BIOGEOGRAPHY SPECIALTY GROUP
2006 GRADUATE STUDENT RESEARCH GRANT COMPETITION

COVER SHEET

Name of Applicant: Scott Markwith

Department: Geography

University: University of Georgia

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University of Georgia
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The proposed study is for (circle one): Doctorate

Anticipated date of graduation: May 2007

Title of project: Application of Hydrologic Modeling for Investigating Hydrochory in the Aquatic Macrophyte *Hymenocallis coronaria*.

Amount requested: $700.00

I am a student member of the AAG (yes/no): Yes

Signature of Applicant:

Date: January 15, 2005

Proof of student eligibility:
I certify that the applicant is currently a graduate student under my supervision and that the proposed project is part of her/his thesis research.

Name of Advisor: Kathleen C. Parker Signature:

Or if submitting by e-mail, Advisor's e-mail address: kcparker@uga.edu

Application of Hydrologic Modeling for Investigating Hydrochory in the Aquatic Macrophyte *Hymenocallis coronaria*

Introduction

Because water movement, the primary seed dispersal agent for many aquatic plants, is unidirectional throughout upland drainage basins, models of gene flow based on terrestrial environments, where seed dispersal is often multidirectional, are likely inadequate for representing patterns of gene flow in aquatic plants. Few studies, however, have investigated the influence of unidirectional stream flow on patterns of genetic variation in aquatic plants; and these studies have reported contradictory results (Ritland, 1989, and Gornall et al., 1998). My dissertation research has largely focused on examining hypotheses concerning gene flow in the aquatic macrophyte *Hymenocallis coronaria*, commonly known as the Shoals spider-lily and Cahaba-lily. One of the tested hypotheses, Ritland's (1989) unidirectional gene flow hypothesis, states that population genetic diversity should increase in each subsequent downstream population as the effective population size increases. As with Ritland's (1989) own findings, my research shows little evidence of increasing genetic diversity along stream courses. The analyses also indicate that the relationship of gene flow to geographic distance between populations of *H. coronaria* does not reflect the expectations of a one-dimensional stepping stone model (Slatkin, 1993). Gene flow between populations found along a river course may approximate a one-dimensional stepping stone model because seeds may move from upstream populations to the next downstream population and so on down the river course in a stepwise fashion.

Population and genetic processes other than gene flow, such as metapopulation processes, selection, or drift, may account for the discrepancy with expectations; however, a lack of stream mediated gene flow may be partially responsible for the observed patterns. Unlike many aquatic plants, the seeds of *H. coronaria* are known to sink (Davenport, 1990, and pers. observation); thus, hydrochory, or the movement of seeds by water, cannot be assumed. Neither Ritland (1989) nor Gornall et al. (1998) actually investigated the efficacy of streams to physically transport and deposit seeds or vegetative matter because the plant matter in question was known to float. Considering the seed morphology of *H. coronaria*, coupled with genetic results inconsistent with unidirectional gene flow, drawing conclusions on the influence of unidirectional stream flow without considering the potential for hydrochory in this species would be spurious.

Because *H. coronaria* only inhabits rocky river shoals, for a gene flow event to occur seeds must be transported through an entire riffle-pool-riffle sequence in order to reach the next downstream habitat. Seeds of *H. coronaria* rupture their relatively hard capsule when mature; the softer and more vulnerable integument is exposed to the environment; and the seed germinates in approximately three weeks. These characteristics, susceptibility to damage and quick germination, leave transport of seeds as bed-load doubtful, and movement as suspended load a likely requirement. Often velocities at mean discharge are not sufficient to maintain seed suspension within shoals. Since pools are areas of relatively low velocity under normal flow conditions seeds may not be suspended and transported through the entire pool. Consequently many questions remain about the dynamics of seed dispersal in this aquatic macrophyte.

Study Objectives

This project will use techniques and analyses common to fluvial geomorphology in order to examine the potential for hydrochory within three of the four streams, the Cahaba, Flint, and Savannah Rivers, where populations were sampled for the unidirectional gene flow analysis. Stream cross section surveys and stream flow modeling will be used to determine whether stream velocities are capable of transporting seeds of *Hymenocallis coronaria* through an entire riffle-pool-riffle sequence, and under what flow conditions these velocities may be reached. Specific questions to be addressed include: 1) What is the necessary stream velocity to maintain suspension of *H. coronaria* seeds, 2) What stream discharges are necessary to maintain these stream velocities through the entire reach in each stream, 3) What are the return intervals of these discharges, and 4) Have similar discharges historically occurred during the mid-summer when the seeds are mature?

Research Methodology

A sample of 5 seeds will be collected at each shoal, for a total of 10 seeds per riffle-pool-riffle sequence. Settling velocity will be determined by applying Stokes Law of Sedimentation (Stokes, 1851), as described in Gee and Bauder (1986). The variables needed for the equation are particle (seed) diameter and density. The weight (g) of each seed, its diameter (mm), and length (mm) will be measured in the field and the seeds returned to the location in which they were found. For the density equation, volume will be calculated based on the equation for a spheroid, which approximates the seed shape. For a seed to remain suspended the horizontal flow velocity must be greater then the settling velocity, so the minimum horizontal flow velocity will be calculated based on settling velocity.

Cross sections will be surveyed at three riffle-pool-riffle sequences that support populations in both the upstream and downstream shoals, one sequence each in the Cahaba, Flint, and Savannah Rivers. At each shoal one cross section will be surveyed, using a total station, from floodplain terrace to opposite terrace at the upstream end, and one at the downstream end. Cross sections will be surveyed at the upstream end, downstream end, and the middle of each pool. Data will be entered into HEC-RAS and flows modeled for each riffle-pool-riffle sequence in the three streams to determine the discharge necessary to sustain flow velocities through the entire reach length that will maintain seed suspension of the fastest and slowest sinking seeds in each stream. The return intervals of such flows will be calculated concurrently.

Seeds of *H. coronaria* mature in mid-summer, late July to early August, a period in the southeastern U.S. characterized by late afternoon thundershowers. This period is typically devoid of sustained or significant rain events. However, hurricanes can cause significant stream flows, and August is the month when tropical activity increases. Gaging station records from the three streams, accessible through the USGS webpage, will be examined for evidence of flows approaching or exceeding those necessary for seed flow during the seed maturation period.

Significance

This research is significant to understanding not only processes affecting gene flow within the species of interest, but those affecting gene flow within the freshwater aquatic environment as a whole. These questions have primarily been approached with population genetics and observation of floating seeds. The use of hydrologic modeling introduces a valuable new technique for addressing fluvial biogeographic questions concerning gene flow and subsurface hydrochory. The results will help clarify which aspects of existing genetic structure and gene flow hypotheses should be revisited to more accurately reflect processes in natural stream systems. Because genetic analyses do not support the hypotheses, evidence of effective hydrochory would indicate that the existing models concerning genetic structure and diversity in freshwater streams need adjustment or replacement to account for the incorporation of metapopulation or other processes. The absence of hydrochory leaves only zoochory, or the movement of seeds by animals, as the dominant seed flow mechanism. Thus, gene flow models applied to terrestrial systems, i.e. two-dimensional models, may also be applicable to stream systems under circumstances of similar plant and propagule morphology.

Determining the ability of streams to transport seeds of this species is important in two additional ways. First, like many other freshwater species, damming has significantly altered the flow environment in which *Hymenocallis coronaria* lives. Proper management of human induced flow disturbances for the viability of this species, and other aquatic organisms, is contingent on knowledge of the role stream flow plays in gene flow. Understanding whether stream flow permits hydrochory will provide an indication of the type of flow management needed on dammed streams to avoid imposing population isolation. Second, measurement of seeds and hydrologic conditions of a number of streams will provide data for the analysis of hydrologic selection pressures on seed size, mass, and density. Although selection analysis is not expressed as a main objective, the results could be of further importance in management considerations, and to the general understanding of evolutionary pressures in the stream environment.

References

Gee, G. W., and Bauder, J. W. 1986. Particle size analysis. In "Methods of Soil Analysis: Part 1, Physical and Mineralogical Methods, Second Edition" (A. Klute, Ed.), pp. 383-411. Soil Science Society of America, Madison, Wisconsin.

Gornall, R. J., Hollingsworth, P. M., and Preston, C. D. 1998. Evidence for spatial structure and directional gene flow in a population of an aquatic plant, *Potamogeton coloratus*. *Heredity*, vol. 80, p. 414-421.

Davenport, L. J. 1990. The cahaba lily. *Alabama Heritage*, no. 16, p. 24-29.

Ritland, K. 1989. Genetic differentiation, diversity, and inbreeding in the mountain monkey-flower (*Mimulus caespitosus*) of the Washington Cascades. *Canadian Journal of Botany*, vol. 67, p. 2017-2024.

Slatkin, M. 1993. Isolation by distance in equilibrium and nonequilibrium populations. *Evolution*, vol. 47, p. 264-279.

Stokes, G. G., 1851. On the effect of the lateral friction of fluids on the motion of pendulums. *Transactions of the Cambridge Philosophical Society*, vol. 9, p. 8-106.

Budget

Travel:

Athens to Savannah River reach – 246 miles round trip – 2 cars	$238.62
Athens to Flint River reach – 284 miles round trip – 2 cars	$275.48
Athens to Cahaba River reach – 510 miles round trip – 1 car	$247. 35
Total Travel Costs:	$761.45

$700.00 is being requested from the Biogeography Specialty Group Graduate Student Research Grant Competition in order to pay for travel costs associated with field research for this project. The standard used by the University of Georgia is $0.485 per mile, which is based on the U.S. federal government standard. The cost of travel to each study location is based on this mileage standard, and reflects the use of either one or two cars for travel, depending on stream access. Two cars are needed at the Savannah and Flint River sites because a canoe must be used. Thus, one car will be driven to the take-out and one to the put-in location. At the Cahaba River location a dirt road along the floodplain provides access, and only one car will be required.

Work Schedule

	06						**07**	
Tasks	**J**	**A**	**S**	**O**	**N**	**D**	**J**	**F**
1	x	x						
2			x	x				
3					x	x	x	x

Project Period: July 15, 2006 through February 28, 2007

Key to tasks:

1. Field work, sample seeds and measure settling velocity and cross sections
2. Stream modeling and gaging station record examination
3. Write up results and submit manuscript

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A. Professional Preparation:

Ph.D. Geography, University of Georgia, In progress, anticipated degree May 2007.
M.S. Geography, University of Georgia, 2001.
B.A Geography, University of Mary Washington, 1997.

B. Teaching Appointments:

Instructor: Introduction to Landforms, University of Georgia, Fall 2004-Present.
Teaching Assistant: Resources and the Environment Discussion Lab, University of Georgia, Fall 2000-Spring 2001, Fall 2003-Spring 2004, Summer 2005.
Teaching Assistant: Physical Geography Lab, University of Georgia, Spring 2003.
Teaching Assistant: Weather and Climate Lab, University of Georgia, Fall 2002.

C. Publications:

Markwith, S.H., Stewart, D.J., and Dyer, J.L. (In press). TETRASAT: A program for the population analysis of allotetraploid microsatellite data. Molecular Ecology Notes.
Markwith, S.H. and Scanlon, M.J. (In press). Characterization of six polymorphic microsatellite loci isolated from *Hymenocallis coronaria* (J. LeConte) Kunth (Amaryllidaceae). Molecular Ecology Notes.
Markwith, S. H. and Parker, K. C. 2003. Regenerative Response of a Southern Appalachian Forest to Surface Wildfire and Canopy Gap Disturbances. Southeastern Geographer, vol. 43, no. 1, p. 54-75.

D. Honors and Awards:

Georgia Commissioner of Agriculture Award for Best Presentation in the Biological Sciences Division, Georgia Academy of Sciences Annual Conference, 2004.
Southeastern Geographer Outstanding Article Award, 2003.
Master's Research Honors Competition Winner, Southeastern Division of the Association of American Geographers, 2002.
Cum Laude, University of Mary Washington, 1997.
Gamma Theta Upsilon, National Geography Honor Society, University of Mary Washington, 1997.
Phi Gamma Mu, National Social Sciences Honor Society, University of Mary Washington, 1997.
President's List, University of Mary Washington, 1996.

E. Grants:

University of Georgia Graduate School Travel Grant, 2005. $500.00
National Science Foundation, Geography and Regional Sciences Program, Doctoral Dissertation Research Improvement Grant for project titled, "Multi-scale Analysis of Gene Flow in the Emergent Aquatic Macrophyte *Hymenocallis coronaria*," 2004. $11,957.00
Sigma Xi Grant-In-Aid of Research for project titled, "Multi-scale Analysis of Gene Flow in the Emergent Aquatic Macrophyte *Hymenocallis coronaria*," 2004. $793.00
Joshua Laerm Academic Support Award, Georgia Museum of Natural History, 2003. $500.00

E. Professional Affiliations:

Association of American Geographers, member since 2003.
Sigma Xi, member since 2003.
Southeastern Division of the Association of American Geographers, member since 2002.