Title: Quantification of hydrologic alteration and relationships to biota in Arkansas streams: Development of tools and approaches for un-gaged streams

Project Summary: Providing adequate water quantity and quality in streams and rivers is a pressing issue in Arkansas and worldwide. For this reason, it is crucial to determine appropriate flows in streams to protect fish and wildlife needs (environmental flows). A crucial component of determining environmental flows is determining hydrologic alteration. Additionally, the ability to determine hydrologic alteration for sites where discharge data does not exist (i.e. un-gaged sites) is crucial to examining environmental flows for most streams in Arkansas and the U.S. Currently, only a small portion of existing biological data are from stream sites where USGS stream gages are in operation, making it difficult to relate stream flow and flow alteration to biological communities. We propose initiating a project with the goal of determining hydrologic alteration at un-gaged stream sites. Knowledge of hydrologic alteration at un-gaged stream sites will allow us to, 1) map flow alteration throughout Arkansas, 2) relate flow alteration to biological data at multiple spatial scales and for multiple stream types and sizes, and 3) relate flow alteration to land use/land cover. Flow alteration will be assessed at all sites statewide for which suitable biological community data exists allowing specific degrees and types of flow alteration to be associated with biological communities. This flow alteration assessment tool will be applied to the Little Red River drainage to provide information relevant to the conservation of this ecologically sensitive drainage. The flow alteration tool will also be available for future flow alteration assessments at any stream site in the state. This proposal adds an important component to our current research in which we have completed a statewide hydrologic classification of rivers (Figure 1), as well as conducting aquatic community sampling at sites within a single flow class and ecoregion, in order to develop ecological-flow relationships within a portion of the Ozarks. Products of this study will form the scientific framework for setting environmental flow standards and understanding impacts of global climate change. This work will positively impact many species and ecosystems statewide, those of greatest conservation need and otherwise.

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Total SWG Funding Requested: $63,000
Total Project Cost: $126,720
Amount and Source of Matching Funds or In-kind Services: $63,720

$28,000 graduate student tuition, University of Arkansas
$27,720 indirect cost, University of Arkansas
$ 8,000 computers and supplies, University of Arkansas

Funding priorities addressed:

- Project that addresses the need to determine and validate environmental flows for one or more of the water regions within Arkansas
- Project that has potential to impact all aquatic SGCN

Ecobasin targeted: Statewide and Little Red River drainage

Need

Providing adequate water quantity and quality in streams and rivers is vital and viewed as a top environmental priority by many global organizations, yet determining adequate levels is often difficult. Water quantity and quality can be impacted by many anthropogenic and natural factors, such as resource development (e.g. natural gas extraction), impoundment, irrigation and drought. Water use in Arkansas and worldwide has increased steadily in the past 50 years (Holland 2007). Flows of water in streams and rivers affect freshwater organisms and ecosystems, but the relationship between them is often little studied and poorly known. Knowledge of the timing, duration, and magnitude of flows needed to maintain particular organisms or ecosystem structure and function (environmental flows) would allow managers and conservation biologists to conserve Arkansas' high quality freshwater resources. Additionally, climate models predict temperatures and extreme precipitation events will increase in Arkansas (Diffenbaugh et al. 2005), so determining environmental flows would allow researchers and managers to assess potential impacts of climate change on stream organisms or ecosystem structure and function (Xenopoulos et al. 2005).

Many approaches are available for determining environmental flows, but most recent approaches recommend examining hydrologic alteration and relating that to biota (Poff et al. 2010). Approaches for determination of hydrologic alteration also vary, and range from expert judgement to indices to estimates of specific flow metrics (Carlisle et al. 2010). A solid estimate of hydrologic alteration is crucial to effectively determining relationships between biota and flow alteration, and ultimately what environmental flows should be. Carlisle et al. 2010 have developed an effective approach to estimating hydrologic alteration using historical stream gage data. Unfortunately, most streams are un-gaged, and therefore unavailable for determination of hydrologic alteration.

Therefore, we propose initiating a project with the goal of determining hydrologic alteration at un-gaged stream sites. Knowledge of hydrologic alteration at un-gaged stream sites will allow us to, 1) map flow alteration throughout Arkansas, 2) relate flow alteration to biological data at multiple spatial scales and for multiple stream types and sizes, and 3) relate flow alteration to land use/land cover. This proposal adds an important component to our current research in which we have completed a statewide hydrologic classification of rivers (Figure 1), as well as conducting aquatic community sampling at sites within a single flow class and ecoregion, in order to develop ecological-flow relationships within a portion of the Ozarks.

Objectives

1. Develop the capability to predict *natural* flow conditions in the absence of daily discharge data. *Natural* flow conditions would be expected in the absence of anthropogenic flow alteration.

2. Develop the capability to predict *actual* flow conditions in the absence of daily discharge data. Flow alteration will be quantified as the ratio of *actual* flow to *natural* flow.
3. Quantify hydrologic alteration in streams with existing biological community data and establish key relationships between flow alteration and the integrity of stream communities.
4. Assess potential biological impact of hydrological alteration for streams of conservation interest, such as the Little Red River.

Approach

Objective 1

Our ongoing research has identified 67 reference streams—with stream flow gages—within the project area that represent least-disturbed hydrologic conditions, based on the Hydrologic Disturbance Index (Falcone *et al.* 2010). A suite of flow metrics were identified that best characterized the flow regimes of each type of stream in the study area using the procedure of Olden and Poff (2003) to ensure that various important aspects of the flow regime were taken into account including magnitude, duration, frequency, timing, and rate of change of stream flows. A subset of 10-15 flow metrics will be selected from this suite of flow metrics to be used in flow alteration assessments described herein. This subset of 10-15 metrics will be used to describe *natural* flow conditions at our 67 reference streams. GIS data will be used to characterize non-anthropogenic basin characteristics of reference streams such as catchment area, topography, soil conditions, and climate using an automated multi-scale GIS data collection tool being developed by us at the University of Arkansas. Predictive "random forest" models will be developed for each flow metric to predict *natural* flow conditions based on non-anthropogenic landscape characteristics (as in Carlisle *et al.* 2010). These predictive models will be applied to un-gaged streams to provide estimates of expected flow conditions in the absence of anthropogenic flow alteration.

Objective 2

The procedure described for Objective 1 will be repeated using *all* gaged streams in the project area, rather than only least-disturbed streams. This will include the Mississippi Alluvial Plain and Crowley's Ridge ecoregions of Arkansas, which were excluded from previous work due to a lack of reference streams with gages. Inclusion of these ecoregions in the current project will facilitate quantification of hydrologic alteration in these significantly altered agricultural landscapes, which is a priority for management of the state's water resources. GIS data will be used to characterize basin characteristics of these streams, including both anthropogenic and non-anthropogenic characteristics such as catchment area, topography, soil conditions, and climate, but also urbanization, water withdrawals, dams, water discharge sites, population, and road density. Predictive "random forest" models will be developed for each flow metric to predict *actual* flow conditions at un-gaged streams based on basin characteristics (both anthropogenic and non-anthropogenic). These predictive models will be applied to un-gaged streams to provide estimates of expected flow conditions in the presence of anthropogenic flow alteration.

To assess flow alteration at an un-gaged site, the model from Objective 1 will be used to predict the expected *natural* flow conditions for each of the 10-15 selected flow metrics. Then, the model from Objective 2 will be used to predict the expected *actual* flow conditions for each

flow metric. Flow alteration will then be quantified for each flow metric as the ratio of *actual* to *natural* flow predictions.

Objective 3

The Arkansas Department of Environmental Quality provides archived biological community data from their Aquatic Macroinvertebrate Database and their Fish Collection and Habitat Data Files (ADEQ 2013). The National Water Quality Assessment (NAWQA 2013) data warehouse and Arkansas Aquatic GAP Project also provide access to similar archived data. We will collate this aquatic biological community data and identify sites within our study area from among which metrics of biological community structure can be compared. Potential community metrics include species richness, species diversity, presence of indicator species, etc. and will be selected depending on availability of suitable data. Flow alteration will be quantified using the approach described in Objectives 1 & 2 (*i.e.* actual flow / natural flow) for every site with suitable biological data. Degree of flow alteration will be statistically related to selected metrics of biological community structure. Significant statistical relationships will be interpreted in terms of how flow alteration of specific types and degrees will likely impact Arkansas stream communities.

Objective 4

Flow alteration will be quantified at sites of particular conservation concern such as the Little Red River. Flow alteration found at these sites will be discussed in terms of relationships between flow alteration and aquatic community structure from Objective 3. Findings will be used to provide information for managing water resources in these ecologically sensitive streams.

Expected Results and Benefits

Results from this work will provide the scientific foundation for ultimately producing environmental flow standards within Arkansas. Developing methods to determine hydrologic alteration in un-gaged streams will dramatically improve our ability to examine issues of flow alteration in Arkansas, particularly in areas that have been heavily modified such as the Arkansas delta region. Relationships developed in these objectives can then form the basis for setting state and regional environmental flow standards and understanding impacts of climate change. This work will positively impact many species and ecosystems statewide, those of greatest conservation need and otherwise. Information for this study will also be useful for dealing with water use issues, such as those from natural gas development.

Principal investigator and students will share information from this project via manuscripts, dissertations, presentations at local to international meetings, and updates of the Arkansas Wildlife Action Plan. As part of this project we will add data to the National Monitoring Partnership database, and we will add the project to the Arkansas Portal in the Conservation Directory. Finally, we will provide annual progress reports and a final report after the completion of the project.

Budget

State Wildlife Grant Input: $63,000
Total Project Match: $63,720

Total Project cost: $126,720

Requested SWG Funds	2013	2014
Salary/Benefits	$25,000	$25,000
Operating Expenses		
Report publication costs		10,000
Capital Expenses	$3,000	
Subtotals	$28,000	$35,000
TOTAL	**$63,000**	

Project Leader

Dr. Daniel D. Magoulick - Assistant Unit Leader/ Professor, USGS, Arkansas Cooperative Fish and Wildlife Research Unit, Department of Biological Sciences, University of Arkansas 2000-present
Ph.D. in Ecology from University of Pittsburgh – 1994
Author of 32 peer-reviewed scientific publications

Previous SWG Grants

Arkansas Game and Fish Commission. Magoulick, D.D., S. Longing, J.W. Quinn, J. Jackson, J. Duzan and J. Petersen. 2011-2014. Classification of Arkansas flow regimes, regional ecological-flow response relationships and environmental flows assessment for the Ozark region. $172,000.

Arkansas Game and Fish Commission. Magoulick, D.D. 2005-2007. Effect of the introduced crayfish, *Orconectes neglectus*, on native crayfish in the Spring River drainage. $68,390.

Project Partners

Douglas R. Leasure, Ph.D. student, Department of Biological Sciences, University of Arkansas
Expertise in GIS and ecology

Recent Related Publications

Hodges, S.W. and D.D. Magoulick. 2011. Refuge habitats for fishes during seasonal drying in an intermittent stream: movement, survival and abundance of three minnow species. Aquatic Sciences 73:513-522.

Ludlam, J.P. and D.D. Magoulick. 2010. Environmental conditions and biotic interactions influence ecosystem structure and function in a drying stream. Hydrobiologia 644:127-137.

Dekar, M.P., D.D. Magoulick and G.R. Huxel. 2009. Shifts in the trophic base of intermittent stream food webs. Hydrobiologia 635:263-277.

Scott, M.K. and D.D. Magoulick. 2008. Swimming performance of five warmwater stream fish species. Transactions of the American Fisheries Society 137:209-215.

Dekar, M.P. and D.D. Magoulick. 2007. Factors affecting fish assemblage structure during seasonal stream drying. Ecology of Freshwater Fish 16:335-342.

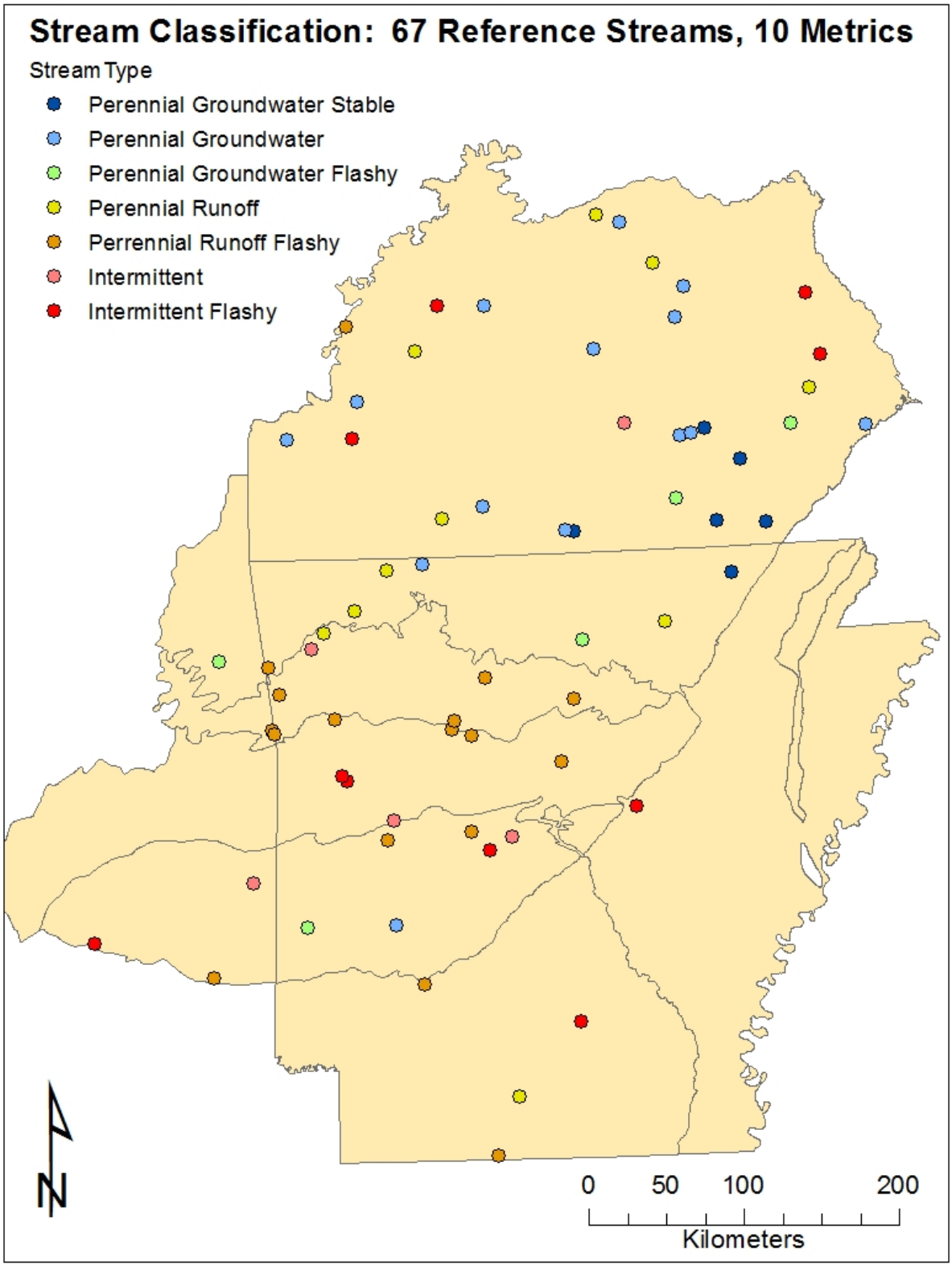

Figure 1. Flow classes in Arkansas and surrounding region for 67 reference gages with >15 years period of record. Class determinations were done using a Gaussian mixture model clustering algorithm based on 10 hydrologic metrics related to magnitude, frequency, duration, timing and rate of change.