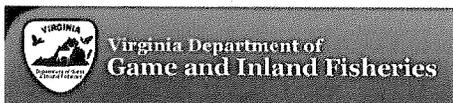


2012 – 2013 ANNUAL REPORT



COOPERATORS:

U.S. Geological Survey

Virginia Polytechnic Institute & State University

Virginia Department of Game & Inland Fisheries

Wildlife Management Institute

U.S. Fish & Wildlife Service



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COMPLETED PROJECTS

Paul L. Angermeier

I. Population ecology of variegate darter in Virginia

DURATION: Start Date: 5-15-2008 End Date: 6-30-2013

SPONSOR: Virginia Department of Mines, Minerals, and Energy (Lead PI: Angermeier)

PROJECT DESCRIPTION: The variegate darter (*Etheostoma variatum*) is endangered in Virginia. The species is known to occur in Virginia in only four streams of the Big Sandy River drainage (BSRD) in Buchanan and Dickenson counties, and has suffered population declines and range contractions due to resource extraction, non-point source pollution, and habitat alteration. Specific threats include coal mining, logging, urban development, road construction, and sewer and waterline construction.

In April 2007, CONSOL Energy installed a diffuser pipe to discharge high-chloride waste water from their Buchanan No.1 mine into Levisa Fork, Buchanan County, Virginia. The pipe will discharge >1000 gal/min; environmental impacts are expected to occur for several hundred meters downstream. Because variegate darters are known to occupy this reach, longterm monitoring is necessary to determine the effects on this species.

An important conservation tactic is to ensure that information is sufficient to accurately describe species distribution, abundance, and status and to assess current human impacts. Although some sites in the BSRD have been surveyed, additional potentially suitable sites remain unsurveyed in recent years. Furthermore, neither habitat quality nor population status for any Virginia population of VD has been rigorously assessed, and the biotic impacts of the diffuser discharge are unknown. This project will address Priority Actions 1, 3, and 4 in the variegate darter recovery plan and will establish a study design to assess biotic impacts associated with the diffuser discharge.

OBJECTIVES:

- 1) Document the geographic extent of variegate darter distribution in Virginia.
- 2) Assess the habitat suitability for variegate darter at all survey sites.
- 3) Estimate population size and age structure of variegate darter in Virginia.
- 4) Estimate genetic distinctiveness and effective population sizes of variegate darter populations in Virginia.
- 5) Develop a protocol to monitor status and trends of variegate darter in Virginia.

SUMMARY: Variegate darters (*Etheostoma variatum*) were listed as endangered in Virginia in 1992. Reasons for listing included habitat degradation and concerns about current and future impacts of coal mining throughout their Virginia range. Prior to this research, little was known about variegate darter distribution, habitat use, or populations in Virginia. Two primary goals of this research were to gain knowledge about the current population ecology and the relationship between landscape-level factors (e.g., land cover changes, watershed size, isolation from other populations) on current and past variegate darter population sizes.

We investigated distribution, habitat suitability, population genetics, and population size and structure of variegate darters in the upper Big Sandy River drainage, Buchanan, Dickenson, and Wise Co., Virginia. Our results indicate variegate darters are primarily found in the Levisa Fork, with highest densities and abundances between its confluence with Dismal Creek and the Virginia-Kentucky border. Sporadic occurrences in smaller tributaries to the Levisa and Tug forks indicate they do exist more widely in low numbers, especially near the confluence with the Tug and Levisa mainstems. Detection of variegate darters in smaller tributaries was inconsistent, with reach-level occupancy varying among years. We detected young-of-year variegate darters every year we sampled. However, age 1+ darters were indistinguishable from older darters based on standard length.

Variegate darter population size and stability in Virginia were estimated via multiple methods, including site occupancy surveys, mark-recapture studies, and population genetic analysis. Using mark-recapture methods at five sites, we estimated overall population size in 2011 to be approximately 12,800 individuals in the 35-km reach between the Levisa Fork - Dismal Creek confluence and the Virginia-Kentucky border. Age structure appeared stable, with breeding adults and young-of-year collected annually during 2008-2011. Population genetic analyses indicated that variegate darters in the Levisa Fork and its tributaries are part of a single genetic population. Historical and current genetic stability were seen in our analysis of the variegate darter population, with no genetic differentiation among riffles across the upper Levisa Fork watershed, indicating dispersal among these sites is enough to overcome random genetic drift. This population is genetically isolated from downstream variegate darter populations by the dam at Fishtrap Lake, Pike Co., Kentucky, and is beginning to show genetic isolation from other nearby populations. As expected, the Virginia population is most closely related to those in the Russell Fork and Levisa Fork downstream of the dam.

Regular monitoring of variegate darters in the Levisa Fork mainstem from the Dismal Creek confluence to the Virginia-Kentucky border would facilitate better understanding of normal fluctuations of population size and distribution, as well as assessments of population status. This reach encompasses the core of the variegate darter population in Virginia, and its persistence will determine long-term viability of this species. Given that little is known about long-term population trends, we suggest that annual site-occupancy and population size estimates be made at ten randomly selected riffles for at least ten years to understand normal levels of variability. Thereafter, these population parameters could be monitored bi-annually as a way to detect changes in distribution or abundance, especially after any fish kill or other pollution event in the Levisa Fork. We further suggest that the sites upstream and downstream of the saline diffusor pipe be monitored to detect changes in the extent of the impact zone. Overall, the variegate darter population in Virginia appears stable, although primarily confined to the lower 35 km of the Levisa Fork. Nevertheless, variegate darters in Virginia do remain susceptible to extirpation due to catastrophic events, both physical (chemical spill) and biological (disease outbreak or invasive species introduction).

2. Spatial analysis of relations among conservation practices, aquatic ecosystem services, and human well-being in the Albemarle-Pamlico basin.

DURATION: Start Date: 8-31-2009

End Date: 9-30-2012

SPONSOR: U.S. Geological Survey (Lead PI: Angermeier)

PROJECT DESCRIPTION: Recent work shows that conservation can affect the flow of ecosystem services (ES), which suggests that conservation can be enhanced by protecting services that exhibit synergies with conservation. Effective management of biodiversity and ecosystem services requires some understanding of the spatio-temporal distribution of the services themselves, their benefit to humans, and the total value of landscapes under alternative management scenarios. We began to document, map, and quantify linkages among conservation practices, ecosystem services, and human well-being (HWB) in the Albemarle-Pamlico basin (APB) of Virginia and North Carolina.

Our goal was to develop a framework for conceptualizing, mapping, quantifying, and valuing services provided by aquatic ecosystems; communicate the framework to stakeholders; and apply the framework to a pilot ecosystem. We want the framework to highlight linkages among freshwater biodiversity, ecosystem services, human well-being, and common management scenarios. We used 4 focal services (water supply, water purification, nitrogen regulation, and wildlife-based recreation) to illustrate patterns.

OBJECTIVES: The work comprises four main objectives:

1. Develop tools and methods for analyzing spatial relations of conservation actions, selected ES, and HWB.
2. Conduct analyses of spatial relations for and among selected ES and HWB.
3. Evaluate influences of conservation actions on ES capacity, ES flow, and HWB.
4. Produce maps, tools, and findings useful to stakeholders and managers in achieving conservation goals.

SUMMARY: Developing novel frameworks for understanding, assessing, and mapping the condition of ecosystem services (ES) have been primary scientists interested in using ES to guide conservation planning. ES are important to conservation because they link ecosystems and their associated biota to anthropocentric values. ES provide new currencies (some still unexplored) for understanding the spatiotemporal structure and social tradeoffs associated with natural resource management. Over the past decade there have been numerous studies that have focused on creating ES inventories and conducting economic valuations, however the methods employed vary dramatically. To advance our understanding of ES and our ability to create accurate ES inventories to guide current and future natural resource and land use decisions, we have focused our attention on enhancing existing ES conceptual frameworks, improving methods for assessing the condition of ES, and expanding the spatial toolbox for mapping ES. We first created a guidance framework that outlines the core elements of ES benefit delivery: the production of a service, the demand for the service, the ecological pressures (both natural and anthropogenic) on the service, and the delivery of service benefits to beneficiaries across the landscape. We then developed conceptual models that illustrate the ecosystem properties and processes that come together to produce ES and developed various techniques for quantifying and mapping ecological pressures, societal demand, and service flow. We used conceptual models to identify existing frameworks or, where needed, to create new analytical frameworks (e.g. non-spatial and spatial equations and models) for quantifying the capacity of ecosystems to generate service. We developed a suite of spatial tools in ArcGIS (*version 10.0*) that automate geoprocessing and mapping of ES capacity based on user-defined inputs and developed a novel approach to measuring the flow of regulating service benefits without considering estimates of the final service produced. We have largely focused on a suite of 5 ecosystem services including: surface water production; sediment retention; riparian filtration; ground water protection; wildlife-based recreation, including bird watching and freshwater recreational fishing. This paper provides an overview of the progress made during a 3-year study of ES in the Albemarle-Pamlico basin. We describe the development of a comprehensive ES delivery framework that distinguishes among

different categories of ES (e.g. regulating), conceptual models for ES capacity, quantitative and mapping approaches for capacity and flow, and the development of ArcGIS tools to simplify and standardize mapping efforts.

3. Bayesian population dynamics modeling to guide population restoration and recovery of endangered mussels in the Clinch and Powell Rivers, Tennessee and Virginia.

DURATION: Start Date: 1-1-2010

End Date: 8-15-2012

SPONSOR: United States Geological Survey (Lead PI: Jiao)

PROJECT DESCRIPTION: The Clinch and Powell rivers upstream of Norris reservoir contain a highly diverse mussel assemblage including 16 endangered species, which is the highest concentration of federally listed mussel taxa in the Appalachian region. Quantitative approaches and criteria have not been rigorously developed or applied to monitor and evaluate success. Hence, population dynamics modeling is needed to identify critical metrics and criteria to quantitatively evaluate these populations. Bayesian population dynamics models were developed to provide a coherent framework to incorporate all of the current population density, length composition data and expert knowledge on freshwater mussels, allowing for robust estimates of parameter uncertainty, and enabling results to be used directly in risk analyses of alternative management strategies.

OBJECTIVES: The objectives are as follows: (1) to develop a Bayesian approach for estimating vital population dynamics parameters by incorporating data collected from different sources and prior knowledge of populations derived from previous studies (ecological studies, scientists' experience and observations); (2) to develop Bayesian statistical models to investigate mussel population dynamics; (3) to evaluate the population dynamics and current status of the examples populations used in this study; and (4) to develop a decision-making framework for risk analyses of alternative management strategies, to advise natural resource agencies.

SUMMARY: Freshwater mussels have played an important role in the history of human culture and also in ecosystem functioning. But during the past several decades, the abundance and diversity of mussel species has declined all over the world. To address the urgent need to maintain and restore populations of endangered freshwater mussels, quantitative population dynamics modeling is needed to evaluate population status and guide the management of endangered freshwater mussels. One endangered mussel species, the oyster mussel (*Epioblasma capsaeformis*), was selected to study its population dynamics for my research. The analysis was based on two datasets, length frequency data from annual surveys conducted at three sites in Clinch River: Wallen Bend (Clinch River Mile 192) from 2004-2010, Frost Ford (CRM 182) from 2005 to 2010 and Swan Island (CRM 172) from 2005 to 2010, and age-length data based on shell thin-sections. Three hypothetical scenarios were assumed in model estimations: (1) constant natural mortality; (2) one constant natural mortality rate for young mussels and another one for adult mussels; (3) age-specific natural mortality. A Bayesian approach was used to analyze the age-structured models and a Bayesian model averaging approach was applied to average the results by weighting each model using the deviance information criterion (DIC). A risk assessment was conducted to evaluate alternative restoration strategies for *E. capsaeformis*. The results indicated that releasing adult mussels was the quickest way to increase mussel population size and increasing survival and fertility of young mussels was a suitable way to restore mussel populations in the long term. The population of *E. capsaeformis* at Frost Ford had a lower risk of decline compared with the populations at Wallen Bend and Swan Island.

Passive integrated transponder (PIT) tags were applied in my fieldwork to monitor the translocation efficiency of *E. capsaeformis* and *Actinonaias pectorosa* at Cleveland Islands (CRM 270.8). Hierarchical Bayesian models were developed to address the individual variability and sex-related differences in growth. In model selection, the model considering individual variability and sex-related differences (if a species has sexual dimorphism) yielded the lowest DIC value. The results from the best model showed that the mean asymptotic length and mean growth rate of female *E. capsaeformis* were 45.34 mm and 0.279, which were higher than values estimated for males (42.09 mm and 0.216). The mean asymptotic length and mean growth rate for *A. pectorosa* were 104.2 mm and 0.063, respectively.

To test for the existence of individual and sex-related variability in survival and recapture rates, Bayesian models were developed to address the variability in the analysis of the mark-recapture data of *E. capsaeformis* and *A. pectorosa*. DIC was used to compare different models. The median survival rates of male *E. capsaeformis*, female *E. capsaeformis* and *A. pectorosa* were high (>87%, >74% and >91%), indicating that the habitat at Cleveland Islands was suitable for these two mussel species within this survey duration. In addition, the median recapture rates for *E. capsaeformis* and *A. pectorosa* were >93% and >96%, indicating that the PIT tag technique provided an efficient monitoring approach. According to model comparison results, the non-hierarchical model or the model with sex-related differences (if a species is sexually dimorphic) in survival rate was suggested for analyzing mark-recapture data when sample sizes are small.

4. Biological monitoring and geomorphological characterization for the USGS Eastern Region Initiative on the Clinch

DURATION: Start Date: 7-31-2009

End Date: 8-30-2012

SPONSOR: U.S. Geological Survey (Lead PI: Ostby)

PROJECT DESCRIPTION: This project was a piece of a larger USGS project to provide a basic foundation of hydrologic, biological, and geographic data collection, summary, and evaluation on the Clinch River to support process-level studies of ecosystem response to stress in response to changes in land use, energy extraction practices and climate. The USGS water science centers in TN and VA monitored water quality and geomorphology within the basin, while the Missouri and Virginia Coop Units completed toxicology studies and population studies respectively.

OBJECTIVES: River discharge, water quality, sediment quality, and juvenile mussel survival were evaluated for three years at two primary monitoring sites and at ~8 other locations.

SUMMARY: Findings from this project are summarized in a paper accepted for publication in Journal of the American Water Resources Association, pending revisions. The abstract of that paper follows.

Several hypotheses have been posed to explain extreme spatiotemporal variation of mollusk assemblages in the Clinch River, including habitat degradation and variation in fluvial geomorphology. Here we examined associations between mollusk assemblage metrics (e.g. richness, abundance, recruitment) and physical habitat (geomorphology, stream bed composition, fish habitat, and riparian condition) at 10 sites selected to represent the range of current assemblage condition. We compared similar geomorphological units among reaches, employing semi-quantitative and quantitative protocols to characterize mollusk assemblages and a mix of visual assessments and empirical measurements to characterize physical habitat. We found little to no evidence that current assemblage condition was associated with 54 analyzed habitat metrics;

only an association between assemblage quality and stream flow direction was strongly supported ($p = 0.015$). When compared to other sites in the Upper Tennessee River Basin (UTRB), Clinch River sites were more similar to each other, representing a narrower range of conditions than observed across a larger geographic extent. A post-hoc analysis suggested stream size and bankfull shear stress may have historically limited species richness in the UTRB ($p < 0.001$). Associations between mollusk assemblages and physical habitat may be obscured by other factors currently limiting richness, abundance and recruitment.

5. An evaluation of freshwater mussel body burdens following in situ exposure to contaminants in Clinch River

DURATION: Start Date: 8-15-2011 End Date: 8-31-2012

SPONSOR: U.S. Geological Survey (Lead PI: Ostby)

PROJECT DESCRIPTION: This project was a piece of a larger USGS project to examine causes of mussel decline in the Clinch River. The USGS evaluated suitability of river flow and water and sediment quality relative to survival of juvenile mussels at several sites in VA and TN. Preliminary data suggested that metal contamination impaired mussel survival, so this project took a more mechanistic look at contaminant uptake relative to individual mussel health and survival.

OBJECTIVES: Main objectives included 1) measure concentrations of selected contaminants in juvenile mussel tissue at degraded and healthy sites, 2) compare tissue concentrations to those in ambient water and sediment and to published toxicity criteria, and 3) disseminate findings to managers concerned with mussel conservation.

SUMMARY: Five continuous water-quality monitors were operated on the mainstem Clinch River and two tributaries. Concurrent, discrete water-quality samples were collected during base-flow and storm-flow conditions at two sites on the Clinch River and on the Guest River, a major tributary flowing off the Appalachian Plateaus physiographic province. Synoptic water-quality samples were collected in July and August 2011 at 15 sites along the mainstem Clinch River. Other analyses included longitudinal sampling along the mainstem of the Clinch River at ten sites for bed-sediment chemistry, habitat condition, and biological status. In situ freshwater mussel growth and mortality experiments were conducted with hatchery-propagated *Villosa iris* (rainbow mussels). Tissue from the *V. iris* as well as tissue from 16 *Actinonaias pectorosa* mussels were analyzed for trace metals and *V. iris* mussel tissue was analyzed for organic compounds. Data collected during this investigation were analyzed by various USGS or US Fish and Wildlife Service laboratories. We deployed hatchery-propagated juvenile *Villosa iris* in mussel silos to 2 reaches supporting high quality mussel assemblages and 2 reaches supporting low quality mussel assemblages. Over the 18 month study, survival did not vary among sites, but differences in growth positively corresponded with water temperature. Almost half of the 25 metal concentrations measured were lower at the high quality site with the richest and densest assemblage, however that site had higher arsenic (As) antimony (Sb) and tin (Sn) concentrations. Compared to control juveniles held at the hatchery where they were propagated, bioaccumulation of most metals (15 out of 25 constituents) in *V. iris* in all Clinch River reaches was greater.

6. Stream surveys for *Villosa perpurpurea* and other native mussels in Beech Creek, Hawkins County, Tennessee

DURATION: Start Date: 2-1-2012 End Date: 12-31-2012

SPONSOR: U.S. Fish and Wildlife Service (Lead PI: Ostby)

PROJECT DESCRIPTION: The purple bean (*Villosa perpurpurea*) is a federally endangered species. Of the 4 known populations, the status of the Beech Creek (Hawkins County, TN) population is least understood. As part of a status review, the U. S. Fish and Wildlife Service (USFWS) wanted Beech Creek surveyed for mussels to quantify any change in the number of sites occupied by *V. perpurpurea*. *Villosa perpurpurea* is more difficult to detect than most species. However, when it is gravid in late winter and early spring, it is more easily detected, because it is at the stream bottom surface. As the most scientifically defensible and powerful method, our surveys used semi-quantitative and occupancy modeling approaches.

OBJECTIVES: Primary objectives were 1) Survey the mussel fauna of Beech Creek to provide data that can be compared to previous surveys and 2) Conduct a comprehensive survey that will provide defensible occupancy estimates for the purple bean in Beech Creek.

SUMMARY: Beech Creek (Hawkins County, Tennessee) harbors one of only four remaining populations of the federally endangered purple bean (*Villosa perpurpurea*). Detection rates for this small, cryptic species appear limited compared to co-occurring species and vary seasonally—improving in late winter and early spring when females are most often gravid. Moreover, this species can be locally rare. Thus, it is difficult to distinguish between true absence and failure to detect. We wedded semi-quantitative surveys and occupancy approaches in a study designed to 1) explicitly parameterize detection rates, 2) approximate site occupancy with better confidence, and 3) compare results to timed qualitative searches conducted 11 years earlier. Over the course of 4 sampling occasions (occurring in February, March, April and June), a total of 29 sites were surveyed at least once. Among all sites initially surveyed, we observed 135 individuals of purple bean representing 5.86% of the mussel fauna. There was no evidence to suggest that catch-per-unit effort for purple bean differed between 2001 and 2012. Likewise, the overall proportion of sites occupied by purple bean in 2001 (65%) and resampled in 2012 were comparable, though the spatial distribution had shifted. Detection was highest during February and March with mean time to initial detection (TID) at 0.67 person hours. Detection decreased through April to June with mean TID at 2.5 person hours among sites. We are currently comparing competing models using program PRESENCE that use covariates (e.g. % habitat scores, weather, flow, date) to better approximate site occupancy and detection probability.

7. Semi-quantitative freshwater mussel surveys in the Wards Creek, Rocky Creek, Buck Mountain Creek, and Swift Run sub-watersheds of the Rivanna River

DURATION: Start Date: 9-1-2011

End Date: 8-31-2012

SPONSOR: The Nature Conservancy (Lead PI: Ostby)

PROJECT DESCRIPTION: This project provided information on the presence and relative abundance of freshwater mussels in the Wards Creek, Rocky Creek, Buck Mountain Creek and Swift Run reaches of the Rivanna River watershed. This information will assist The Nature Conservancy's development of management recommendations, especially regarding effects of flow on occupied habitats. The distributions of habitat types and the occupancy of those habitats by mussels is critical information for their assessments.

OBJECTIVES: Main objectives included 1) Conduct stream-wide habitat assessments to inform site selection for mussel surveys, 2) Conduct semi-quantitative surveys for mussels at selected sites, and 3) Describe habitat conditions in the surveyed reaches.

SUMMARY: This project was intended to inform TNC's management recommendations and provide management agencies with recent status information on the federally endangered *Pleurobema collina*. Because we had limited *a priori* knowledge about mussel assemblages in these streams, we worked with TNC to pursue an adaptive approach in the design and execution of this study, which explicitly acknowledged limited detection rates and assumed low abundance. Ultimately, we conducted semi-quantitative searches over 30 km of instream habitat for evidence of freshwater mussels, used visual assessment tools to gage stream condition, and provided baseline data for monitoring mussel assemblages in reaches both inhabited by *P. collina* and supporting high-density assemblages. All surveyed streams were occupied by the federally endangered *P. collina*. We observed this species in 21.4% of surveyed reaches. Based on the number of reaches occupied and the number shells and live individuals observed during semi-quantitative efforts, Rocky Creek and the upstream reaches of Swift Run appeared to support the largest populations of *P. collina*. Most surveyed/assessed stream reaches flowed through minimally disturbed, forested riparian corridors, however visual assessment scores suggest instream habitat is considerably disturbed. Embeddedness and sediment deposition scores were low. The degree of incision, dominance of sand in the stream bed and the presence of sand bars in many reaches suggest these streams transport large volumes of fine sediments. We observed only a few signs of recent erosion or obvious sources of sediment in surround landscapes. It is possible that higher fine sediment loads and incised channels are the result of past land use ranging from intensive agriculture to timber harvest. Many of these degraded habitats supported *P. collina*, suggesting visual habitat rubrics may not be good predictors of mussel presence and that factors other than physical habitat degradation may affect distribution.

OTHER FACULTY COOPERATORS

Sarah Karpanty and James Fraser

I. *Assessing the responses of breeding shorebirds to military jet overflights of the Core MOA at Cape Lookout National Seashore*

DURATION: Start Date: 08/09 End Date: 07/13

SPONSOR: U.S. Marine Corps, Cherry Point Air Station

PROJECT DESCRIPTION: The U.S. Marine Corps and the National Park Service (NPS) have recently agreed to lower the floor for tactical speed operations (>250 kts) in the Core Military Operations Area (Core MOA, Figure 1) over Cape Lookout National Seashore (CALO) from 10,000 ft to 3,000 ft above ground level. The Core MOA allows high speed (> 250 knots) ingress/egress over a portion of CALO. A conservation question emanating from this change is whether the change could increase the disturbance of nesting shorebirds. In particular, the NPS is interested in understanding the effects on state- and local-listed nesting shorebirds, including the American Oystercatcher (*Haematopus palliatus*), Least Tern (*Sternula antillarum*), Common Tern (*Sterna hirundo*), Black Skimmer (*Rynchops niger*), and Wilson's Plover (*Charadrius wilsonia*) which are all listed as Species of Special Concern in North Carolina, and the Gull-Billed Tern (*Gelochelidon nilotica*) which is listed as threatened in North Carolina and is a species of low population size and conservation concern according to the National Audubon Society Watchlist. This interest in studying the potential effects of aircraft overflights on these

nesting shorebird species arises from NPS Management Policy 4.4.2.3. Additionally, the NPS is mandated to protect wildlife (Migratory Bird Treaty Act), ensure wilderness values, comply with NEPA, and comply with Public Law 100-91 "National Parks Overflights Act." To address these statutory responsibilities related to the Core MOA, the NPS proposes the need to study the effects of reducing the overflight floor from 10,000 to 3,000 ft on nesting shorebirds at Cape Lookout National Seashore.

OBJECTIVES: 1) To determine if military overflights through the Core MOA over CALO change the behavior and/or demography of nesting American Oystercatchers, Least Terns, Common Terns, Black Skimmers, Wilson's Plovers, and Gull-Billed Terns; 2) to attempt to place any potential behavioral- and demographic-level responses of the previously named nesting shorebirds to Core MOA military overflights in the context of other natural and anthropogenic disturbance factors, including but not limited to, natural and feral predators, off-road vehicles, foot-traffic, and non-military aircraft; and 3) to conduct our research in a manner as to maximize the application of our data to the varied management needs of the NPS, U.S. Marine Corps

PROGRESS: Two master's students have completed their studies on this project. all field work is completed. Two articles have been accepted in refereed journals, and additional articles are in preparation. Students Completed: Audrey Derose Wilson 2012. Demography, Nest Site Selection, and Physiological and Behavioral Responses to Overflights and Other Human Activities by Wilson's Plover (*Charadrius wilsonia*) at Cape Lookout National Seashore, North Carolina. M.S. Thesis, Virginia Tech Matthew Dean Hillman, 2012. Evaluating the Impacts of Military and Civilian Overflights and Human Recreation on Least Terns, Common Terns, Gull-billed Terns, and Black Skimmers at Cape Lookout National Seashore, North Carolina. M.S. Thesis, Virginia Tech.

Emmanuel Frimpong

1. Preliminary Application of a framework for modeling habitat suitability and distribution of stream fishes with field testing

DURATION: Start Date: 06/12

End Date: 6/13

SPONSOR: U.S. Geological Survey Aquatic Gap Analysis Program

PROJECT DESCRIPTION:

Current species distribution models used in the aquatic gap analysis and conservation decisions are based on presence-only data because of the pervasive lack of true absence in available databases. The goal of this project was to develop high resolution distribution maps for representative species in the New River basin by utilizing historical fish presence data available in atlases and deriving absences based on meta-community theory for presence-absence models.

OBJECTIVES:

- 1) To develop models for 11 freshwater and one diadromous fish species of the New River basin for predictive mapping.

PROGRESS:

Based on the area under the receiver operating characteristic curves (AUC), gradient boosted trees and Bayesian hierarchical models outperformed random forests and maximum entropy in 10-fold cross validation and independent field validations. Thus the species distribution modeling approach deriving presence-absence data from historical presence-only data and metacommunity

theory is superior to the presence-only approach that emphasizes maximum entropy. The most important habitat variables explaining the distribution of fishes included Basin flow index (C_BFI), Minimum January temperature (C_Min01 Tem), Road density (C_RoadLen), and Latitude (reflecting physiography). Higher resolution maps at the resolution of NHD+v2 were created based on boosted regression trees and the maps so created form the template for future work that is intended to scale up the distribution map development effort initially at the regional scale and ultimately at the national scale to cover all freshwater and diadromous fish species of the United States

CURRENT PROJECTS

Paul L. Angermeier

1. Assessing post-construction impacts of the Roanoke River Flood Reduction Project on the endangered Roanoke logperch

DURATION: Start Date: 7-16-2012 End Date: 3-31-2015

SPONSOR: U.S. Army Corps of Engineers (Lead PI: Roberts)

PROJECT DESCRIPTION: The United States Army Corps of Engineers (USACE) partnered with the City of Roanoke to complete the Roanoke River Flood Reduction Project (RRFRP), a suite of channel modifications. The United States Fish and Wildlife Service (USFWS) has required USACE to monitor populations of the federally endangered Roanoke logperch (*Percina rex*) prior to (Phase A), during (Phase B), and after (Phase C) construction to estimate effects of incidental take during the course of the project. The USACE contracted with the U.S. Geological Survey and the Virginia Cooperative Fish and Wildlife Research Unit to conduct Phase-A monitoring during 1997-2003 and 2005 and Phase-B monitoring during 2006-2011. Construction for RRFRP was completed in spring 2012. The primary purpose of this work is to perform Phase-C monitoring during 2012-2014.

OBJECTIVES: The goal of the research is to determine the effects of the RRFRP on the population density and availability of suitable habitat of Roanoke logperch within the construction-affected reach. Primary study objectives are to: (1) estimate population density and distribution of Age-1+ Roanoke logperch in the RRFRP construction reach (CR) and in a reference reach (RR), (2) estimate population density and distribution of Age-0 logperch in CR and RR, (3) identify, map, and quantify the availability and distribution of habitat suitable for Age-1+ logperch in CR and RR, (4) identify and quantify the availability and distribution of habitat suitable for Age-0 logperch in CR and RR, (5) assess the suitability of water quality conditions in CR and RR, and (6) assess compliance of RRFRP with its incidental take permit. Secondary study objectives are to explore logperch population dynamics and identify key factors driving those dynamics.

PROGRESS: Monitoring of Roanoke logperch in the Roanoke River for the Roanoke River Flood Reduction Project (RRFRP) continued in 2012. Twelve permanent monitoring sites were sampled using electrofishing methods in the summer and fall, and nine sites were visually surveyed for young-of-the-year (YOY) logperch. In addition to standard monitoring, we investigated spatial and temporal trends of Age-1+ logperch abundance and density, while accounting for imperfect detection of individuals. Our findings demonstrated that both detection

of individuals and Roanoke logperch abundance varied dramatically over the course of the study (i.e., 1997 to 2012). Despite the substantial fluctuation in both abundance and detection, we found no statistical evidence for an impact of RRFPP construction.

The initial summer fieldwork for 2013 is in progress but has been delayed by the unusually wet July. Anecdotal observations indicate that the wet spring and summer have resulted in late spawning and weak logperch recruitment.

2. Habitat suitability for Roanoke logperch near Philpott Reservoir

DURATION: Start Date: 7-1-2012 End Date: 9-30-2013

SPONSOR: US Army Corps of Engineers (Lead PI: Roberts)

PROJECT DESCRIPTION: The entire known range of the endangered Roanoke logperch (*Percina rex*) comprises 4 disjunct areas in Virginia, including the Smith River drainage. Developing an effective conservation strategy requires accurate knowledge of the species' distribution and abundance. The U.S. Army Corps of Engineers (USACE) is responsible for protecting and recovering logperch associated with their water projects, including Philpott Reservoir on Smith River. In particular, the USACE must survey their waters for logperch and suitable habitat, and monitor and manage populations therein. Roanoke logperch were recently discovered to be relatively common throughout Smith River upstream of Philpott Reservoir. Additional surveys are warranted to monitor logperch abundance and to assess habitat suitability.

OBJECTIVES: Project objectives are as follows: 1) estimate population density and distribution of Age-1+ Roanoke logperch in the project area; 2) measure and map, by suitability class, the distribution of habitat suitable for Roanoke logperch in the project area; 3) assess water quality relative to Roanoke logperch habitat in the project area; 4) use the data on logperch abundance, habitat suitability, and water quality to test the general validity of correlates of logperch abundance from other locations; 5) identify opportunities and threats related to protecting and enhancing Roanoke logperch habitat; and, 6) provide recommendations on the necessity and scale of future studies and monitoring related to logperch in and near USACE waters.

PROGRESS: Sampling protocols will follow prior monitoring for logperch near Philpott Reservoir. Fieldwork will begin in September 2012.

3. Population viability analysis for Roanoke logperch

DURATION: Start Date: 9/2012 End Date: 3/2014

SPONSOR: US Fish and Wildlife Service (Lead PI: Roberts)

PROJECT DESCRIPTION: Assessing the conservation status and recovery progress of Roanoke logperch requires knowledge of the minimum viable population size (MVP) necessary to confer a low probability of extinction, and whether or not populations exceed this threshold. No MVP threshold has been estimated for logperch, which complicates managers' assessments of recovery progress and of how viability might change as a result of potentially harmful (e.g., pollution spills) or beneficial (e.g., habitat restoration) actions. We will conduct a population viability analysis (PVA) on Roanoke logperch. PVA is a simulation modeling framework used to project the effects of life-history, demographic, genetic, and environmental factors on population persistence and illustrate important uncertainties and sensitivities about these relationships. PVA

models require the input of life-history and demographic parameters such as fecundity and survival rate. We will estimate these parameters using published and unpublished data for logperch, borrowing information from surrogate species as necessary.

OBJECTIVES: Main objectives are to 1) use simulation models to assess viability of populations of Roanoke logperch and 2) evaluate the potential effects on viability of alternative management strategies.

PROGRESS: We plan to conduct simulations in the software package Vortex. Models will require various input parameters, including demographic rates and genetic statistics. To this end, we have begun to compile available biological and genetic information for Roanoke logperch and acceptable surrogate species. Model building, refinement, and analysis will be conducted primarily during fall 2013, and the final report will be written primarily during winter-spring 2014.

4. Comparison of habitat suitability among sites supporting strong, localized, and extirpated populations of candy darters (*Etheostoma osburni*).

DURATION: Start Date: 7/2012 End Date: 8/2013

SPONSOR: Virginia Department of Game and Inland Fisheries (Lead PI: Dunn)

PROJECT DESCRIPTION: The candy darter (*Etheostoma osburni*) has been extirpated from much of its former range. Protecting remaining *E. osburni* populations or creating new ones will become increasingly important as threats increase. Effective protection of extant candy darter populations and potential translocation to create more populations require basic understanding of habitat suitability. To date, however, habitat suitability and availability have received little study. While the loss of *E. osburni* populations in Virginia is a concern, it creates an opportunity to compare streams that vary in their ability to support *E. osburni*.

OBJECTIVES: The overall goal of the work is to better understand the specific habitat needs of *E. osburni*. The specific objectives are to: (1) develop habitat suitability models based on streams with strong populations of *E. osburni*, (2) compare suitability to habitat availability in streams where *E. osburni* is rare or extirpated, and (3) compare seasonal temperatures among streams, as water temperature has been implicated as a possible limiting factor for *E. osburni* survival.

PROGRESS: The final report is in preparation; main findings are summarized below. Candy darters exhibit habitat specialization at multiple spatial scales. At a small spatial scale, age-0 candy darters occupied slower moving areas of streams and gradually shifted habitat until almost exclusively occupying the swiftest stream flows available as adults. Using this information, we developed models to identify streams suitable for the reintroduction candy darters. We implemented these models in streams that currently or formerly supported populations. Models showed streams that currently support candy darters, also contained more suitable instream habitat relative to a stream where the species was extirpated.

At a landscape spatial scale and across the species range, we found significant differences between places where the species is present or absent. Using targeted methods, we successfully collected candy darters in 16 streams across the New River drainage, including the discovery of a new population. However, we failed to collect candy darters in 12 streams, including seven streams with historical populations. Given the high efficacy of our methods, this indicates the species has declined over the last half-century. In both studies, streams where candy darters

persist have fewer fine sediments, and in the second study, had cooler stream temperatures across all seasons.

Due to the correlative nature of these studies, these patterns cannot be definitely linked to the growth and fitness; however, warmer stream temperatures and increases in fine sediments have been linked to certain land use practices and declines of more-widely studied species in the area. These early efforts should help guide future studies to aim beyond occupancy and to mechanistically link these patterns to the population dynamics of the species. In the wake of declining populations and uncertainty surrounding future climate projections, managers could use this information to focus efforts to improve stream habitat and potentially reestablish former populations.

5. Assessment of the distribution and degree of introgression of Roanoke Bass populations in Virginia

DURATION: Start Date: 1/2013

End Date: 12/2014

SPONSOR: Virginia Department of Game and Inland Fisheries (Lead PI: Roberts)

PROJECT DESCRIPTION: The geographic distribution of Roanoke bass has decreased sharply over the past few decades; where it persists, the genome is widely introgressed with rock bass, as introduced congener. Little is known about the extent, size, and genetic quality of Roanoke populations in Virginia. This project aims to collect basic information on population ecology and genetics of Roanoke bass to aid fish managers in developing conservation plan.

OBJECTIVES: The objectives of this study are to 1) make field collections of *Ambloplites* specimens throughout the historical native range of Roanoke bass, 2) assess the degree of hybridization between Roanoke bass and invasive rock bass (*Ambloplites rupestris*) based on a laboratory analysis of meristic and morphometric characters, and 3) assess the degree of genetic introgression between Roanoke and rock bass based on a genetic analysis of DNA markers.

PROGRESS: Jamie Roberts (postdoctoral associate) is being assisted by Brandon Plunkett and Devon Kessler, two Virginia Tech undergraduate students. Several field collections have been made, including some coordinated with fish biologists from the NC Wildlife Resources Commission. We have collected bass from approximately one-third of the watersheds that are intended to be sampled. The remaining watersheds will be sampled in summer-fall 2013. Students have begun analyzing meristic and morphometric characters on collected specimens. During fall 2013, we will send bass DNA samples to a laboratory to have genetic markers developed, and then begin screening DNA samples for genetic variation and evidence for introgression. Laboratory work for this project will be completed by summer 2014 and the final report will be completed during fall 2014.

6. Endangered fish surveys for the Virginia Department of Transportation

DURATION: Start Date: 9-13-1990

End Date: 6-30-2014

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.

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

PROGRESS: Two surveys (Waqua Creek, Sturgeon Creek) were conducted in 2012, two (Abrams Creek, North Fork Holston River) have been approved for 2013, and four more are in review.

7. Development and assessment of tools for evaluating stream fish community responses to climate change along thermal gradients

DURATION: Start Date: 8/2010 End Date: 9/2013

SPONSOR: U.S. Forest Service (Lead PI: Villamagna)

PROJECT DESCRIPTION: This project is part of a collaboration between several USGS and USFS scientists to examine effects of climate change on stream-fish communities and aquatic ecosystem services (AES), including effects via altered temperature, water-flow, and habitat regimes. The study will use existing data on climate projections, land cover, hydrology, hydrography, topography, and fish-habitat associations to model spatiotemporal changes in fish-community composition and the ability of watersheds to deliver selected ecosystem services. We will compare findings from two study basins: the upper Chattahoochee River (UCR) and the upper Roanoke River (URR). The work in the Virginia Unit will focus on mapping and analyzing AES. Focal AES include surface water supply, water purification, and water temperature regulation. This project provides partial support for Beatriz Mogollon (new MS student).

OBJECTIVES: Specific objectives are: 1) estimate and map capacity and flow for each focal AES across watersheds within the study basins; 2) assess long-term sustainability of current AES delivery in the study basins; 3) work with stakeholders to develop and map plausible future scenarios of AES delivery, for use in conservation planning and land/water use decisions in the study basins.

PROGRESS: Air and stream temperature data have been continuously sampled on a total of 50 streams in the Roanoke River and Chattahoochee River basins (n=28, n=22, respectively). During seasonal visits to sites, we have collected stream flow and water chemistry samples that will be used to estimate seasonal nitrogen loading. Stream temperature sensitivity to air temperature has been modeled statistically for 2011 and 2012 data and preliminary analyses have been conducted for other seasons. In addition, site-based watersheds have been delineated and a geo-database of watershed and site characteristics has been developed. The geo-database comprises a suite of potential explanatory factors that will be used in further statistical analysis of stream temperature regulation in the study basins. Preliminary results will be presented at the Mountain Stream Symposium at James Madison University in September 2013. The 3-year stream temperature monitoring for this project is scheduled to be completed in September 2013 for the Roanoke River study sites and March 2014 for the Chattahoochee River study sites, after which 2011 and 2012 summer air-stream sensitivities will be compared and analyzed in concert with geophysical explanatory factors.

8. Evaluating air-water temperature linkages in Shenandoah National Park streams

DURATION: Start Date: 3/2012 End Date: 9/2013

SPONSOR: U.S. Geological Survey (Lead PI: Villamagna)

PROJECT DESCRIPTION: Stream temperature is one of the most important habitat characteristics for stream fishes, and each species has specific thermal tolerance limits for spawning, development, and survival. Several recent studies have reviewed factors affecting the thermal regime of rivers and these include topography (moderated by aspect, topographic shading), vegetation cover (tree canopy shading), local atmospheric conditions (solar radiation, air temperature, wind speed, evaporation), stream discharge, and surface water and stream bed heat exchanges (including evaporation and groundwater inputs). Many of these characteristics can be assessed spatially using readily available data and geographic information systems (GIS) modeling. For example, topographic attributes derived from digital elevation models can be used to model topographic shading, aspect, and air temperature lapse rates due to elevation. The goal of this research is to apply GIS and statistical modeling techniques to identify the spatial structure of air-water temperature relationships within Shenandoah National Park. We hypothesize that (a) stream temperatures will exhibit non-uniform spatial relationships to air temperatures and (b) these relationships will be influenced by geophysical features of the stream such as valley form and aspect. To evaluate these hypotheses, models will be developed from empirical temperature measurements during periods of summer maximum temperatures.

OBJECTIVES: The three objectives of this study were to 1) to predict air temperature at sites where it was not measured, 2) assess the relationship between mean daily air temperature and mean daily water temperature for each site using linear regression, and 3) model the influence of landscape factors on the air-water temperature relationships (i.e., regression slopes).

PROGRESS: Stream and air temperature data were collected during the summer of 2012 (May – September) from which air-water sensitivity analyses were conducted. We installed HOBO temperature loggers at 80 stream sites in nine watersheds. We found substantial variation among air-water temperature relationships (i.e., linear regression slopes) among the 79 sites in SHEN. Air-water temperature relationships ranged from very weak at some sites to very strong at others. We also found that the magnitude of air-water temperature regression slopes were highly variable within individual watersheds. Moreover, sites with particularly strong or particularly weak air-water temperature relationships showed no consistent relationship with basin area or geology. Vegetation class, aspect, percent granitic bedrock, percent basaltic bedrock, total solar radiation at the site, and terrain shape - planform curvature were found to be the most influential predictor variables for summer 2012, but their influence varied between sites with weak versus strong air-water relationships.

9. Regulating services as measures of ecological resilience on DoD lands

DURATION: Start Date: 5/2011

End Date: 1/2014

SPONSOR: U.S. Department of Defense, ESTCP (Lead PI: Angermeier)

PROJECT DESCRIPTION: This project will demonstrate the utility of using information on aquatic ecosystem services (AES) in land-use planning on two military bases (Fort Pickett, VA and Cherry Point, NC). Our overall objective is to provide the Department of Defense (DoD) with clearer insight into the current and future provision of AES germane to environmental constraints, including imperiled species, water quality, and urban encroachment. The ecological resilience provided by AES may be important when planning land uses, whether for environmental stewardship or military training. Spatially explicit knowledge of AES capacity and flow can help DoD land managers make planning decisions that enhance cost-effectiveness, minimize

environmental damage, and maximize the resources available for their military mission. Land-use choices by the DoD must be made in the context of dynamic demographic, land-use, and climatic conditions on adjacent lands, which ultimately regulate AES capacity and flow. These dynamics can be depicted in future scenarios that enable land managers to plan more effectively for environmental conflicts. We will identify areas a) with high and low ecological resilience based on water purification (i.e. sediment and nutrient regulation) and water regulation (i.e. flood and drought modulation) capacity and b) likely to be affected by changes to precipitation and sediment and nutrient transport regimes as well as sea-level rise.

OBJECTIVES: Our specific technical objectives are to 1) estimate current capacity of and demand for selected AES within DoD lands, 2) forecast the effects of future DoD land use (i.e. planned military and environmental operations) and climate changes on the capacity of these AES, and 3) forecast how land-use and climate changes in nearby lands might affect future demand for AES within DoD lands.

Our main research objectives include: a) Refine and demonstrate a new approach for quantifying and mapping ecosystem services. b) Examine the strengths and weaknesses of distinguishing between ES capacity and flow. c) Compare the utility of the analytical approach used herein with an analogous approach applied at a larger spatial scale in previous studies. d) Examine the utility of stakeholder-designed future scenarios for informing decisions about land-use planning.

PROGRESS: In its second full year, we accomplished a suite of objectives regarding the mapping and evaluation of regulating services on DoD lands, including ANG-MTC Fort Pickett (VA) and MCAS Cherry Point (NC). We have developed and applied GIS-based models for quantifying regulating services (nitrogen regulation, surface water regulation, riparian filtration, and sediment retention) to both installations. We have prepared several static maps that can be used by installation personnel as well as ESTCP, the Army National Guard, and the Marine Corps. During 2012 and 2013, we interviewed several key natural and cultural resource managers, military operations planners, and NEPA compliance officers at Fort Pickett. From these interviews, we have developed two hypothetical scenarios that depict alternative futures regarding the management of Fort Pickett lands and buffer areas adjacent to the installation. This process requires the development and application of new GIS tools in conjunction with existing tools to map ecosystem service capacity. We are currently in the same process with Cherry Point personnel, with whom we will meet in August 2013. A paper summarizing the conceptual underpinnings of our work on DoD lands is currently in press at *Ecological Complexity*.

W. Mark Ford

1. Evaluating ecological threats under climate change

DURATION: Start Date: 3/2011

End Date 12/2014

SPONSOR: U.S. Army Environmental Command, Army Environmental Requirements and Technology Assessment 6.2/6.3 Program (Lead PI: Ford; Ph.D. student: Richard Odom)

PROJECT DESCRIPTION: Biome-level models of climate change are abundant, however, there have been few efforts to apply these models to DOD installations and their immediate landscapes in spatially and temporally explicit manners. Moreover, necessary efforts to link climate-induced changes within the context of other extant and future environmental stressors similarly are lacking for the changes in the context of multiple stressors from an integrated,

ecological process oriented perspective. This also leads to uncertainty as to what ecological communities will result from climate change based on current stewardship. Failure to proactively prepare for possible climate-induced biome shifts could have profound impacts to installation stewardship, i.e., management of endangered species, provision of ecosystem services, creation of untenable states and more importantly to mission and training critical to national defense. For example, predicted shifts from mesophytic deciduous systems to a pyrogenic pine or mixed pine types in the mid-South and lower Midwest would affect stewardship by shortening fire intervals, modifying soil ecology, and potentially altering fate and transport of contaminants. For this and other biome shifts, installation-level changes might result in changed timing of moisture deficits, altered hydrology (with increased erosion or flooding) or novel presence or absence of endangered species. Installations affected by such changes might experience physiognomic or “structural” changes that require additional management inputs to maintain suitable training platforms that possibly are unsustainable or wholly disruptive to mission needs. Installation managers need to know whether they are at risk of climate change impacts; if so, what are the ranges of possibilities of those risks, in spatial and temporal detail; what underlying conditions form the basis on the risks; what are the uncertainties; and what are the possible mitigation strategies.

OBJECTIVES: 1) Define climate change scenarios (low, medium, high impacts); compile climate change-induced biome shift predictions of CONUS DOD installations; 2) develop initial, generic conceptual models for ecological response and environmental management impacts for each biome transition; 3) identify conceptual model critical endpoints that will allow feedback to refine/prune conceptual models (GIS, monitoring data, lit. review, expert elicitation) to characterize significant complete pathways; 4) conduct multivariate analyses on installations’ critical endpoint susceptibilities and underlying explanatory variables from conceptual models to cluster or aggregate CONUS installations by common attributes, i.e., environmental, geographic, or military role; and 5) down-select representative CONUS installations by aggregated category to construct spatially- and temporally-explicit stand-level biotic change scenarios.

PROGRESS: Biome shifts for CONUS installations using changes in Holdrich Life Zone position and first approximation installation risk matrix has been completed through 2080. Fort Drum, New York was selected for an installation-level examination of projected vegetation change under variable management and climate scenarios using LANDIS II as modified by landform variables. GIS data acquisition and coordination with installation staff occurred in 2012 and data analyses are ongoing.

2. *Effects of a hierarchal and spatially differential disruption of roosts and roost areas on non-random assorting (social) dynamic in bats using ephemeral forest conditions*

DURATION: Start Date: 3/2011 End Date 12/2014

SPONSOR: U.S. Army Environmental Quality of Installations 6.1 Program (Lead PI: Ford; Ph.D. student; Alexander Silvis)

PROJECT DESCRIPTION: This study at Fort Knox, Kentucky, examines how disruption of primary (node) and secondary day-roosts affect the non-random assorting roost dynamic for the northern bat (*Myotis septentrionalis*). This species, similar to other forest-dwelling myotids, such as the endangered Indiana bat (*Myotis sodalis*) displays a cyclic spatio-temporal maternal colony system known as fission-fusion. Within this social structure, larger groups of bats, presumably matriline-dominated aggregates, may begin the maternity season at a single or a small number of

centralized “node” roost trees as would be described via network analysis. Typically occurring in spatially-definable “roost-area, often these groups will disassemble into smaller groups and disperse to nearby secondary boles with periodic reassembly (in-part) at the centralized node tree in a scale-free network. The exact socio-behavioral mechanisms causing dispersal from node trees to secondary trees and back again are unknown. Nonetheless, the modularity of this system provides for various levels and combinations of nested patterns that allow bats and their conspecifics to gather and share relevant ecological information on roost location and availability within roost areas. Individual and group knowledge of roost location and availability is particularly important as suitable roosts such as snags or trees with cavities or other wounds often are ephemeral products of forest disturbance from fire, wind, flooding, drought, ice, and insect or disease damage. In many temperate forest conditions, these suitable roosts are ephemeral and therefore present in a shifting mosaic on the landscape that follows single-tree to stand disturbance or other processes such as stand senescence. The temporal scale of the disturbance return-interval dictates when roosts are created on the landscape. Longevity of roost suitability and multiple secondary roost acquisition by non-random aggregations serves to hedge bets against node loss within a season or between years for non-random assorting groups that are philopatric to defined roost areas. Such acquisition also serves as possible future node establishment, suggesting that the larger social group moves roost areas on the landscape in concert with disturbance and consequent shifting of suitable conditions. Understanding response to differential loss or accelerated availability of nodes and/or secondary roosts in a fission-fusion context should provide insights into how bats respond to extrinsic perturbations such as training and stewardship activities (short-term) or climate change (long-term). Conceivably, such information could be useful to implement forest management or ecological restoration actions that either will minimize impacts to extant roosting habitat or might enhance and expand roosting habitat. Perhaps more importantly, these data could allow managers the ability to place roosting habitat on the landscape where benefits to bats could be maximized while simultaneously reducing impacts of regulatory liabilities or impediments on landscape needs.

OBJECTIVES: 1) removal of a node roost causes disassociation and reassembly at secondary roosts as novel social groups of northern bats on the landscape; 2) removal of secondary roosts lengthens node tree use and strengthens group cohesion; and 3) nonrandom assorting groups will switch roost areas if node and secondary roosts are simultaneously removed and new supplemental roosts are created.

PROGRESS: The third summer of catching and tracking northern bats to maternity roosts at Fort Knox has been completed. More than 250 day-roosts in 4 roost areas have been identified and measured. Female northern bats at Fort Knox display socially structured networks that are not readily apparent within the forested landscape, however, once identified and delineated, their boundaries are useful from a management perspective. Unfortunately, white-nose syndrome has affected bats in the region and the population of northern bats has decreased dramatically. Northern bats still are preferentially choosing suppressed or dead sassafras (*Sassafras albidum*). Analysis of social networks for the 2011 and 2012 summers has been completed. Networks vary by nodes (bat-roost combinations, overall size of the network) depending upon timing, i.e., pre-maternity, maternity and post-maternity. Simulations suggest that removal of > 20% of roost nodes will fragment a network. Nonetheless, prior to white-nose syndrome, roost areas and their networks were remarkably constant between the two years and the networks with experimental roost removal did not change to any appreciable extent. Response of northern bats to roost creation was unknown due to the population reductions from white-nose syndrome. A fourth field season in 2014 is anticipated and efforts to examine these observations at other installations are being explored.

3. *Acoustical sampling following white-nose syndrome at Fort Drum, New York: pilot test to determine efficacious techniques to address surveillance needs*

DURATION: Start Date: 6/2011

End Date 5/2014

SPONSOR: U.S. Army Installation Command and U.S. Geological Survey (Lead PI: Ford; M.S. student: Laci Coleman; Post-doctoral Associate: David Jachowski)

PROJECT DESCRIPTION: Of all Federal ownerships, Department of Defense land managers are faced with the most unique stewardship challenges of balancing training and mission needs with National Environmental Policy Act and Endangered Species Act compliance. Significant portions of the agency's ownership contain habitats with numerous threatened, endangered, and at-risk species. For installations in the Northeast and mid-Atlantic such as Fort Drum, New York, bats constitute a faunal group of high conservation concern to installation managers. Formal consultation with the U.S. Fish and Wildlife Service and the necessity of expensive mist-netting surveys is an annual reality for project clearance; many natural resource management activities, such as forest management and range maintenance, often are modified or seasonally restricted to account for these species' ecological needs and to avoid Section 7 "take". However as bat populations decline from the impacts of White-nose Syndrome, mist-netting survey methods increasingly fail to provide data for regulatory clearance due to low catch-per-unit-effort (also higher "per bat" costs), yet population declines and additional listings will require increased monitoring efforts. To meet this critical need and to potentially significantly reduce monitoring costs by eliminating the need for inefficient mist-netting, use of acoustical sampling (frequency division Anabat SD2) of bat echolocation could serve as an alternative, less costly method with greater detection power. Development and validation of detector placement design and analytical strategies to characterize temporal variation in bat activity, e.g., day, month, season (emphasis on maternity roost areas) and movement route/timing for both short- and long-distance migrants also are needed.

OBJECTIVES: 1) Demonstrate the potential for multiple acoustical device placements (15-25 units) and multiple continuous sampling (3-10 nights per site per unit) to assess bat species assemblages, occupancy modeling, and detection probabilities for monitoring and regulatory clearance; 2) demonstrate the potential value of these data to assess relative bat activity at landscape- and stand-level scales (upland and riparian habitat associations and spatial and temporal patterns of movement, i.e., along known and presumed corridors and between day-roost areas/woodlots); 4) ascertain potential sampling and test analytical protocols for effective use of multiple detectors deployed over long duration efforts. 4) compare cost and logistical considerations of acoustical methods in comparison to contractor-supported mist-netting generally and in the context of declining catch and cost efficiencies following WNS.

PROGRESS: Laci Coleman successfully defended her thesis "Assessing the Impacts of White-nose Syndrome Induced Mortality on the Monitoring of a Bat Community at Fort Drum Military Installation" in April. Habitat analysis of radio telemetry data and occupancy models of acoustic data were congruent in confirming nocturnal spatial use of forested riparian zones by little brown bats (*Myotis lucifugus*). Additionally, occupancy models of passive versus active sampling revealed that passive acoustic sampling is preferable to active sampling for detecting declining species in the post-white-nose syndrome context. Assessment of detection probabilities at various arrays of acoustic detector layouts in an expected area of use revealed that a grid of detectors covering a wide spatial extent was more effective at detecting Indiana bats (*Myotis sodalis*) and little brown bats than permanent stations, transects, or double transects. My findings suggest that acoustic monitoring can be affectively implemented for monitoring Indiana and little brown bats

even in areas of severe decline. Future efforts should be aimed at determining effective sampling designs for additional declining species. Examining acoustic data from 2003-2010, we monitored bat summer activity at the Fort Drum Military Installation in New York, USA tested the hypothesis that spatial and temporal niche partitioning was relaxed following the outbreak of white-nose syndrome. Little brown bats exhibited the greatest decline in activity levels. This decline corresponded with most other bat species shifting their evening activity hours and their foraging locations to times and areas previously utilized and dominated by little brown bats. Results provide evidence that disease can alter ecological assemblages through the relaxation of both temporal and special niche partitioning, and that white-nose syndrome has direct and indirect effects on bat communities. Because this disease is a recent occurrence and bat species simultaneously face growing threats of climate change and other anthropogenic disturbances from landscape change and wind-energy development, it is still unclear how these changes in bat community assemblage will influence long-term population viability, as well as broader ecosystem structure and function.

4. Assessing occupancy and detection rates for the Carolina northern flying squirrel: examination of nest-box surveys in Program Mark and Program Presence and development of acoustical survey techniques

DURATION: Start Date: 8/2011

End Date 7/2014

SPONSORS: U.S. Fish and Wildlife Service Asheville Field Office and North Carolina Wildlife Resources Commission (Lead PI: Ford; Ph.D. student: Corinne Diggins)

PROJECT DESCRIPTION: The Carolina northern flying squirrel (CNFS) occurs on a limited number of isolated, disjunct mountain peaks > 1400 m in North Carolina, Tennessee and Virginia in northern hardwood forests and mixed forests of northern hardwood-red spruce (*Picea rubens*), red-spruce-Fraser fir (*Abies fraseri*), and northern hardwood-eastern hemlock (*Tsuga canadensis*). Naturally isolated, CNFS habitat was further degraded by exploitative logging and wildfire at the turn of the 20th century. Subsequent habitat recovery has been tempered by continued threats to these forest communities from exotic insect infestation, (i.e., balsam woolly adelgid, *Adelges piceae*; hemlock woolly adelgid, *A. tsugae*), atmospheric acid deposition, recreational development, and climate change. On private land, further habitat loss occurs with second-home development. Den site and parasite-mediated competition with southern flying squirrels (*G. volans*) is an added stressor that probably limits CNFS at mid-elevations, particularly in the presence of significant hard mast species such as northern red oak (*Quercus rubra*). Survey protocols using nest box transects to determine presence/absence and persistence of the CNFS have changed little since listing in 1986. As an inventory technique, nest boxes produce results slowly and with considerable bias. Although the Recovery Plan requires three years of nest box surveys, field applications have demonstrated that boxes often must be checked far longer to ascertain presence or definitively show absence, i.e., > 5 years. Low capture rates and infrequent recaptures renders nest box surveys largely insufficient for analysis of abundance using mark-recapture models. The fixed nature of nest box networks does not lend itself to accurate conclusions about occupancy beyond the point of the nest box or along the linear transect of a collection of boxes – occupancy findings therefore are very conservative. Few attempts beyond preliminary analyses have been made to examine the efficacy of nest box data to provide robust occupancy estimates (and therefore an index to population stability) over time or among high-elevation habitat type and patch size variables.

Because nest box monitoring has precluded surveying large areas of potential habitat and provided little demographic data, it is worthwhile to develop a more efficient presence-absence survey technique. Because many members of Rodentia produce high-frequency vocalizations (≥ 15 kHz), acoustical monitoring techniques similar to those used with bats may hold promise as a new presence/absence monitoring technique for CNFS. A call library of vocalizations has been developed by Michelle Gilley of Auburn University for northern and southern flying squirrels from captive colonies. Discriminant function analysis of the captive calls can reliably distinguish between the two species. If acoustical monitoring can be shown to readily record CNFS in the wild in a standardized method, it could be an invaluable survey tool that will assist in making Section 7 determinations easier and cheaper as well as provide managers a better understanding CNFS distribution and habitat associations..

OBJECTIVES: 1) Attempt mark-capture population analysis of CNFS nest box data from 1996-2011; 2) Analyze CNFS nest box capture data for occupancy rate and detection probability over time relative to a finer resolution of habitat classification, patch size, and habitat patch connectivity/isolation to develop a Southern Appalachian specific CNFS habitat model; 3) Radio-collar 5-10 CNFS to provide known den locations and known subjects for field testing of acoustical monitoring; 3) Determine effectiveness of acoustical monitoring by field-testing in known and predicted (but unconfirmed) habitat.

PROGRESS: Despite considerable nest box-line replication across several mountain ranges monitored over successive years, the low number of recaptures shows that meaningful, unbiased population estimations cannot be obtained from the current CNFS monitoring program. Even assuming modeled estimation were not essentially 1:1 correlations with actual capture data from these nest boxes, relating population estimations to a unit of area and habitat type for extrapolation to the larger mountain ranges is conjecture without a greater understanding of nest box transect effect size or a more complete understanding of squirrel home-range and habitat use in North Carolina. Radio-telemetry data from collared CNFS suggests that similar to the Virginia subspecies, CNFS denned primarily in cavities in live trees or snags of yellow-birch (*Betula alleghenensis*) or dreys in red spruce. Foraging occurs primarily in red spruce-dominated stands. Nest box occupancy is related to increasing elevation within sheltered positions with low or negative landform indices scores and proximity to montane boreal conifer. Time-expansion acoustic detectors do appear suitable for determining presence of CNFS and differentiating from southern flying squirrels whereas zero-crossing (Anabat) detectors fail to provide enough of the vocalization spectrum to allow differentiation. Detection probabilities generated from acoustical surveying suggest 6 and 10 detector-nights in known geographic recovery areas and potential habitat, respectively are necessary to prove absence at levels $> 90\%$. A comprehensive CNFS literature review, habitat management plan and a state-of-our knowledge CNFS workshop for Blue Ridge Parkway and Great Smoky Mountains National Park employees is planned for late 2013 or early 2014.

5. *Micro-habitat characteristics of Virginia northern flying squirrel (Glaucomys sabrinus fuscus) foraging sites: relating structure, composition and soils to habitat identification, conservation and restoration needs*

DURATION: Start Date: 10/2012

End Date 12/2014

SPONSORS: West Virginia Division of Highways, U.S. Fish and Wildlife Service Elkins Field Office and Snowshoe Resort (Lead PI: Ford; Ph.D. student: Corinne Diggins)

PROJECT DESCRIPTION: Within the central Appalachian Coalfields, efforts to minimize and mitigate impacts from surface coal mining have been complicated by incongruent restoration goals and poorly validated post-mine monitoring protocols that are unable to quantify ecosystem change relative to system recovery. Traditionally, research and monitoring of aquatic ecosystems has focused on the effects of landuse practice disturbances. However, the ability to distinguish natural stream variability from the additive effects of anthropogenic influences is currently limited. Furthermore, there is little known about the multiple temporal and spatial dynamics of the biological recovery of a degraded aquatic system. Currently, even identifying and quantifying aquatic ecosystem structure and function of undisturbed systems can be very difficult. It is, however, imperative to establish scientifically-backed bench marks of success for watershed remediation efforts and/or coal mine reclamation. In central Appalachian headwater streams absent of fish, salamanders are the dominant, most abundant vertebrate predator. In undisturbed areas salamanders have been shown to have relative stable populations with high densities of up to 1.4/m² in central Appalachia. Stream salamander species are considered to be sensitive to aquatic stressors and environmental degradation, and low stream salamander abundance have been shown to be closely linked to terrestrial watershed. Land managers and researchers have begun to examine stream salamander responses to habitat degradation of either surface or underground coal mining, however, many impacts of coal mining on stream salamanders are poorly known. Most of the amphibian research on mined lands focuses on constructed settling ponds and use/recolonization by pond salamanders or have examined the effect of acid mine drainage on stream salamanders. Stream-level and landscape-level relationships between salamander species presence and abundance relative to less disturbed, actively mined and reclaimed habitats have not been established.

OBJECTIVES: 1) To investigate the foundational correlations between salamander presence, community assemblage and habitat parameters at both a microhabitat level and a large-scale landuse level in the southwest Virginia Coalfields; 2) To assess the utility of using stream salamanders rather than relying solely on aquatic macro-invertebrates and various water chemistry measures to assess post-mining biological integrity.

PROGRESS: Over 70 streams reaches in 5 watersheds in Dickenson and Wise counties have been surveyed for stream salamander presence (by species and age/size class) this summer. Each reach has been sampled 3 times to permit occupancy and detection probability analyses relative to field and GIS-derived habitat variables in Program PRESENCE this fall. Planning is ongoing to resample a subset of these streams for fish presence in later winter and early spring 2014 is underway.

8. *Cerulean warbler response to variable density thinning in the ridge and valley*

DURATION: Start Date: 9/2012

End Date 12/2015

SPONSORS: U.S. Geological Survey, Virginia Department of Game and Inland Fisheries, and the Appalachian Mountain Joint Venture. (Lead PI: Ford; Ph.D. student: Keri Parker)

PROJECT DESCRIPTION: Populations of cerulean warblers (*Setophaga cerulea*), a neotropical migratory songbird ranging throughout much of the Appalachian Mountains, have declined at one of the steepest rates relative to other North American warbler species based on estimates from the North American Breeding Bird Survey. The Cerulean Warbler is among the

most specialized (in terms of habitat requirements) and threatened birds of the deciduous forest and is in need of focused conservation attention throughout its range. During the breeding season, they have highly specific preferences for mature forests with complex vegetation/structure physiognomy in the canopy. Currently there are three significant threats to breeding habitat that are impacting Cerulean Warblers: 1) outright loss of mature deciduous forest, 2) forest fragmentation at the intra- and inter-landscape scales, and 3) loss or modification (anthropogenic or natural) of appropriate vegetation structure within mature deciduous forest. These birds breed in large blocks of mature forest containing large diameter trees, but have highly specific preferences for complex vegetation structure in the canopy that include a well-developed mid- and understory and a broken canopy with spreading crowns and long horizontal limbs. These conditions are relatively uncommon in most forest stands. Recently research in the Appalachian Plateau and adjacent Central Hardwoods regions has shown that cerulean warblers benefit from forest management practices that promote a heterogeneous canopy structure. Shelterwood harvests that retain 40-50 ft² basal area/acre that favor white oak (*Quercus alba*), chestnut oak (*Quercus prinus*), hickory (*Carya* spp.), and sugar maple (*Acer saccharum*) residuals showed an increased in cerulean warbler abundance and nesting success over surrounding uncut stands. Nonetheless, transferability to other Appalachian habitats such as the Ridge and Valley or Blue Ridge as well as responses of other avifauna and game species from these harvest regimes is unknown.

OBJECTIVES: 1) To assess changes in relative abundance of cerulean warblers to variable density retention harvesting in the Ridge and Valley physiographic province at Gathwright and Highland WMAs using a before-after-control impact design and contribute data to a larger central Appalachian wide harvest-cerulean warbler response meta-study; 2) To understand temporal changes in detection probability of cerulean warblers over the breeding and nesting season; 3) To dynamically model future conditions, i.e., species composition and wildlife value of Ridge and Valley forest stands subjected to variable retention density thinning.

PROGRESS: Three-visit avian point counts along established transects were conducted in control and pre-harvest areas at Gathwright and Highland WMA from mid-May through the beginning of July, 2013. Point count site habitat variables also were recorded. Data compilation and preliminary analyses are underway. A multi-state wildlife grant to fund, support and coordinate among several states and study areas was submitted to the U.S. Fish and Wildlife Service by the Appalachian Mountain Joint Venture on behalf of Virginia Department of Game and Inland Fisheries, Virginia Tech, West Virginia Division of Natural Resources, West Virginia University, Kentucky Department of Fish and Wildlife Resources, Ohio Division of Natural Resources, Pennsylvania Game Commission and Indiana University of Pennsylvania.

9. Distribution and habitat use of eastern spotted skunks (*Spilogale putorius*) in western Virginia

DURATION: Start Date: 7/2013

End Date: 6/2016

SPONSORS: Virginia Department of Game and Inland Fisheries and the U.S. Forest Service Northern Research Station (Lead PI: Ford; Post-doctoral Associate: David Jachowski)

PROJECT DESCRIPTION: The eastern spotted skunk (*Spilogale putorius*) was once regarded as a fairly common furbearer throughout much of the Appalachians, Midwest and Ozark-Ouachita Highlands through the 1950's as reported in trapping tallies. Anecdotal evidence suggests that the spotted skunk has been rare or largely absent from most of the central and

southern Appalachians over the last two decades with only occasional sightings and captures. While regarded as “globally secure”, the spotted skunk is classified as vulnerable or a sensitive species in need of management in North Carolina, Tennessee and Virginia. It has been suggested that spotted skunk decline probably has been a result of the loss of old field habitats due to expanding modern agricultural practices and maturation of early successional forests. In addition to habitat change, declines may be linked to increases in other meso-mammalian predators (i.e., striped skunks (*Mephitis mephitis*), raccoons (*Procyon lotor*), and coyotes (*Canis latrans*)) since the 1980’s when overall trapping pressure declined and a series of rabies outbreaks in the mid-Atlantic and Midwest beginning in the 1970’s also may have continued to suppress spotted skunk populations. In the central and southern Appalachians, perceived rarity of spotted skunks is increased by the overall low detection probability of spotted skunks using traditional live-trapping methods. Very little is known about the distributional status or ecology of this species in this region. Anecdotal information from the ongoing multi-state golden eagle (*Aquila chrysaetos*) wintering distribution study in the Appalachians using camera-bait stations has recorded spotted skunks in West Virginia in the Peters-Potts Mountain, Shenandoah Mountain, and Great North Mountain areas along the Virginia border, and also within Shenandoah National Park. These recent records, along with data from Virginia Department of Game and Inland Fisheries does suggest that spotted skunks probably are extant over a large portion of the Blue Ridge and Ridge and Valley in Virginia. Others in the central and southern Appalachians have noted the occasional capture or sighting near emergent rock usually as a result of accidental captures during Allegheny woodrat (*Neotoma magister*) monitoring. Whether these rocky habitats and riparian zones with dense ericaceous shrub growth are primary spotted skunk habitat in the Appalachians or are merely a function of the decreased amount of early successional forest habitat on the wider landscape is unknown.

OBJECTIVES: 1) To use camera trap methodologies to describe spotted skunk general distribution and coarse habitat correlates in western Virginia; 2) to deploy camera traps and track plates within focal areas to examine at second-order habitat selection by spotted skunks; 3) to capture and utilize radio-telemetry in combination with space use and resource selection analyses to assess third-order selection (usage of habitat components within the home range); 4) to food habits and prevalence of parasites and disease from fecal and blood analyses.

PROGRESS: Project coordination and planning for fall camera-trapping in Augusta and Rockingham counties (northern Ridge and Valley study site), Shenandoah National Park (Blue Ridge site) and Giles and Craig counties (central Ridge and Valley study site) with project cooperators is underway.

OTHER FACULTY COOPERATORS

James Fraser, Daniel Catlin, and Sarah Karpanty

1. Missouri River piping plover population dynamics in relation to natural and artificial sandbars; least tern and piping plover response to flooding on the Missouri River

DURATION: Start Date: 05/11

End Date: 9/30/14

SPONSOR: U.S. Army Corps of Engineers

PROJECT DESCRIPTION: This work is a multi-year project evaluating the effects of the operations of the U.S Army Corps of Engineers on the Missouri River and the impacts of the

2010 Gulf oil spill. The Corps operates a series of Dams on the Missouri, the longest river in North America. These dams potentially affect many species including the Federally threatened piping plover, a shorebird that nests on Missouri River sandbars. Gulf habitats also are important nesting and wintering habitat.

OBJECTIVES: 1) evaluate the foraging ecology of piping plovers below high head and low head dams; 2) evaluate the colonization of newly constructed sandbars; and 3) evaluate the effects of the floods of 2010 and 2012 on piping plovers.

PROGRESS: To date, 2 doctoral students and one master's student have found that plover prey biomass was greater adjacent to the warmer water below the low head dam (Gavins Point Dam), than adjacent to the colder water below the high head (Garrison) Dam. Survival was lower adjacent to the warm water, however, apparently due to higher predation there. Piping plovers selected the engineered sandbars more than would be expected based on habitat availability, and that in early years, reproductive output was high. However, over time, reproductive output fell, due to increasing predation. A predator removal effort by the Corps and USDA wildlife Service, aimed at great horned owls, increased reproductive output. Chick growth rates were higher with moderate discharges from Gavins point Dam. When discharges were high, food abundance dropped and chick growth rates were lower. Overall, we found evidence of density dependent effects reproduction, chick survival and emigration. Preliminary results indicate that adult females are more likely to disperse to new sandbars than adult males, and that birds with successful nests on the largest sandbars were less likely to disperse. Overall, both yearlings and After second year birds selected for engineered habitat over natural habitat, probably because the engineered habitat was largely vegetation free, whereas the natural habitat has been succeeding to dense vegetation sine the sandbars were laid down in high water of the late 90's. Evaluation of the impact of the Gulf on piping plovers in ongoing; along the Missouri River in the 2011 breeding season most plover habitat was covered by high water. In 2012 most plovers returned to the few sandbars that were not covered by water in the previous year. Predation rates were high on these crowded sandbars. As the season progressed, previously inundated sandbars began to be colonized. In 2013, the population grew, and preliminary data suggest that reproductive output remained high overall. Data analysis is in progress.

Fred Benfield

1. Evaluation of the functional role of freshwater mussel beds in maintaining water quality and suitable habitat for fishes and endangered freshwater mussels

DURATION: Start Date: 4/11 End date: 12/13.

SPONSOR: U.S. fish and Wildlife Service

PROJECT DISCRPTION: We will measure a variety of ecosystem level processes e.g., nutrient storage and cycling and organic matter processing, in stream reaches containing mussel beds with a density of 10 mussels m^{-2} . The overall objective is to evaluate the importance of mussel beds in providing ecosystem services to aquatic life in streams.

OBJECTIVES: 1) Measure seston upstream and downstream of mussel beds in terms of particle size, organic content, CHN ratios, and Chlorophyll-a; 2) measure organic matter and nutrient (N & P) accumulation and loss from stream substrates colonized by mussels; 3) measure stream

metabolism (as 48 hr dissolved oxygen flux) associated with mussel beds; and 4) measure spiraling of N by mussel beds.

PROGRESS: The instream experiments are being conducted in the Nottaway River Basin within Ft. Pickett boundary in eastern Virginia. We explored 40 possible sites within Ft. Pickett and immediately to the east. The original idea was to construct 30 meter fences that divided three streams down the middle, to plant mussels on one side of the fence, and then to measure a suite of ecosystem level processes on both sides of the fences and compare the mussel side to the non-mussel side. Three fences were constructed and mussels planted at one site where preliminary measurements of various ecosystem processes were made over a period of about 1.5 years in order to test for proof of concept. Unfortunately, severe flooding eventually destroyed the fences and the concept was abandoned. The experimental design was altered to use 3 streams. Within each stream a no mussel reach (upstream) and a mussel reach (downstream), each 30m in length separated by at least 60m will be used to measure the effects of mussel beds on selected ecosystem processes within Fort Pickett. Freshwater mussels (*Elliptio complanata*) are being stocked in the mussel reaches at a density of 10m². These experiments are ongoing and will continue for the remainder of the summer and through the fall 2013.

Jess W. Jones

1. *Recent precipitous declines of endangered freshwater mussels in the Clinch River: An in situ assessment of water quality stressors related to energy development and other land-uses*

DURATION: Start Date: January 1, 2012

End Date: December 31, 2014

SPONSER: U.S. Geological Survey

PROJECT DESCRIPTION: The goal of this project is to evaluate exposure and toxicological effects of contaminant stressors in the water and sediment of the Clinch River in areas of high mussel decline in Virginia and in areas of high abundance and recruitment in Virginia and Tennessee. The investigation will include assessment of tributary streams with varied histories of degradation, recovery and disturbance. Progress towards this research project has continued by the collaborating investigators at North Carolina State University (NCSU), Virginia Tech (VT), The Nature Conservancy (TNC), Virginia Department of Environmental Quality, Tennessee Department of Environmental Conservation, U.S. Fish and Wildlife Service, and the U.S. Environmental Protection Agency (Maryland). The following summary of the project objectives and progress to date is from NCSU's 2nd Quarterly Report of 2013:

OBJECTIVES: (1) Integrate existing data sets on mussel populations, NPDES discharges, mining and other energy permitted activities, pesticide use, and land use, (2) Using passive sampling devices, measure water concentrations of a suite of polar and non-polar organic contaminants, including current use pesticides, polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), legacy organochlorine pesticides (OCPs), and natural and synthetic hormones at each site, (3) Measure water concentrations of inorganic contaminants (e.g., metals and metalloids), and nutrients (e.g., nitrate, nitrite, total ammonia nitrogen, total phosphorus) at each site, (4) Measure sediment concentrations (bed and pore water) of a suite of organic and inorganic contaminants, including current use pesticides, PAHs, PCBs, legacy OC pesticides, natural and synthetic hormones, metals and metalloids, nutrients (e.g., nitrate, nitrite, total ammonia nitrogen, total phosphorus), and total organic carbon at each site, (5) Conduct ASTM Method E 2455-06 toxicity tests with juvenile mussels using sediment pore water collected from each site, (6) Compare the results of the toxicity tests to measured concentrations of contaminants in surface and pore water and sediment compartments (objectives 2-4) from the study sites and to published

criteria and toxicity benchmark values for standard aquatic test organisms and mussels, (7) Assess growth and survival of mussels *in situ* at each site over two years, (8) Synthesize the findings to inform management efforts for aquatic species and water quality in the Clinch River watershed and elsewhere.

PROGRESS: Research toward Objective 1 is in progress and on schedule. The fine scale streams layer for the entire Clinch River basin has been completed and is ready for use in comparison with land use characteristics. Validation of NLCD 2006 data has been conducted by comparing similar vintage (2007) aerial photos with NLCD classifications. Misclassification rates have been determined to be 20-28% depending on the specificity of classification expected. Further analysis with land use, discharges, permitted activities and riparian zones is ongoing.

Research toward Objective 2 is in progress and on schedule. Collaborators at NCSU deployed the 3rd set of Passive Sampling Devices (PSDs) for the spring sampling period on May 7, 2013 and retrieved them on June 5-6, 2013. The 4th set of PSDs for the summer sampling period will be deployed mid to late July. Analyses of the first and second set of PSDs (July/August and September/October 2012) for 48 current use pesticides (CUPs), 28 OPCs, 21 PCBs, and 50 PAHs has been completed. From July – August 2012, concentrations of PAH were measured in the PSD and total PAH ranged from 2.68 ng/L (Copper Creek) to 58.17 ng/L (Guest River). The PAH pattern in the latter could indicate the source being coal tar, while the other could be highly weathered and diluted coal tar or even creosote or a mixture of petroleum products. No PCBs or OCPs were detected in any sample. Of the CUPs, only atrazine and a primary metabolite atrazine-desethyl were detected at one site, Cleveland, and at less than 1 ng/L. From September – October 2012, concentrations of PAH in the PSDs were lower than the July sampling and mostly not detectable in the PSDs with the exception of moderately high concentrations at Artrip. As with July, we found nearly all PCBs, OCPs, and CUPs not detectable in October. Overall, the initial PSD data indicate very low exposure to the organic chemicals being measured.

Research toward Objective 3 is in progress and is on schedule. TNC with VADEQ and TDEC conducted their spring quarterly Clinch River sampling event on April 2-3, 2013. NCSU sent TNC supplies to collect, filter, and preserve samples from the 4 tributary sites around the time the mainstem sites are sampled and this was completed on April 9-10, 2013. These samples were sent to the U.S. Environmental Protection Agency's laboratory at Fort Meade, MD (Region III) for contaminant analyses. The summer quarterly sampling event is scheduled for the mainstem Clinch River sites is scheduled for July 10-11, 2013, weather and river conditions permitting. DEQ and TDEC are ready and equipped to sample and EPA is expecting the samples. The tributary site sampling will probably occur the following week due to logistical constraints.

Research Objective 4 is in progress and is on schedule. Sediment samples collected by collaborators from NCSU from all 8 Clinch River and 4 tributary sites in late August (21-22) 2012 have been prepped for contaminant analyses and submitted to RTI International for metal analyses and Dr. Damian Shea's Lab at NCSU for organics analyses. We received the data for nitrogen and carbon stable isotopes from Cornell University Stable Isotope Laboratory on May 8, 2013. The first pore water collection occurred June 5-6, 2013 at all 12 mainstem and tributary sites. Pore water was collected using MHE PushPoint Samplers and pore water samples were submitted to RTI International for metal analyses, Dr. Damian Shea's Lab at NCSU for organics analyses, and NCSU Soil Science Department's Environmental & Agricultural Testing Services laboratory for total anions/cations (Ca, Cl, K, Mg, Na, SO₄), total suspended solids, total dissolved solids, alkalinity, total nitrogen, ammonia nitrogen, nitrate + nitrite, and phosphorous.

Research toward Objective 5 is in progress and is on schedule. Collaborators from NCSU conducted a 96-hr acute toxicity test on June 10-14, 2013 using pore water from all 12 mainstem and tributary sites with ~8 week-old juvenile *V. iris* cultured at VT. Pore water from all sites was found to not be acutely toxic to juvenile *V. iris*. Collaborators from VT are culturing *L. fasciola* to have juveniles (≥350 juveniles) available for a pore water toxicity test in July/August.

Research toward Objective 6 is in progress. This objective will be completed near the end of the study after more data has been collected in objectives 2-4. Currently, collaborators from NCSU, VT, and TNC are in the process of compiling a Clinch River Bibliography of relevant papers and reports to be used by the group. Gray literature still may need to be scanned into PDF to make them accessible for everyone.

Research toward Objective 7 is in progress and is on schedule. The juvenile *V. iris* deployed in 2012 in the sediment in cages at the 8 Clinch River sites and in the water column in silos in all 8 Clinch River and 4 tributary sites, as well as, the resident mussels collected in the end of October 2012 have been prepped for contaminant analyses and submitted to RTI International for metal analyses and Dr. Damian Shea's Lab at NCSU for organics analyses. We received the data for nitrogen and carbon stable isotopes from Cornell University Stable Isotope Laboratory on May 8, 2013. Rain and high water levels in the Clinch River have delayed the deployment of a new cohort of juvenile *L. fasciola* into the cages and silos this spring. Collaborators at VT are ready to deploy the juvenile mussels as soon as the conditions are appropriate. Twelve *L. fasciola* will be deployed in each cage and silo in the river for the full growing season similar to 2012, and will allow the advantage of having a comparison to the pore water toxicity test outcomes because both *V. iris* and *L. fasciola* will be tested there.

Research toward Objective 8 is in progress. This objective will be completed near the end of the study.

2. Development of demographic metrics to evaluate success of mussel reintroductions in the upper Tennessee River system

DURATION: Start Date: 9/2011

End Date: 2/2014

SPONSER: U.S. Geological Survey

PROJECT DESCRIPTION: The purpose of this project is to develop demographic metrics to quantitatively assess how populations of translocated adults and released propagated juveniles of various species are performing over time at release sites in the Upper Tennessee River System, to include in the Clinch, Powell and Nolichucky rivers. In addition, the project is developing standardized monitoring protocols to assess status of reintroduced mussel populations.

OBJECTIVES: 1) Develop demographic metrics to evaluate the success of mussel release efforts; 2) conduct releases of adult and juvenile mussels at restoration sites, to include tagging and data recording of released mussels; and 3) conduct quantitative monitoring at release sites to estimate mussel survival and individual growth rate.

PROGRESS: This project started in September 2011 and is partially funding Tim Lane's Master of Science (MS) degree project, which he began in January 2012. Tim already has completed most of the required course work for the degree, formed his graduate committee and completed his project working plan in July 2013. His field work for 2013 is ongoing and on schedule.

3. Restoration of freshwater mussel populations to high priority geographic areas in the upper Tennessee River system

DURATION: Start Date: 4/2011

End Date: 12/2013

SPONSER: U.S. Geological Survey

PROJECT DESCRIPTION: The purpose of this project is to reintroduce and establish new populations of endangered mussel species to the upper Clinch River, Virginia at Cleveland Islands, to the lower Powell River, Tennessee just downstream of Brooks Bridge, and to the lower Nolichucky River, Tennessee below Hale Bridge. Juvenile mussels of four endangered species, the oyster mussel (*Epioblasma capsaeformis*), Cumberlandian combshell (*E. brevidens*), dromedary (*Dromus dromas*) and birdwing (*Lemiox rimosus*) and one federal candidate species, the fluted kidneyshell (*Ptychobranchus subtentum*) will be propagated and hatchery-reared to 15-30 mm for release at each site and adult mussels will be collected for translocation. These species were selected because their current population abundance in the lower Clinch River, Tennessee and the Duck River, Tennessee is high enough to allow for both the collection of gravid females for propagating juveniles and the translocation of adults. Hence, it is expected that hundreds of larger-sized juveniles and adults will be tagged and released at selected sites in each river. Quantitative monitoring will determine the relative success of releasing juvenile versus adult mussels at each site. Survival, growth and basic demographic information will be assessed from recaptured individuals.

OBJECTIVES: 1) Propagate, tag and release 100-400 juveniles per species per site of *Epioblasma capsaeformis*, *E. brevidens*, *Dromus dromas*, *Lemiox rimosus* and *Ptychobranchus subtentum* to the Clinch, Powell and Nolichucky rivers; 2) collect, tag and translocate up to 400 adults per species per site of *Epioblasma capsaeformis*, *E. brevidens*, *Lemiox rimosus* and *Ptychobranchus subtentum* to the Clinch, Powell and Nolichucky rivers; and 3) conduct quantitative monitoring of released juvenile and adult mussels using systematic quadrat sampling and mark-recapture methodologies to estimate survival and growth of released individuals of each species.

PROGRESS: This project started in April 2011 and is partially funding Tim Lane's Master of Science (MS) degree project. Staff at the Freshwater Mussel Conservation Center (FMCC) at Virginia Tech University have initiated the propagation, culture, translocation and monitoring of targeted mussel species. Thousands of larger sized (20-30 mm) juveniles of *Epioblasma capsaeformis* and *E. brevidens* have been cultured at FMCC. The mussels have been tagged and released at two sites in the Powell River, Tennessee and one site in the Clinch River, Virginia in 2011 and 2012. Monitoring of released mussels was initiated in the fall of 2012 and will continue in 2013 and through 2014. Additional mussels of *Epioblasma capsaeformis*, *E. brevidens*, *Dromus dromas*, *Lemiox rimosus* and *Ptychobranchus subtentum* are being cultured at FMCC for release in fall 2013-2014.

Emmanuel Frimpong

1. *Modeling how traits mediate fish vulnerabilities to specific habitat alterations*

DURATION: Start Date: 07/11

End Date: 8/13

SPONSOR: U.S. Geological Survey Aquatic Gap Analysis Program

PROJECT DESCRIPTION: Future environmental changes expected from population growth, increased resource consumption, and climate change will predictably affect large numbers of aquatic biota over large spatial extents. This project will integrate trait-based modeling of fish-habitat relationships with Geographic Information Systems to develop spatially explicit predictions of effects of various anthropogenic driven habitat changes on freshwater fishes across major drainage basins of the United States. The project will also improve the FishTraits database and work with the Aquatic Gap Analysis Program (AGAP) to facilitate data sharing among AGAP-sponsored projects

OBJECTIVES: 1) Develop habitat-traits relationships that are plausibly responsive to habitat changes; 2) map the geographic distribution of traits and incidence of threatened, endangered, and vulnerable fish species at the 8- or 12-digit HUC level for selected drainage basins; 3) construct the profile of traits vulnerable to major habitat alterations such as reduced minimum and maximum stream flows, reduced habitat connectivity, and siltation; 4) identify species whose trait profiles render them vulnerable to specific habitat alterations, and develop a spatially explicit risk index maps for various habitat alterations and species groups; 5) expand the trait set and increase the resolution of data in the FishTraits database; and 6) Develop a mechanism for rapid sharing of regional fish trait information through the AGAP program.

PROGRESS: August 2, 2013

Because species traits, species distribution, and habitat data are the foundations for achieving objectives 1-4, much of the initial work of the project has concentrated on gathering these data, which is in furtherance of objective 5-6. FishTraits moved to a private website www.fishtraits.info with technical support from the Virginia Tech library. The collaboration between the PI and VT libraries in the development of the online database was featured as front page story in the Roanoke Times on Monday March 4, 2013

<http://www.roanoke.com/news/nrv/1743797-12/libraries-stack-up-in-new-digital-world.html> .

In collaboration with Dr. Zhiwu Xie, a library information technology expert at the VT library and a VT Computer Science PhD candidate Sunshin Lee, the capabilities of the database has been developed to link individual records in the database to references and geographic location of each record. In addition, the database can now support the distribution of high-resolution shape files such as the ones being developed under a related USGS Aquatic Gap project led by the PI.

By invitation, the PI and his PhD student presented two papers in the data sharing symposium led by Dr. Ryan Utz (NEON project of the NSF) and Dr. Ryan McManamay (Oakridge National Laboratories) at the AFS annual meeting to be held in St. Paul, MN, in August 2012. A third paper highlighting the new capabilities of the database was presented by Dr. Zhiwu Xie at the Joint Conference on Digital Libraries in Indianapolis in July 2013.

The collaboration with OakRidge National laboratories continues under the current no-cost time extension to develop flow-ecology relationships for fish, which will fulfill objectives 1-4 of this project. The Oakridge lab has developed numerous hydrologic metrics at the HUC-8 level nationally based on the available USGS gauge data. We have are working with them on relating these metrics to fish and traits distribution using the FishTraits database. The FishTraits database continues to enjoy widespread use nationwide by universities and research institutions, co-op units, students, and private consultants, making it a useful model for the Aquatic GAP program to incorporate explicit objectives of data sharing into its future funded projects.

2. *Refining Stream Fish Distribution Models Regionally for a Nationally-Consistent Aquatic GAP Analysis*

DURATION: Start Date: 07/13

End Date: 5/15

SPONSOR: U.S. Geological Survey Aquatic Gap Analysis Program

PROJECT DESCRIPTION:

Current species distribution models used in the aquatic gap analysis and conservation decisions are based on presence-only data because of the pervasive lack of true absence in available databases. Nationally available fish distribution maps served through NatureServe www.NatureServe.org are even worse because they lack an underlying model for linking

distribution to habitat and effect of anthropogenic impacts such land use and climate change. The goal of this project is to develop high resolution distribution maps for representative species by utilizing historical fish presence data available in atlases and deriving absences based on metacommunity theory for presence-absence models. Field-based validation using occupancy-based modeling as well as non-occupancy models utilizing nationally available recent fish collections is planned.

OBJECTIVES:

- 1) Collate historical species occurrences nationally based primarily on published paper atlases and all other sources available such as online databases
- 2) Develop habitat suitability and distribution models for 50-60 selected species in four regionally diverse river basins using historical occurrences and corresponding habitat
- 3) Conduct non occupancy-based model validation for all 50-60 species distributions models using samples collected in the respective basins from 1990 to present
- 4) Conduct occupancy-based field-test of model performance and calibrate models by repeat sampling of sites in the New River basin for two consecutive years

PROGRESS: August 2, 2013

This project has been active for on one month but much progress has been made because it built on a previous project funded by the AGAP that ended in June 2013. Fifty of 70 sites that were supposed to be sampled in the New River basin in 2013 have been sampled and the crew is on track to completing sampling in August 2013. The development of GIS-based presence database out of which presence-absence database will be created for each species is far advanced. Currently, data from over 26 national atlases constituting over 2000 maps have been scanned and georeferenced. A third-party software (Feature Analyst) has been used to digitize all maps and collated. The digital fish presence database now has over 300,000 observations for a combined greater than 800 species.

Carola Haas

1. Restoration of Pine Flatwoods Wetlands on Eglin Air Force Base

DURATION: Start Date: 1 July 2011 End Date: 01 June 2015

SPONSOR: U.S. Geological Survey

PROJECT DESCRIPTION: The endangered reticulated flatwoods salamander (*Ambystoma bishopi*) breeds in the wiregrass ecotone of ephemeral pine flatwoods wetlands where the larvae develop and metamorphose into the terrestrial form. These wetlands, which serve as breeding and larval habitat, have degraded over time as vegetative structure has been influenced by a shift away from natural fire regimes (Bishop and Haas 2005, Gorman et al. 2009, USFWS 2009). We partnered with the state of Florida (FWCC AHRE program), US Fish and Wildlife Service (Panama City office), Department of Defense Legacy Resource Management Program, and Eglin Air Force Base to conduct an adaptive management experiment to restore natural hydrologic regimes and herbaceous understory to several wetlands.

OBJECTIVES:

The results of this study will help managers to develop appropriate management strategies to maintain and restore breeding habitat for the reticulated flatwoods salamander and a diverse suite of other amphibians and plants that occur in the same habitats. Specifically, we:

1. Monitored drift fences to capture reticulated flatwoods salamanders and other amphibians.
2. Investigated how a range of potential vegetation management treatments influences herbaceous vegetation, hydroperiod, and use by the amphibian community (with emphasis on reticulated flatwoods salamanders).

SUMMARY:

Objective 1 - The high number of captures in November 2010 was a welcome surprise given low numbers of larvae detected in recent years and compared with a partial drift fencing study on Eglin in 2002 (Bishop 2004), when only three individuals were captured. There is a breeding population of at least 115 adults at Pond 4 (Season 1) and 54 adults at Pond 5 (largest number of unique captures in a single season, Season 2). These two adjacent wetlands are used by apparently separate groups of breeding adults. However, because we had relatively low recapture rates, we are unlikely to have detected movements between ponds if they occur at low frequency. The total number of individuals captured at both ponds declined each year over the three-year study period. This is likely a result of mortality of adults and lack of recruitment of young into the breeding population. Given the complete reproductive failure over the past three years, the likelihood that females do not enter the breeding population until at least age 2 (Palis 1997), and the apparent short life-span of flatwoods salamanders (Palis et al. 2006), we expect that the population could decline more precipitously in subsequent years, especially if dry conditions persist. Alternatively, it is possible that low numbers of captures in season 3 could be a result of early movement into and out of the ponds during the late summer storms that occurred in 2012.

Objective 2 - Mechanical treatments reduced canopy cover (from 55.7% to 41.4%) to similar levels as high-quality sites (36.7%), however, herbaceous groundcover did not increase (17.2% post-treatment compared to 37.3% at high-quality sites). Fire reduced the canopy cover (from 41.3% to 33.0%), and herbaceous groundcover was similar (33.2% post-treatment) to high-quality sites as of 4-months post burn (Gorman et al. 2013). More time will be required to assess the response of herbaceous groundcover and whether mechanical methods can be used as a surrogate for fire to restore amphibian breeding habitat. Identifying surrogates for fire could add an important technique to our management toolbox.

PROPOSED PROJECTS FOR 2013-2014

Paul L. Angermeier

Bridging Terrestrial and Aquatic GAPS: Knowledge of Watershed Processes Improves Assessments of Threat and Protective Status for Aquatic Species and Habitats

PI: Amy Villamagna, Paul Angermeier

Funding: \$40,250

Source: USGS Gap Analysis Program

Student: TBA

Habitat associations for young-of-year Roanoke logperch (*Percina rex*) in Roanoke River

PI: Jane Argentina, Paul Angermeier

Funding: \$18,500
Source: VDGIF
Student: Jane Argentina

Fish and habitat survey of the Nottoway River at Fort Pickett, with special emphasis on endangered Roanoke logperch

PI: James Roberts, Paul Angermeier, Greg Anderson
Funding: \$24,050
Source: EEE Consulting Inc.
Student: Greg Anderson

Development of non-invasive survey techniques for Roanoke logperch based on environmental DNA

PI: James Roberts, Greg Anderson, Paul Angermeier
Funding: \$16,100
Source: VDGIF (from AEP)
Student: Greg Anderson

Development and application of a multiscale model of habitat suitability for Roanoke logperch

PI: Gregory Anderson, Jamie Roberts, Paul Angermeier
Funding: \$19,550
Source: VDGIF (from AEP)
Student: Greg Anderson

Assessment of behavioral shifts in habitat use by Roanoke logperch in response to short term changes in river flow

PI: Gregory Anderson and Paul Angermeier
Funding: \$24,150
Source: VDGIF (from AEP)
Student: Greg Anderson

Cost-effectiveness of riparian restoration as a recovery tactic for Roanoke logperch

PI: Amy Villamagna, Paul Angermeier, Jamie Roberts
Funding: \$20,000
Source: VDGIF (from AEP)
Student: TBA

W. Mark Ford

A Virginia-specific Effort to Estimate Potential Non-hibernating Distribution of Indiana and Northern Bats and Updated Distributional Forested Habitat Relationships Review

PI: W. Mark Ford
Funding: \$90,000
Source: U.S. Fish and Wildlife Service Virginia Field Office and the National Council for Air and Stream Improvement
Post-doctoral Associate: Alexander Silvis

Bat Monitoring on the George Washington-Jefferson National Forest and Mountain WMAs: Emphasis on Assessing Population Status of Small-footed Bats and Assessing Foraging and Day-roosting Value of Prescribed Burns

PI: W. Mark Ford
Funding: \$200,000
Source: Virginia Department of Game and Inland Fisheries
Students: John Huth and TBD

PUBLICATIONS and PROFESSIONAL PAPERS PRESENTED

Published

- Carey, C.S., J.W. Jones, R.S. Butler and E.M. Hallerman. 2013. Determining optimal rearing temperatures to maximize survival and growth of laboratory-propagated juveniles of two federally endangered species, Cumberlandian combshell (*Epioblasma brevidens*) and oyster mussel (*Epioblasma capsaeformis*), and one non-listed species, wavyrayed lampmussel (*Lampsilis fasciola*). North American Journal of Aquaculture (Accepted).
- Catlin, D. H., J. H. Felio, and J. D. Fraser. 2013. Effects of water discharge on fledging times, growth, and survival of piping plovers on the Missouri River. Journal of Wildlife Management, 77: 525–533
- Crimmins, S.M., J.W. Edwards, P.D. Keyser, J.M. Crum, W.M. Ford, B.F. Miller, T.A. Campbell, and K.V. Miller. 2013. Survival patterns of female white-tailed deer on an industrial forest following a decline in population density. In: G.W. Miller, T.M. Schuler, K.W. Gottschalk, J.R. Brooks, S.T. Grushecky, B.D. Spong and J. Rentch, eds) Proceedings of the 18th Central Hardwood Forest Conference; 2012 March 26-28; Morgantown, WV; General Technical Report NRS-P-117. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 487–496.
- Hunt, K.L., N. Taygan, D.H. Catlin, J.H. Felio, and J.D. Fraser. 2013. Demography of Snowy Plovers (*Charadrius nivosus*) on the Missouri River. Waterbirds 36(2): 220–224.
- Kirby, L., S. Sweeten and J.R. Crayon. 2013. Exploring benthic impairment and total dissolved solids in the Dumps Creek Watershed. In: J. R. Crayon (ed) Environmental considerations in energy production. Society for Mining, Metallurgy, and Exploration, Inc., Englewood, Colorado: 362-370.
- Lapointe, N.W.R., J. S. Odenkirk, and P.L. Angermeier. 2013. Seasonal movement, dispersal, and home range of Northern Snakehead *Channa argus* (Actinopterygii, Perciformes) in the Potomac River catchment. Hydrobiologia 709: 73-87.
- Lapointe, N.W.R., J.T. Thorson, and P.L. Angermeier. 2012. Relative roles of natural and anthropogenic drivers of watershed invasibility in riverine ecosystems. Biological Invasions 14: 1931-1945.
- Saylor, R.K., N.W.R. Lapointe, and P.L. Angermeier. 2012. Diet of non-native northern snakehead (*Channa argus*) compared to three co-occurring predators in the lower Potomac River, USA. Ecology of Freshwater Fish 21: 443–452.

- Schuler, T.M., M/ Thomas-Van Gundy, M.B. Adams, and W.M. Ford, W.M. 2013. Analysis of two pre-shelterwood prescribed fires in a mesic mixed-oak forest in West Virginia. In: G.W. Miller, T.M. Schuler, K.W. Gottschalk, J.R. Brooks, S.T. Grushecky, B.D. Spong and J. Rentch, (eds) Proceedings of the 18th Central Hardwood Forest Conference; 2012 March 26-28; Morgantown, WV; General Technical Report NRS-P-117. Newtown Square, PA: U.S. Department of Agriculture, Forest Service, Northern Research Station: 430-446.
- Silvis, A., W.M. Ford, E.R. Britzke, N.R. Beane and J.B. Johnson. 2012. Forest succession and maternity roost selection by *Myotis septentrionalis* in a mesophytic hardwood forest. *International Journal of Forestry*. doi:10.1155/2012/148106. 8 p
- Sweeten, S., J. Sweeten, J. R. Craynon, W.M. Ford and S. Schoenholtz. 2013. Evaluation of current measures of aquatic biological integrity in the central Appalachian Coalfields: efficacy and implications. In: J. R. Craynon (ed) Environmental considerations in energy production . Society for Mining, Metallurgy, and Exploration, Inc., Englewood, Colorado: 381-394.
- Tang, M., Y. Jiao, J.W. Jones. 2013. A hierarchical Bayesian approach for estimating freshwater mussel growth based on tag-recapture data. *Fisheries Research* (Accepted).

In Press

- Hunt, K.L., D.H. Catlin, J.H. Felio, and J.D. Fraser. 2013. Effect of capture frequency on the survival of Piping Plover chicks. *Journal of Field Ornithology*, in press.
- Johnson, J.B., J.L. Rodrigue and W.M. Ford. 2013. Nightly and yearly bat activity before and after white-nose syndrome on the Fernow Experimental Forest in West Virginia, Tucker County, USA. USDA Forest Service Northern Research Station Research Paper NRS-Research Paper (*in press*)
- Roberts, J.H., P.L. Angermeier, and E.M. Hallerman. 2013. Distance, dams and drift: What structures populations of an endangered, benthic stream fish? *Freshwater Biology*, in press.
- Villamagna, A.M., P.L. Angermeier, and E.M. Bennett. 2013. Capacity, pressure, demand, and flow: a conceptual framework for analyzing ecosystem service provision and delivery. *Ecological Complexity*, in press.

In Review

- Coleman, L.S., W.M. Ford, C.A. Dobony, and E.R. Britzke. 2013. Comparison of radio-telemetric home range analysis and acoustic detection for little brown bat habitat evaluation in northwestern New York, USA. *Acta Chiropterologica*
- Ford, W.M., C. A. Kelly, J.L. Rodrigue, R.H. Odom, D. Newcomb, L. M. Gilley and C. A. Diggins. 2013. Late winter and early spring home range and habitat use of the

endangered Carolina northern flying squirrel in western North Carolina. Endangered Species Research

- Johnson, J.B., J.H. Roberts, T.L. King, J.W. Edwards, W.M. Ford and D.A. Ray. 2013. Genetic structuring of northern myotis (*Myotis septentrionalis*) at Multiple Spatial Scales. *Acta Chiropterologica*
- Ostby, B. J. K, J. L. Krstolic and G. C. Johnson. 2013. Reach-scale comparison of habitat and mollusk assemblages for select sites in the Clinch River with regional context. *Journal of the American Water Resources Association*, accepted pending revisions.
- Owen, S.F., J.W. Edwards, W.M. Ford, P.B Wood, and J.L. Berl. 2013. Raccoon (*Procyon lotor*) diurnal den use within an intensively managed forest in central West Virginia. *Forest Ecology and Management*.
- Silvis, A., W.M. Ford, E.R. Britzke, and J.B. Johnson. 2013. Roost and social networks of *Myotis septentrionalis* maternity colonies. *Behavioral Processes*
- Silvis, A, E.R. Thomas, W. M. Ford, E. R. Britzke and M. J. Friedrich. 2013. Cavity characteristics of northern long-eared bat (*Myotis septentrionalis*) maternity day-roosts. *Journal of the Kentucky Academy of Science*
- Villamagna, A.M. and P.L. Angermeier. A methodology for measuring and mapping ecosystem services provided by watersheds. Chapter XX in L. Chicharo, F. Muller, N. Fohrer, and E. Wolanski (eds.), *Ecosystem Services and River Basin Ecohydrology*, Springer.
- Villamagna, A.M., P.L Angermeier, and N. Niazi. Opportunities to enhance ecosystem services in public use areas. *Ecosystem Services*.
- Villamagna, A.M., B. Mogollon, and P.L Angermeier. A multi-indicator framework for mapping cultural ecosystem services: the case of freshwater recreational fishing. *Ecological Indicators*.

Technical and Semi-Technical

- Carey, C.S., J.W. Jones and E.M. Hallerman. 2012. Determining optimal rearing temperatures to maximize survival and growth of laboratory-propagated juveniles of two federally endangered species, Cumberlandian combshell (*Epioblasma brevidens*) and oyster mussel (*Epioblasma capsaeformis*), and one non-listed species, wavyrayed lampmussel (*Lampsilis fasciola*). Final Report. U.S. Fish and Wildlife Service, Asheville, North Carolina. 46 pp.
- Krstolic, J.L., G.C. Johnson, B.J.K.Ostby, 2013, Clinch River: Water Chemistry, Sediment Chemistry, Aquatic Habitat, Geomorphology, and Freshwater Mussel Population Status, 2009 – 2011, US Geological Survey Data Report: 2013-XXXX, 30 pp.
- Lane, T.W., D. Hua and J.W. Jones. 2013. Reintroduction of Endangered Freshwater Mussel Populations to High Priority Geographic Areas in the Upper Tennessee River System. Final Report. U.S. Fish and Wildlife Service, Asheville, North Carolina. 18 pp.

- Ostby, B.J.K. and P.L. Angermeier. 2012. Semi-quantitative freshwater mussel surveys in the Wards Creek, Rocky Creek, Buck Mountain Creek, and Swift Run sub-watersheds of the Rivanna River. Project report to The Nature Conservancy, Charlottesville, VA. 56 pp.
- Roberts, J.H. and P.L. Angermeier. 2012. Monitoring of endangered Roanoke logperch (*Percina rex*) in Smith River upstream from the Philpott Reservoir on U.S. Army Corps of Engineers property near Martinsville, Virginia. United States Geological Survey Open-File Report 2012-1221, 11 pp.

Theses and Dissertations

- Coleman, L.S. 2013. Assessing the impacts of white-nose syndrome induced mortality on the monitoring of a bat community at Fort Drum Military Installation. M.S. Thesis. Virginia Polytechnic Institute and State University, Blacksburg. 117 p.

Papers/Posters Presented

- Argentina, J.E. and P.L. Angermeier. 2012. Surface mining impacts on physical, biological, and chemical variables in the upper Big Sandy River drainage. Annual meeting of American Fisheries Society.
- C.M. Bergeron, M. Johnson, A. White, J. Rogers, P.R. Lazaro, J.W. Jones, B. Beaty, B. Evans, S. Alexander, W. Gregory Cope. 2013. Recent precipitous declines of freshwater mussels in the Clinch River: Influence of sediment and water quality stressors. 8th Biennial Symposium of the Freshwater Mollusk Conservation Society, March 11-15, Guntersville, Alabama.
- Carey, C.S., J.W. Jones, R. Butler, E.M. Hallerman and M.J. Kelly. 2013. Demographic assessment of a reintroduced population of the endangered oyster mussel (*Epioblasma capsaeformis*) in the upper Clinch River, Virginia. 8th Biennial Symposium of the Freshwater Mollusk Conservation Society, March 11-15, Guntersville, Alabama.
- Catlin, D.H. 2013. Rangewide status of piping plovers. Presented to the Missouri River Recovery Implementation Committee (MRRIC), Least Tern and Piping Plover Task Group. January 16th, 2013.
- Catlin, D.H., K. Hunt, J. Felio, J. Fraser, and D. LeFer. 2013. A Decade of Behavioral and Demographic Studies on Piping Plovers on the Missouri River. Presented to the Missouri River Recovery Implementation Committee (MRRIC), Least Tern and Piping Plover Task Group. January 16th, 2013.
- Catlin, D. H., K.L. Hunt, M.J. Friedrich, J.D. Fraser, and S.M. Karpanty. 2013. Noah's Ark or the Titanic: What is the Useful Lifetime of a Sandbar to a Piping Plover? Paper Presented at the Missouri River Natural Resources Conference and Biological Opinion Forum, March 11th–March 14th, Jefferson City, MO.
- Catlin, D. H., K.L. Hunt, M.J. Friedrich, J.D. Fraser, and S.M. Karpanty. 2013. The Effects of Piping Plover Fledgling Condition on Lifetime Fitness: Why Fat Plovers are Better Plovers. Paper Presented at the Missouri River Natural Resources Conference and Biological Opinion Forum, March 11th–March 14th, Jefferson City, MO.

- Coleman, L.S., C.A. Dobony, W.M. Ford and E.R. Britzke. 2013. An overview of little brown bat habitat preference at Fort Drum Military Installation. 23rd Colloquium of Conservation of Mammals in the Southeastern United States. Fall Creek Falls, Tennessee.
- Coleman, L.S., W.M. Ford, C.A. Dobony and E.R. Britzke. 2013. A comparison of mist-netting and acoustic sampling for detecting bat species in the post-white-nosed syndrome world. 2013 Virginia Wildlife Society Meeting. Smith Mountain Lake, Virginia.
- Coleman, L.S., C.A. Dobony, W.M. Ford and E.R. Britzke. 2013. Uncertainty in home range estimates of little brown bats at Fort Drum Military Installation. Northeast Bat Working Group. Albany, New York.
- Coleman, L.S., W.M. Ford, C.A. Dobony and E.R. Britzke. 2013. Doubting Thomas probably did not own an Anabat. 2013 Northeast Bat Working Group. Albany, New York.
- Dunn, C.G. and P.L. Angermeier. 2013. Distribution of candy darter reflects range-wide variation in stream temperature regime and substrate composition. Annual meeting of American Fisheries Society.
- Dunn, C.G. and P.L. Angermeier. 2013. Factors shaping the fish fauna of the New River drainage. New River Symposium.
- Evans, A., W.M. Ford, L. Resler and R.H. Odom. 2012. Modeling the distribution of northern hardwoods in the Carolina northern flying squirrel, *Glaucomys sabrinus coloratus*, recovery areas of North Carolina and Tennessee. Southeast Division Association of American Geographers Annual Meeting. Asheville North Carolina.
- Ford, W.M., C.A. Kelly, J.L. Rodrigue, R.H. Odom, L.M. Gilley and C.A. Diggins. 2013. Spring break 2012: where the Carolina northern flying squirrels are. 23rd Colloquium of Conservation of Mammals in the Southeastern United States. Fall Creek Falls, Tennessee.
- Francl, K.E., R. Reynolds, W. Orndorff, and W.M. Ford. 2013. Assessing population and demographic trends in Virginia's cave bats, 2008-2012. 2013 Virginia Wildlife Society Meeting. Smith Mountain Lake, Virginia.
- Fraser, J.D., D.H. Catlin, S.M. Karpanty, K.L. Hunt, M.J. Friedrich. 2013. The More Things Change, the More They Stay the Same: Key Features of Plover Population Dynamics on the Missouri River. Paper Presented at the Missouri River Natural Resources Conference and Biological Opinion Forum, March 11th–March 14th, Jefferson City, MO.
- Friedrich, M.J., K.L. Hunt, D.H. Catlin, J.D. Fraser, and S.M. Karpanty. 2013. Mate Retention and Nest Success in Piping Plovers (*Charadrius melodus*). Paper presented at the 125th Annual Meeting of the Wilson Ornithological Society, March 7th–10th, Williamsburg, VA.
- Friedrich, M.J., K.L. Hunt, D.H. Catlin, J.D. Fraser, and S.M. Karpanty. 2013. Piping Plover Mate Fidelity or Lack Thereof: What Sleeping Around Tells us about Plover

- Management. Paper Presented at the Missouri River Natural Resources Conference and Biological Opinion Forum, March 11th–March 14th, Jefferson City, MO.
- Frimpong, E. A. The future of traits-based fish ecology and the FishTraits database. Invited symposium presentation. 142nd Annual Meeting of the American Fisheries Society, Minneapolis-St Paul, MN, 19-23 August 2012.
- Hillman, M.D., S.M. Karpanty, J.D. Fraser, and D.H. Catlin. 2013. Effects of Camera Monitoring on Least Tern Nest Success at Cape Lookout National Seashore, North Carolina. Paper presented at the 125th Annual Meeting of the Wilson Ornithological Society, March 7th–10th, Williamsburg, VA.
- Huang, J., and E. A. Frimpong. Modeling optimal habitat for stream fish species with derived historical metacommunity samples. 142nd Annual Meeting of the American Fisheries Society, Minneapolis-St Paul, MN, 19-23 August 2012.
- Hunt, K.L., M.J. Friedrich, D.H. Catlin, J.D. Fraser, and S.M. Karpanty. 2013. Rags to Riches: Preliminary Post-Flood Comparison of Gavins Pint Piping Plover Demography to Long-Term Population Estimates. Paper Presented at the Missouri River Natural Resources Conference and Biological Opinion Forum, March 11th–March 14th, Jefferson City, MO.
- Hunt, K.L., N. Taygan, D.H. Catlin, J.H. Felio, and J.D. Fraser. 2013. Demography of Snowy Plovers (*Charadrius nivosus*) on the Missouri River. Paper presented at the 125th Annual Meeting of the Wilson Ornithological Society, March 7th–10th, Williamsburg, VA.
- Kelly, C.A., W.M. Ford, L.M. Gilley, C.A. Diggins and A.M. Evans. 2013. Toward a better understanding of the distribution and monitoring needs of the Carolina northern flying squirrel. 23rd Colloquium of Conservation of Mammals in the Southeastern United States. Fall Creek Falls, Tennessee.
- Kniowski, A.B., A. Silvis, S.D. Gehrt and W.M. Ford. 2013. Network structured and social assortment by the Indiana bat at an Ohio maternity site. 23rd Colloquium of Conservation of Mammals in the Southeastern United States. Fall Creek Falls, Tennessee.
- Lane, T.W., J.W. Jones, and B.J.K. Ostby. 2013. Longterm monitoring and demographic assessment of mussel populations in the upper Clinch River, Tennessee. 8th Biennial Symposium of the Freshwater Mollusk Conservation Society, March 11-15, Guntersville, Alabama.
- Mogollón, B., A. Villamagna, and P. Angermeier. 2012. Mapping recreational capacity and delivery in natural areas: freshwater fishing in the Albemarle-Pamlico basin. Annual meeting of Natural Areas Conference.
- Mogollón, B., A. Villamagna, and P. Angermeier. 2013. An ecosystem service framework to evaluate landscape-level sustainability of freshwater recreational fishing. Annual meeting of Virginia Chapter, American Fisheries Society.
- Ostby, B., P. Angermeier, and M. Pinder. 2013. Semi-quantitative surveys of the freshwater mollusk assemblages in the Little River, Virginia. Poster at Eighth Biennial Symposium of Freshwater Mollusk Conservation Society.

- Roberts, J.H., P.L. Angermeier, and E.M. Hallerman. 2013. A new framework to evaluate and avert risks to fragmented populations of stream fish. Annual meeting of International Congress for Conservation Biology.
- Silvis, A, W.M. Ford, E.R. Britzke and J.B. Johnson. 2012. Northern bat day-roost ecology, sociality and management: progress at Fort Knox. 2012 Kentucky Bat Working Group Meeting. Frankfort Kentucky.
- Silvis, A., W.M. Ford, E.R. Britzke, and J.B. Johnson. 2013. Identification and delineation of *Myotis septentrionalis* day-roost networks. 23rd Colloquium of Conservation of Mammals in the Southeastern United States. Fall Creek Falls, Tennessee.
- Villamagna, A.M., P.L. Angermeier, and B. Mogollon. 2012. An ecosystem services framework to inform management of natural areas. Annual meeting of Natural Areas Conference.
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