GEO-ECOLOGICAL MODELING OF RIVERINE HABITAT OCCURANCE
AND NUTRIENT RETENTION

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Amount Requested: $32,000 Project Duration: two years (6/15/13-6/14/15)

1. INTRODUCTION

The U.S. EPA has identified accelerated nutrient (phosphate and nitrogen) loading and loss of aquatic habitat as the two primary causes of river impairment in the United States, with **55% of U.S. rivers and streams incapable of supporting healthy aquatic life due to the presence of excess nutrients and/or excess sediment** (EPA, 2013). Because the number of rivers affected by non-point source nutrient contamination is so large, improving the biological integrity of American waterways requires research that can be applied at regional and continental scales, which coupled geospatial-ecological models are uniquely able to achieve. Due to this pressing need for regional to continental-scale models to address water quality issues, modeling has become an increasingly requested component of many of the current grant competitions in Biological and Geosciences NSF directorates. Thus, this proposal requests funds for the development of a model that addresses nutrient retention in rivers, and highlights the importance of habitat frequently lost to river regulation. The funds we request here are critical to successfully competing for larger, external competitions in the future. Our ideas progressed from several synergistic activities amongst team members:

- The awarding of a UA research stimulation 2-year postdoctoral grant to our team in January, 2013, for the explicit purpose of addressing the objectives listed below. The post-doc fellow will arrive at UA this fall, 2013. The award only covers the cost of the post-doc salary.
- A manuscript in press in *Ecology* that was co-authored by Jennifer Edmonds (Dept. of Biology) and Behzad Mortazavi (Dept. of Biology) measuring microbial N retention in the Cahaba River.
- Work by two Davis graduate students (Edmonds and Cohen serving as committee members) exploring geologic constraints on Cahaba River shoal formation, and fine sediment transport and storage associated with plant growth.

2. STATEMENT OF RESEARCH OBJECTIVES

The proposed research has two objectives to be completed initially in the Cahaba River, AL: (1) developing a geomorphic numerical model using geospatial technology to understand and predict bedrock shoal formation and occurrence (Fig. 1) and, (2) integrating the geomorphic numerical model with in-channel measurements of nitrogen (N) retention both within the shoals and Coastal Plain river portions.

3. SUMMARY OF RESEARCH DESIGN AND RESPECTIVE FACULTY CONTRIBUTIONS

Objective 1: Within this objective we will first develop a geo-spatial model that predicts the occurrence of shoal habitat in the Cahaba River (Fig. 1). Bedrock shoals are renowned for their biodiversity (Argentina et al 2010, Davenport 1996, Lydeard et al 2004), but

Figure 1. (below) Aerial photograph of run-shoal complex in the Cahaba River. (right) Ground-level pictures of *Justicia americana* in shoals.

despite being such biologically rich areas worthy of conservation, existing research, of which there is very little, has been limited to the formation of alluvial shoals (Duncan et al., 2009). To date, no one has ever completed work on bedrock shoal formation or the ecosystem services (such as excess nutrient removal) they provide. Davis and her student recently developed a statistical model capable of correctly predicting the location of bedrock outcroppings that form shoals in the Cahaba River with 96% accuracy based on rock strike and its orientation relative to streamflow direction and rock integrity (Bishop, 2013). Davis is currently working with her students to measure sub-meter scale geologic and geomorphic factors including (a) the influence of rock void space available for root development on macrophyte patch density and (b) sediment trapping by shoal macrophytes. Davis and students are also currently making system-wide measurements of rock dip to examine its effect (if any) on shoal width, which could influence patch density. Summer graduate student support is requested to help complete this portion of the research, which will not only support the geophysical portion of the model but will also aid in the biogeochemical characterization of the shoals. Edmonds' lab found a direct correlation between the ability of shoal plants to encourage N retention and the density of the rooting zone of a plant patch, therefore relationships found between rock void space, sediment trapping, and macrophypte density will be directly linked to N retention in the shoals through our computer modeling.

Dr. Cohen will work with Davis and the post-doc to build a computer model predicting bedrock shoal occurrence for the Cahaba River, eventually applying it in other watersheds to identify shoal habitat, both current and former, in rivers across the eastern U.S. **Modeling shoal distribution would broaden our appreciation of the habitat loss due to damming, as well as suggest possible habitat and ecosystem services that could be gained from dismantling old dams on rivers with geomorphologic and geologic conditions favoring shoal formation.** This modeling effort would also include quantifying the distribution of *Coastal Plain* river habitat, as previous work by Edmonds and Mortazavi (Tatariw et al 2013) found fine benthic sediments in these rivers were "hot spots" of nitrogen (N) retention via denitrification (conversion of nitrate to N_2 (g) by microbes), and therefore important for evaluating linkages between geomorphic structure and excess nutrient removal in large river ecosystems (Obj. 2). Funds are requested for a mid-range computer for the new post-doc and geospatial software packages essential for completing this goal.

Objective 2: Objective 2 will focus on the biological implications of variation in geomorphic structure in the Cahaba River, to link N retention to changes in geomorphology as rivers move from the Valley and Ridge physiographic province onto the Coastal Plain. Drs. Mortazavi and Edmonds will guide the design and implementation of this work, comparing several important N retention processes mediated by microorganisms in both shoal and Coastal Plain river sediments using stable isotope (^{15}N) tracers

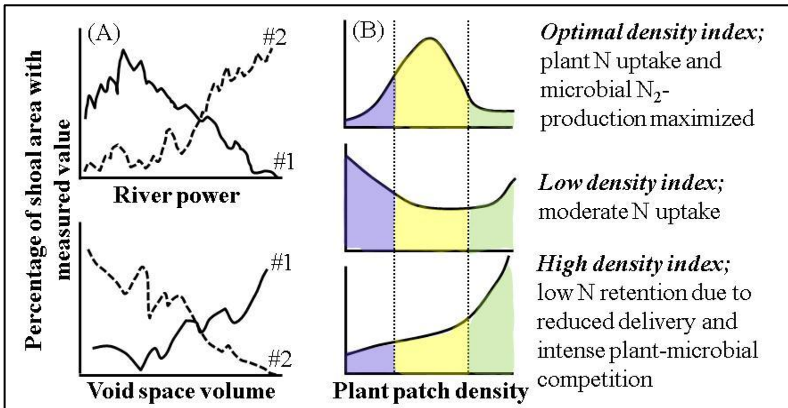

Figure 2. Y-axis is identical in (A) and (B). (A) Hypothetical distributions of void volume and river power in 2 contrasting shoals, conditions in shoal #1 are hypothesized to generate greater plant patches of higher density as compared to shoal #2 (B) Hypothetical variations in plant density distributions (used to calculate a Density Index) between 3 shoals; purple indicates patches with moderate N retention capabilities, yellow indicates optimal patch density at which N retention by plants and microbes is maximized, and green indicates high density patches that have low N retention capacity.

added to intact sediment cores to determine rates of N removal. The movement of ^{15}N between inorganic, organic, and gaseous forms would be determined within the intact sediment cores using a mass inlet mass spectrometer (MIMS) housed in Dr. Mortazavi's laboratory at Dauphin Island Sea Lab (DISL). The goal is to develop empirical relationships (i.e., Fig. 2) that would inform our modeling efforts, linking geomorphic structure and N removal in rivers. Funds are requested for lab supplies to conduct these analyses.

To scale up our conceptual ideas on N-retention capacity of the Cahaba River stretching from Helena, AL, to its junction with the Alabama River (~200 river kilometers), we are requesting CFS funds to purchase a self-contained YSI sensor that can be deployed in the field to measure several water chemistry parameters simultaneously (nitrate, chlorophyll a, turbidity, temperature, and conductivity). Large-scale changes in water chemistry along the river can then be measured in "real-time" to allow us to look for spatial and temporal patterns suggesting nutrient retention mechanisms functioning at this large spatial scale. **This is a unique opportunity for ecological processing along the river to be "scaled up" such that funding agencies can better appreciate the broader importance of this work, and increase our ability to earn grants.** Funds are requested to increase the impact of this research through conference presentations and publications.

4. EXTERNAL FUNDING OPPORTUNITIES STRENGTHENED

- An NSF proposal will be submitted in July, 2013, to the Geomorphology Landuse Dynamics program. This CFS funding would decrease the budget request for this proposal by covering a portion of the equipment costs, making the proposal more competitive. ***$450,000***
- An NSF pre-proposal will be submitted to the Ecosystems Panel for co-review by Geography Spatial Science in Jan., 2014. Full proposal submissions in July, 2014. CFS funding would allow us to collect additional data for inclusion, making our submission more competitive. ***$700,000***

5. BUDGET AND BUDGET JUSTIFICATION

$13,000	YSI data sondes, which includes a five port sensor platform for measuring water column nitrate, conductivity, temperature, pH, chlorophyll a, and turbidity. Cost also includes calibration/storage chamber, maintenance kit, power pack, weight kit, and 50-foot cable.
$6,893	Funds to support a masters student for four months (15 June-15 Aug, 2013 & June, July 2014). Salary will be $1,600/month with fringe at 7.7% x salary ($555 for 4 months).
$3,000	Computer for the new post-doc, including a 2.9GHz Quad-core Intel Core i5, 16GB 1600MHz DDR3 SDRAM, 3TB Serial ATA Drive @ 7200 rpm, and a time capsule 3TB
$1,000	Computer software (MATLAB, Adobe Illustrator and Photoshop, Microsoft Visual Studio)
$5,000	Travel funds for the post-doctoral fellow to attend the annual meeting of the American Geophysical Union (AGU) in San Francisco, and a second meeting at a more ecology-focused meeting (ASLO, ESA, or SFS). Total of 3 meetings for two years.
$3,107	Supplies for water chemistry and MIMS analyses. Includes facility costs for water chemistry parameters, as well as stable isotope measurements at an off-campus facility. Will also cover costs for reagents, sampling containers, gas tanks for the instruments, etc.

6. RESEARCH TIMELINE

	Summer 2013	Fall 2013	Spring 2014	Summer 2014	Fall 2014	Spring 2015	Summer 2015
Objective 1 data collection	■	■	■				
Objective 2 data collection			■	■	■		
Meeting presentations				■	■		■
Model development		■	■	■	■	■	■
Proposal submission	■		■	■			

7. REFERENCES CITED

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