for using acoustic recorders

Preliminary results:
We detected over 75 species with point count surveys from May 10 – July 3, 2017 at 51 sites within 47 unique private loblolly pine stands. Tufted Titmouse, American Crow, Northern Cardinal, Eastern Towhee, and Carolina Chickadee were the most common species detected, each with over 200 independent detections (i.e. not counting individual members of flocks).

Forest management activities (conducted with cost-share assistance or not) produced different structural conditions of the 47 loblolly pine stands we studied. With an increasing number of prescribed burns, stands tended to have decreased canopy cover, decreased proportion of hardwoods to pine cover in the canopy layer, and increased number of forbs and grasses at low heights in the understory. Stands treated with herbicide tended to have lower densities of hardwood vegetation at 10-50cm heights. Stands tended to be thinned predictably as they aged.

We have assessed important predictors of abundance for some individual species, birds within 4 nesting guilds, birds within 3 behavior guilds, and for overall species richness of a site. From this analysis, we have learned that predictors of high species abundance vary by species or group characteristics. A few species seem to be sensitive to the timing of Farm Bill management activities, including the Indigo Bunting, which is more abundant more recently after a fire or thinning. For other species, the most important characteristics for abundance were tree height and canopy cover. Other species appear to be more affected by landscape conditions than local forest stand conditions; for example, the Prairie Warbler, Pine Warbler, and Yellow-Breasted Chat are more abundant when there is less developed/built cover at 1km or 5km from the site. For these landscape-affected species, which included foliage-gleaning birds, local stand management practices may be less important than the regional context. By contrast, shrub-nesting, ground-nesting, and ground foraging bird abundance tended to be more affected by local stand conditions. Using raw, unadjusted species richness, we found sites with three or more prescribed burns had more bird species than sites with no burns or one burn (Fig. 2). Similarly, average species richness increased with two or more thins. However, the statistical significance of these results is limited at this time.

A comparison of species inventory by point count data to audio recorder data is underway. To date, we have not detected a species using recorder data that we did not detect with point count surveys or site observations, but analysis is far from complete. Work toward objective 2 (assessing transferability of audio recorder technology to monitoring objectives) is underway anecdotally, but no formal analysis has been completed yet.

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Figures:

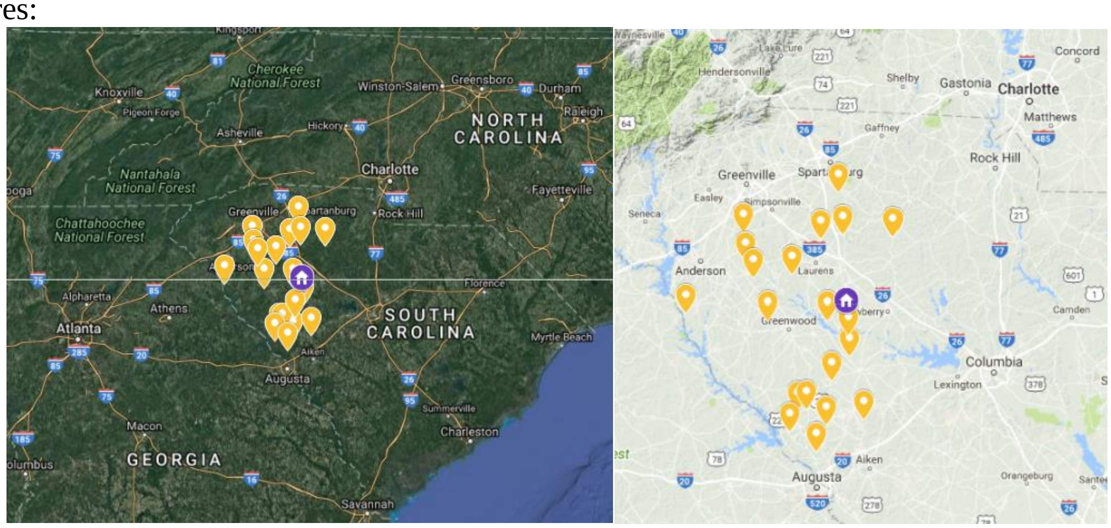

Figure 1. Study area and sites (yellow markers) in context of Southeast (left) and Upstate of South Carolina (right).

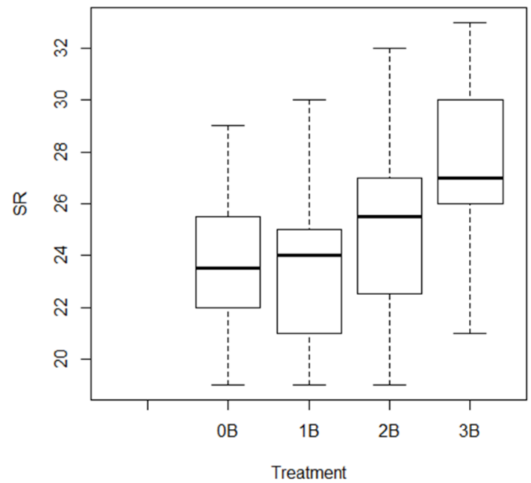

Figure 2. Boxplot of mean site species richness (from 3-4 point count survey visits across all 51 sites) by “Treatment” type (0B: no burns, 1B: one burn, 2B: two burns, 3B: three or more burns).

Appendix 3. Examples of press releases with information on the conservation of land birds.

DNR News

June 21, 2012

Feeding summer hummingbirds provides entertainment and beauty

Hummingbirds, which artist John J. Audubon called "glittering fragments of the rainbow," are once again darting around flowers and feeders in South Carolina, say state natural resources officials.

"Hummingbirds are as fascinating to study as they are beautiful to watch," said Lex Glover, wildlife technician with the S.C. Department of Natural Resources (DNR) in Columbia. Glover encourages South Carolina residents to landscape with flowers, hang out a feeder and invite hummingbirds to lunch: "In return, they'll entertain you with their antics and add a little color to your life."

Thousands of South Carolina residents enrich their summers by feeding hummingbirds. Male ruby-throated hummingbirds, which feature the characteristic metallic blood-red throat bib, began showing up in South Carolina in late March, with their white-throated mates arriving from the tropics about a week later. Most hummingbird activity around feeders, however, does not really pick up until midsummer. Do not despair if you had hummers at your feeder early during the migration period and now there are none. Some of those birds continued flying north and others stayed here but are busy raising young and taking advantage of plentiful natural food sources.

Under natural conditions, hummingbirds obtain sugar by eating the nectar of flowers and the sap of trees. Homeowners can duplicate this part of a hummer's diet by placing a sugar solution in a hummingbird feeder, with the added attraction of getting to witness the antics of one of nature's most delightful and colorful birds. "Hummingbirds consume 50 percent of their body weight daily in sugar, which makes it one of the most important food items in a hummer's diet," Glover said.

A wide variety of hummingbird feeders are now available on the market. If you have used the feeders in previous seasons, Glover said, be sure to wash the hummingbird feeder with hot water and vinegar or hot water and bleach to destroy all mildew and mold left over from last year, then rinse thoroughly with clean water. This is the most important thing to do to make these birds' stay in the Palmetto State more enjoyable.
The sugar-water mixture for the feeders should be a ratio of four parts water to one part sugar; an easy-to-remember mixture is one cup of sugar per quart of water. This solution closely

approximates the sugar content of nectar. Red dye is unnecessary—the red coloring on the feeder will suffice. Honey should not be used as a sweetener because honey-water solutions often harbor a fungus that can be harmful to the hummer.

"If you are putting a feeder up for the first time, don't be discouraged if hummingbirds do not come right away," Glover said. "It may take a while for them to find it and establish a visitation routine." Be sure to keep the solution fresh especially as the days get warmer, because birds will not be attracted to a fermented solution.
Hummingbirds are attracted to tubular red flowers like red salvia, bee balm, trumpet creeper, cypress vine, cross vine, firecracker vine, red buckeye, native azaleas (Oconee, flame and plumleaf) and woodbine, and they will readily seek out others such as hibiscus, hollyhock, petunia and impatiens. Hummingbirds also feed on small insects.

Feeders can be left up well into the fall season, and this will not cause the hummers to delay their migration. Migratory birds base their departure date primarily on the changing day length, not on the availability of food. Actually, leaving feeders up into the fall will help the late migrants that stop for a rest on their way back to Mexico and Central America as their natural food sources may be limited at that time.

DNR News

December 20, 2010

State's migratory songbirds could use a helping hand

The numbers of many Neotropical migratory birds are declining precipitously, but the state wildlife agency says people can help by taking some simple steps.

Neotropical migratory birds are those species that nest in North America and migrate to the tropics to spend the winter. In South Carolina 47 percent, or 53 species, of our nesting land birds are considered Neotropical migrants. They include such familiar birds as purple martins, ruby-throated hummingbirds and whip-poor-wills but also less-well-known groups such as warblers, vireos, tanagers, orioles, flycatchers and thrushes. Neotropical migrants are among our most beautiful and musical birds.

"Neotropical migratory birds are facing a triple whammy," said Lex Glover, wildlife technician with the S.C. Department of Natural Resources (DNR). "Their habitat is being degraded on the breeding grounds here in the United States, in the tropics where they spend the winter, and on the migration corridors in between. So these birds are getting hit coming, going and in the middle."

For a brochure or more information on South Carolina's Neotropical migratory birds, write Neotropical Migrants, DNR, PO Box 167, Columbia, SC 29202 or call the DNR at (803) 734-3886 in Columbia.

Neotropical migratory birds are highly sensitive to highways, powerlines, urban sprawl and other development that subdivides and fragments habitats. Other hazards include pesticide poisoning, especially on the wintering grounds, and excess mortality from flying into tall buildings, windows and tall towers, especially during migration.

Despite the litany of woes suffered by these birds at the hands of people, Glover said there are many ways average citizens can help Neotropical migratory birds:

- Drink "shade-grown" coffee. Research shows these older-type coffee plantations in the tropics support far more Neotropical migrants in winter than the newer "sun-grown" coffee plantations where most of the forest vegetation has been removed. Shade-grown coffee tastes better too.
- Keep cats indoors. Unconfined cats kill millions of birds each year in the United States.
- Support wise land-use practices and get involved in planning and zoning issues that protect forests, fields, wetlands and other Neotropical bird habitat.

- Support conservation organizations that protect bird habitat and conduct monitoring, management, research and education programs. Some good ones (most with state chapters) are The Nature Conservancy, National Wildlife Federation, National Audubon Society, Sierra Club and the American Bird Conservancy. Local land trusts in South Carolina actively protect undeveloped land and other open space that protect birds.
- The creation of greenways, parks and forest and wetland corridors in urban areas can help birds, especially during migration. Conserve native plant communities and forests in home landscapes.
- Be aware of development projects in migration flyways such as tall towers, buildings and other structures that may increase bird mortality. Conservative estimates show that 100 million birds are killed annually in the United States by flying into glass windows.

DNR News

September 15, 2015

DNR offers guidelines to keep bird feeders clean, backyard birds safe

Many South Carolina residents enjoy feeding wild birds. Several bird species commonly visit feeders providing an opportunity for residents to enjoy watching them nearby. However, S.C. Department of Natural Resources biologists are asking the public to be mindful of proper maintenance of their feeders. Without proper care bird feeders can harm rather than benefit the local bird population. Dirty feeders can harbor spoiled feed, seed hulls, and waste which can become a source of bacteria, mold, and other diseases that can be transmitted between birds.

The risk is greatly reduced when bird feeders are cleaned regularly. Not only will the birds benefit, but so will the resident because clean feeders will likely attract more wild birds. With thoughtful planning and care the public can enjoy healthy and safe backyard birds. Fortunately, bird feeder care is easy just follow these guidelines:

* Keep Feeders Clean: Seed feeders should be thoroughly cleaned at least once per month with one part liquid chlorine bleach to 9 parts hot water. Make enough solution to immerse the feeders. Allow the feeder to soak for 10 minutes to loosen debris. Wear rubber gloves and wash all feeder parts inside and out where birds may perch or waste may collect including feeding ports, perches, lids, platforms, reservoirs, and feeder hooks and poles using a stiff brush. After cleaning, rinse the feeder and all parts for at least 10 seconds in clean water to remove all chemical residue. Allow the feeders to air dry completely, especially wooden

feeders, before refilling with seeds. Nectar feeders need special care because of their design.

Nectar feeders should be cleaned each time they are refilled. Change the nectar before it is spoiled or cloudy, or 3 – 4 days during warmer months. If the birds are not emptying the feeder, it's unnecessary and wasteful to fill it completely. Frequent cleaning will reduce mold and help prevent deadly fermentation. Clean feeders using 4 parts hot water to 1 part vinegar or 9 part hot water to 1 part bleach using a special bottle brush to clean small holes. Visually inspect the entire feeder for black mold. Rinse all parts of the feeder with water for at least 3 times and allow it to air dry completely before refilling. Don't try to deter bees, or other insects, with oil or other sticky substances around the feeding ports. It may contaminate the nectar. If insects become a problem, try relocating the feeder.

* Clean Surrounding Area: In addition to keeping the birdfeeders clean, it is essential to clean all nearby areas. Many birds prefer to forage on the ground or will eat spilled seed when feeders are crowded. These areas should be cleaned at least once a month to remove the build-up of hulls, uneaten seeds, and other waste to reduce mold & disease for ground-feeding birds and help prevent rodent infestations. A rake, broom, shovel, or workshop vacuum all work well to remove the waste. Then hose down the area and dispose of the waste appropriately. Periodically moving bird feeders can also reduce the accumulation of waste in one area.

* Offer Fresh Food: Spoiled food is unhealthy both for birds, and if left on the ground, also your outside pets. Store food in a cool area in rodent and water proof containers. Dispose of any food that is wet, smells musty, or appears moldy. Contaminated storage containers and scoops need to also be cleaned. Typically provide only as much food as the birds will eat in one or two days to keep seed from spoiling. It will also make cleaning the feeders easier. During wet weather, provide only enough seed to last several hours.

* Use Safe Feeders: While cleaning the feeder, inspect it for sharp points or edges that can scratch or cut birds. Even small injuries can enable bacteria and viruses to infect otherwise healthy birds. Be sure to place feeders at least 10 feet from low shrubs or bushes that provide cover for cats and other predators who will wait to ambush birds at the feeder. To help prevent mortality from window collisions, place feeders either farther than 30 feet or closer than 3 feet from windows.

* Provide Space: Use multiple feeders and spread them out over a large area to reduce crowding. While seeing several birds at a single feeder may look appealing, the potential for disease transmission between sick and healthy birds increases. Birds are crowded if they have to jostle each other to reach food. Crowding can also cause stress which may make birds more vulnerable to disease.

* Promote Healthy Birds: Don’t wait until sick or dead birds are seen before cleaning feeders. But if the situation should occur, it is best to stop feeding immediately. Remove the dead bird by wearing rubber gloves and placing the bird in a plastic, leak proof bag. Dispose of the sealed bag and rubber gloves in a normal trash receptacle out of reach of pets or scavengers. Wash hands immediately. Clean all feeders and the surrounding area following these guidelines and wait at least two weeks before rehanging feeders.

Appendix 4. Updated SCDNR bald eagle web pages.

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Raptors of South Carolina

Eagles

Species and Statuses

Falconry

News Releases

- DNR biologists document Golden Eagles at Marsh WMA in Marion County - June 26, 2015
- Singular effort initiates DNR Barn Owl nest box program - February 23, 2015
- Public asked to report sightings of state-endangered swallow-tailed kite - March 21, 2013
- Peregrine falcon pair at Jocassee Gorges fledges two birds for fourth year in a row - December 19, 2011

Staff

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Information

- Welcome
- Bands
- Biology
- Nest Locations
- Current Regulations
- Disease
- Mortality
- Past Surveys
- More Information

South Carolina's Bald Eagles - Current Regulations

Bald eagles (*Haliaeetus leucocephalus*) are protected under the Bald Eagle Protection Act as of June 8, 1940, as amended on October 23, 1972 and the Migratory Bird Treaty Act of 1918.

Bald eagles below the 40th parallel were listed as endangered on March 11, 1967 and subsequently received protection under the Endangered Species Act of 1973. On February 14, 1978, listing status was changed to endangered throughout the lower United States except for Washington, Oregon, Minnesota, Wisconsin and Michigan, where the bald eagle was designated as threatened. Bald eagles were reclassified as threatened in all lower 48 states on July 12, 1995 and were removed from the federal list of threatened and endangered species on August 8, 2007. More Information

Federal Protection Legislation

Bald eagles remain protected under the Bald and Golden Eagle Protection Act. This act prohibits take where "take" is defined as "pursue, shoot, shoot at, poison, wound, kill, capture, trap, collect, destroy, molest or disturb". The U.S. Fish and Wildlife Service defines disturb as "to agitate or bother a bald or golden eagle to the degree that causes, or is likely to cause, based on the best scientific information available, 1) injury to an eagle, 2) a decrease in its productivity, by substantially interfering with normal breeding, feeding, or sheltering behavior, or 3) nest abandonment, by substantially interfering with normal breeding, feeding, or sheltering behavior". The Bald and Golden Eagle Protection Act outlines the federal prohibitions regarding the "take" and "disturbance" of bald or golden eagles, including their parts, nests, or eggs.

- Bald and Golden Eagle Protection Act

The Migratory Bird Treaty Act outlines the prohibitions regarding the "taking" of any migratory bird or any part, nest, or egg, except as permitted by regulation.

- Migratory Bird Treaty Act

It is illegal to possess, dead or alive, any eagle or part of any eagle such as feathers or talons. If you know of such a violation, report it immediately to any state or federal wildlife officer or call the hotline at 1-800-922-5431

State Protection Legislation

Bald eagle is listed as a state threatened species (regulation 123-150 Article 5 pages 67-85) and receives state protection as a nongame species (law 50-15-10) in South Carolina.

Management Guidelines to Avoid Disturbance

U.S. Fish and Wildlife Service has developed bald eagle management guidelines to advise landowners, land managers, and others to minimize impacts to bald eagles and not cause "disturbance".

- Bald Eagle Management Guidelines

How do I obtain a USFWS permit?

Permits are issued by USFWS Regional Offices, Contact the Migratory Bird Office (321) 972-9089.

- Guidelines and Application for Non-purposeful Take Permits
- Annual Report for Non-purposeful Eagle Take Permit

Permits for removing nests are only issued by USFWS to alleviate a safety emergency to people or eagles, to ensure public health and safety, where the nest prevents the use of a human-engineered structure, or the activity or mitigation for the activity will provide a net benefit to eagles.

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Information

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- Past Surveys
- More Information

South Carolina's Bald Eagles - Nest Locations

The current SCDNR bald eagle monitoring program includes nesting season aerial flight surveys. A subset of the documented nesting territories are surveyed each year resulting in the entire state being surveyed once every three years. Therefore nest locations provided cannot be assumed to be current and inclusive of all nesting activity. Not all nests within SC have been documented by SCDNR. Non-documented nests receive the same level of protection as nests documented by SCDNR.

- Current SCDNR documented bald eagle nests in SC*, with the date of the last survey

*Note: After downloading this file you must have Google Earth installed to open the file on your computer or device. Google Earth is available for free for computers at http://www.google.com/earth/, or on smartphones from the Apple or Android Stores.

The information contained in the map above shows bald eagle nests documented by SCDNR estimated to be within 0.1 miles of the true location.

Report a Nest

If you think you have discovered a new nest, please make sure it is an undocumented nest using the Current SCDNR documented bald eagle nests in SC link above. If you have reviewed SCDNR's documented nests and think the nest is undocumented, or are unsure, please inform SCDNR.

For South Carolina technical assistance contact Amy Tegeler at TegelerA@dnr.sc.gov or (803) 521-2119.

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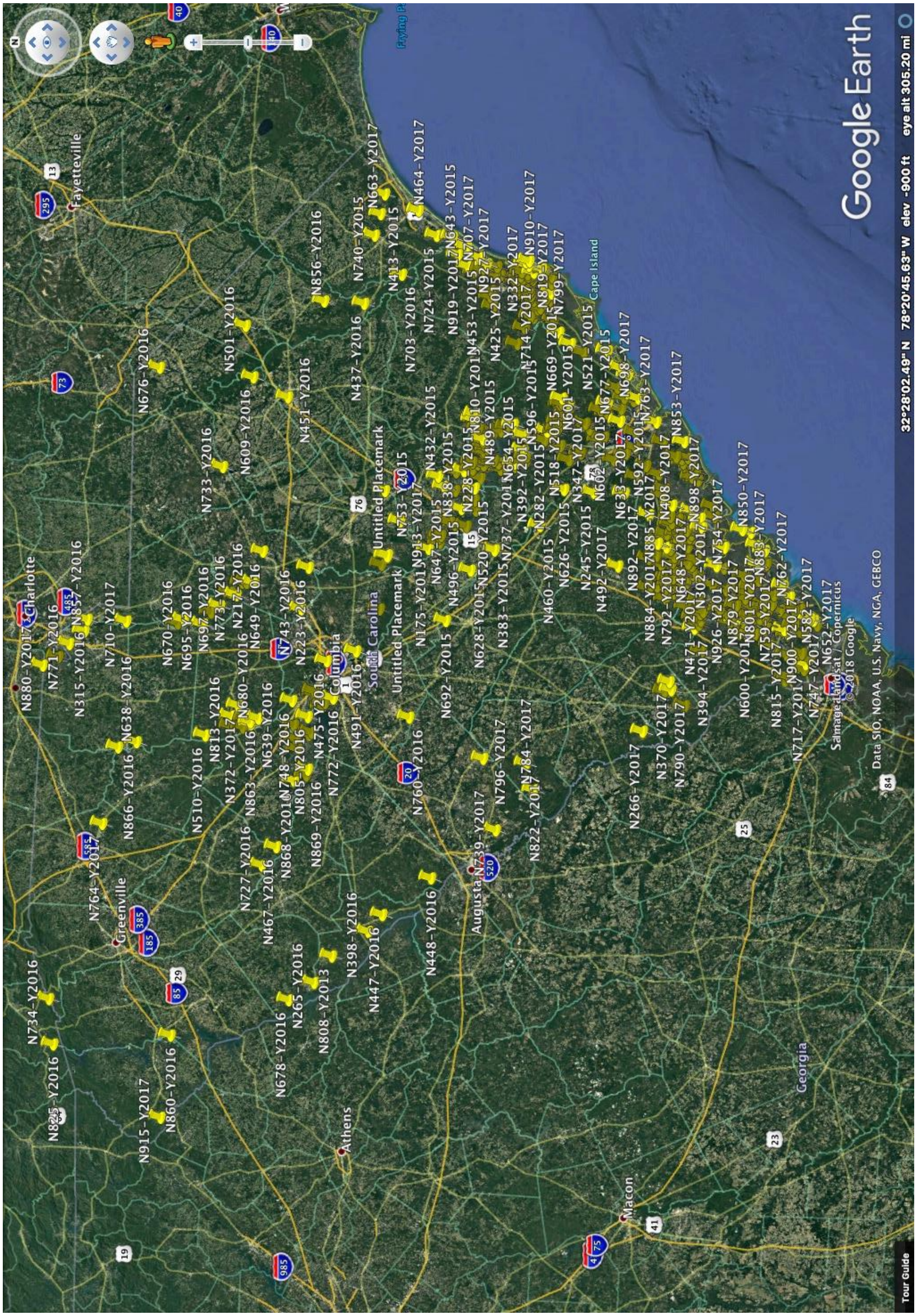
Map available from the SCDNR bald eagle webpages the shows the approximate location of all documented bald eagle nests.



Appendix 5. Updated SCDNR non-game bird webpages.


Game Birds
Raptors
Wading Birds
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Landbirds of South Carolina

Research and Montoring

Species and Statuses

Viewing Landbirds in SC

Additional Resources

The landbirds of South Carolina are a diverse and fascinating group of birds. The purpose of this website is to provide information about the ecology, conservation, and management of landbirds in South Carolina. One hundred twenty seven species of landbirds are known to nest in South Carolina. Additionally, 104 species are regularly observed in the state but have not been recorded nesting in South Carolina as of 2008.

The terminology used to describe landbirds can be confusing. In North America, the term "landbird" is used to refer to species that occupy terrestrial habitat including warblers, thrushes, sparrows, finches, hummingbirds, flycatchers, raptors and other species groups.

News Releases

- Feeding summer hummingbirds provides entertainment and beauty - June 22, 2016
- Baltimore Oriole Winter Survey finds S.C. with largest number of orioles wintering second year in a row - April 29, 2016
- Audubon workshops aim to help landowners and songbirds - April 21, 2016
- Workshop on managing forests for songbirds, income set April 14 at Wateree River wildlife area - March 9, 2016
- S.C. Baltimore Oriole Winter Survey and Great Backyard Bird Count set Feb. 12-15 - February 11, 2016
- Here are some simple ways to help wildlife during holidays - December 29, 2015
- DNR offers guidelines to keep bird feeders clean, backyard birds safe - September 15, 2015
- Hummingbirds returning to South Carolina - June 1, 2015

- Want to help wildlife during holidays? Here are some simple ways - December 23, 2014
- Many animal species benefit from snags, so leave some standing dead trees - December 23, 2014
- Feed summer hummingbirds for entertainment, beauty - May 29, 2014
- Nesting chimney swifts are source of noise now heard in fireplaces - June 13, 2012
- Welcome migratory songbirds to your yard - April 6, 2012
- Now is the time to put up gourds to attract purple martins - April 27, 2011

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Landbirds Species and Statuses

Species Table. Landbird species of conservation concern in South Carolina. Conservation status from SC State Wildlife Action Plan (SWAP 2015).

Species	Scientific Name	Conservation Priority
Acadian Flycatcher	*Empidonax virescens*	High
Bachman's Sparrow	*Aimophila aestivalis*	Highest
Baltimore Oriole	*Icterus galbula*	High
Belted Kingfisher	*Megaceryle alcyon*	High
Bewick's Wren	*Thryomanes bewickii*	Moderate, SC Endangered
Black-and-white Warbler	*Mniotilta varia*	High
Black-billed Cuckoo	*Coccyzus erythropthalmus*	High
Black-throated Blue Warbler	*Setophaga caerulescens*	Moderate
Black-throated Green Warbler	*Setophaga virens*	Highest
Black-throated Green Warbler (Wayne's)	*Setophaga virens waynei*	Highest
Blue Grosbeak	*Passerina caerulea*	Moderate
Blue-winged Warbler	*Vermivora cyanoptera*	Moderate
Brown Thrasher	*Toxostoma rufum*	High
Brown-headed Nuthatch	*Sitta pusilla*	Moderate
Carolina Chickadee	*Poecile carolinensis*	Moderate
Carolina Wren	*Thryothorus ludovicianus*	Moderate
Cerulean Warbler	*Setophaga cerulea*	Highest
Chestnut-sided Warbler	*Setophaga pensylvanica*	Moderate
Chimney Swift	*Chaetura pelagica*	High
Chuck-will's-widow	*Antrostomus carolinensis*	High
Common Ground-Dove	*Columbina passerine*	Highest, SC in Need of Management
Common Raven	*Corvus corax*	Moderate
Dark-eyed Junco	*Junco hyemalis*	Moderate
Dickcissel	*Spiza americana*	Moderate
Downy Woodpecker	*Picoides pubescens*	Moderate
Eastern Kingbird	*Tyrannus tyrannus*	High
Eastern Meadowlark	*Sturnella magna*	High
Eastern Towhee	*Pipilo erythrophthalmus*	High
Eastern Wood-Pewee	*Contopus virens*	High
Field Sparrow	*Spizella pusilla*	High
Golden-crowned Kinglet	*Regulus satrapa*	Moderate
Golden-winged Warbler	*Vermivora chrysoptera*	Highest

Grasshopper Sparrow	*Ammodramus savannarum*	Highest
Gray Kingbird	*Tyrannus dominicensis*	Moderate
Henslow's Sparrow	Ammodramus henslowii	Highest
Hooded Warbler	*Setophaga citrina*	Moderate
Indigo Bunting	*Passerina cyanea*	Moderate
Kentucky Warbler	*Geothlypis formosa*	High
Loggerhead Shrike	*Lanius ludovicianus*	Highest
Louisiana Waterthrush	*Parkesia motacilla*	High
Northern Parula	*Setophaga americana*	Moderate
Orchard Oriole	*Icterus spurius*	Moderate
Painted Bunting	*Passerina ciris*	Highest
Pileated Woodpecker	*Dryocopus pileatus*	Moderate
Pine Warbler	*Setophaga pinus*	Moderate
Prairie Warbler	Setophaga discolor	High
Prothonotary Warbler	*Protonotaria citrea*	Moderate
Purple Martin	*Progne subis*	High
Red Crossbill	*Loxia curvirostra*	Highest
Red-bellied Woodpecker	*Melanerpes carolinus*	Moderate
Red-breasted Nuthatch	*Sitta Canadensis*	Moderate
Red-cockaded Woodpecker	*Picoides borealis*	Highest, Federal and SC Endangered
Red-headed Woodpecker	*Melanerpes erythrocephalus*	Moderate
Rusty Blackbird	*Euphagus carolinus*	Highest
Scarlet Tanager	*Piranga olivacea*	Moderate
Seaside Sparrow (McGillivray's)	*Ammodramus maritimus macgillivraii*	Moderate
Sedge Wren	*Cistothorus platensis*	Highest
Summer Tanager	*Piranga rubra*	Moderate
Swainson's Warbler	*Limnothlypis swainsonii*	High
Whip-poor-will	*Antrostomus vociferus*	High
White-eyed Vireo	*Vireo griseus*	Moderate
Wood Thrush	*Hylocichla mustelina*	High
Worm-eating Warbler	*Helmitheros vermivorum*	Moderate
Yellow-billed Cuckoo	Coccyzus americanus	High
Yellow-breasted Chat	*Icteria virens*	High
Yellow-throated Vireo	*Vireo flavifrons*	Moderate
Yellow-throated Warbler	*Setophaga dominica*	Moderate

Additional information about the status of landbirds in South Carolina can be found at the SC State Wildlife Action Plan website.

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Viewing Landbirds of South Carolina

SCDNR Public Lands

The landbirds of South Carolina are a diverse and fascinating group of birds. One hundred twenty seven species of landbirds are known to nest in South Carolina. Additionally, 104 species are regularly observed in the state but have not been recorded nesting in South Carolina as of 2008.

The SCDNR owns and manages Wildlife Management Areas (WMA) and Heritage Preserves which are protected areas for the conservation of fish, wildlife and other natural resources.

Related Links

- Audubon Society Important Bird Areas
- Carolina Bird Club
- Cornell Lab of Ornithology eBird

Common Backyard Birds

There are many common backyard birds in South Carolina. A few species are listed below.

- Baltimore Oriole
- Blue Jay
- Brown Thrasher
- Carolina Chickadee
- Carolina Wren
- Chipping Sparrow
- Common Grackle
- Downy Woodpecker
- Eastern Bluebird
- Eastern Towhee
- House Finch
- Mourning Dove
- Northern Cardinal
- Northern Mockingbird
- Painted Bunting
- Red-bellied Woodpecker
- Tufted Titmouse