

MUSEUM OF NATURAL HISTORY

2019 Annual Report


Auburn University Museum of Natural History

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Alabama Natural Heritage Program®

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Auburn University Museum of Natural History

The mission of the Auburn University Museum of Natural History is to document, understand, and preserve biodiversity in order to educate people of all ages about our planet's rich natural history. Our vision is to emerge as the primary repository for all natural history collections currently maintained at Auburn University and to function as a center of excellence for biodiversity research, education, and outreach. We will capitalize on strengths of the biodiversity heritage collections in our care and the vast organismal knowledge base of the curators and staff to establish a gateway through which all segments of society can come discover the natural sciences and appreciate the relevance of biodiversity to human health and quality of life. We will preserve and document the rich natural heritage of Alabama while concurrently creating opportunities for students and teachers from regional schools, the general public, students at Auburn University, and researchers to explore our planet's biodiversity. We seek to inspire an appreciation of nature and the environment so that we might better conserve it for future generations.

Location

AU Museum of Natural History
Biodiversity Learning Center
381 Mell Street
Auburn Unversity

Alabama Natural Heritage Program®
1090 South Donahue Drive
Auburn University, AL 36849

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AUMNH: (334) 844-9234
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Websites

Auburn University
Museum of Natural History:
aumnh.org

www.facebook.com/AUMNH

AL Natural Heritage Program®:
http://www.auburn.edu/cosam/natural_history_museum/alnhp/

Affiliated Websites

NatureServe
www.natureserve.org

From the Director:

The museum has worked over the past year to expand its outreach, teaching, and research operations. Toni Bruner came on as our new Outreach and Education coordinator last April and has hit the ground running. Toni comes to us from Alabama Legacy and the Cook Museum of Natural Science. She has taken over our existing programs and has added in some new programs like teacher training. In addition, Toni helped to spearhead the completion of our dinosaur egg display, which was set to open in April until COVID-19. We hope to open this display in September tied with the return of our open house.

Research was upped with our hire of Dr. Katie Lawson as our new GIS Administrator. Katie brings GIS experience from her Ph.D. works as well as her time with the United States Geological Survey. In addition to that, Katie is an ichthyologist that worked in fisheries and invasion ecology, and she brings essential skills here to the Alabama Natural Heritage program.

The museum has been wrapping up its survey of Redstone Arsenal in Northern Alabama and ramping up its exploration of wetlands. Redstone Arsenal contains a lot of natural areas along the Tenneessee River. Habitat ranges from floodplain to montane along with a considerable underground fauna, all of which has been examined by museum scientists. For the Environmental Protection Agency, we are charged with establishing reference wetlands for the state. This will involve surveys of some of the best wetlands in the state for plants and animals to learn the qualities of the best of each type of wetland.

Curator of marine invertebrates, Dr. Ken Halanych, received an NSF grant to survey invertebrates off of Antarctica. Ken will complete two expeditions to add to the already extensive holdings of invertebrates of the region held by the museum.

Closer to home, Dr. Les Goertzen, Curtis Hansen, and Al Schotz are completing a survey of the plants of Chewacla State Park. Over the last several years, they have found over 600 plant species in this area. Chewacla is a small park inside of Auburn and along Chewacla Creek. This area is right on the Fall Line (the transition between the Appalachians and Coastal Plain), and the diversity of the region is influenced by this unique geography.

The museum, along with the Davis Arboretum, and Auburn University Veterinary Medicine, held its second Boos and Bones exhibit. We brought out skeletons and other specimens to the Arboretum grounds in October. The event was staffed by many, and my heartfelt thanks goes to all of our volunteers for this and all of our projects. We hope to transition to a system of alternating Boos and Bones with museum open houses in the fall with this year being dedicated to an Open House and our new Dinosaur Egg display.

We also enhanced the museum a bit. A couple of years ago, Joel Sartore from Natural Geographic came to Auburn to photograph live animals for his PhotoArk project. The museum contributed some of its own living specimens, including the Auburn Trapdoor Spider, a species endemic to the Auburn region.

Photos of several of these species now grace our second-floor corridor. Make sure you come to the open house to see them!

Like all institutions, COVID-19 has made for changes within the museum that will dominate next year's report.

For us, it is time for backlog of electronic databasing. Museums were some of the first places to utilize databases for the storage and free presentation of data, and we all have years of work just to get everything to the place we want them to be.

Dr. Jonathan Armbruster

Director, Auburn University Museum of Natural History

Katie Lawson dipnetting fish in a North Alabama pond.

Outreach and Education Coordinator, Toni Bruner, teaching elementary school students about cave ecosystems.

Primary funders (in alphabetical order)

Alabama Department of Conservation and Natural Resources, Division of Wildlife & Freshwater Fisheries
- Escambia Map turtles
- Green Salamander modeling and survey
- Mississippi gopher frog survey
- Hellbender multi-state survey
- Indigo snake monitoring
- Alligator snapping turtle
- White Fringeless Orchid Modeling
- Dysbiosis of Freshwater Mussels
- Southeastern Cooperative Fish Parasite and Disease Project
- Propagation Bottlenecks for Freshwater Mussels

Alabama Department of Conservation and Natural Resources, State Lands Division
- Environmental Science and Art - AUMNH Outreach at Wehle

Department of Defense
- Arnold Air Force Base gopher frog survey

National Science Foundation
- RAPID: Aquatic refuge and recovery in the face of drought in a biodiversity hotspot
- Compactorized Shelving for the Wet Collections of AUMNH
- Collaborative Research: Red Carotenoids as Signals of Respiratory Chain Function
- DDIG: Copepod Mate Choice

NatureServe
- Mountain Longleaf Vegetation Assessment

The Nature Conservancy
- Waterdog and musk turtle eDNA survey

U.S. Army Garrison - Redstone
- Planning Level Survey of Redstone Arsenal for At-risk Species and Ecologically Significant Communities

U.S. Environmental Protection Agency
- Establishment of Wetland Reference Sites in Alabama

U.S. Fish and Wildlife Service
- Gentian Pinkroot Status Assessment
- Bog Spicebush Status Assessment
- Wherry's Phlox Status Assessment
- Turkey Creek Musk Turtle
- Biodiversity, phylogeny of *Myxobolus* spp.
- ANS, *Myxobolus cerebralis*, whirling disease in salmonids

U.S. Forest Service
- eDNA analysis for Bankhead National Forest

Virginia Department of Conservation and Recreation
- Southeastern Cooperative Fish Parasite and Disease Project
- Biosecurity of trout fish hatcheries
- Hatchery checks supporting salmonid culture

AUMNH COLLECTIONS

John D. Freeman Herbarium

Accessions/Acquisitions/Exchanges/Loans

The herbarium continues to be very active and growing collection including over 80,000 specimens of vascular plants, mosses, liverworts, lichens and fungi from all over the world. Exchange specimens and acquisitions have added greatly to the broad diversity and growth of the international collections. The herbarium received 350 specimens on exchange or as gifts and sent out 500 on exchange to other institutions. A multi-year effort to mount and prepare over 2100 sheets of grapevines (the genus *Vitis*), is now complete and the final step of georeferencing specimens is taking place prior to entering all the information into the database. Auburn will have one of the premier collections of *Vitis* in the southeastern US and beyond.

Digitization/Database Development

Over 3,100 specimens were glued, processed and added to the Specify database during 2019. These include vascular plants (2,657), mosses (163) and lichens (325). Our vascular plants, lichens, bryophytes and fungi, are searchable online at the AUMNH website (aumnh.org/research-collections/plants/search-plant-database/). Our Alabama vascular plants are searchable on the Alabama Plant Atlas website (www.floraofalabama.org), Morphbank (www.morphbank.net) and SERNEC portal (www.sernecportal.org). Many of our lichen specimens may be searched at the Consortium of North American Lichen Herbaria (www.lichenportal.org/cnalh/) and our bryophyte specimens are on the Consortium of North American Bryophyte Herbaria (https://bryophyteportal.org/

Curtis Hanson and students pressing plants during Curious Curators Camp - June 2019

Teaching, Students, & Volunteers

Volunteers continue to play a critical role in the overall success of managing the Freeman Herbarium. In 2019, we had volunteer help from Phillip Barlow, Colton Seals, Adekola Ouoyemi (grad student) and Brannan Cliver. They have all done a job gluing specimens and working through our backlog. Chris Taylor has been working on several projects including the Chewacla State Park flora and repairing/mounting the historic St. Bernard Collection. Several honors biology students spent volunteer hours helping to glue plants. Systematic Botany continues to be successfully taught every spring semester with students gaining knowledge and experience in plant identification.

Research & Collections Related Activities

Graduate student Adekola Ouoyemi is doing research with Dr. Leslie Goertzen on the origin of *Eleusine* (Poaceae, Goose grass) in Africa and species distributions throughout the World. He's using herbarium loans and specimen data online to understand the native range of the different species. In addition, he is examining the morphological distinctions among the species.

Marc Johnson, also a graduate student, is doing a bio-inventory of vascular plant species in the Yates Lake Wildlife Management Area, Elmore County, AL, including collecting specimens for the Freeman Herbarium and using museum resources to identify plants.

Curtis Hansen has done field work across the state including the Forever Wild Tracts of Uchee Creek and Hinds Road Rock, Chewacla State Park, Desoto State Park, Cheaha State Park, Flat Rock Park, and Redstone Arsenal, among other places. He has authored or coauthored papers on lichen floristics, a newly discovered lichen in Alabama and a newly discovered plant in North America.

The Freeman Herbarium houses historic plant collections from the St. Bernard Herbarium, formerly located in Cullman Co., AL and that were transferred to the herbarium in 1995. These historic and important collections are now getting more attention by being repaired and prepared for incorporation into the main collection.

PhD Student Marc Johnson pressing plants for his research

Ichthyology Collection

The fish collection continues to grow in both species diversity and geographic spread. In 2019 the collection added 7,089 voucher specimens in 878 lots and 1,401 tissue samples. The majority of the new material came from collections made in Alabama by AUMNH personnel and Dr. Carol Johnston's lab in Fisheries and Allied Aquaculture. Additionally, we accessioned material collected by natural resources personnel in Florida and Georgia. Dr. Richard Mayden of St. Louis University donated a large volume of material collected by students in his laboratory. These specimens came from a variety of localities in Australia, Bangladesh, Cambodia, Chile, India, Japan, Nepal, Russia, and Thailand.

The fish collection continues to receive a high volume of loan requests from researchers around the world. In 2019 the fish collection loaned out 655 specimens in 284 lots with half of those going to international laboratories in Brazil, Canada, and Switzerland. A large amount of the material loaned domestically (200 specimens) was requested for CT scanning as part of the oVert Project. Once processed, scans of these specimens will be made freely available to researchers, students, and the public. The fish collection also hosted four visiting researchers this year working on projects in North and South America.

The fish collection had four graduate students and multiple undergraduates work on the collections this year. One undergraduate student, Holden Paz, recently was co-author on a paper on South American catfishes of the genus *Trichomycterus*. Results of two long-term studies were published in 2019 on South American catfishes from around the Guiana Shield. These include descriptions of eight new species and one new genus. Altogether, 14 papers were published that cited AUMNH specimens or records.

Ancistrus kellerae, a newly described species of catfish from the Guiana Shield

Yaluwak primus, a newly described genus and species from the Brazilian-Guiana Shield

Herpetological Collections

The Division of Herpetology continues its efforts to uphold and advance the museum's mission to document, study and educate the public about the biodiversity of Alabama and the world. Division staff, students and associates continue to conduct and promote collection growth and curation, participate in collections-based research, and in facilitate the dissemination of information through scholarly publication and museum outreach.

Accessions/Acquisitions/Exchanges/Loans

The herpetological collections were once again fully operational after being shut down for much of last year to allow for the installation of compactors and tank racks in the alcohol room. 2019 saw a return to growth in the herpetological collections. Close to 1000 amphibian and reptile specimens were accessioned into the various herpetological collections representing a collection growth of close to 2%. The specimens included adults, larvae, and even a few stomach contents. A good portion of the growth this year was due to the accessioning of the museum's backlog of larval salamanders. Many thanks to Dr. Brian Folt for identifying the majority of the salamander specimens and to Ryan Cook for accessioning them. Other new specimens arrived as a result of ongoing research associated with the herpetology labs on campus. These include the last of the backlog of south Florida snakes associated with Dr. Melissa Miller's work as well as Brown Anoles from Dr. Amelie Fargevieille's research, Kerry Cobbs Alabama toads and Randy Klabacka's whiptails from Texas and New Mexico.

There was also considerable growth in our frozen tissue collection with over 900 tissues and DNA extracts added. These include tissues from our accessioned specimens, as well as some from animals that were photo vouchered and others from animals that were not collected. An important addition was the 400+ indigo snake DNA extracts that were part of a research project spearheaded by AUMNH personnel and associates which led to the publication of "Taxonomic and conservation implications of population genetic admixture, mito-nuclear discordance, and male-biased dispersal of a large endangered snake, *Drymarchon couperi*" (Folt et al., 2019) which aided in the conservation of the Eastern Indigo, by demonstrating that there is only one species present in the southeastern United States.

Last, we also added over 75 digital vouchers to our photo/audio/video voucher collection. These virtual vouchers help us fill in gaps in our knowledge of Alabama's amphibians and reptiles as well provide important records of sensitive and threatened species.

The herpetology collections were also well utilized by researchers in 2019. During this year, a total of 16 loans were processed and more than 20 data and tissue requests were processed. We were also happy ot host 2 visiting scientist, which utilized the museum's specimens

Digitization/Database Development

The work of digitizing and serving the herpetological databases online continues. The majority of the wet collections are available online through the museum's website. The frozen tissue collection has been organized and is now digitized. It now awaits being inputted in to Specify. Additionally, we continue also to add to and maintain a series of ecological databases that are available online through our website. Last year also saw the beginnings of efforts to photograph the museum's specimens. These photographs will be added to our Specify database and be made available online, allowing researchers and the public to see each individual specimen as they search the database.

Teaching, Students, & Volunteers

The Museum's herpetological scientific and teaching collections were also extensively utilized by undergraduate and graduate courses for class use, class projects and individual research. The availability of room 251 as a lab instructional area has allowed several courses to teach their labs within the museum. These include Vertebrate Biodiversity and Herpetology. Not only did students utilized the herpetological teaching collections for lab, several student class projects were based out of the herpetological collections as well and several undergraduate research projects were conducted in the herpetological collections.

A crucial component of our museum family is the group of dedicated and talented volunteers and interns that work with us at the museum. In 2019, the herpetology collections benefited from hundreds of hours of tireless work of over 8 volunteers and interns (see list) who worked in the wet collections, the skeletal collection, the beetle colony, the frozen tissue collection and in the live animal room. Their work is invaluable to the mission of the museum.

<u>Volunteers</u>
Cindy Scruggs
Miles Bennett
Landon Rakestraw
Sydney Spurlock
Li Cheng
Morgan Meeker
Genevieve Rice
Emily Taylor

Citizen Science

The museum continues to participate in citizen science programs that allow Alabamians to participate in the collection of real scientific data and add to our knowledge base on the calling phenology of our state's frog species as well as the geographic distribution of our herpetofaunal diversity. The AUMNH is home to a chapter of FrogWatch USA, a nation-wide citizen science program where volunteers monitor frog call activity to help conserve amphibians and wetlands. Over the last two years, several volunteer workshops have been held throughout the state. The museum is also home to the Alabama Herp Atlas Project (AHAP), a citizen science program where citizens can send in photo, audio or video documentation of any amphibian or reptile species. These records are curated and added to both our photo voucher catalog our geographic distribution maps for those species. As describe above, over 75 vouchers were accessioned in 2019, several of which represented county records. We hope to soon develop educational components to each of these programs.

Live Animal Collection

Continuing our long tradition, the live animal room, now located in nearby Funchess Hall, has been an indispensable resource, which we utilized during both tours and outreach programs. Moreover, our live animals are utilized by other campus programs and departments, further increasing both the impact of the museum collections and the visibility of the museum. In all, live animals were utilized in over 25 events in 2019 and interacted with over 2,500 people of all ages.

Collections manager David Laurencio at the Sustainability Picnic

Research & Collections Related Activities

Herpetology personnel continued producing original collections-based and collections-related research. In 2019, close to 20 publications were produced related to the herpetological collections were published by museum staff and students. These papers showcase the breadth of research being conducted at the AUMNH.

Ornithological Collections

Accessions/Acquisitions/Exchanges/Loans

The ornithological research collection consists of about 2500 bird skins, 50 bird nests with eggs, and 50 empty bird nests. A great majority of the material originates in Alabama. Of the remaining material, the skins are primarily from elsewhere in the Southeast, although a few specimens collected in Central America and Europe are represented. Many of the skins represent the first documentation of that species in the state, and a few remain the only documentation of the species for the state.

Digitization/Database Development

The ornithological collections are housed in Specify and are available online. There is more data available for each bird however. These data are located on the hand written specimen tags which are affixed the foot of each specimen. The process of digitizing all remaining data located on the specimen tags continues.

Teaching, Students, & Volunteers

In addition to the research collection, the AUMNH houses a large teaching collection consisting of about 100 bird skins, bird nests, and taxidermy mounts of birds. Most of the skins in the teaching collection were prepared from salvaged carcasses by students taking Ornithology. The teaching collection is used by several classes in the Department of Biological Sciences to teach bird identification and avian anatomy. The two spring semesters saw over 70 students enrolled in Ornithology, and the Vertebrate Biodiversity courses had over 80 enrollees.

Research & Collections Activities

The ornithological collection received one data request during 2019.

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Mammal Collection

Accessions/Acquisitions/Exchanges/Loans

The AUMNH mammal collection is comprised of just over 5750 specimens, primarily from east-central Alabama. The collection has a focus on insectivores, bats, rodents and carnivores and consists of traditional skin and skull preparations with numerous taxidermy mounts, completed skeletons, fluid-preserved specimens and frozen tissues. Museum specimens are accompanied by standard measurements, such as tail length, mass, and total length, along with information about the collection site and date. To complement its research collections, the museum houses a separate teaching collection used in courses such as Mammalogy and Vertebrate Biodiversity. Four new mammal skins were added over the last year, and the collection received three data requests and welcomed one visiting researcher to the mammal collection.

Teaching, Students, & Volunteers

During 2019, the collection benefited greatly from one dedicated and highly motivated volunteer, Genevieve Rice. Her efforts helped prepare several dozens of skins and hundreds of skulls and skeletons that were prepared during the year. These specimens are now properly prepared and ready to be accessioned into the collection.
The Museum's Mammalogy research and teaching collections were also extensively utilized by undergraduate and graduate courses. These collections were utilized to teach both Vertebrate Biodiversity and Mammalogy. Throughout the year, mammal specimens were used to teach species identification, skeletal specimens were utilized for a lab assignment, and each lab section toured the museum to learn about the importance and utilization of the collections.

Digitization/Database Development

As with all of the museum collections, the mammal database is in the process of moving over to the Specify platform.

Outreach

The mammal collection (and the curator) were used to provide instruction during the Boy Scout's Merit Badge University.

Mammal skulls

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Vertebrate Paleontology Collection

Accessions/Acquisitions/Exchanges/Loans

The vertebrate paleontology collections at Auburn University include close to 2,500 specimens. The collection focuses on the state of Alabama, but also includes significant material from other portions of the southeastern United States. The Vertebrate Paleontology Collection contains Mesozoic and Cenozoic material, both terrestrial and marine, primarily from the Cretaceous period. This includes terrestrial dinosaurs as well as marine groups such as Plesiosaurs and Mosasaurs. It also contains important collections of terrestrial mammals form the Cenozoic Era.

This past year saw the start of preparations for the museum's first public display. The first display will be of our dinosaur egg! Originally discovered by Prescott Atkinson, the egg represents the only dinosaur egg known from east of the Mississippi River and the only egg in the world found in marine sediment. The museum has now developed a public display for the egg on the campus of Auburn University and eagerly awaits its grand opening.

Dinosaur Egg. Photo Credit: Joel Sartore/National Geographic Photo Ark

Teaching, Students, & Volunteers

Our vertebrate paleontology volunteers continued to provide incredible help in organizing the vertebrate paleontological collection. Through their continuing efforts, the collection is being more accessible and organized and the fossils' housing is being improved.

Volunteers
Claire Wilson
Skye Walker
Lorrianny Martinez

Invertebrate Paleontology Collection

Accessions/Acquisitions/Exchanges/Loans

The museum's invertebrate paleontological collections were first curated in 2016. The museum is home to a small collection of over 120 invertebrate fossils.

Digitization/Database Development

The invertebrate paleontology database is digitized and awaits preparation and transfer to the Specify platform.

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Entomology Collection

Accessions/Acquisitions/Exchanges/Loans

Curator Dr. Charles Ray and his lab added 7,000 pinned specimens to the collection this year. Dr. Fredericka Hamilton added 1,200 slide-mounted scale insects and AUMNH staff added specimens collected from the Redstone Arsenal survey during the summer of 2019.

This year, we had four outgoing loans and five data requests. We recently published our digitized specimens to GBIF, iDigBio, SCAN, and InvertEBase, and are continually adding more digitized specimens.

The entomology collection was in good hands while our collection manager, Melissa, was on maternity leave. Cory Unruh, PhD in Entomology, filled in for her and kept the collection running smoothly.

Digitization/Database Develop-

Over 4,500 specimens were digitized in 2019. To date, we have almost 209,000 insects and 11,000 arachnids and myriapods digitized. The data are available through iDigBio: http://ipt.idigbio.org/resource?r=aum-entomology

Teaching, Students, & Volunteers

We are thankful for all of the students working and volunteering in the entomology collection this year. They worked diligently prepping specimens, digitizing, and helping with outreach events!

Holly Goodwin

Alan Jeon

Chloe Kaczvinsky

Charles Stephen

Jordan Sykes

Dr. Cory Unruh

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Invertebrate Collection

Accessions/Acquisitions/Exchanges/Loans

The Invertebrate Collection saw continued growth in 2019, adding 90 lots to the collection. The specimens included representatives of all major invertebrate taxa. Most of the new specimens came from museum trips with some from private collectors. We had a total of three out-going loans totaling 9 specimens. Six of which were soft corals sent to Harvey Mudd College and three of which were freshwater mussels sent to Appalachian State University. We also had an internal loan of freshwater mussels for display purposes of 23 specimens.

Digitization/Database Development

We digitized 90 lots in 2019, as the invertebrate collection is continually digitized as it is accessioned. All of the information is added to our Specify database, and each specimen is given a barcode for more efficient tracking. The data should soon be available online at the AUMNH website, and shared with GBIF, iDigBio, as well as other online sources.

Research & Collections Related Activities

There have not been many collecting expeditions by personnel in the Invertebrate collection this year. Most of the effort is still moving Kenneth Halanych's collections into the Auburn University Museum of Natural History.

Teaching, Students, & Volunteers

The invertebrate collection has benefitted from the amazing students and volunteers who have worked on specimen collection, upkeep, accessioning, digitization, and outreach. We are grateful for all of their contributions.

Lauren Wilson (Undergraduate, DBS)

Brittany Woodruff (Undergraduate, DBS)

Jade Halanych (High School volunteer)

The public checking out some invertebrate specimens at the Sustainability Picnic

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AUMNH Research Projects

Redstone Arsenal Planning Level Surveys

Redstone Arsenal contracted with ALNHP and AUMNH to conduct planning-level surveys to document the precise number of species of conservation concern on the installation. Surveys focused on areas designated as Ecologically Sensitive Areas but also included other areas of suitable habitat for rare species. Surveys in 2019 focused on insects, arachnids, fishes, and plants.

Much of the remaining field work was completed in 2019 for this project. Insect and arachnid surveys were completed in May 2019, and lab work has been ongoing to identify specimens and add them to museum collections. Several fish surveys were completed in 2019 with only a few sites remaining for 2020. Most individuals were preserved, identified, and added to the museum's collection. Many individuals of the state protected Tuscumbia darter *Etheostoma tuscumbia* were caught, identified, and released. This species is a Tennessee River endemic, and it appears to be doing well in several spring and spring-fed systems on the Arsenal.

Additional plant surveys were completed in 2019 for a more species-specific inventory. Numerous specimens were collected for incorporation into the herbarium's collections as well. Photo-vouchers were taken of even more plant specimens by Dr. Les Goertzen and those records will also be included in the final report. Field work for this project will conclude in 2020.

The fish survey team seining a creek.

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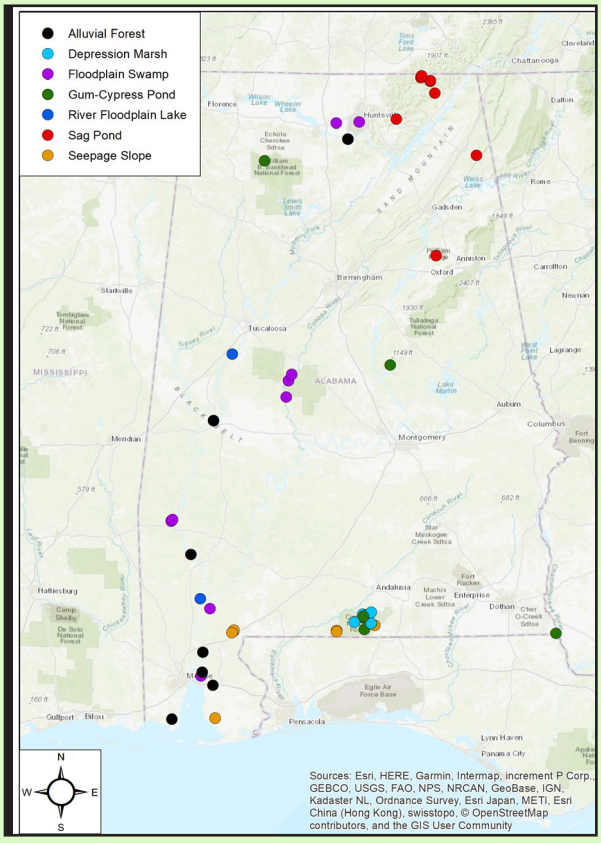
Reference Wetlands Study

In 2018, the Environmental Protection Agency awarded AUMNH/ALNHP a grant to conduct a reference wetland study. The Museum has partnered with Troy University to accomplish the study, whose primary goal is to enhance recognition and protection of wetlands throughout Alabama by establishing permanent wetland reference sites across the state using an Ecological Integrity Assessment framework. This framework developed by NatureServe and the Natural Heritage Network, was designed to support planning and management for the conservation of wetlands and other natural communities through quantifying ecological integrity based on metrics of biotic and abiotic condition, size, and landscape context. Reference wetland sites will provide a standard against which to measure the condition of similar wetland types – a starting point for establishing desired future conditions to inform land management and conservation efforts. Wetland integrity will be evaluated focusing on intensive field assessments of flora and fauna. These assessments will include collecting data to support a floristic quality assessment and indices of biotic integrity for faunal taxa.



Map of high quality wetlands from which reference sites will be selected.

The final product is anticipated to complement and strengthen the state's ability to implement a comprehensive water quality monitoring and wetlands assessment program by providing baseline data to fill information gaps. The collection of vegetation data has begun, and will be part of the deliverables that include GIS data and maps, a database of completed field assessment forms, and hard and electronic copy of final report summarizing the project results. This information can be used for setting conservation priorities, identifying restoration strategies, and monitoring the effectiveness of conservation actions.

ALABAMA NATURAL HERITAGE PROGRAM[SM]

The mission of the Alabama Natural Heritage Program[SM] (ALNHP) is to provide the best available scientific information on the biological diversity of Alabama to guide conservation action and promote sound stewardship practices. ALNHP is administered by the Auburn University Muesum of Natural History, Department of Biological Science. Established by The Nature Conservancy in 1989, it is one of a network of such programs across the United States, Canada, and Latin America, collectively known as the Natural Heritage Network (NHN). As a member of the NHN, ALNHP is represented by its membership organization NatureServe. NatureServe works to aggregate data from individual Network Programs and is dedicated to the furtherance of the Network and the application of Heritage data to biodiversity conservation.

Natural Heritage Programs have three broad functions:

- to collect information on the status and distribution of species and natural communities,
- to manage this information in a standardized way, and
- to disseminate this information to a wide array of users.

Natural Heritage Programs use a standardized information management system to track biodiversity data including taxonomy, distribution, population trends, condition, and viability. ALNHP provides the following services: biodiversity data management, inventory, biological monitoring, conservation planning, Geographic Information System services, and land management expertise.

NatureServe
A Network Connecting Science With Conservation

NatureServe is a non-profit conservation organization that provides the scientific information and tools needed to help guide effective conservation action.

NatureServe represents an international network of biological inventories - known as natural heritage programs or conservation data centers - operating in all 50 U.S. states, Canada, Latin America and the Caribbean. NatureServe and its network of natural heritage programs are the leading source for information about rare and endangered species and threatened ecosystems.Together we not only collect and manage detailed local information on plants, animals, and ecosystems, but develop information products, data management tools, and conservation services to help meet local, national, and global conservation needs. The objective scientific information about species and ecosystems developed by NatureServe is used by all sectors of society - conservation groups, government agencies, corporations, academia, and the public - to make informed decisions about managing our natural resources.

Project Summaries

Black Warrior waterdog and flattened musk turtle eDNA survey of Locust Fork

The Locust Fork of the Upper Black Warrior River basin supports a suite of federally listed aquatic species including snails, fish, and mussels, plus an amphibian and reptile. The U.S. Fish and Wildlife Service, Alabama Department of Conservation and Natural Resources, and Geological Survey of Alabama have prioritized watersheds in the state to focus management and conservation actions for aquatic species restoration and recovery. These watersheds have been designated Strategic Habitat Units (SHUs) and the Locust Fork is one of the recognized SHUs.

The Black Warrior waterdog (*Necturus alabamensis*) and the flattened musk turtle (*Sternotherus depressus*) are endemic to the Upper Black Warrior River, are ecologically linked by habitat, and are federally listed. Based on recent survey work using eDNA and conventional sampling outside of the streams within the Bankhead National Forest, the Locust Fork appears to have the best remaining populations of these species. This project, as part of a larger project funded by the National Fish and Wildlife Foundation to The Nature Conservancy, is to survey the entire free-flowing reach of the Locust Fork for both species using eDNA. Results from these surveys will be used in a larger landscape and water quality analysis to provide guidance for habitat restoration and watershed conservation.

Flattened Musk Turtle

Occurrence of Western Chicken Turtle in Louisiana

The Western Chicken Turtle (*Deirochelys reticularia miaria*), is distributed west of the Mississippi River in Arkansas, Louisiana, Missouri, and Texas. Records for the Chicken Turtle in Louisiana are distributed through much of the state exclusive of the toe east of the Mississippi River; subspecies east of the Mississippi River is the nominate *D. r. reticularia*. In the Louisiana Wildlife Action Plan the Western Chicken Turtle is in the Tier I category, those species most in need of immediate conservation action. Chicken Turtles inhabit wetlands and use surrounding upland habitats for nesting and overwintering. Threats reported in others states include conversion of bottomland hardwood and cypress swamps to agriculture (Trauth et al. 2004; Buhlmann et al. 2008). In this project, we help the state address survey needs for the Western Chicken Turtle in Louisiana as laid out by the State Wildlife Action Plan (SWAP). We expect to provide baseline data on the presence of the Chicken Turtle

Although few formal surveys have been conducted within the range of the Western Chicken Turtle the species is assumed to be in decline due to habitat loss and alteration. Louisiana recognizes the paucity of information on the status of the Western Chicken Turtle and the need is to collect information on the current distribution of the species. The objective is to determine current occurrence and distribution of the Western Chicken Turtle in Louisiana.

Survey locations will be selected based on historic Western Chicken Turtle records, and will include 35 of the localities presented in Buhlmann et al. (2008). We will conduct site visits to selected localities based upon accessibility and sample for Western Chicken Turtles with visual wading and trapping. Trap sets will be baited hoop nets, with or without leads, box traps, and crawfish traps depending upon water depth and wetland type being sampled. All species of turtles captured will be evaluated to determine sex, weighed, measured, marginally notched for unique identification, and a tissue sample taken. Chicken Turtles are active from March through September (Buhlmann et al. 2008; Carr and Tolson 2017) therefore we will target our sampling during this time. Based on our trapping we will provide an update on the current distribution of the Western Chicken Turtle, and information on turtle species assemblages affiliated with Western Chicken Turtle wetlands

Chicken Turtle

Alligator Snapping Turtle Status Survey

Diversity of fish, molluscs, and other freshwater species of the southeastern United States is well known. Comparably, the freshwater turtles also achieve a peak of diversity within the southeastern United States. One species of particluar interest is the alligator snapping turtle (*Macrochelys temminckii*), the largest freshwater turtle in North America, which may attain a maximum size of 80 cm carapace length and a weight of 143.3 kg. The species is almost wholly aquatic, seldom leaving the water except to lay eggs (Mount 1975, Dobie 1986). In Alabama the turtle has been reported from the major drainages, except the streams on the north side of the Tennessee River. Creeks, rivers, oxbows, sloughs, and occasionally brackish waters are habitats in which the turtle is found.

ALNHP Herpetologist, Jim Godwin

Photo: U.S. Fish and Wildlife Service

The U.S. Fish and Wildlife Service has been petitioned to list the turtle but this action has yet to be taken (Dobie 1986, Pritchard 1989). Reed et al. (2002) have summarized information on the alligator snapping turtle published since Pritchard's (1989) work and have drawn the conclusion that populations of the species are incapable of long-term survival when subjected to a loss of adult females as low as 2% annually. Although the turtle is no longer subjected to commercial harvest in Alabama, such has not always been the case (Pritchard 1989, Reed et al. 2002), and the degree to which the turtle has recovered since coming under state protection is not known. Survey work in Alabama would provide important information regarding the need for federally listing this species, or implementing other conservation measures through watershed plans or at the state level. Objective of this study is to obtain and update information on the status of the alligator snapping turtle mainly in the Mobile Bay Basin of Alabama.

Data collected from this study was compared to data collected in 1995-96, 2004-2005 and 2008-2014 on alligator snapping turtles collected from the Coosa, Tallapoosa, lower Tombigbee,

Mobile-Tensaw Delta, and rivers associated with Mobile Bay plus the Conecuh River although outside the Mobile Bay drainage basin. Eighteen sites were sampled from 1995 to 2019. Four were resampled during the 2018-2019 period, Fowl River, Magnolia River, Tallapoosa River, and Conecuh River. Figure 1 displays the distribution of sites sampled for alligator snapping turtles.

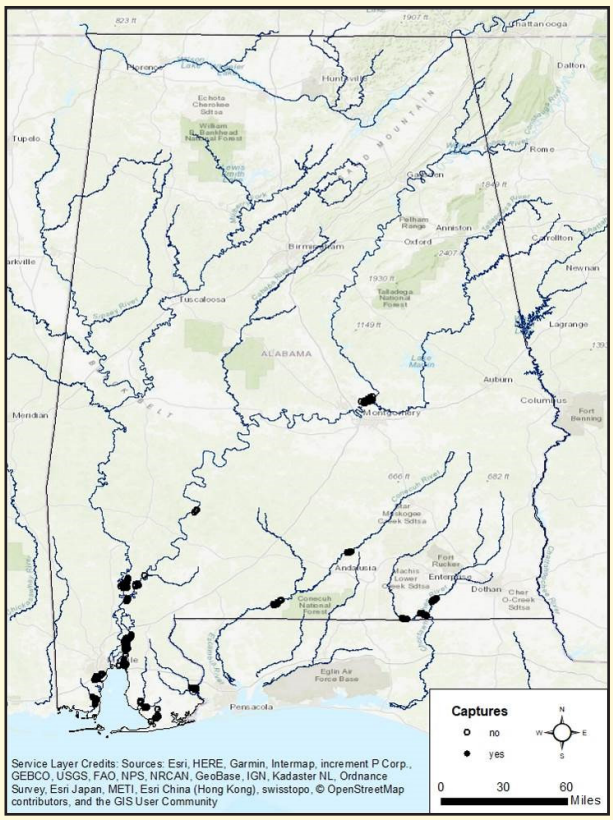


Figure 1. Distribution of rivers sampled for alligator snapping turtles 1995-2019.

River stretches or tributaries sampled were selected based on available distributional records contained within the database of the Alabama Natural Heritage Program or where alligator snapping turtles were known to occur during prior research on other turtle species. At each sampling site large hoop nets were set in shallow waters, with the top of the net exposed to air to avoid the drowning of captured turtles. During the 1995 to 2005 sampling period, traps consisted of four fiberglass hoops covered with nylon netting with a mesh size of 10 cm x 5 cm, and dimensional measurements as follows: diameter 122 cm, funnel length 75 cm with an inner throat diameter of 35 cm, body length 240 cm, and total length 300 cm. In 2018-2019 in riverine channel settings a single hoop net, 1.2 m (4 ft) in diameter and double-throated (i.e. with a pair of funnels) and 4.3 m (14 ft) in length, was used .

During the 2008 to 2019 sampling period trap methodology varied depending on site. In Mobile Bay drainage sites hoop nets with lead lines (trammels) were used for trapping turtles; this is the most effective technique for large herbivorous aquatic turtles which respond poorly to baited traps. The intervening lead net functions as a drift fence to intercept and direct turtles into the hoop nets. Hoop nets were 1.2 m (4 ft) in diameter and double-throated (i.e. with a pair of funnels) and 4.3 m (14 ft) in length. A single 3 gallon plastic jug was placed in the rear of each hoop net to provide flotation and prevent drowning of turtles. Two hoop nets were set with an intervening lead net such that the openings of the nets were facing. Lead nets were 1.2 m (4 ft) in height and 13.7 m (45 ft) in length. Nets were anchored with PVC tubing driven into the soft mud substrate. PVC poles were 3.8 cm (1.5 in) in diameter and 3.1 m (10 ft) in length. Four poles were needed for one hoop net set of two nets plus the lead net. One pole anchored the hoop opening with a second pole anchoring the tail of the net, with this arrangement repeated at the other hoop net.

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Traps were baited with fresh fish (i.e. frozen catfish nuggets, frozen whole gutted Tilapia, or frozen fish and entrails) as fish has been shown to be preferred bait (Jensen 1998) except with the double trap-lead net set. For each sampling period 8 to 12 nets were set from one to four nights with locational data collected for each trap set. Trap data was compared on a trap-night basis as an index to abundance. Trap sites were selected based on water depth, flow conditions, and downstream proximity of suitable-appearing structural features of the habitat. Traps were tied to a stout anchor, such as a tree trunk or thick limb, with the opening of the net facing downstream.

Macrochelys uses underwater structures such as downed trees, snags, and undercut banks, and trap sites were selected whereby the trap would be positioned just upstream of such submerged features. A plastic bottle (approximately 0.5 l in volume), with numerous holes cut in it, containing the bait was tied to the rear and center of the trap. Preferable flow conditions were those in which some flow was present but not excessive. With too strong a flow the lower end of the net, with the funnel, will float off the bottom, even with a 4.5 kg weight tied to the funnel end.

Measurements for each captured alligator snapping turtle included, weight (kg), straight line carapace length at the midline and maximum carapace length, maximum plastral length, maximum plastral width, carapace width and body depth at the 2nd and 3rd vertebral suture. Two tail measurements were made, one from the posterior edge of the plastron to the vent and a total length from the posterior edge of the plastron to the tip. Each captured turtle was uniquely marked to facilitate identification if recaptured. Using a portable drill with a 1/8" drill bit, a hole was drilled in one or more of the marginal scutes, and a Phillips pan head stainless steel screw (#10 x ½") was then secured in the hole.

Trap-night totals across the sites ranged from 8 to 570 for a total of 1873 throughout the study period. Alligator snapping turtles trapped by site ranged from 0 to 42 for a total of 141 throughout the study period. Catch per unit effort (CPUE) rates (number of turtles/trap-night) ranged from 0 to 0.30. The highest CPUE was in the Fowl River (2019) at 0.30 with the lowest CPUE in the Tensaw Delta (2008-11) at 0.02, but trap sets in the Tensaw Delta were placed to target Alabama red-bellied turtles (*Pseudemys alabamensis*) with any alligator snapping turtle captures being incidental. In a study in Georgia (Jensen and Birkhead 2003) the overall capture rate in which 55 *M. temminckii* were trapped over 281 trap-nights was 0.20, while in Arkansas (Trauth et al. 1998) the overall rate was 0.28 (98 turtles and 352 trap-nights). State CPUE average for Alabama was 0.15 for the 14 river and time period samples in which CPUE exceeded 0.

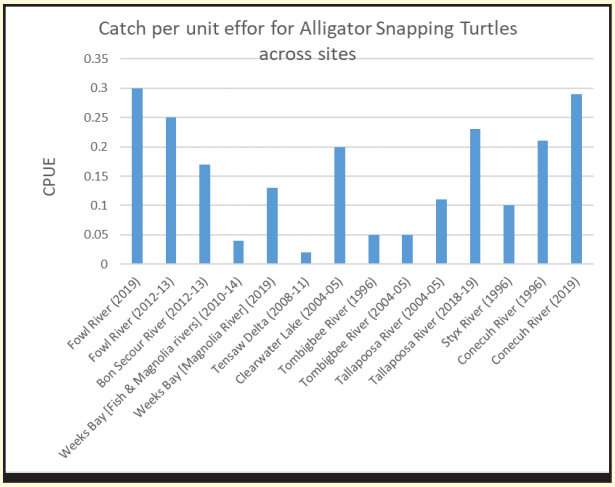

Figure 2. Catch per unit effort for Alligator Snapping Turtles across sites.

Jensen and Birkhead (2003), for Georgia turtles, reported a mean weight of 18 kg with a range from 1 to 46 kg. This is comparable to the overall weights of the Alabama turtles in which the mean was 20.5 kg with a range from 0.6 to 51 kg. Similar data are not available from the Arkansas study (Trauth et al. 1998). A grouping of turtles by weight category demonstrates that the majority of captured turtles fell within the 10 to 20 kg and 20 to 30 kg categories (Figure 3). Represented within this category would primarily be females. Lower weight categories of 1 to 5, and > 5 to 10 would include immature turtles. The higher weight categories were composed of larger females and males. The category of >30 category was predominantly male.

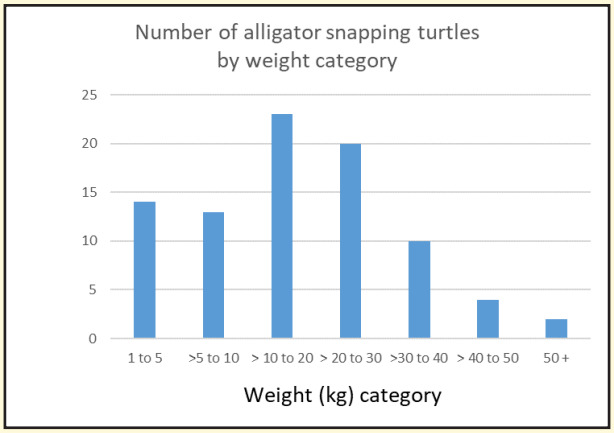

Figure 3. Weight categories of alligator snapping turtles, with all sites pooled.

Male average weight was 36.2 kg, female average weight was 19.9 kg, and immature average weight was 5.5 kg. These average weight distributions are shown in Figure 4. Female weight tends to reach a plateau of approximately 30 kg because the energetic needs of egg production outweigh those of mass increase and body growth. Conversely males tend to continue growth after maturity has been attained. Size is an advantage to males as they engage in male-to-male sparring over females.

Criteria for determining the age class and sex of individuals followed procedures used by Dobie (1971) and Trauth et al. (1998). Dobie (1971) found that the preanal tail length for mature males ranged from 115 to 266 mm, and for mature females from 48 to 114 mm. The minimum mature size of males was 370 mm carapace length and for females was 330 mm carapace length. Pooled data for preanal tail length (PTL) and total tail length for male and female turtles clearly shows that the preanal length for males was greater than that for females and was the one character best used in determining the sex of individuals. In general a preanal tail length of 11 cm is used as the division between males and females, males having a length exceeding 11 cm. Trauth et al. (1998) used a carapace length/preanal tail length (CL/PTL) ratio in sexing individuals. Males tended to have a ratio < 3.5, while females and immatures had ratios > 3.5. In the current study, using this ratio the sex identifications made in the field conformed well to these categories.

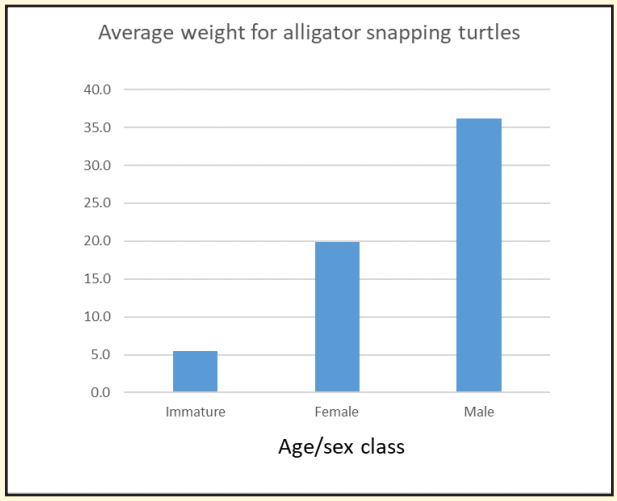

Figure 4. Average weights of alligator snapping turtles by age/sex category, with sites pooled.

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Studies in other states (Arkansas, Trauth et al. 1998; Georgia, Jensen 2003) report sex ratios close to 1:1. Results during this study differ in that the overall ratio was approximately a 1.7:1 ratio favoring females (Table 4). The ratio of adult to immature individuals was 2:1. In Georgia the ratio of adult to immature was 4:1 which differed significantly from the Alabama ratio.

Six turtles were recaptured in the Tallapoosa River, four females and one male, and one immature. Intervening time between capture and recapture events ranged from one day to 5,350 days. Two female turtles first captured in 2004 were recaptured in 2018-19 with the intervening interval of 14+ years. One female from the Magnolia River was first captured in 2011 and recaptured in 2019, a time span of 8 years. A male in the Bon Secour River was recaptured twice in 2013 after being first captured in 2012. Distance between capture and recapture localities ranged from 100 m to 1800 m. Insufficient recaptures were obtained to draw any conclusions regarding movement differences based on sex or age class (Table 6).

Harrel and Allen (1996) studied movement in subadult *M. temminckii* in Louisiana. Subadult females in their study moved significantly shorter distances than subadult males (160.3 m vs. 352.2 m). In the Louisiana study turtles were fitted with radio transmitters and tracked, therefore their movements could be followed quite closely with exact locations pinpointed. In the Tallapoosa, Magnolia, and Bon Secour rivers trap sites were set at a variety of locations; thus recaptures would not identically conform to absolute turtle movements. Results from a movement study in northeastern Arkansas show that turtles move from 110 to nearly 1800 m (Trauth et al. 1998), with the average distance traveled being 191 m. In both the Arkansas and Louisiana studies, turtle movement was found to be both up and downstream. Insufficient data were obtained in this study to draw any definitive conclusions regarding movement.

The alligator snapping turtle is the largest freshwater turtle in North America yet a cryptic species due to its highly aquatic biology. While the presence of the species within river systems may be documented through incidental observation, to collect data focused trapping is needed. During these studies sixteen rivers were trapped with alligator snapping turtles being captured in 10, although records from other sources document the turtle's occurrence in an additional four river systems. Lack of documentation from trapping during these studies may be attributable to lack of experience in the early years, timing of trapping, or lack of suitable trap sites in river sections surveyed. The apparent absence of the alligator snapping turtle in the Choctawhatchee and Pea rivers may be due to the above listed reasons or an actual low density of alligator snapping turtles.

Habitat protection and education are the best approaches to alligator snapping turtle conservation. While expansive tracts of optimum habitat are protected within the Mobile-Tensaw Delta, this is only a small percentage of the occupied range of the turtle within the Mobile Basin, and there are no other landscapes of comparable size and protective status within the Basin. Throughout the Mobile Basin take still occurs, whether incidental or purposeful. Habitat protection is one major step in the overall conservation of the alligator snapping turtle. Other processes critical to long-term protection of the alligator snapping turtle include education and enforcement of regulations.

For example, regarding education, large individuals when encountered, are often captured and presented as a novelty in the local paper, or taken to the local zoo; instead these individuals should be left in the wild or released at the point of capture. Removal of adult individuals from the population is the equivalent of death as they may no longer contribute reproductively. Regarding enforcement and from the standpoint of turtle conservation in general, Burke et al. (2000) have recommended the inclusion of an identification tag on trotlines which would allow wildlife personnel to confiscate and fine (if regulations allow) owners of under-checked or abandoned trotlines. This is a measure that could be implemented in Alabama to the benefit of fish and other turtles.

The alligator snapping turtle was given a P2 status during the Amphibian and Reptile Technical Team Review in the first State Wildlife Action Plan (Soehren and Godwin 2004). The turtle's status was revised to P3 during the Amphibian and Reptile Technical Team Review of the second revision of the SWAP (Shelton-Nix 2017). The downward ranking is supported with the data collected during this study that indicates stability of the species in Alabama. Where data have been collected the status of the alligator snapping turtle appears stable, and new populations have been discovered outside of this study by other researchers, i.e. Cahaba River in Birmingham during the Urban Turtle Project, yet maintaining protective status through non-regulation is prudent due to the collectability of this species.

Status Assessment of Harper's Ginger (*Hexastylis speciosa*)

Harper's ginger is a narrowly restricted species endemic to a three-county region in central Alabama. The plant is a low-growing perennial herb that was first brought to the attention of the scientific community by Roland Harper in 1924, from specimens collected in Autauga County. Because of a low number of occurrences (less than 10) and an unknown status, the U.S. Fish and Wildlife Service has contracted with the AUMNH/ALNHP to gather data related to the biology of the species and to assess conservation needs. A final report was submitted in December 2020, highlighting the range-wide status for a total of 16 known occurrences.

Harper's Ginger *Hexastylis speciosa*

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Escambia Map Turtle

There are more than 400 "at-risk" species in the southeast US currently petitioned for federal listing under the Endangered Species Act (ESA). Both Alabama and Florida contain more of these at-risk species than any other southeastern US state (NatureServe Central Databases January 2012). In response to a mega-petition filed by the Center for Biological Diversity to evaluate the need for listing of these approximate 400 aquatic species, the USFWS Southeast Region has implemented an at-risk species conservation strategy to work proactively with public and private partners to conserve these species over the next decade with the goal to preclude the need to list these species under the ESA (http://www.fws.gov/southeast/candidateconservation/). One of the thirteen reptile species in the petition is the Escambia map turtle (*Graptemys ernsti*). The Escambia map turtle is found only in Alabama and Florida in the Conecuh-Escambia, Yellow, and Choctawhatchee-Pea rivers (Lovich et al. 2011; Lindeman 2013; Godwin et al. 2014; Ennen et al. 2016). Conducting species status surveys prior to listing is more cost effective than conducting status surveys as a component of the listing or recovery process. In addition, these prior surveys may reveal a relatively secure status, thus preclude listing.

Current information on the status of the Escambia map turtle in Alabama and Florida is limited (Lindeman 2013); it is a SWAP Priority 2 (Godwin 2017) species thus up-to-date information is needed for ADCNR in formulating conservation strategies for this species and for the USFWS decision regarding listing. The objective of the study is to obtain information on the current distribution and abundance of the Escambia map turtle (*Graptemys ernsti*) in Alabama and assess the conservation status of the species.

Map turtles as a group are noted for their drainage-specific endemism (Lovich and McCoy, 1992) and well-developed basking behavior (Shealy 1976). Data on basking map turtles is easily gathered with visual survey methods. Suitable riverine stretches, those with an abundance of dead wood for basking (Lindeman, 1998, 1999), were previously sampled in 2000 and 2002 with supplemental data collected in 2012 (Godwin et. al. 2014). Data on turtles was collected through basking surveys by identifying turtles; all individuals seen were identified to species, and when possible, sex, and age class. Distinguishing sexual characters between male and female include 1) females achieving a much larger size, 285 mm carapace length, males ca. 170 mm carapace length; 2) females with conspicuously large head; 3) males with long and enlarged tail (Lovich et. al. 2011).

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Basking turtles of large size and enlarged head were categorized as "female," turtles of smaller size with noticeably large tail were categorized as "male," turtles without distinguishable characters were categorized as "unclassifiable," these individuals may have immature female, immature male, or adult male in which the tail could not be observed. Data was recorded per river kilometer, date, and river stretch to allow for a metric of turtles/river kilometer to be calculated for each sampling session.

In this study, selected river stretches in the Conecuh River from the 2000 surveys were re-surveyed, additionally sections not surveyed in 2000 were included in 2018 and 2019. Surveys were conducted from either canoe or a 14' flat bottom boat equipped with 25 hp outboard motor. Water depth was the primary determinant in the mode of transportation. Use of a motorized boat allowed both up- and downstream surveys while a canoe permits only downstream surveys. Image stabilization binoculars were used to spot, identify, and sex basking turtles. Survey end points and survey length were recorded with a GPS. In smaller rivers, those with channel width of less than 75 m, both banks could be scanned for turtles. In large river channels, over 75 m wide, only one bank per survey effort could be sampled effectively.

During 2019, surveys were conducted in the Conecuh, Sepulga, Yellow, and Pea rivers with turtle count data from these surveys added to the 2018 data and compared to the 2000-2002 data. Total river sections surveyed in 2000, 2002, 2018, and 2019 are presented in Figure 1.

In 2000-02 the highest average number of basking *G. ernsti* observed was in the Conecuh River, followed by the Sepulga, Pea, and Yellow rivers. In 2018-19 the

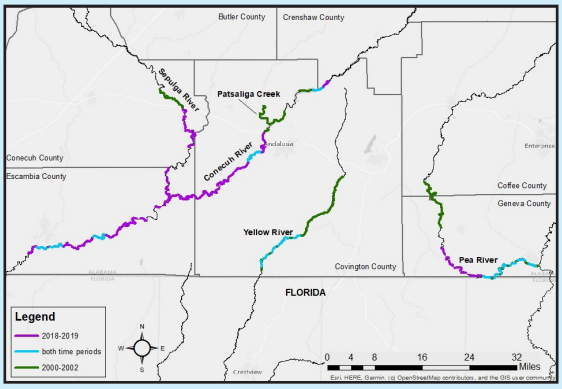

Figure 1. Surveyed river reaches.

highest average number of basking *G. ernsti* observed was in the Pea River, followed by the Conecuh, Sepulga, and Yellow rivers (Figure 2). Average observed number of basking Escambia map turtles on the Conecuh River declined between 2000-02 and 2018-19 from 11.3 to 6.3. Average observed number of basking Escambia map turtles increased on the Pea River from 0.75 in 2000-02 to 9.38 in 2018-19. Average observed number of basking Escambia map turtles on the Sepulga River had a small decline between 2000-02 and 2018-19 from 1.78 to 1.11; whereas the average on the Yellow River had an increase from 0.66 to 1.7.

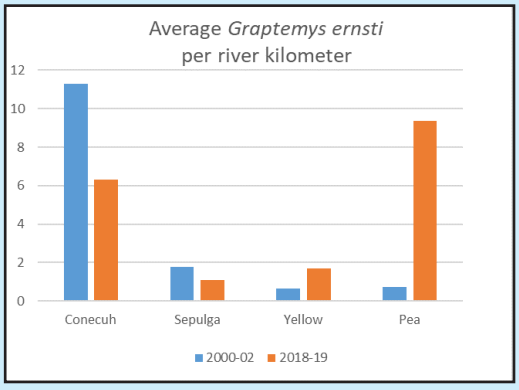

Figure 2. Average number of basking Escambia map turtles (*Graptemys ernsti*) observed by river during each survey period.

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During each survey period the adult female age class was the most observed on the Conecuh River. In the Sepulga and Yellow rivers for both survey periods adult female turtles and those of the unknown category were observed almost equally. During the 2000-02 survey period adult female turtles were most often observed, but during the 2018-19 survey period the turtles in the unknown category were most often observed.

During 2000-02 basking data was collected on four species of turtles with the Escambia map turtle the most abundantly observed species. Two additional species were added to the basking turtle list during the 2018-19 period with the Escambia map turtle again observations being the most numerous. In total 2021 Escambia map turtles have been counted with the river cooter (P*seudemys concinna*) being the second most observed species with a cumulative count of 489.

During both survey periods the Escambia map turtle *G. ernsti* was the most commonly seen species basking. Overall average number of Escambia map turtles per river kilometer in 2000-02 was 1.85 while in 2018-19 the number was 5.62. This difference could be attributed to seasonal variation and changing river conditions. During each survey period and each river sampled the Escambia map turtle was consistently the most observed species basking indicating that while the Escambia map turtle has a narrow distribution of occurrence in the three rivers of occurrence the species is locally abundant.

This project is being funded by the Alabama Department of Conservation and Natural Resources.

Eastern Hellbender

The Eastern Hellbender (*Cryptobranchus alleganiensis*) is one of the largest salamanders of North America and in Alabama occurs only in the Tennessee River system. Ideal habitat for this aquatic salamander is clear flowing streams with an abundance of slab rock and boulders over a substrate of clean gravel. Stream channelization, impoundment, and alteration of riparian habitats have degraded aquatic conditions resulting in increased water temperatures, sedimentation, and siltation, consequently leading to suspected declines in hellbender populations. Historical hellbender records include 11 localities in Franklin, Colbert, Lauderdale, Limestone, Madison, and Morgan counties. The earliest Alabama record is from the 1920s with records peaking in the 1960s and 1970s. The decline of records through the 1980s to the present support the need for renewed survey effort in Alabama.

Standard sampling techniques for the Eastern Hellbender include trapping and visual searches while wading or snorkeling. These methods can be effective in the capture of hellbenders but may be affected by limited access to sites, efficacy due to water level and clarity, and trap security. A newer survey technique commonly known as environmental DNA (eDNA) has become widely used for detecting aquatic species yet yields only presence data. Success with this technique for the hellbender has been demonstrated in Missouri, Indiana, Kentucky, and North Carolina. Environmental DNA can be used to complement standard sampling or can be employed as the sole survey method at sites where standard sampling is constrained. In this study we are surveying historic and other localities for the presence of the Eastern Hellbender using standard sampling techniques and eDNA.

Eleven streams in nine counties were sampled and positive eDNA detections resulted from five streams. Although Eastern Hellbenders have been collected in February-December in Alabama, field work is typically conducted in May-October with most effort occurring in August and September to coincide with the breeding period to increase our probability of positive eDNA detection. Water samples for eDNA analysis were processed and analyzed in the lab of Dr. Eric Larson, University of Illinois Urbana-Champaign.

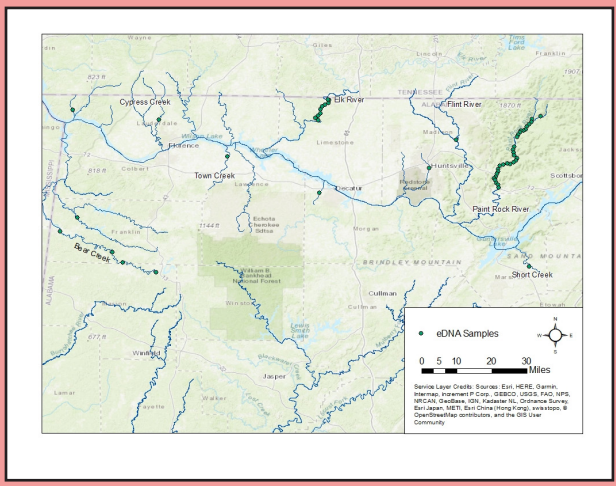

Figure 1. Distribution of Alabama eDNA collection sites in 2019.

Substrate habitat data was collected in 12 stream sections across the range of the hellbender in Alabama. Data categories included substrate type and particle size ranging from 2.8 mm to >2 m. Ten transverse samples across the stream channel were taken at each sampling station. Distribution of substrate habitat sample sites is presented in Figure 2.

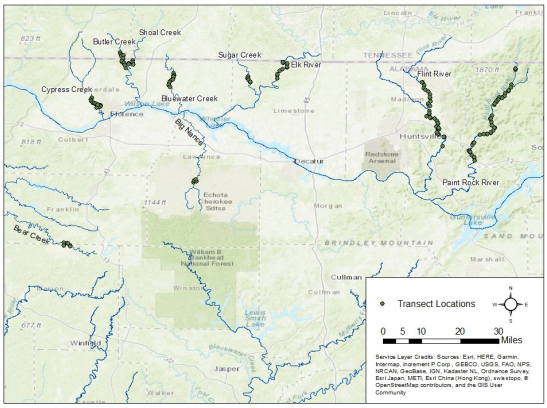

Figure 2.Distribution of sites sampled for substrate habitat conditions in Alabama during 2019.

Conventional sampling methodology of wading and snorkeling sites with lifting or searching under rocks for hellbenders was employed in 15 streams with a total of 111 sample points and cumulative time of 105 person-hours. In general, limited visibility due to turbid waters from widespread siltation and sedimentation affected conventional sampling effectiveness. No hellbenders were observed and only one mudpuppy (*Necturus maculosus*) was captured (Butler Creek); the limited observations of mudpuppies is additional indication of widespread degraded water quality. Distribution of sites conventionally sampled for hellbenders is presented in Figure 3.

Graham et.al. (2011) failed to detect

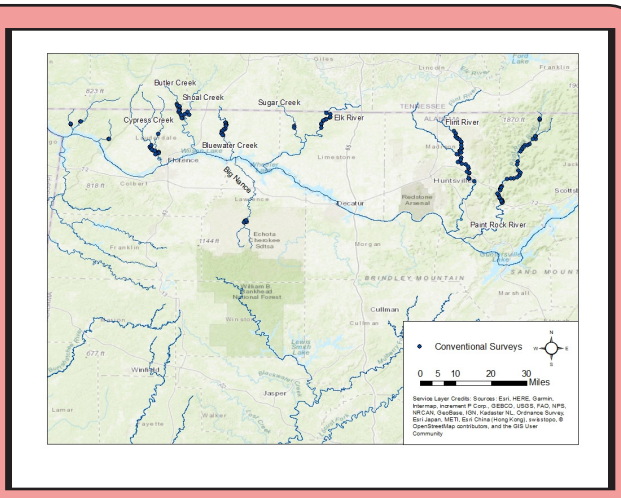

Figure 3. Distribution of sites conventionally sampled for hellbenders in Alabama during 2019.

hellbenders during their survey efforts and concluded that the hellbender may still occur in the state in low numbers and may be facing extirpation. The low numbers of recent hellbender reports tend to support their conclusion, with only one record each in 2014, 2015, and 2016, the recent 2018, plus a 2013 observation from the Flint River. Suitable habitat remains in many of the streams of the Tennessee River basin but siltation is pervasive. Positive eDNA detections in 2015, 2016, 2017, 2018, and 2019 suggest that hellbenders continue to occupy streams of historic record, and the eDNA results suggest the Eastern Hellbender may occur in streams from which the species has not been reported.

Hellbenders photographed in 2013, collected in 2014, 2015, and 2018 and observed in 2016 were all adults. Viability of populations of these hellbenders cannot be determined based on these individual reports and captures. Although eDNA detections suggest more widespread distribution in occupied streams, the eDNA cannot return results on population viability, density, sex ratio, or other

population parameters needed to adequately assess the status of populations of the hellbender. Habitat restoration through improvements in water quality are needed for the hellbender's survival in Alabama and additional studies on occupancy modeling of landscape parameters are needed to guide land-and-stream use conservation efforts.

Watershed conservation and restoration for the improvement of water quality is critical to the survival of the Eastern Hellbender. The Tennessee River basin supports 115 aquatic species of greatest conservation need (SGCN), or approximately 1/3 of the total of SGCN in Alabama. Land use actions to promote improved water quality for the Eastern Hellbender would confer benefits to other aquatic species, thus the Eastern Hellbender could serve as an umbrella species for Tennessee River basin watershed conservation and restoration. Strategic Habitat Units (SHU) (http://alh2o.org/shus/) are watersheds and river segments that have been selected as a focus of conservation actions for restoration and recovery of rare aquatic species. SHU selection is based on the presence of rare fishes, mussels, snails, and crayfishes plus stable geomorphology, stream flow regimes that support normal biologies of aquatic species, acceptable water-quality conditions, diversity of channel substrate types, and few to no competitive of predaceous nonnative species. Tennessee River basin in Alabama contains 10 SHUs, the eastern hellbender is known or suspected in six SHUs and sampling and survey actions are being implemented in each of the SHUs that may support hellbenders (http://www.alh2o.org/uploadedFiles/SM248B.pdf).

This project is funded by the Alabama Department of Conservation and Natural Resources.

Status Assessment of Wherry's Phlox (*Phlox pulchra*)

Wherry's phlox is a globally imperiled species currently known from five occurrences worldwide, distributed across four counties in central Alabama. The plant is endemic to the state, likely occurring historically in forest openings maintained by stochastic events and periodic fire. An herbaceous evergreen perennial, the species was described in 1929 by Edgar Wherry from plants he collected near Oakman in Walker County. Because of a low number of historical and extant occurrences, the U.S. Fish and Wildlife Service commissioned the AUMNH/ALNHP to gather data related to the biology of the species and to assess conservation needs. A final report was completed in December 2020.

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Eastern Indigo Snake

The Eastern Indigo Snake was once an important species, and apex predator, of the longleaf pine ecosystem of south Alabama; it is now presumed extirpated from the state with the exception of the released snakes in Conecuh National Forest. The return of the Eastern Indigo Snake as an ecological element of the longleaf pine and associated ecosystems of southern Alabama is being done through a reintroduction of the species. Captive breeding is the most efficient route to acquire the number of young snakes needed for this endeavor, and a concerted release effort at one site is in progress for the establishment of a viable population.

Conecuh National Forest (CNF) is situated within the historic range of the Eastern Indigo Snake and has been selected as the initial reintroduction site for several reasons: (1) the U.S. Forest Service has undertaken a progressive longleaf restoration project; (2) CNF possesses the habitat heterogeneity needed for Eastern Indigo Snakes, which includes the presence of gopher tortoises; (3) and CNF is well placed in the GCPEP Apalachicola-Blackwater River State Forest-Conecuh National Forest-Eglin Air Force Base corridor.

Our objective is to establish a self-sustaining population of Eastern Indigo Snakes at Conecuh National Forest by introducing 30 snakes/year to reach 300 snakes released.

All snakes released into Conecuh National Forest will be the offspring of captive snakes maintained at the Orianne Center for Indigo Conservation. Snakes have been raised in captivity for at least 21 months prior to release, this relatively large size reduces their risk to natural predators. We will follow the general framework for releases that was established at the beginning of the project.

Fifteen snakes were released in Conecuh National Forest on 25 April 2019. Sex ratio of released snakes was almost equal with seven males and eight females. All snakes were hatched in 2017, thus approximately 1 2/3 years old. All female snakes had been housed at the Welaka National Fish Hatchery (WNFH) during the previous year, two male snakes were reared at the OCIC, and the remaining five male snakes had been reared at Zoo Tampa over the previous year. All snakes were captive hatched at OCIC and held until approximately one year of age before transport to either WNFH or ZT for housing. Snakes were released at or in natural refugia, i.e. gopher tortoise burrow.

Male snout-vent lengths (SVL) ranged from 991 to 1198 mm with an average of 1102 mm. Female SVLs ranged from 1035 to 1190 mm with an average of 1092 mm. Male mass ranged from 348 to 818 g with an average of 572 g. Female mass ranged from 575 to 812 with an

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average of 727 g.

To assess survivorship, sex ratio, and, ultimately, demographics of the population of Eastern Indigo Snakes we are conducting pedestrian surveys for indigo snakes and sampling vertebrate assemblages (amphibian, reptile, bird, small mammal) with drift fence arrays.

Eighteen drift fence arrays were open from 30 January to 1 November to trap Eastern Indigo Snakes. Drift fence traps were operational for a total of 161 out of a potential of 275 days, or 59% of time available. Each of the traps were operational for a total of 161 days and closed for 46 days this yielded a total of 2,898 trap-days (18 traps * 161 days). While Eastern Indigo Snakes (3 total) were captured in drift fences the result was quite low, 0.001 per trap-day, but this provided data on growth and movement that otherwise would have been lacking.

Three Eastern Indigo Snakes were captured in traps, one female and two males. Female was recaptured on 24 October 2019, in trap TB about 1.3 km north of her release point. One male was recaptured in trap CC, on 11 June 2019, about 1 km NW of his release point. Both of these snakes were born in 2016 and released May 2018 at Nellie Pond.

A second male was recaptured in trap SR on 23 July 2019. This snake, a male, was previously recaptured during pedestrian survey on 7 February 2019. On scanning the snake no PIT tag was detected and we assume, based on the adult size of the male snake, that this individual was captive reared and released and the PIT tag was expelled. This snake was re-implanted with a PIT tag and recaptured in trap SR on 23 July 2019. His recapture at trap SR was 1.5 km NE of his capture point from February.

Thirteen species of snakes were captured in drift fences. Eastern Indigo Snakes were captured at a higher frequency than five of the 13 species (Table 1).

Standardized visual searches were conducted between 13 January and 7 May at 22 discrete sites. Sites were sampled from one to 47 times for a total of 371 surveys and 311.57 man-hours (Table 2). Site selection was either the original release site, Nellie Pond release site, or clusters of gopher tortoise burrows. With each survey location, date, time, observer(s), refuge type, and evidence of activity was recorded. The type of refuge (tortoise burrow, armadillo burrow, or stump hole) encountered was tallied. Snake evidence categories were snake, snake track on a tortoise burrow apron, or shed skin. Eastern Indigo Snakes were observed 28 times, all at Nellie Pond. Other snake species observed were Black Racer (*Coluber constrictor*), Eastern Coachwhip (*Coluber flagellum*), *Crotalus adamanteus*, Gray Ratsnake (P*antherophis obsoletus*), Southeastern Crowned Snake (*Tantilla coronata*), and Eastern Ribbonsnake (*Thamnophis sauritus*). All snakes encountered were captured, identified, and measured.

Eight indigo snakes were recaptured for a total of 14 recapture events. Sex ratio was evenly split and all snakes recaptured were from the 2018 release. Three snakes were recaptured once, four snakes recaptured twice, and one snake recaptured three times. Number of intervening days between capture-recapture events ranged from 2 to 579.

Snakes when recaptured were scanned for a PIT tag, weighed, and measured.

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Table 1. Drift fence snake captures from 30 January to 1 November 2019.

Species	Total captured	CPUE	Relative frequency
Black Racer (*Coluber constrictor*)	44	0.0152	0.404
Copperhead (*Agkistodon contortix*)	18	0.0062	0.165
Eastern Coachwhip (*Coluber flagellum*)	17	0.0059	0.156
Gray Ratsnake (*Pantherophis obsoletus*)	7	0.0024	0.064
Red Cornsnake (*Pantherophis guttatus*)	5	0.0017	0.046
Banded Watersnake (*Nerodia fasciata*)	4	0.0014	0.037
Florida Pinesnake (*Melanoleucus lodingi*)	4	0.0014	0.037
Eastern Indigo Snake (*Drymarchon couperi*)	3	0.0010	0.028
Florida Cottnmouth (*Agkistrodon piscivorous*)	2	0.0007	0.018
Eastern Diamond-backed Rattlesnake (*Crotalus adamanteus*)	2	0.0007	0.018
Eastern Hog-nosed Snake (*Heterodon platirhinos*)	1	0.0003	0.009
Eastern Gartersnake (*Thamnophis sirtalis*)	1	0.0003	0.009
Eastern Ribbonsnake (*Thamnophis sauritus*)	1	0.0003	0.009

Male snakes had an average growth rate of 1.48 g/day and female snakes 0.80 g/day. Male snakes had an average growth rate of 0.82 mm/day for SVL and female snakes an average growth rate of 0.66 mm/day. The average distance between capture points for male snakes was 0.345 km and for female snakes 0.280 km.

We are also testing for changes in prey communities (amphibian, reptile, small mammal) between sites with and without Eastern Indigo Snakes to document the effect upon the prey base by the introduction of the Eastern Indigo Snake.

Eighteen drift fence arrays were open from 30 January to 1 November to trap prey species of Eastern Indigo Snakes with an emphasis on snakes. Eleven species of frogs and toads, two species of salamanders, five species of lizards, 13 species of snakes, nine species of birds, and, and eight species of mammals were captured.

This project is funded with a State Wildlife Grant through the Alabama Department of Conservation and Natural Resources

Gopher Frog Environmental DNA (eDNA) Survey at Arnold Air Force Base

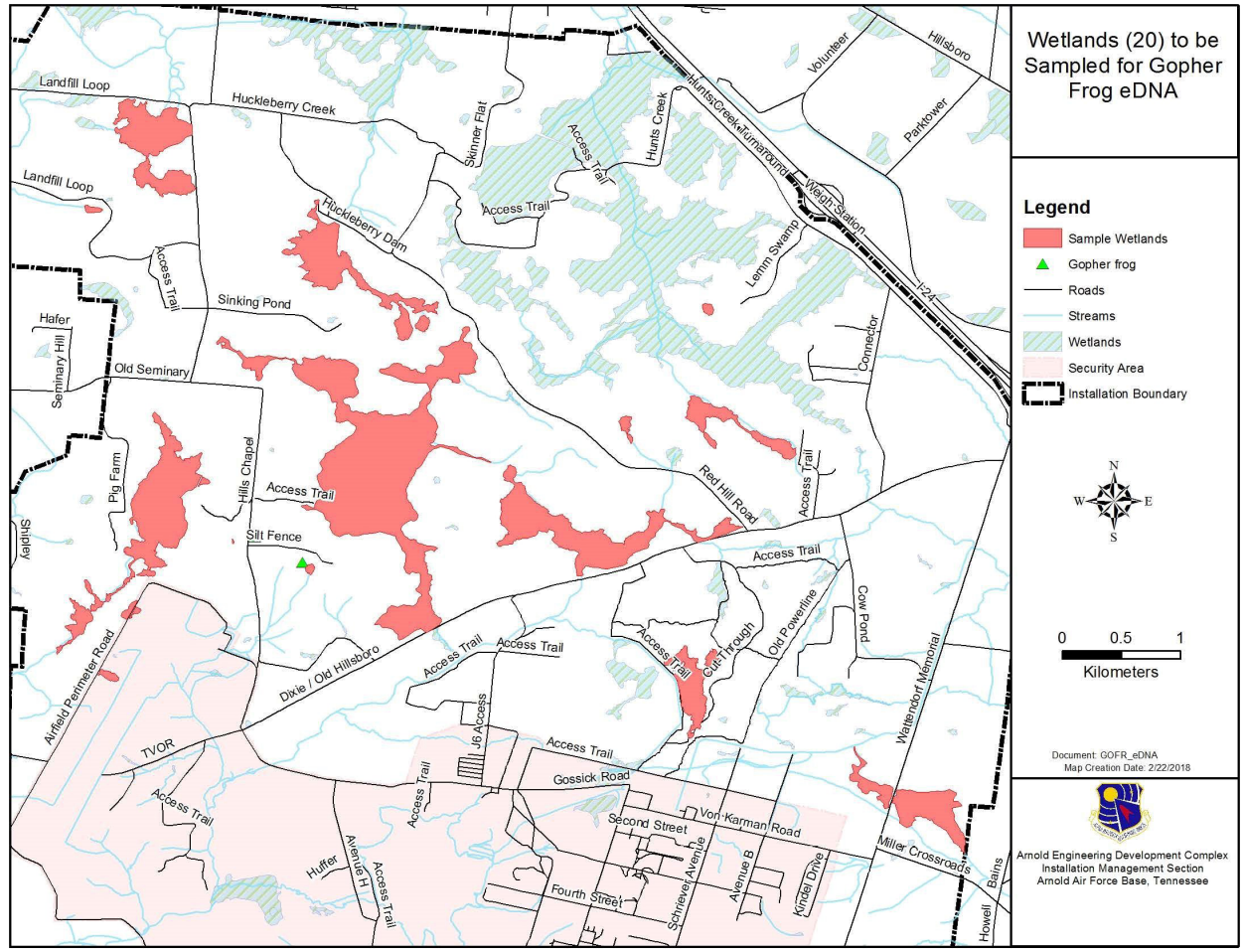
The gopher frog (*Lithobates capito*), formerly *Rana capito*, is under review for listing by the U.S. Fish and Wildlife Service. Primarily an inhabitant of the Coastal Plain, the gopher frog is a winter breeding species using ephemeral ponds that typically dry during summer months and fill with fall and winter rains. Metamorphic frogs exit ponds in early summer. Outside of the Coastal Plain, one historic population was documented in the Ridge and Valley of Alabama plus a second approximately 100 km north at Arnold Air Force Base (AFB) in Tennessee. The presence of the gopher frog at Arnold AFB is an anomaly, yet disjunct populations outside of the Coastal Plain have been reported, for example one in Shelby Co., AL. Two individuals, one a gravid female, were collected at Arnold AFB in the 1990s, yet no breeding ponds have been located despite intensive sampling efforts which have included night-time and automated aural surveys for calling males, egg mass and tadpole surveys, and drift fence trapping.

Environmental DNA (eDNA) is an effective detection tool for rare species that can be used when conventional sampling fails. In Conecuh National Forest in south Alabama eDNA has been used to detect gopher frogs at known and undocumented breeding sites. In the ponds at Arnold Air Force Base we will be using eDNA to sample for gopher frog presence. Approximately 20 wetlands on Arnold AFB have been identified as potential breeding sites for the gopher frog and from this list 12 have been selected as ponds to be sampled.

The gopher frog, if present, likely occurs in low density on Arnold AFB based on the collection of only two adult specimens, and presumably the adult breeding and tadpole developmental period is similar to that of other gopher frog populations from January to May. Sample collection during the activity period of the target species is critical to the detection of species with eDNA. We began water sample collections in December and continued through May when tadpoles were expected to be in the ponds and eDNA concentrations to be elevated. One hundred sixty-nine samples were collected over the winter and spring. All water samples were negative for gopher frog eDNA.

The second goal of this project is to determine which population the two gopher frogs captured from Arnold AFB in the late 1990s are nearest to genetically. Because these frogs have been preserved in formalin, new challenges must be overcome to successfully extract DNA from their tissues. Once that is done, we will compare the ultraconserved elements of the Arnold AFB gopher frogs to corresponding DNA segments from gopher frog tissues collected from southeastern US populations.

Photo by Kevin Enge



Map of 20 wetlands on Arnold Air Force Base in Tennessee that will be sampled for Gopher Frog eDNA

In this study we first attempted to extract DNA from specimens of related species, green frog and leopard, housed in the Auburn University Museum of Natural History. Frog specimens used had been deposited in the museum within the past 30 years. DNA was successfully extracted from tissues within a 10 and 20 year time interval. Based upon this success we proceeded to utilize tissues from the pair of gopher frogs from AFB and successfully extracted usable DNA samples from each. Our next step will be to genetically compare the AFB frogs to other populations.

This project is funded through the Department of Defense.

Mississippi Gopher Frog

The Mississippi gopher frog (*Lithobates (Rana) sevosa*), is currently known to have extant populations only in southeastern Mississippi, yet historically ranged from southern Louisiana to southwest Alabama. This gopher frog is a state protected Priority 1 species, federally endangered, and likely historically ranged into Alabama in Mobile and Washington counties (Mount 1975; Bailey and Means 2004). One recovery criterion is to have a metapopulation in eastern Mississippi or Alabama (USFWS 2015), therefore, surveys are needed to determine if extant populations of the Mississippi gopher frog are present in Alabama. If so, conservation and management actions should be implemented for the species. Objectives of the study are to perform a habitat modeling analysis to guide search efforts for potential pond and upland habitat and to survey ephemeral ponds in Mobile and Washington counties for the presence of the Mississippi gopher frog.

The Mississippi gopher frog is an inhabitant of longleaf pine sandhills ecosystem, often associated with the presence of the gopher tortoise, and breeds in fishless, isolated ponds. Potential ponds will be visited and surveyed for adults, calling males, and with eDNA. The use of GIS will be the first step to locate potential ponds. Potential ponds will likely be natural depression ponds surrounded with suitable gopher tortoise soils and/or known gopher tortoise localities. Once ponds are identified landowners will be contacted for permission to sample for the presence of the Mississippi gopher frog.

Surveys will be during the breeding period and done with visual surveys for adult frogs and egg masses. Ponds will be surveyed a minimum of two times with water samples being collected for an environmental DNA (eDNA) analysis

We conducted a preliminary species distribution model to identify potential Mississippi gopher frog breeding habitat in southwestern Alabama using the Maximum Entropy species distribution model algorithm. Our occurrence data consisted of 23 presence records of *Lithobates capito*, which we believe occupy nearly identical habitats to that of *Lithobates sevosus*. The presence records are all located in Covington and Escambia Counties, Alabama. The modeling extent was set to include the state of Alabama, below the Fall Line. Categorical environmental variable raster layers included 1) potential breeding ponds with 2km buffer, 2) karst formations, 3) suitable soils for gopher tortoise, and 4) priority soils for gopher tortoise. Continuous environmental variable raster layers included 1) distance to nearest potential breeding pond, 2) amount of East Gulf Coastal Plain longleaf with open understory habitat within a 10 cell radius (300m), 3) amount of developed land within a 100 cell radius (3km), 4) distance to nearest developed land, 5) amount of agriculture land within a 100 cell radius (3km), 6) distance to nearest agriculture land, 7) elevation, and 8) soil pH.

All spatial analyses were conducted in ArcGIS Pro 2.0.1 (Redlands, CA). Potential breeding ponds were extracted from the National Hydrography Dataset "waterbodies" shapefile using a multiple-step process. First, all reservoir features were removed along with all water bodies occurring within 200m of a

stream/river or those that were larger than 0.05km2. Next, the wetlands polygon feature class from the National Wetlands Inventory was used to identify the remaining waterbodies, and only semi-permanently, seasonally, temporarily, or intermittently flooded ponds were retained. This layer was then buffered and rasterized to create the potential breeding ponds with 2km buffer layer. It was also used as the input to create the distance to nearest potential breeding pond layer using the Euclidean distance tool in the Spatial Analyst toolbox.

A vector dataset generated by the US Geological Survey contains polygons where karst occurs. This layer was rasterized and pixels where karst occurs were given a value of 1 and pixels with no data were set to 0. Gopher frogs utilize gopher tortoise burrows as adults, therefore suitable and priority gopher tortoise soils were extracted from NRCS SSURGO data to create two categorical soils layers. The layers were then rasterized where the target soil pixels were given a value of 1 and all other pixels were set to 0. The GAP Land Cover Map of Ecological Systems for the State of Alabama (Kleiner et al. 2007) was used to derive land cover layers. East Gulf Coastal Plain longleaf (EGCF) with open understory, row crop and pasture, and developed land uses were extracted into three separate layers. The focal statistics tool was used to calculate the amount of each type of land use within the specified radius. The agriculture and developed land layers were also as the input to create the distance to each land use type using the Euclidean distance tool in the Spatial Analyst toolbox.

The National Elevation Dataset for Alabama with 30m resolution was used for the elevation layer. Mean soil pH between 5-15cm depth data were downloaded from POLARIS (Chaney et al. 2016). All datasets were masked to the model extent and assigned a consistent cell size (i.e. resolution) and geographic coordinate system. After all layers were masked to the modeling extent, they were converted into .asc format and loaded into the MaxEnt graphical user interface along with presence locations. Default settings were retained, and a logistic output format was selected.

The MaxEnt model identified habitats in Covington and Escambia counties with high gopher frog (*L. capito*) probability of occurrence (Figure 1) and failed to identify any habitats in Mobile County of moderate to high gopher frog probability.

Our initial species distribution model failed to identify any potential ponds in Mobile County for the Mississippi gopher frog. We will be revising this model for improved performance. This project was not fully approved until after the 2019 breeding and tadpole development periods thus no field work was conducted in 2019.

This project is funded through the Alabama Department of Conservation and Natural Resources

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Habitat Modeling and Site Verification for the White Fringeless Orchid in Alabama

The white fringeless orchid is one of many southern Appalachian plant species that are listed under the Endangered Species Act, for which suitable habitat is likely plentiful but remains unverified. The species assumes a relatively broad but sporadic distribution across the mountainous region of seven southeastern states. In Alabama, nine extant occurrences are known, all documented within the typical habitats reported for the species, which includes seepage wetlands generally associated with the origins of small streams and streamside seepage slopes. The plant was listed as a federally threatened species in October 2016 based on a small number of occurrences, a low reproductive capacity, and various threats that include habitat degradation (alteration, fragmentation, succession, and forest management practices) as well as direct damage to individual plants.

The objective of the project is intended to promote conservation of the white fringeless orchid in Alabama. The project will determine the rate of success in locating new occurrences of the species based on species occupancy models. The study will also focus on evaluating environmental conditions and assessing reproductive potential (e.g., census of reproductively active plants) in extant occurrences, thus enabling land managers and conservationists to prioritize sites for long-term protection.

The study is sponsored by ADCNR through Section 6 funding, and will be completed in December 2020.

Range-wide Status Assessment of Bog Spicebush

Bog spicebush (*Lindera subcoriacea*) is one of several southeastern Coastal Plain plant species that has become globally imperiled as an artifact of adverse modifications of its habitats: permanently moist to wet, shrub-dominated seepage wetlands embedded in a matrix of pine and mixed pine-hardwood uplands. The taxon is a clonal species currently represented by approximately 105 extant occurrences across seven southeastern states, several of which are small consisting of 1-5 genetic individuals. The small size of many occurrences, impending threats such as fire exclusion, and its inherently relatively narrow ecological niche serve as a testament to the dire conservation need the species now faces. This study is focusing on updating existing records for known occurrences across the range of the species to further assess threats that will enable land managers determine appropriate conservation strategies. A comprehensive field assessment of the species was completed in 2019, where surveys focused on visiting occurrences in the Carolinas and Georgia to acquire data population biology, habitat, threats, and landowner use. A final report will be completed and submitted to the U.S. Fish and Wildlife Service in early 2020.

Habitat Modeling and Site Verification for the Whorled Sunflower in Alabama

The whorled sunflower (*Helianthus verticillatus*) is one of many southeastern plant species that are listed under the Endangered Species Act, for which suitable habitat is likely plentiful but remains unverified. The species assumes a relatively broad but sporadic distribution across four southeastern states. In Alabama, two extant occurrences are known, both documented within the typical habitats reported for the species - wet, calcareous prairies and woodlands. The plant was listed as a federally threatened species in August 2014 based on a small number of occurrences and various threats that include habitat degradation (alteration, fragmentation, succession, and forest management practices), as well as direct damage to individual plants.

The objective of the project is intended to promote conservation of the whorled sunflower in Alabama. The project will determine the rate of success in locating new occurrences of the species based on species occupancy models. The study will also focus on evaluating environmental conditions and assessing reproductive potential (e.g., census of reproductively active plants) in extant occurrences, thus enabling land managers and conservationists to prioritize sites for long-term protection.

The study is sponsored by ADCNR through Section 6 funding, and will be completed in December 2020.

Noxious weed mapping and monitoring at Redstone Arsenal

The AUMNH/ALNHP entered into an agreement with Redstone Arsenal to undertake mapping and monitoring of invasive species on select sites within the installation beginning in late 2019. The project is focusing on three management objectives centered on eradication, containment, and suppression to assist resource managers in preparing successful treatment plans to control weed infestations. The study is designed to extend for a minimum of six years, where annual mapping and monitoring will be conducted to determine the extent invasive species invade new areas and the degree a given infestation expands or contracts. Invasive species monitoring specifically involves repetitive surveys to track weed populations over time, providing reliable information that can be compared year to year. A final report will be submitted at the end of each calendar year that summarizes results and subsequent treatment of targeted noxious weeds, emphasizing changes that were observed from previous years. The report will also provide species specific recommendations regarding treatments of infestations based on observations of monitoring, as well as findings of treatment efforts.

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Monitoring of Price's Potato-bean at Sauta Cave National Wildlife Refuge

Beginning in 2015 AUMNH/ALNHP entered into an agreement with the U.S. Fish and Wildlife Service to assist with recovery efforts of the Price's potato-bean (*Apios priceana*) at Sauta Cave National Wildlife Refuge (SCNWR) in north Alabama. The species was listed as federally threatened by the U.S. Fish and Wildlife Service (USFWS) in 1989, and is currently ranked as G3 by NatureServe suggesting it to be globally vulnerable. At the time of listing, the species had been collected from 21 sites in Alabama, Mississippi, Kentucky, Tennessee, and Illinois, with only 10 extant occurrences having been known and with 60% of those threatened by destruction. Since the discovery of the species on the refuge in August 2002, USFWS staff and Al Schotz had detected a marked decrease in reproduction and an overall decline in the vigor and number of plants. It was hypothesized that a high level of canopy closure was correlated to attrition of the species throughout the refuge. The amount of canopy closure in the area of plant disappearance has been observed numerous times during the

course of several years by USFWS staff and has shown a marked increase to nearly 100% coverage. Occurrences having the greatest vigor appear to be often associated with clearings in forests and along rights-of way, including roadsides and power lines. As of this study, it is unknown how much canopy opening is desirable to promote optimal growth and reproduction of Price's potato-bean.

This study was designed to span a five-year period in which canopy reduction efforts will be implemented to determine the ideal canopy cover necessary to promote and maintain optimal growth and reproduction of Price's potato-bean at SCNWR. It is anticipated the results of the project will have broader applications, serving as a resource guide as it relates to management across the range of the species. The project will be completed in 2020, with the results of the study proposed for publication in a peer-reviewed journal.

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Teaching, Students, & Volunteers

Francesca Erickson, in the Conor McGowan lab, School of Forestry and Wildlife, had GRA support on Eastern Indigo Snake State Wildlife Grant

ALNHP Outreach Events & Participation

• Katie Lawson presented at the NRCS Natural Resources Youth Camp, Mussel Creek Lodge, Butler County. June 4, 2019. 30 participants.

• Jim Godwin - Eastern Indigo Snake release at Conecuh National Forest, 25 April 2019. Representatives present from Auburn University, Alabama Department of Conservation and Natural Resources, U.S. Forest Service, U.S. Fish and Wildlife Service, Zoo Atlanta, Orianne Center for Indigo Conservation, Birmingham Zoo, Longleaf Alliance.

• Jim Godwin - Eastern Indigo Snake & Wildlife Festival at Conecuh National Forest. 3 May 2019. Participants were school groups and public. Partners were Alabama Department of Conservation and Natural Resources, U.S. Forest Service, U.S. Fish and Wildlife Service, Alabama A&M and Auburn Extension, Orianne Center for Indigo Conservation, Zoo Atlanta, Birmingham Zoo.

•Al Schotz and Katie Lawson taught school environmental education programs at Wehle Nature Center Sept-Oct, 2019.

•Al Schotz taught various school programs at the Davis Arboretum June-October, 2019.

• Al Schotz and Katie Lawson Participated in the Davis Arboretum's Boos and Bones October 12, 2019.

• Katie Lawson participated in outreach activities at the Azalea Festival (April 20), Sustainability Picnic (August 21), COSAM Open House (August 28), and Destination STEM (September 20), 2019.

National Geographic videos ALNHP's Jim Godwin and partners at the 2019 Indigo snake release in Conecuh National Forest

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Database Development

Biotics Biodiversity Database

ALNHP maintains a comprehensive database on the location and conservation status of species and ecological communities in Alabama. Biotics 5 is an integrated, web-enabled platform for tabular and spatial data management that centralizes the data and software hosting in a shared "cloud" environment. The database is maintained by NatureServe using a software-as-a-service delivery model. Biotics 5 provides a common data management platform for members of the NatureServe network to achieve and maintain a unified taxonomy and consistent application of our shared data standards and methodology. Biotics 5 provides the framework for managing taxonomic and biological data on elements of biodiversity and mapping known locations for elements of concern.

The Biotics database is supported by funding through our inventory and conservation planning projects. Although building and improving the database has always been a primary goal of the program, securing funding to support this important program area remains a challenge. ALNHP is currently tracking 1,648 rare plant and animal taxa (Fig. 1). There are 1,100 individual occurrences of these species and natural communities documented in Biotics, with the majority of the Element Occurrences (EO) being for vascular plants or aquatic species (Fig. 2).

Since March 2008, we have been working on improving our database compliance with the Benchmark Data Content Standards (BDCS) for natural heritage data. This past year's efforts focused on Updating the State Wildlife Action Plan status to match the latest SGCN list revisions and last observation date. Another focal area for database improvement was addressing the data backlog. In 2019, this effort resulted in the addition of 3 new Elements (species) to the database with several Element records updated and the creation of 275 new occurrence records with many other occurrence records updated. We will continue working to improve the database with the goal of meeting all BDCS goals and reducing the backlog. The focus in the coming years will be reducing the data backlog, continued review of Benchmark Data Content Standards, and QC of EO Rank, EO Rank Date, and Survey Date.

One of the important tasks each heritage program performs is the regular compilation of a Rare Species Inventory List for the state that ranks each element tracked by the program based on the number and quality of occurrences. Our latest revised Alabama Inventory List was published August 2019, with the list distributed to cooperators and other interested parties and posted to the ALNHP website.

Data Requests

Over the past year, ALNHP has responded to 84 requests for data or information. This included 10 paid data requests and 74 requests from academia, conservation non-profits, government agencies, NatureServe, other Heritage Network members, or cooperating partners. The number of requests was larger than usual due to an increased number of requests for species lists that were not available on our website.

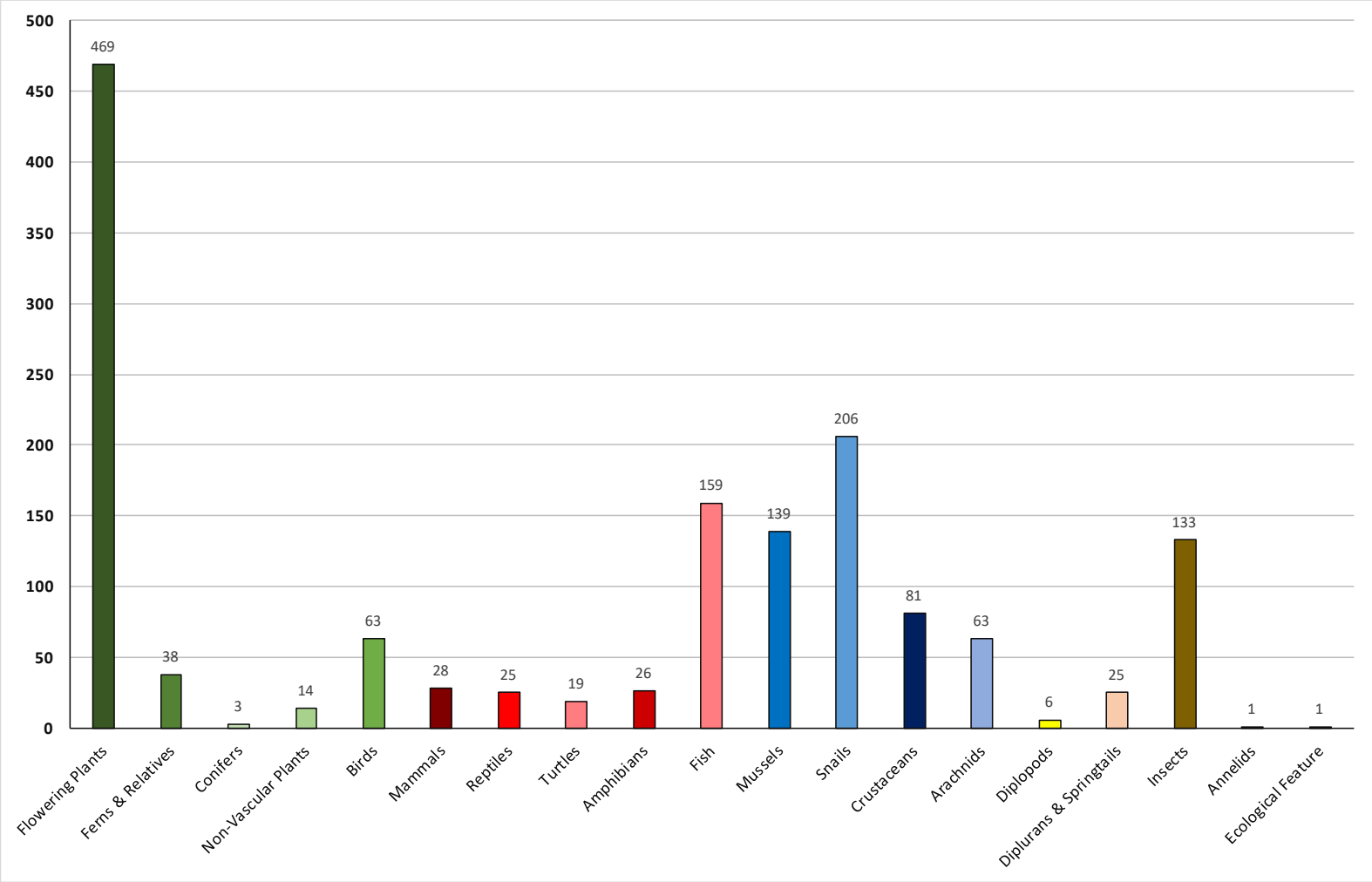


Figure 1. Number of rare plant and animal species tracked by ALNHP (total 1,499).

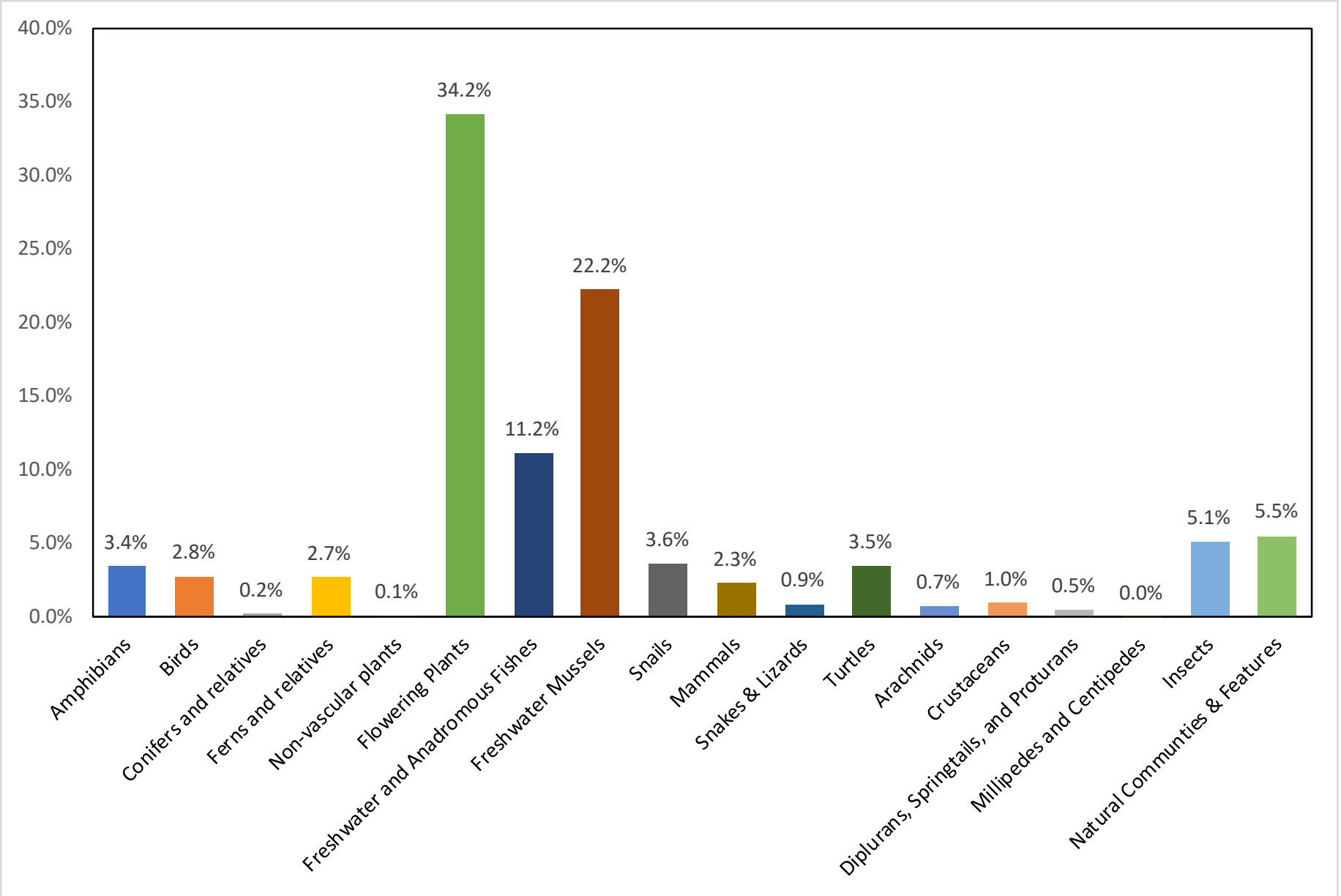
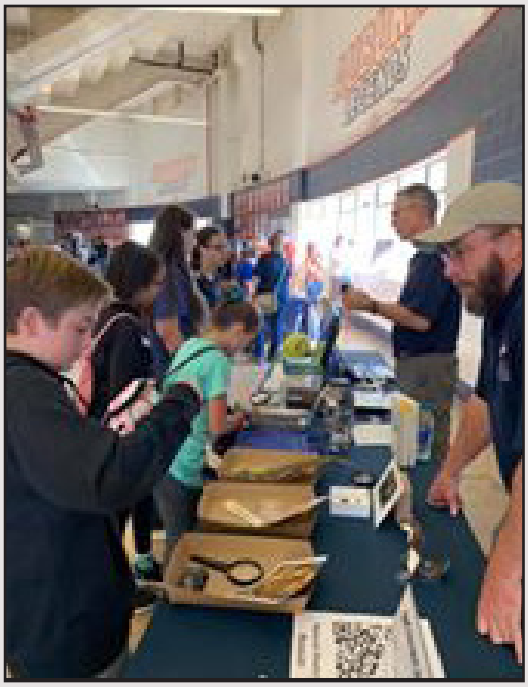


Figure 2. Percentage of 10,100 Element Occurrences in Biotics by major taxonomic group.

OUTREACH

The Auburn University Museum of Natural History (AUMNH) is committed to serving Auburn, the state of Alabama and the southeast region by conducting a variety of Outreach Programs. These programs range from monthly public tours to presentations at Alabama State Parks. Highlighting the research and education aspects of the Museum's work, outreach promotes conservation, awareness and enthusiasm for the natural world around us.



AUMNH at Destination STEM

2019 Curious Curators Camp with Outreach Co-ordinator Toni Bruner and Collections Managers Dr. Melissa Callahan, David Laurenco, and David Werneke.

AUMNH served thousands of citizens in 2019 with ages ranging from preschoolers to members of senior organizations. Programs included two weeks of Junior Curator Camps in the summer, school programs for K-12 students in four east-central Alabama Counties, and the Boos and Bones event held in the Davis Arboretum.

Highlights of 2019 included hosting a field trip for participants attending the GAM-AMA Conference, presenting at the 2019 Alabama Bat Blitz, and presenting awards at the 2019 Green Ribbon Award ceremony.

Collaborations with on-campus entities and outside organizations continue to produce greater impacts in education and public awareness of the Museum's research and conservation efforts.

AUMNH, AU College of Veterinary Medicine and Donald E. Davis Arboretum held our second annual Bones and Boos event on Saturday, October 12, 2019. This year's event exceeded our expectation with over 500 attendees, and 51 volunteer workers.

Other on campus program worthy of mentioning included:

- Destination STEM (1,100 students from 18 local schools)
- COSAM Open House (300 Auburn University students)
- Sustainable Picnic (375 people)
- Azalea Festival (450-500 people)

OUTREACH

Beyond the AU Campus, the Museum engaged with the Alabama Department of Conservation and Natural Resources, State Lands Division to conduct 13 educational programs reaching a total of 293 students at the Wehle Nature Center for underserved schools in Macon, Bullock and Barbour Counties. Dr. Nate Hardy also taught 7th graders from Barbour County about insect diversity at the Wehle Center.

Class at the Wehle Nature Center for Field Days

Class at the Wehle Nature Center for Field Days

AUMNH partnered with many organizations to bring outreach programs to their students included Eufaula Lake Day #156 students, Forest in the Classroom #70 students, and the Indigo Snake Festival with 175 students

Collections Manager Nusrat Noor giving a tour of the aquatic invertebrates collection.

Museum tours served a variety of groups including various campus organizations, the Birmingham Audubon Society, Santuck Baptist Church and the general public during our monthly "First Wednesday" tours.

SIGNIFICANT DISCOVERIES

Significant Botanical Discoveries

Thirty lichen species were reported new to Alabama in a publication by England et al. (2019) which documented the lichens of the Kathy Stiles Freeland Bibb County Glades Preserve.

The lichen species, *Phaephyscia leana* was discovered as a new state record from the Redstone Arsenal (Hansen & Lendemer 2019).

The small vascular plant *Chevreulia acuminata*, a South American endemic, was identified from collections in Auburn and Opelika, AL and Troup County, GA. These were the first reports of this species from North America (Hansen et al. 2019).

Significant Zoological Discoveries

Genome of tubeworms in northern Gulf of Mexico published.

Li, Y, M. G. Tassia, D. S. Waits, V. E. Bogantes*, K. T. David, K. M. Halanych. 2019. Genomic adaptations to chemosymbiosis in the deep-sea seep-dwelling tubeworm *Lamellibrachia luymesi* (Siboglinidae, Annelida). BMC Biology 17:91.

PUBLICATIONS & PRESENTATIONS

Asterisks (*) denote Auburn University student authors or presenters.

Peer-Reviewed and Published Articles

AUMNH Collections

Herbarium

England, J.K, C.J. Hansen, J.L. Allen, S.Q. Beeching, W.R. Buck, V. Charny, J.G. Guccion, R.C. Harris, M. Hodges, N.M. Howe, J.C. Lendemer, R.T. McMullin, E.A. Tripp and D.P. Waters. 2019. Checklist of the lichens and allied fungi of Kathy Stiles Freeland Bibb County Glades Preserve, Alabama. Opuscula Philolichenum 18: 420–434

Hansen, C.J., L.E. Urbatsch & J.F. Pruski. 2019. Noteworthy collections: the first occurrences of *Chevreulia acuminata* (Gnaphalieae, Asteraceae) in North America. Castanea 84: 259–266.

Hansen, C.J. and J.C. Lendemer. 2019. The first report of the rare lichen species *Phaeophyscia leana* (Physciaceae) from Alabama. Evansia 36: 1–4.

Fish

Lujan, N.K., J.W. Armbruster, D.C. Werneke, T.F. Texeira, and N.R. Lovejoy. 2019. Phylogeny of the shield-restricted *Corymbophanes* clade (Loricariidae: Hypostominae: Ancistrini), with descriptions of two new species and one new genus. Zoological Journal of the Linnean Society, XX:1–23.

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Herpetology

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Tiatragul S, Hall JM, Pavlik NG, Warner DA. 2019. Lizard nests differ between suburban and forested habitats. Biological Journal of the Linnean Society 126:392-403.

Lloyd RB, Warner DA. 2019. Maternal nest-site choice does not affect egg hatching success in an invasive turtle population. Behaviour 156:265-285.

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Grismer, L. L., Wood, Jr., P. L., Quah, E. S. H., Anuar, S., Poyarkov, N. A., Thy, N., Orlov, N. L., Thammachoti, P. 2019. Integrative taxonomy of the Asian skinks Sphenomorphus stellatus (Boulenger, 1900) and S. praesignus (Boulenger, 1900) and the resurrection of S. annamiticum (Boettger, 1901). Zootaxa 4683 (3): 381–411.

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Joyce, K.L., M.M. Hayes, J. Potter, and C. Guyer, 2019. Phylogeography of the Slimy Salamander Complex (*Plethodon*: Plethodontidae) in Alabama. Copeia 107(4): 701-707.

Entomology

Bird, G., Kaczvinsky, C., Wilson, A.E. and Hardy, N.B., 2019. When do herbivorous insects compete? A phylogenetic meta-analysis. Ecology letters, 22(5), pp.875-883.

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P.J., 2019. A revision of *Lachnodius* Maskell (Hemiptera, Coccomorpha, Eriococcidae). ZooKeys, (818), p.43.

Invertebrates

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Redak, C., K. M. Halanych. 2019. Mitochondrial genome of *Parborlasia corrugatus* (Nemertea:Lineidae). Mitochondrial DNA Part B: Resources.4:332-334.

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Mammalogy

Gilley, L. M., C. A. Diggins, S. M. Pearson, and T. L. Best. 2019. Vocal repertoire of captive northern and southern flying squirrels (***Glaucomys sabrinus*** and ***G. volans***). Journal of Mammalogy, 100:518-530.

Hunt, J. L., M. E. Grilliot, T. L. Best, C. S. Deen, D. Lozano-Lopez, E. R. Neilson, and T. R. Schlegel-Ridgway. 2019. Energy content of seeds of Texas doveweed (***Croton texensis***) from the diet of mourning doves (***Zenaida macroura***) from southeastern New Mexico. Proceedings of the Arkansas Academy of Science, 73:18-20.

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ALNHP

Barger, T.W., A. Cressler, B. Finzel, A. Highland, W.M. Knapp, F. Nation, A.R. Schotz, D.D. Spaulding, and C.T. Taylor. New and noteworthy vascular plant records for Alabama. Phytoneuron 2019-17: 1–7.

Ennen, Joshua R., Mary Lou Hoffacker, Will Selman, Christopher Murray, James Godwin, Rocko A. Brown, and Mickey Agha. 2019. The effect of environmental conditions on body size and shape of a freshwater vertebrate. Copeia 107:550-519.

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Goessling, Jeffrey M., Craig Guyer, James C. Godwin, Sharon M. Hermann, Franzisca C. Sandmeier, Lora L. Smith, and Mary T. Mendonca. 2019. Upper respiratory tract disease and associated diagnostic tests of mycoplasmosis in Alabama populations of Gopher tortoises, *Gopherus polyphemus*. PloS ONE 14:e0214845.

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Book Chapters

Halanych, K. M., J. T. Cannon, M. G. Tassia. 2019. Hemichordate:Pterobranchia. In Ed A. Schmidt-Rhaesa, Handbook of Zoology, Miscellaneous Invertebrates. Vol 9. Pp 267- 282. De Gruyter, Berlin.

Tassia, M. G., J. T. Cannon, K. M. Halanych. 2019. Hemichordate:Enteropneusta. In Ed A. Schmidt Rhaesa, Handbook of Zoology, Miscellaneous Invertebrates. Vol 9. Pp 283-311. De Gruyter, Berlin.

Publications Acknowledging AUMNH Specimens and/or Staff

Herbarium

Beckman, E., Meyer, A., Denvir, A., Gill, D., Man, G., Pivorunas, D., Shaw, K., & Westwood, M. 2019. Conservation Gap Analysis of Native U.S. Oaks. Pp. 221. Lisle, IL: The Morton Arboretum.

England, J.K, C.J. Hansen, J.L. Allen, S.Q. Beeching, W.R. Buck, V. Charny, J.G. Guccion, R.C. Harris, M. Hodges, N.M.

Howe, J.C. Lendemer, R.T. McMullin, E.A. Tripp and D.P. Waters. 2019. Checklist of the lichens and allied fungi of Kathy Stiles Freeland Bibb County Glades Preserve, Alabama. Opuscula Philolichenum 18: 420–434.

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Spaulding, D.D., T.W. Barger, H.E. Horne, and B.J. Finzel. 2019. Flora of Northern Alabama, part 4. Basal Monocots. Phytoneuron 2019-47: 1–132.

Fish

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Huie, J.M., A.P. Summers, and M.A. Kolmann. 2019. Body shape separates guilds of rheophilic herbivores (Myleinae: Serrasalmidae) better than feeding morphology. Proceedings of the Academy of Natural Sciences of Philadelphia. 166(1):1–50.

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de Santana, C.D., Crampton, W.G.R., Dillman, C.B. et al. 2019. Unexpected species diversity in electric eels with a description of the strongest living bioelectricity generator. Nature Communications 10, 4000.

Schmidt, R.C., M.N. Dillon, N.M. Kuhn, H.L. Bart Jr., and F. Pezold. 2019. Unrecognized and imperilled diversity in an endemic barb (Smiliogastrini, Enteromius) from the Fouta Djallon highlands. Zoologica Scripta 45(5): 605–613.

Vanegas-Rios, J.A., R. Britzke, and J.M. Mirande. 2019. Geographic variation of *Moenkhausia bonita* (Characiformes: Characidae) in the rio de la Plata basin, with distributional comments on M. intermedia. Neotropical Ichthyology

17(1):e170123.

Entomology

AdPoole, E. M., Ulyshen, M. D., Horn, S., Cram, M., Olatinwo, R., & Fraedrich, S. (2019). Biology and distribution of Agrilus macer LeConte (Coleoptera: Buprestidae), a species associated with sugarberry (*Celtis laevigata* Willd.) mortality in the southeastern USA. Annals of Forest Science, 76(1), 7.

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Invertebrates

Redak, C., K. M. Halanych. 2019. Mitochondrial genome of *Parborlasia corrugatus* (Nemertea:Lineidae). Mitochondrial DNA Part B: Resources.4:332-334

Project Reports

ALNHP

Godwin, James. 2019. Escambia Map Turtle (*Graptemys ernsti*) Status Survey. Report submitted to the Alabama Department of Conservation and Natural Resources, Division of Wildlife and Freshwater Fisheries, Montgomery, Alabama. Alabama Natural Heritage Program®, Auburn University, Alabama. 12 pages.

Godwin, James. Status Survey for the Alligator Snapping Turtle (*Macrochelys temminckii*) in Alabama. 2019. Report submitted to the Alabama Department of Conservation and Natural Resources, Division of Wildlife and Freshwater Fisheries, Montgomery, Alabama. Alabama Natural Heritage Program®, Auburn University, Alabama. 34 pages.

Godwin, James. 2019. Hellbender Status Survey in Alabama using Standard Methods and Environmental DNA (eDNA). Report submitted to the Alabama Department of Conservation and Natural Resources, Division of Wildlife and Freshwater Fisheries, Montgomery, Alabama. Alabama Natural Heritage Program®, Auburn University, Alabama. 7 pages.

Godwin, James. 2019. Mississippi Gopher Frog (*Lithobates sevosus*) Survey. Report submitted to the Alabama Department of Conservation and Natural Resources, Division of Wildlife and Freshwater Fisheries, Montgomery, Alabama. Alabama Natural Heritage Program®, Auburn University, Alabama. 9 pages.

Godwin, James. 2019. Eastern Indigo Snake Reintroduction in Conecuh National Forest: Future Release Site Selection and Impact on Prey Species. Report submitted to the Alabama Department of Conservation and Natural Resources, Division of Wildlife and Freshwater Fisheries, Montgomery, Alabama. Alabama Natural Heritage Program®, Auburn University, Alabama. 10 pages.

Schotz, A. 2019. Range-wide Status Assessment of *Hexastylis speciosa* Harper (Aristolochiaceae), Harper's Ginger. Unpublished report for the U. S. Fish and Wildlife Service. 64 pp. including two appendices.

Schotz, A. 2019. Range-wide Status Assessment of *Phlox pulchra* (Wherry) Wherry (Polemoniaceae), Wherry's Phlox. Unpublished report for the U.S. Fish and Wildlife Service. 40 pp. including two appendices.

Meeting Attendance

ALNHP

Eastern Indigo Snake Reintroduction Committee meeting. 22-23 January 2019. Ichauway Plantation, Georgia.

Biology (oral). Population demographics of an invasive lizard following experimental introduction on small islands.

Hall JM, Warner DA. Society for Integrative and Comparative Biology (oral). Constantly fluctuating in an inconsistent way: comparing the effects of sinusoidal and naturally fluctuating incubation temperatures on embryo development.

Pruett JE, Fargevieille AK, Warner DA. Society for Integrative and Comparative Biology (oral). Maternal choice and the effects of nest microclimate on egg survival in the brown anole.

DeSana AN, Fargevieille AK, Warner DA. Society for Integrative and Comparative Biology (poster). Lizard egg predation by marsh crabs: effects of microhabitat and crab density on egg survival.

Turner MK, Tiatragul S, Hall JM, Warner DA. Society for Integrative and Comparative Biology (poster). Testing different methods for creating ecologically-relevant incubation treatments in the lab.

Warner DA, Mitchell TS. AL Partners in Amphibian and Reptile Conservation (oral). Effects of population density and timing of hatching on phenotypic selection in an invasive lizard.

Fargevieille A, Gunderson AR, Cook TO, Dees AG, Schweikart OG, Warner DA. AL Partners in Amphibian and Reptile Conservation (oral). Effects of early-life thermal stress on phenotypic traits and heat tolerance in ***Anolis sagrei***.

Murphy KM, Watkins MM, Finger JW, Kelley MD, Elsey RM, Warner DA, Mendonca MT. AL Partners in Amphibian and Reptile Conservation (oral). Xenobiotic estradiol-17β and the microbial gut communities of hatchling American alligators (***Alligator mississippiensis***).

Scruggs C, Miracle J, Cobb K, Warner DA. AL Partners in Amphibian and Reptile Conservation (poster). The influence of water availability on maternal and egg hydration in the brown anole.

Schweikart OG, Fargevieille A, Warner DA. AL Partners in Amphibian and Reptile Conservation (poster). Effects of thermal stress during incubation on post-hatching development in ***Anolis sagrei***.

Cook TO, Fargevieille A, Warner DA. AL Partners in Amphibian and Reptile Conservation (poster). Dorsal pattern polymorphism in female brown anoles: testing the "male-mimicry hypothesis".

ALNHP

Schotz, A. 2019. Trilliums of Alabama and their Conservation. Trillium Workshop, Mt. Cuba Center, Delaware; Oct. 4-6.

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Funded Projects

Funding Source	Project Name	Responsible Party	Amount	Status
ADCNR	Indigo Snake monitoring	Godwin and Warner	$250,973	Ongoing
ADCNR	Hellbender multi-state	Godwin and Armbruster	$80,183	Completed
USFWS	Turkey Creek musk Turtle	Godwin and Armbruster	$5,000	Completed
ADCNR	Escambia Map turtle	Godwin and Armbruster	$25,985	Ongoing
ADCNR	Mississippi gopher frog	Godwin and Armbruster	$27,403	Ongoing
ADCNR	Alligator snapping turtle	Godwin and Armbruster	$25,000	Completed
Department of Defense	Arnold Air Force Base gopher frog	Godwin and Armbruster	$47,500	Ongoing
Louisiana Department of Wildlife and Fisheries	Occurrences of western chicken turtle in Louisiana	Godwin and Oaks	$136,436	Ongoing
The Nature Conservancy	Waterdog and Musk Turtle eDNA Survey 2018-20	Godwin and Armbruster	$60,191	Ongoing
ADCNR	Habitat improvement and population expansion of green pitcher plant at Desoto State Park, AL	Schotz and Hansen	$23,557	Ongoing
USFWS	Gentian Pinkroot Status Assessment	Schotz	$15,000	Completed
USFWS	Bog Spicebush Status Assessment	Schotz	$25,000	Ongoing
USFWS	Wherry's Phlox Status Assessment	Schotz	$30,000	Ongoing
ADCNR	White Fringeless Orchid Modeling	Schotz and Hansen	$39,000	Ongoing
NatureServe	Mountain Longleaf Vegetation Assessment	Schotz	$9,000	Completed
EPA	Reference Wetland Study	Armbruster et al.	$229,452	Ongoing
U.S. Army Garrison	Redstone Arsenal Biological Inventory	Armbruster et al.	$100,000	Ongoing
NSF	Compactorized Shelving for the Wet Collections of AUMNH	Armbruster et al.	$195,450	Ongoing
NSF	Aquatic refuge and recovery in the face of drought	Armbruster et al.	$170,986	Ongoing
NSF	Collaborative Research: Red carotenoids as signals of respiratory chain function	Hill	$480,000	Ongoing
PAIR (internal)	Auburn Mitomobile	Hill	$600,000	Ongoing
NSF	DDIG: copepod mate choice	Hill/Weaver	$22,000	Ongoing

Funded Projects

USFWS	Biodiversity, phylogeny *Myxobolus* spp.	Whelan, Bullard	$102,000	Ongoing
AL-MRD	Fish disease monitoring, coastal	Bullard, Arias	$26,369	Ongoing
TWRA	Southeastern Cooperative Fish Parasite and Disease Project	Bullard, Arias	$80,000	Ongoing
ADCNR	Dysbiosis fw mussels	Arias, Bullard	$50,000	Ongoing
USWFS	ANS, *Myxobolus cerebralis*, whirling disease, salmonids	Bullard et al	$25,000	Ongoing
VDCR Inland Fisheries Division	Biosecurity, trout hatcheries	Arias, Bullard	$55,000	Ongoing
NCWRC	Whirling disease epidemiology	Bullard et al	$298,765	Ongoing
SRAC	LAMP assay for amyloodinium	Bullard et al	$99,987	Ongoing
ADCNR	Southeastern Cooperative Fish Parasite and Disease Project	Bullard, Arias	$60,000	Ongoing
NCWRC	Southeastern Cooperative Fish Parasite and Disease Project	Bullard, Arias	$80,000	Ongoing
SCDCNR	Southeastern Cooperative Fish Parasite and Disease Project	Bullard, Arias	$80,000	Ongoing
VDCR Inland Fisheries Division	Southeastern Cooperative Fish Parasite and Disease Project	Bullard, Arias	$80,000	Ongoing
GADNR	Southeastern Cooperative Fish Parasite and Disease Project	Bullard, Arias	$60,000	Ongoing
ADCNR	Propagation bottlenecks for freshwater mussels	Bullard, Arias	$213,058	completed
AL-MRD	Fish disease monitoring, coastal	Bullard, Arias	$26,309	completed
VDCR Inland Fisheries Division	Hatchery checks supporting salmonid culture	Arias, Bullard	$55,000	completed