2020-2021
Annual Report
Virginia Fish and Wildlife Cooperative Research Unit
PAUL ANGERMEIER

1. Development of a Structured Decision-making Framework to Guide Translocation of Imperiled Aquatic Species in the Roanoke and Dan River Basins

DURATION: 4/2018-10/2020

SPONSOR: National Fish and Wildlife Foundation (Lead PI: Jamie Roberts, Georgia Southern University; Co-PI: Dave Smith, U.S. Geological Survey - Leetown Science Center; post-doctoral researcher: Dan Gibson)

PROJECT DESCRIPTION: Habitat loss, degradation, and fragmentation are important drivers of imperilment for aquatic species, such as Roanoke Logperch (Percina rex) and James Spiny mussel (Pleurobema collina), in the Roanoke and Dan river basins (RDRB). Translocation, the intentional human-mediated movement of wild or propagated organisms between populations, is a potential tactic for mitigating extinction risks for imperiled species. Translocation can re-establish gene flow, but may also undermine local adaptations. Thus, biologists must weigh the relative risks due to population isolation versus population mixing when considering the use of translocation to promote recovery of an imperiled species. Decisions about whether, where, and
how many animals to translocate could be made more quickly, objectively, and transparently if based on criteria that were previously agreed-upon by species experts and pre-approved by management agencies. This project developed a structured decision-making framework to guide translocation planning for two imperiled aquatic species (one fish, one mussel) in the RDRB. Project outcomes include optimized translocation strategies for these species, as well as a flexible decision-support tool that can be used to weigh risks and optimize population-management actions for recovery of many other aquatic species.

OBJECTIVES: 1) convene stakeholders to identify conservation goals, objectives, actions, and performance measures, so success can be measured under alternative actions; 2) synthesize stakeholder input and best available data regarding relationships between potential actions and performance measures; 3) develop demographic models to forecast conservation outcomes under alternative actions; and 4) use the models to recommend optimal strategies for meeting species-specific conservation objectives.

PROJECT SUMMARY: Through a series of in-person and remote workshops that brought together local and regional stakeholders involved in decision-making regarding the recovery and conservation of imperiled fish and mussels in the Roanoke and Dan river basins (RDRB), stakeholders 1) identified components of the decision problem regarding the use of translocations to improve conservation objectives; 2) identified potential recovery actions and perceived barriers to population recovery for population models to explore and evaluate; and 3) provided data and expert opinions that were necessary to inform the proposed population model. Based on information provided and the perceived underlying constraints regarding the translocation of fishes and mussels in the RDRB, a model was developed that formally linked a population forecasting model with a decision-making process to produce an adaptive decision-making tool, which together produced a translocation roadmap that outlined procedures to allocate limited resources (e.g., numbers of individuals available for translocation, agency capacity to produce or distribute individuals) to most effectively achieve the user-specified recovery objectives (e.g., a specified number of populations exceeding a specified abundance threshold). Subsequently, a graphical user-interface was developed for this decision-making tool to facilitate its general use by conservation practitioners for a variety of potential recovery-based scenarios, such as allowing local environmental conditions to either improve or degrade through time as a function of ancillary management actions or shifts in habitat function. Together, this tool provides users with a tool to monitor potential benefits and consequences of specific management decisions regarding the recovery of fishes and mussels within the RDRB based on the current ecological understanding of local and regional population dynamics, environmental uncertainty, and perceived threats and constraints to both population persistence and conservation actions. This overall procedure offers a novel solution for how to jointly model conservation actions with population dynamics for data-sparse, but imperiled species; the approach can be applied to other freshwater systems and beyond.

2. Assessment of the Dynamics and Biotic Impacts of Fine Sediment to Assist Conservation of Stream Fishes in the Dan and Roanoke River Basins

DURATION: 4/2018-11/2020

SPONSOR: National Fish and Wildlife Foundation (Lead PI: Angermeier; Co-PIs: Amy Villamagna, Plymouth State University and Jon Czuba, Biological Systems Engineering; Master’s students: Mallory Hirschler [Plymouth State University] and Elizabeth Pratt.
**PROJECT DESCRIPTION:** Siltation commonly contributes to impairment of streams and aquatic species imperilment, but the dynamics of sediment transport and deposition and the effects of siltation on fish distribution and abundance are poorly documented. Analytical methods to identify which species are sensitive to silt, key sources and fates of silt, effects of silt-loading on benthic habitat condition (BHC) and effects of BHC on distribution and abundance of silt-sensitive fishes would help managers prioritize actions to best enhance recovery of silt-sensitive fishes. This project integrates spatially explicit analyses of relations among sediment sources and fates across upland, riparian, and instream components of watersheds, BHC and the distribution/abundance of benthic stream fishes. The study area encompasses the Piedmont portion of the Roanoke and Dan river basins in VA and NC, where the endangered Roanoke Logperch (*Percina rex*) occurs. Findings from this project will help managers decide where, how much, and what kinds of riparian and floodplain management are most likely to protect and enhance recovery of silt-sensitive fishes.

**OBJECTIVES:** 1) estimate sediment erosion, transport, and deposition among watersheds representing a gradient of land use, 2) test a traits-based model for predicting species’ silt sensitivity, 3) quantify fish species occupancy and density and BHC, and 4) test relationships among species occupancy/density, BHC, and a suite of sediment metrics.

**PROJECT SUMMARY:** We tested several crucial assumptions about the sediment linkages among landscape features, instream habitat, and fishes. Comparisons between remotely-sensed landscape predictors, such as slope, land cover, soil loss estimates, revealed that traditional measures of estimating upland soil erosion (e.g., (RUSLE)) were not accurate in predicting in-channel turbidity and sediment conditions. Instead, presence of low slopes, hay/pasture, and steep banks were more predictive, suggesting near-channel conditions were more likely responsible for instream sediment conditions than were upland areas. Additionally, we found that instream measures of deposition, specifically embeddedness, could be predicted from channel properties alone. Remotely-sensed landscape data helped explain occupancy of a few sediment-sensitive fish species during the 2-year study period, but did not consistently explain significant proportions of observed variability. Our 2-year assessment of fish populations and benthic habitat conditions revealed few statistically significant relationships between instream sediment deposition and fish species occupancy. Rapid assessments of silt cover did not explain observed occupancy variability across fish species considered highly sensitive to sediment, based on their life history and functional traits. Overall, sediment-related metrics typically explained less variability in observed occupancy than stream size, suggesting unmeasured factors may be influencing current fish occupancy and community composition. We developed a traits framework for scoring presumed species sensitivity to instream deposited sediment, measured as silt cover and embeddedness. We assigned sensitivity scores (an aggregate of four trait-based measures) to all freshwater fishes in the Roanoke River basin. Using data from electrofishing surveys, we assessed relations between deposited sediment and occurrences of eight traits and 47 species. Species observed at out sites exhibited sediment-sensitive traits more commonly than unobserved species, suggesting the regional history of sedimentation has not eliminated many sensitive species. Variation in occurrence of multiple feeding and reproductive traits indicated population responses to deposited sediment, especially embeddedness. Feeding preference was most strongly related to embeddedness, with specialists and generalists exhibiting negative and positive relations, respectively. Species with high sensitivity scores responded negatively to embeddedness, whereas species with low sensitivity scores responded positively. Traits were more strongly correlated with embeddedness than with silt cover. Overall, our findings support the hypothesis that sediment deposition can be a major driver of stream-fish assemblage composition.
3. **Phenology, Distribution, and Dispersal of Larval Candy Darters in Laurel Creek, Bland County, Virginia – Phase 1**

**DURATION:** 9/2020-1/2021

**SPONSOR:** Virginia Department of Wildlife Resources (Lead PI: Angermeier; Co-PIs: Eric Hallerman, Emmanuel Frimpong; Doctoral student: Emma Hultin.

**PROJECT DESCRIPTION:** Basic knowledge of early life history of the endangered Candy Darter (CD) is poorly known. CD is now limited to four streams in Virginia, including Laurel Creek in Bland County. Spatiotemporal patterns of emergence and dispersal of larval CD are undocumented and there is little information available to distinguish CD larvae from those of other darters. Such knowledge is crucial to assessing vulnerability of CD populations to anthropogenic impacts (e.g., water withdrawals, urbanization). Hallerman et al. (2017) developed a polymerase chain reaction assay for the mitochondrial cytochrome oxidase I (COI) gene and used it to identify larval darters in the Roanoke River watershed. The proposed study builds on this work to identify sampling localities and train staff to conduct field and laboratory protocols in preparation for a subsequent focused study (Phase 2) on CD larval ecology.

**OBJECTIVES:** 1) explore GIS layers to identify suitable stream reaches and potential study sites; 2) visit potential study sites to verify accessibility and suitability and seek permission for access from relevant landowners and residents; and 3) train staff regarding field sampling protocols, genetic protocols, and analytic techniques.

**PROGRESS:** Emma Hultin led this work. Satellite image maps of the Laurel Creek and Wolf Creek confluence were compiled in ArcGIS. Stream access points, large riffles, and instream structures were identified and labelled. Eight study sites were identified based on proximity to access points and presence of substantial riffles. We visited the potential sites to confirm suitability for sampling and noted access points and parking locations. We used Bland County online property records to identify property boundaries adjacent to target sites and access points, then contacted landowners to get access permission. We trained a crew of undergraduate and graduate students to conduct the field sampling and sample processing to be used in the Phase 2 study.

W. MARK FORD

4. **Northern Long-eared Bats of the Upper Ohio River Valley**

**DURATION:** 3/2019-12/2020

**SPONSORS:** U.S. Fish and Wildlife Service White-nose Syndrome Program (Lead PI: Ford; Doctoral student: Jesse De La Cruz)

**PROJECT DESCRIPTION:** Following the advent of White-nose Syndrome in the East, the northern long-eared bat (*Myotis septentrionalis*) has suffered precipitous declines in numbers leading to listing as a threatened species (U.S. Fish and Wildlife Service 2016). Declines in the inland Northeast through the central and southern Appalachians have exceeded >90% with the formerly common species being largely absent in most of the landscape. Within the central Appalachians specifically, functional extirpation occurred rapidly with the infection of caves in karst areas of the High Appalachian Plateau where long hibernation periods occur. Due to the
wide-spread and year-round development of the Marcellus Shale gas play and associated pipeline construction, in the upper Ohio Valley of western West Virginia and eastern Ohio within the Low Appalachian Plateau of the central Appalachians. U.S. Fish and Wildlife Service-mandated survey work has resulted in the capture of >1500 northern long-eared bats during 2015–2018, despite being bracketed by unoccupied habitat adjacent to the east in the High Appalachian Plateau. Over this period, numerous northern long-eared bat maternity colonies displaying high juvenile recruitment in forest stands (>50 trees and snag) similar to pre-WNS conditions were documented and in mitigation area artificial roosts without any apparent decrease in abundance and local distribution. Anecdotal evidence suggests a somewhat analogous non-disease exposure to the Coastal Plain, whereby northern long-eared bats in the upper Ohio Valley overwinter in small legacy coal adits or emergent rock features (the area does not geologically support karst) that have minimized exposure to vectoring little brown bats (Myotis lucifugus) and/or provide unsuitable substrates for Pseudogymnoascus destructans persistence and growth.

**OBJECTIVES:** 1) assess capture/detection rate and continued use of bat boxes; 2) assess site fidelity, survivorship and recruitment, fungal presence, inter- and intra-maternity colony relatedness; and 3) determine if legacy mines are used as hibernacula in the upper Ohio River Valley portion of West Virginia.

**PROGRESS:** Bat capture occurred at 72 artificial roosts resulting in the documentation of 564 northern long-eared bats. Observed maternity colonies of northern long-eared bats used 65 artificial roosts, with rocket boxes accounting for 57 of the structures. Total captures from maternity colonies did not differ between years and averaged between 6.7 and 11.6 captured animals per roost per year. These results suggest that, even in areas having abundant natural roosts, artificial roost may serve as effective tools in identifying and monitoring residual populations of northern long-eared bats. Furthermore, 44 northern long-eared bats were recaptured at least once and resulting capture-recapture models suggested increasing rates of survival/site fidelity over time. Additionally, we captured 97 northern long-eared bats during 356 mist net nights of sampling. Captures of northern long-eared bats per net per night did not differ between years, with resulting occupancy models estimating approximately n = 6 mist net nights needed to confidently determine absence of the species in the local landscape. The study area has been WNS positive for several years but, despite this, both our artificial roost and mist netting capture results suggest population stability rather than decline. Our final species distribution models documenting use of artificial roosts by both maternity colonies and individual northern long-eared bats were highly predictive. Artificial roosts used by maternity colonies of northern long-eared bats generally appear closer in proximity to edges/perforations of dry-mesic oak and dry oak-pine forests than random, whereas individual bat artificial roosting habitat appears more associated with forest edges nearer aquatic resources. Random forest species distribution models identified 86 km² and 99 km² of habitat suitable for the installation of artificial for maternity colonies and individual northern long-eared bats, respectively. Since 2014, northern long-eared bats have been captured from Alkol Portals (Lincoln County), Laurel Run #3 (Marion County), Chaffey Run Strip (Tucker County), Squires Creek (Moats) Refuse and Portal (Preston County), and the Kevin Dials Bat Trail (Kanawha County). Additionally, acoustic sampling at the Rosby Rock Tunnel, located in Marshall County, suggest the presence of northern long-eared bats during the fall swarm. While no northern long-eared bats were captured or acoustically documented during 2019, and no hibernacula were surveyed during 2020 due to the SARS-CoV-2 (COVID-19) pandemic, documented use of abandoned mines and tunnels suggest that northern long-eared bats readily use these features as hibernacula in West Virginia. While speculative, such features may be inhospitable to the growth of Pseudogymnoascus destructans (i.e., acidic substrate) and may limit exposure of local bats to WNS-vectoring little brown bats.
5. Development of a Bat Guano and Acoustic Sampling Testing Protocol to Identify Species Occupying VDOT Bridges

DURATION: 1/2019-9/2021

SPONSORS: Virginia Department of Transportation and U.S. Fish and Wildlife Service (Lead PI: Ford; Master’s student: Hila Taylor)

PROJECT DESCRIPTION: Over half of Virginia’s extant bat species, including five imperiled bat species, have been documented using bridges as night or day roosts. To protect these species, VDOT performs surveys to detect bat use in transportation structures to prevent or minimize potential harm when essential infrastructure maintenance must occur. Current indicators used by VDOT to inspect bridges for bat use include documenting staining, guano piles, or presence of live bats. Still, without trained personnel, there is little way to positively identify species use. Without an identification of roosting species use, regulatory agencies cannot discount use by a sensitive species such as the endangered gray bat (*Myotis grisescens*). Most acoustic detection survey methods allow identification of bat species active in an area but cannot confirm if a species is using a transportation structure as a day or night-roost with certainty. Because acoustic detection methods are relatively inexpensive and not labor-intensive, if properly designed, they can monitor areas for an extended period to determine the likelihood of bat presence and provide region-wide predictive modeling to assess risk. When denoted, a subsequent, genetics-based approach could confirm what species roosted in the structure.

OBJECTIVES: 1) test a protocol for detecting bat species roosting in bridges using a combination of long-term acoustic monitoring and DNA barcoding of guano found at bridge sites; and 2) correlate bat species occupancy as derived from guano assessment with relative activity from acoustic monitoring at each site, develop models of multi-bat species presence/predicted probability of occurrence relative to bridge type, riparian characteristics and surrounding landscape metrics singularly with DNA results, acoustic results, and in combination.

PROGRESS: From March through November 2019, we observed bat activity with acoustic sampling gray throughout the Clinch, Powell, Holston, and Big Sandy, and New River watersheds. Gray bat activity at bridges was correlated with proximity to the known summer maternity roost in the Bristol area and mean cave density in the surrounding landscape. Combined with pilot acoustic data from 2018 and a partial continuation in 2020, we observed high year to year variation in gray bat activity and that long acoustic sample duration is necessary to discern monthly presence and relative abundance patterns across the year from emergence to the initiation of hibernation. The spatio-temporal pattern we observed can help VDOT assess risk to gray bats from transportation structure management activities. Two hundred eighty-three guano samples were collected from 29 bridges for subsequent DNA analysis. Although 245 of samples were amplified, only 77 were of good enough quality to find a species match (27% of collected samples). Nine bridges had guano with DNA that matched big brown bat (*Eptesicus fuscus*), 12 bridges had guano matching gray bats, and three bridges had guano matching northern long-eared bat (*Myotis septentrionalis*). All sites with guano-derived DNA also had those bat species recorded acoustically. For guano DNA analysis, additional work refining techniques will be needed, however as proof of concept, the combined approach to bat sampling we developed can aid VDOT managers in assessing bat use of bridges, which is particularly invaluable in areas such as the New River drainage where gray bat (or other sensitive species) presence is newly expanding into.
6. **Wood turtle (Glyptemys insculpta) Spatial and Temporal Survey and BMP Design on Fort Drum for Fort Drum Natural Resources Program, Fort Drum, New York**

**DURATION:** 1/2017-12/2020

**SPONSORS:** U.S. Army Fort Drum Military Reservation (Lead PI: Ford; Post-doctoral Researcher: Sara Sweeten)

**PROJECT DESCRIPTION:** The wood turtle (*Glyptemys insculpta*) is a long-lived, medium-sized turtle that ranges from northern Virginia to southeastern Ontario, through Maine and Nova Scotia, west to eastern Minnesota and northern Iowa. They are seasonally aquatic and terrestrial with a home range that centers along streams or rivers. Human activities such as urbanization, logging, stream channelization, damming and declines in water quality from pollution have had major impacts on wood turtle populations. Wood turtles are currently under review by the U.S. Fish and Wildlife Service for listing under the Endangered Species Act. Though not state-listed in New York, the species is either listed or considered a species in need of conservation in most mid-Atlantic and New England states. Presence of a potentially listed species impacted by stewardship or mission activities is a concern for managers at Fort Drum.

**OBJECTIVES:** 1) examine wood turtle movement and habitat use; and 2) provided best management practices for local conservation at Fort Drum.

**PROGRESS:** A total of 19 wood turtles were observed between 2017 and 2019. On average, each turtle was located using radio-telemetry twice a month. All observed wood turtles were located in the central portion of the installation to the east of the airfield within the Black Creek watershed. The overall, all-season mean MCP home range for woods turtles at Fort Drum during this survey period was 43.9 ha (SD = 72.3 ha). Eight probable nesting areas were identified in this study. All nesting areas had high solar exposure with sandy/gravel, well-drained soil. Seven of the probable nesting areas are within very close proximity (< 30m) to roads where the turtles may be nesting in the shoulder and banks of the road. Overall, females showed fidelity returning to the same nesting area every year. At the 2nd order scale of Fort Drum, females and males selected wetland shrub and water more than expected based on availability. They avoided developed and upland shrub habitats. Use of wetland forest and grass types was equitable with availability. At the 3rd order scale within turtle home ranges, females and males selected for wetland shrub and water more than expected. They avoided upland forest. Distance to water, wetland shrub habitat and the interaction between these two variables were highly robust in predicting wood turtle probability of occurrence at Fort Drum. Female distance from stream was highly variable with 91% of all female wood turtle locations occurred within 150 m of streams; 95% of locations were within 190 m (range 0-313 m) 100% of all male locations occurred within 80 m of streams (Max. = 77.7 m).

ELIZABETH HUNTER

7. **Henslow’s Sparrow Population Ecology and Wintering Habitat in Georgia**

**DURATION:** 1/2019-5/2021

**SPONSORS:** Georgia Department of Natural Resources (Lead PI: Hunter; Master’s student: Abbie Dwire [Georgia Southern University])
PROJECT DESCRIPTION: Henslow’s Sparrow (*Centronyx henslowii*, HESP) is a declining grassland bird species that winters in longleaf pine savannas and other fire-managed grasslands in the southeastern US. Most of what is known about the species’ ecology on the wintering grounds comes from Louisiana, where studies of habitat use and selection have found that fire regime has large effects on abundance of wintering populations, with greater HESP abundance immediately following a growing season fire. Many questions remain about whether these patterns pertain to other areas of the species’ range and how management of secondary habitats (e.g., powerline rights-of-way) may benefit the species’ status. Three sites in southeast Georgia have reliable wintering populations (Paulk’s Pasture Wildlife Management Area [WMA], Townsend WMA, and Moody Forest WMA). With a better understanding of the habitat use and requirements within these areas, more potential HESP populations could be discovered, the status of the population could be better estimated, and habitat could be better managed for HESP and other grassland species.

OBJECTIVES: 1) Describe the microhabitat use and selection of HESP in the three known sites and estimate differences based on management practices (e.g., fire regime); and 2) Estimate site fidelity, home range size, diet, and survival using a combination of long-term mark-recapture data and radio-telemetry, and estimate differences based on microhabitat and management practices (e.g., fire regime).

PROGRESS: Over 3 years of winter surveys, 166 HESP were captured, with 39 outfitted with transmitters for radio telemetry. Fecal samples were obtained from 133 individuals, with samples currently being processed for DNA sequencing for diet analysis. We used a robust design Cormack-Jolly-Seber model to estimate probability of detection and apparent survival across 11 years of mark-recapture data. Within-year detection probability was moderately high at 38.8% (35.9-42.0%, 95% credible interval [CI]), but apparent survival was very low at 13.1% (8.4-17.8%, 95% CI). This low apparent survival was likely due to low return rates (and not necessarily low survival). However, birds that did return to the study sites had extremely high site fidelity, with an average of 289 m between across-year recaptures, and 67.9% of across-year recaptures were less than 200 m apart. This apparent incongruity between low apparent survival rates (likely due to emigration from the study sites) and high site fidelity for returning individuals could be explained by the dependability of the right-of-way habitat, which differs from typically patchy and temporally variable wintering habitats. Dependable habitat may allow for higher site fidelity than this species would otherwise have. Our radio-telemetry study also revealed very small use areas (mean 0.14 hectares) compared to studies conducted in natural grasslands and savannas, indicating that rights-of-way can provide high quality habitats for Henslow’s Sparrows, and potentially other species. Initial results from resource selection functions indicate that HESP are selecting habitat with higher forb diversity, likely indicating that management with prescribed burning would improve habitat quality.

CURRENT PROJECTS

PAUL ANGERMEIER

1. **Endangered fish surveys for the Virginia Department of Transportation**

DURATION: 9/1990-6/2022

SPONSOR: Virginia Department of Transportation (Lead PI: Angermeier)
**PROJECT DESCRIPTION**: An agreement was established to provide fish surveys at road and bridge projects as requested by Virginia Department of Transportation. The Unit conducts each survey for a fixed price; funds are used to support graduate students. VDOT also refers various construction firms to Angermeier to set up short-term contracts to remove fishes trapped behind coffer dams during construction projects. Removals are performed as needed.

**OBJECTIVES**: Surveys and removals provide information on distribution and abundance of rare fishes and habitats suitable for them. This information and service is used to reduce construction impacts on fishes.

**PROGRESS**: No surveys were conducted for FY2021, but three fish removals were conducted.

2. **Evaluating Efficacy of Agricultural BMPs in the Upper Clinch, Powell, and Holston River Drainages**

**DURATION**: 9/2018-12/2022

**SPONSOR**: Natural Resources Conservation Service (Lead PI: Angermeier; Co-PI: Serena Ciparis; Doctoral student: Joshua Mouser)

**PROJECT DESCRIPTION**: This work focuses on the use and efficacy of agricultural best management practices (BMPs) in the upper Tennessee River drainage in Virginia. Watershed models, such as the Soil and Water Assessment Tool (SWAT), integrate existing data on landscape features such as precipitation, topography, soil type, land cover, and implementation of BMPs. We are using SWAT models to estimate loadings of sediment and nutrients (N and P) into surface waters at the spatial resolution of 12-digit hydrologic units (HUC12s) and larger. Model outputs will be compared to existing data on water quality metrics such as concentrations of N, P, and E. coli, as well as to data on biotic metrics such as the number of Ephemeroptera, Plecoptera, and Trichoptera taxa, fish-based Index of Biotic Integrity scores, and the presence of priority at-risk aquatic species. Model outputs also will be compared to newly collected data on instream conditions of water quality and benthic habitat quality in selected focal watersheds. Ultimately, we will assess BMP effectiveness in terms of reducing silt and nutrient loads to streams and improving water and habitat quality for priority at-risk aquatic species.

**OBJECTIVES**: 1) characterize spatial patterns (at HUC12 resolution) of BMP implementation and predicted sediment and nutrient loading in the Clinch-Powell river drainage upstream of Norris Reservoir and in the Holston River drainage upstream of the Virginia-Tennessee line (collectively, the upper CPH); 2) analyze the influences of BMPs, relative to other watershed features, on predicted sediment and nutrient loads in HUC12s across the upper CPH; 3) quantify relations among BMP implementation, observed instream water quality and habitat quality, and observed biotic assemblages; and 4) quantify cost-effectiveness of BMP implementation in HUC12s across the upper CPH.

**PROGRESS**: Joshua Mouser (PhD) began work on Jun 1, 2019. Recent work has focused on objectives 1 and 3. We obtained Best Management Practice (BMP) data from the Natural Resource Conservation Service (NRCS) and the Virginia Department of Conservation and Recreation (VDCR). We also obtained data needed for SWAT modeling (i.e., topography, stream network, land use, soil, climate, and streamflow) and completed an uncalibrated run of the SWAT model. The SWAT model generally predicted streamflow (m³/sec) well, but underpredicted a few high-flow events, resulting in poor Nash-Sutcliffe efficiency values for some watersheds. We are
now conducting additional calibration runs to enhance model accuracy. We mapped BMP installation intensity, sediment yield (tons/ha), phosphorus yield (kg/ha), and nitrogen yield (kg/ha) to streams in each HUC-12 watershed of the upper Clinch-Powell-Holston (CPH) drainage area. We also obtained biotic collection data from the Tennessee Valley Authority (TVA) and Virginia Department of Environmental Quality (VDEQ). Lastly, each spring and autumn we are collecting macroinvertebrate and instream data from 31 sites within the Copper Creek, Laurel Creek, Big Moccasin Creek, and Big Cedar Creek HUC-10 watersheds (Clinch River and North Fork Holston River HUC-8 watersheds). Future work will focus on adding to the BMP, biotic collection, and water quality databases. We will also collect more instream data and relate water quality, landscape factors, and instream habitat measures to biotic indices of stream condition.

3. Effects of BMPs and Land Use on Stream Macroinvertebrates and Fishes in the Chesapeake Basin

DURATION: 11/2020-8/2025

SPONSOR: U.S. Geological Survey (Lead PI: Sally Entrekin; Co-PI: Emmanuel Frimpong; Doctoral students: Joe Buckwalter and Abigail Belvin [Entomology])

PROJECT DESCRIPTION: A key scientific gap in stream restoration is understanding and predicting how effects of management efforts propagate through watersheds, then influence the in-stream habitat conditions that determine macroinvertebrate and fish responses. This mechanistic view is required to provide USGS partners with the information they need to revise management strategies. The goal of this project is to provide an integrated and detailed understanding of how stream ecosystems respond to management efforts. It is part of larger study funded by USGS’s Priority Ecosystems Science program to inform adaptive management of the Chesapeake Bay basin. The larger study is being conducted by a large multidisciplinary team (“Stream Team”) of USGS and academic scientists. This project focuses on collecting and analyzing the biological data that feed into the larger synthesis by the Stream Team regarding BMP efficacy. The Stream Team will collect a standardized suite of stream ecosystem data to link BMPs and land-use change in small watersheds to responses of individual reaches and the biota living there. By sampling across broad gradients of BMP implementation and land use – and across distinct geographic settings – we will model effects of collective management actions on stream habitats, macroinvertebrates, and fishes in the Chesapeake basin. We will measure organismal responses at multiple organizational levels, including whole macroinvertebrate and fish communities, selected multi-species functional groups, selected fish populations, and individuals of selected fish species.

OBJECTIVES: 1) quantify responses of macroinvertebrate and fish communities along gradients of land use and BMP implementation in selected geographic settings; 2) identify biotic attributes at community and population levels of organization that seem especially useful in assessing BMP efficacy; 3) disentangle effects of land use, BMPs, and selected physicochemical factors (e.g., physical habitat, water quality) on macroinvertebrate and fish communities; and 4) compare the relative importance of these effects among selected geographic settings.

PROGRESS: Joe Buckwalter began his graduate work in Jan 2021. He played a significant role in conducting field reconnaissance of potential sites, seeking permission from landowners to access potential sites, and compiling existing data on fish distributions near potential sites. The whole Virginia Tech team participated in multiple discussions to choose the 30 sites to be
sampled in 2021. All 2021 sites are in watersheds in the Valley and Ridge physiographic region, with pasture as the predominant land use. Collections of macroinvertebrate and fish samples were completed in June and July, respectively. Work during the rest of 2021 and early 2022 will focus on data compilation and analysis, as well as selecting study sites for 2022.

4. Development and Application of a Multiscale Model of Habitat Suitability for Candy Darter

DURATION: 2/2021-5/2023

SPONSOR: Virginia Department of Wildlife Resources (Lead PI: Angermeier; Co-PI: Emmanuel Frimpong; Doctoral student: Emma Hultin)

PROJECT DESCRIPTION: This project will develop a range-wide quantitative model (i.e., species distribution model) to estimate suitability of stream segments and watersheds (12-digit USGS hydrologic units) for the endangered Candy Darter (CD), which is a habitat specialist occurring in fast-flowing, cool-water streams with little siltation. CD’s range in Virginia is now limited to four widely separated streams. Comprehensive assessments of which landscape features (e.g., watershed size, land use, channel gradient, network position, connectivity) predict CD occurrence have not been performed, thereby precluding development of range-wide maps of habitat suitability. The proposed species distribution model will assist managers (e.g., VDWR, USFWS) in identifying streams and watersheds that are most likely to a) support undiscovered populations, b) be suitable reintroduction sites, and c) provide refugia from invasion by Variegate Darter.

OBJECTIVES: 1) Synthesize all existing geo-referenced presence/absence data on CD range-wide; 2) Use publicly available GIS data to relate CD occurrence (presence and absence) to a suite of instream, near-stream, and upland watershed features via statistical models; and 3) Conduct field surveys to test model predictions and facilitate model refinement.

PROGRESS: Emma Hultin began her graduate work in Aug 2021. We are compiling and screening available data on CD occurrence, and assembling georeferenced spatial layers across CD’s range to characterize biophysical features that may help predict CD occurrence. After developing a preliminary species distribution model, we plan to begin collecting field data in autumn of 2021 to test the model. Field work is contingent on USFWS approving our Recovery Permit; we applied for the permit in Apr 2021.

W. MARK FORD

5. Determination of Fort A.P. Hill, Fort Meade, Joint Base Langley-Eustis, Fort Pickett, Fort Meade Marine Corps Base-Quantico Bat Communities with Emphasis on Occupancy, Detection Probability and Day-roost Habits of the Northern Long-eared Bat, Indiana Bat, and Tri-colored bat

DURATION: 7/2013-12/2021

SPONSORS: U.S. Army Installation Command, Virginia Army National Guard, Navy Facilities and Engineering Command and Air Force 622nd Wing (Lead PI: Ford; Doctoral students: Mike St. Germain, Samuel Freeze and Jesse De La Cruz; Master’s student: Amber Litterer)
PROJECT DESCRIPTION: Department of Defense natural resource managers in the East have been tasked with surveying, monitoring and managing endangered Indiana bat (Myotis sodalis) habitats and populations for > 40 years. For certain installations with known maternity colony activity and/or close to over-winter hibernacula, Indiana bat presence can mean heightened regulatory scrutiny of Integrated Natural Resource Management Plans with the need for formal consultation with the U.S. Fish and Wildlife Service, seasonal clearing restrictions and modification of training and range use in/near colonies in the growing season. Additional population declines associated with White-nose Syndrome has heightened conservation concern for Indiana bats. Moreover, the precipitous drop in northern long-eared bat (Myotis septentrionalis) numbers from the disease has moved the U.S. Fish and Wildlife Service to a proposed rule to list as endangered. With partially similar day-roosting habits, but with a far wider pre-disease distribution, including portions of the mid-Atlantic into the Piedmont and upper Coastal Plain and with far more cosmopolitan forest habitat associations, Northern long-eared bat listing may provide a management challenge far greater in extent than the Indiana bat. Additionally, White-nose Syndrome impacts to hibernating bat species along bat mortalities associated with coastal and montane wind energy development to some migratory bat species generally have increased the level of conservation concern for all bat species – all of which are poorly known with regard to most aspects of foraging ecology, day-roost use and requirements and seasonal presence on the landscape in the mid-Atlantic region such as Fort AP Hill, Fort Eustis, Fort Pickett and Quantico. With population declines associated with White-nose Syndrome concomitant with decreasing detection probabilities associated with traditional mist-net surveys, acoustical survey methods are moving to the forefront for initial bat surveys in terms of establishing species presence per the revised U.S. Fish and Wildlife Service Indiana Bat monitoring guidance. Although acoustics can provide much of the bat monitoring data needed by installation resource managers, recording Indiana bat and now northern long-eared bat in the post-White-nose Syndrome landscape can still trigger the need for follow-up mist-net surveys. If either species is present, determination of day-roost characteristics such as tree and snag species, surrounding forest stand establishment history, structural condition, and disturbance history.

OBJECTIVES: 1) Document the extant bat community using acoustic and mist-netting survey techniques at Fort AP Hill, Joint Base Langley-Eustis, Fort Meade, Fort Pickett and Quantico; 2) delineate generalized associations of upland and riparian habitat condition (e.g., forest stand-age, fire-return interval, proximity to edge, proximity to developed areas) to bats using acoustic survey techniques; 3) develop bat species-specific, spatially explicit predictive occupancy GIS coverages; and 4) describe day-roost characteristics and social network structure of northern long-eared bats, Indiana bats and/or evening bats if encountered in mist-net surveys.

PROGRESS: Acoustic and netting work has been ongoing since May 2014 at Fort AP Hill to the present, at Quantico in the summer of 2015 to the present and Fort Meade in the summer of 2016 to the present. Work at Fort Pickett and Fort Eustis ended in the summer of 2016. To date, over 7000 “detector nights” and approximately 190 net-nights have been completed. Acoustic data suggest northern long-eared bats are still present at very low densities at Fort A.P. Hill, Quantico and Pickett. Northern long-eared bats have been mist-netted at Fort Pickett and Joint Base Langley-Eustis, Quantico and nearby on the National Park Service’s Prince William Forest. Captures of Indiana bats occurred at Fort A.P. Hill in May and June – the first known maternity colony recorded in Virginia was discovered by radio-tracking tagged bats. One maternity roost site over approximately 10 ha was located. Indiana bat females roosted primarily in pine beetle-fire killed loblolly pine (Pinus taeda) boles in large canopy gaps. Exit counts suggested a colony of at least 20 individuals. No Indiana bats were netted in 2016, or 2017 suggesting that the colony is no longer active. However, a juvenile female was caught in 2018 indicating Indiana bat maternity activity still occurs on Fort A.P. Hill or the surrounding landscape. Acoustic data on all
installations is being used to inform U.S. Fish and Wildlife Service consultation efforts with high density sampling efforts now being concentrated at Quantico with emphasis on examining bat response to prescribed burning, wildfire and landform. As part of this effort, 12 artificial bat houses were placed at Fort A.P. Hill in close proximity to the known Indiana bat maternity areas in winter of 2019 in an attempt to establish a permanent colony per protocols developed at Fort Knox, Kentucky. To date, no bat use has been recorded however. Netting efforts for all installations was suspended in 2020 due to the Covid-19 pandemic, though acoustic monitoring continued albeit at a lower intensity than years past at Fort A.P. Hill and Quantico. Acoustic and mist-netting at Langley Air Force Base shifted to fall-winter work in 2019 and 2020 based on suspected acoustic presence of northern long-eared bats in the hibernating season there. Two female northern long-eared bats were caught at Quantico in 2021, but day-roosts were not found.

6. **Regional-specific Effort to Estimate Potential Non-Hibernating Distribution of Indiana Bats and Northern Long-eared Bats**

**DURATION:** 5/2014-12/2024

**SPONSORS:** U.S. Fish and Wildlife Service, Virginia Field Office and WNS Program, U.S. Geological Survey, Ecosystem Division, National Park Service Northeastern Region, National Park Service Capital Areas Region, U.S. Forest Service Monongahela National Forest, Bat Conservation International, NASA Wallops Test Flight Facility and Virginia Department of Wildlife Resources (Lead PI: Ford; Post-doctoral Researcher: Sabrina Deeley; Doctoral students: Jesse De La Cruz, Samuel Freeze and Mike St. Germain; Master’s students: Katherine Gorman, Nicholas Kalen and Amber Litterer)

**PROJECT DESCRIPTION:** Although, work to predictively model suitable Indiana bat (*Myotis sodalis*) habitat have been conducted at relatively large landscape scales or with coarse habitat correlates, efforts to examine biological and physical environmental parameters coupled with expert opinion/weight of evidence to model suitable habitat as well as occupied habitat is limited. Pre-White-nose Syndrome, Virginia’s overwintering population of Indiana bats was < 1000 and assuming 80-90% reductions post-WNS, the spring-fall occurrence of Indiana bats on the landscape outside of localized areas, i.e., such as males within 5-10 km of known hibernacula should be discountable. However, the discovery of several West Virginia maternity sites since 2000, including one at an elevation of approximately 1000 m in Tucker County, West Virginia and a Piedmont site in Carroll County, Maryland suggests that Indiana bat maternity activity may not be as rare as suggested for the region, pre-WNS. Indeed, stable isotope data collected from Indiana bats at Hellhole Cave in Pendleton County, West Virginia and Canoe Creek Cave, Blair County, Pennsylvania suggest a high likelihood of a common summer maternity area for females from those hibernacula. Because female Indiana bats from Canoe Creek have been tracked to Carroll County, Maryland it is possible that females from Hellhole Cave (> 10,000 individuals, pre-WNS) also migrate to that area, thereby increasing the probability of some Indiana bat occupancy in Virginia. Accordingly, assumptions that the catchment area for Virginia’ minor hibernacula and counties presumed to be in the catchment of Hellhole Cave, i.e., Highland, Rockingham and Augusta probably are overly conservative in spatial extent – this is particularly true in light of the observation of Indiana bat maternity activity in Caroline County, Virginia. Moreover, landscape-level reintroduction of fire in the Appalachians of Virginia, particularly on the George Washington and also the Monongahela national forests likely is improving the condition of Indiana bat day-roosting and foraging habitat and future climate scenarios suggest that the mountains of western Virginia and West Virginia may be more suitable habitat from a
temperature-precipitation regime than current conditions. Drastic population decline of myotids has rendered physical capture of Indiana bats to document presence and/or to develop habitat relationships via radio-tracking problematic. Fortunately, acoustical survey methods and their use to assess occupancy and general habitat relationships are now widely applied in the Appalachians and elsewhere. With the rule to list the northern long-eared bat (Myotis septentrionalis) as threatened in early 2015, similar questions have been raised and needs identified for this species that was previously more common by several orders of magnitude than the Indiana bat.

OBJECTIVES: 1) Use Virginia-specific landform, vegetation/forest condition and climate data (USFS FIA, Conservation Management Institute, Southeast GAP, etc.) in the context of proximity to in-state and surrounding state hibernacula and documented maternity area “catchment” zones to construct predictive habitat models of non-hibernating Indiana bat occurrence for resident males and potential female maternity areas and the same for northern long-eared bats within the Appalachian Plateau, Ridge and Valley, Blue Ridge, Piedmont and Coastal Plain physiographic provinces; 2) gather supporting model input data and subsequent model validation using a combination of mist-netting and acoustical survey techniques on landscapes of interest in Virginia and the surrounding mid-Atlantic; 3) develop Virginia and wider mid-Atlantic-specific landscape- and local-level best management practice guidelines to protect and improve extant and potential future Indiana bat and northern long-eared bat foraging and day-roost habitat; 4) assess potential mid-Atlantic and Northeast locations of residual northern long-eared bat presence; and 5) describe distribution, duration and ecology non-hibernating northern long-eared bats in the winter within the Coastal Plain.

PROGRESS: Acoustical survey efforts in 2014 have focused on the western portion of the state on the George Washington-Jefferson National Forest, Shenandoah National Park, Virginia Tech Fishburne Forest and scattered private lands. The 2015 efforts have focused on the Piedmont and Coastal Plain in Virginia including the addition of Manassas National Battlefield and Prince William Forest Park as well as Harper’s Ferry National Monument in West Virginia and Catoctin Mountain Park in Maryland. Northern long-eared bat presence, albeit much declined, has still been found in western Virginia and echolocation passes indicative of Indiana bats have been recorded in the Blacksburg-area and Shenandoah National Park and along the Fall Line in Virginia. Exclusive of other ongoing bat projects in Virginia involving mist-netting on DoD sites and the Warm Springs Mountain project, mist-netting for northern long-eared bats has been ongoing throughout western and northern Virginia in 2015 and mainly in southeastern Coastal Plain and south-central Piedmont in 2016. Focal work expanding mist-netting and acoustics on all National Capital Region National Park lands in Virginia, Maryland and the District of Columbia began in 2016 whereas a similar effort on Northeast Region National Park lands, i.e., Shenandoah National Park and various battlefields also commenced. Based on the few captures recorded, preliminary analysis suggests that the detection probability for northern long-eared bats in the western mountains is essentially zero in Virginia but somewhat higher along the Piedmont/Coastal Plain Fall Line. Evidence of northern long-eared bat maternity activity has been observed in the Rapidan Camp area of Shenandoah National Park through 2017 and Rock Creek Park in the District of Columbia, with several female bats radio-tagged and tracked to day-roosts, respectively in 2016, 2017 and 2018. In 2019, an additional colony in the late-summer break-up was located in the center portion of Prince William Forest Park. Day-roost used was varied, with large eastern hemlock snags (Tsuga canadensis) and mid-story black birch (Betula lenta) used at Shenandoah National Park whereas bats at Rock Creek and Prince William Forest Park used small red maple (Acer rubrum), American beech (Fagus grandifolia) and black locust (Robinia pseudoacacia) saplings to mid-story trees. Exit counts suggest maternity colony dissolution occurred early at Shenandoah National Park. Up to 8 females were noted in one exit
count at Rock Creek and subsequent July mist-netting confirmed the presence of juveniles in 2016. Northern long-eared bats were also mist-netted at Prince William Forest Park. Mist-netting efforts in northern New Jersey indicate a very low density of persisting northern long-eared bats; though 2017 netting in southeastern New York indicated possible local extirpation. Coastal southern New Jersey and Martha’s Vineyard, Massachusetts continue to have active maternity colony activity for the species providing some evidence of residual populations less or unaffected by White-nose Syndrome. Summer surveys have been expanded to include the Eastern Shore of Virginia at NASA Wallops Island Flight Facility. Addition of Gettysburg National Battlefield in Pennsylvania and Fire Island National Seashore in 2018 and 2019 also revealed the presence of northern long-eared bat maternity colonies with numbers and densities at Fire Island being similar to pre-disease levels though by 2021, no apparently colony existed at Fire Island. Winter acoustic sampling in eastern Virginia in 2016-2019 suggests that northern long-eared bats leave northern and east-central Virginia by early to mid-November and are present on the landscape in December-March in and around Suffolk, Portsmouth, Norfolk and Virginia Beach areas corresponding to the 220-240 growing season day isopleth. Work using a variety of sampling tools, i.e., acoustics, mist-netting, genetics and stable-isotope analysis will be used to determine if overwintering populations in the Coastal Plain represent the same population during the summer in the District of Columbia area and how they differ if any from populations in the Ohio Valley and New England coast. Efforts to link over-wintering bats to extant summer populations in northern Virginia and eastern North Carolina still are ongoing but resulting to date have been equivocal. Evidence that WNS presence is limited throughout Virginia and eastern North Carolina is limited during the winter was confirmed Pseudogymnoascus destructans assays performed by the U.S. Geological Survey Wildlife Health Lab from bats mist-netted in this effort provides some explanation for continued occurrence of these bats on the coastal landscape. Analyses of both summer and winter acoustic data from southeastern Virginia and northeastern North Carolina suggest that northern long-eared bat presence and activity is closely tied to large woody wetland habitats (presumably used for foraging habitat) adjacent to large patches of upland hardwood habitat (presumably used for day-roost habitat). On the Monongahela National Forest, successive years of acoustical monitoring are showing limited Indiana bat and northern long-eared bat presence above 1,000 m in elevation. Most Indiana bat activity is concentrated on the western slope of the Alleghenies at low elevations and also in the Ridge and Valley near known hibernacula. Northern long-eared bats are most associated with mixed mesophytic types throughout. Acoustics surveys for 2020 and 2021 will guide intensive mist-netting in 2022 there.

7. **Coastal Bat Acoustic and Nano-tag Survey**

**DURATION:** 1/2017-6/2022

**SPONSORS:** Virginia Department of Wildlife Resources, New Jersey Department of Fish and Wildlife, Rhode Island Department of Environmental Management and U.S. Geological Survey (Lead PI: Ford; Master’s student: Michael True)

**PROJECT DESCRIPTION:** Two major issues, white-nose syndrome and wind energy development, have been impacting bat species across the eastern and mid-western United States. While the spores of the fungus Pseudogymnoascus destructans have been found on tree bats (eastern red bat Lasiurus borealis, hoary bat Lasiurus cinereus and silver-haired bat Lasionycteris noctivigilans), the disease and impacts therein have been limited to cave bats (little brown bat Myotis lucifugus, Indiana bat Myotis sodalis, eastern small-footed bat Myotis leibii, and tri-colored bat Perimyotis subflavus) in Virginia. Wind energy development has had the opposite effect, impacting tree bats to a greater extent than cave bats. With the move to develop wind
energy along and off the eastern coast, it is imperative to understand the use and movements of bats along the coast. Acoustic detectors provide an efficient means to assess how passage rates vary temporally and in association with climatic variables. These data have been helpful in developing mitigation strategies for on-shore wind facilities. However, this method does not provide information on how different species’ age and sex classes migrate coastally or the path of travel. Nano-tags, affixed to bats, in association with fixed telemetry receivers can detect specific movements of individuals between stations (receivers). This technique provides additional detailed data on bat migration movements by species and age group. In conjunction with Virginia Department of Wildlife Resources, we propose to conduct a combination acoustic and nano-tag study to assess bat passage rates and migration paths along the coast of Virginia using zero-crossing frequency division detectors as well as Sensorgnome systems are capable of tracking multiple nano-tagged individuals (>100) on the same frequency. Both methods are currently being used in the Northeast to track both bird and bat movements coastally through the Northeast Regional Migration Monitoring Network. Our effort will work in collaboration with the efforts in the network.

**OBJECTIVES:** 1) assess coastal bat migration in the mid-Atlantic in relation to temporal and climatic conditions; 2) determine relative fall bat migration pathways by species, sex, and age, focusing on tree bats in coastal Virginia; and 3) coordinate with the network with data exchange across the mid-Atlantic and Northeast.

**PROGRESS:** Seven towers, with either Sensor-gnomes or Lotek receivers have been assembled and deployed on U.S. Fish and Wildlife Service (2), Virginia Department of Conservation and Recreation (1), Langley Air Force Base (1), Virginia Agricultural Experiment Station (1) and Nature Conservancy (1) properties on the Eastern and Western Shore. Since fall 2019, > 100 red bats were tagged throughout coastal Virginia, Delaware, Rhode Island and New Jersey to take advantage of the larger MOTUS network to document fall movements. Numerous single-night open water crossings of Delaware Bay and Chesapeake Bay were observed. Three extralimital captures of Seminole bats (*Lasirurus seminolus*) occurred further providing evidence that this species is expanding its range with increasing temperatures and where suitable pine cover types for day-roosting occur. Additionally, long-term acoustic data collected by Virginia Department of Wildlife Resources since 2015 through 2019 was analyzed to understand the full temporal and spatial extent of bat activity on the coast relative to season and weather to develop patterns to inform wind-energy development mitigation. Bat activity on the coast is tied to temperature, wind speed and presence of forests on barrier islands – data from this appears to be suitable for informing wind-energy BMPs.

8. **Statewide Bat Acoustic Monitoring Following NABAT Protocol**

**DURATION:** 2/2018-12/2022

**SPONSORS:** Virginia Department of Wildlife Resources (Lead PI: Ford; Post-doctoral researcher: Sara Sweeten)

**PROJECT DESCRIPTION:** In Virginia, although there is a wealth of acoustic bat data generally and specifically for sites requiring regulatory clearance work, data were not collected following NABAT protocols. Accordingly, Virginia has been unable to contribute to this nationwide program. Efforts to either modify existing winter hibernacula, summer mist-netting and acoustic surveys or install new sampling regimes are needed.
OBJECTIVES: 1) implement a statewide monitoring program for bats to assess population trends and distribution over a 5-year period; 2) participate in the North American Bat Monitoring Program by following protocols so data can be used at the national level; and 3) compare these protocols with past, ongoing and future focal acoustic efforts to better understand inference limitations.

PROGRESS: Thirty-seven NABAT grids throughout Virginia were chosen and 75 frequency-division, zero-crossing detector sites were deployed June-August 2019 and again in 2020. Approximately 20 sites were surveyed in 2021. Analysis of 2019 and 2020 echolocation call data has been completed and uploaded to the NABAT program for use in the U.S. Fish and Wildlife Service multi-bat species status assessment. A master “plan forward” is being created to guide subsequent efforts in Virginia.


DURATION: 5/2020-12/2022

SPONSORS: U.S. Fish and Wildlife Service Region 4 SSP and White-nose Syndrome Program (Lead PI: Ford; Post-doctoral research associate: Emily Thorne; Doctoral student: Jesse De La Cruz; and Master’s student: Hila Taylor)

PROJECT DESCRIPTION: With the onset and advance of White-nose Syndrome (WNS) across United State Fish and Wildlife Service (Service) Legacy Regions 3, 4, and 5, managers realized that then current Indiana bat (Myotis sodalis) survey and monitoring guidelines for regulatory clearance efforts, were insufficient due to population declines. In essence, mist-netting survey protocols were not sufficient to adequately determine true presence or absence of the Indiana bat, and later the northern long-eared bat (Myotis septentrionalis), stemming from the decrease in detection probability. Starting in 2013 with Region 4 as the lead, the Service began working with the U.S. Geological Survey Virginia Cooperative Fish and Wildlife Research Unit and Virginia Tech (hereafter “the Unit”) to calculate necessary mist-netting and acoustic levels of efforts (duration and extent) from historic data from across the Indiana bat range. From this, the revised Indiana bat monitoring guidance was developed (https://www.fws.gov/midwest/endangered/mammals/inba/inbasummersurveyguidance.html). Also, owing to the rapid spread of WNS and continued population declines and/or small residual population density, reliance on both historic mist-netting and acoustic data created a data gap whereby acquisition of a wider array of detection probability values from mist-netting and acoustic surveys across more variable habitat conditions on the Atlantic Coast, Appalachians, Interior Low Plateau and Gulf Coastal Plain was needed to formulate range-wide survey recommendations. A study designed to identify the necessary acoustic and mist-netting level of effort at upland, riparian and field edge sites in Kentucky, New York, Ohio, Virginia and West Virginia occurred in 2017 to provide data input for the 2018 and 2019 monitoring guidance. Results from this work established that acoustic surveys for Indiana bats required a minimum of 8 nights per detector to provide adequate detection when present. In addition to informing regulatory requirements, this effort highlights the need to incorporate detection probability considerations in post- and onset-WNS environments for affected bats for the North American Bat Monitoring Program. Current NABat acoustic sampling duration standards underestimate WNS-affected species such as Indiana bat, as well as the threatened northern long-eared bat.
(Myotis septentrionalis) and the petitioned little brown bat (Myotis lucifugus) and tri-colored bat (Perimyotis subflavus). This, combined with the recognition that the NABat sampling scheme may not in its current configuration allow managers to understand local bat population status and habitat associations are concerns that may limit widespread or long-term NABat participation in the East. Apart from insufficient sampling duration for WNS-affected bats, ongoing Unit research in the Potomac River corridor is showing a disparity in final bat species community richness values among NABat, Service regulatory monitoring guidelines and multi-week research purpose sampling. Accordingly, calculation of adequate level-of-effort sampling durations is vitally important to ensure the accuracy and success of NABat coupled with regulatory needs by the Service. Unit research has shown that while software programs can be highly variable on a file-by-file basis among bat species in the East, assuming high-quality acoustic site selection and sufficient echolocation file numbers, nightly agreement sufficient to provide similar individual species occupancy values typically occurs (Nocera et al. 2019). Nonetheless, because of the conservation costs associated with both false positive and false negative results from software use relative to the Indiana bat and northern long-eared bat in the East, the Service has worked with the Unit to establish, implement and conduct identification software testing protocols to approve or disapprove packages for regulatory clearance work in the WNS-impacted environments. Assessment of software performance is a critical component for the NABAT effort. At present, 2 software packages, BCID and Kaleidoscope meet established protocol standards for reliable identification of Indiana bats and northern long-eared bats, however, NABAT currently allows data accession using 2 additional, either failed or unexamined software programs for these species: Echoclass and Sonobat. Accordingly, managers in the post- and onset-WNS environment participating in NABAT might be providing errant data that either over- or underestimates Indiana bat and northern long-eared bat status. Expanding beyond these two species, assessment of identification software for all bat species (i.e., provision of producer and user classification rates and cross-species confusion matrices) acoustically monitored is necessary for NABAT program needs in the East, and from the perspective of the Service to begin tracking the status of the little brown bat and tri-colored bat effectively relative to WNS declines, and for species facing other stressors such as the endangered Virginia big-eared bat (Corynorhinus townsendii virginianus), the endangered gray bat (Myotis grisescens), and the hoary bat (Lasiurus cinereus).

OBJECTIVES: 1) create single-season, multiple surveys with habitat and weather covariates, and a Unit-developed “time since WNS” spatially explicit layer in Program Presence, Mark or R analog in a standard approach and false-positive occupancy approach to evaluate level-of-effort values from acoustic sampling data for Indiana bats and northern long-eared bats for consideration in setting geographically-specific acoustic monitoring guideline standards for Service regulatory support; 2) determine if similar approaches are sufficient to inform similar approaches for little brown bat, gray bat and tri-colored bat; 3) delineate hourly, nightly and whole survey period activity levels with the likelihood of maternity activity to establish conservative, but robust threshold levels indicative of maternity activity among the species in question; and 4) continue to test automated bat identification software that has been submitted to the Service, by following the protocols and standards developed for Indiana bats and northern long-eared bats by evaluating maximum likelihood performance, producer’s accuracy and user’s accuracy.

PROGRESS: Data collection started in May of 2020 and continued through August 2021 with acoustic field sites established in Alabama (2), North Carolina (1), Virginia (4), West Virginia (4), Kentucky (4), Ohio (1), Indiana (2), Illinois (1), Vermont (1), New Jersey (2), Missouri (1), Arkansas (1), Georgia (2), Tennessee (2), Wisconsin (2) and New York (1). Analysis of 2020 survey data suggested that necessary level of effort will increase in the Midwestern and Ozark
recovery zones due to declining detection probability and decrease in the Appalachian recovery zone for Indiana bats due to regional extirpation of Indiana bats. Northern long-eared bat acoustic and mist-netting necessary levels of effort were similar in contrast to that of Indiana bats. In 2021, additional sites were added to acquire additional information on little brown bats and tricolored bats and to increase spatial coverage in the Midwest and Northeast. Testing of one new software submission occurred in April of 2020.

10. Bat Acoustic Monitoring in Maine Following NABAT Protocol

DURATION: 1/2021-12/2021

SPONSORS: Maine Department of Wildlife and Inland Fisheries (Lead PI: Ford; Doctoral student: Jesse De La Cruz)

PROJECT DESCRIPTION: Biologists in Maine have acoustically surveyed bats throughout the state since 2015. However, with little capacity to collate and upload to NABAT or perform analyses on distribution and abundance, questions about effective sampling intensity and location have been raised relative to tracking listed species such as the northern long-eared bat (Myotis septentrionalis) and state species of concern such as eastern small-footed bat (Myotis leibii) and/or the ability to track declines associated with White-nose Syndrome.

OBJECTIVES: 1) implement and refine a statewide monitoring program for bats to assess population trends and distribution; 2) participate in the North American Bat Monitoring Program by following protocols so data can be used at the national level; and 3) compare these protocols with past, ongoing and future focal acoustic efforts to better understand inference limitations.

PROGRESS: Probability of abundance and occupancy spatial layers have been created and annually updated for Maine’s bat species. Northern long-eared bat occurrence primarily is limited to coastal landscapes whereas eastern small-footed bats are concentrated in the southwestern portion of the state where suitable emergent rock habitats occur. Power analyses suggest that current sampling is sufficient to detect change for common species but that statewide efforts for rare species is not obtainable with high resolution. Therefore, for rare species, surveys should be targeted local efforts. 2015-2020 data have been uploaded to NABAT.

11. Establishing a Regional Mid-Atlantic Bat Hub

DURATION: 10/2020-12/2024

SPONSORS: U.S. Geological Survey (Lead PI: Ford; Post-doctoral researcher: Sabrina Deeley, Doctoral student: Jesse De La Cruz)

PROJECT DESCRIPTION:

OBJECTIVES: 1) assist regional partners and stake-holders with data collection to support the NABAT program; 2) provide region-specific analyses on regional trends on bat populations; 3) assist with U.S. Fish and Wildlife Species Status Assessments; and 4) begin disease surveillance relative to enzootics in bats with implications for human health

PROGRESS: Most effort has concentrated on assembling regional partner acoustic data to support the Species Status Assessment and analyzing for that all nationwide bat mist-net capture
data. For most of the distribution of northern long-eared bats (*Myotis septentrionalis*), little brown bats (*Myotis lucifugus*) and tri-colored bats (*Perimyotis subflavus*), ten-year trends in abundance and catch-per-unit effort from mist-netting have significantly declined following the advent of White-nose Syndrome.

12. **Acoustic Phenology of Bat Activity at and within Close Proximity to Hibernacula (Fall Swarm, Hibernation, and Spring Emergence); Fall Swarm Habitat Preference; and Index of Hibernating Bats**

**DURATION:** 1/2021-12/2022

**SPONSORS:** Virginia Department of Wildlife Resources (Lead PI: Ford; Doctoral student: Jesse De La Cruz)

**PROJECT DESCRIPTION:** White-nose syndrome (WNS) has severely impacted both hibernacula and summer populations of bats in Virginia with population declines greater than 95% for some species. In addition to population declines, WNS has influenced behavioral adaptations in bats with the assumption these changes promote survivorship and productivity. These may have included earlier emergence due to fat depletion and the need to forage and later entry into hibernacula to promote weight gain and shorten hibernation time/exposure to WNS. Understanding the timing and extent of activity at hibernacula will help managers plan habitat enhancements for bats at and near hibernacula (e.g., timber stand improvements, prescribed fire, artificial prey patches, and artificial roosts). In addition, understanding the habitat configuration around areas with high acoustic activity in the fall will aide managers in understanding and managing preferred fall swarm habitats.

**OBJECTIVES:** 1) use targeted acoustic sampling to monitor bat acoustic activity at and around hibernacula during fall swarm, hibernation, and spring emergence periods; 2) use available remotely sensed imagery (i.e., Landsat derived NLCD or USDA NAIP) to classify and quantify habitat characteristics around fall swarm acoustic stations; 3) use general additive models or non-parametric or localized regression to assess passage rates in relation to hibernacula counts, date, weather, and surrounding habitat correlates.

**PROGRESS:** Acoustic detectors were deployed at 12 cave sites in Virginia in February of 2021 and operated through early May. Preliminary analyses show that bat activity around caves was highly variable relative to elevation, latitude and weather but in most cases began in March. Overall peak activity that presumably is attributable to spring emergence occurred at the end of March through mid-April which is not substantively different from pre-WNS timing. Fall swarm deployment began in August and will occur through mid-November.

13. **Estimating Elk Abundance and Herd Demographics in Virginia**

**DURATION:** 3/2020-7/2023

**SPONSORS:** Virginia Department of Wildlife Resources (CO-PI’s: Ford and Cherry; Master’s student: Braiden Quinlan; Post-doctoral researcher: Emily Thorne)

**PROJECT DESCRIPTION:** Elk (*Cervus canadensis*) were once widely distributed across eastern North America including the Appalachian Mountains of Virginia. However, unregulated hunting resulted in wide spread extirpation of elk during the 19th century and the last elk was
harvested in Virginia in 1855. Virginia Department of Wildlife Resources attempted to restore elk in the early 1900’s by stocking elk in 15 counties. Outside of the portions of Giles County, largely these efforts failed and by 1970s, the agency terminated protection for remaining elk. In 1997, the Kentucky Department of Fish and Wildlife Resources began restoring elk within the eastern portion of the state, including areas along the Virginia-Kentucky border. Consequently, Kentucky elk began to disperse into Virginia, West Virginia and Tennessee. In 2011, VDWR established the Elk Restoration Area (now referred to as the Elk Management Zone [EMZ]) in Buchanan, Dickenson and Wise counties by prohibiting harvest of elk within the EMZ. The following year VDGIF began an active agency-led elk reintroduction into the EMZ. Many of the goals stated in the Virginia Elk Management Plan require assessment of herd abundance and demographics. Careful monitoring of populations is especially important when managers seek to balance finely controlled harvests (e.g., harvesting only 6 males per year ) with other sources of mortality. However, even minimal harvest of adult males in a small herd could inhibit reproduction and slow population growth. Minimum counts are commonly used to estimate the abundance of small populations but these methods generally underestimate abundance and lead to overly conservative management. Therefore, a method is needed to estimate spatial variation in density and herd demographics of elk through time tailored for Virginia.

**OBJECTIVES:** 1) assessment and development of a mark-resight method for estimating density and herd dynamics of elk specific for the Virginia EMZ; 2) develop annual estimates of population demography (i.e., sex ratios, cow-calf ratios), abundance, and spatial variation in density; and 3) technical assistance with analysis of historical elk data such as development of resource selection functions/habitat associations from GPS-collared individuals.

**PROGRESS:** Driving transect areas were established counts occurring from November 2002 through early May 2021. Analysis of GPS-collar data from release through 2019 show that elk select reclaimed mine sites with low topographic complexity above all other habitats. Home range analysis by season showed on average that areas were ~ 2,000 ha in spring, summer and fall, but are reduced to < 1,000 ha in the winter. Movement of collared elk from reintroduction area with animals expanding throughout much of the EMZ and into Kentucky have occurred.

**14. Efficacy of Nest-boxes to Enhance and Remote Cameras to Monitor Southeastern Fox Squirrel Populations on the Big Woods/Piney Grove Complex and Fort Pickett**

**DURATION:** 12/2018-6/2023

**SPONSORS:** Virginia Department of Wildlife Resources and Virginia Army National Guard (CO-PI’s: Ford and Klopfer; Master’s student: Marissa Guill)

**PROJECT DESCRIPTION:** Within in the Appalachians in Virginia, particularly portions of the Ridge and Valley, eastern fox squirrels (*Sciurus niger vulpinus*) appear to be stable to increasing whereas throughout most of the Piedmont and Coastal Plain, southeastern fox squirrel (*Sciurus niger niger*) populations are localized and relatively rare or uncommon mirroring trends in most other southeastern states. Populations in the Appalachians, Interior Highlands and Midwest have benefited from farm abandonment, increased localized edges (often associated with wildland-urban interface development), and decreased forest basal area (but older residuals) from prescribed fire use restoration and a decadal increase in diameter-limit harvesting and thinning from the mid-1990s to mid-2000s. Piedmont and Coastal Plain populations have been adversely affected by landscape-scale mixed pine-hardwood and hardwood conversion to homogenous, short-rotation, high density pine plantations along with continued fire suppression and/or limited
use of fire as a management practice. Short-rotations of highly stocked pine stands with closed canopies, limited cavity availability and reduced hard-mast production have combined to provide landscapes with poor foraging and denning habitat for southeastern fox squirrels in much of the Piedmont and Coastal Plain. Southeastern fox squirrels routinely use drey-nests (leaf) year-round in the southern Coastal Plain in South Carolina, Georgia and Florida, however, populations in the Piedmont and into the more northern portions of the squirrel’s distribution in the Coastal Plain, i.e., northeastern North Carolina and eastern Virginia, and elsewhere for the other subspecies may require cavity dens in the winter which therefore could be a limiting factor in Virginia. In Virginia, recolonization of areas of suitable habitat east of the Appalachians, i.e., in the central Piedmont and western Coastal Plain including Ft. Pickett in Nottoway County, have been uncommon. Whereas research from more austral portions of the Coastal Plan and Piedmont in the Southeast have provided insights into eastern fox squirrel habitat and population management approaches and needs, sufficient differences in current and potential habitat types and landscape condition result in considerable data gaps moving forward in Virginia. For example, in the core-county distribution area in Virginia, no estimates of density, characterization of den use or home-range size exist.

**OBJECTIVES:** 1) assess current distribution and abundance using nest-box survey, survey transects, and camera trapping throughout eastern Virginia; 2) determine efficacy of artificial nest box structures as a fox squirrel management tool; and 3) delineate habitat association and home range size of radio-tagged fox squirrels at Big Woods and Fort Pickett.

**PROGRESS:** 150 nest boxes were constructed and placed at Fort Pickett and Big Woods in the spring of 2019. Camera-trapping at both sites in a variety of habitat types has occurred seasonally from fall of 2019 through fall of 2020 and nest-box checks have occurred simultaneously. Preliminary results from both techniques are showing fox squirrel occupancy only at Big Woods and with those individuals being the Southeastern subspecies. Initial radio-collaring efforts from box checks and live-trapping were curtailed by the Covid-19 pandemic, however 1 female was radio-tagged and successfully tracked in March for several weeks following collar failure. For this one individual, the 50% adaptive kernel home-range suggested a strong selection for mature pine savanna habitat at Big Woods. Trapping and radio-tracking at Big Woods will resume in late fall of 2021.

**15. Modeling Climate Change Impacts and Spruce Restoration Priorities for Appalachian Northern Flying Squirrels**

**DURATION:** 6/2018-12/2023

**SPONSORS:** U.S. Fish and Wildlife Service North Carolina Field Office and U.S. Forest Service Monongahela National Forest (PI: Ford; Post-doctoral researcher: Corinne Diggins)

**PROJECT DESCRIPTION:** The Appalachian northern flying squirrels (*Glaucomys sabrinus coloratus* and *G. s. fuscus*) are a nocturnal arboreal Sciurids that were listed as federally endangered in 1985. Both subspecies are found in high-elevation red spruce (*Picea rubens*) – Fraser fir (*Abies fraseri*) forests in the southern and central Appalachians which is considered one of the most endangered forested ecosystems in the United States. Range-wide industrial-logging and subsequent fires negatively impacted spruce-fir forests reducing the extent of the forest type by 35-57% in the southern Appalachians and > 80% in the central Appalachians. Additionally, spruce-fir forests in the region are extremely vulnerable to climate change), which may lead to extirpation of this forest type and the squirrel. Red spruce restoration to expand habitat and create
corridors to connect populations is an important action to help recover the species. In addition, red spruce restoration will lead to more resilient habitat in the face of climate change and should help limit range expansion of southern flying squirrels. However before federal and state agencies as well as various NGOs can proceed, better Appalachian northern flying squirrel predictive maps encompassing the full suite of location and habitat use data need to be developed to be used to prioritize current and future land management efforts in this restoration program and/or to fully inform land managers of the likelihood of squirrel presence relative to ESA requirements.

**OBJECTIVES:** 1) create an updated, expansive habitat model using historic and recently collected nest box, telemetry, and acoustic data to model the effects of climate change on Appalachian northern flying squirrels; 2) use the same base habitat model to create site prioritization for red spruce restoration; 3) determine southern flying squirrel (*Glaucomys volans*) invasion of by modeling their presence in long-term nest box monitoring data; and 4) determine red spruce reference conditions from historical data and old-growth forests to help guide restoration efforts and determine which habitat features might increase habitat quality for Appalachian northern flying squirrels at restored sites.

**PROGRESS:** Collated Appalachia northern flying squirrel presence-data from nest-box records, live-trapping, radio-telemetry fixes and acoustic recordings have been assembled for resource utilization function analyses. This has been completed for the central Appalachians using existing data layers. For the southern Appalachian study area, these have been delineated and raster conversion of remotely-sensed imagery has been completed to provide a new, seamless red spruce and other montane conifer layer at 1x1 m resolution for model input. For both regions, assessments of project climate change impacts are planned.

16. **Assessing Distribution and Seasonal Activity Patterns of Bats in 5 Utah Parks Prior to White-nose Syndrome Arrival**

**DURATION:** 6/2019-3/2022

**SPONSORS:** National Park Service (Lead PI: Corinne Diggins)

**PROJECT DESCRIPTION:** The fungus that causes White-nose Syndrome (WNS) has recently been found in the Southwest. This new finding creates an urgent need to fill data gaps on bat ecology and distribution in the Southwest. Limited-to-no work had been conducted on bats in southeastern Utah national parks. Our goal is to implement a 2-year regional bat acoustic monitoring project in 5 national parks (Arches, ARCH; Canyonlands, CANY; Capitol Reef, CARE; Hovenweep HOVE; and Natural Bridges, NABR) to determine seasonal activity patterns and bat species diversity across the landscape. Using information obtained from acoustic surveys, we will determine predictive landscape-scale species distribution maps and establish protocols for long-term bat monitoring within all 5 NPS units.

**OBJECTIVES:** 1) determine year-round occupancy of bat species across the study area; 2) evaluate seasonal variation in activity patterns of bat species among various habitat types and elevations; 3) develop standardized protocol for long-term acoustic monitoring programs for all 5 NPS units including training NPS staff on the deployment of acoustic units and aspects of data analysis; and 4) share information gathered with other entities (i.e., other federal and state partners) conducting bat research to better understand bat communities on the Colorado Plateau.
PROGRESS: We deployed 45 acoustic sites 2019 (2 at HOVE, 3 at CARE, 25 at CANY, 5 at NABR, 10 at ARCH) in addition to 15 sites that were established in CARE in 2018 for a total of 60 sites. All detectors have been checked on a bi-annual basis to download data and check detector function.

17. Impact of Exotic Tree Species Removal on Bird Communities in Canyon de Chelly National Monument

DURATION: 7/20–12/22

SPONSORS: National Park Service (Lead PI: Corinne Diggins)

PROJECT DESCRIPTION: In the Southwestern United States, riparian corridors along rivers and streams are important habitat for avifauna. However, riparian corridors have been invaded by salt cedar (Tamarix ramosissima) and Russian olive (Elaeagnus angustifolia), two non-native invasive species that decrease bird diversity and have negative impacts on river shoreline dynamics. As part of restoration efforts in Canyon de Chelly National Monument, a project will remove ~80 acres of salt cedar and Russian olive in 2021 and 2022 within the riparian corridor of lower Canyon de Chelly. I will monitor for changes in the bird community using passive acoustic surveys at 10 sites in June 2021/2022. Detectors will be set to record during the morning chorus to survey breeding bird communities and at nighttime to survey for Mexican Spotted Owls.

OBJECTIVES: 1) to determine the impacts of exotic riparian removal treatments on breeding bird communities and Mexican Spotted Owls using passive acoustic surveys.

PROGRESS: Acoustic surveys were implemented this summer following the COVID-19 delay in access to the Navajo Nation during this time. Processing of acoustic data from the first season will commence this fall. The second field season will occur in June 2022.

ELIZABETH HUNTER

18. Avian Community Response to Grassland Restoration at Rappahannock River Valley National Wildlife Refuge

DURATION: 4/2021-4/2023


PROJECT DESCRIPTION: Rappahannock River Valley National Wildlife Refuge (RRVNWR) in the tidewater of Virginia is a network of both remnant and restored grasslands (with more restorations planned). Whether existing grasslands can serve as bird population sources to restored grasslands will prove critical to the success of maintaining viable metapopulations. Within the RRVNWR complex, three units contain large, managed grasslands: Wilna, Hutchinson, and Tayloe units. Over the past several years, surveys of grassland sites confirmed the presence of target grassland bird species, including obligate and facultative breeders. This project aims to determine whether ARUs can be used to monitor avian metapopulation dynamics in grassland ecosystems at RRVNWR and collect baseline community and abundance data for long-term assessment of grassland restoration success.
OBJECTIVES: 1) determine which species present in RRVNWR can be reliably surveyed by ARUs and detected by automated call identification software; 2) estimate species occupancy and indices of abundance (estimated by call frequency and duration) across grassland habitat patches that vary in terms of size, isolation, and habitat characteristics, and management; and 3) evaluate community similarity among habitat patches as a function of area, distance metrics, and other habitat characteristics.

PROGRESS: In May 2021, we placed 10 SongMeter Mini ARUs in the 3 focal areas at RRVNWR. During 5-minute validation point counts, northern bobwhite calls were counted in the field by human observers at 3 of the 10 ARUs. Upon listening to recordings, 97% of bobwhite calls heard in the field were recorded by the ARU. BirdNET (an artificial neural network software program) classification of sonograms as bobwhite varied among the 3 samples as a function of call signal strength, background noise, and overlapping calls from other species. At 2 of the 3 ARUs where bobwhite were detected, ~ 50% of calls were detected by BirdNET, but at the third ARU (where signal strength was greatest), 88% of calls on the recording were detected by BirdNET. These results are all substantially better than the published identification rate from other uses of investigator-developed classifiers using Kaleidoscope software by >30%. BirdNET also did not have any false positive detections, i.e., no misclassifications of other bird species’ calls as bobwhite, and accurately identified several other grassland bird species including indigo bunting (Passerina cyanea), prairie warbler (Dendroica discolor), and field sparrow (Spizella pusilla).

19. Remote Sensing of Habitat for At-Risk Early Successional Bird Species in Georgia

DURATION: 8/2021-5/2023

SPONSORS: Georgia Department of Natural Resources (Lead PI: Hunter; M.S. student: Cory Allred)

PROJECT DESCRIPTION: In Georgia, two early successional bird species that are declining and could benefit from more targeted habitat management are Bachman’s Sparrow (Peucaea aestivalis, BACS) and Loggerhead Shrike (Lanius ludovicianus, LOSH). BACS occupy pine savanna ecosystems and need a high diversity of grasses and forbs with fewer woody plants in the understory. LOSH also use early- to mid-successional grassland habitat, but they are dependent on the presence of some woody vegetation within the grassland context. BACS habitat is successfully managed with prescribed burning that maintains openness and a rich understory herbaceous community; whereas LOSH do not have a strong response to burning and are more sensitive to management that affects perching and nesting opportunities. Although general habitat requirements and management practices are documented for BACS and LOSH, the species’ specific needs in Georgia requires additional study. There are many areas with seemingly suitable habitat in Georgia that are not occupied (particularly for LOSH), and so greater knowledge on specific habitat requirements in the state is needed to understand the species’ distributions and how their populations could be bolstered. Using remotely sensed data for habitat quantification will allow for a thorough analysis of many possible drivers of habitat suitability at multiple scales, which would not be possible with only on-the-ground vegetation surveys. This project aims to determine whether the fine scale habitat features favored by BACS and LOSH are detectable with remotely sensed data. To answer this question and develop targeted monitoring and management strategies, more detailed information is needed on the specific habitat requirements and tolerances of each species and how habitat characteristics are shaped by management actions.
OBJECTIVES: 1.a) create predictive models of species occurrence (and abundance, if possible) using existing Georgia Department of Natural Resources survey data and remotely sensed data (e.g., canopy cover, NDVI, etc.); 1.b) compare influential remotely sensed variables to on-the-ground vegetation monitoring data for connection to management; 1.c) assess models for transferability among eco-regions (e.g., Piedmont and Coastal Plain) and for validity in predicting external datasets; and 2) use model predictions from objective 1, design field survey protocols to determine model accuracy and improve species monitoring across the state in areas of likely habitat.

PROGRESS: This project is still in the contracting stage, but a graduate student (Cory Allred) has been selected and is in the hiring process.

20. Effects of Origin Location on Translocated Gopher Tortoise Overwintering Behavior, Probability of Reproduction, and Adult Survival

DURATION: 8/2021-6/2024

SPONSORS: Florida Fish and Wildlife Conservation Commission (Lead PI: Hunter; Research Associate: Kevin Loope)

PROJECT DESCRIPTION: Translocation success depends on whether translocated individuals can survive and reproduce in their new environment to ultimately produce a self-sustaining population. Both survival and reproduction may depend on how different the translocation environment is from the origin environment. Translocation and origin sites could differ by climate, soils, and social or population structure. In Florida, rules governing translocation of gopher tortoises (Gopherus polyphemus) are currently based on arbitrary distance guidelines (e.g., the “100-mile” rule) and not on whether differences between translocation and origin sites are great enough to cause a reduction of fitness in translocated individuals, likely due to a lack of data on this critical question. Understanding how both geographic distance and environmental differences between translocation and origin sites influence a translocated tortoise’s ability to adjust to its new surroundings is important for establishing biologically sound guidelines for future translocations. This project investigates the effects of origin location on translocated tortoise behavior, survival, and reproduction at Nokuse Plantation in the panhandle of Florida.

OBJECTIVES: 1) monitor overwintering behavior and relate overwintering duration to origin location through both geographic and climatic differences between the origin and translocation sites, as well as time since translocation; 2) monitor female probability of reproduction and relate to overwintering duration, time since translocation, and origin location.; 3) estimate the effects of origin location and time since translocation on adult survival rates using existing data and additional mark-recapture data collected in the process of addressing the first two objectives.

PROGRESS: Initial project planning is underway.

21. Marsh Migration on Virginia’s Eastern Shore Farmlands: Decision Planning for Farmers and Bird Habitat in the Face of Sea Level Rise

DURATION: 8/2021-6/2022
SPONSORS: Virginia Tech Center for Coastal Studies (Lead PI: Hunter)

PROJECT DESCRIPTION: Virginia’s coastal marshes are being lost to sea level rise (SLR) while simultaneously migrating onto upland habitats, which presents both challenges and opportunities for human and wildlife communities. Coastal marshes provide critical habitat for many declining wildlife species (e.g., American Black Ducks and Saltmarsh Sparrows), and it is not clear whether migrating marshes will provide sufficient and suitable habitat for the persistence of viable populations. Agricultural land will transition to marsh habitat more readily than forests, but such transitions will depend on the actions of farmers who are experiencing saltwater inundation on their land. Thus, maintaining marsh habitat area for at-risk species and increasing the resilience of agricultural practices in the face of SLR is a linked social-ecological problem requiring an interdisciplinary approach by ecologists, social scientists, decision scientists, marsh migration researchers, and agricultural extension experts. Many organizations are already engaging in research and extension activities related to marsh migration, but a holistic framework for linking the social and ecological sides of the problem is needed to devise optimal marsh migration strategies that could provide for both wildlife and human communities.

OBJECTIVES: 1) develop a network of researchers, agency scientists, and extension specialists working on marsh migration issues on the eastern shore to engage with and meet the applied needs of conservation NGOs, agricultural extension, and natural resource management and agriculture agencies; 2) assemble existing datasets on bird distributions, marsh extent, and marsh migration potential and identify spatial information gaps for targeted bird community sampling; 3) build upon the group of eastern shore farmers that we have worked with on previous projects (unrelated to marsh migration) and identify agricultural producers’ barriers to conservation program participation and needs that would support marsh migration; and 4) develop the structure of a Bayesian decision analysis model that will account for uncertainty in ecological, social, and land motion parameters and the efficacy of alternative stakeholder actions, which will ultimately form the basis for identifying policies, incentives, and resources (such as decision support tools) to support adaptive action.

PROGRESS: Project planning has started and field site visits to the Eastern Shore have occurred.

22. Critical Habitat Breadth for *Gopherus* Tortoises: A New Paradigm for Managing Threatened and Endangered Species in a Non-Stationary World

DURATION: 7/2018-1/2023

SPONSORS: Department of Defense Strategic Environmental Research and Development Program (SERDP) (Co-PIs: Hunter and Kevin Shoemaker [University of Nevada, Reno])

PROJECT DESCRIPTION: As ectotherms with temperature-dependent sex determination, gopher tortoises (*Gopherus polyphemus*) may be vulnerable to climate change throughout their range. However, given that the species has weathered substantial climatic variation in the past, gopher tortoise populations may be resilient to a wider range of environmental changes than some current models that ignore demographic plasticity suggest. Gathering the data for this project requires (1) measuring population growth and survival rates using existing, long-term survey datasets; (2) conducting detailed field studies at prior translocation sites to investigate the relative importance of local adaptation and phenotypic plasticity; and (3) investigating within-population changes in key vital rates across the climatic gradients of the species’ range. Field data-collection
efforts focus on measuring vital rates for which linkages with environmental drivers are poorly understood, including offspring production, age-at maturity, hatchling sex ratios, and hatching success. Field data collection is designed to sample across the broadest possible range of environmental conditions. These data will be used, along with a suite of field-validated climate and habitat datasets (GIS layers), to model critical habitat breadth for gopher tortoises, specifically through integrated Structural Equation Models (SEM) to estimate population growth rate as a function of pathways involving inter-correlated vital rates, body condition and spatiotemporally varying environmental conditions. Finally, fitted SEMs will be used to produce spatiotemporal projections of population growth rates and critical habitat, and to assess metapopulation viability under multiple plausible future scenarios.

OBJECTIVES: 1) understand the complex pathways through which environmental conditions influence population vital rates for gopher tortoises; 2) use this information to derive population growth rates, assess viability, and quantify critical habitat for this species; and 3) develop a conservation planning tool to aid conservation managers in protecting populations and planning for an uncertain future.

PROGRESS: Fieldwork is complete for this project and has moved to the analysis and publication stage. We have made substantial progress on objective 1 by determining the effects of prescribed burning on adult tortoise survival, and by examining temperature effects on probability of reproduction and clutch size. Analyses are being completed for effects of nest environment on hatching success both across a latitudinal gradient and at a translocation site (which allows for testing of local adaptation). Results of assays for sex identification are also being finalized with implications for sex ratio analyses.

OTHER FACULTY COOPERATORS

VERL EMRICK

23. Faunal Survey and Assessment to Support Integrated Natural Resource Planning for Fort George G. Meade, Maryland

DURATION: 3/2021-3/2022

SPONSORS: Army Installation Command, Fort George G. Meade (Lead PI: Emrick)

PROJECT DESCRIPTION: The Sikes Act requires the DoD to develop and implement Integrated Natural Resource Management Plans (INRMP) for military installations with significant natural resources across the United States. INRMP are intended to organize and consolidate, assess, available ecological data, and other technical information required to manage natural resources into a single document and serve as the basis for ecosystem management in support of the training mission on US managed military installations. Comprehensive faunal surveys are essential for effective stewardship of military lands and to support the effective implementation of INRMP as mandated by the Sikes Act. As part of the INRMP process at Fort George G. Meade (FGGM) managers identified three faunal surveys critical to support the installation INRMP: pollinators, wood turtles and birds.

OBJECTIVES: 1) conduct a survey of pollinator insect species including potential rare, threatened and endangered species with emphasis on bees and lepidopterans; 2) survey habitats identified in 2020 for wood turtles and collect morphological metrics, ages, and sexes for any
turtles found for use in management recommendation development; and 3) conduct systematic spring migratory, summer resident, and fall migratory avian surveys with emphasis on species of concern identified by: federal and state threatened, endangered and sensitive species lists/

PROGRESS: Spring surveys for the wood turtle were completed in May 2021, along with the initial avian and pollinator surveys. Summer avian and pollinator surveys are ongoing.

24. Assessing the Role of Exotic Plants in Providing Habitat for Native Wildlife and other Ecosystem Services at Manassas National Battlefield Park

DURATION: 2/2021-2/2022

SPONSORS: National Park Service and U.S. Geological Survey NRPP (Lead PI: Emrick)

PROJECT DESCRIPTION: Current management practices in National Park Service lands emphasize the control and removal of exotic plant species where possible. This management approach is predicated on the assumption that the removal of exotic plant species will result in the return of native, ‘natural’ plant communities that are more valuable in terms of wildlife conservation and ecosystem services. Although the goal of removing exotic plant species and replacing them with natives is undoubtedly desirable, removing exotics without adequately planning for the restoration of natives can have unintended consequences. A number of native taxa use nonnative, and often invasive, plant species during their life cycle including avifauna, pollinators, and mammals. Often the most easily controlled exotic plant species are targeted first, thus opening niches for other exotics that are more difficult to control. In smaller, “historical” parks within the urban or suburban-rural matrix, where native plants may not be abundant, exotic species may be playing a role normally filled by native species in fulfilling a variety of ecosystem services including but not limited to, wildlife habitat provision, erosion control/soil stabilization, nitrogen fixation, and enhancement of the visitor experience. At Manassas National Battlefield Park (MANA), many exotic plant species are potentially playing a critical role in providing wildlife habitat to a variety of taxa. Removal of these species without adequate restoration with natives may negatively impact wildlife and other ecosystem services. Thus, establishing the functional ecology of each exotic plant species at MANA in terms of wildlife habitat contribution and ecosystem services will provide park managers the ability to better target or allocate resources to control exotic species in a manner to not adversely impact wildlife and other ecosystem services. Accordingly, there are two overarching questions for the proposed research.

OBJECTIVES: 1) identify the abundance, distribution, and habitat specificity of exotic plant species on MANA; 2) identify taxa (e.g., insect pollinators, herpetofauna, birds, and small mammals) that utilize and/or depend upon specific exotic plant species at MANA for a critical part(s) of their life cycle, with emphasis on Virginia sensitive species-of-concern as the larger group, along with any federally listed species or NPS species of concern; 3) for all exotic plant species, identify potential (non-wildlife related) ecosystem services provided (e.g., N-fixation, erosion control/soil stability, and visual enhancement); 4) predict and rank the potential impacts and outcomes (likely replacement) of the removal of each exotic species on plant community composition, wildlife response, and ecosystem services; and 5) identify native plant species recommended for restoration that would replace and/or enhance the wildlife conservation and
other ecosystem services lost from the removal of exotic plant species and the necessary management practices thereof to accomplish at MANA.

**PROGRESS:** Preliminary annotated database has been developed. Initial field site visits have been completed.

**MICHAEL SORICE**

25. **An Evaluation of the Partners for Fish and Wildlife Program in the Southeast United States: Understanding Landowner Participation and Ongoing stewardship behaviors**

**DURATION:** 6/2019-1/2022

**SPONSORS:** U.S. Geological Survey (Lead PI: Michael G. Sorice; Post-doctoral researcher: Kyle Clifton)

**PROJECT DESCRIPTION:** The U.S. Fish & Wildlife Service’s (Service) Partners for Fish and Wildlife (Partners) Program provides financial and technical support to private landowners, while also improving habitat for listed and at-risk species. The Partners Program provides a platform for private landowners to voluntarily participate and contribute to wildlife conservation through a 10-year landowner agreement, where cost share and/or technical assistance are available to improve habitat. In the Southeast Region, the Partners Program has worked with more than 4,000 private landowners to restore and enhance over 500,000 acres. The Partners Program would like evaluate the outcomes of their work with private landowners by assessing the degree to which private lands habitat improvement projects support sustainable populations of target wildlife species. Achieving sustainable populations through the cooperation of private landowners requires individual project documentation that includes biological monitoring to understand the dynamics of the habitat and social monitoring to understand landowner behavior. Recognizing why wildlife stewardship behaviors cease or continue is essential in assessing the overall habitat conservation contribution of the Partners Program.

**OBJECTIVES:** The primary objective of this evaluation is to identify factors that lead to private landowner participation in the Partners Program, as well as those factors impacting the actions/behavior and attitudes of private landowners during and after the life of a landowner agreement. Furthermore, the evaluation will provide insight into landowner engagement approaches that promote post-agreement/program persistence.

**PROGRESS:** The post-doc visited North Carolina, Tennessee, Kentucky, and Mississippi to interview landowners and conducted 1 focus group in 2019. The post-doc and PI developed survey items and drafted/pre-tested questionnaire and obtained OMB approval in 2020. Our questionnaire was distributed in spring 2020 and data entered from a response rate of 42%. Analyses are ongoing.
PROPOSED PROJECTS FOR 2020-2021

PAUL ANGERMEIER

1. Identification of Larval Darters Collected Near Niagara Dam on Roanoke River
   PI: Paul Angermeier
   Funding: $57,400
   Source: HDR, Inc.
   Graduate students: Joe Buckwalter and Emma Hultin

2. Phenology, Distribution, and Dispersal of Larval Candy Darters in Laurel Creek, Bland County, Virginia – Phase 2
   PI: Paul Angermeier
   Funding: $97,400
   Source: Virginia Department of Wildlife Resources
   Graduate students: Emma Hultin and Joe Buckwalter

3. Improving Agricultural Sustainability Through Understanding Landowner Persistence in Best Management Practices
   PI: Paul Angermeier
   Funding: $16,500
   Source: Sustainable Agriculture Research and Education
   Graduate students: Joshua Mouser

4. Coupling Social Science and Watershed Modeling to Improve Ecological Health of Streams in Agricultural Landscapes
   PI: Paul Angermeier
   Funding: $15,000
   Source: Virginia Tech Global Change Center
   Graduate students: Joshua Mouser

5. Targeted surveys to prevent the extinction of Slender Chub *Erimystax cahni*
   PI: Paul Angermeier
   Funding: $60,000
   Source: U.S Fish and Wildlife Service
   Graduate students: Emma Hultin

W. MARK FORD

6. Handbook on Deterring and Excluding Bats from Transportation Structures
   PI: Nicole Abaid, W. Mark Ford and Michael Roan
   Funding: $500,000 (pending)
   Source: National Academy of Science
   Graduate students: Hila Taylor and TBD

7. System Assessment and Decision Support Framework for Prioritizing Climate Adaptable Restoration and Reestablishment Strategies in High-elevation Red Spruce and Eastern Hemlock Riparian Forests of the Central Appalachians
PIs: W. Mark Ford, Elizabeth Hunter, Andrew Dolloff, David Carter, Corrine Diggins and Adam Coates
Funding: $362,555 (pending)
Source: U.S. Geological Survey Northeast Climate Adaptation Center
Graduate students: TBD

8. Characterizing Deadwood in Catoctin Mountain Park and Prince William Forest Park
PIs: Adam Coates and W. Mark Ford
Funding: $39,000 (pending)
Source: National Park Service National Capitol Region
Graduate students: TBD

ELIZABETH HUNTER

9. Autonomous Recording Unit Arrays for Northern Bobwhite and Other Avian Species Population Monitoring and Density Estimation on Department of Defense Lands
PIs: Elizabeth Hunter, W. Mark Ford, Verl Emrick and Scott Klopfer
Funding: $320,219 (pending)
Source: Department of Defense ESTCP
Graduate students: TBD

10. Multi-species Habitat Management at Piedmont National Wildlife Refuge: Using Remote Sensing to Determine Habitat Requirements and Management Strategies for Bachman’s Sparrow and Northern Bobwhite in Red-cockaded Woodpecker managed habitat
PIs: Elizabeth Hunter, Carolyn Johnson, Todd Schneider
Funding: $25,000 (pending)
Source: U.S. Fish and Wildlife Service Region 4 QR
Graduate students: Cory Allred

PUBLICATIONS

Published


Diggins, C.A. 2021 Behaviors associated with vocal communication of squirrels. Ecosphere. doi.org/10.1002/ecs2.3572


**In Press**


**In Review**


BOOKS and BOOK CHAPTERS


THESES and DISSERTATIONS


PRESENTATIONS


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**Post-doctoral Researchers:** Sabrina Deeley¹, Corinne Diggins, Daniel Gibson and Sara Sweeten

**Doctoral Students:** Joe Buckwalter, Catlin Carey, Jesse De La Cruz, Samuel Freeze, Joshua Mouser and Michael St. Germain.

**Master’s Students:** Katie McBane², Katherine Gorman, Marissa Guill, Nicholas Kalen, Amber Litterer, Braiden Quinlan, Hila Taylor and Michael True

¹Now Environmental Protection Agency
²Defended 2021, now Idaho Department of Fish and Game