Report of Activities
October 2007-September 2008

alabama cooperative

fish and wildlife research unit

Alabama Cooperative Fish and Wildlife Research Unit

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U.S. Geological Survey
Alabama Department of Conservation and Natural Resources, Wildlife and Freshwater Fisheries Division
Auburn University
Wildlife Management Institute
U.S. Fish and Wildlife Service

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Program Direction Statement

The Cooperative Fish and Wildlife Research Unit program facilitates cooperation among the U.S. Geological Survey, Biological Resources Division; universities; state fish and wildlife agencies; and private organizations in programs of research and education related to fish and wildlife resource management. The objectives of the program are: 1) to conduct research on fish and wildlife ecology and to investigate the production, utilization, management, protection, and restoration of populations of fish and wildlife; 2) to provide technical and professional education and continuing education primarily on the graduate and professional level in the fields of fish and wildlife management, teaching, research, demonstration and administration; and 3) to make facts, methods, and new findings discovered through research available to scientists, landowners, sportsmen, outdoor recreationists, conservationists, extension workers, teachers, and local, state and federal agencies. The Unit shall also continue to work closely with the U.S. Fish and Wildlife Service to be informed of, and where requested, assist with the development of that agency's initiatives ecosystem management system. The operations of the Alabama Unit are governed by a Coordinating Committee operating under a formal cooperative agreement signed by the U.S. Geological Survey, Biological Resources Division; Auburn University; the Alabama Department of Conservation and Natural Resources, Division of Wildlife and Freshwater Fisheries; U.S. Fish and Wildlife Service, and the Wildlife Management Institute.

The Alabama Unit has identified four areas in which to concentrate its research efforts: 1) determining the effects of forest management techniques on wildlife species, 2) investigating the ecology and management of stream corridors, 3) investigating the status, life history and habitat requirements, and of endangered or threatened species to obtain information necessary for the development of comprehensive recovery plans, and 4) investigating the ecology and management of fish and wildlife species on landscape scales. The Unit will not be restricted to these areas of investigation; however, it will work towards the development of comprehensive research programs in each.

Effects of Forest Management on Wildlife Populations

Approximately 70% of non-urban land in Alabama is forested, much of it managed intensively for the production of forest products. Wildlife populations can be valuable components of forestlands. However, in some forests wildlife may be quite scarce. The abundance of wildlife in woodlands depends upon available food and cover resources that are in turn determined by forest management practices. Timber management can have major impacts on wildlife populations, and information is required to enable adequate evaluation of these impacts and to permit provision for support of wildlife species in the timber program. Many questions need to be answered relative to the relationships between wildlife species or groups and timber management practices. The response of wildlife to such factors as rotation schedule, species composition of forests, burning and thinning schedules, snag retention or removal, and size of clear cuts, needs to be determined. Area sensitive species need to be identified and their area requirements determined. Response of wildlife species to reforestation efforts requires evaluation. Wildlife is of high economic and aesthetic value and represents an important component of our forest ecosystem. It is important that we obtain the necessary information to ensure the retention of wildlife populations as forest management intensifies.

Ecology and Management of Stream Corridors

A typical southeastern stream corridor is a wetland complex composed of flowing-water aquatic habitats, adjacent riparian habitats, and periodically flooded bottomland habitats. Also, any particular stream corridor is just a segment of a drainage system with a sequence of corridor zones associated with streams from headwaters to large rivers. Stream corridors are important sources of renewable resources such as commercial and recreational fisheries, aquatic-oriented wildlife, and terrestrial wildlife utilizing productive bottomland areas. In addition, stream corridors are highly valued recreation and aesthetic areas due to high biological productivity and landscape diversity.

Stream corridors have always been, and continue to be, the focus of many forms of economic and land developments that exert some effect on these systems. Impacts to stream and river systems basically stem from two general factors, altered hydrologic conditions (i.e., water quality and quantity) and physical alterations of streams and associated lands (e.g., agricultural plots, backwater draining, navigation improvements). Both land and water changes tend to influence the integrity of instream, riparian, and bottomland communities since all these habitats are dependent on water/land relationships. The natural flowing-water processes of erosion and deposition impose a dynamic character to instream, riparian, and bottomland habitats and their associated fish and wildlife communities. Human modifications to stream corridors tend to intensify this dynamic character and frequently require continual human intervention to maintain artificial stream corridor conditions.

The most pressing areas of research involving stream corridors concern the interactions between fish and wildlife communities and the physical and chemical processes of flowing waters. The Unit intends to develop research that integrates fish and wildlife resource characteristics and functions with the hydrologic processes that influence stream corridor habitats. Specific areas for development include: renewable resource management, conservation of species, preservation of communities, impact assessment and prediction of effects, and mitigation and restoration.

Endangered Species

One hundred sixteen* species or subspecies that occur in Alabama have been declared endangered or threatened by the federal government (Threatened and Endangered Species System, USFWS); included are **98** animals and **18** plants. Information on the status, habitat requirements, and life history of these taxa is required to permit identification and declaration of critical habitat and to enable the formulation of management practices providing for their protection and, where possible, eventual recovery. Three hundred three species appear on the list of species of greatest conservation need in Alabama. Addressing the needs of these species now may prevent the need for listing them as threatened or endangered in the future. Research needs vary greatly by taxon; however, the Unit is capable of enlisting a diversity of expertise in addressing identified needs. Research in this area will be developed primarily in response to specific requests for assistance by cooperating agencies.

Landscape Ecology

Traditionally, research in wildlife and fisheries has focused on population or community dynamics on relatively small or undefined spatial scales, with the size of a study area defined by protocols for collecting data or by management units such as forest stands or

agricultural fields. Recent work in the field of landscape ecology strongly suggests that many ecological processes of interest to wildlife and fisheries researchers and managers occur on a variety of spatial scales, ranging from local (e.g., stand-scale) to regional (e.g., landscape-scale) dynamics. Landscape processes often are an emergent ecological property that cannot be directly extrapolated from observations collected on small scales. Inferences from small-scale or aspatial studies could be misleading in addressing the large scale ecological effects of increasing urbanization, changes in land use, and habitat fragmentation evident on modern landscapes.

Recent advances in technology are making spatially explicit data covering large areas widely available at relatively low cost. These data and the tools required to access and interpret them are rapidly becoming essential and affordable to wildlife and fisheries biologists. The Unit will develop research that quantifies and evaluates large-scale, landscape processes for wild populations and the ecological communities that sustain them. The Unit will also be involved in other landscape approaches, including the development and application of spatially explicit, individual-based behavioral models and the use of landscape characteristics to predict the distribution of wild populations.

*Text in bold represents a revision.

EFFECTS OF FOREST MANAGEMENT ON WILDLIFE POPULATIONS

Mapping the distribution of longleaf ecosystems for herpetofauna conservation

Funding Source: U.S. Fish and Wildlife Service

Principal Investigator: James B. Grand

Co-principal Investigator: Mark MacKenzie (Auburn University)

Research Assistant: Kevin Kleiner

Duration: August 2007 – August 2010

Over the last two centuries, the longleaf pine ecosystem has been dramatically altered by logging, replanting with other pine species, and fire suppression. Current estimates, suggest that longleaf occupies 5% of its pre-European settlement extent. This reduction in habitat has affected numerous birds, reptiles, and amphibians. The best known example of this is the red-cockaded woodpecker (*Picoides borealis)*, a federally endangered species that inhabits old growth longleaf pine woodlands. A reduction in the amount of habitat available to this species has led to corresponding reductions in population size.

The gopher tortoise (*Gopherus polyphemus*) and the black pine snake (*Pituophis melanoleucus lodingi*) are also longleaf ecosystem inhabitants whose abundance is in decline. Successful management of both the gopher tortoise and the black pine snake requires knowledge of the current distribution of the longleaf pine ecosystem. Currently, the course scale spatial distribution of longleaf pine can be obtained from the USDA Forest Service's Forest Inventory and Analysis Program (FIA, Prasad and Iverson 2003). While useful for visualizing where longleaf exists and perhaps planning at a regional scale, this product is not of sufficient resolution for site specific wildlife conservation and management. Another source that has the potential to provide the spatial distribution of longleaf pine is remote sensing. In 2005, John Hogland, a graduate student at Auburn University working with the Alabama Gap Analysis Project, created a fine-grain (30 meter) probability distribution of longleaf pine ecosystems (Hogland 2005). Currently, this is the only large extent, fine grain map of the current distribution of the longleaf pine ecosystem. The goal of this project is to assess what is mapped and what can be improved in the Hogland Longleaf Pine Ecosystem Map for the purpose of enhancing the ability to manage and conserve the gopher tortoise and black pine snake. Additionally, we intend to relate gopher tortoise burrow density to the improved predicted probability map.

Status - We have begun the process of collecting additional data for map assessment and potential improvement. Recently acquired data includes Forest Inventory and Analysis (FIA) plot data in Alabama and Florida, Mississippi Institute for Forest Inventory (MIFI) plot data, and U.S. Forest Service Continuous Inventory of Stand Condition (CISC) data. Additionally, an existing crosswalk of the Soil Survey Geographic Database (SSURGO) soil classes to a longleaf suitability index has been identified and we are currently planning to assemble the individual county soil maps and stratify by this layer in any subsequent image classification

Ecological assessment of habitats occupied by breeding birds at Redstone Arsenal, Alabama

Funding Source: Department of Defense

Principal Investigator: Troy Best (Auburn University)

Graduate Students: Lisa A. McWilliams, Charles A. Kilgore

Undergraduate Students: Rebecca Roper, Francisco Cartaya

Duration: April 2007 – December 2010

The state of Alabama has one of the richest faunal biodiversities in the United States (Mirarchi 2004). There are 420 species of birds comprising the official American Ornithological Society state list (Mirarchi 2004). This is almost half the total species recognized for the continental United States by the American Birding Association.

Redstone Arsenal encompasses a variety of habitats within its 38,248 secured acres. It contains extensive wetland areas associated with the Tennessee River, several local springs, woodlands, and fields. The varied habitats attract a large percentage (~290 species) of Alabama's avifauna either as residents, migrants, or rare visitors (Porter 2001). The area's variable water levels of ponds, sinks, and cypress swamps, much of which is maintained by the Wheeler National Wildlife Refuge, attract many winter waterfowl, herons, egrets, and shorebirds (Porter 2001). The Redstone Arsenal area also attracts many raptors and passerines of both woodland and field species.

Twenty-eight species of birds are of special concern in Alabama. Many species of these birds of special concern may occur in the Redstone Arsenal area of the Tennessee Valley region. Alabama provides critical breeding, wintering, or migratory habitats necessary for the overall success of these species.

Considering the need for information on avian diversity and ecological associations in the region, an assessment of species present, distribution, breeding activity, habitats occupied, etc., is highly desirable. These data would be useful in developing management plans for the Redstone Arsenal, and would provide baseline data for comparisons and future research. This study will be a significant contribution to overall assessment of presence, distribution, breeding activities, and habitat associations of avian species of special concern in Alabama.

Status – Preliminary data on occurrence of birds at Redstone Arsenal were gathered during 2006 and 2007. These data formed the basis for a preliminary report submitted to Redstone Arsenal in September 2007. During January-August 2008, field work was conducted at Redstone Arsenal to assess species present, distribution on the facility, breeding activity, and habitats occupied. During January-August 2009, remaining field work will be completed. The final report will be submitted by 31 December 2009.

ECOLOGY AND MANAGEMENT OF STREAM CORRIDORS

Relations between occupancy rates, fish health and water quality parameters for fishes inhabiting Wheeler NWR

Funding Source: U.S. Geological Survey, U.S. Fish and Wildlife Service

Principal Investigator: Elise Irwin

Research Associate: Kathryn Kennedy

Duration: August 2007 – December 2008

Wheeler National Wildlife Refuge (WNWR) located in North Alabama adjacent to Wheeler Reservoir on the Tennessee River encompasses 35,000 acres, and includes several satellite Refuges. During recent Biological Review of WNWR, recommendations were made to complete an assessment of occupancy rates and overall fish health in relation to water quality for nongame fishes on refuge lands. In addition to Wheeler Reservoir, streams that drain to the reservoir are located on refuge lands and current information is lacking regarding fish populations in these systems. Refuge personnel are also concerned about overall health of the aquatic systems on the Refuge and are interested in the incidence of disease or other abnormalities expressed by fishes inhabiting aquatic systems on the Refuge. It is hypothesized that water quality is compromised in several water bodies on the Refuge, therefore warranting a quantitative assessment of how water quality parameters may be affecting both fish occupancy rates and overall fish health.

The objective of this project is to estimate occupancy rates and health for fish species inhabiting Wheeler Reservoir and streams located on refuge lands. Specifically, we will 1) provide Refuge staff with probability of occurrence for each species in water bodies on the Refuge 2) conduct a fish health assessment for fishes encountered during the survey, 3) measure water quality parameters and other covariates that may affect occupancy and fish health at each site, and 4) investigate relations between physical and chemical characters of the streams and reservoir and fish population characters.

Status - We conducted fish sampling on Wheeler NWR in July 2008. Seven watersheds were surveyed based on recommendations by Refuge Personnel. Specific sites within each watershed were selected in a systematic random fashion and visited within a 3-week period in July 2008. The most common species, bluegill *Lepomis macrochirus*, was selected for the health analysis. Thirty individuals (TL > 60mm) were collected from each of the 7 watersheds either with backpack electrofishing or by hook-and-line. A gross health assessment, which considered gross abnormalities, parasites, and condition of internal organs, was conducted on individual bluegill. In addition, tissue samples were collected for histological analysis and otoliths were extracted for growth estimation. Fish identification, otolith processing for growth analysis, and histological analysis is presently underway. Species occupancy rates, as well as lesion and disease rates, will be related to landscape characters to make initial predictions on relation of land use/land cover to fish assemblage structure and overall health. A final report will be prepared December 2008.

ENDANGERED/DECLINING POPULATIONS

Assessment of habitats in areas historically used by Ivory-billed Woodpeckers in southern and western Alabama and the Florida panhandle

Funding Source: US Fish and Wildlife Service

Principal Investigator: James B. Grand

Co-principal investigators: Geoffrey Hill, Dan Mennill

Graduate Students: Brian Rolek, Karan Odom

Research Technicians: Jesse Swift, Elizabeth Wright, John Konyha, Timothy Lee

Duration: August 2006 – December 2008

The recent re-discovery of Ivory-billed Woodpeckers (IBWO) in Arkansas has spawned interest in surveys of suitable habitat within the former range of the species. In the mid- to late-1860s IBWO were shot along the Tombigbee River in Marengo County and the Warrior River west of Greensboro in Alabama. In 1907, one was reported killed in the Conecuh swamps north of Troy. Numerous birds were collected in river-swamps of the Florida panhandle during that time period. Large tracts of bottomland hardwoods and river-swamps still exist in the Tombigbee, Mobile, Tensaw, Black Warrior, Conecuh/ Escambia, Pea/Choctawhatchee, Appalachicola/Chipola, Rivers in Alabama and panhandle Florida.

IBWO are reclusive, wary, and easily confused with related Pileated Woodpeckers, which frequent habitats similar to those once occupied by IBWO. Due to presumably low numbers, reclusive behavior and similarity to Pileated Woodpeckers intensive monitoring techniques capable of recording evidence for later review are required. The objectives of this project are to: research and document historical and recent reports of IBWO along the rivers in Alabama and in panhandle Florida, estimate the extent or remaining mature, bottomland hardwood forest in suitable areas of Alabama and panhandle Florida with the historic range of IBWO using remotely-sensed data, conduct field searches for IBWO in areas of suitable habitat, and characterize the habitats associated with all potential IBWO observations and sign.

Status – We have gathered substantial evidence that Ivory-billed Woodpeckers persist in the forests along the Choctawhatchee River south of Interstate 10. At this point we know far too little about the foraging behavior of Ivory-billed Woodpeckers in this part of Florida to recommend any sort of detailed forest management such as girdling trees as has been done in Arkansas. We do feel confident in stating that these are shy birds that require large tracts of forest for survival. Our recommendations for management of the forested areas where we have found evidence for the existence of Ivory-billed Woodpeckers are: 1) Minimize disturbance on lands owned by the Northwest Florida Water Management District. 2) Exclude use of off-road vehicles from NWFWMD lands except on designated roadways. Hunting and fishing should be permitted because there is no evidence that these activities disturb Ivory-billed Woodpeckers and restricting such activities would alienate the many local people who enjoy such recreation. 3) Acquire areas of forest wetland not already owned by NWFWMD and land adjacent to forested wetlands. Acquire corridor creeks that could facilitate dispersal to adjacent bottomlands.

Integrated analysis of spring pygmy sunfish habitat in Limestone and Madison Counties, Alabama

Funding Source: U.S. Geological Survey

Principal Investigator: Elise Irwin

Research Associate: Kathryn Mickett Kennedy

Student: TBA

Duration: August 2008 – September 2009

Alabama is experiencing rapid growth in many parts of the state; one of the fastest growing is the Huntsville/Madison County region. Human population growth and associated changes in land use in the region will increase and impose potential stress on natural resources such as water quality and quantity and biodiversity. The region has multiple species of conservation need and FWS is in the process of considering the listing of at least one additional species, spring pygmy sunfish *Elassoma alabamae* identified as imperiled.

Evaluation of effects of landscape change on natural ecosystems is needed. Often water resources (quality and quantity) equate to common currency in systems where multiple competing uses for water have been identified. In the case of the Huntsville, Alabama area, consumption of groundwater and surface water for human uses is needed; however, several issues related to imperiled aquatic species (fish and snails) have also been identified by State and Federal agencies. Understanding water sources and effects of increased use on water quality and quantity for multiple competing objectives will require development of models to 1) define linkages among abiotic and biotic components of ecosystems; 2) identify key uncertainties regarding ecosystem function; and 3) quantify effects of management on state variables (see influence diagram; Figure 1). The goal of this project is to integrate the expertise in USGS Water and Biology to assist FWS with evaluating the effects of ground water and surface water on the persistence of spring pygmy sunfish habitat. Ultimately, the project will provide FWS with a product that could be incorporated into or become a recovery plan or Habitat Conservation Plan for the species of concern.

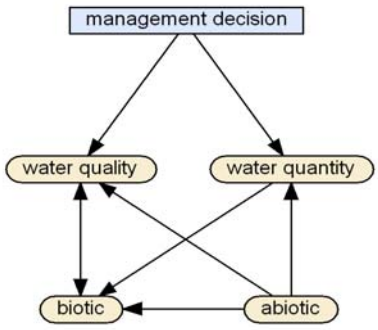


Figure 1. Influence diagram illustrating the relations among management, water quality and quantity and biotic and abiotic components of an ecosystem.

Status – Identification of key ecosystem components, uncertainties, links, and stakeholder values is underway. Meetings with experts in the fields of ecology, water resource management, and groundwater geochemistry have been scheduled. These meetings will provide the necessary expert opinion and sources for empirical data to inform a structured decision model for management of spring pygmy sunfish.

Conservation genetics of the federally endangered Alabama leather flower, Clematis socialis (completed)

Funding Source: U.S. Fish and Wildlife Service

Principal Investigators: Robert Boyd and Leslie Goertzen (Auburn University)

Graduate Students: Irene (Rena) Miller

Research Technicians: Jennifer Trusty (Post-doctoral Associate)

Duration: April 2006 - December 2007

The endangered Alabama Leather Flower, Clematis socialis (USFWS1989) is found in five populations in three Alabama counties, Cherokee, Etowah and St. Clair, as well as in Floyd County, Georgia (Garrett 1004). In order to ensure the long-term preservation of this rare plant species, conservation programs based on informed management decisions are necessary. The success of these programs is dependent on knowledge of the genetic diversity within and among natural populations of these species. Expanding human populations in Alabama have directly impacted Clematis socialis through the loss of habitat to urbanization and by road building activities. What is unknown is how to best ensure the long-term survival of this species in the remaining populations. An analysis of the genetic diversity within and among populations of rare species is an important tool that can help direct conservation efforts. Maximizing the genetic diversity in ex-situ populations of this Clematis species is the best protection we can provide against future environmental challenges. In addition, reintroduction to extirpated sites will benefit from data on which genotypes were most likely found (and adapted) to that site and the amount of genetic diversity necessary to maintain the re-introduced populations into the future.

Status –Project is complete and final report submitted to the U.S. Fish and Wildlife Service.

LANDSCAPE ECOLOGY

Gap Analysis for Alabama (completed)

Funding Source: U.S. Geological Survey

Principal Investigator: James B. Grand, Elise Irwin, Mike Mitchell, and Mark MacKenzie (Auburn University)

Project Coordinator: Amy Silvano

Research Assistants: Kevin Kleiner, Ben Taylor, Gareth Turner

Student: John Hogland

Student Workers: James Grand, William Grand

Duration: August 2000 –December 2008

Alabama spans five physiographic provinces from the Coastal Plain through the Interior and Appalachian Low Plateaus, more than any other state. Within these provinces unique and often rare communities and diverse assemblages of plants and animals exist. Without adequate planning for conservation based on sound scientific information these communities may ultimately disappear. Gap analysis is directed towards identifying native animal species and natural communities that are underrepresented in conservation efforts. The objectives of the project are: (1) to promote cooperative approaches toward the development and use of Gap data, (2) to map the existing natural and semi-natural land cover; (3) to produce maps of the predicted distributions of every vertebrate species; (4) to map the ownership of public and private conservation lands; (5) to categorize all lands according to management status; (6) to produce a database of the total surface area and relative representation for each class of land cover and animal species relative to land stewardship categories; (7) to produce a written report of the mapping, assessment, analysis methods, results, accuracy, and limitations; and (8) to develop a plan for the maintenance and updating of the information.

Status – All products for the gap analysis have been completed, including the land cover map, vertebrate predicted distribution maps, and stewardship maps. Provisional versions of these data sets are currently available to the public for download from our website (www.auburn.edu/gap). A gap analysis of land cover and vertebrate species has been compiled. Richness maps for each major taxa group and overall species richness have been generated. Metadata for each GAP component has been completed and a written report of methods is currently underway. The final methods report will be turned into our National GAP office for review by year end 2008. All GAP products will be considered provisional until the reviews of the report have been completed.

Biodiversity of terrestrial vertebrates on the J.D. Martin Skyline Wildlife Management Area and adjacent lands

Funding Source: Alabama State Lands Division

Principal Investigator: James B. Grand, Eric Soerhen, and Yong Wang (Alabama A&M University)

Research Associate: Nick Sharp and Shannon Allen

Student(s): Alan Hitch (Ph.D.), Florence Chan (M.S. - AAMU)

Research Assistant(s): Megan Binkley, Helen Czech, Jeff Sorrell, Carrie Johnson, James Fuller, Phillip Massey

Duration: January 2005 – November 2008

Little has been published regarding the composition and habitat requirements of terrestrial vertebrate communities using the forests of the southwestern Appalachian Ecoregion in Alabama. This region represents the southernmost extent of the range for many species native to Appalachian Mountains. Thus, the native fauna and flora includes many vertebrates that are found nowhere else in the state. Recent land acquisitions in Jackson County bring the total acreage under state management on the J.D. Martin Skyline Wildlife Management Area and Forever Wild lands (SWMA) to over 30,000 acres. We are performing a comprehensive inventory of terrestrial vertebrates using these lands based on methods that incorporate rigorous statistical design, and estimation of detection rates, which often obfuscate the results of wildlife inventories. Inventory data will be used to develop probabilistic models of wildlife habitat relationships that can in turn be used to map the distribution of the dominant ecological systems and animal communities on the area. These results will ultimately be used to develop a GIS for use in planning conservation and management based on high probability of use by high priority species and areas of high biodiversity. This is a collaborative project with the Alabama Lands Division Natural Heritage Program, and Alabama A&M University (AAMU).

Status – Based on strata derived from models of landform and solar exposure a stratified random sample of 176 points was selected for surveys. Repeated point counts were used to survey breeding birds at each site six times during May 15-June 30 2005 and 2006. Students at AAMU used line transect methods to survey reptiles and amphibians during April-July and again in August-November 2005 and 2006 at the same points. Live traps were used to sample small mammals for five nights at 88 points 15 September-15 November 2005 and 2006. We measured vegetation structure in August 2006. GIS data from AL-Gap Project and public domain were used to estimate landscape characteristics at each survey site, and we used occupancy analysis to determine factors related to the distribution of each species on the area, and to estimate the total area on SWMA occupied by each species. These data also were used to develop maps of species richness for all species and for priority species identified in Alabama's Comprehensive Wildlife Conservation Strategy (ALCWCS). A report is in review that details the analysis of the survey data and the implications to management recommendations in ALCWCS. We are now analyzing avian productivity data that we collected in conjunction with this project.

Adaptive management and monitoring for restoration and faunal recolonization of shoal habitats

Funding source: Alabama Power Company, Alabama Division of Wildlife and Freshwater Fisheries

Principal Investigator: Elise Irwin

Research Associate (s): Kathryn Mickett Kennedy

Student (s): Taconya Piper (Ph.D.), Ben Martin (M.S.), Molly Martin (M.S.)

Duration: October 2006 – September 2011

High imperilment rates of fishes and mussels in the state of Alabama are related to impoundment and regulation of riverine flows. Specifically, the inundation and disruption of natural flow regimes of shoal habitats in medium sized rivers was hypothesized to be the primary cause for imperilment of 53% of fishes in Southeastern Rivers. In Alabama, loss of functional shoal has likely affected 64% of fish species of greatest conservation need (GCN). Restoration and protection of functional shoal habitat in the remaining unimpounded (i.e., free flowing) fragments of rivers of the State is a critical element of conservation of aquatic species. However, effects of specific flow regimes (i.e., magnitude, duration and timing and their combinations) on shoal habitats and ultimately on biotic processes are not well known. Therefore, we propose to evaluate effects of experimental flow regimes on shoal dependent aquatic fauna in the Piedmont region of Tallapoosa River. Specific objectives are to: 1) Compare fish and invertebrate assemblages and population structure between flow-managed and naturally flowing river reaches (including all GNC species); 2) Assess habitat stability (i.e., shoals) and persistence for GCN species and other species of concern; and 3) Determine applicability of flow management and habitat restoration for other river systems.

Status - Analysis of a long-term (1981-1991) historical data set collected throughout the Tallapoosa basin after dam construction suggested populations of shoal-dwelling fish species have been either stable or in possible recovery since dam construction. Monitoring of faunal response to flow management changes at Harris Dam has been conducted in both spring and fall of 2005-2008. Results from 2005 indicated group (regulated vs. unregulated) and/or distance from the dam were important factors in explaining the variance in occupancy for several species, including black redhorse, lipstick darter, and muscadine darter. In preliminary analysis of the 2005-2008 data, these species showed greater fluctuations in population parameters in unregulated sites compared to regulated sites. This is possibly due to the regional drought conditions experienced in the region from 2006-2008. Over the four years of data, black redhorse population parameters were again a function of group (regulated vs. unregulated) and/or distance from the dam, suggesting a strong influence of the dam on this species. Population parameters for lipstick and muscadine darters were more a function of habitat characters, suggesting a lesser influence of the dam. In addition to population analysis, spawning windows for fishes are being evaluated for GCN species from both assessment of reproductive condition of adults and collection and aging of juveniles. Data from 2005-2008 continue to be processed and analyzed...

Inventory and conservation planning for species of greatest conservation need on Alabama DCNR lands

Funding Source: Alabama Division Wildlife and Freshwater Fisheries

Principal Investigator: James B. Grand

Co-principal investigators: Mike Gangloff, Craig Guyer, Elise Irwin, Carol Johnston, Mark MacKenzie, Ed Loewenstein, Todd Steury

Project Coordinator: Amy Silvano

Graduate Students: Carrie Johnson, Patricia Spears, Dan Holt, Kevin White (ASU),Eva Kristofik, Jimmie Stiles, Sierra Stiles, Michele Tacconneli, Rob Allgood, Jessie Boulerice

Duration: October 2006 – December 2011

During this five-year project the Alabama Cooperative Fish and Wildlife Research Unit will coordinate the development of multi-species Inventory and Conservation Plans (ICPs) for selected lands managed by the Alabama Department of Conservation and Natural Resources. The project will potentially include lands in six ecological regions, and could affect 303 species of greatest conservation need (GCN), of which 118 are listed as threatened or endangered. During the first year, a steering committee will be established, lands and species for inclusion in the plan will be identified, information needs assessment will begin, and an outreach plan will be developed. Subsequent years will be used to gather information and develop decision support tools, conduct outreach programs, and develop the ICPs. The overall goal is to provide a science-based plan for the conservation of GCN species and the habitats they depend on as they occur or could occur on ADCNR managed lands. Additional goals are to establish a protocol and a baseline for monitoring GCN species, to provide a basis for the development of new ICPs, to provide guidance for the improvement of populations of GCN species, to improve upon our understanding of the issues affecting the conservation of GCN species, and to foster relationships among public and private stakeholders.

Status –This year we conducted surveys on four of the 13 study areas—Gulf State, Perdido, Barbour, and Stimpson. We selected survey sites for terrestrial vertebrates using a stratified random design based on land cover-land use data from ALGAP. We measured habitat structure at each of the 243 terrestrial survey sites. We will use these data in conjunction with landscape characteristics to determine the habitat preferences for terrestrial vertebrates encountered in the surveys. We conducted herpetological surveys at four subplots on 179 survey sites in January and March 2008. Crews conducted bird surveys at 243 selected sites and 60 additional sites as part of a graduate student designed project to test hypotheses regarding the relationship of bird communities to the size and context of wildlife openings. Mammal surveys began in mid-September and will be completed in mid-December at a subsample of 108 sites. Stream networks were developed from updated National Hydrological Data, stratified by stream order, and a stratified random sample of stream segments was selected for aquatic surveys (fish, mussels, crayfish, amphibians, and reptiles). Aquatic amphibians and reptiles were surveyed at the 109 sites selected. We surveyed fish populations in June-October at 106 locations and mussel and crayfish populations in May-October.

Climate change in the Southeast U.S. and its impact on bird habitat

Funding Source: U.S. Geological Survey

Principal Investigator: James B. Grand

Research Associate: Kevin Kleiner

Student(s): Vacant

Duration: September 2008 – September 2010

Many fish and wildlife agencies are preparing to respond to projected changes in climate local, regional, and global scales. Numerous climate models were developed under the Intergovernmental Panel on Climate Change (IPCC) that predict changes in temperature and rainfall patterns throughout much of North America. These changes are expected to cause substantial alteration to habitat conditions and thus species distributions. Current models, run at a continental scale, have been inconsistent with regard to predicting temperature trends and trends in storm duration and intensity over the Southeastern U.S. Understanding the impact of potential changes in climate on wildlife habitat adds yet another dimension of uncertainty when agencies attempt formulate management plans based on historical trends of population abundance. Terrestrial landscapes are expected to change yielding altered forest and terrestrial ecotypes, to the extent that species distributions and migratory patterns for birds and other species may dramatically change. However, this change may be obfuscated by land use change in many areas. Still, state fish and wildlife agencies will need information on potential changes to wildlife habitat for long-range planning efforts. Unfortunately, climate change predictions from the current suite of Global Circulation Models (GCM) have not been scaled appropriately for state or local level planning. This project seeks to develop historical land use and land cover data (LULC) at decadal intervals from the late-1970's through 2006 and examine change in relation to observed climate and land use. These data will complement ongoing projects at North Carolina State University (NSCU) to examine changes in bird distribution over the same time period. Data from both projects will be used in conjunction with climate change predictions based on Regional Circulation Models (RCM) that are in development at Texas Tech University to examine the potential changes in bird distribution in the southeastern U.S

Status – Partial funding was provided by U.S. Geological Survey. We have obtained the necessary remote-sensing data for mapping the historical LULC, and are coordinating with USFWS and NCSU researchers to determine the appropriate classification scheme and develop spatially explicit information on historical climate. We are currently searching for a graduate student to assist with the mapping and change detection.

Decision Support Models for Multi-species Bird Conservation (new)

Funding Source: North Carolina State University

Principal Investigator: James B. Grand

Graduate Student: Allison Moody

Duration: January 2008 – December 2010

Populations of many game and non-game bird species in the eastern US are declining relatively rapidly. With limited funding for bird conservation, there is an urgent need to make informed decisions because in many areas lands suitable for bird conservation are increasingly limited. Moreover, programs to conserve and manage those lands are competing with land uses that drive the cost effectiveness of conservation programs even higher. To further improve conservation design and make the best use of limited conservation funds for bird populations, planning efforts need to be spatially explicit, large-scale, based on physiographic not political boundaries, and they need to consider the relative conservation potential of the landscape as well as the relative need for conservation of each bird species. We are developing a framework for the biological planning and conservation design elements of strategic habitat conservation that will ensure the sustainability of bird populations in the South Atlantic Migratory Bird Initiative (SAMBI) area. The framework will be based on identified assumptions that can be evaluated and updated through monitoring and applied research. This framework will be applied based on projections of land use and land cover and emergent projections of animal distribution that incorporate both urbanization and predicted climate change developed by cooperators at the North Carolina Cooperative Fish and Wildlife Research Unit (NC CFWRU) at NCSU. The products are expected to identify strategically important areas for bird conservation efforts through partnerships forged by the Atlantic Coast Joint Venture (ACJV).

Status – In conjunction with researchers at NC CFWRU and ACJV staff, we hosted four workshops within the SAMBI area to inform land managers and ACJV partners of this effort and to solicit their input on the review of animal distribution models, selection of priority species, and conservation design objectives through a structured decision making exercise. The results of the workshops are currently being compiled and will be used to inform the decision model framework.

OTHER PROJECTS

Using time-lapse cameras to estimate abundance and structure of Eastern wild turkeys (Meleagris gallopavo) in Alabama

Funding Source: ADCNR, Alabama Wild Turkey Federation

Principal Investigator: James B. Grand

Graduate Research Assistant: Phil Damm

Duration: August 2007 – December 2009

The increased harvest of Eastern Wild Turkey populations in recent years has led to questions regarding the sustainability of this harvest. We propose a statistically rigorous population survey using time-lapse cameras and bait to estimate age and sex ratios, abundance, and annual poult production to assess harvest sustainability in the state of Alabama. Hypotheses of density in relation to habitat characteristics at the landscape level have been developed *a priori* from the literature to determine the sources of variability that cause unequal distribution of wild turkeys at an ecoregional scale. The objectives of the study are to 1) estimate the abundance (through estimates of density and incorporation of models of detectability) of turkeys using repeated time lapse camera surveys in a nine county area in southwest Alabama; 2) estimate annual production (poults per hen) and age and sex structure of the population; and 3) determine sources of heterogeneity in habitat that cause bias in estimates of turkey density and detectability. An important assumption to this survey is that each trapping occasion (photograph) is independent. If turkeys become faithful to bait sites that would not normally use those sites, then density estimates could be overestimated. To explore the possible bias, we intend to conduct a short term telemetry study to determine the effects of bait on density of use of space by turkeys. Upon completion, this proposal will provide land managers with critical information required to maintain current population levels of wild turkeys through sustainable harvest.

Status - A two-stage sampling process was used to choose random square plots. This procedure produces clusters of survey points to reduce travel among survey sites, and provides a robust sampling design. In the winter of 2007/2008 landowner contact information was researched by internet and visitation to county courthouses. The landowners were contacted by phone and in person for permission to perform the survey on their property. During the summer of 2008, the camera survey was conducted in District V of the ADCNR Division of Wildlife which consists of nine counties. Division of Wildlife personnel conducted surveys in Mobile, Baldwin, Monroe and Clarke counties. Auburn University personnel conducted surveys in Conecuh, Choctaw, Washington and Wilcox counties. In each survey plot, a point close to plot center in potential brood rearing habitat was chosen as a camera bait station. A tree on the south side of the plot was chosen to hang the camera, and the area to the North of the tree was cleared of vegetation obstructing the camera's view. Sites were pre-baited for one week with cracked corn, bait was replenished, and time lapse cameras on a four minute interval were deployed for one week. Upon retrieval of the cameras, data was retrieved by computer and stored for later analysis. One hundred and one plots were surveyed, and 178,951 images were captured. Three Auburn University technicians and one graduate student are processing images for analysis.

Population status and host plant population status of the Gulf Coast solitary bee, Hesperapis oraria

Funding Source: U. S. Fish and Wildlife Service

Principal Investigator: George Folkerts (Auburn University)

Research Assistant: Katie Glynn

Duration: March 2006 – March 2009

Hesperapis oraria was described in 1996 (Cane et al. 1996) from specimens ranging from Horn Island off the coast in Jackson County, Mississippi, eastward to St. Andrews State Park in Bay County, Florida. This species is the only representative of its genus east of the Mississippi River and thus represents a unique geographical disjunct from other species which inhabit the western U.S. and Mexico. As far as is known the species is restricted to coastal dune habitats and sandy barrier islands. Coastal Plain honeycomb head (*Balduina angustifolia)* is thought to be the sole pollen host for this species (Cane et al. 1996). Although the host plant ranges farther inland and occurs in coastal Georgia and throughout the Florida peninsula, no specimens of the bee have been taken in most areas of the host plant range. Thus, it is possible that the species is restricted to the area from which it is presently known. Nests of this species have not been reported in the literature and were not found during previous survey work. Thus, the conservation significance of many life history parameters of the species cannot be assessed. Since the last survey for this species was completed in 1995, Cane (1997) reported that ten populations, located during 1993-1994, survived the effects of Hurricane Opal (October 1995) which impacted essentially the entire known range of the species to some extent. Since that time, tropical storms or hurricanes have impacted portions of the known range of *Hesperapis oraria.* An additional factor that may have affected populations of *H. oraria* relates to the accelerated coastal development that has occurred throughout its range since the bee was discovered. In areas such as the Fort Morgan peninsula in Baldwin County, Alabama, development has markedly changed habitats in the last decade. Cane (1997) reported that a site from which the species was known at Romar Beach, Baldwin County, Alabama, had been destroyed by building construction.

Status – Visits to sites where the bee has been found or could be present were made August 18, 2007 – October 26, 2007. Because a few bees were seen on October 26, a final visit was made on November 3, 2007. No bees were seen on that visit. As far as is presently known, the only pollen host of *Hesperapis oraria* is the asteraceous plant *Balduina angustifolia*. Pollen loads examined from two bees captured on October 6, 2007 revealed only pollen from the known host plant. During the 2007 active season of the bee, the pollen host was far more abundant at all sites visited than it was during the 2006 season.

Carbon sequestration and natural longleaf pine ecosystems (completed)

Funding Source: U.S. Geological Survey, U.S. Fish and Wildlife Service

Principal Investigator: John Kush (Auburn University)

Graduate Student(s): Ram Thapa, John Gilbert, William Whitaker

Student Technicians: Anshu Shrestha, Arpi Shrstha

Duration: July 2003 – September 2008

Forested ecosystems have a significant potential for sequestering large amounts of carbon through land management. To fully realize the potential carbon sequestration capabilities of these ecosystems there is a need to develop strategies and methods for increasing carbon sequestration. A fire-maintained, longleaf pine dominated ecosystem may offer one of the best options for carbon sequestration among the forested ecosystems of the southeastern US while providing habitat for a number of threatened and endangered plant and wildlife species, including red-cockaded woodpeckers, gopher tortoises, indigo snakes, etc … (Hardin and White 1989, Landers et al. 1995, Jackson 1989). Among the southern pines, longleaf may offer the best opportunity for carbon sequestration. It is the longest-living of the southern pines, capable of growing to 500 years (Platt et al. 1988). It will continue to put on growth, even at older ages (West et al. 1993). Products from longleaf pine will sequester carbon longer than most since they are likely to be solid wood products like structural lumber and poles. In addition to the tree itself, a fire-maintained longleaf pine ecosystem supports a productive understory of grasses and herbaceous plants which themselves may offer more carbon storage than the trees. Objectives of the study are: Phase I – Develop a detailed literature review/bibliography of research literature related to longleaf pine, above and below ground biomass, and carbon sequestration; Phase II – Determine the relationships between prescribe fire treatment and above/below ground biomass and carbon sequestration; Phase III – Determine the relationships between root biomass/carbon sequestration and the density, site quality, and age of the longleaf pine overstory.

Status – The season of burn study plots on the Escambia Experimental Forest in Brewton, AL have been extensively sampled to address the status of carbon in the no-burn, spring, summer and winter season prescribed burn plots. Longleaf pine heights and diameters were measured. Longleaf pine biomass was calculated from these measurements using developed weight and volume equations. Herbaceous (forbs and grasses) and woody (tree and vine) vegetation and litter were collected from each plot. The vegetation and litter was oven-dried and weighed. A sub-sample of the dried vegetation from each component from each plot was ground up and analyzed for carbon. The resulting percent carbon was used to calculate the carbon sequestered in each component. Phase II of the study has been completed and the results appear in the master's thesis of Ram Thapa. Phase III has been completed and is reported on in the master's thesis of William Whitaker.

PRODUCTIVITY

Publications

Folk, T.H., Holmes, R.R., Grand, J.B. 2007. Variation in northern bobwhite demography along two temporal scales. Population Ecology. 49:3 (211-219).

Folk, T.H., J.B. Grand, W.E. Palmer, J.P. Carroll, D.C. Sisson, T.M. Terhune, S.D. Wellendorf, H.L. Stribling. 2007. Estimates of Survival from Radiotelemetry: A Response to Guthery and Lusk. Journal of Wildlife Management 71(4):10271033.

Hill, G.E., D.J. Mennill, B.W. Rolek, T.L. Hicks, and K.A. Swiston. 2006. Evidence suggesting that Ivory-billed Woodpeckers (*Campephilus principalis*) exist in Florida. Avian Conservation and Ecology. 1(3):2 http://www.ace-eco.org/vol1/iss3/art2/.

Koons, D.N., Holmes, R.R., Grand, J.B. 2007. Population inertia and its sensitivity to changes in vital rates or initial conditions. Ecology 88(11)2857-2867 Nov. 2007

Miller, D.A., Grand, J.B., Fondell, T.F., and Anthony, R.M. 2007. The Contribution: Optimizing Nest Survival and Female Survival: Consequences of Nest Site Selection for Canada Geese. Condor 109:4(769-780) Nov

Miller, D.A., Grand, J.B., Fondell, T.F., and Anthony, R.M. 2007. The Contribution: Optimizing Nest Survival and Female Survival: Consequences of Nest Site Selection for Canada Geese. Condor 109:4(769-780).

Terhune, T.M., D.C. Sisson, J.B. Grand, H.L. Stribling. 2007. Factors Influencing Survival of Radiotagged and Banded Northern Bobwhites in Georgia. Journal of Wildlife Management 71(4):1288-1297.

Whitaker, B., L. Samuelson. T. Stokes, and J. Kush. 2008. Influence of forest structure on soil respiration in longleaf pine. *In:* Kush, J.S. and S.M. Hermann (comps.), Proceedings of the Third Montane Longleaf Conference. Longleaf Alliance Report 13, pages 71-76.

Sakaris, P.C., E.R. Irwin. 2008 Verification of daily ring deposition in the otoliths of age-0 channel catfish. North American Journal of Fish Management 28:212-218

Publications Pending

Hayer, C-A. and E. R. Irwin. Influence of gravel mining and other factors on detection probabilities of Coastal Plain Fishes in the Mobile River Basin, Alabama. Transactions of the American Fisheries Society.

Irwin, E. R., K. D. M. Kennedy, M. C. Freeman, and J. Peterson. (submitted) Adaptive Management of a Regulated River: A Template for Stakeholder Involvement and Structured Decision Making. Ecology and Society

Sakaris, P. C. and E. R. Irwin. (Accepted pending revision). Application of stochastic models for examining the effects of hydrologic alteration and variable mortality on the population dynamics of lotic fishes in regulated river systems. Ecological Applications xx:xxx-xxx

Irwin, E. R. and J. Hornsby. (Accepted pending revision) Measuring change associated with hydrologic alteration: the Tallapoosa River fish assemblage in 1951 and 1996. Fisheries Management and Ecology.

Irwin, E. R., K. D. M. Kennedy, M. C. Freeman, J. Peterson and B. J. Freeman. (Accepted pending revision). Using Aquatic GAP models to prioritize conservation efforts: a framework. GAP Bulletin 16:xx-xx.

Jolley, J. C. and E. R. Irwin. *In press*. Use of a modified fish health assessment and liver lipid content to describe condition of three catfish species in the Coosa River, Alabama Proceedings of the Southeastern Association of Fish and Wildlife Agencies 61:xxx-xxx.

Hayer, C. A., and E.R. Irwin. 2008. Influence of Gravel Mining and Other Factors on Detection Probabilities of Coastal Plain Fishes in the Mobile River Basin, Alabama. Transactions of the American Fisheries Society 137:1606-1620.

Sakaris, P.C. (60%) and E.R. Irwin . 2008. Verification of daily ring deposition in the otoliths of age-0 channel catfish. North American Journal of Fish Management 28:212-218

Reports

None

Presentations

Grand, J.B, Kleiner, K.K., Vogt, A.M. Decision support tool for birds associated with open-pine ecosystems. 4th International Partner's in Flight Conference, McAllen, TX 13-16 February 2008.

Grand, J.B., Silvano, A.L., MacKenzie, M.D., Lowenstein, E.F. Using GAP data to design and inform field research. National Gap Conference, Asheville, NC. 10-13 September 2007.

Hitch, A.T., Grand, J.B., Allen, S.L. Are Avian Habitat Relationships Estimated from Remotely Sensed Data Applicable on a Regional Scale? 4th International Partner's in Flight Conference, McAllen, TX 13-16 February 2008.

Irwin, E. R. and K. D. M. Kennedy. September 2008. Engaging stakeholders for adaptive management. Interagency Conference on Watersheds. Estes Park, Colorado (Invited).

Irwin, E. R. February 2008. Healthy wetlands-healthy people. Plenary Session. World Wetlands Day, UNA, Heredia, Costa Rica (Invited).

Irwin, E. R. March 2008. Adaptive management of a regulated river: sound science for stakeholders. United States Geological Survey Seminar Series. USGS Headquarters, Reston, Virginia (Invited).

Irwin, E. R. September 2008. Alligator gar conservation: perspectives and future directions. II International Lepistosidae Congress. Heredia, Costa Rica (Invited).

Johnson, C.B. Hitch, A.T., and Grand, J.B. Predicting the occurrence of Brown-headed Cowbirds in northeastern Alabama. 4th International Partner's in Flight Conference, McAllen, TX 13-16 February 2008.

Kennedy, K. D. and E. R. Irwin. September 2008. Using Occupancy Rates of Selected Shoal-Dwelling Fishes to Evaluate Flow Management in the Tallapoosa River Basin. Alabama Water Resources Conference, Orange Beach, Alabama

Kennedy, K.D. and E.R. Irwin. November 2007. Occupancy rates of selected shoal-dwelling fishes in the Tallapoosa River basin. Southeastern Fishes Council Annual Meeting. Chattanooga, Tennessee.

Martin, B. and E.R. Irwin. February 2008. Examination of redbreast sunfish nest survival and spawning behavior below R.L. Harris dam on the Tallapoosa River, Alabama. Alabama Fisheries Association Annual Meeting, Orange Beach, Florida.

Whitaker, B., L. Samuelson, J.S. Kush, and T. Stokes. Influence of Forest Structure on Soil Respiration in Longleaf Pine. 15th Biennial Southern Silvicultural Research Conference, October 17-20, 2008, Hot Springs, AR.

Whitaker, B., L. Samuelson, J.S. Kush, and T. Stokes. Longleaf Pine Forest Structure Influence on Soil Respiration. 7th Longleaf Alliance Regional Conference, October 28-Novembr 2, 2008, Sandestin, FL.

Whitaker, B., L. Samuelson, T. Stokes, and J. Kush. Influence of Forest Structure on Soil Respiration in Longleaf Pine. Third Montane Longleaf Conference, March 11-12, 2008, Auburn University, AL.

Graduate Theses and Dissertations

Thapa, R. 2008. Biennial seasonal burning and hardwood control effects on the carbon sequestration in a natural longleaf pine ecosystem. Master's thesis, Auburn University. 100 pp.

Invited Lectures

None

Outreach/Technical Assistance

Dr. Grand

East Gulf Coastal Plain Joint Venture Management Board. Longleaf decision support tool update. Charleston, WV October 2007.

Presentation to Coordinator of America's Longleaf Initiative and the Director of the Longleaf Alliance. A decision support tool for open pine habitats in the East Gulf Coastal Plain. Auburn, AL January 2008.

Presentation to Coordinator of America's Longleaf Initiative and the Director of the Longleaf Alliance. A decision support tool for open pine habitats in the East Gulf Coastal Plain. Auburn, AL January 2008.

East Gulf Coastal Plain Joint Venture Longleaf Workshop. Longleaf decision support tool review and ground work for additional tools. Mobile, AL May 2008.

Provided assistance using the EGCP JV Decision Support Tool for Open Pine Ecosystems to the Alabama Partners for Wildlife proposal evaluation team. Teleconference July 2008

Presentation to Focal Areas working group at Longleaf Charrette organized by America's Longleaf Initiative. A decision support tool for open pine habitats in the East Gulf Coastal Plain. Auburn, AL March 2008.

Provided assistance using the EGCP JV Decision Support Tool for Open Pine Ecosystems to the ADCNR Landowner Incentives Program coordinator June 2008.

Presentation to USFWS Daphne Field Office Staff. A decision support tool for open pine habitats in the East Gulf Coastal Plain. Auburn, AL July 2008.

Dr. Irwin

May 2008. At the request of the Nature Conservancy I engaged in discussions relative to fish passage on the lower Alabama River. A working group has been formed and I will be actively involved in future work by the group.

International Activities

Dr. Irwin

February 2008-Traveled with Auburn University delegation to the National University of Costa Rica (UNA) to discuss opportunities for collaboration. Interacted with scientists at UNA who are interested in conservation and management of tropical gar.

September 2008-Attended the II International Gar Congress in Heredia, Costa Rica and presented paper in Plenary session.

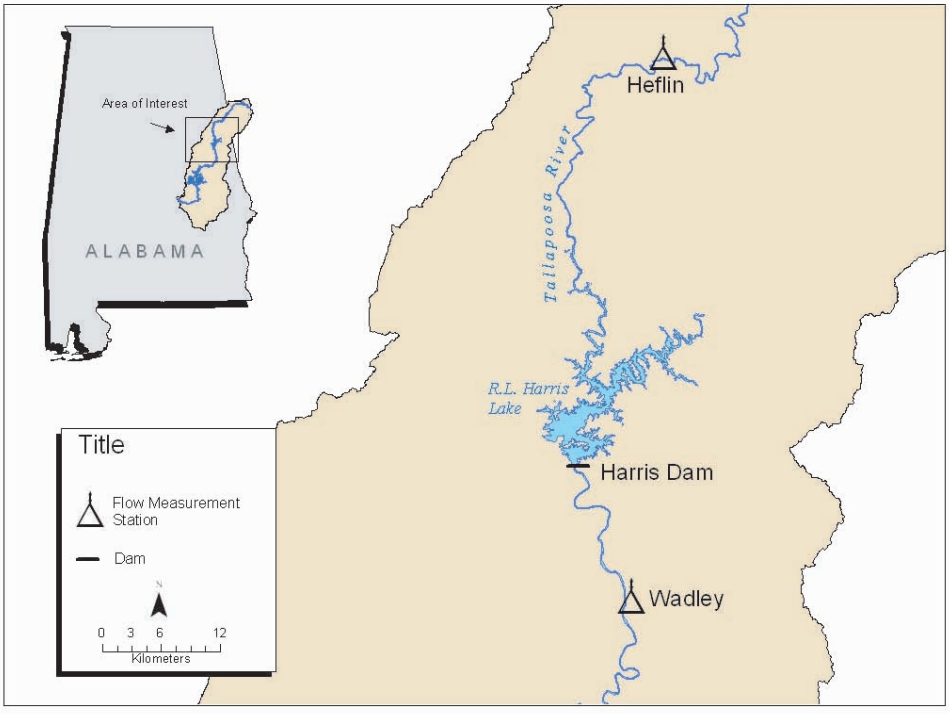
Teaching

Dr. Grand

Summer 2008 – Directed Study: Conservation Design

Spring 2008 – Special Problem in Wildlife Science: MATLAB programming for Biologists


U.S. Fish & Wildlife Service
Wheeler National Wildlife Refuge
Limestone, Madison, and Morgan Counties, Alabama
Management Boundary for Wheeler NWR
Whiteside
Mooresville
Decatur
Triana
Priceville
Flint City
Legend
Local Cities
Wheeler NWR Management Boundary
Redstone Arsenal Military Installation


Area of Interest
ALABAMA
Heflin
Tallapoosa River
R.L. Harris Lake
Harris Dam
Wadley
Title
Flow Measurement Station
Dam
0 3 6 12
Kilometers