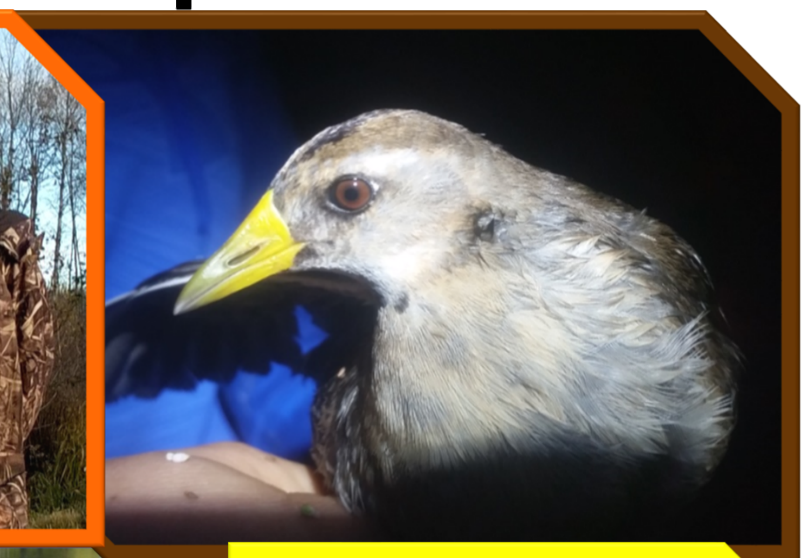
2015 Annual Report

Arkansas Cooperative Fish



& Wildlife Research Unit

Arkansas Game & Fish Commission

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ARKANSAS COOPERATIVE
FISH AND WILDLIFE
RESEARCH UNIT

2015 ANNUAL REPORT

Arkansas Cooperative Fish and Wildlife Research Unit
University of Arkansas
Department of Biological Sciences
Science and Engineering Building, Room 601
Fayetteville, AR 72701

Arkansas Cooperative
Fish & Wildlife Research Unit

The unit is a cooperative program of the:

U.S. Geological Survey
Arkansas Game and Fish Commission
University of Arkansas
Wildlife Management Institute

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INTRODUCTION

Arkansas Cooperative Fish and Wildlife Research Unit first opened its doors in August of 1988 as one of the four units initiated that year, and one of the 40 coop units across the country associated with land grant universities, state fish and wildlife agencies, and the U.S. Geological Survey, Biological Resources Division. The purpose of these units is to train graduate students in scientific methods of fish and wildlife management.

Over the past 27 years, the Arkansas Cooperative Research Unit has become an active part of state and federal research efforts in Arkansas and across the Nation. By the end of our twenty-seventh year, Arkansas Cooperative Research Unit will have initiated many research projects with Arkansas Game and Fish Commission, US Fish and Wildlife Services, U.S. Geological Survey, National Park Services, and other federal, state and private organizations as sponsors. These projects have funded the research of 57 MS and 11 PhD students, most of which are now working a professional biologists. Presently those students are employed by federal, state, and private agencies, colleges and universities, or are continuing their graduate degrees at other schools. Arkansas Cooperative Research Unit leaders and students have published 147 scientific and technical publications listing the unit and our cooperators in byline and acknowledgements, and another six publications have been accepted or submitted for publication. Unit leaders and Assistant leaders have taught many classes I fisheries and wildlife. Finally, including base funds and contracts, Arkansas Cooperative Research Unit has brought more than $18,602,987 directly into the community.

During the past quarter of a century, Arkansas Cooperative Research Unit has gone through a number of changes. We have changed our federal cooperator from U.S. Fish and Wildlife Services to National Biological Survey to National Biological Service, and we now reside within the U.S. Geological Survey. Our university department changed from Zoology to Biological Sciences and then incorporating the departments of Botany and Microbiology. We have seen ten departmental chairs (Amlaner, Geren, Kaplan, Talburt, Rhoads, Roufa, Davis, Smith, Spiegel, and Beaupre), two unit leaders (Johnson and Krementz), six assistant unit leaders (Annette, Martin, Griffith, Kwak, Thompson, and Magoulick), four administrative assistants (Kimbrough, Koldjeski, Parker and Moler), three post-doctoral assistants (LeMar, Lehnen, and Longing), and nine research specialist/technicians (Neal, Aberson, Vaughn, Thogmartin, Lichtenberg, Piercey, Bahm, Nault, and Kitterman).

MISSION STATEMENT

The mission of the Arkansas Cooperative Fish and Wildlife Research Unit is to conduct programs of research, graduate education, and technical assistance that address the needs of the State of Arkansas, the region, and the nation. Research programs will pursue both basic and applied scientific questions that are relevant to the management of fish, wildlife, and their habitats. Research topics will be pursued according to Cooperator priorities, availability of collaborative expertise from cooperators, and funding opportunities.

The educational mission of the Arkansas Cooperative Fish and Wildlife Research Unit shall focus on graduate and post-graduate students. Activities will include teaching of formal graduate-level classes, chairing and serving on advisory committees, mentoring the professional development of students, and participation by unit scientists in academic programs of the University of Arkansas. Students should be educated to prepare for advancement in broad areas of natural resource management to serve as future leaders of resource management in the State of Arkansas, region and country. Educational programs of the Arkansas Cooperative Fish and Wildlife Research Unit will be consistent with the professional standards and hiring practices of the cooperators, similar agencies elsewhere, and relevant professional societies involved with natural resource management.

Technical assistance will be provided to unit cooperators in the areas of scientific expertise of the unit. This can include assistance with interpretation of data, preparation and review of experimental designs, identification of specific research voids or needs, ad rendering professional judgment. Such activities will generally serve to link the scientists' previously established expertise to specific needs of the cooperators or other related agencies.

Front row, left to right: Dustin Lynch, Christopher Middaugh, Lindsey Bruckerhoff, Nicole Graham, Cari Sebright. Second row, left to right: Daniel Magoulick, Robert Fournier, Phillip Stephenson, Joseph Moore, Auriel Fournier. Third row, left to right: David Krementz, and Diane Moler. Not pictured: John Herbert, Doug Leasure, and Jeremiah Flannery. Photo by Angela Hamilton 2015 (AR Coop Unit)

PERSONNELL AND COOPERATORS

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CURRENT GRADUATE STUDENTS

Lindsey Bruckerhoff, (M.S., Fisheries – Magoulick)
Auriel Fournier (Ph.D., Wildlife – Krementz)
Robert Fournier (Ph.D., Fisheries – Magoulick)
Brittany Furtado, (Ph.D., Fisheries – Magoulick)
Nicole Graham (M.S., Fisheries – Magoulick)
John Herbert (M.S., Wildlife – Krementz)
Doug Leasure (Ph.D., Fisheries – Magoulick)
Dustin Lynch (Ph.D., Fisheries – Magoulick)
Jacob McClain (M.S., Wildlife – Krementz)
Christopher Middaugh (Ph.D., Fisheries – Magoulick)
Joseph Moore (M.S., Wildlife – Krementz)
Cari Sebright (M.S., Wildlife – Krementz)
Phillip Stephenson (M.S., Wildlife – Krementz)
Allyson Yarra (M.S., Fisheries – Magoulick)

RECENTLY GRADUATED

Doug Leasure, Ph.D. – Fisheries

HOURLY TECHNICIANS AND VOLUNTEERS

Mr. Tevin Douglas – REU
Mr. Jonathan H. Fournier – Rails
Ms. Nicole Graham – Crayfish
Mr. John Herbert – Mallards
Ms. Brin Kessinger – REU
Dr. Doug Leasure – Hydrological
Mr. Jacob McClain – Bobwhite
Ms. Elizabeth Moore – Woodcock
Mr. Joseph Moore – Woodcock
Dr. H. Tyler Pittman – Turkey
Ms. Cari Sebright – Woodcock
Mr. Nicolas Seeger – Rails
Ms. Bailey Stein – REU
Mr. Phillip Stephenson – Pollinator
Mr. Jeremy Wood – Woodcock
Ms. Allyson Yarra – REU & Crayfish

RESEARCH AND FACULTY COLLABORATORS

Dr. David Andersen – U.S. Geological Survey, Minnesota Cooperative Fish and Wildlife Research Unit
Mr. Benny Bowers – Arkansas Game and Fish Commission
Dr. Bret Collier – Louisiana State University
Mr. Dan Collins – U.S. Fish and Wildlife Services
Dr. Tom Cooper – U.S. Fish and Wildlife Service
Dr. Jack Cothern – University of Arkansas
Mr. Richard Crossett – U.S. Fish and Wildlife Service
Mr. Robert J. DiStefano – Missouri Department of Conservation
Dr. Marlis Douglas – University of Arkansas
Dr. Michael Douglas – University of Arkansas
Dr. Ashley Dowling – University of Arkansas
Dr. Jeff Duguay – Louisiana Department of Wildlife and Fisheries
Mr. Josh Duzan – Biohydrologist, The Nature Conservancy
Mr. Kevin Eads – National Park Service
Dr. Michelle Evans-White – University of Arkansas
Dr. James Fetzner – Carnegie Museum of Natural History
Mr. Houston Havens – Mississippi Department of Wildlife, Fisheries and Parks
Mr. Kyle Hedges – Missouri Department of Conservation
Mr. Mark Hutchings – Arkansas Game and Fish Commission
Mr. Clifton Jackson – Arkansas Game and Fish Commission
Mr. JA “Buck” Jackson – Arkansas Game and Fish Commission
Dr. John Jackson – Department of Biological Sciences, Arkansas Tech University
Dr. Sarah Lehnen – U.S. Fish and Wildlife Service
Mr. Frank Loncarich – Missouri Department of Conservation
Mr. Kevin Lynch – Arkansas Game and Fish Commission
Dr. Doreen Mengel – Missouri Department of Conservation

Mr. Nolan Moore – National Park Service
Dr. Kusum Naithani – University of Arkansas
Mr. Luke Naylor – Arkansas Game and Fish Commission
Mr. Shaun Oldenburger – Texas Parks and Wildlife
Dr. Jim Petersen – Hydrologist Study Unit Chief, Ozark Plateaus Study Unit USGS Arkansas Water Science Center
Mr. Jeffrey W. Quinn – Arkansas Game and Fish Commission
Dr. Andy Radaeke – Missouri Department of Conservation
Mr. Al Stewart – Michigan Department of Natural Resources
Dr. Jason Tullis – University of Arkansas
Mr. Brian Wagner – Arkansas Game and Fish Commission
Mr. Andy Weik – Ruffed Grouse Society
Mr. Jacob Westoff – PhD. Student, University of Missouri
Ms. Rhea Whalen – U.S. Forest Service
Dr. J.D. Willson – University of Arkansas

COMPLETED WILDLIFE PROJECTS

Joe Moore holding a radio marked American woodcock, photo by Liz Moore (AR Coop Unit)

Female Mallard

The Abundance and Distribution of Mallards in the Lower Mississippi Alluvial Valley of Arkansas

Funding Source:	University of Arkansas Arkansas Cooperative Fish and Wildlife Research Unit U.S. Fish and Wildlife Services
Project Duration:	August 2013 to December 2015
Principle Investigator:	DAVID G. KREMENTZ
Graduate Student:	JOHN HERBERT (M.S. Student)

Research Objectives:

1. Relate waterfowl distributions and abundances to environmental and habitat covariates.
2. Analyze the temporal and spatial changes in waterfowl abundance during a single season and amongst years.

Management Implications:

1. This study will provide land managers with information to improve waterfowl conservation strategies during the winter months in Arkansas. Since we will be using agriculture and flood data, this information can better inform farmers in the Mississippi Alluvial Valley (MAV) on how

they can contribute to waterfowl conservation. Further cooperative measures with farmers and land managers in the MAV can contribute to higher waterfowl yields during the winter.

Project Summary:

Arkansas winters large numbers of dabbling ducks, diving ducks and geese (Reinecke et al. 1989). In particular, Arkansas is the primary wintering area for mallards (*Anas platyrhynchos*) in North America (Bellrose 1976, Reinecke et al. 1989). Arkansas consistently has the highest mallard harvest per year of any state, and the Arkansas Delta contains the majority of those harvested mallards (Green and Krementz 2008). For this reason, studying the factors that influence winter distribution and abundance of mallards will help biologists better manage this species and likely other dabbling ducks. This research will address the effect that surface water and other environmental covariates has on the spatial movements and abundance of mallards over time.

The Arkansas Game and Fish Commission (AGFC) conducts aerial waterfowl surveys four times each winter. In 2009, the AFGC began to conduct surveys using a stratified random design by separating the MAV into five strata. The AGFC further advanced the survey design by developing a new stratified random sampling design based on U.S. Geological Survey watersheds, which separated the MAV into eleven separate strata. This new sampling design increased the precision and accuracy of the survey results. We are using data obtained by the AGFC aerial winter waterfowl surveys from November 2009 through January 2015.

Using spatial hierarchical models and breaking covariate data to 2x2 km grid cells, we analyzed how covariates relate to the changes of abundance and distributions (Chakraborty et al. 2010) within a single survey and within a single year. All models had a response of mallard abundance corrected for a combination of covariates. We developed an agriculture model to assess whether agriculture land in the form of rice, soy, corn and fallow fields along with waste crop explained mallard abundance. Land cover interactions with surface water models were developed by using land cover types explained to be important to mallards in previous studies and we added surface water as an interaction term or as a main effect. Finally, we modeled to see if water alone (surface water, permanent water) best explained mallard decisions with no other covariates.

Within a single survey, surface water was consistently positively associated with mallard abundance. As a main effect, surface water had a positive association with mallard abundance and as an interaction with land cover covariates. Rice fields, wetlands, fallow fields, soy fields and permanent water all had parameter (β) estimates positively associated with mallard abundance. Comparing beta estimates by importance (mean/standard deviation), surface water was the most important covariate positively associated with mallard abundance in 11 out of 19 months. Corn fields, EQIP land, and managed land did not influence mallard abundance.

Model performance for within-year was similar to the within-month models. The land cover + surface water model and the global model were again the best performing models. Land cover + surface water was the top performing model in the 2009-10, 2010-11, and 2012-13 winter seasons. The global model was the top-performing model in the 2011-12 and 2013-14 winter seasons. Surface water was consistently positively associated with mallard abundance. As a main effect, surface water had a positive association with mallard abundance and as an interaction with land cover covariates. Rice fields, wetlands, fallow fields, soy fields and permanent water all had beta estimates positively associated with mallard abundance. WSI had beta estimates negatively associated with mallard abundance in 13 months. Comparing beta estimates by importance (mean/standard deviation), surface water was the most important covariate positively associated with mallard abundance in 11 out of 19 months. WSI ranked 13 highest among covariates in 6 out of 19 months.

Managers can use our results to make more informed decisions when managing for waterfowl in the MAV. We showed that soybean fields, rice fields and wetlands are important habitat for mallards in the MAV. Land in the MAV managed by state or federal agencies only covers ~5% of the total land in the MAV, meaning that a lot of waterfowl habitat is private land. This research can be used to show private land owners the important role their land has to waterfowl over a large spatial scale.

Cari Sebright holding an American Woodcock at the Wedington Wildlife Management Area, photo by John Herbert (AR Coop Unit)

Spring Migration Ecology of American Woodcock (Scolopax minor) in the Central Management Region of the United States

Funding Source:	University of Arkansas Arkansas Cooperative Fish and Wildlife Research Unit
Project Duration:	August 2013 to May 2015
Principal Investigator:	DAVID G. KREMENTZ
Graduate Student:	CARI SEBRIGHT (M.S. Student)

Research Objective:

1. Document habitat use of American woodcock during spring migration in Arkansas, Missouri, Iowa and Illinois.

Management Implications:

1. Knowledge of habitats used during spring migration will allow managers to better manage for American woodcock across the Central Management Region.

Project Summary:

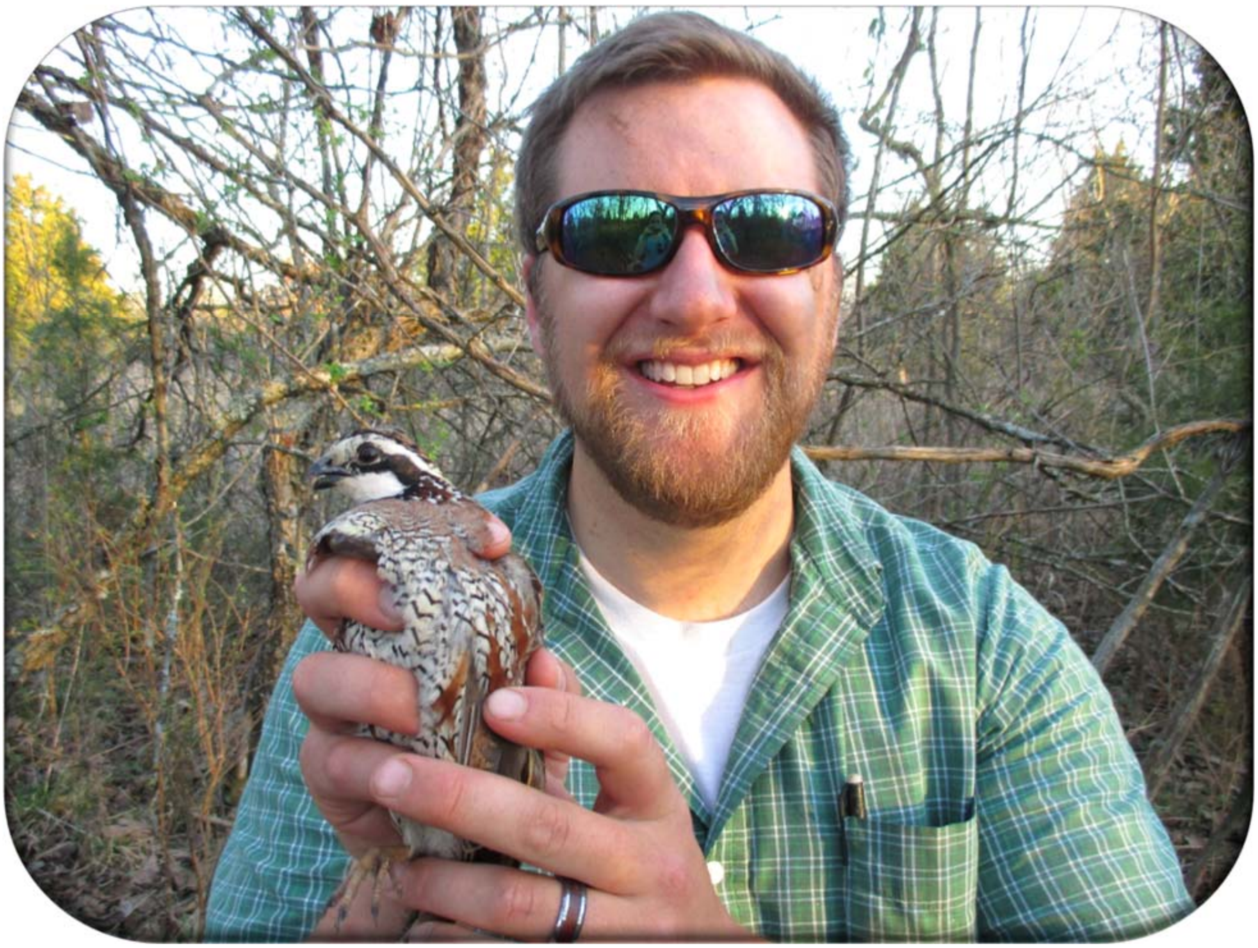
The American woodcock (*Scolopax minor*) is an elusive and sought after game bird. However American woodcock (hereafter called woodcock) populations have been in steady decline since 1968 in the Central and Eastern Management Regions in the United States (Cooper and Rau 2013). In 2006 a Migratory Shore and Upland Game Bird Support Task Force was established to develop research priorities to better manage woodcock habitat (Case et al. 2010). One of the priority information needs listed by the Task Force is to document habitat use during migration (Case et al. 2010). Most studies to date have focused on both the northern breeding grounds and the southern wintering grounds while little to no research has been conducted on the migration routes.

We solicited both citizen scientists and volunteers from federal and state agencies to conduct surveys on woodcock in Arkansas, Missouri, Iowa and Illinois which are located between the breeding and wintering grounds of the Central Region. We conducted surveys from 15 January to 20 April during the spring migration in 2014 and 2015. We conducted surveys in a wide variety of habitat types to collect abundance data and location information. From these locations we described habitats used. We investigated potential diurnal habitats used by these birds using a GIS analysis. First, we estimated the average distance a woodcock flies from a nocturnal roosting field to the surrounding diurnal habitat. We accomplished this by capturing a sample of woodcock in Arkansas and fitting them with VHF transmitters. We determined locations for each marked bird at least twice a day during the diurnal period to determine distances traveled from nocturnal to diurnal habitat. Once we had an estimate of these distances, we used these estimates to describe the habitat surrounding the singing grounds using large scale vegetation GIS layers like LANDFIRE data.

Preliminary Results:

During both field seasons, 268 volunteers conducted 1,341 surveys during the crepuscular period from 15 January to 20 April. Of these surveys, 860 surveys were considered valid. No woodcock were detected on 433 surveys, 389 surveys had some (1-5) woodcock detected, and 38 had many (>6) woodcock detected. We caught and marked six woodcock in Arkansas. We located all marked woodcock at least once before they migrated. Marked woodcock remained in the area a median of 4 days, with a range of 9 days before migrating. We recorded 24 diurnal locations for marked woodcock. The average distance moved between nocturnal and diurnal habitat was 370 m (SE 25.3 m). No marked woodcock moved >650 m between nocturnal and diurnal habitat. We used a 700 m buffer to examine habitats used both diurnally and nocturnally by migrating woodcock. Survey areas where woodcock were detected had less agriculture (specifically row crops) and more hardwood cover, especially where tree cover was 70-80%, than present in the study area. Survey areas where woodcock were detected also had high patch size coefficients of variance, this indicated that large ranges of patch sizes and high habitat variability were within close proximity to survey locations. Our data suggest that hardwood forested stands may be more important to spring migrating woodcock than previously thought.

CURRENT WILDLIFE PROJECTS



Jake McClain holding Radio marked Northern Bobwhite at Pea Ridge National Military Park, photo by Jennifer McClain (AR Coop Unit)

American Woodcock with a 9.5 g Satellite Transmitter

American Woodcock Migration Ecology

Funding Source:	Arkansas Cooperative Fish and Wildlife Research Unit, Minnesota Cooperative Fish and Wildlife Research Unit, U.S. Fish and Wildlife Service, Ruffed Grouse Society and American Woodcock Society, Texas Parks & Wildlife Department, Glassen Foundation, Michigan Department of Natural Resources, Louisiana Department of Wildlife & Fisheries, University of Arkansas, Woodcock Limited
Project Duration:	August 2014 to August 2016
Principal Investigator:	DAVID G. KREMENTZ
Graduate Student:	JOSEPH D. MOORE

Research Objectives:

1. Document timing of migration, rate and distance traveled, stopover length, and routes taken for both spring and fall migration of American woodcock.

Management Implications:

1. This project will generate data on both American woodcock migratory stopover habitat characteristics and migration routes used. Combining the information from both spatial scales

will allow us to identify priority areas to focus habitat management and acquisition efforts for American woodcock along these routes.

2. An increased understanding of the timing of migration initiation and migratory routes can be used to fine-tune hunting-season dates.

Project Summary:

American woodcock (*Scolopax minor*) are a species of conservation concern across eastern North America. Results from the Singing-ground Survey, an index used to monitor woodcock populations, show long-term declines across the species' range. Understanding American woodcock migration as it relates to population ecology is a high-priority information need–in part, because the migratory period is believed to be a period of high mortality. The current understanding of woodcock migration ecology has been limited by available technology such as VHF telemetry, band-recovery, and wing collection survey data. Recent developments in the miniaturization of satellite transmitters (PTTs) now allow satellite telemetry of American woodcock. We are deploying PTTs on woodcock in their breeding and wintering grounds of the Central Management Region, an area with boundaries similar to that of the Mississippi Flyway. This will allow us to document timing of migration initiation, rate of migration, stopover length, routes taken, and final destination for both spring and fall migration.

Between September 2013 and February 2016 we deployed 75 PTTs on woodcock on their breeding (n = 24) and wintering grounds (n = 51). Three types of transmitters were used in this project; a 9.5 g PTT, a 5 g PTT, and a 4.9 g GPS PTT. The 9 g and 5 g PTTs are solar-powered and transmit messages every two and a half days. A passing satellite receives these messages and relays them to a receiving station. The woodcock's location is estimated by measuring the amount of Doppler shift between subsequent messages. The Doppler shift occurs when the source of an energy wave (e.g., sound) is moving relative to where the wave is detected. The locations collected by these transmitters are received live. The other type of tag used is a combination GPS receiver and satellite transmitter. This tag triangulates its position every three days using messages transmitted by GPS satellites. This tag is battery powered and only has enough charge to collect thirty locations along one migration path. Once the season is complete, the tag then transmits all the GPS locations to a satellite in one burst. We deployed forty-four 9.5 g PTTs over the course of the study. We deployed ten 5 g PTTs during January 2015. These tags performed poorly and were not used in future seasons. We deployed twenty-one 4.9 g GPS PTTs in October 2015 and January 2016. We attached PTTs using a modified thigh harness. Woodcock were trapped using night-lighting with hand nets and mist-netting techniques.

Through the fall 2015 migration forty-one full migration paths have been documented showing that American woodcock can be successfully studied using these miniature tracking devices. A preliminary analysis of the data shows that during the 2015 spring migration the median date of migration initiation was on March 4, the median date of arrival on the breeding grounds was on April 25, and the median duration of migration was 57 days. During the 2015 fall migration, the median date of migration initiation as on November 11, the median date of arrival on the wintering grounds was on November 19, and the median duration of migration was 33 days. As of March 9, 2016, we are tracking the spring migration of twenty-five woodcock with solar PTTs. We may additionally receive information from up to eleven woodcock outfitted with GPS PTTs for a spring 2016 sample size of thirty-six woodcock.

We have created a publicly accessible website showing up-to-date locations of tagged birds (www.ruffedgrousesociety.org/woodcockmigration). This page has had over 30,000 views between fall 2014 and spring 2016. Data from this project will provide an insight into woodcock migration ecology that could form a basis for directing woodcock management along migration routes.

Sora at Fountain Grove Conservation Area, photo by Auriel Fournier (AR Coop Unit)

Effects of Wetland Management Strategies on Habitat Use of Autumn Migrating Rails on Intensively-Managed Wetland Complexes in Missouri

Funding Source:	U.S. Fish and Wildlife Service Missouri Department of Conservation Arkansas Cooperative Fish and Wildlife Research Unit
Project Duration:	July 2012 to June 2017
Principal Investigator:	DAVID G. KREMENTZ
Graduate Student:	AURIEL M.V. FOURNIER (Ph.D. Student)

Research Objectives:

1. Evaluate the tradeoffs in response of rails and waterfowl in early versus late flooding of wetlands in the autumn.
2. Estimate Sora, Virginia, Yellow and King Rail abundance in relation to water level management and wetland habitat management regimes during autumn migration.

Management Implications:

1. Understanding how management of impoundments for waterfowl impacts rails will result in better wetland management decisions for rails and waterfowl during autumn migration.

Project Summary:

The Migratory Shore and Upland Game Bird Support Task Force for rails and snipe identified four priority information needs of which one, estimate vital rates to support population modeling, requires information on where sora concentrate during autumn migration to improve capture efficiency. While autumn may provide an opportune time to capture Sora for a telemetry study to estimate vital rates, it first will be useful to determine characteristics of habitat most likely to support rails during autumn migration.

We are surveying impoundments in four different regions of Missouri, each containing at least one Missouri Department of Conservation (MDC) Conservation Areas (CA) and one U.S. Fish and Wildlife Service (USFWS) National Wildlife Refuge (NWR). We are employing a distance-sampling based approach to survey managed wetland impoundments at night using ATVs and spotlights between 15 August and 31 October 2012-2015. From this data set, we will estimate detection probabilities, occupancy rates and abundances. We will relate these estimates to habitat and management covariates at local and landscape levels

Based on our 2012 and 2013 field seasons we initiated a three-year management experiment in 2014 at the 10 sites. At each site, two impoundments were selected and were randomly assigned to one of two flooding treatments. The first treatment - early flooding - began flooding on 1 August and brought the impoundment to 'full pool' by 15 September. The second treatment – late flooding – began flooding on 31 September and brought the impoundment to full pool by 31 October. In 2015 the treatments will be switched (i.e., early in 2014 will be late in 2015) and in 2016 they will be held constant (early in 2015 will be early in 2016). We will survey for rails in the same manner each year and each property manager will conduct weekly ground counts for waterfowl throughout waterfowl season. We will obtain hunter effort and harvest data from MDC. These data will allow us to compare the response of both rails and waterfowl to the two treatments and assess if early flooding provides better habitat for rails, and if it does, what impacts that has on subsequent waterfowl use and harvest.

We only observed 12 Yellow Rail in 2015 and their timing was similar to previous years. No Black Rails or King Rails were detected during the 2015 survey period. Correcting for survey effort, we detected similar numbers of rails in 2015 as during previous years with the exception of 2012, which had higher abundances, possibly due to the drought that year. Each year we have detected fewer numbers of Yellow, Virginia and King Rails.

We found a similar inner quartile range and median date for the peak of Sora migration in 2015 compared with 2012 and 2013. Our visual comparison of the three years of Virginia Rail distributions suggests the peak of migration was slightly later in each successive year.

We estimated Sora density using the gdistsamp() function. We found a significant difference in Sora density between the two treatments (p=<0.01). In 2015-16, we did not find a significant difference in waterfowl use between the two treatments (p=0.09) or between hunter harvest (p=0.25). At the time of this writing, the 2015-16 waterfowl data are not yet available.

We intend to survey 10 August – 31 October, 2016 using the same methods. In 2015 the flooding treatments will be kept the same as 2015.

Phillip Stephenson processing a pan trap sample, Woodruff County, Arkansas

Pollinator Communities on Actively and Passively Managed Emergent Wetlands in the Lower Mississippi Alluvial Valley of Arkansas

Funding Source:	U.S. Fish and Wildlife Service United States Department of Agriculture Arkansas Cooperative Fish and Wildlife Research Unit University of Arkansas
Project Duration:	August 2014 to December 2016
Principal Investigator:	DAVID G. KREMENTZ ASHLEY P.G. DOWLING
Graduate Student:	PHILLIP STEPHENSON (M.S. Student)

Research Objective:

1. Compare pollinator community metrics between passively and actively managed emergent wetlands throughout the flowering season, and
2. Document whether pollinators visiting flowers in wetlands are also visiting flowers in adjacent croplands.

Management Implications:

1. These data should assist wetland biologists in making better management decisions on public and private emergent wetlands for the health of pollinator communities.

Project Summary:

Insect pollinators supply an ecological service to both crops and wild flowering plants by pollinating those plants which in turn increases the size and quality of harvest of agriculture crops. Despite the honeybee's effectiveness as a pollinator for many crops, the risks associated with reliance on a single managed pollinator species have become evident over the past decades as North American honeybee populations have declined by 25% due to the parasitic mite *Varroa destructor*, Colony Collapse Disorder, farming intensification, habitat fragmentation, habitat loss, and agrochemicals. Though cotton, rice, and soybeans are considered autogamy (self-pollinating), cross-breeding (via pollinators) helps increase yield, produce more viable seed, and enhance genetic diversity of the crop. Emergent wetlands occur adjacent to croplands throughout the southeastern United States and create valuable floral resources for pollinators throughout the growing season. Some of these emergent wetlands on public lands are actively managed for annual plants that produce abundant seed resources for migratory waterfowl while some emergent wetlands are more passively (less frequently or less intensely) managed for perennial plants. Pollinator communities that use emergent wetlands have been poorly documented and their benefits to plant communities on surrounding lands are not fully appreciated.

We surveyed passively and actively managed emergent wetlands across the lower Mississippi Alluvial Valley of Arkansas during the 2015 field season. We selected 14 sites there because of the high abundance of lowland areas and close proximity to agricultural production. Sites surveyed included five Wildlife Management Areas (WMA) managed by the Arkansas Game and Fish Commission (AGFC), three National Wildlife Refuges (NWR) managed by the U.S. Fish and Wildlife Service (USFWS), one Natural Area (NA) managed by the Arkansas Natural Heritage Commission (ANHC), and two private lands. The number of sampling sites used varied by ownership and management practice. We surveyed for species richness and abundance of native bees (Hymenoptera: Anthophila) using pan traps, blue-vane traps, and sweep nets. Preliminary sampling for all pollinators was not effective, so we restricted our sampling to bees. We have processed 1,746 individual bees but samples are still being processed.

Future Direction:

We intend to survey May –September, 2016. Because of the large number of bees collected in 2015 and the time necessary to process these samples is a concern, we will reduce our sampling effort per site next year. However, we will include more sites to get a better handle on among-site variation in bee diversity and abundance.

NEW WILDLIFE PROJECTS

King Rail at Red Slough WMA, Oklahoma

Radio-collared raccoon on Stony Podaint Prairie CA, Missouri

Abundance, Foraging Behavior, and Spatial Ecology of Potential Northern Bobwhite (*Colinus virginianus*) Nest and Brood Predators under two Management Models

Funding Source:	Missouri Department of Conservation University of Arkansas Arkansas Cooperative Fish and Wildlife Research Unit Pea Ridge National Military Park
Project Duration:	May 2015 to May 2017
Principal Investigators:	DAVID G. KREMENTZ
Graduate Student:	JACOB C. MCCLAIN (M.S. Student)

Research Objectives:

1. Estimate abundance of raccoon (*Procyon lotor*) and Virginia opossum (*Didelphis virginiana*) for Conservation Areas managed either intensively or extensively.
2. Estimate home ranges of mesopredators living on Conservation Areas managed either intensively or extensively.
3. Estimate the likelihood of a mesopredator encountering northern bobwhite nests or broods for both intensively and extensively managed Conservation Areas.

Management Implications:

1. Understanding how management of Conservation Area landscapes affects the abundance, spatial ecology, and foraging behavior of mesopredators will allow managers to better manage sites to achieve population goals for northern bobwhite.

Project Summary:

Northern bobwhite (*Colinus virginianus*) populations have declined steadily during recent decades in Missouri and across their range. Concerned public and private stakeholders including the Missouri Department of Conservation (MDC) have begun efforts to benefit populations of this ecologically and economically important game species on public Conservation Areas (CAs). Currently CAs are managed using either an intensive or extensive approach. The Intensive Management Model (IMM) includes creating small, rectangular, interspersed patches of grass, cropland, woodlands, and bare ground. The Extensive Management Model (EMM) includes using prescribed fire and grazing to produce the desired patchy habitat mosaic that northern bobwhite prefer. Preliminary results of a nest success study by MDC indicate that nest success is higher on EMM sites than IMM sites. IMM potentially creates an environment that allows for more efficient prey searching by mammalian mesopredators that may result in high predation of nests and broods in CAs and other lands similarly managed.

In 2015 we conducted our research on two state-owned Conservation Areas in southwest Missouri: Robert E. Talbot (IMM) and Stony Point Prairie (EMM) from May 20-August 10. We trapped raccoons and opossums using live and hand-hold traps in June and July. We marked opossums and raccoons with a unique identifiable mark using ink. We marked 4 and 7 raccoons and 10 and 9 opossums on Talbot and Stony respectively. Likewise, we outfitted a subset of raccoons (4) and opossums (4) with radio collars in order to determine home range size and examine movements. Game cameras took images of marked and unmarked individuals. We set up 23 and 17 cameras in a variety of habitats on Talbot and Stony respectively.

Our game cameras detected 854 potential nest and brood predators of the northern bobwhite Using 17 cameras on Stony Point, we recorded multiple images of raccoons (300), armadillos (14), coyotes (16), opossums (28), and bobcats (4). Using 23 cameras on Talbot we recorded multiple images of raccoons (209), armadillos (86), coyotes (37), opossums (155), and bobcats (5). Camera density was higher on Stony (4.3 cameras/km^2) than on Talbot (1.3 cameras/km^2). Taking into account the different camera density, our data suggests that Talbot had higher indices of opossums (6.7/camera), armadillos (3.7/camera), and coyotes (1.6/camera) compared to Stony which had 1.6 opossums per camera, 0.8 armadillo per camera, and 0.9 coyote per camera. Based simply on our camera indices, density of opossums, coyotes, and armadillos were higher on Talbot, while raccoon density was higher on Stony Point. Additionally, we feel these data suggest that mesopredator abundance and diversity was higher on the intensively managed Talbot.

Individually identifiable marks on the mesopredators did not last long, which resulted in few (4) individuals recaptured during the resighting periods. Radio-collared individuals were more easily observed due to the collar material. To increase the number of resightings, we are considering implementing a different marking method as well as increase the number of cameras deployed on each area.

Radio-marked individuals were tracked 2-3 times per week for a period of 1 hour. Locations were recorded every 10 minutes. Using the location data for each collared individual, we created minimum convex polygons to determine crude estimates of home range size. Home range sizes were smaller than anticipated, which may indicate an abundance of resources available during mid-summer. Average home range size for raccoons on Talbot was 76,256 m^2 (3 individuals: 26,915-101,915 m^2), while for Stony the average was 200,231 m^2 (1 individual). The average opossum home range was 79,133 m^2 (1 individual) and 286,986 m^2 (3 individuals: 7,174-709,143 m^2) for Talbot and Stony respectively. These averages do not likely represent the real home range sizes due to small sample sizes for most individuals radio-collared.

In 2016 we will expand our study area to include four Conservation Areas in southwest Missouri (Talbot, Stony Point Prairie, Wah-Kon-Tah Prairie, and Shawnee Trail). We plan to outfit 10 raccoons with GPS transmitters to investigate how foraging movements differ between individuals on EMM and IMM sites and to estimate the likelihood of mesopredators encountering northern bobwhite nests. Using both camera and telemetry data we will formally estimate abundance of both raccoons and opossums on for each of the four study areas using a spatial mark-resight (SMR) model.

COMPLETED FISHERIES PROJECTS

Brin Kessinger photo by Christopher Middaugh (AR Coop Unit)

Crooked Creek, Arkansas

Quantification of Hydrologic Alteration and Relationships to Biota in Arkansas Streams: Development of Tools and Approaches for Un-Gaged Streams

Funding Source:	Arkansas Game and Fish Commission University of Arkansas Arkansas Cooperative Fish and Wildlife Research Unit
Project Duration:	March 2014 to June 2016
Principal Investigator:	DANIEL D. MAGOULICK
Graduate Student:	DOUGLAS R. LEASURE (Ph.D. Student)

Research Objectives:

1. Develop the capability to assess flow alteration at un-gaged streams in Arkansas.
2. Quantify hydrologic alteration in streams with existing biological community data and establish key relationships between flow alteration and the integrity of stream communities.
3. Assess potential biological impact of hydrological alteration for streams of conservation interest, such as the Little Red River.

Management Implications:

1. Results from this work will contribute to a scientific foundation for environmental flow standards in Arkansas.

2. Developing methods to assess hydrologic alteration for *un-gaged* streams will allow existing biological data to be used to examine issues of flow alteration in Arkansas, saving resources otherwise needed to collect biological data at gage sites.
3. This work will positively impact many species and ecosystems statewide, those of greatest conservation need and otherwise.
4. Information from this study will also be useful for dealing with water use issues, such as those from natural gas development.

Project Summary:

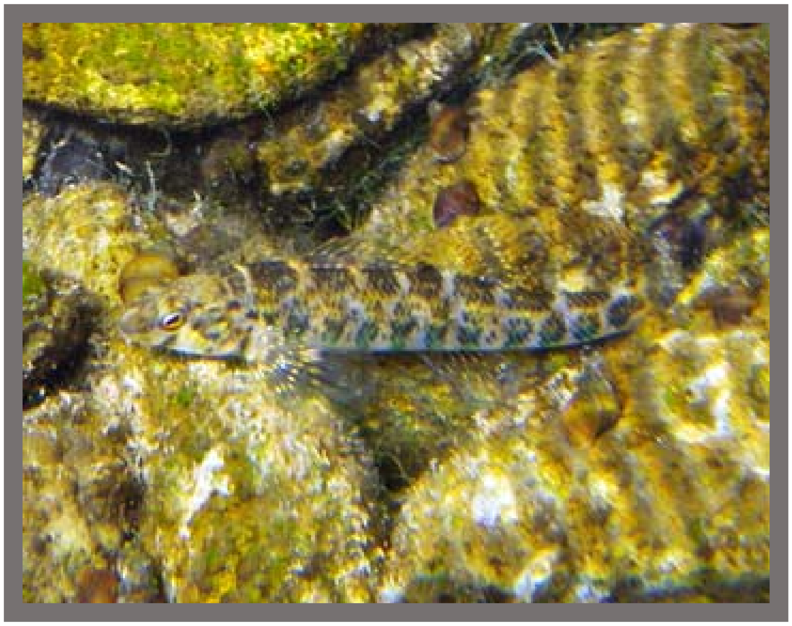
Providing adequate water quantity and quality in streams and rivers is a pressing issue in Arkansas and worldwide. For this reason, it is crucial to determine appropriate flows in streams to protect fish and wildlife needs (environmental flows). A crucial component of determining environmental flows is determining hydrologic alteration. Additionally, the ability to determine hydrologic alteration for sites where discharge data does not exist (i.e. un-gaged sites) is crucial to examining environmental flows for most streams in Arkansas and the U.S. A method has been proposed (Carlisle *et al.* 2010) to assess hydrologic alteration at gaged sites by comparing observed flow characteristics of a gaged stream to expected natural flow characteristics predicted based on catchment and climate characteristics. Currently, only a small portion of existing biological data are from stream sites where USGS stream gages are in operation, making it difficult to relate stream flow and flow alteration to biological communities.

We will develop an approach to assess flow alteration at un-gaged sites in portions of Arkansas, Oklahoma, and Missouri that include the Ozark Highlands, Boston Mountains, Arkansas Valley, Ouachita Mountains, and Arkansas' South Central Plains. We will first use the (Carlisle *et al.* 2010) method to quantify flow alteration at gage sites within our study area. We will then use relationships between flow alteration and catchment characteristics at these sites as the basis for predicting flow alteration at un-gaged sites. Catchment characteristics will include things like agricultural intensity, dam storage, and degree of urbanization. This approach will allow us to, 1) relate flow alteration to land use/land cover, 2) map natural flow characteristics and flow alteration throughout our study area, and 3) relate flow alteration to existing biological data for multiple stream types and sizes.

We have now completed the first step using the (Carslisle *et al.* 2010) method to assess flow alteration histories of 211 stream sites with USGS gages. To do this, we first identified 64 streams that were in least-disturbed reference condition. Climate and catchment characteristics of these sites were related to stream hydrology using random forest models (Breiman 2001). A model was built for each of 187 flow metrics that we used to describe stream hydrology. Prediction errors were assessed using several approaches and found to be acceptable for most flow metrics. These models were used to estimate natural hydrology at all sites with stream gages. Gage data were used to calculate 187 flow metrics representing actual flow conditions for every 15 year period within each gage's record.

Next, we will use current flow alteration estimates along with catchment characteristics of all 211 gage sites as training data to build a new random forest model to predict flow alteration at un-gaged sites. Flow alteration will be assessed at all sites with existing biological data that would be suitable to associate specific degrees and types of flow alteration with biological community responses. We have obtained and formatted the Arkansas Stream GAP data and are now working to quantify climate and catchment characteristics at these sites in preparation for assessing flow alteration. Existing biological data from the ecologically-sensitive Little Red River drainage will also be used as a case study.

Our tool will be available for future assessments of flow alteration throughout the state, except the Mississippi Alluvial Plain. This project adds an important component to our current research in which we have completed 1) a regional hydrologic classification of rivers, and 2) aquatic community sampling in the field to develop ecological-flow relationships within groundwater flashy streams of the Ozark Highlands ecoregion. Our research program contributes to a scientific framework for setting environmental flow standards in Arkansas and will positively impact many species and ecosystems statewide, those of greatest conservation need and otherwise.



Banded darter, photo by Dustin Lynch (AR Coop Unit)

Classification of Arkansas flow regimes, regional ecological-flow response relationships and environmental flows assessment of the Ozark region

Funding Source:	Arkansas Game and Fish Commission Arkansas Cooperative Fish and Wildlife Research Unit University of Arkansas
Project Duration:	September 2010 to July 2014
Principal Investigator:	DANIEL D. MAGOULICK
Graduate Student:	DOUGLAS R. LEASURE
Graduate Student:	DUSTIN LYNCH

Objectives:

1. Classify stream types within Arkansas based on hydrology and geomorphology.
2. Develop regional-level hydrology-biology response relationships for a portion of the Ozarks.

Management Implications:

1. Products of this study, including a statewide river classification system and regional ecological-flow relationships, will form the scientific framework for environmental flow standards and aid studies involving the impacts of global climate change on Arkansas's unique streams and rivers.

Project Summary:

Providing adequate water quantity and quality in streams and rivers is a pressing issue worldwide. It is crucial to determine appropriate environmental flows in streams. This proposal develops the first phase in a multi-year study, involving many partners and a series of steps towards the goal of producing the scientific basis for environmental flow standards within Arkansas. Products of this study, including a statewide river classification system and regional ecological-flow relationships will form the scientific framework for setting environmental flow standards and understanding impacts of global climate change. These ecological-flow response relationships will help determine instream flow needs in the Ozarks and will provide the basis for conservation of at least 9 fish species, 11 crayfish species, and 11 insect species of greatest conservation need, including yellowcheek darter, Arkansas darter, Ozark shiner, longnose darter, silver redhorse, stargazing darter, Ozark chub, and current darter. This work will positively impact many species and ecosystems statewide, those of greatest conservation need and otherwise.

Hydrologic classification has been widely adopted in eco-hydrology, often with the goal of characterizing flow-ecology relationships and crafting appropriate water management for individual types of rivers or streams. We have now completed a regional river classification and quantitative descriptions of each natural flow regime for the Ozark-Ouachita Interior Highlands region of Arkansas, Missouri, and Oklahoma. Sixty-four reference streams in relatively undisturbed condition were identified based on the hydrologic disturbance index and by screening GIS databases for potential sources of hydrologic alteration such as dams, water discharge sites, urbanization, and agriculture. Based on daily flow records from 64 reference streams, seven natural flow regimes were identified using mixture model cluster analysis: Groundwater Stable, Groundwater, Groundwater Flashy, Perennial Runoff, Runoff Flashy, Intermittent Runoff, and Intermittent Flashy. Sets of flow metrics were selected that best quantified nine ecologically important components of each natural flow regime. An uncertainty analysis was performed to avoid selecting metrics strongly affected by measurement uncertainty that can result from short periods of record. Measurement uncertainties (bias, precision, and accuracy) were quantified for 170 commonly used flow metrics produced by the USGS Hydrologic Index Tool. The ranges of variability expected for select flow metrics under natural conditions were quantified for each flow regime to provide a reference for future assessments of hydrologic alteration. A random forest model was used to predict the natural flow regimes of all stream segments in the study area based on climate and catchment characteristics and a map was produced. The geographic distribution of flow regimes suggested distinct eco-hydrological regions that may be useful for conservation planning. This classification system provides a hydrologic foundation for future examination of flow-ecology relationships in the region, including our own study of ecological communities in Groundwater streams of the Springfield Plateau.

We examined flow-ecology relationships in the Ozark Highlands over two years with contrasting environmental conditions, a drought year (2012) and a flood year (2013) in flashy groundwater streams on the Springfield Plateau. We examined metrics of community structure in fish, crayfish, and macroinvertebrates using an IT multiple regression approach with *a priori* selected predictor variables incorporating hydrology, habitat, geomorphology, and water quality. Additionally, we used a canonical ordination approach relating these same biological response variables to metrics of flow alteration using a small apriori selected set of flow alteration variables and via an exploratory forward selection procedure examining all flow alteration variables.

We found that hydrology was an important variable influencing fish, crayfish and macroinvertebrate community structure, but often less important than other types of environmental variables, especially in a drought year. We found substantial between-year variation in flow-ecology relationships. We found less significant relationships overall during the flood year than the drought year. When a small set of *a priori* flow alteration metrics were examined, we did not see strong flow alteration-ecology relationships.

Exploratory canonical ordination showed strong flow alteration-ecology relationships varying among taxonomic and sample type groups and most flow alteration metrics examined showed significant reductions relative to expected. Crayfish communities were most influenced by changes in frequency and duration of high flows, whereas macroinvertebrates were sensitive to timing of low flows, and fish responded to alteration in a combination of duration, frequency, and magnitude of flow variables. Flow alteration, along with habitat, geomorphology and water quality, appear to have important influences on fish, crayfish and macroinvertebrate community structure. Variables and relationships highlighted by this study could be used by managers to conserve stream communities in the Ozark Highlands.

CURRENT FISHERIES PROJECTS

Gastric Lavage, photo by Chris Middaugh (AR Coop Unit)

Longear sunfish (Lepomis magalotis), photo by Dustin Lynch (AR Coop Unit)

Biological Responses of Ozark Stream Communities to Compounding Stressors: The Convergence of Drought, Land Use, and Novel Predation

Funding Source:	University of Arkansas Arkansas Cooperative Fish and Wildlife Research Unit University of Oklahoma Sigma Xi Research Grant
Project Duration:	July 2014 to July 2017
Principal Investigator:	DANIEL D. MAGOULICK
Graduate Student:	ROBERT J. FOURNIER (Ph.D. Student)

Research Objectives:

1. To determine the effects of drought and nutrient pollution on the growth and survival of stream community.
2. To examine the effects of a novel predator (largemouth bass) and native predator (smallmouth bass) on the growth and survival of stream ecosystem structure and function in normal and drought conditions.
3. To examine the ecological dynamics of apex predation and nutrient enrichment in streams.
4. To construct and parameterize a model that explores community dynamics under varying predation pressures and drought conditions.

Management Implications:

1. Little is known regarding the combined ecological effects of common anthropogenic and natural stressors on aquatic communities. Information gained from this research will help managers to

establish regulations or mitigate factors negatively affecting fish populations in severely impacted streams.

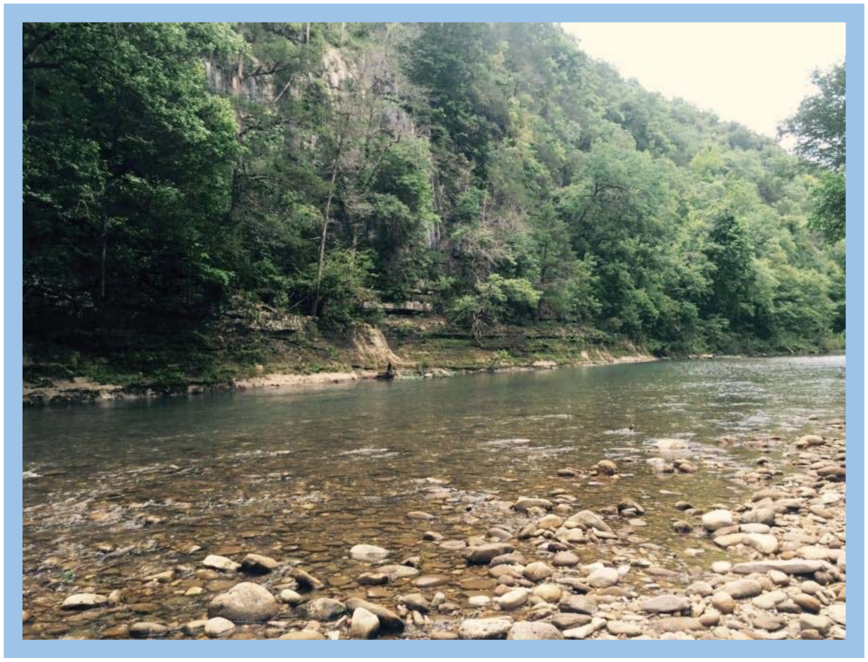
2. Information gained through this study will help assess the potential invasion impacts of an apex predator on Ozark stream communities.
3.

Project Summary:

Anthropogenic degradation of freshwater ecosystems represents a severe threat to global aquatic biodiversity (Benke 1990). Three of the most detrimental ecological disturbances to stream systems—hydrological alteration, nutrient pollution, and invasive species—have profound and diverse impacts on aquatic communities and are often some of the most pervasive threats to biodiversity in developed countries. Increasing demand for freshwater resources and the increased frequency of extreme climatic events might exacerbate the biological effects of drought conditions in streams (Beniston et al. 2007). Anthropogenic introduction of bioavailable nutrients to freshwater systems is increasing globally (Vitousek et al. 1997) with dramatic, bottom-up effects on ecosystem structure and functionality (Woodward et al. 2012). Introduced predators might destabilize food webs with extreme hunting pressure and naïve prey might not possess adequate defenses to increased predatory threats. While the individual effects of drought, nutrient pollution, and invasive predation have been studied across multiple systems, little work has been done regarding their combined effects on freshwater communities. This research will continue to explore the dynamics of severely impacted ecosystems by exposing cross sections of Ozark stream communities to combinations of common ecological disturbances.

Throughout the project, we will explore the compounded effects of drought, nutrient enrichment, and introduced predators across a series of experiments. The first was carried out in summer 2014 and explored the dynamics of drought and nutrient pollution treatments on two species of Ozark stream fish in large, outdoor mesocosms. However, preliminary results were inconclusive. It is likely that high mortality rates across all treatments during the experiment obscured important ecological dynamics. The second experiment—to be carried out spring 2016—will compare growth and survivorship of communities exposed to combinations of drought, and apex predation treatments with either a native smallmouth bass or a novel largemouth bass. The third experiment in the series will cross nutrient pollution and predation treatments. We will also construct mathematical models that explore the metapopulation dynamics of three demographically distinct species in normal and drought conditions.

We anticipate that the results of this study will provide managers with tools to make more informed decisions regarding both the levels of the individual disturbance factors we explore as well as helping to create disturbance management plans which take into account the compounded effects of multiple stressors within one system.



Buffalo River, Arkansas, photo by Christopher Middaugh (AR Coop Unit)

Current Distribution and Relative Abundance of Lotic Black Bass in Arkansas and Potential Effects of Anthropogenic and Climate Induced Stressors

Funding Source:	University of Arkansas Arkansas Cooperative Fish and Wildlife Research Unit
Project Duration:	January 2014 to January 2017
Principal Investigator:	DANIEL D. MAGOULICK
Graduate Student:	CHRISTOPHER R. MIDDAUGH (Ph.D. Student)

Research Objectives:

1. Determine relative influence of angler harvest, and climate change on smallmouth bass *Micropterus dolomieu* abundance in the Buffalo River and Crooked Creek, AR at present and future time periods.
2. Use a bioenergetics model to predict future growth rate potential in streams in Arkansas, Oklahoma, and Missouri.
3. Evaluate current differences in relative weights over the course of the summer of smallmouth bass among two different stream types.
4. Determine what factors are most influential in structuring distributions of black bass species in Arkansas and how distributions could shift due to climate change.

Management Implications:

1. The relative effects of harvest and climate change on smallmouth bass abundance and growth will be compared and managers could use this information in future regulation changes
2. Regulation strategies to maximize growth and/or abundance may be examined.

3. Results could better prepare managers for future challenges that may be presented by climate change.

Project Summary:

Many river ecosystems have been extensively altered by anthropogenic influences such as channelization, riparian vegetation removal, and urbanization. Many of these land use factors are interrelated and can affect river ecosystems in complex ways including altering flow regimes and increasing water temperatures. Further, climate change could exacerbate the effects of altered land use on discharge and water temperature by increasing precipitation stochasticity and increasing air temperatures. River discharge and temperature are particularly influential factors on fish populations such as smallmouth bass *Micropterus dolomieu*, especially at larval and juvenile stages. Better understanding of how abiotic factors structure smallmouth bass populations is critical for better management of this species, especially as climate change alters lotic habitats.

There are several components to our project. First, we will create an age-structured model to explore the influences of climate change and angler harvest on smallmouth bass abundance and growth using two time periods: present and future (similar to Peterson and Kwak 1999). Smallmouth bass data have been provided from long-term AGFC Buffalo River and Crooked Creek sampling. This data set indicates that age-0 smallmouth bass catch-per-unit-effort is significantly related to May temperature and April discharge in the Buffalo River, AR. We will use USGS river gauges and NOAA climate data to model present river discharge and temperature. We will use existing climate models to extrapolate precipitation and temperature to future conditions. We will then model smallmouth bass population dynamics under future habitat conditions.

The second component of our project uses bioenergetics models to predict future growth potential of smallmouth bass across two flow regimes, runoff and groundwater. We created bioenergetics models and parameterized them from literature values. These models indicate that at the southern extent of their range, smallmouth bass may have an increased capacity for growth during winter months and a substantial decrease in capacity for growth during summer months after climate change in runoff dominated streams. Changes in growth rate were much smaller in groundwater dominated streams with many showing very little change in growth during summer months. These results indicate that smallmouth bass in runoff dominated streams may be more at risk due to climate change and that groundwater streams could provide a thermal refuge.

The next component of our research is a field based project designed to examine current effects of stream drying on smallmouth bass body condition, specifically relative weight. We have sampled smallmouth bass from streams in two different flow regimes, runoff flashy and groundwater flashy, across northern Arkansas during two summers. We hypothesized that relative weights would decrease over the course of the summer for smallmouth bass from runoff flashy streams as the streams dried into a series of isolated pools. In contrast, we did not expect a significant change in relative weights of smallmouth bass from groundwater dominated streams. Preliminary results indicate a slight decrease in relative weights for smallmouth bass in some runoff streams. However, both years of data were from relatively cool, wet summers, reducing the difference in environmental conditions experienced by fish between the two stream types.

The final component of our research is a landscape scale model relating smallmouth bass, largemouth bass *Micropterus salmoides*, and spotted bass *Micropterus punctulatus* distributions to geomorphometric habitat variables, community metrics, and population metrics of the other black bass species. This portion of our research will help elucidate drivers of distributions of these three species and interactions among these species. This model will also be used to better understand how climate change could affect distributions of these species and predict future distributions of each species in streams throughout the Ozark-Ouachitau Interior Highlands. This work could provide managers with additional insight into what factors are most influential for determining lotic black bass distributions, as well as how climate change could affect distributions.

Rainbow Darters (Etheostoma caeruleum), photo by Dustin Lynch (AR Coop Unit)

Trait Composition of Fish Assemblages along Hydrologic Gradients

Funding Source: University of Arkansas
Arkansas Cooperative Fish and Wildlife Research Unit
Project Duration: August 2013 to May 2016
Principal Investigator: DANIEL D. MAGOULICK
Graduate Student: LINDSEY A. BRUCKERHOFF (M.S Student)

Research Objectives:

1. Characterize the fish assemblages of different hydrologic regimes in Arkansas based on the relationship between hydrologic metrics and fish traits.
2. Determine how relationships between fish traits and hydrologic metrics differ between flow regimes.
3. Assess the role of spatial autocorrelation in structuring the trait composition of fish assemblages across hydrologic regimes.

Management Implications:

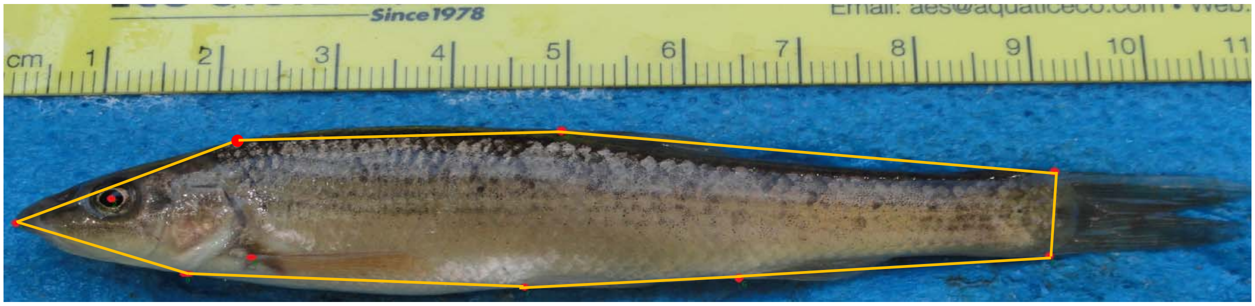
1. This study contributes to the knowledge of flow-ecology relationships to aid in determining environmental flow standards.
2. This study highlights the importance of accounting for spatial autocorrelation when developing flow-ecology relationships.
3. Identification of traits useful for monitoring changes in fish assemblages will help predict consequences of alterations to natural flow patterns due to climate change, as well as anthropogenic influence.

Project Summary:

In lotic systems, environmental pressures are largely determined by the hydrologic regime (Naiman et al. 2008). Ecologically important components of the hydrologic regime include the magnitude of discharge and frequency, duration, timing, and rate of change of flow events (Poff and Ward 1989, Richter and Baumgartner 1997, Poff et al. 1997). These components influence habitat volume, current velocity, channel geomorphology, substratum stability, suspended sediments, temperature, chemistry, and channel connectivity (Poff and Ward 1989, Jowett and Duncan 1990), which are all important habitat characteristics influencing which species are present (Poff 1997). Because hydrology controls so many attributes of the physical environment in streams, organisms adapt and evolve in response to maintained variation of hydrologic regimes (Lytle and Poff 2004).

Traits can be used to describe patterns of community assemblages along hydrological gradients (Poff and Allan 1995, Mims and Olden 2012). Trait based approaches assume that species traits converge when environmental pressures are similar (Southwood 1988). Based on this theory, categorizing species by different traits allows for the study of community assemblages across biogeographic boundaries (Schluter 1986). We assessed how the relationship between trait compositions of fish assemblages and hydrologic metrics differ across flow regimes. We used hydrological and fish survey data from Arkansas streams within the Ozark Highland, Arkansas Valley, Boston Mountains, and Mississippi Alluvial Plains ecoregions. Fish community survey data from the ARGAP program and flow data developed by Leasure et al. (2014) were analyzed using a combination of RLQ and four-corner analysis to determine the relationship between flow metrics, suites of flow metrics, single traits, and suites of traits (trait syndromes). In general, fish traits were structured differently across flow regimes and different hydrologic metrics describe trait structure across regimes. Duration of low flows was related to spawning characteristics in runoff streams, while variability of daily flows and constancy were important in intermittent streams. Across all flow regimes combined, variability of daily flows described the most variability in spawning characteristics.

Establishing ecological-flow relationships is a crucial component of managing lotic systems within an environmental flow framework. Species traits may be useful for developing ecological-flow relationships because they can be used to make comparisons across biogeographical boundaries. Fish traits, such as life history strategies and spawning characteristics, have been linked to hydrologic metrics and classified flow regimes at relatively large spatial scales, but not smaller, management level scales, and the role of spatial autocorrelation in driving trait distributions in stream networks has not been assessed. We used mixed moving average spatial stream network (SSN) models to (1) determine the relationship between fish traits and hydrologic metrics within classified flow regimes at a management (state) level spatial scale, (2) determine how traits are spatially auto-correlated within a stream network, and (3) compare the degree of spatial autocorrelation between flow regimes. We observed weak relationships between fish traits and hydrologic metrics, and these relationships were different between flow regimes. Spatial factors described more variability in the distribution of fish traits than hydrologic metrics within and between flow regimes and different types of spatial auto-correlation structured trait patterns across flow regimes. This study highlights the importance of considering spatial patterns when developing ecological-flow relationships.



Central Stoneroller, photo by Lindsey Bruckerhoff (AR Coop Unit)

Phenotypic divergence of *Campostoma anomalum* across hydrologic regimes

Funding Source:	University of Arkansas Arkansas Cooperative Fish and Wildlife Research Unit
Project Duration:	August 2013 to May 2016
Principal Investigator:	DANIEL D. MAGOULICK
Graduate Student:	LINDSEY A. BRUCKERHOFF (M.S Student)

Research Objectives:

1. Test for morphological variation between fish inhabiting different hydrologic regimes.
2. Determine the relative roles of genetic divergence and phenotypic plasticity driving morphological variation.

Management Implications:

1. Understanding how organisms have adapted to different flow regimes may provide insight into the evolutionary consequences of disrupting natural hydrologic patterns, which are increasingly threatened by climate change and anthropogenic alterations.

Project Summary:

In lotic systems, environmental pressures are largely determined by the hydrologic regime (Naiman et al. 2008). Ecologically important components of the hydrologic regime include the magnitude of discharge and frequency, duration, timing, and rate of change of flow events (Poff and Ward 1989, Richter and Baumgartner 1997, Poff et al. 1997). These components influence habitat volume, current velocity, channel geomorphology, substratum stability, suspended sediments, temperature, chemistry, and channel connectivity (Poff and Ward 1989, Jowett and Duncan 1990), which are all important habitat characteristics influencing which species are present (Poff 1997). Because hydrology controls so many attributes of the physical environment in streams, organisms adapt and evolve in response to maintained variation of hydrologic regimes (Lytle and Poff 2004).

Some species are able to survive across a diverse range of hydrologic conditions and large geographic regions. Species distributed across heterogeneous environmental conditions (space and/or time) may exhibit intraspecific variation in physiology, morphology, and behavior. Intraspecific variation is commonly documented in fish (reviewed in Robinson and Wilson 1994) and may be the result of a combination of abiotic and biotic selective pressures. Because flow regimes influence abiotic (Poff &

Ward 1989, Jowett & Duncan 1990) selection pressures and potentially influence biotic interactions (by influencing community composition), fish species may exhibit intraspecific variation across hydrologic gradients. Adaptations in response to hydrologic variation may be apparent by examining morphological variation of fish between different hydrologic regimes. Observed morphological variation may be the result of phenotypic plasticity or genetic divergence. This study aims to determine what morphological features of fish vary across hydrologic gradients. Further, this study will address whether phenotypic plasticity or genetic divergence is predominantly driving morphological variation.

Variation in morphology between fish occupying different hydrologic regimes was investigated using geometric morphometrics. Over 600 fish were collected and photographed from 20 sites within two different flow regimes (groundwater streams and intermittent). We digitized 10 landmarks on each specimen representing major features of fish morphology. Preliminary analysis indicates that deeper bodied fish are characteristic of intermittent streams, while more streamlined fish are characteristic of groundwater streams. Centroid size (mean geometric size) also differs between the two regimes. The observed difference in shape are likely due to the interaction between centroid size and shape, indicating that populations may differ in their allometric growth patterns across flow regimes.

We also conducted a 20 week long, fully factorial mesocosm experiment to determine if phenotypic plasticity or genetic divergence is driving morphological variation. We reared young of the year from two natural populations, one from a stable high flowing groundwater stream (population 1) and the other from an intermittent stream that experiences seasonally extreme low flows (population 2). The four treatment groups included: population 1 young reared in low flow conditions, population 1 young reared in high flow conditions, population 2 young reared in low flow conditions, and population 2 young reared in high flow conditions. At the end of the experiment, fish were photographed and geometric morphometric analysis was implemented using the same methods used in the comparative field study. Morphological variation due to genetic predisposition was indicated by differences in shape variables between populations. Phenotypic plasticity was indicated by differences in shape variables between treatments in each of the populations. We observed larger differences between source populations than flow treatments, indicating that divergence between populations may influence body shape more than plasticity.

Ringed crayfish, photo by Allyson Yarra (AR Coop Unit)

Predicting the Spread and Understanding the Ecological Impacts of Invasive Crayfish

Funding Source:	University of Arkansas Arkansas Cooperative Fish and Wildlife Research Unit
Project Duration:	March 2015 to December 2016
Principal Investigator:	DANIEL D. MAGOULICK
Graduate Student:	NICOLE E. GRAHAM (M.S. Student)

Research Objectives:

1. Examine the factors influencing the abundance and distribution of *Orconectes neglectus* (ringed crayfish) within its native and invaded ranges.
2. Predict the potential distribution of *Orconectes neglectus* using *Orconectes rusticus* (rusty crayfish) and *Orconectes virilis* (northern crayfish) as 'avatar' species.
3. Examine the effects of stream drying and comparative effects of native *Orconectes eupunctus* (coldwater crayfish), *Orconectes neglectus* from an extralimital population, and *Orconectes neglectus* from an extraregional population on stream structure and function.

Management Implications:

1. This study will aid in identifying environmentally sensitive areas that may be susceptible to future invasions by *Orconectes neglectus.*
2. Examining relative effects of extralimital and extraregional invasions may provide insight into potential ecosystem impacts based on the geographic origin of the invader.

Project Summary:

Crayfish are considered keystone species that impact multiple aquatic tropic levels (Momot 1995), substantially influence aquatic production through the processing of course particulate organic matter (Whitledge and Rabeni 1997), and serve as prey for more than 200 species (DiStefano 2005). Out of 571 crayfish species and subspecies worldwide, 77 percent are native to North America (Taylor 2002). Around half of North American crayfish are considered in need of protection, and the spread of invasive crayfish is of notable concern (Taylor et al. 1996). Displacement of native crayfish by invaders is often attributed to predation, competition, transmission of diseases and interference with reproduction (Lodge et al. 2000). However, the role of abiotic disturbance in mediating the distributions and ecological impacts of invasive crayfish has received recent attention (Larson et al. 2009).

Abiotic disturbances can facilitate the establishment and spread of invasive species, as well as alter their ecological impacts (Hobbs and Huenneke 1992, D'Antonio 2000, Facon et al. 2006). Stream drying is a frequent disturbance in the Ozark Highlands of Missouri and Arkansas, an area with an array of diverse and endemic crayfish (Tissevil et al. 2013). One such endemic crayfish, *Orconectes eupunctus,* is being extirpated from areas within its range following the invasion of *Orconectes neglectus* (Pflieger 1996, Flinders and Magoulick 2005, Magoulick and DiStefano 2007). Recent research has demonstrated that stream drying may play a role in the effective establishment of *O. neglectus* and the subsequent displacement of *O. eupunctus* (Larson et al. 2009).

Currently, little is known about the factors influencing the abundance and distribution of *O. neglectus* within its native and invaded ranges. Understanding these factors is necessary in order to predict potential regions susceptible to invasion. Recent research demonstrates the applications of using information from data rich 'avatar' invaders to model the potential distribution for incipient invaders in the absence of data concerning their non-native distributions. This can be accomplished by examining niche shifts of 'avatar' invaders from their native to total ranges, and extrapolating invasion potential to data-poor invaders assuming they will undergo niche shifts of a similar extent (Larson and Olden 2012).

We propose to examine the species-environment relationship of *O. neglectus* in order to investigate factors of importance in determining this species' abundance and distribution. This will be accomplished by using GIS to link abundance data from previous surveys to abiotic landscape data and using a random forest model to select environmental variables influencing abundance of *O. neglectus* within its native and invasive ranges. This information will be used to produce a current distribution map of *O. neglectus*. In addition, we will use the avatar concept of Larson and Olden (2012) to project a potential future distribution of *O. neglectus* based on hydrologic niche shifts of the well-studied congeners *O. rusticus* and *O. virilis.* This will aid in identifying environmentally sensitive areas that may be susceptible to future invasions by *O. neglectus*.

Furthermore, previous research has examined the comparative ecological impacts of native versus invasive crayfish species, however, few studies have investigated the relative impacts due to invaders from adjacent watersheds (extralimital invaders) versus invaders from distant regions (extraregional invaders). We conducted a fully factorial mesocosm experiment examining the effects of stream drying and the effects of native, extralimital, and extraregional crayfish on stream structure and function. Crayfish treatments included: *O. eupunctus* (native), *O. neglectus* from an extralimital population, and *O. neglectus* from an extraregional population. Additional treatments included simulated stream drying and control. Response variables indicative of stream structure and function included: primary production and community respiration, leaf breakdown, periphyton ash free dry mass, macroinvertebrate abundance, and sediment levels. Additional response variables included crayfish growth and survival.

We are using two-way Analyses of Variance (ANOVAs) to evaluate the effects of crayfish identity and drying on individual response variables. Multivariate Analysis of Variance (MANOVA) will be used to investigate the effects of drought and crayfish treatments on response variables and to examine the effects of drought and crayfish identity on crayfish growth and survival. All analyses will be conducted in R (R Foundation, Vienna, Austria) using an alpha value of 0.05.

Currently, we have analyzed the effects of crayfish identity and drying on leaf breakdown and crayfish growth and survival using two-way ANOVAs. There was no effect of an interaction between crayfish identity and drying treatment on any of these response variables. Additionally, drying did not have a significant effect on leaf breakdown or crayfish growth and survival. Crayfish identity did not significantly affect crayfish survival. However, crayfish growth (increase in mass and increase in carapace length) was significantly affected by crayfish identity ($p=0.0286$ and $p=0.0004$ respectively). A Tukey's post hoc examination for all pairwise comparisons revealed that *O. neglectus* from the extralimital population showed a significantly greater increase in carapace length than both *O. neglectus* from the extraregional population and *O. eupunctus*. In addition, mass of *O. neglectus* from the extralimital population increased significantly more than mass of *O. eupunctus*. Furthermore, crayfish identity had a significant effect on leaf breakdown ($p=0.007$). A Tukey's post hoc examination for all pairwise comparisons showed that *O. eupunctus* broke down significantly less leaves than both *O. neglectus* from the extralimital and extraregional populations.

Results thus far indicate that *O. eupunctus* and *O. neglectus* are not ecologically redundant. In addition, this study provides evidence that invaders from extralimital populations may differ from invaders from extraregional populations in terms of redundancy with and displacement of natives and effects on ecosystem functions. This is significant for invasive species management because not only does it matter what species is introduced into a system, but also to where the introduced species is native. With the future culmination of this study we hope to provide further insight into the potential ecosystem impacts of an invader in relation to the invader's native geographic origin.

Sulphur Springs Diving Beetle, photo by Scott Longing (AR Coop Unit)

Multi-scale habitat associations and predictive habitat modelling of *Heterosternuta sulphuria* (Coleoptera: Dytiscidae) in Ozarks streams

Funding Source:	University of Arkansas Honors College Arkansas Cooperative Fish and Wildlife Research Unit
Project Duration:	May 2014 to May 2016
Principal Investigator:	DANIEL D. MAGOULICK
Graduate Student:	DOUGLAS R LEASURE (Ph.D. Student)
Undergraduate Student:	JEREMIAH NATHAN FLANNERY (Student)

Research Objectives:

1. Identify factors that contribute to or prevent the existence of viable habitats for the Sulphur Springs Diving Beetle.
2. Identify habitats in a new, expanded range that likely contain this beetle.
3. Examine the effect of human development on presence of Sulphur Springs Diving Beetle in headwater streams.

Management Implications:

1. This study will shed light on the behavior and environmental preferences of a species that is classified as critically imperiled but has little research conducted on it.
2. Understanding the proximity at which human development affects the Sulphur Springs Diving Beetle may be useful to establishing guidelines for ecologically sound land development.

Project Summary:

Understanding the human and environmental factors that play into whether a location is suitable for an organism is an important factor in prediction of potential new locations (Newton-Cross, White, & Harris 2007). Heterosternuta sulphuria (pictured on the previous page), (syn. Hydroporus sulphurius, Heterosternuta sulphurius; Wolfe 2000; Nilsson 2007), is a species of diving beetle commonly found in small headwater streams (figure 1) and is classified as endemic to Arkansas with a priority score of 80/100, a state conservation rank of S1, and a global conservation rank of G1 (Longing & Haggard 2009).

Sherfield Cave Stream

This study has reexamined and continues to examine data collected by Scott Longing related to H. sulphuria distribution. This study aims to achieve analytical depth by focusing on the environmental factors which impact H. sulphuria. This is important to do because little is known of its full distribution or habitat requirements. We hypothesized that H. sulpuria is more widespread than its current classification suggests, and that a riparian buffer of forest can offset the negative impact of urbanization on H. sulphuria presence.

Attributes of watersheds and riparian zones associated with H. sulphuria collection sites (e.g. forest cover in the watershed) were quantified using software recently developed at the University of Arkansas. Variables of interest for this project include: forest canopy cover, urban area, concentration of roads, impervious surfaces, groundwater flow, and hayfields.

Logistic regression models were compared using a handful of variables that were perceived to be ecologically significant at different radii/buffer sizes around sample locations in order to choose the scale at which each variable has the strongest relationship with H. sulphuria presence. Throughout the analysis, the relative weight of competing hypotheses was/continues to be assessed by comparing model fit using Akaike Information Criterion, which favors parsimonious models. Area Under Curve was used as a general measure of model fit appropriate for logistic regression because it is "threshold-independent" (Venables & Ripley 1994; Hanley & McNeil 1982).

We have found that urban development and high percentage of impervious surfaces negatively affected the diving beetle. Increased forestation had a tiny, but positive impact on presence. Each of these variable effects on H. sulphuria were predetermined hypotheses. Another hypothesis which we were unable to prove was that forest cover and urbanization would have a significant interaction. Random Forest was used to create a more accurate model and test potential for other sample sites in the region. We gathered data for 18000 small stream segments in the Ozark and Ouchita Valley and the majority of them were shown to have likely characteristics for H. sulphuria presence. This supports a more widespread population of this beetle.

NEW FISHERIES PROJECTS

Chris Middaugh weighing fish, photo by Brin Kessinger (AR Coop Unit)

Orconectes marchandi

Influence of drought, predation and invasive species on crayfish in the Ozark Highlands with an emphasis on species of greatest conservation need (*Orconectes marchandi*, *Orconectes eupunctus* and *Cambarus hubbsi*)

Funding source:	Arkansas Game and Fish Commission National Science Foundation University of Arkansas Arkansas Cooperative Fish and Wildlife Research Unit
Project Duration:	May 2015 to May 2017
Principal Investigator:	DANIEL D. MAGOULICK
Graduate Student:	ALLYSON N. YARRA (M.S. Student)

Research Objectives:

1. Determine crayfish occupancy and species density in two hydrologic regimes in the White River drainage and assess the relationship between hydrologic regime, crayfish occupancy, species density, and habitat covariates.
2. Assess the significance of crayfish as a prey item for centrarchids and mammals in the White River drainage and determine variation among seasons and hydrologic regimes.
3. Examine the population status of *O. marchandi, O. eupunctus,* and *C. hubbsi* in the Spring River drainage and assess the potential for invasion impacts by *O. neglectus*.
4. Determine if differential predation is driving the displacement of *O. eupunctus* by *O. neglectus* in the Spring River drainage.
5. Evaluate *O. marchandi*'s ability to use the hyporheic zone as refugia during drying events in intermittent streams within the Spring River drainage.

Management Implications:

1. This study will contribute to the establishment of flow-crayfish ecology relationships which may provide insight into the importance of sustainable water use in the Ozark Highlands.
2. Assessing the population status of three imperiled crayfish species in the face of an invader will help to guide monitoring programs.

Project Summary:

Stream drying is an important mechanism that influences predator-prey relationships and crayfish behavior. During drought, biotic interactions (e.g., competition, predation) may intensify (Hodges and Magoulick 2011). Drying not only increases predation risk, it also elicits differential behavioral responses such as reduced foraging, shifts in distribution, and burrow construction (Gelwick 2000). Over time, crayfish populations may suffer reductions in population densities, shifts in reproductive timing, and reduced average body size (Taylor 1988). Especially when coupled with seasonal drought, invasive species are a major threat to ecosystem integrity (Secretariat of the Convention of Biological Diversity 2010). The mechanisms by which a native species of crayfish becomes displaced by an invasive species have been identified as competition, reproductive interference or hybridization, differential predation, and disease transmission (Lodge et al. 2000). The establishment of many invasive crayfish is often related to change that creates environments that are more favorable to introduced species and unfavorable to native species which may include habitat loss due to seasonal stream drying (Larson et al. 2009).

In the Ozark Highlands of Arkansas and Missouri, *Orconectes neglectus* has invaded portions of the Spring River drainage in southern Missouri and northern Arkansas (Flinders and Magoulick 2005). Since the Spring River drainage houses three species of crayfish that are Species of Greatest Conservation Need, this region is in need of monitoring. Currently, *Orconectes eupunctus*, which was once abundant in the Spring River drainage has been displaced by *O. neglectus*. *O. neglectus* is now the dominant crayfish species in portions of the West Fork Spring River and the upper South Fork Spring River where *O. eupunctus* was formerly abundant. *O. eupunctus* still persists in the Spring River drainage, but its abundance has declined in the upstream areas that *O. neglectus* inhabits (Flinders and Magoulick 2005). The mechanism of *O. eupunctus* displacement by *O. neglectus* remains unclear. It does not appear that *O. neglectus* displaces *O. eupunctus* by forcing them into different habitats (Rabalais and Magoulick 2006, a), and both juvenile (Larson and Magoulick 2009) and adult male (Rabalais and Magoulick 2006, b) competition did not appear to drive displacement. Nonetheless, *O. neglectus* has shown to be a successful invader in the Spring River drainage as demonstrated by the decline of *O. eupunctus* in its former range. Since *O. neglectus* may continue to spread throughout the drainage, conservation of *O. eupunctus* and the other imperiled crayfish species in the Spring River drainage (*C. hubbsi*, *O. marchandi*) requires identifying the mechanisms of displacement by *O. neglectus*.

It is vital to understand the combined effects of stream drying, predation, and the impacts of invasive species on native crayfish. While the seasonal drying of intermittent streams in this region is a natural process, the pressures of human water use coupled with global climate change may induce additional stress on the region's sensitive aquatic biota in the future. Information gained from the establishment of flow-crayfish ecology relationships may provide insight into the importance of sustainable water use in the Ozark Highlands. Specifically in the Spring River drainage, where an invasive species is spreading and where two of our most geographically-restricted stream crayfish occur (*O. eupunctus* and *O. marchandi*), we intend to understand the status and threats present so that we may inform future conservation decisions. Findings from this research will inform conservation and management of crayfish of greatest conservation need in the Ozark Highlands.

We conducted a mensurative field study to determine crayfish abundances, species composition, and habitat quality in 20 Ozark streams (10 with seasonal drying, 10 with stable flow) in summer 2014 and 2015. In these same streams, we conducted snorkel surveys in pools adjacent to crayfish sampling locations and collected scat from semi-aquatic mammals along each stream during each season to understand how crayfish are utilized as a prey item between flow regimes and seasons.

We are currently examining the population status of three imperiled crayfish species in the Spring River drainage and are using GIS to understand species-environment relationships. We are determining occupancy rates of these species using Program PRESENCE and are developing simulation models in the program R to determine potential effects of *O. neglectus* invasion.

In summer 2016, we will conduct a crayfish tethering experiment in the Spring River drainage to assess the impact of stream drying on predator-prey relationships between invasive *O. neglectus* and native *O. eupunctus*. In addition, we will examine *O. marchandi*'s use of the hyporheic zone as refugia during drying events by assessing their densities from 0-15 cm below the surface and 15-30 cm below the surface during pre-drying, drying, and rewetting.

Brock Creek, Van Buren County, AR, photo by Brittany Furtado (AR Coop Unit)

Measuring the influence of flow regime on biological communities: investigating abiotic and biotic determinants of assemblage structure and function

Funding Source:	University of Arkansas Arkansas Cooperative Fish and Wildlife Research Unit
Project Duration:	January 2016 to January 2017
Principal Investigator:	DANIEL D. MAGOULICK
Graduate Student:	BRITTANY FURTADO (Ph.D. Student)

Research Objectives:

1. Establish flow-ecology relationships between flow metrics representing floods, droughts, and flow variability and metrics representing key aspects of biotic assemblage structure for algae, macroinvertebrate, and fish assemblages in the contiguous United States.
2. Determine the relative influences of flow regime, landscape composition, and physical habitat on assemblage structure of algae, macroinvertebrates, and fishes in the contiguous United States.

Management Implications:

1. Elucidation of flow-ecology relationships will better inform management of flow and potential flow alterations.
2. Understanding the role of flow regime with respect to other environmental conditions will help inform future riverine management.

Project Summary:

Flow has been recognized as a “master variable” influencing biotic assemblage structure in riverine ecosystems (Poff et al. 1997, Bunn and Arthington 2002, Carlisle et al. 2010). Biodiversity and abundance of certain freshwater biota is greatly influenced by key hydrological characteristics

(Townsend et al. 1997a). For instance, frequency of extreme flows (high and low) directly influence patch dynamics which interacts with biota tolerance, ultimately determining biotic abundance and assemblage composition (Booker et al. 2015).

Alterations to the flow regime (i.e. natural range and variation of flows) due to anthropogenic factors including increased water abstraction, flow diversion, and climate change have been cited as one of the greatest emerging threats to stream biodiversity (Poff et al. 1997, Poff et al. 2010, Davies 2010). Alterations to the flow regime have the potential to disturb aquatic assemblages through several different pathways including disturbance of benthic habitat, increased hydrologic variability, and increased likelihood of invasion by non-native aquatic species (Bunn and Arthington 2002). To address the emerging issue of flow alteration and better inform riverine management, recent studies have explored characterization/implementation of environmental flows or e-flows. Environmental flows are characterized by the quantity, timing, and quality of flows necessary to maintain ecological integrity (Brisbane Declaration 2007, Poff et al. 2010).

Effective management of environmental flows can only be achieved through an explicit understanding of the influence of flow regime characteristics on biotic assemblages (Bunn and Arthington 2002, Poff et al. 2010). Quantitative flow-ecology relationships need to be established to gain a better understanding of the relationship between biological communities and natural flow regime characteristics (Bunn and Arthington 2002, Jowett and Biggs 2008, Poff et al. 2010). However, it can be difficult to elucidate robust relationships between flow regime characteristics and biological assemblages because often the influence of flow regime can be convoluted or hidden by co-varying abiotic and biotic factors (Monk et al. 2006). Large-scale factors including land cover, climate, and geomorphology as well as local physical habitat and biological interactions can be strong determinants of biotic assemblage composition (Booker et al. 2015). Relationships between flow regime characteristics and measurements of biotic assemblage structure can be misinterpreted if these other factors are not accounted for in the study design.

We are currently investigating the relative influence of flow on biotic assemblage structure of algae, macroinvertebrates, and fishes when additional landscape/local factors are considered.
A collated flow time-series database will be assembled using data collected from USGS gauging stations. The flow time-series database will then be used to calculate flow metrics that represent aspects of flow regime including floods, droughts, and flow variability. Biotic data were obtained from the Water Quality Portal, an online service that has compiled sampling data from the USGS National Water Information System (NWIS), the EPA STOrage and RETrieval (STORET) Data Warehouse, and the USDA ARS Sustaining The Earth's Watersheds - Agricultural Research Database System (STEWARDS). Biotic data will be used to calculate measurements of assemblage structure that represent taxa richness, proportion of tolerant taxa, and key traits of dominant taxa (e.g. feeding guild and habitat preference (macroinvertebrates and fishes) and spawning method (fishes only)). We will examine metrics of assemblage structure following an IT multiple regression approach using a priori selected predictor variables representing hydrology, land use, climate, and local physical habitat. This study will highlight the role of flow in shaping biotic assemblages as well as identify assemblage structure metrics that can be used as indicators of flow alteration for algae, macroinvertebrates, and fishes.

PRODUCTIVITY

Chris Middaugh, Allyson Yarra & Lindsey Bruckerhoff sampling at St. Joe School for Career Day.

HONORS AND AWARDS:

Fournier, A.M.V. – University of Arkansas Graduate School, Distinguished Doctoral Fellowship, 2012-2016

Fournier, A.M.V. – American Ornithologists Union, Cooper Ornithological Society Conference, Travel Grant, 2015.

Fournier, A.M.V. – Association of Field Ornithologist, Wilson Ornithological Society, Society of Canadian Ornithologists Conference, Travel Grant, 2015.

Fournier, A.M.V. – The Frances M. Peacock Scholarship for Native Bird Habitat 2015.

Fournier, A.M.V. – The Use of Stable Isotopes, eBird Species Distribution Models to Assess Migratory Connectivity of Fall Migrating Rails, 2015.

Fournier, A.M.V. – Associate Wildlife Biologist, The Wildlife Society, 2015.

Fournier, R.J. – University of Arkansas Graduate School, Doctoral Academy Fellowship, 2013-2017.

Furtado, B.V. – University of Arkansas Graduate School, Doctoral Academy Fellowship, 2015-2019.

Lynch, D.T. – University of Arkansas Graduate School, Distinguished Doctoral Fellowship, 2011-2015.

McClain, J.C. – Harold and Margaret Hedges Memorial Scholarship in Ornithology, 2015.

Middaugh, C.R. – University of Arkansas Graduate School, Doctoral Academy Fellowship, 2014-2018.

Stephenson, P.L. – Arkansas Audubon Society Annual Trust Award Recipient, 2015.

Stephenson, P.L. – University of Arkansas Provost Office, Provost's Collaborative Research Grant, 2015.

Stephenson, P.L. – Southeastern Wildlife Conclave, 1st Place Orienteering, 2015.

Yarra, A.N. – University of Arkansas Biology Department, GT Johnson Endowed Scholarship for Outstanding First Year, Graduate Student, 2015.

COURSES TAUGHT:

Bruckerhoff, L.A. – Human Physiology Laboratory – Fall 2014, Spring 2015, Summer 2015.

Fournier, A.M.V. – Wetlands Ecology Laboratory – Spring 2015.

Fournier, R.J. – Principles of Biology Laboratory – Fall 2014, Spring 2015.

Graham, N.E. – Principles of Biology Laboratory – Fall 2014, Spring 2015.

Herbert, J.A. – Principles of Biology Laboratory – Fall 2014, Spring 2015.

Krementz, D.G. – Wetlands Ecology – Spring 2015.

Krementz, D.G. – Animal Space Use and Selection Seminar – Spring 2015.

Lynch, D.T. – Human Anatomy – Fall 2014, Spring 2015.

Lynch, D.T. – Principles of Biology – Summer 2015.

Magoulick, D.D. – Introduction to R – Spring 2015.

Middaugh, C.R. – Human Physiology Laboratory – Fall 2014, Spring 2015.

Moore, J.D. – Principles of Biology Laboratory – Fall 2014, Spring 2015.

Sebright, C.E. – Principles of Biology Laboratory – Fall 2014, Spring 2015.

Stephenson. P.L. – Principles of Biology Laboratory – Fall 2014, Spring 2015.

PUBLICATIONS AND PROFESSIONAL PAPERS PRESENTED:

Scientific Publications:

Fournier, A.M.V., M.C. Shieldcastle, T. Kashmer, K.A. Mylecraine. 2015. Comparison of Arrival Dates of Spring Rail Migration in the Southwest Lake Erie Marshes, Ohio, USA. Waterbirds 38:312-314 doi:10.1675/063.038.0313

Fournier, A.M.V., A.L. Bond. 2015. Volunteer field staff are bad for wildlife ecology, The Wildlife Society Bulletin 39:819-821 doi:10.1002/wsb.603

Carroll J.M., and **D.G. Krementz.** 2014. Density and abundance of withering Wilson's snipe in the Mississippi Flyway. Wildlife Biology 20:108-114. – IPDS: FT-011577 IP-034478: BAO Date: December 12, 2011.

Krementz, D.G., R. Crossett, and **S.E. Lehnen.** 2014. Nocturnal Field Use by Fall Migrating American Woodcock in the Delta of Arkansas, USA. Journal of the Southeast Associations of Fish and Wildlife Agencies – IPDS: IP-059541; BAO Date: September 2, 2014.

Magoulick, D.D. and **D.T. Lynch.** 2015. Occupancy and abundance modeling of the endangered yellowcheek darter in Arkansas. Copeia 103:433-439. DOI:http://dx.doi.org/10.1643/CE-14-116; IP-056381.

Strickland, P.A., and **C.R. Middaugh.** 2015. Validation of annulus formation in spotted sucker otoliths. Journal of Fish and Wildlife Management. 6:208-212.

Bitz, R.D., P.A. Strickland, T.J. Alfermann, **C.R. Middaugh,** and J.A. Bock. 2015. Shoal bass nesting and associated habitat in the Chipola River, Florida. Pages 237-248 in M.D. Tringali, J.M.Long, T.W. Birdsong, and M.S. Allen, editors. Black bass diversity: multidisciplinary science for conservation. American Fisheries Society, Symposium 82, Bethesda, Maryland.

Ronke, M.E., and **D.G. Krementz.** 2015. Changes in distribution of Canada geese nesting in Arkansas. Human Wildlife Interactions 9:101-109. IPDS: IP059459; BAO Date: August 27, 2014.

Technical Publications:

Butler, C.J., and **A.M.V. Fournier.** 2015. Using Multiple Stable Isotopes to Investigate Migratory Connectivity in Yellow Rails, Le Conte's Sparrows, Nelson's Sparrows and Sedge Wrens. U.S. Fish and Wildlife Services (Region 3) and Prairie Pothole Joint Venture.

Butler, C.J., and **A.M.V. Fournier.** 2015. Using Multiple Stable Isotopes to Investigate Migratory Connectivity in Yellow Rails, Le Conte's Sparrows and Sedge Wrens. U.S. Forest Service.

Fournier, A.M.V., K. Willard, and **D.G. Krementz.** 2015. King rail nesting and brood rearing ecology in managed wetlands. Final report USFWS Division of Migratory Birds Webless Program.

Herbert, J.A. 2015. The Abundance and Distribution of Mallards in the Lower Mississippi Alluvial Valley of Arkansas. M.S. Thesis. University of Arkansas, Fayetteville, Arkansas.

Leasure, D.R. 2015. Quantification of hydrologic alteration and relationships to biota in Arkansas streams: Development of tools and approaches for un-gaged streams. Ph.D. Dissertation. University of Arkansas, Fayetteville, Arkansas.

Sebright, C.E. 2015. Spring migration ecology of American woodcock (*Scolapax minor*) in the Centeral Management Region of the United States. M.S. Thesis. University of Arkansas, Fayetteville, Arkansas.

Papers Presented:

Bruckerhoff, L.A., D.R. Leasure, and **D.D. Magoulick.** 2015. Trait composition of fish communities across hydrologic regimes. American Fisheries Society. Portland, Oregon.

Bruckerhoff, L.A., and **D.D. Magoulick.** 2015. Morphological variation in *Campostoma anomalum* across hydrologic regimes. Society for Freshwater Science Annual Meeting. Milwaukee, Wisconsin.

Fournier, A.M.V., and K. Drake. 2015. Active capture of rails during the breeding season and fall migration. Inland Bird Banders Association Meeting. Gulfport, Mississippi.

Fournier, A.M.V., A.R. Sullivan, J.K. Bump, M. Perkins, M.C. Shieldcastle, and S.L. King. 2015. Combining citizen science derived species distribution models and stable isotope analysis reveals migratory connectivity in a secretive species, the Virginia Rail (*Rallus limicola*). American Ornithologists Union, Cooper Ornithological Society Meeting. Norman, Oklahoma

Fournier, A.M.V., D.C. Mengel, and **D.G. Krementz.** 2015. Timing of Autumn Migration in the Mississippi Flyway by Rails. Association of Field Ornithologists Meeting. Wolfville, Nova Scotia

Herbert, J.A. 2015. Role of Surface Water and Food Availability on the Abundance and Distribution of Wintering Waterfowl in the Arkansas Mississippi Alluvial Valley. Arkansas Wildlife Society. Russellville, Arkansas.

Herbert, J.A. 2015. Abundance and Distribution of Wintering Waterfowl in the Arkansas Mississippi Alluvial Valley. Arkansas Audubon Society Annual Meeting. Fort Smith, Arkansas.

Kessinger, B., C.R. Middaugh, and **D.D. Magoulick.** 2015. Projected effects of climate change on growth rate potential of smallmouth bass. Arkansas Water Resources Center Conference. Fayetteville, Arkansas.

Lynch, D.T., and **D.D. Magoulick.** 2015. Flow-ecology relationships in the Ozark Highlands. Arkansas American Fisheries Society. Benton, Arkansas.

Lynch, D.T., and **D.D. Magoulick.** 2015. Temporal variation in flow-ecology relationships in the Ozark Highlands. American Society of Ichthyologists and Herpetologists. Reno, Nevada.

Magoulick, D.D. 2015. Classification of natural flow regimes and flow-ecology relationships in the Ozark-Ouachita Highlands region. Hydrological Alteration Workgroup Meeting. Little Rock Arkansas.

Magoulick, D.D. and **D.T. Lynch.** 2015. Flow-ecology relationships of fishes in the Ozark Highlands. American Fisheries Society. Portland, Oregon.

Middaugh, C.R., and **D.D. Magoulick.** 2015. Forecasting effects of angler harves and climate change on smallmouth bass at the southern edge of their range. Symposium on Warm Water Fishes in a Warming World: Imacts of Climate Change on Populations, Distributions, and Habitat. American Fisheries Society. Portland, Oregon.

Middaugh, C.R., **B. Kessinger***, and **D.D. Magoulick.** 2015. The projected effects of climate change on growth rate potential of smallmouth bass in the Ozark and Ouachita highlands. Missouri/Arkansas White River Cooperators Meeting. Eureka Springs, Arkansas.

Middaugh, C.R., B. Kessinger*, and **D.D. Magoulick.** 2015. The projected effects of climate change on growth rate potential of smallmouth bass in the Ozark and Ouachita highlands. National American Fisheries Society Conference. Portland, Oregon.

Middaugh, C.R., and **D.D. Magoulick.** 2015. Forecasting the effects of angler harvest and climate changes on smallmouth bass abundance in the Buffalo River, AR. Arkansas Chapter of the American Fisheries Society. Benton, Arkansas.

Middaugh, C.R., P. Nguyen, T. Alfermann, and P.A. Strickland. 2015. The exploitation of largemouth bass and Suwannee bass in northwest Florida. Southern Division of the American Fisheries Society Conference. Savannah, Georgia.

Middaugh, C.R., and **D.D. Magoulick.** 2015. Forecasting the effects of angler harvest and climate changes on smallmouth bass abundance in the Buffalo River, AR. Southern Division American Fisheries Society. Savannah, Georgia.

Pittman, H.T., and **D.G. Krementz.** 2015. Vegetative Response to Landscape Scale Woodland and Savanna Restoration at Multiple Spatial and Temporal Scales in the Ozark Highlands of Arkansas. Midwest Fish and Wildlife Conference. Indianapolis, Indiana.

Pittman, H.T., and **D.G. Krementz.** 2015. Effects of Frequent Landscape Disturbance on Breeding Dispersal and Nest-site Searching of Eastern Wild Turkey in the Ozark Highlands of Arkansas. Midwest Fish and Wildlife Conference. Indianapolis, Indiana.

Pittman, H.T., and **D.G. Krementz.** 2015. Consideration of scale in the restoration of woodland and savanna ecosystes in the Central Hardwoods of North America. Ecological Society of America. Baltimore, Maryland.

Stein, B., A.N. Yarra, and **D.D. Magoulick.** 2015. The Importance of Substrate Size for Crayfish in Intermittent and Ground Water Streams. Arkansas Water Resources Center Conference. Fayetteville, Arkansas.

Stephenson, P.L. 2015. Emergent Wetland Pollinators: An Unknown Story. Entomological Society of America Annual Meeting. Minneapolis, Minnesota

Stephenson, P.L. 2015. Pollinator Communities on Native and Managed Emergent Wetlands in the Lower Mississippi Alluvial Valley of Arkansas. Natural Areas Conference. Little Rock, Arkansas

Stephenson, P.L., A.P.G. Dowling and **D.G. Krementz.** 2015. Emergent Wetland Pollinators: An Unknown Story. Joint Kansas Entomological and Arkansas Entomological Society Meeting. Fayetteville, Arkansas.

Yarra, A.N., L.A. Bruckerhoff, and **D.D. Magoulick.** 2015. Crayfish occupancy in response to hydrologic regime and geomorphology in Ozark streams. Symposium on Conservation, Ecology, and Taxonomy of Southeastern Crayfish. Southern Division American Fisheries Society. Savannah, Georgia.

Posters Presented:

Bruckerhoff, L.A. and **D.D. Magoulick.** 2015. Morphological variation across hydrologic regimes. American Fisheries Society Annual Meeting. Portland, Oregon.

Middaugh, C.R., and **D.D. Magoulick.** 2015. Forecasting the effects of angler harvest and climate change on smallmouth bass abundance in the Buffalo River, AR. Southern Division of American Fisheries Society Conference. Savannah, Georgia.

Committees/Task Forces/Recovery Teams:

Fournier, A.M.V. – Treasurer – Student Working Group – The Wildlife Society National. 2015.

Fournier, A.M.V. – Treasurer – Wetlands Working Group – The Wildlife Society National. 2015.

Fournier, A.M.V. – Science Fair Judge Regional/Local Science Fairs NW Arkansas. 2015.

Graham, N.E. – Secretary – University of Arkansas American Fisheries Society. 2015.

Graham, N.E. – Member – Biological Graduate Student Association, University of Arkansas. 2015.

Krementz, D.G. – Member – Graduate Studies Committee – University of Arkansas. 2012-present.

Krementz, D.G. – Member – Facilities Committee – Department of Biological Sciences, University of Arkansas. 2008-2015.

Krementz, D.G. – Graduate Student Advisory Committee – Kelly Halloran, M.S. Department of Biological Sciences, University of Arkansas. 2015.

Krementz, D.G. – Graduate Student Advisory Committee – Heather Wallace, Ph.D. Department of Biological Sciences, University of Arkansas. 2015.

Krementz, D.G. – Graduate Student Advisory Committee – Brenna Levine, Ph.D. Department of Biological Sciences, University of Arkansas. 2015.

Krementz, D.G. – Graduate Student Advisory Committee – Hanna Ford, M.S. Department of Geosciences, University of Arkansas. 2012-present.

Krementz, D.G. – Chair – Donald H. Rusch Memorial Game Bird Research Scholarship Committee. The Wildlife Society. 2011-2015.

Krementz, D.G. – Member – The Wildlife Society. 1998-present.

Krementz, D.G. – Member – National Resources Conservation Service Marshbird Working Group. 2011-present.

Krementz, D.G. – Member – West Gulf Coastal Plain JV landbird technical group. 2009-present.

Krementz, D.G. – Chair – Webless Committee, Mississippi Flyway Technical Section. 2006-present.

Krementz, D.G. – Member – U.S. Fish and Wildlife Service Webless Migratory Game Bird – Proposal selection committee – 2015.

Krementz, D.G. – Member – Arkansas Game and Fish Commission – Arkansas Wildlife Action Plan – 2015.

Magoulick, D.D. – Member – North American Benthological Society. 1986–present.

Magoulick, D.D. – Member – American Fisheries Society. 1990–present.

Magoulick, D.D. – Member – Ecological Society of America. 1990-present.

Magoulick, D.D. – Member – Sigma Xi Scientific Research Society. 1984-present.

Magoulick, D.D. – Member – Project Kaleidoscope Faculty for the 21st Century. 1999-present.

Magoulick, D.D. – Graduate Student Advisory Committee – Chelsea Kross, Ph.D. Department of Biological Sciences, University of Arkansas. 2015.

Magoulick, D.D. – Graduate Student Advisory Committee – Allyn Dodd, Ph.D. Department of Biological Sciences, University of Arkansas. 2015.

Magoulick, D.D. – Graduate Student Advisory Committee – Kayla Sayre, M.S. Department of Biological Sciences, University of Arkansas. 2015.

Magoulick, D.D. – Graduate Student Advisory Committee – Brooke Howard-Parker, M.S. Department of Biological Sciences, University of Arkansas. 2015.

Magoulick, D.D. – Graduate Student Advisory Committee – Kyler Hecke, M.S. Department of Biological Sciences, University of Arkansas. 2014-present.

Magoulick, D.D. – Graduate Student Advisory Committee – Mallory Jeffers, M.S. Department of Biological Sciences, University of Arkansas. 2014-2015.

Magoulick, D.D. – Graduate Student Advisory Committee – Jacqueline Guzy, Ph.D. Department of Biological Sciences, University of Arkansas. 2014-present.

Magoulick, D.D. – Graduate Student Advisory Committee – Melissa Welch, M.S. Department of Biological Sciences, University of Arkansas. 2013-present.

Magoulick, D.D. – Graduate Student Advisory Committee – Shrijeeta Ganguly, Ph.D. Department of Biological Sciences, University of Arkansas. 2013-present.

Magoulick, D.D. – Graduate Student Advisory Committee – Whitney Nelson, Ph.D. Department of Biological Sciences, University of Arkansas. 2013-present.

Magoulick, D.D. – Graduate Student Advisory Committee – Philip Vogrinc, M.S. Department of Biological Sciences, University of Arkansas. 2013-present.

Magoulick, D.D. – Graduate Student Advisory Committee – Auriel Fournier, Ph.D. Department of Biological Sciences, University of Arkansas. 2012-present.

Magoulick, D.D. – Graduate Student Advisory Committee – Hal Halvorson, Ph.D. Department of Biological Sciences, University of Arkansas. 2012-present.

Magoulick, D.D. – Graduate Student Advisory Committee – Kapil Khadka, Ph.D. Department of Biological Sciences, University of Arkansas. 2012-present.

Magoulick, D.D. – Faculty Search Committee – Invertebrate Ecologist, Department of Biological Sciences, University of Arkansas. 2015.

Magoulick, D.D. – Faculty Search Committee – Aquatic Ecologist, Department of Biological Sciences, University of Arkansas. 2014-2015.

Magoulick, D.D. – Yellowcheek Darter Recovery Plan Team – U.S. Fish and Wildlife Services. 2013-present.

Magoulick, D.D. – Adaptation Science Management Team for Gulf Coastal Plain Ozarks Landscape Conservation Cooperative – U.S. Fish and Wildlife Services. 2012-present.
Magoulick, D.D. – Inter-agency Climate Change Working Group. 2010-present.
Magoulick, D. D. – Nature Conservancy Science Advisory Board. 2010-present.
Magoulick, D.D. – Fish Taxa Team – Arkansas Wildlife Action Plan. 2010-present.
Magoulick, D.D. – Crayfish Taxa Team – Arkansas Wildlife Action Plan. 2010-presnt.
Magoulick, D.D. – International Union for Conservation of Nature (IUCN) Australia Freshwater Fish Conservation Work Group. 2009-present.
Magoulick, D.D. – U.S. Fish and Wildlife Service Aquatic Nuisance Species Task Force. 2007-present.
Magoulick, D.D. – Arkansas Invasive Species Task Force. 2007-present.
Magoulick, D.D. – Science Fair Advisory Panel for Haas Hall Academy. 2011-2015.
Middaugh, C.R. – Treasurer – University of Arkansas Subunit of the American Fisheries Society. 2015.
Stephenson, P.L. – Member – Donald H. Rusch Memorial Game Bird Research Scholarship Selection Committee for The Wildlife Society. 2015.
Stephenson, P.L. – President – University of Arkansas Student Chapter of The Wildlife Society. 2014-present.
Stephenson, P.L. – Treasurer – Isley-Baerg Entomology Club, University of Arkansas. 2015.
Yarra, A.N. – President – University of Arkansas Chapter American Fisheries Society – 2015.
Yarra, A.N. – Member – Student Resources Committee – Society of Freshwater Sciences – 2015.

TECHNICAL ASSISTANCE:

Training Received:

Fournier, A.M.V. – Adult First Aid/CPR/AED American Red Cross – University of Arkansas – 2015.
Fournier, A.M.V. – Software Carpentry Instructor Training – Iowa State University – 2015.
Fournier, A.M.V. – Editing in Ornithology Workshop – Norman, Oklahoma – 2015.
Graham, N.E. – Adult First Aid/CPR/AED American Red Cross – University of Arkansas – 2015.
Graham, N.E. – Defensive Driving – U.S. Department of Interior – 2015.
Graham, N.E. – Safety: Authorities, Roles and Responsibilities – U.S. Department of Interior – 2015.
Graham, N.E. – Safety: DOI Safety and Occupational Health Overview – U.S. Department of Interior – 2015.
Graham, N.E. – Safety: Field Employee Orientation – U.S. Department of Interior – 2015.
Graham, N.E. – Safety: USGS Safety and Occupational Health Program Overview – U.S. Department of Interior – 2015.
Graham, N.E. – Safety: USGS Safety Program Requirements – U.S. Department of Interior – 2015.
Graham, N.E. – Safety: USGS Industrial Hygiene Program – U.S. Department of Interior – 2015.
Graham, N.E. – Safety: Laboratory Safety – U.S. Department of Interior – 2015.
Krementz, D.G. – Sustainability and environmental management systems awareness – USGS – 2015.
Krementz, D.G. – Uniform services employment and re-employment rights act – USGS – 2015.
Krementz, D.G. – Veteran Employment Training for Hiring Manages – U.S. Department of the Interior – 2015.
Krementz, D.G. – Boat U.S. Foundation's Online Boating Safety Course – Boat U.S. Foundation – 2015.
Krementz, D.G. – NSC Defensive Driving II – U.S. Department of the Interior – 2015.
Krementz, D.G. – Federal Information Systems Security Awareness + Privacy and Records Management – U.S. Department of Interior – 2015.
Magoulick, D.D. – Stream Interment Workshop – U.S. Forest Service, Boise, Idaho – 2015.

Magoulick, D.D. – Stream Network Spatial Statistics Workshop – U.S. Forest Service, Boise, Idaho – 2015.

McClain, J.C. – Wilderness First Aid Certification – National Outdoor Leadership School – 2015.

Stephenson, P.L. – Adult First Aid/CPR/AED American Red Cross – University of Arkansas – 2015.

Stephenson, P.L. – Safety: Authorities, Roles, and Responsibilities – U.S. Department of the Interior – 2015.

Stephenson, P.L. – Safety: USGS Safety Program Requirements – U.S. Department of the Interior – 2015.

Stephenson, P.L. – USGS Safety and Occupational Health Program Overview – U.S. Department of the Interior – 2015.

Stephenson, P.L. – USGS Industrial Hygiene Program – U.S. Department of the Interior – 2015.

Stephenson, P.L. – Safety: DOI Safety and Occupational Health Overview – U.S. Department of the Interior – 2015.

Outreach:

Fournier, A.M.V. – Outdoor Education Volunteer – Hobbs State Park

Fournier, A.M.V. – Curated RealScientists and Bio Tweeps Twitter Accounts

Fournier, A.M.V. – Presentation, Fayetteville Public Library & Elkins Public Library as part of summer STEM program, Arkansas

Fournier, A.M.V. – Presentation, Springdale Alternative High School

Fournier, A.M.V. – Presentation at Camp War Eagle

Magoulick, D.D. – Regional Science Fair Judge 2008-present

Magoulick, D.D. – Crayfish research featured in Arkansas Game and Fish Commission circular. Article was picked up and circulated by various news agencies regionally

Middaugh, C.R. – Career Day Presentation, St. Joseph Catholic School

Middaugh, C.R. – Northwest Arkansas regional science fair judge, University of Arkansas

Moore, J.D. – American Woodcock migration ecology website overseer – located on Ruffed Groused Society website

Moore, J.D. – American Woodcock migration ecology research featured in various newspapers, magazines and websites regionally, nationally, and internationally

Stephenson, P.L. – Bird Banding Demonstration – Hobbs State Park

Stephenson, P.L. – Presentation, Cave Springs 4-H Club

Stephenson, P.L. – Presentation, Owl Creek Elementary