SOUTH CAROLINA COOPERATIVE FISH & WILDLIFE RESEARCH UNIT

ANNUAL REPORT

2022

In 2022, the South Carolina Cooperative Fish & Wildlife Research Unit continued to engage our cooperators to address pertinent issues in the conservation and management of our natural resources. Unit scientists advised and mentored graduate students in both M.S. and Ph.D. programs, taught graduate classes, and provided technical assistance to cooperators.

South Carolina Cooperative Fish & Wildlife Research Unit

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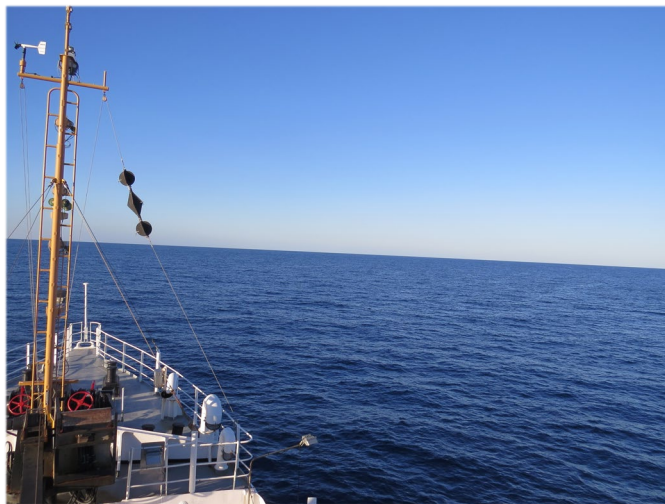Clemson University
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Cooperators:

U. S. Geological Survey
Clemson University
South Carolina Department of Natural Resources
U. S. Fish and Wildlife Service
Wildlife Management Institute

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COOPERATORS AND PERSONNEL

COORDINATING COMMITTEE

United States Geological Survey

Jonathan Mawdsley, Chief, Cooperative Research Units

John Thompson, Deputy Chief, Cooperative Research Units

Barry Grand, Regional Supervisor, Cooperative Research Units

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Robert Boyles, Director, South Carolina Department of Natural Resources

Emily Cope, Deputy Director for Wildlife and Freshwater Fisheries, South Carolina Department of Natural Resources

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Keith Belli, Dean, College of Agriculture, Forestry and Life Sciences, Clemson University

Paula Agudelo, Associate Dean of Research, College of Agriculture, Forestry and Life Sciences, Clemson University

Todd Petty, Chair, Forestry and Environmental Conservation, Clemson University

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Steve Williams, President, Wildlife Management Institute

UNIT PERSONNEL

Patrick Jodice, Unit Leader, U.S. Geological Survey, and Professor, Department of Forestry and Environmental Conservation, Clemson University

Luke Bower, Assistant Unit Leader-Fisheries, U.S. Geological Survey, and Assistant Professor, Department of Forestry and Environmental Conservation, Clemson University

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Yvan Satgé, Research Specialist, South Carolina Cooperative Fish & Wildlife Research Unit and Department of Forestry and Environmental Conservation, Clemson University

Welcome

Dr. Erin Buchholtz

Dr. Erin Buchholtz joined the SC CRU in May 2022 as our Assistant Unit Leader - Wildlife. Prior to joining the SC Unit, Erin was at the USGS Fort Collins Science Center where she was conducting research on wildlife movement ecology, landscape ecology, and socio-ecological systems. We look forward to Dr. Buchholtz developing her research and teaching programs at Clemson University.

COLLABORATORS

Clemson University

Robert Baldwin, Department of Forestry and Environmental Conservation
Kyle Barrett, Department of Forestry and Environmental Conservation
Troy Farmer, Department of Forestry and Environmental Conservation
Cathy Jachowski, Department of Forestry and Environmental Conservation
David Jachowski, Department of Forestry and Environmental Conservation
Brandon Peoples, Department of Forestry and Environmental Conservation
Robert Powell, Parks, Recreation and Tourism Management
Matt Brownlee, Parks, Recreation and Tourism Management
Shari Rodriguez, Department of Forestry and Environmental Conservation

South Carolina Department of Natural Resources Cooperators

Jason Bettinger, Fisheries Biologist
Jay Cantrell, Assistant Big Game Program Coordinator
Jamie Dozier, Tom Yawkey Wildlife Center
Christy Hand, Wildlife Biologist
Michael Hook, Small Game Program Coordinator
Molly Kneece, Waterfowl Biologist
Mary Catherine Marin, Wildlife Biologist
Mark McAlister, Wildlife Biologist, Tom Yawkey Wildlife Center
Charles Ruth, Big Game Program Coordinator
Felicia Sanders, Wildlife Biologist
Mark Scott, Fisheries Biologist
Michael Small, Assistant Small Game Program Coordinator
Amy Tegeler, Bird Conservation Coordinator
Janet Thibault, Wildlife Biologist

Federal Agency Cooperators

Cameron Aldridge, USGS FORT
Laurel Barnhill, USFWS
Sarah Dawsey, USFWS Cape Romain Natural Wildlife Refuge
Dean Demarest, USFWS
Deborah Epperson, USGS WARC
Lance Garrison, NOAA/NMFS
Jeff Gleason, USFWS
Kristin Hart, USGS
Scott Johnston, USFWS
Mona Kalil, USGS

Meg Lamont, USGS
Susan Loeb, Southern Research Station, USFS
Jim Lyons, USGS
Michael O'Donnell, USGS FORT
John Stanton, USFWS
Melanie Steinkamp, USGS
Craig Watson, USFWS Ecological Services, Charleston, SC
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Barry Wilson, USFWS
Randy Wilson, USFWS
Bureau of Ocean Energy Management
USFWS Region 4, Cape Romain Natural Wildlife Refuge
USFWS Migratory Bird Program
USFWS Ecological Services
USFS Southern Forest Experiment Station
National Park Service, Congaree National Park
Smithsonian Migratory Bird Center

Private Sector Cooperators

Lisa Ferguson, Wetlands Institute
Chris Haney, Terra Mar, LLC Nemours Wildlife Foundation
Juliet Lamb, The Nature Conservancy
Brad Keitt, American Bird Conservancy
Ernst Rupp, Grupo Jaragua, the Dominican Republic
BirdsCaribbean
Weyerhaeuser Company

Cooperating Scientists from other Colleges, Universities, and Institutes

Auriel Fournier, Illinois Natural History Survey
Autumn-Lynn Harrison, Smithsonian Institute
Julie Heinrichs, Colorado State University
Rainer Lohman, University of Rhode Island
Hannah Madden, Wageningen University, Netherlands
Brad Wilkinson, Duke University
Mark Woodrey, Mississippi State University
Elise Zipkin, Michigan State University

GRADUATE EDUCATION

CURRENT and RECENTLY GRADUATED STUDENTS

Michael Adams, M.S. Wildlife & Fisheries Biology (Graduated 2021, Advisor: Ross)
Jacob Daley, Ph.D. Wildlife & Fisheries Biology (Advisor: Bower)
Janelle Grehan, M.S. Wildlife & Fisheries Biology (Graduated 2022, Advisor: Ross)
Mikayla Thistle, M.S. Wildlife & Fisheries Biology (Graduated 2021, Advisor: Ross)
Bradley Wilkinson, Ph.D. Wildlife & Fisheries Biology (Graduated 2021, Advisor: Jodice)

CURRENT & RECENTLY COMPLETED RESEARCH

Quantifying the Effect of Instream Flow on Larval Fish Abundance in the Edisto River Basin
Principal Investigator: Luke Bower (SC CRU)
Students: Daniel St. Amand (Undergraduate, Clemson University), Ty'Celia Young (Undergraduate, Clemson University), Andrew Peel (Undergraduate, Clemson University), Anna Pereda (Undergraduate, Clemson University), Charles Jackson (Undergraduate, Clemson University), and Brianna Taylor (Undergraduate, Clemson University)
Sponsors: USGS/South Carolina Water Resources Center and Clemson University CI
Dates: 2020-2021

Determining Flow-Ecology Relationships to Inform Flow Standards
Principal Investigator: Luke Bower (SC CRU), Joseph Mruzek (SC CRU), and Brandon Peoples (Clemson University)
Sponsors: SC DNR
Dates: 2022-2024

Edisto River Flow Effects on Summertime Water Temperatures: Are Thermal Tolerances of SWAP Fishes Exceeded at Low Flows?
Principal Investigator: Luke Bower (SC CRU)
Student: Search underway
Sponsors: SC DNR
Dates: 2023-2025

Variation of Chronology of Wild Turkey Gobbling in the Upstate of South Carolina
Principal Investigator: Beth Ross (SC CRU)
Student: Janelle Grehan (M.S., Clemson University)
Sponsors: SC DNR
Dates: 2019-2022

Habitat Use and Breeding Ecology of Bachman's Sparrow in a Wiregrass-free Longleaf Pine Ecosystem in South Carolina
Principal Investigator: Beth Ross (SC CRU)
Student: Mikayla Thistle (M.S., Clemson University)
Sponsors: SC DNR
Dates: 2019-2021

Effects of Forest Management on Early-Successional Avian Species in South Carolina
Principal Investigator: Beth Ross (SC CRU)
Student: Michael Adams (M.S., Clemson University)
Sponsors: SC DNR
Dates: 2020 – 2022

Spatial & Disturbance Ecology of Eastern Brown Pelicans in the South Atlantic Bight
Investigators: Patrick Jodice (SC CRU)
Student: Bradley Wilkinson (Ph. D., Clemson University)
Sponsors: USGS and Bureau of Ocean Energy Management
Dates: 2017–2023

Gulf of Mexico Marine Assessment Program for Protected Species
Principal Investigator: Patrick Jodice (SC CRU)
Collaborators: Jeff Gleason (USFWS), Chris Haney (Terra Mar LLC)
Post-Doctoral Research Associate: Pamela Michael (Clemson University)
Research Associates: Yvan Satgé (SC CRU & Clemson University), Kathy Hixson (SC CRU & Clemson University)
Sponsors: US FWS and Bureau of Ocean Energy Management
Dates: 2017-2022

Ecology and Conservation of the Endangered Black-capped Petrel
Principal Investigators: Patrick Jodice (SC CRU) and Yvan Satgé (SC CRU & Clemson University)
Sponsors: US FWS, BirdsCaribbean, SC CRU
Dates: 2018-2023

Seabird Colony Atlas for the Northern Gulf of Mexico
Principal Investigator: Patrick Jodice (SC CRU)
Collaborator: Jeff Gleason (USFWS)
Research Associates: Kathy Hixson (SC CRU & Clemson University) and Yvan Satgé (SC CRU & Clemson University)
Sponsors: Gulf Coast Joint Venture, US FWS
Dates: 2022-2023

Understanding Past and Present Connectivity Patterns for Sagebrush Habitat and Associated Wildlife
Principal Investigator: Erin Buchholtz (SC CRU)
Collaborators: Julie Heinrichs (Colorado State Univ), Michael O'Donnell & Cameron Aldridge (USGS-FORT)
Sponsor: Bureau of Land Management - Wyoming State
Dates: 2021-2023

Quantifying the Effect of Instream Flow on Larval Fish Abundance in the Edisto River Basin

The management and conservation of riverine fishes has focused primarily on adult life stages, generally excluding the early life stages of many fishes. Yet, the population dynamics, assemblage structure, and year-class strength of adult fishes are strongly influenced by the responses of early life stages to abiotic and biotic stresses. Larval fishes are often more sensitive to abiotic and biotic stresses than adults. Additionally, larval fishes frequently have distinct habitat requirements, diets, and responses to environmental stresses than those of adult and juvenile fishes.

Habitat requirements and specialization has been reported for some riverine larval fishes However, information of the habitat requirements and specialization of riverine larval fish is lacking, and quantitative analysis of microhabitat preference remains limited. Larval fish habitat requirements and specialization can also vary among taxa and regions. Therefore, site-specific information on larval fish habitat requirements and specialization is needed to better understand how larval and adult fish assemblages will respond to environmental alteration.

Quantifying microhabitat use can also aid in identifying potential nursery habitats that are needed for larval fish survival. The goal of this study was to quantify the microhabitat characteristics and temporal changes in larval fish assemblages to identify microhabitat characteristics that influence larval fish assemblage structure in a small river. Our objectives were to: 1) identify the timing of peak larval fish counts; 2) quantify the microhabitat preference of larval fish at the family level to identify potential nursery habitats; 3) determine the influence of microhabitat characteristics on larval fish assemblage structure.

We used handheld dipnets to sample larval fishes at equidistant points along 20 transects weekly from May to July 2021 along a 200 m stream reach. We also collected microhabitat data at each larval fish capture location. Larval fish specimens were identified to the family level. A distance-based redundancy analysis indicated that water velocity and depth contributed to changes in larval fish assemblage structure. Larval fishes tended to use a subset of the available habitat, characterized by low water velocity, non-*Podostemum* substrate, and shallow habitats close to shore or bed rock structure. We also detected temporal patterns in larval fish counts, with peak darter (Percidae) and minnow (Leuciscidae) counts in late July and the highest sucker (Catostomidae) counts in late May-early June. Our results suggest that larval fish select habitats with low water velocity and shallow habitats close to shore microhabitat characteristics and that riffle-pool sequences may serve as a nursery habitat for Percidae, Catostomidae, and Leuciscidae larvae.

Determining Flow-Ecology Relationships to Inform Flow Standards

Natural flow regime (i.e. magnitude, frequency, duration, timing and rate of change of flow events) is crucial for maintaining freshwater biodiversity and ecological integrity. Appropriation of water resources will continually increase with the rapidly growing human population in South Carolina, increasing 11.3% from 2010 to 2019. Protecting instream flows for ecosystem services will be one of society's great challenges this century. South Carolina is a water-rich state that will face unique challenges and opportunities as demand increases. Protecting instream flow from anthropogenic alterations and maintaining ecosystem services of water resources first requires an understanding of the relationship between aquatic organisms and instream flow. Accordingly, the goal of the proposed project is to identify key relationships between flow metrics and biotic response (flow-ecology relationships) in the State's eight, major river basins and to use these relationships to predict the response of aquatic organisms to changes in streamflow and water withdrawals to inform river basin planning across the State.

The South Carolina State Water Planning Framework, released in October 2019, describes the process for developing a stakeholder-driven water supply plan (River Basin Plan). A major component of the Planning Framework is the convening a River Basin Council (RBC) in each of the eight planning basins (Broad, Catawba, Edisto, Pee Dee, Salkehatchie, Saluda, Santee, and Savannah) to develop a River Basin Plan that addresses anticipated water needs and water-related issues. One of the key guiding principles for RBCs and River Basin Plan is that water is a limited natural resource and a major factor for economic development and environmental protection. Specifically, River Basin Plans should 1) "strive for the equitable use of water resources with the goal of ensuring water is available for all uses, when and where needed, throughout the Planning Horizon and under drought conditions", and 2) "protect the public's health and well-being and should balance social, economic, and environmental needs." Protecting instream flows for ecosystem services will be one of the many challenges RBCs will face during the development of a River Basin Plan. To address these challenges, we will: 1) determine key relationships between instream flow and biotic responses in all major SC river basins; and 2) predict the biological response of aquatic organisms to estimated changes of instream flows due to water withdrawals.

Edisto River Flow Effects on Summertime Water Temperatures: Are Thermal Tolerances of SWAP Fishes Exceeded at Low Flows

The Edisto River supports an immense diversity of aquatic species, including fifteen freshwater fish species listed as species of greatest conservation need in the South Carolina 2015 State Wildlife Action Plan (SWAP). Despite a lack of dams and low development in the watershed, aquatic species of greatest conservation need in the Edisto River Basin face a severe threat from increasing water withdrawals for agriculture and public use. The Edisto River has the highest number of water withdrawal registrations and the highest maximum monthly withdrawals of any river basin in the state of South Carolina. High levels of recent water withdrawals have resulted in declining flows, especially during dry summer months when water demand for agricultural uses peaks. Comparing historical (1932-1985) to recent (1986-2015) flow data from the South Fork of the Edisto River, the median days per year with extremely low flows had increased to 60 days per year (Figure 2). Decreased flow during summer may cause water temperatures to exceed thermal tolerances of SWAP species, such as Striped Bass (*Morone saxatilis*) and Bannerfin Shiner (*Cyprinella leedsi*) and could result in a reduction in critical habitat as the volume or numbers of coolwater refuges declines. Therefore, this project aims to: 1) Monitor Edisto River water temperature at 40 sites from the freshwater-brackish water interface to the headwaters in the North and South fork of the Edisto River for three years; 2) Conduct laboratory experiments quantifying Edisto River Striped Bass and Bannerfin Shiner thermal tolerance under a range of acclimation temperatures; 3) Develop a statistical model to predict Edisto River mean and maximum daily summer water temperature in response to flow and regional air temperature; 4) Develop a spatially structured model to forecast the effects of climate change and water withdrawals on Edisto River

Striped Bass, Bannerfin Shiner, and juvenile Shortnose Sturgeon (*Acipenser brevirostrum*) summertime thermal habitat under differing downscaled climate projections.

This project will provide critical information necessary for protecting SWAP listed freshwater and diadromous fish species in the Edisto River Basin. Specifically, this project will determine maximum thermal tolerances for two SWAP freshwater fish species in the Edisto River Basin (Bannerfin Shiner [high priority], Edisto River Stiped Bass [moderate priority]) and create detailed maps of available thermal habitat under a range of current and projected, future flow scenarios for the two SWAP fish species listed above as well as the Shortnose Sturgeon). This project will provide critical information that will help anticipate and plan adaptive management strategies in the face of climate change and increasing water demand in the Edisto River Basin. Additionally, once thermal thresholds are quantified and field work identifies the locations of critical summertime thermal refuges, on-the-ground habitat restoration and enhancement efforts can be planned to protect these critical thermal refuges.
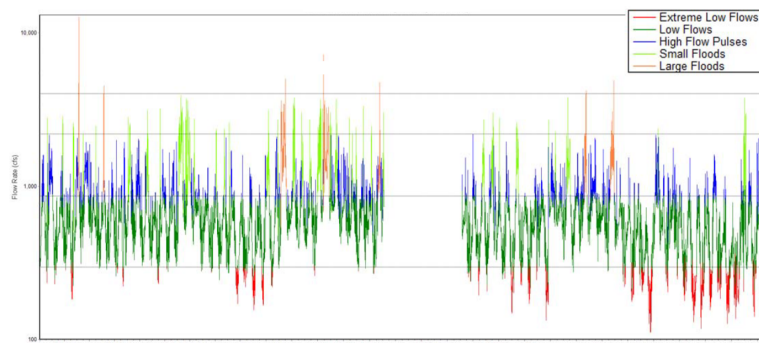

Figure 2. Mean daily flow in the Edisto River from 1932-2015 at USGS station 02173000 on the South Fork of the Edisto River at the Highway 321 bridge near Denmark, South Carolina. Flow data from 1972-1980 is missing from the historical record. Colors in the legend represent Environmental Flow Components (EFCs) that represent ecologically relevant hydrological patterns. An increasing prevalence of low flows have been observed since 2000. Figure from Berzinis 2016.

Variation of Chronology of Wild Turkey Gobbling in the Upstate of South Carolina

Wild turkey is a highly popular game species harvested primarily during the reproductive season. Due to the popularity of the species, there have been substantial efforts to establish sustainable harvest regulations while balancing hunter satisfaction. Hunter satisfaction is strongly correlated with hearing vocalizing males, or "gobbling", thus wildlife agencies have used gobbling data to evaluate regional gobbling peaks and population responses to hunting activity and harvest.

Gobbling activity and associated habitat selection has been increasingly assessed through deployment of autonomous recording units (ARU), yet *post hoc* processing of audio data has been time-intensive particularly due to high false positive rates and streamlining this process would benefit future research. Our project goals are to assess upstate South Carolina gobbling chronology using monitoR as an alternative auto-recognition software and incorporate detection data from monitoR into occupancy models to inform management decisions. We created two templates to detect relatively soft and loud gobbles, resulting in different false positive rates for each template due to associated sensitivity.

We deployed 38 ARUs throughout Upstate SC and collected daily 3-hour recordings from March 1 to May 31 in 2019 and 2020. We used an acoustic template finder, monitoR, to identify detections which we incorporated into hierarchical single-season occupancy models to evaluate site use across Upstate South Carolina and quantify factors affecting detection probability and false positives. Our occupancy models used audio templates as independent "observers" for repeat sampling. For both years, false positive probabilities increased as

distance to water increased. Additionally, false positive rates in 2019 were correlated positively with average wind speed in 2019 (β = 0.54, 0.21–0.87; 85% CI), and in 2020 differed by template choice (β = 0.70, 0.54–0.86; 85% CI). The top-ranked detection models for both years included terms for template, humidity, and date. Percentage of pasture was positively correlated with seasonal turkey site use and was the most predictive model in 2019 and 2020. Gobbling activity did not exhibit any discernible patterns between years or within seasons, demonstrating the challenge managers face when structuring harvest seasons based on highly variable results from gobbling chronology studies.

Habitat Use and Breeding Ecology of Bachman's Sparrow in a Wiregrass-free Longleaf Pine Ecosystem in South Carolina

Through much of its range, Bachman's Sparrow (*Peucaea aestivalis*) uses the wiregrass (*Aristida spp.*) dominant understory typical of longleaf pine (*Pinus palustris*) forest. The central South Carolina Coastal Plain, however, lies within the "wiregrass gap" where longleaf pine understories are absent of wiregrass and instead are dominated by bluestem grasses (*Schizachyrium spp.* and *Andropogon spp.*), bracken fern (*Pteridium aquilinum*), and shrubs. Habitat use of Bachman's Sparrow in this region has yet to be studied and declining Bachman's Sparrow populations necessitate a better understanding of habitat selection processes and population dynamics across regional habitat types.

The goal of this study is to describe breeding season habitat use and breeding ecology of Bachman's Sparrow in the unique wiregrass-free longleaf pine ecosystem of Tom Yawkey Wildlife Center, Santee Coastal Reserve, and Washo Reserve, South Carolina to inform best management practices for Bachman's Sparrow. The objectives of this study are to (1) identify management treatments and landscape scale characteristics that Bachman's Sparrows select for home ranges, (2) identify vegetation characteristics that Bachman's Sparrows select for nest-sites, (3) quantify nest-success, (4) relate nest-site selection to reproductive success, and (5) collect preliminary data on movement and survival of Bachman's Sparrow within a wiregrass-free ecosystem

During the 2020 and 2021 breeding seasons, we conducted repeated visit point count surveys at 95 sites and used open *N*-mixture models to estimate the effects of habitat management and forest stand characteristics (e.g. prescribed burns, basal area, stem density, pine species, canopy closure) on Bachman's Sparrow abundance, apparent survival probability, and recruitment rates. We also located nests to identify vegetation composition and structure characteristics

that Bachman's Sparrows select for nest-sites. To determine if habitat selection in the study population was adaptive, we monitored nests and related nest-site selection to nest survival rates by comparing habitat characteristics related to selection with those related to survival. Across the nine primary sampling periods, we estimated the abundance of male Bachman's Sparrows within the study area to be between 23 and 49 individuals. Initial abundance and recruitment rate were strongly predicted by the proportion of longleaf pine to other pine species within the sample area, with abundance and recruitment rate increasing with longleaf pine dominance. Apparent survival probability decreased as the density of stems between 10 and 25 cm DBH increased. Nest-site selection in the study population was non-adaptive. Bachman's Sparrows selected nest-sites that had intermediate groundcover densities compared to available nest-sites; however, nest survival rates decreased at intermediate groundcover densities. The results of this study can be used to inform region-specific management plans and restoration of degraded habitats, which often lack typical understory species like wiregrass, to increase Bachman's Sparrow abundance and reproductive success.

Early Successional Habitat Monitoring for Ruffed Grouse and Golden-winged Warblers

Early successional habitats are a critical habitat type for ruffed grouse (*Bonasa umbellus*) and golden-winged warblers (*Vermivora chrysoptera*). In the southern Blue Ridge Ecoregion, early successional habitats have declined over the last 70 years, and the extent of which ruffed grouse and golden-winged warblers occupy these habitats at the edge of their ranges is unknown. The goal of this project was to assess the status and distribution of golden-winged warblers and ruffed grouse in the southern Blue Ridge Ecoregion. We also aimed to determine how management of early successional habitats influences presence/absence of ruffed grouse and golden-winged warblers on public lands, and to evaluate the use of Autonomous Recording Units (ARUs) to detect and monitor both species.

Our first objective was to examine the effects of landscape-scale habitat features on Ruffed grouse occupancy. Ruffed Grouse in the Southern Blue Ridge Ecoregion seem influenced by habitats not typical of their northern range and occur more frequently in landscapes with higher mixed forest and woody wetland cover. In the absence of early-successional forests, Ruffed Grouse may be seeking habitats that act as structural mimics to early-successional forests. Our second objective was to examine the effects of multi-scale habitat parameters on Golden-winged Warblers, Chestnut-sided Warblers, Prairie Warblers, Common Yellowthroat, and Field Sparrow. As a whole, these species seem to be influenced by landscape and composition, ground cover metrics, vegetation structure, and elevation. Chestnut-sided Warblers may act as the most effective habitat indicator for Golden-winged Warbler habitat, as they exhibit similar preference for habitat features including elevation and vegetative visual obstruction. Our third objective was to examine the efficacy of human-observer surveys and autonomous recording unit surveys to detect Ruffed Grouse, Golden-winged Warblers, and 2 early-successional habitat indicator species. Autonomous recording units performed

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

Spatial & Disturbance Ecology of Eastern Brown Pelicans in the South Atlantic Bight

As a nearshore marine predator and species of conservation concern, Brown Pelicans (*Pelecanus occidentalis*) in the southeastern United States constitute a valuable study population for investigating coastal ecological systems. Despite occupying a highly visible and elevated trophic position in estuarine and oceanic ecosystems, movement parameters describing habitat use patterns, foraging behaviors, and migratory corridors are undeveloped at multiple spatial and temporal scales. The goal of this dissertation was to identify important drivers of movement behavior and to describe the ecological outcomes of movement decisions in Eastern brown pelicans (*Pelecanus occidentalis carolinensis*) from the South Atlantic Bight.

A total of 86 individual pelicans were outfitted with solar-powered GPS satellite transmitters in coastal South Carolina and Georgia, USA, from 2017 – 2020. Two cohorts of pelicans tracked during the passage of three tropical cyclones demonstrated a reduction in movement correlated with anomalies in barometric pressure and wind speed relative to ambient conditions, indicating a shelter-and-wait strategy for increasing survival during these extreme weather events. By measuring the concentrations of an environmental contaminant, poly- and perfluoroalkyl substances, in the eggs of pelicans from three colonies located near Charleston, South Carolina, we demonstrated that eggs contained relatively elevated concentrations of chemicals regardless of proximity to likely point sources. GPS tracking of adults from the same colonies further suggested that variations in urban habitat use for foraging adults during the breeding season were also not reflected in egg contaminant concentrations. In contrast, the relative risk to foraging adult pelicans of

encountering surface oil from a ship-based spill near Charleston Harbor was significantly influenced by location, as demonstrated through the use of an oil spill modeling toolkit combined with pelican telemetry data. Finally, the partial migration strategy of brown pelicans in the South Atlantic Bight is likely maintained by the ontogenetic migration of their primary prey, Atlantic menhaden (*Brevoortia tyrannus*), and aligns with the fasting endurance hypothesis of partial migration. Understanding the causes and consequences of movement in brown pelicans in the South Atlantic Bight has important implications for the ecology and conservation of this species throughout their range.

Gulf of Mexico Marine Assessment Program for Protected Species

The Gulf of Mexico is simultaneously one of the most ecologically important and industrialized marine ecosystems globally, yet limited seabird research has occurred in this region. The Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS) is a federal partnership between the Bureau of Ocean Energy Management, the U.S. Fish and Wildlife Service, the U.S. Geological Survey, and the National Oceanic and Atmospheric Administration that seeks to fill historic information gaps regarding species composition, distribution, and abundance in the northern Gulf.

From April 2017 to September 2019, we conducted seabird surveys on 14 pelagic cruises as a part of GoMMAPPS. Surveys took place on 293 ship days representing 2,300 hours of observer effort and 41,700 km of transects during all four seasons. GoMMAPPS surveys substantially enhanced seabird survey coverage of northwest and southwest regions of the Gulf in spring and southwest and south-central regions in the summer.

We tallied 9,347 detections of 44,029 seabirds representing 44 species and identified 85.9% of observed seabirds as species. We characterized the origins of species using the northern Gulf and found that most were not locally breeding. The majority breed in locations within the northern interior of continental North American, the southern Gulf, or the Caribbean, demonstrating that the northern Gulf supports both local and migratory species from distant ecosystems throughout the year.

We developed an oil vulnerability index for seabirds in the northern Gulf. Exposure variables characterized the potential to encounter oil and gas

(O&G). Sensitivity variables characterized the potential impact of seabirds interacting with O&G and are related to life history and productivity. We found that the percent of seabirds' habitat defined as highly suitable within 10 km of an O&G platform ranged from 0%-65% among 24 species. Though O&G platforms only overlap with 15% of highly suitable seabird habitat, overlap occurs in areas of moderate to high vulnerability of seabirds, particularly along the shelf-slope. Productivity-associated sensitivity variables were primarily responsible for creating the gradient in vulnerability scores and had greater uncertainty than exposure variables. Highly vulnerable species (e.g., Northern gannet (*Morus bassanus*)) tended to have high exposure to the water surface via foraging behaviors (e.g., plunge-diving), older age at first breeding, and an extended incubating and fledging period compared to less vulnerable species (e.g., Pomarine jaeger (*Stercorarius pomarinus*)). As offshore energy development in the Gulf continues, managers and researchers could use these vulnerability ranks to identify information gaps to prioritize research and focal species.
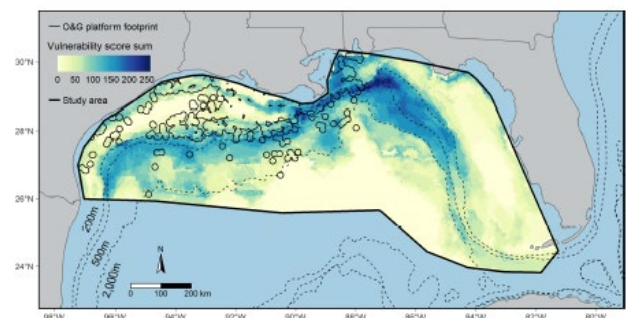
Overlap of cumualtive seabird vulnerability with oil and gas platforms. From Michael et al. 2022.

Ecology and Conservation of the Endangered Black-capped Petrel

The Black-capped Petrel (*Pterodroma hasitata*) has a fragmented and declining population, is considered Endangered throughout its range, and is under consideration for listing under the Endangered Species Act by the U.S. Fish and Wildlife Service. The only confirmed breeding sites have been located in the mountain ranges of Hispaniola, where habitat loss and degradation are continuing threats. Other nesting populations may still remain undiscovered but, to locate them, laborious in situ nest searches must be conducted over expansive geographical areas. We have partnered with various agencies and both national and international NGOs to conduct various studies of the species in both its terrestrial breeding habitat and its marine foraging range.

Marine Habitats: We used tracking data from petrels captured at sea off the coast of Cape Hatteras to assess their distribution. Petrels were tracked for 11 – 255 d ($\bar{x}$ = 102.1 d ±74.2). During the non-breeding period, all individuals ranged from 28.4 – 43.0 degrees latitude. Light and dark phenotypes had significantly distinct non-breeding distributions. We recorded two trips (1 individual of each form) to known breeding areas, with the light form initiating breeding 1.5 months before the dark form. Phenotypic differences in the Black-capped Petrel were linked to differences in nesting phenology, non-breeding marine distribution, and at-sea threat exposure.

We also used at-sea survey data from the Gulf of Mexico from GoMMAPPS and a previous NRDA survey effort to assess the marine range of the species in that region where the distribution of the species was in question. Based on a combination of observations and predictive models our analysis indicated that the northern Gulf be included on the marine range of the species. recognizing that distribution may be more clumped in the eastern Gulf

and that occurrence in the southern Gulf remains unknown due to a lack of surveys there

Analyses are also ongoing that are focused on assessing diet through metabarcoding of DNA samples and measuring mercury levels of feather samples.

Nesting Habitats: We will initiate a new research effort in 2023 (delayed start due to Covid, funded through the Quick Response program) to assess the nesting status of Black-capped Petrels following acute predation and fire events at key nesting area in the Dominican Republic. We also will evaluate the deployment of artificial burrows as a recovery technique. Such an assessment of resiliency is consistent with objectives of the 2018 SSA developed for the species. We also plan to deploy more satellite tags on adults at nest sites during the 2023 nesting season.

Locations of all Black-capped Petrels tracked between May 2019-January 2020 (blue = dark forms, yellow = light forms). Purple polygons locate petroleum leases, and red polygons offshore wind leases. Solid grey line shows the general location of the western edge of the Gulf Stream. Dotted grey line indicates the -250-m isobath. From Satgé et al. 2022.
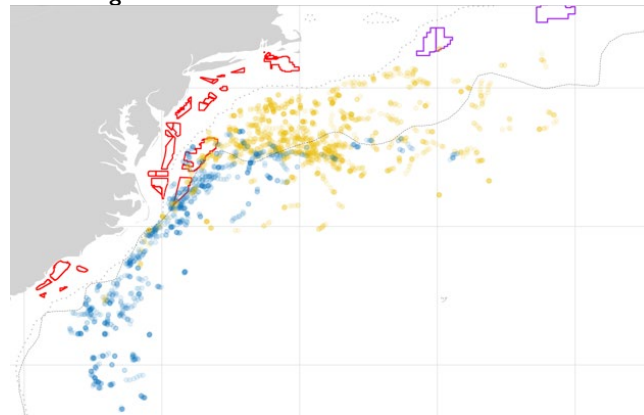
An Atlas and Registry for Seabird Colonies and Associated Habitats in the Northern Gulf of Mexico

The coastal zone of the northern Gulf of Mexico supports a diverse array of breeding nearshore seabirds. Most of these species are colonial and nest on islands although some may also nest in marshes, on mainland beaches, or human-made structures. Although nest-site fidelity is common among seabirds, the dynamic nature of the coastal zone in the northern Gulf can result in inter-annual shifts in the locations of colonies and in the existence, size, or stability of the islands or habitats that support them. Overlaid on this dynamic system is a stakeholder network responsible for management of these species and their breeding habitats that includes natural resource agencies from five states, multiple federal agencies (e.g., USFWS, NPS, BLM, DOD, ACOE), and numerous private organizations (e.g., National Audubon Society, Nature Conservancy).

In an effort to coordinate and facilitate the management and conservation of avian taxa throughout this wide range of habitats and across this complex network of stakeholders in the northern Gulf, the Gulf of Mexico Avian Monitoring Network (GoMAMN) recently released strategic monitoring guidelines (Wilson et al. 2019). The Guidelines highlighted the need for a spatial inventory of breeding sites for seabirds. Currently, there is no single source of information for seabird nesting sites in the northern Gulf of Mexico that is current or readily accessible. Instead, information and data regarding the location and status of colonies of nearshore seabirds in the northern Gulf of Mexico is scattered among numerous agencies and web locations and difficult to source.

We received funding to develop an atlas and registry for seabird colonies in the northern Gulf of Mexico that will integrate existing data from the stakeholder network. The primary objective is to map and catalog seabird colonies in the study area. Therefore, the primary product will be a spatial database that provides the location and status of each seabird colony in the region. This atlas will be accompanied by a registry that will house both data and meta-data for each colony in the atlas. Supporting both of these items will be a text document that provides background on the project, definitions and descriptions of data fields used in the atlas and registry, and instructions for how to navigate and use the atlas and registry. The development of these products is a critical step in understanding the distribution and status of breeding seabirds in the region.

Understanding Past and Present Connectivity Patterns for Sagebrush Habitat and Associated Wildlife

Connectivity is a key component of functioning ecosystems, and there has been an increasing emphasis on management actions to maintain, restore, or increase connectivity. For restoration and management actions to be successful, it is crucial to understand how the spatial patterns of landscape connectivity may vary over time and how wildlife with different needs may be affected by such structural changes.

We investigated temporal connectivity patterns for the sagebrush biome of the western United States using an omnidirectional circuit theory approach. We identified regions of the sagebrush biome that indicated lost connectivity, persistent connectivity, and changes in relative flow patterns for connectivity among sagebrush patches from 1985 to 2020.

This work is being used to support prioritization of sagebrush management actions in Wyoming with the PReSET 2.0 tool. Connectivity is just one of the inputs to help consider where to restore sagebrush (e.g., where it used to be connected but now is fragmented) and where to conserve sagebrush (e.g.,

where it contributes to important existing connectivity among sage grouse leks).

Upcoming work will compare sagebrush connectivity for wildlife with different needs. These findings could help characterize opportunities for proactive conservation of remaining sagebrush structural connectivity and identify degraded areas where targeted management could increase connectivity, benefiting multiple wildlife species.
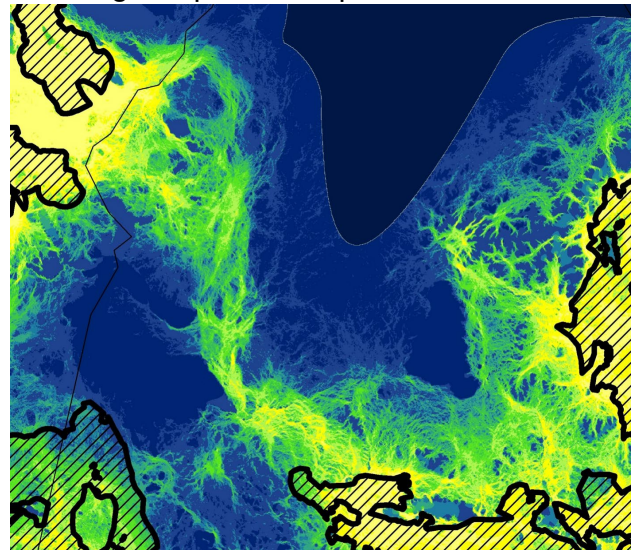
PUBLICATIONS

JOURNAL ARTICLES and TECHNICAL REPORTS

*Graduate student author, ^PostDoc or RA, †Undergraduate student author

Bower, LM, BK Peoples, MC Eddy, MC Scott. 2022. Quantifying flow–ecology relationships across flow regime class and ecoregions in South Carolina. Total Science of the Environment 802:149721.

Eddy, MC, B Lord, D Perrot, LM Bower, BK Peoples. 2022. Assessing uncertainty in flow metrics calculated from a distributed hydrological model: implications for developing flow-ecology relationships. Ecohydrology 15:e2387.

Fournier, AMV, JE Lyons, RR Wilson et al. *In Revision*. Structured decision making to establish regional bird monitoring priorities. INFORMS Journal of Applied Analytics.

Grady, JT, LM Bower, CM Gienger, RE Blanton. 2022. Fish scale shape follows predictable patterns of variation based on water column position, body size, and phylogeny. Evolutionary Ecology 36:93-116.

Jodice, PGR, JS Lamb*, YG Satgé^, C Fiorello. 2022. Blood biochemistry and haematology of adult and chick Brown Pelicans in the northern Gulf of Mexico: Baseline health values and ecological relationships. Conservation Physiology 10:coac064.

Jodice, PGR, PE Michael^, JS Gleason, JC Haney, YG Satgé^. 2021. Revising the marine range of the endangered black-capped petrel *Pterodroma hasitata*: Occurrence in the northern Gulf of Mexico and exposure to conservation threats. Endangered Species Research 46: 49-65

Kubicek, KM, R Britz, AK Pinion, LM Bower, KW Conway. 2022. Three scleral ossicles in the West African Denticle herring *Denticeps clupeoides* (*Clupeiformes: Denticepitidae*). Journal of Fish Biology 100:852-855.

Lawson, AJ*, PGR Jodice, TR Rainwater, KD Dunham, M Hart, JW Butfiloski, PM Wilkinson, KW McFadden, CT Moore. *In Press*. Hidden in plain sight: integrated population models to describe partially observable latent demographic structure. Ecosphere.

Madden, H*, M Leopold, F Rivera-Milan, K Verdel, E Eggermont, PGR Jodice. *In Press*. Reproductive success of Red-billed Tropicbirds on St. Eustatius, Caribbean Netherlands is affected by temporal and oceanographic factors, but not by factors at the nest site. Waterbirds.

Madden, H*, YG Satgé^, BP Wilkinson, PGR Jodice. *In Press*. Foraging ecology of Red-billed Tropicbirds in the Caribbean during early chick-rearing revealed by GPS tracking. Marine Ornithology.

Michael, PE^, KM Hixson^, JC Haney, YG Satgé^, JS Gleason, PGR Jodice. 2022. Seabird vulnerability to oil: exposure potential, sensitivity, and uncertainty in the northern Gulf of Mexico. Frontiers in Marine Science 9:880750.

Plumpton, HM*, ED Silverman, BE Ross. 2021. Black Scoter habitat use along the southeastern coast of the United States. Ecology and Evolution 11:10813-10820.

Satgé, YG^, A Brown, J Wheeler, and K Sutherland. [In Review]. Black-capped Petrel (*Pterodroma hasitata*), version 2.0. In Birds of the World (T. S. Schulenberg, Editor). Cornell Lab of Ornithology, Ithaca, NY, USA.

Satgé, YG^, BS Keitt, CP Gaskin, JB Patteson, and PGR Jodice. 2022. Temporal and spatial segregations between phenotypes of the Diablotin Black-capped Petrel *Pterodroma hasitata* during the breeding and non-breeding periods. bioRxiv 2022.06.02.491532

Streker, RA*, JS Lamb*, J Dindo, PGR Jodice. 2021. Fine-scale weather patterns drive reproductive success in the Brown Pelican. Waterbirds 44:153-166.

Takahashi, F*, F Sanders, PGR Jodice. 2021. Spatial and temporal overlap between foraging shorebirds and spawning Horseshoe Crabs (*Limulus polyphemus*) in the Cape Romain - Santee Delta Region of the U.S. Atlantic Coast. Wilson Journal of Ornithology 133:58-72.

Wheeler, J, Y Satgé^, A Brown, J Goetz, B Keitt, H Nevins, E Rupp. 2021. Black-capped Petrel conservation update and action plan: conserving the Diablotin. International Black-capped Petrel Conservation Group

Wilkinson, BP*, AR Robuck, R Lohmann, HM Pickard, PGR Jodice. 2022. Urban proximity while breeding is not a predictor of perfluoroalkyl substance contamination in the eggs of brown pelicans. Science of the Total Environment 2021:150110.

Wilkinson, BP*, PGR Jodice. 2022. Interannual colony exchange among breeding Eastern Brown Pelicans. Journal of Field Ornithology 93:5.

Wilkinson, BP*, and PGR Jodice. *In Revision*. Support for the fasting endurance hypothesis of partial migration in a nearshore seabird. Ecosphere.

DATA RELEASES

Gleason, J, RR Wilson, PGR Jodice, Y Satgé^, PE Michael^, K Hixson^, A. Sussman, Bureau of Ocean Energy Management. 2022. Seabird visual surveys using line-transect methods collected from NOAA vessels in the northern Gulf of Mexico for the Gulf of Mexico Marine Assessment Program for Protected Species (GoMMAPPS) project from 2017-07-21 to 2019-09-25 (NCEI Accession 0247206). NOAA National Centers for Environmental Information. Dataset. https://doi.org/10.25921/afrq-h385.

Wilkinson, BP, PGR Jodice. 2022. Movement data of partially migratory Brown Pelicans in the South Atlantic Bight. U.S. Geological Survey data release, https://doi.org/10.5066/P9YH2U8D.

Wilkinson, BP*, PGR Jodice. 2022. Interannual Breeding Movements of Brown Pelicans in the South Atlantic Bight: U.S. Geological Survey data release, https://doi.org/10.5066/P9BZ5TL9.

Wilkinson, BP, PGR Jodice, AR Robuck. 2021. Concentrations of Perfluoroalkyl Substances in the Eggs of Brown Pelicans from Charleston, SC (2019): U.S. Geological Survey data release, https://doi.org/10.5066/P9SKDFZU.

ACTIVITIES

TEACHING

L. Bower, Creative Inquiry: Fish Ecology and Morphometrics, Fall 2021, 2022

L. Bower, Readings in Ecology, Fall 2022

L. Bower, Functional Ecology, Spring 2022

P. Jodice, Physiological Response of Wildlife to Global Change, Fall 2022 w/ Dr. Kyle Barret.

P. Jodice, Philosophy of Ecology, Spring 2022.

PRESENTATIONS AND SEMINARS

Invited presentations

Jodice, PGR 2021. Ecological drivers of seabird distribution in nearshore and pelagic .systems. Department of Wildlife, Fisheries, and Conservation Biology, University of Maine.

Contributed papers / Presentations / Posters

Bower, LM, BK Peoples. 2022. Future flow and diversity across South Carolina. Joint Meeting of Aquatic Sciences. Grand Rapids, MI.

Bower, LM. 2022. Evolutionary and ecological consequences of flow. Clemson University. Invited by Forestry and Environmental Conservation Department seminar. Clemson, SC.

Bower, LM, BK Peoples. 2022. Quantifying flow–ecology relationships across South Carolina. Southern Division of the American Fisheries Society. Charleston, SC.

Buchholtz, EK, JA Heinrichs, MS O'Donnell, CL Aldridge. 2022. Patterns of structural connectivity in the sagebrush biome (1985-2018). North America Congress for Conservation Biology, Reno, NV.

Buchholtz, EK, JA Heinrichs, MS O'Donnell, CL Aldridge. 2022. Patterns of structural connectivity in the sagebrush biome (1985-2018). Western Agencies 33rd Sage & Columbian Sharp-Tailed Grouse Workshop, Ogden, UT (virtual).

Heinrichs, J, EK Buchholtz, H Sofaer, C Jarnevich, M Roche, C Aldridge, M Crist. 2022. Assessing the cover, connectivity, and future proliferation of invasive fine fuels. North American Congress for Conservation Biology. Reno, NV.

Jodice, PGR, Y Satgé^, AL Harrison, W Mackin. 2021. Wintering site fidelity in a tropical seabird: a 5-year case study. 3rd World Seabird Conference (virtual).

Madden, H, YG Satgé^, BP Wilkinson, PGR Jodice. 2022. Foraging in unproductive waters: GPS tracking of Red-billed Tropicbirds in the Caribbean. American Ornithological Society – BirdsCaribbean Joint Conference. San Juan, Puerto Rico

Michael, PE^, KM Hixson, JS Gleason, JC Haney, YG Satgé^, PGR Jodice. 2022. Seabird communities in the northern Gulf of Mexico: Spatial overlap with oil and gas platforms. Gulf of Mexico Conference, New Orleans, LA.

Michael, PE^, KM Hixson, JS Gleason, JC Haney, YG Satgé^, PGR. Jodice. 2021. Marine bird distributions in the Gulf of Mexico: informing marine spatial planning. 3rd World Seabird Conference (virtual).

Michael, PE^, KM Hixson, JS Gleason, JC Haney, YG Satgé^, PGR Jodice, 2021. Seabird vulnerability to oil spills and knowledge gaps: exposure, susceptibility, and uncertainty in the northern Gulf of Mexico. Annual Conference of the Waterbird Society (virtual).

Roche, M, J Saher, EK Buchholtz, M Crist, D Shinneman, C Aldridge, B Brussee, P Coates, C Roth, J Heinrichs. 2022. A Spatial Data Synthesis of Fuel Breaks in the Sagebrush Biome in Relation to Wildfire, Invasive Annual Grasses, and Sagebrush Obligate Wildlife. Oral presentation, North American Congress for Conservation Biology. Reno, NV.

Roche, M, J Saher, EK Buchholtz, M Crist, D Shinneman, C Aldridge, B Brussee, P Coates, C Roth, J Heinrichs. 2022. A spatial synthesis of fuel breaks in the sagebrush biome in relation to wildfire, invasive annual grasses, and Greater Sage-Grouse. Western Agencies 33rd Sage & Columbian Sharp-tailed Grouse workshop. Logan, UT.

Satgé, YG, PGR Jodice, B Keitt, C Gaskin, G Clucas, and SE Janssen. 2022. A tale of two petrels: Temporal and spatial segregations between phenotypes in the endangered Diablotin Black-capped Petrel. American Ornithological Society – BirdsCaribbean Joint Conference. San Juan, Puerto Rico

Satgé, YG^, PGR Jodice. 2021. Looking for the devil's nest: Modelling the nesting habitat of the endangered Black-capped Petrel in the Caribbean. 3rd World Seabird Conference (virtual).

Satgé, YG^, PGR Jodice, B Keitt, C Gaskin, G Clucas, SE Janssen. 2021. Recent advances in the ecological study of the endangered Diablotin Black-capped Petrel: at-sea distribution in the western North Atlantic, diet, and threat exposure. Atlantic Marine Bird Cooperative Annual Meeting (virtual).

Satgé, YG, PGR Jodice, B Keitt, G Clucas, SE Janssen. 2021. Recent advances in the ecological study of the endangered Diablotin Black-capped Petrel: at-sea distribution, diet, and threat exposure. Annual Conference of the Waterbird Society (virtual).

Satgé, YG, PGR Jodice, B Keitt, C Gaskin, G Clucas, and SE Janssen. 2022. A tale of two petrels: Recent advances in the ecological study of the endangered Diablotin Black-capped Petrel. The Seabird Group 15th International Conference. Cork, Ireland.

Shyvers, JE, BC Tarbox, CJ Duchardt, AP Monroe, DR Edmunds, BS Robb, NJ Van Lanen, EK Buchholtz, JA Heinrichs, CL Aldridge. 2022. Optimizing conservation and restoration of imperiled sagebrush ecosystems to benefit multiple avian species. Oral Presentation. American Ornithological Society and BirdsCaribbean Ornithological Conference, Puerto Rico.

Shyvers, JE, BC Tarbox, CJ Duchardt, AP Monroe, DR Edmunds, BS Robb, NJ Van Lanen, EK Buchholtz, MS O'Donnell, ND Van Schmidt, JA Heinrichs, CL Aldridge. 2022. Optimizing conservation and restoration of imperiled sagebrush ecosystems to benefit multiple species. Lightning Talk. WAFWA - 33rd Sage and Columbian Sharp-tailed Grouse Workshop, Hybrid format, Logan, UT.

Wilkinson, BP*, PGR Jodice. 2021. Brown pelicans and the fasting endurance hypothesis of partial migration. Annual Conference of the Waterbird Society (virtual).

Wilkinson, BP*, PGR Jodice. 2021. Brown pelicans as a model of partial migration in nearshore seabirds. 3rd World Seabird Conference (virtual).

Young†, T, D Amand†, LM Bower2022. The influence of instream flow and microhabitat on larval fish abundance. Southern Division of the American Fisheries Society. Charleston, SC.

SERVICE

L. Bower, Search Committee for AUL-wildlife biology position, Clemson University, 2021
E. Buchholtz, Associate Editor, Tropical Conservation Science Journal. (2020 - current)
P. Jodice, Graduate Coordinator, Dept. Forestry & Environmental Conservation
P. Jodice, Chair, World Seabird Union (2015 – 2021)
P. Jodice, Past Chair, World Seabird Union (2022 – 2025)
P. Jodice, Steering Committee Member, Atlantic Marine Bird Cooperative
P. Jodice, Planning Committee Member, Cooperative Research Units All-Hands Meeting
P. Jodice, Chair, Search Committee, Assistant Unit Leader - Wildlife SC CRU
P. Jodice, Chair, Departmental Chair Review, Dept. Forestry & Environmental Conservation
P. Jodice, Topic Editor, Frontiers in Marine Science, Special Issue Ecological and Behavioral Traits of Apex
    Predators in Oceanic Insular Ecosystems: Advances and Challenges in Research and Conservation
Y. Satgé, Co-Chair, BirdsCaribbean Seabird Working Group. 2020 – 2025
Y. Satgé, Board Member, Environmental Protection in the Caribbean. 2021-2026

AWARDS AND HONORS

P. Jodice as member of Gulf of Mexico Avian Monitoring Network, US Fish and Wildlife Service, South
    Atlantic-Gulf and Mississippi Basin Interior Regions Regional Director Honor Award for Conservation
    Partners: Awarded to the Gulf of Mexico Avian Monitoring Network (P. Jodice, Steering Committee
    and Seabird Taxa Lead).
B. Wilkinson, Columbus Hammond Townsend Fellowship, Clemson University, 2021.

PRESS / PUBLIC OUTREACH

Conservationists Pen Action Plan to Protect Extremely Elusive and Endangered Seabird. BirdsCaribbean.
January 2022. https://www.birdscaribbean.org/2022/01/conservationists-pen-action-plan-to-protect-extremely-elusive-and-endangered-seabird/

Researchers Confirm Presence of Endangered Diablotin Black-capped Petrel on Dominica, Raising Hopes
of Finding Nesting Area. American Birds Conservancy. April 2022. https://abcbirds.org/news/black-capped-petrel-dominica-sighting/

Looking for the 'little devil'. Clemson News. December 2021. https://news.clemson.edu/looking-for-the-little-devil/

Annual Newsletter of the Caribbean Seabird Working Group #2. April 2022.
https://www.birdscaribbean.org/2022/05/seabirds-research-and-advocacy-check-out-the-latest-birdscaribbean-seabird-working-group-newsletter/

The Black-capped Petrel Flies Again. The Sun, Dominica. February 2022.
http://sundominica.com/articles/the-black-capped-petrel-flies-again-6636/