Research to Support Integrated Management Systems of Aquatic and Terrestrial Invasive Species

A Collaborative Partnership between
Mississippi State University's GeoResources Institute
and the U.S. Geological Survey

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Introduction

Invasive species are an enormous problem for terrestrial and aquatic ecosystems in the United States, degrading their biodiversity and the ecosystem services they provide to our society. As a result, over the past decade federal and state agencies and nongovernmental organizations have begun to work more closely together to address it.

While awareness of the problem is becoming more widespread, efforts to address the threat are often piecemeal and fragmented, and new tools to deal with the problems are needed. In particular, the states in the Mid-South Region (AL, AR, LA, MS, and TN) need assistance in developing additional capacity, expertise, and resources for addressing the invasive species problem.

This report presents progress on a program of planned research, extension, and regional coordination for implementation by the GeoResources Institute (GRI) of Mississippi State University (MSU) in collaboration with the U.S. Geological Survey (USGS).

We propose three areas of directed, peer-reviewed research to enhance the management of invasive species: aquatic invasive plants, terrestrial invasive plants, and the renegade biocontrol agent, cactus moth (*Cactoblastis cactorum*). Specific results and deliverables are proposed for each of the main tasks described below. Specialists in USGS and other entities that are providing information, perspective, and/or oversight for the project are identified as collaborators. The research addresses invasive species issues that are often complex and require long-term cooperation.

MSU Investigators and Participants

Dr. John Madsen, Principal Investigator
GeoResources Institute and Department of Plant and Soil Sciences

Mr. Clifton Abbott
GeoResources Institute

Dr. Richard Brown
Department of Entomology and Plant Pathology and Mississippi Entomological Museum

Dr. Lori Bruce
Department of Electrical and Computer Engineering and GeoResources Institute

Dr. John Byrd, Jr.
Department of Plant and Soil Sciences

Dr. Eric Dibble
Department of Wildlife and Fisheries

Dr. Gary Ervin
Department of Biological Sciences

Dr. Victor Maddox
GeoResources Institute

Dr. David Shaw
GeoResources Institute and Department of Plant and Soil Sciences

(Background summaries from each of the MSU researchers
are provided on the following pages.)

Student Involvement:

Ryan Wersal, PhD, MSU Department of Plant and Soil Sciences
Joshua Cheshier, MS, MSU Department of Plant and Soil Sciences
Wilfredo Robles, PhD, MSU Department of Plant and Soil Sciences
D. Christopher Holly, MS, MSU Department of Biological Sciences
Jefferey Linville, MS, MSU Department of Biological Sciences
Lucas Majure, MS, MSU Department of Biological Sciences
Heather Theel, MS, MSU Department of Wildlife and Fisheries
Alex Perret, MS, MSU Department of Wildlife and Fisheries
Edda Martinez, PhD, MSU Department of Entomology

John D. Madsen
Principal Investigator

As an undergraduate at Wheaton College in Illinois, I became intrigued by the relationship of plants with their environment. Working in plant ecology seemed a perfect opportunity to be paid to spend time outside. I attended University of Wisconsin-Madison, where I completed a Master of Science project on the aquatic plant communities of two trout streams in Wisconsin. My dissertation research at UW-Madison examined how a normally desirable native plant, sago pondweed, could become a nuisance problem in flowing water. Although I was a classically trained plant ecologist, I was beginning a journey into weed science. For my postdoctoral research, I worked on a recent invasion of Eurasian Watermilfoil (*Myriophyllum spicatum*) into pristine Lake George, New York. I studied all aspects of Eurasian Watermilfoil biology and ecology, from population studies on seeds and vegetation propagation, to physiological ecology and photosynthesis, and the impact of Eurasian Watermilfoil on native plant communities in that incredibly diverse lake from 1987 to 1990. In 1990, I left Rensselaer Polytechnic Institute to work at the US Army Engineer Research and Development Center field laboratory in Lewisville, Texas. For ten years, I worked as an aquatic plant ecologist with USAERDC on aquatic plant ecology and management literally across the country (with projects in Alabama, Alaska, California, Florida, Georgia, Idaho, Illinois, Kentucky, Louisiana, Minnesota, Mississippi, New York, North Carolina, South Carolina, Oregon, Tennessee, Texas, Vermont, Virginia, Washington, and Wisconsin). I left the USAERDC for a faculty position at Minnesota State University-Mankato for three years, where I taught limnology, plant ecology, wetland ecology, and environmental science. While I enjoyed teaching, I missed active research even more. I joined the faculty of Mississippi State University as Assistant Research and Extension Professor in 2003, with positions in GeoResources Institute and the Department of Plant and Soil Sciences. My responsibilities include coordinating research projects on invasive species in Mississippi, the southeastern US, and around the country. I am also responsible for education and outreach on invasive aquatic plants. I am a member of the Mississippi Aquatic Nuisance Species Task Force, serve on the board of the MidSouth Aquatic Plant Management Society, and am active in the Aquatic Plant Management Society, Southern Weed Science Society, and Weed Science Society of America. I am a past editor of the Journal of Aquatic Plant Management, past associate editor of Wetlands, and a former member of the editorial board of the Journal of Freshwater Ecology.

Clifton Abbott

My interest in computers started while in high school. That interest led me to taking college night courses during high school, thus setting my path towards computer science. During my time with Mississippi State University as a student (B.S. in C.S., 1995), I entered into the Cooperative Education Program. For two terms, I worked for International Business Machines (IBM) where I was responsible for setting up a test network for a banking system that was being developed for a Japanese bank. Being part of the test team, I developed software to wrap around certain modules of the system to mimic certain operational conditions. In addition to my work with IBM, I worked two terms with the Center for Air Sea Technology (CAST), an MSU research and development center located at the John C. Stennis Space Center. In 1995, my relationship with CAST became permanent. After being a team member on some smaller projects, the opportunity for me to take over a big contract as project manager and technical lead was presented to me. Though not as experienced as others, I jumped at the opportunity to take over the Naval Interactive Data Analysis System (NIDAS) contracted to the Naval Oceanographic Office. To date, NIDAS is one of the longest funded projects for MSU research with planning starting in 1992, and funding staring in early 1993. Though what was known as CAST in now part of the GeoResources Institute (GRI), opportunities continue to appear causing growth as my field of expertise widens. I have been the project manager and lead on several contracts with the Naval Oceanographic Office, the Naval Research Laboratory, and the Warfighting Support Center, and team players on many other contracts. I have served as software design/engineer, database design/administrator, system administrator, and web design/developer among others. My work at the Stennis Space Center has given me experience with oceanographic, atmospheric, and hurricane modeling. Some of my current work puts me in the depths of a system interfacing the web with a relational database to GIS mapping software for the cactus moth project.

Richard Brown

I began collecting insects during the 1960's in northwestern Arkansas. As a student at University of Arkansas (M.S., 1973), I became interested in the Lepidoptera, especially the "micros" of the southern Ozarks. After serving as a medical entomologist in the military for two years, I concentrated on the systematics of Epinotia and other tortricids at Cornell University. Upon completing my doctorate in 1980, I was employed as Director of the Mississippi Entomological Museum and Assistant Professor to teach taxonomy courses at Mississippi State University. Following collecting trips to Chile, Venezuela, New Caledonia and Fiji Islands, I began concentrating on the relatively unknown moth fauna in southeastern U.S., especially in unique and threatened habitats in Alabama, Louisiana, and Mississippi. In addition to faunistic work, I am continuing long term work on systematics of tortricid moths and am interested in evolution of wing patterns and the role of abiotic selection factors on feeding strategies and other adaptations. I am currently project director of the Mississippi Arthropod Survey, technical editor of the Mississippi Entomological Museum Publication Series, and organizer of the annual William H. Cross Expedition.

Lori Mann Bruce

Dr. Lori Mann Bruce is a native of Flintville, TN. She earned her Bachelor of Science degree in 1991 and Doctor of Philosophy degree in 1996 from the University of Alabama in Huntsville and her Master of Science degree in 1993 from the Georgia Institute of Technology. All three degrees are in Electrical and Computer Engineering.

Dr. Bruce is a Professor in Electrical and Computer Engineering at Mississippi State University. She is also the Director of the Signal Processing Research and Applications Laboratory at Mississippi State University. Prior to joining Mississippi State, Dr. Bruce was a faculty member at the University of Nevada, and she previously worked on the research staff of the U.S. Army Strategic Defense Command.

Dr. Bruce has been awarded approximately $5million for her research in satellite remote sensing and medical imaging. Her work in remote sensing has led to the use of satellite imagery for detecting and tracking the spread of invasive species in the U.S. Her work in medical imaging has led to the design of computer aided diagnosis systems for the early detection of breast cancer. Dr. Bruce's research has primarily been funded by the National Aeronautics and Space Administration (NASA), the U.S. Department of Energy (DOE), and the National Science Foundation (NSF). She has been invited to present her research around the nation and the world, including Belgium, France, Italy, and Australia. Dr. Bruce's outstanding research has led to more than 85 refereed journal and conference publications.

Dr. Bruce has taught more than 40 courses, including graduate courses in the areas of digital signal processing, digital image processing, and automated target recognition, as well as undergraduate courses such as digital devices, electronics, and signals and systems. Dr. Bruce greatly values her role as an educator, and it is no surprise that she is well loved by her students. She has won several awards for her teaching and her work to increase the number of women and minorities in the engineering profession.

John D. Byrd, Jr.

John D. Byrd, Jr. was raised on a small tobacco, cotton and soybean farm near Hartsville, SC. His father's resistance to any herbicide other than Treflan provided an early opportunity to experience mechanical weed management, primarily, with cultivator and hoe, as well as weed biology, toting mature cockleburs out of the fields before they released seed. He spent a few summers employed at Coker's Pedigreed Seed Company getting first hand experience with hybrid corn development, but failed to appreciate the monotony of plant breeding.

It was not until he enrolled in a weed science course at Clemson University that he realized he could actually pursue a career studying weeds. He completed both M.S. and Ph. D. degrees at North Carolina State University in weed science, under the direction of Drs. Alan York and Harold Coble, respectively.

His real education began when he accepted a position at Mississippi State University as the Extension Weed Specialist for horticulture crops and cotton in 1989. His responsibilities were changed in 1992 to include all crops and noncropland. He was promoted to Professor of Weed Science and Extension Specialist in 1998. In addition, he coordinates and assists with in-service and continuing education weed control programs for county agricultural agents and numerous other groups involved with weed management.

Dr. Byrd's current research addresses emerging issues in weed science, including improved turf, pasture, and right of way weed management and management of noxious, invasive weeds of natural areas. He completed 1 M. S. and 2 Ph. D. students in 2005 and has six other M. S. graduate students. He has served on committees of more than 38 other graduate students.

Dr. Byrd has received several awards for his research and outreach activities, including the Education and Distinguished Service Awards from the Mississippi Weed Science Society, the Specialist Appreciation and Distinguished Service Awards from the Mississippi Association of County Agricultural Agents, Extension Award of Merit from Gamma Sigma Delta, the Service Award from the Mississippi State University Alumni Association, and the Outstanding Young Weed Scientist Award from the Southern Weed Science Society.

Eric Dibble

I am an Associate Professor of Ecology/Fisheries in the Department of Wildlife and Fisheries at Mississippi State University. I received my Ph.D. in ecology from the University of Arkansas (1992), and a MS and BS degree in biology from the University of Wisconsin (1979 and 1982, respectively). Previously to receiving my doctorate I worked as a teaching & research faculty at the University of Wisconsin, Menomonie, where I investigated exotic/invasive species in temperate lakes. For 25 years I have conducted research in littoral and riparian zone ecology with specific interests in the cause and effect of habitat alteration. This last decade, I have received considerable attention for my research on the potential impact that exotic/invasive aquatic plant species have on aquatic communities. I currently have on going research in southern reservoirs, Midwestern lakes, and tropical systems in Brazil. Much of this research has used experimental manipulation to isolate mechanisms responsible for the structural change in vegetated habitat important to growth, survival and maintenance of aquatic organisms (i.e., fishes and invertebrates). Prior to my current position I was a research biologist for the U.S. Army Corps of Engineers Aquatic Plant Control and Research Program. I have served as President for the Mississippi Chapter of the American Fisheries Society, and was invited to serve as Research Director at the Lake Superior Aquarium, Duluth, MN. I have graduated 3 PhD and 7 Masters students since starting at Mississippi State University, and currently serve as Undergraduate Student Coordinator for the Department of Wildlife and Fisheries.

Gary N. Ervin

As an undergraduate, I studied forestry at Mississippi State for three years, but later received my B.S. in Biological Sciences from The University of Alabama. During my final year of undergraduate work, I began conducting research on the biology of wetland plants, using radiocarbon methods to investigate carbohydrate allocation patterns in clonal perennial rushes. In 1997, I began Ph.D. studies in the Aquatic Biology Program at Alabama, during which time I expanded my studies of wetland plants to include seed ecology and interspecific interactions during vegetation succession in a former beaver pond. I then was employed as a post-doctoral researcher in the Department of Entomology at The University of Arkansas, where I worked on physiological and biochemical interactions between plants and insect herbivores, primarily larvae of heliothine moths. I began my present position as Plant Ecologist in the Department of Biological Sciences at Mississippi State University during 2001, and my work currently spans the areas of wetland plant ecology, wetlands bioassessment, and, of course, invasive species ecology – including such markedly non-wetland species as the prickly pear cacti that serve as hosts for *Cactoblastis cactorum*.

Victor L. Maddox

I grew up in the Ozarks and developed an interest in plants at around age 10, and continue to collect plants for personal observations to this day. These include approximately 500 species of xerophytes, and hundreds of other plants with a living collection that includes flowering plants from over 200 families (over 1/3 of angiosperm families occurring on Earth), and numerous Pinophyta (conifers) and Pteridophyta (ferns and allies) species. I have a personal collection of approximately 5000 native and exotic plant pressed specimens, and a seed collection of grasses (over 500 species) and other plants (approx. 1000 global species). After attending Southeast Missouri State University, I received a B.S. in Horticulture with a minor in Botany. At Mississippi State University, I worked on algal species and population dynamics for my Master of Science thesis. I received a Ph.D. in Agronomy with a minor in Plant Taxonomy working with the management of five species of native grasses (29 selected ecotypes) for natural areas for my dissertation. I am interested in interdisciplinary invasive species projects requiring interdisciplinary teams to resolve issues impacting national ecosystems and economic security. I am also intrigued by the influence of human activities upon invasive species and subsequently natural ecosystems. Currently, I am a Postdoctoral Associate working with invasive species ecology and mapping, and *Opuntia* spp. ecological data collection and mapping in the United States. In this effort, I am a plant identifier, data collector, and mapper for a regional invasive species database and an *Opuntia* spp.Data Collector, Plant Identifier, and Dataform Verifier for the National Cactus Moth Detection and Monitoring Network database. Collaborators include GeoResources Institute, Mississippi Cooperative Extension Service, United States Geologic Survey, and the United States Department of Agriculture. I am a plant identifier for the Mississippi State University Cooperative Extension Service and various ecological and weed science research projects. In addition, I identify plants for the Mississippi Department of Agriculture, Bureau of Plant Industry. I have taught Plant Materials at Mississippi State University, and provided many guest lectures on various botanical topics at various forums. I have been a Consulting Botanist working on environmental reviews for the Tennessee Valley Authority (TVA) for approximately 10 years and I am a Plant/Weed Identifier for The Southern Plant Diagnostic Network (SPDN). I have assisted over 50 private and public landholders with task ranging from plant inventories to restoration plans and wetland delineations. I have served as a Board Member with the Institute for Botanical Exploration (IBE), directed by Dr. Sidney McDaniel.

David R. Shaw

I currently serve as the Director of the GeoResources Institute at Mississippi State University, a recently created institute at MSU that brought together the Mississippi Water Resources Research Institute, the Remote Sensing Technologies Center, the Computational Geospatial Technologies Center, and the Visualization, Analysis and Imaging Laboratory. I received my Ph.D. from Oklahoma State University in 1985, my M.S. from OSU in 1983, and his B.S. from Cameron University in 1981. I am also a William L. Giles Distinguished Professor at MSU. I began my career at Mississippi State in 1985 as an Assistant Professor of Weed Science, with research focused particularly on optimizing weed management practices to maintain farm productivity while improving surface water protection and management, and development of Best Management Practices for protection of surface waters from pesticides. Because of developmental efforts in applying spatial technologies to these research areas, MSU appointed me as the first Director of the Remote Sensing Technologies Center in 1998. More recently, I have focused on developing applications of spatial technologies in site-specific agriculture and in assessing natural resources. We currently work with numerous federal agencies, including NASA, US EPA, US DOT, USGS, DoC, NOAA, DoD, and NSF. Honors and awards include MSU's highest distinction as a William L. Giles Distinguished Professor in 1998, the Ralph E. Powe Research Award (MSU's highest recognition for research) in 2000, election as a Fellow in the Weed Science Society of America in 2002, the Outstanding Alumnus Award from Cameron University in 1999, and the Grantsmanship Award from the Mississippi Agricultural and Forestry Experiment Station in 1997. I am currently serving as the President for the Southern Weed Science Society, and also on the Board of Directors for the Universities Council on Water Resources.

Project Publications, Presentations, Awards and Recognition

Trade Journals:

Ervin, G. N. 2006. Managing invasive species in the face of natural disaster: Obstacles and opportunities. Wildland Weeds. Vol. 10. 9-10.

Peer-Reviewed Journals:

Bried, J. T., G. N. Ervin. 2006. Abundance patterns of dragonflies along a wetland buffer gradient. Wetlands. Vol. 26. 878-883.

Bruce, L. M., A. Mathur, J.D. Byrd. 2006. Denoising and Wavelet-Based Feature Extraction of MODIS Multi-Temporal Vegetation Signatures. GIScience & Remote Sensing. Vol. 43. 170-180.

Ervin, G. N., M. Smothers, C. Holly, C. Anderson, J. Linville. 2006. Relative importance of wetland type vs. anthropogenic activities in determining site invasibility. Biological Invasions. Vol. 8. 1425-1432.

Ervin, G. N., L. C. Majure, J. T. Bried. 2006. Influence of long-term GTR impoundment on stand structure, species composition, and hydrophytic indicators. Journal of the Torrey Botanical Society. Vol. 113. 468-481.

Ervin, G. N., B. D. Herman, J. T. Bried, D. C. Holly. 2006. Evaluating non-native species and wetland indicator status as components of wetlands floristic assessment. Wetlands. Vol. 26. 1114-1129.

Holly, D. C., G. N. Ervin. 2006. Characterization and quantitative assessment of rhizome penetration by cogongrass (*Imperata cylindrica* (L.) Beauv.). Weed Biology and Management. Vol. 6. 120-123.

Madsen, J. D., R. M. Wersal, M. Tyler, P. D. Gerard. 2006. The distribution and abundance of aquatic macrophytes in Swan Lake and Middle Lake, Minnesota. Journal of Freshwater Ecology. Vol. 21. 421-429.

Wersal, R. M., J. D. Madsen, B. R. McMillan, P. D. Gerard. 2006. Environmental factors affecting the biomass and distribution of Stuckenia pectinata in the Heron Lake System, Minnesota, USA. Wetlands. Vol. 26. 313-321.

Peer-Reviewed Conference Papers

Cheshier, J. C., R.M. Wersal, J.D. Madsen. 2006. Efficacy of three aquatic herbicides for the control of swamp smartweed. Proceedings Southern Weed Science Society. Vol. 59. 201.

Madsen, J. D., R.M. Wersal. 2006. Regulation of giant salvinia (*Salvinia molesta* Mitchell) growth by pH and available nutrients. Proceedings Southern Weed Science Society. Vol. 59. 202.

Mathur, A., L. M. Bruce, W. Robles, J. D. Madsen. 2006. Identification of pertinent regions in spectro-temporal maps for vegetative target detection. ASPRS 2006 Annual Conference, Reno, NV.

Robles, W., J.D. Madsen, A. Mathur, L.M. Bruce. 2006. Ground-truthed hyperspectral data for remote sensing of waterhyacinth. Proceedings Southern Weed Science Society. Vol. 59. 194.

Wersal, R. M., J.D. Madsen, M.L. Tagert. 2006. Mapping invasive aquatic macrophytes in the Ross Barnett Reservoir. Proceedings Southern Weed Science Society. Vol. 59. 195.

Wersal, R. M., J. D. Madsen, M. L. Tagert. 2006. Mapping Invasive and Native Plants in the Ross Barnett Reservoir. Proceedings of the 36th Annual Mississippi Water Resources Conference. 55-58.

Non-Refereed Conference Papers, Abstracts, or Posters

Byrd, J. D., J. D. Madsen, V. Maddox, D. R. Shaw. 2006. Impact of natural disasters on invasive weed spread. Weeds across Borders 2006 Conference, Hermosillo, Sonora, Mexico.

Cheshier, J. C., J. D. Madsen. 2006. Common reed: Phragmites australis (Cav.) Trin. Ex Steud: Biology, ecology, distribution and management. 15th Annual NALMS Southeastern Lake and Watershed Management Conference, Columbus, GA.

Cheshier, J. C., J. D. Madsen, R. M. Wersal. 2006. Common Reed: Phragmites australis Cav. Trin. Ex. Steud: Life History in the Mobile River Delta, AL. MidSouth Aquatic Plant Management Society 25th Annual Meeting.

Cheshier, J. C., R. M. Wersal, J. D. Madsen. 2006. Efficacy of Three Aquatic Herbicides for Control of Swamp Smartweed. Aquatic Plant Management Society 46th Annual Meeting.

Dibble, E., S. Thomaz, J. Higuti, and A. Padial. 2006. Scale effect on available complexity and influence of complexity as a fractal dimension on invertebrate richness in aquatic plants. Ecological Society of America 91st Annual Meeting. August 6-11, 2006. Memphis, TN.

Dibble, E., and J. Slade. 2006. Evaluation of an herbicide application on vegetated habitat and the structure of a fish and macroinvertebrate community. NE-Aquatic Plant Management Society and Weed Science Annual Meeting, December. Providence, RI.

Ervin, G. N. 2006. Invasion risk of *Rotala rotundifolia* (roundleaf toothcup) in southeastern US wetlands. Mid-South Aquatic Plant Management Society Conference, Orange Beach, AL.

Ervin, G. N., M. J. Linville. 2006. The Landscape Context of Plant Invasions in Mississippi Wetlands. Proceedings of the 36th Mississippi Water Resources Conference. Vol. 36. 34-41.

Ervin, G. N. 2006. Human-caused disturbance and plant invasion in Mississippi wetlands. Proceedings of the Mississippi Delta Water Resources Review Meeting, Stoneville, Mississippi. CDRom.

Holly, D. C., G. N. Ervin. 2006. Relative importance of propagule pressure, light availability, and nutrient concentration upon the establishment and physiology of a model invasive species, *Imperata cylindrica*. Ecological Society of America 91st Annual Conference, Memphis, TN.

Maddox, V. L., D. Lang, G. Hawkey, B. Chow. 2006. Revegetation success at the Red Hills Lignite Mine in Ackerman, Mississippi. Billings Land Reclamation Symposium, Billings, Montana.

Maddox, V. L., J. D. Madsen, R. L. Brown, C. F. Abbott, R. G. Westbrooks, J. F. Floyd, A. Simpson. 2006. Collaborative effort to protect native Southwestern pricklypear (*Opuntia* P. Mill.) from the invasive cactus moth (*Cactoblastis cactorum* Berg.). 33rd Annual Natural Areas Conference, 20-23 Sept., Northern Arizona University, Flagstaff, AZ.

Madsen, J. D. 2006. Techniques for Managing Invasive Aquatic Plants in Mississippi Water Resources. Proceedings of the 36th Annual Mississippi Water Resources Conference. Vol. 36. 42-51.

Madsen, J. D. 2006. Management of aquatic weeds and algae. Central Kentucky Ornamental and Turf Association 26th Conference, Lexington, KY.

Madsen, J. D., K. D. Getsinger, R. M. Wersal. 2006. Combinations of Endothall with 2, 4-D and Triclopyr for Control of Eurasian Watermilfoil. MidSouth Aquatic Plant Management Society 25th Annual Meeting.

Majure, L. C., G. N. Ervin, J. D. Madsen, R. Westbrooks, A. Simpson, E. Sellers. 2006. Assessing habitat requirements for host plants (*Opuntia* spp.) of *Cactoblastis cactorum* in the Southeastern United States. Ecological Society of America International Meeting, Merida, Mexico.

Majure, L. C., G. N. Ervin. 2006. The morphological plasticity of *Opuntia pusilla* (Haw.) Nutt. induced by differentiations in environmental variables. Ecological Society of America 91st Annual Conference, Memphis, TN.

Majure, L. C., G. N. Ervin, J. D. Madsen, R. Westbrooks, A. Simpson, E. Sellers. 2006. Assessing habitat requirements for host plants (*Opuntia* spp.) of *Cactoblastis cactorum* Berg. in the Southeastern United States. Southeastern Ecology and Evolution Conference, University of Alabama, Tuscaloosa.

Perret, A. J., and E. Dibble. The effects of non-native macrophyte invasion on juvenile largemouth bass (Micropterus salmoides) NALMS: 15th Annual Southeastern Lake and Watershed Management Conference. March 8-10, 2006. Columbus, GA.

Robles, W., J. D. Madsen. 2006. Aquatic Vegetation Diversity in Lake Columbus, Lowndes County, MS. Proceedings of the 36th Annual Mississippi Water Resources Conference. Vol. 36. 52-54.

Robles, W., J. D. Madsen. 2006. Rate Response and Biomass Reduction of Waterhyacinth by Imazapyr and Glyphosate. 15th Annual NALMS Southeastern Lake and Watershed Management Conference, Columbus, GA.

Robles, W., J. D. Madsen, V. L. Maddox, R. M. Wersal. 2006. The Invasive Status of Giant Salvinia and Hydrilla in Mississippi. MidSouth Aquatic Plant Management Society 25th Annual Meeting.

Theel, H. J. and E. Dibble. 2006. Hydrilla's altering effects on aquatic plant complexity and bluegill foraging behavior. The 25th Annual Meeting of the MidSouth Aquatic Plant Management Society. October 24-26, 2006. Orange Beach, Alabama.

Theel, H. J. and E. Dibble. 2006. Habitat alteration by an invasive species and its implication on fish foraging and macroinvertebrate colonization. Ecological Society of America 91st Annual Meeting. August 6-11, 2006. Memphis, TN.

Theel, H. J. and E. Dibble. 2006. Habitat alteration by an invasive species and its implication on fish foraging and macroinvertebrate colonization. The 46th Annual Meeting of the Aquatic Plant Management Society. July 16-19, 2006. Portland Oregon.

Theel, H. J. and E. Dibble. 2006. Heterogeneous vs. homogeneous aquatic habitat induced by the invasive Hydrilla verticillata: Implications for macroinvertebrate colonization and bluegill foraging. NALMS: 15th Annual Southeastern Lake and Watershed Management Conference. March 8-10, 2006. Columbus, Georgia.

Theel, H. J. and E. Dibble. 2006. Heterogeneous vs. homogeneous aquatic habitat induced by the invasive Hydrilla verticillata: Implications for macroinvertebrate colonization and bluegill foraging. The Joint Annual Meeting of the Mississippi and Louisiana Chapters of the American

Wersal, R. M., J. D. Madsen, M. L. Tagert. 2006. The use of hand held computers for mapping aquatic macrophytes during point intercept surveys. Southeastern Lakes Management Society Annual Meeting.

Wersal, R. M., J. D. Madsen, M. L. Tagert. 2006. Survey of Invasive and Native Aquatic Plants in the Ross Barnett Reservoir. Proceedings of the 36th Annual Mississippi Water Resources Conference. Vol. 36. 55-58.

Wersal, R. M., J. D. Madsen, M. L. Tagert. 2006. Mapping invasive macrophytes in the Ross Barnett reservoir, Jackson, MS. Southern Weed Science Society Annual Meeting, San Antonio, TX.

Wersal, R. M., J. D. Madsen, M. L. Tagert. 2006. Using Point Intercept Surveys to Map Aquatic Plants in the Ross Barnett Reservoir, Mississippi. Aquatic Plant Management Society 46th Annual Meeting.

Wersal, R. M., J. D. Madsen. 2006. Giant Salvinia (*Salvinia molesta* Mitchell) Growth as Regulated by pH and Available Nutrients. Aquatic Plant Management Society 46th Annual Meeting.

Articles in Trade Journals and Popular Press

Maddox, V. L. 2006. Impact of invasive plant species on golf courses. Tee to Green. 17-18.

Wersal, R. M. 2006. Aquatic Plant Community Composition of the Ross Barnett Reservoir. MidSouth Aquatic Plant Management Society. Vol. 24. 3.

In-House GRI Publications

Herman, B. D., J. D. Madsen, G. N. Ervin. 2006. Development of Coefficients of Conservatism for Wetland Vascular Flora of North and Central Mississippi. Mississippi State University, MS. 15. GRI #4001.

Maddox, V. L., J. D. Byrd, Jr., R. G. Westbrooks. 2006. Benghal dayflower [*Commelina benghalensis* (L.) Small]. GeoResources Institute. GRI #5005.

Madsen, J. D., R.M. Wersal, W. Robles. 2006. Distribution of Hydrilla and Giant Salvinia in Mississippi in 2005. GeoResources Institute, Mississippi State University. GRI #5002.

Madsen, J. D., C. Abbott, R. Brown, L. Bruce, J. Byrd, E. Dibble, G. Ervin, J. Fowler, V. Maddox, D. McBride, D. Shaw, R. Westbrooks. 2006. Research to Support Integrated Management Systems of Aquatic and Terrestrial Invasive Species. Mississippi State University. GRI #5004.

Wersal, R. M., J. D. Madsen, M. L. Tagert. 2006. Aquatic Plant Survey of Ross Barnett Reservoir for 2005. GRI #5003.

Professional Presentations

Abbott, C. F. 2006. The Cactus Moth Detection and Monitoring Network Mapping Tool. NBII Technology Conference, Keystone, CO.

Abbott, C. F. 2006. Cactus Moth Detection Network Website Status. USGS Cactus Moth Detection Network Meeting, GRI, MSU.

Bryson, C. T., V. L. Maddox. 2006. Key characteristics of common invasive plants. Identification and Management of Invasive Terrestrial and Aquatic Plants Common to Coastal MS Workshop, 16-17 Nov, Gulf Coast Comm. Coll., Gautier, MS.

Ervin, G. N. 2006. Using Invasive Plants as Ecological Indicators in Freshwater Wetlands. Interdisciplinary Working Group on Water Resources, University of Mississippi.

Ervin, G. N. 2006. Managing invasive species in the face of natural disaster: Obstacles and opportunities. MS Exotic Pest Plant Council, Jackson, MS.

Ervin, G. N. 2006. Habitat modeling for invasive species in Mississippi and the Mid-South. MS Exotic Pest Plant Council, Jackson, MS.

Ervin, G. N. 2006. Temporal shifts in the relative importance of microhabitat factors influencing invasion success. Ecological Society of America 91st Annual Conference, Memphis, TN.

Holly, D. C., G. N. Ervin. 2006. Characterization and quantitative assessment of a potential rhizome-mediated root disturbance mechanism in cogongrass (*Imperata cylindrica* (L.) Beauv.). Southeastern Ecology and Evolution Conference, University of Alabama, Tuscaloosa.

Maddox, V. L. 2006. Distributed project information and conducted plant identifications. The Gulf Coast Garden and Patio Show, Hattiesburg, MS.

Maddox, V. L. 2006. Germination characteristics of four potentially invasive grass species. Mississippi Exotic Pest Plant Council Annual Meeting, 9 Nov., Mississippi Natural History Museum, Jackson, MS.

Maddox, V. L. 2006. Invasives Species Identification and Management. October 20-21, 28th Annual Fall Flower and Garden Fest, Truck Crops Branch Exp. Stat., Crystal Springs, MS.

Maddox, V. L. 2006. The invasive plant atlas of the Mid-south (IPAMS) database. Identification and Management of Invasive Terrestrial and Aquatic Plants Common to Coastal MS Workshop, 16-17 Nov, Gulf Coast Comm. Coll., Gautier, MS.

Maddox, V. L. 2006. Locating and mapping invasive plants. Annual Meeting of the Mississippi Chapter of the Soil and Water Conservation Service, Forrest County Extension Office, Hattiesburg, MS.

Maddox, V. L. 2006. Overview of Invasive Plant Species of the MidSouth. MSU Forest Herbicide Workshop, Mississippi State University, MS.

Maddox, V. L. 2006. Distributed project information and conducted plant identifications. Garden Show, Evergreen Ag., Mathiston, MS.

Maddox, V. L. 2006. Impact of natural disasters on the spread of invasive species. MSU Forest Herbicide Workshop, Mississippi State University, MS.

Maddox, V. L. 2006. Native grasses for golf course natural areas. Golf Course Management Workshop, Dancing Rabbit Golf Course, Choctaw, MS.

Maddox, V. L. 2006. Distributed project information and conducted plant identifications. 9th Annual Jackson Garden and Patio Show, Mississippi State Fairgrounds, Jackson, MS.

Maddox, V. L., B. Burdine, L. Kelly, T. Needham. 2006. Identification of 100 Common Landscape Plants. MSUES In-Service Training, 128 Dorman Hall, Mississippi State, MS.

Maddox, V. L. 2006. Distributed project information and conducted plant identifications... Oktibbeha County Co-op Master Gardener Volunteer Gardener's Night Out, Oktibbeha County Co-op, Starkville, MS.

Madsen, J. D., R. M. Wersal. 2006. Limitation of giant salvinia (*Salvinia molesta* Mitchell) by nutrients and pH. 14th International Conference of Aquatic Invasive Species.

Madsen, J. D. 2006. Biology and management of Eurasian watermilfoil. ID Co. Weed Coordinator Meeting, Weiser, ID.

Madsen, J. D. 2006. Advantages and disadvantages of aquatic plant control methods. Eurasian watermilfoil symposium, US Fish and Wildlife Service Office, Lakewood, CO.

Madsen, J. D. 2006. Biology of Eurasian watermilfoil. Eurasian watermilfoil symposium, US Fish and Wildlife Service Office, Lakewood, CO.

Madsen, J. D. 2006. The ten most unwanted invasive aquatic plants of the Southeast. 15th Annual NALMS Southeastern Lake and Watershed Management Conference, Columbus, GA.

Madsen, J.D. 2006. Biology of aquatic weeds: Growth and dispersal. 2006 Aquatic Weed School, University of California-Davis, 31 October – 1 November 2006, Davis, CA.

Madsen, J.D. 2006. Physical and mechanical control: Benthic barriers. 2006 Aquatic Weed School, University of California-Davis, 31 October – 1 November 2006, Davis, CA.

Madsen, J.D. 2006. Aquatic weed control update. Mississippi Vegetation Management Association, 14-15 November 2006, Starkville, MS.

Madsen, J.D. 2006. Changes in the littoral aquatic plant community of Onondaga Lake from 1991 to 2006. Eighth Annual Onondaga Lake Scientific Forum, 17 November 2006, Liverpool, NY.

Madsen, J.D., K.D. Getsinger, and R.M. Wersal. 2006. Combinations of endothall with 2,4-D and triclopyr for control of Eurasian watermilfoil. Midsouth Aquatic Plant Management Society 25th annual meeting, 24-26 October 2006, Orange Beach, AL.

Madsen, J. D., R. M. Wersal. 2006. Regulation of giant salvinia (*Salvinia molesta* Mitchell) growth by pH and available nutrients. Weed Science Society of America 46th Annual Meeting, New York, NY.

Madsen, J. D., R. M. Wersal. 2006. Invasive Aquatic Plant Research. Mississippi Exotic Pest Plants Council.

Madsen, J. D., G. N. Ervin, R. Westbrooks, J. P. Floyd, A. Simpson, E. Sellers. 2006. The National Cactus Moth Detection Network and Database. Ecological Society of America International Meeting, Merida, Yucatan, Mexico.

Majure, L. C., G. N. Ervin, J. D. Madsen, R. Westbrooks, A. Simpson, E. Sellers. 2006. Assessing habitat requirements for host plants (*Opuntia* spp.) of *Cactoblastis cactorum* Berg. in the Southeastern United States. Graduate Student Research Symposium, MSU.

Wersal, R. M. 2006. GIS In Aquatic Plant Management. GeoResources Institute.

Wersal, R. M., V. L. Maddox, J. D. Madsen. 2006. Invasive Aquatic Plants: Should We Care? Identification and Management of Invasive Terrestrial and Aquatic Plants Common to Coastal Mississippi.

Awards and Recognitions

Robles, W. 2006. 2nd Place - Specimen - close-up of an invasive plant. SouthEast Exotic Pest Plant Council's 2006 Photo Contest.

Robles, W. 2006. 2nd Place - Other - for subjects that don't conveniently fit into another category. SouthEast Exotic Pest Plant Council's 2006 Photo Contest.

Wersal, R. M. 2006. Scholarship Awarded by the Midwest Aquatic Plant Management Society. MSU.

Wersal, R. M. 2006. MidSouth Aquatic Plant Management Society 2006 Scholarship $1500. MidSouth Aquatic Plant Management Society.

Task 1.
Aquatic Plants

Task 1.1. Aquatic Plant Remote Sensing

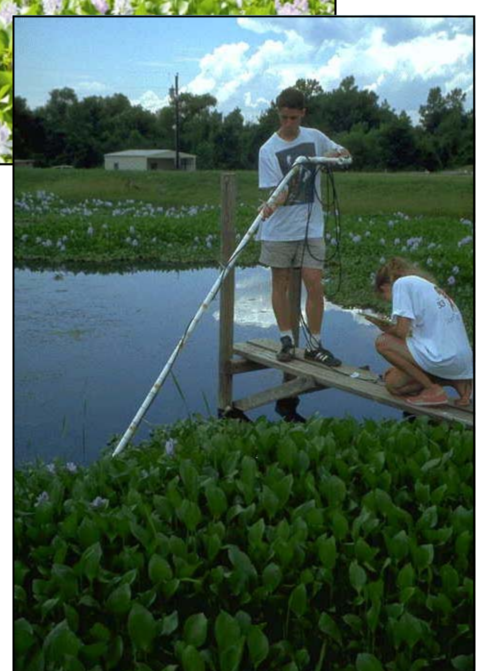
PI: Lori Bruce, Co-PI: John Madsen

Accomplishments:

- Presented research results at IEEE International Geoscience and Remote Sensing Symposium (IGARSS) in Denver, Colorado.
- Met with invasive species researchers in Fort Collins, CO at the USGS Science Center and Colorado State University, specifically Dr. Tom Stohlgren and Paul Evangelista. The goal of the meeting was to establish collaborative research.
- Obtained hyperspectral signatures of Tamarisk, Russian Olive, Willow, etc from field studies conducted in Grand Staircase-Escalante National Monument. The data was collected by Paul Evangelista and NASA Stennis Space Center personnel. Our goal is to determine if the analysis techniques developed in this project for cogongrass, kudzu, and water hyacinth, can be applied to other invasive species, such as tamarisk and Russian olive. Preliminary analysis is being conducted.

Future Plans:

Have begun process of obtaining Hyperion imagery for Grand Staircase-Escalante National Monument. The imagery was collected and preprocessed by Dr. Jeff Morisette at NASA Goddard Space Flight Center. The objective is to apply the analysis techniques developed in this project to satellite-based remotely sensed imagery. The goal is to determine if the analysis techniques can be applied to imagery at various scales, i.e. airborne and satellite. During the months of Oct-Dec, we plan to apply our analysis techniques to this imagery and measure the efficacy.



Task 1.2.1A. Aquatic Plant Habitat Invasibility Models

PI: Gary Ervin
Co-PI: John Madsen

We developed a stratified, randomly selected set of sample points to be visited beginning in the 2006 field season. Vegetation and habitat data collected at those points is to be used in the development of statistical models to estimate the likelihood of exotic plant invasion. Based on readily available coverages of federal public lands in Mississippi and Alabama, ArcGIS was used to place random points on public lands, stratified by land use/land cover data for the eastern Gulf Coastal Plain (Southeast Gap Analysis Project). Forty points were selected randomly from within each of the sixteen Anderson Level II land cover classes (Homer et al. 2004). At each of these points, we were collect data on plant species present and microhabitat characteristics (using a modification of the Beyond NAWMA guidelines [Stohlgren et al. 2003], with the addition of soil analyses), and augment those data with geospatial information, such as climatic data, land use/cover, soil associations, and proximity to such features as urban areas and transportation corridors. Data ultimately will be analyzed via methods described in Task 2.1 ([Terrestrial Plant] Habitat Invasibility Models).

Data collection began this year, and we were able to collect the desired data at 69 of the points (see Task 2.1 for detailed information on results of this year's work). Of these 69 points, only ten were located in wetland land cover types, nine of which were in the category of "woody wetlands." The random placement of sampling points placed thirty-three of the forty herbaceous wetland points in the brackish coastal marshes on the Alabama peninsula that contains Fort Morgan and Bon Secour NWR (Figure 1.2.1A-1). This was only one of the difficulties encountered with this random set of sampling points (others discussed under Task 2.1). Because of these difficulties, a new set of points will be generated with more care applied in the manner with which points are stratified across the landscape and among land use categories.

As we continue development of the dataset to be used in modeling, we are undertaking other efforts aimed at understanding local-scale mechanisms involved in successful invasion in aquatic and terrestrial habitats and at application of this knowledge to natural resource management. Among the work reported in the following three sections are projects involved with developing bioassessment criteria for wetlands and direct ecological assessment of the invasion potential of a new exotic plant, *Rotala rotundifolia* (roundleaf toothcup).

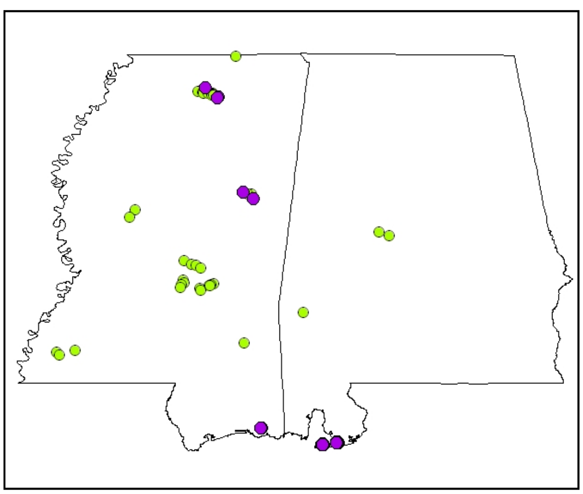


Figure 1.2.1A-1. Points from the random set that fell within wetland land cover classes. Purple points indicate the forty herbaceous wetland points, thirty-three of which are in coastal Alabama.

References:

Homer, C., C. Huang, L. Yang, B. Wylle, and M. Coan. 2004. Development of a 2001 national Land-Cover Database for the United States. Photogrammetric Engineering & Remote Sensing 70: 829-840

Stohlgren, T. J., D. T. Barnett, and S. E. Simonson. 2003. Beyond North American Weed Management Standards. Available at: http://www.nawma.org/documents/Mapping%20Standards/ BEYOND%20NAWMA%20STANDARDS.pdf

Task 1.2.1B. Evaluating Non-native Species and Wetland Indicator Status as Components of Wetlands Floristic Assessment

PI: Gary N. Ervin

We evaluated a potential index for quantifying wetland floristic quality, based on the Floristic Quality Assessment Index (FQAI) that was developed in the Mid-West and has been tested there and in a few states in other regions of the United States. The index that we evaluated, termed the Floristic Assessment Quotient for Wetlands (FAQWet), incorporated information on total plant species richness, wetland affinity of species present, and the contribution of native versus exotic species to wetland vegetation quality. The intent was for this index to incorporate factors demonstrated to be influenced by the degree of human activity on the landscape as well as including both native and non-native plant species, while using information that is readily available for most plant species encountered in wetlands of the United States. This latter criterion was meant to ensure transferability of the index among regions of the US. The FAQWet index was evaluated with wetland plant data collected in 53 wetlands across northern Mississippi (Figure 1.2.1B-1). Results suggested the FAQWet index was comparable with the currently used FQAI; however, all indices tested displayed low correlation with indicators of human activity. Analyses of the floristic indices against individual components of human disturbance (indexed by a method called the Anthropogenic Activity Index), along with information on hydrogeomorphology (HGM) and hydrologic alteration in and around the wetlands, helped account for some unexplained variation in the relationship between floristic quality and disturbance. For example, there were more exotic species and a lower overall wetland affinity of vegetation of depressional wetlands in Mississippi than in lake fringe and riverine wetlands (e.g., Figure 1.2.1B-2). The most important advantages of the FAQWet index in these studies was a lack of correlation with total plant species richness (and thus sampling effort), a stronger correlation with non-native species richness than was the case with the FQAI, and the ease of obtaining wetland indicator status and nativity status for FAQWet calculations. Of equal importance is that results also highlighted the potential danger of ignoring exotic species in floristic assessments because of the relatively strong correlations of non-native species richness with human activity, hydrologic impairment, and floristic index scores (e.g., Figure 1.2.1B-3).

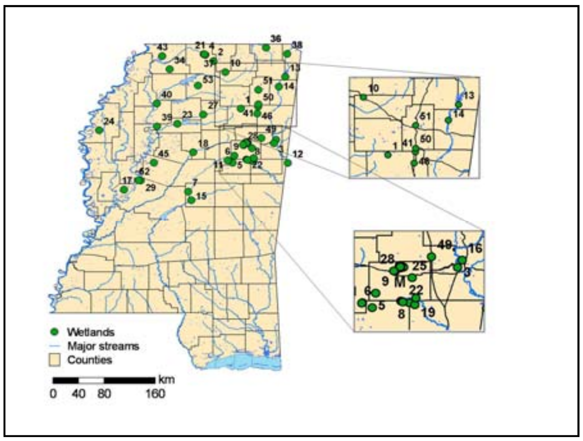


Figure 1.2.1B-1. Locations of wetlands included in this study. Inset sections show some areas of higher concentrations of wetlands, especially within 40 km of the Mississippi State University campus (“M” in center of lower inset). Inset maps also include major US highways within MS for spatial reference. Numbers correspond to wetland sites in Table 2 of Ervin et al. (2006).

Figure 1.2.1B-2. Residuals analyses indicated no significant correlation of residuals with either HGM class or hydrologic impairment, but riverine wetlands tended to be of higher-than-average quality. Illustrated are residuals from the regression of the Floristic Quality Assessment Index on a qualitative Anthropogenic Activity Index. Upper: one-way ANOVA indicated no significant difference in residuals between riverine and depressional wetlands; lower: comparison of FQAI among wetlands of three HGM classes.

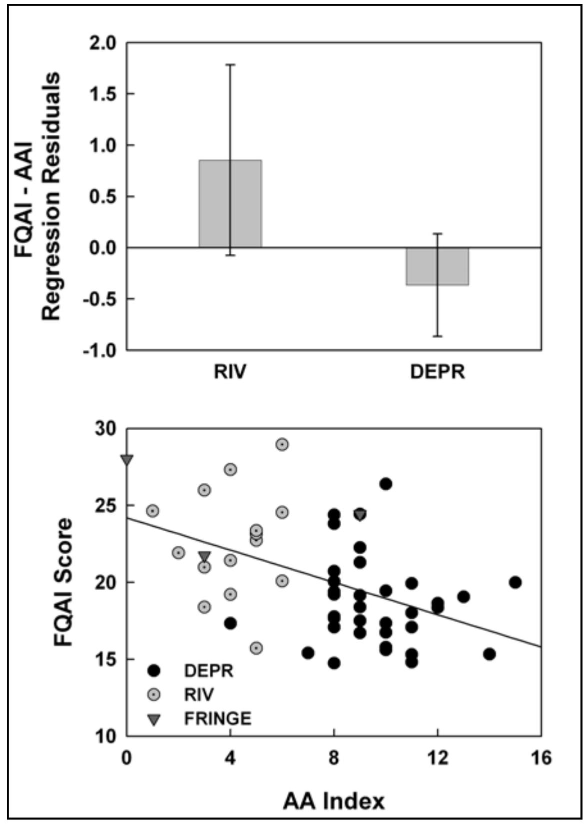
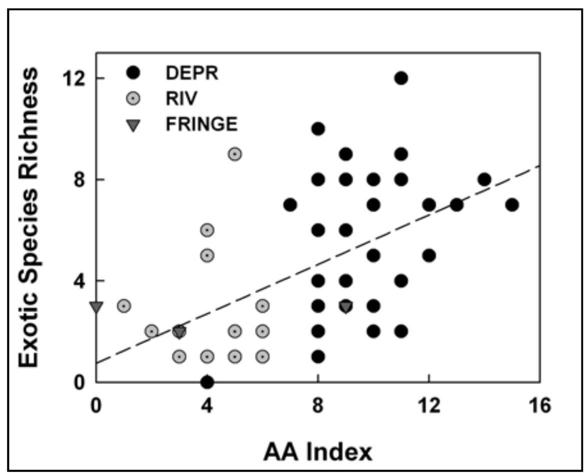


Figure 1.2.1B-3. Correlation of exotic species richness with Anthropogenic Activity Index, differentiating among HGM classes represented by the 53 surveyed wetlands. Anthropogenic Activity Index varied significantly among classes ($F_{2,50} = 40$; $P < 0.001$).



Modified from a paper published in *Wetlands*:
Ervin, G. N., B. D. Herman, J. T. Bried, and D. C. Holly. 2006. Evaluating non-native species and wetland indicator status as components of wetlands floristic assessment. *Wetlands* 26: 1114-1129.

Task 1.2.1C. Assessment of the vegetative regrowth potential of exotic *Rotala rotundifolia* (Roxb.) Koehne (Lythraceae)

PI: Gary N. Ervin

Invasive plant screening protocols rely on published information on potential introductions to assess species risk. However, tests of these protocols typically fail to find adequate information for 15 to 75% of species screened. *Rotala rotundifolia* (Roxb.) Koehne (Lythraceae) is a species that presents a relatively new invasion risk for Australia and the United States, and a species for which biological data are lacking outside of its native range in southeastern Asia (Figure 1.2.1C-1). The present studies were conducted to compare vegetative regrowth of *Rotala rotundifolia* with six aquatic species currently established in the southeastern US: *Alternanthera philoxeroides*, *Cabomba caroliniana*, *Ceratophyllum demersum*, *Hydrilla verticillata*, *Myriophyllum aquaticum*, and *Salvinia minima*. Results of comparative greenhouse and growth chamber experiments demonstrated that vegetative regeneration in *Rotala rotundifolia* was comparable to that of these well established species (Figure 1.2.1C-2). In fact, based on its shoot regenerative capacity and overall relative growth rates, *Rotala* exhibited among the highest vegetative regeneration potential of the species tested. These experimental results, in combination with observations from field and greenhouse-grown *Rotala rotundifolia* indicate that this species may indeed pose a serious threat to wetlands of the southeastern US, and the data presented help to fill a vacancy in the database on potential invasive species.

Figure 1.2.1C-1. *Rotala rotundifolia* persisting in gravel along what used to be the pond shoreline on the University of Alabama campus (Tuscaloosa, AL).

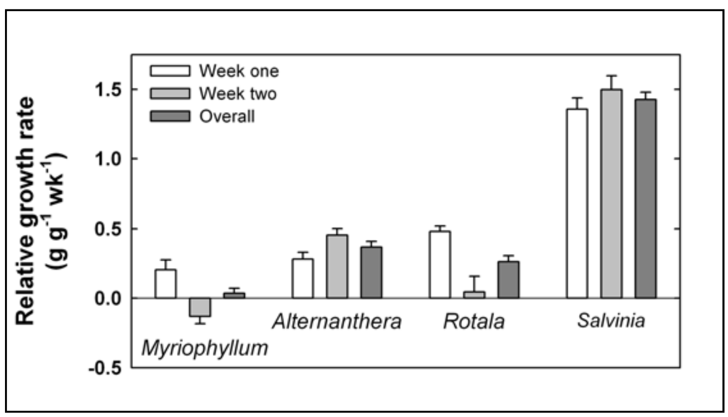


Figure 1.2.1C-2. Growth responses of four of the assayed species in greenhouse assays, based on the largest initial fragment size for *Myriophyllum*, *Alternanthera*, and *Rotala*. *Salvinia* clones disintegrated such that monitoring of individual clones was not possible, preventing analysis by initial fragment size. *Cabomba*, *Hydrilla*, and *Ceratophyllum* all died during the experimental assays, presumably because of the small initial fragment sizes and inhospitable greenhouse conditions.

Modified from a manuscript submitted to *Wetlands Ecology & Management*:

Ervin, G. N., R. A. White, R. F. Hardy, D. C. Holly, L. C. Majure, G. C. Eakins, M. T. Calloway. 2006. Vegetative regrowth potential of exotic *Rotala rotundifolia* (Roxb.) Koehne (Lythraceae) suggests high invasion potential. *Wetlands Ecology & Management*, In Review.

Task 1.2.1D. Using survey data to develop conservation tools: An evaluation of aquatic plant and insect assessment tools using the Umbrella Index

Jason T. Bried and Gary N. Ervin

The conservation umbrella approach is meant to focus management efforts on individual species that confer indirect protection to an optimal number of co-occurring species. This approach can guide natural resource management by maximizing conservation returns per unit effort (e.g., total species richness or at-risk species protected with a minimal management input). Unfortunately the umbrella concept, represented quantitatively by the Umbrella Index, has received little attention with respect to management of wetland ecosystems. We used the Umbrella Index to assess the umbrella species potential of vascular plants and dragonflies (Odonata) from 15 wetlands in northern Mississippi. Cross-taxon analyses suggested transferability of plant and dragonfly umbrella protection scenarios (plant-based conservation plans protected odonates and vice-versa) and non-random association between the plants and dragonflies in these wetlands (Table 1.2.1D-1). The results of these cross-taxon analyses supported growing evidence for spatial and functional relationships between wetland plants and adult odonates, and perhaps the more easily measured assemblage could be used to set priorities for wetland conservation planning under resource constraints. It is anticipated that tools such as these would be useful in prioritizing management efforts, and future studies are planned to investigate the degree to which exotic invasive species might impact the efficacy of umbrella-based conservation plans.

Table 1.2.1D-1. Multivariate cross-taxon correlations (*r*, standardized Mantel statistic) from Mantel tests. In six cases, including one of the significant differences, the cross-taxon umbrella scheme offered more protection than the same-taxon umbrella scheme.

	All Plants		**Graminoids**		**Forbs**		**Woody**	
	r	*P*	*r*	*P*	*r*	*P*	*r*	*P*
Odonata	0.438	<0.001*	0.368	0.003*	0.404	<0.001*	0.189	0.078
Damselflies	0.480	<0.001*	0.399	0.002*	0.429	<0.001*	0.211	0.075
Dragonflies	0.148	0.072	0.123	0.129	0.163	0.071	0.079	0.218

* indicates significant inter-taxon correlations, based on a conservative Bonferroni-corrected error rate ($\alpha = 0.05 \div 12 = 0.0042$).

Modified from a manuscript submitted to *Journal of Applied Ecology*:
Bried, J. T, B. D. Herman, and Ervin, G. N. 2007. Conservation umbrella potential of wetland plants and dragonflies: a quantitative case study using the Umbrella Index. *Journal of Applied Ecology*, Accepted, pending final edits.

Task 1.2.2. Development of a Three-Dimensional Growth Model for Common Reed (*Phragmites australis*)

PI: John D. Madsen, GeoResources Institute, Mississippi State University
Collaborators: David Spencer, USDA ARS Exotic & Invasive Weeds Research Unit
Joshua C. Cheshier, GeoResources Institute, Mississippi State University

Common reed (*Phragmites australis*) is a non-native invasive perennial grass that creates a nuisance in aquatic and riparian environments across the United States. The ability of common reed to reproduce quickly combined with its ability to cycle nutrients has made it an aggressive invader of riparian and wetland ecosystems. *Phragmites* often forms monotypic stands that displace native vegetation more desirable as wildlife food and cover than *Phragmites*. *Phragmites* has been differentiated into 27 haplotypes, 11 haplotypes being native to North America, and 16 non-native haplotypes. The European haplotype M and South American/Asian haplotype I are of concern due to their ability to out compete native vegetation; alter hydrology, and change community structure of aquatic and riparian habitats. A model of *Phragmites* (types I & M) growth can be used as a predictive tool in management regimes and wetland planning and restoration. Our goal was to develop a robust growth model based on empirical data from the plants at different growth stages rather than a mathematical model that is based on allometric relationships. *Phragmites* populations were grown from rhizome fragments in six tanks located at the R.R. Foil Experiment Station, Mississippi State University and at the USDA-ARS Aquatic Weed Laboratory, University of California-Davis (Photo 1). *Phragmites* haplotypes I and M were grown in sterile builder and fertilized with 10 grams of Osmocote ® slow release fertilizer. Air, soil moisture, water chemistry and temperature were monitored to optimize growth. *Phragmites* plants were digitized every two weeks from emergence to senescence using a Polhemus Fastrak 3-dimensional digitizer system, utilizing Floradig software (Figure 1). This is the first year in a two-year study and a model will be based on both years of data.

Photo 1. Dr. David Spencer (right) and John Madsen (left) examine common reed (*Phragmites australis*) at the USDA ARS facility at University of California-Davis.

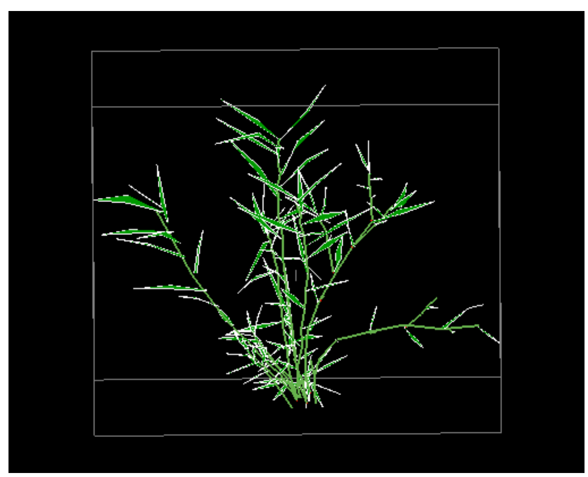


Figure 1. A digital common reed plant as an output from FloraDig.

Task 1.2.3. Regulation of Giant Salvinia (*Salvinia molesta*) Growth by the Availability of Nitrogen and Phosphorus

PI: John D. Madsen, GeoResources Institute, Mississippi State University
Collaborators: Ryan M. Wersal, GeoResources Institute, Mississippi State University
Kurt D. Getsinger, U.S. Army Engineer Research and Development Center

Giant salvinia (*Salvinia molesta* Mitchell) is an invasive floating aquatic fern native to South America. Giant salvinia has been a detrimental noxious pest in Australasia, Africa, South America, and the Caribbean. Giant salvinia was first reported to have escaped cultivation in South Carolina in 1995, and has since been reported in Texas, Louisiana, Mississippi, Alabama, Florida, North Carolina, Arizona, California, and Hawaii. Past research has indicated that giant salvinia is dependent on dissolved nutrients in the water for growth and has optimal growth at circumneutral to slightly acid (pH of 6) water. In a previous study (2005), we determined that the growth of giant salvinia was regulated by available nutrients and not by water pH. In 2006 we examined giant salvinia growth under differing nitrogen and phosphorus water column concentrations to determine which nutrient is limiting to the growth of giant salvinia. In July (2006) approximately 100.00 grams wet weight of giant salvinia was placed into 27, 378 L tanks and amended weekly with combinations of nitrogen and phosphorus. Nitrogen concentrations were 0.40, 0.80, and 1.80 mg L^{-1} (low, medium, and high) and phosphorus concentrations were 0.01, 0.03, and 0.09 mg L^{-1} to simulate oligotrophic to eutrophic nutrient availability. Each combination of rates was replicated three times. Biomass was collected at three-week intervals for 9 weeks using a 0.01 m^2 quadrat. Two biomass samples per tank were harvested, dried to a constant mass, and weighed. A one-way Analysis of Variance was used to determine differences in giant salvinia biomass according to nitrogen and phosphorus concentrations after nine weeks. Analyses were conducted at an a = 0.05. Our results indicate that phosphorus was not a significant factor in giant salvinia biomass (p=0.16), while nitrogen levels significantly affected growth (p<0.001) most notably an increase in giant salvinia growth in the highest (1.80 mg L^{-1}) nitrogen treatment (Figure 1). While phosphorus may not be as important as nitrogen for growth; giant salvinia will likely succeed best in waters with high availability of both nitrogen and phosphorus, and may not survive or compete in waters of low nutrient loading rates.

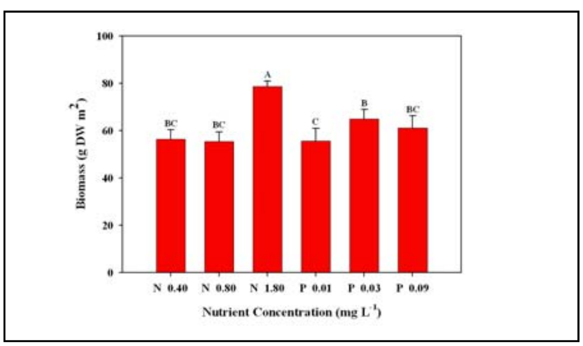


Figure 1. Giant salvinia biomass (g DW m^{-2}) was significantly influenced by available nitrogen in the water column, but was not influenced by available phosphorus. Bars sharing the same letter do no differ significantly at an a = 0.05.

Task 1.3. Assessment of Aquatic Plant Populations

PI: John Madsen, Collaborators: Randy Westbrooks, USGS

Environmental Parameters Affecting the Growth of Giant Salvinia in the River Bend Swamp of Pender County, North Carolina.

Randy Westbrooks[1], Janine Lloyd[1], Teresa Lengner[1], Rebecca Westbrooks[2], Audrey Cribb[2], Wayne Batten[3], John Madsen[4] and Ryan Wersal[4], [1]U.S. Geological Survey BRD, National Wetland Research Center, Whiteville, NC; [2]Southeastern Community College, Whiteville, NC; [3]Pender County Cooperative Extension Service, Burgaw, NC; [4]GeoResources Institute, Mississippi State University

A 30-acre infestation of giant salvinia (*Salvinia molesta*) was first detected by state and local officials at the River Bend Community in Pender County, in the heart of the Coastal Plain of southeastern North Carolina, in 2003. Since it occurs in a blackwater swamp adjacent to the Northeast Cape Fear River near the junction with NC Hwy 53, the infestation poses a serious threat to 200,000+ acres of wetlands and waterways throughout southeastern North Carolina. In 2003, the North Carolina Giant Salvinia Task Force was established to address the problem. Since that time, the task force, which is led by Wayne Batten, Director, Pender County Cooperative Extension Service, has worked to eradicate Giant Salvinia from several small infestations in eastern North Carolina. Over the past three years, the infestation at River Bend has been reduced to about 4 acres. Work on the project is supported by task force partners (Pender County, NCDA, NCSU, NC-DENR, USGS, and Land Owners), as well as by a grant from the National Fish and Wildlife Foundation (funded by USFWS). This project is being conducted as part of a larger effort under the USGS-MSU Invasive Species Partnership to determine environmental parameters that affect the growth of giant salvinia under field conditions.

The main goal of the project is to determine how the growth of giant aalvinia is affected by different water quality parameters and management treatments under natural field conditions.

The objectives of this project were to: 1. Evaluate effect of temperature, dissolved oxygen, pH, conductivity, nitrogen, and phosphorus on growth of giant salvinia under natural field conditions; and 2. Evaluate the relative growth of giant salvinia under different management regimes (herbicide treatments versus biological control release site).

On a monthly basis, from July until the first heavy frost in 2006, field data were collected from four designated sampling sites (infested and uninfested waters) in the River Bend Swamp and Northeast Cape Fear River for analysis by SCC and MSU: weather conditions, water temperature, water conductivity, pH, dissolved oxygen, nitrogen level, phosphorus level, and biomass samples. At each site with giant salvinia biomass, 20 samples were taken using a 0.018 m^2 sampling device, and sent to MSU for sorting, drying, and weighing. For the two selected salvinia sites, one was treated with Diquat herbicide, and the other was used as a release site for the biological control agent, *Cyrtobagous salviniae*.

Although samples have been collected monthly from July through December, only data from July and August were used for this analysis.

Biomass decreased in the herbicide treated site from 209 gDW m^{-2} in July to 178 gDW m^{-2} in August. Meanwhile, the biomass in the salvinia weevil plot increased from 140 gDW m^{-2} in July to 438 gDW m^{-2} in August. These means are significantly different, based on an analysis of variance ($p<0.0001$). While these analyses are not definitive nor was this a controlled experiment, it does suggest that, for the purposes of Early Detection and Rapid Response of small populations, treatment with herbicide may be a more rapid approach to bringing these populations under control.

Giant salvinia (*Salvinia molesta*) covering a small pond near Leaf, MS.

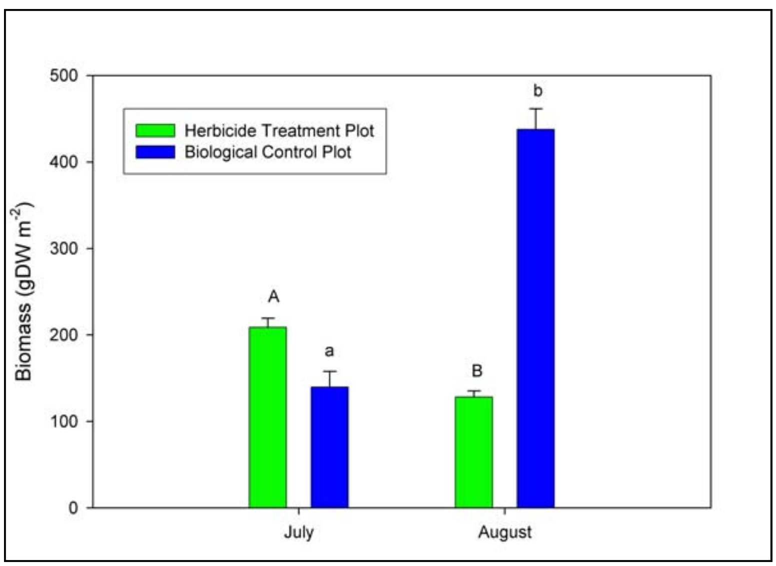


Figure 1. Giant salvinia biomass (gDW m^{-2}) for a site treated with Diquat herbicide ("herbicide Treatment Plot") and a site at which the biological control insect *Cyrtobagous salviniae* was released ("Biological Treatment Plot") for July and August. Bars represent the mean of 20 samples, with one standard error of the mean.

Task 1.4A. Environmental Impact of Invasive Aquatic Plants on Aquatic Habitat

PI: Eric Dibble, Co-PI: John Madsen

Habitat Alteration by an Invasive Plant and its Impact on Fish Foraging and Macroinvertebrate Colonization
Authors: Heather J. Theel and Eric D. Dibble, Department of Wildlife and Fisheries, Mississippi State University

Aquatic plants mediate ecological processes in aquatic habitats, specifically predator-prey (bluegill (*Lepomis macrochirus*)-macroinvertebrate) interactions. Individual growth rates of many fish species are positively related to foraging success. Exotic invasive plant species may alter the available structure in aquatic habitat thus affecting foraging. We investigated the hypothesis that a shift from a native aquatic plant bed to an invasive plant bed would alter aquatic plant bed complexity and therefore alter bluegill foraging success. Experimental treatments included: (i) intermediate densities of native-mixed plants and (ii) 50% native, 50% hydrilla, (iii) hydrilla, (iv) high density of hydrilla, and (v) no plants. We observed a significant treatment effect on aquatic plant bed complexity and bluegill foraging behavior. Bluegill searched faster, exhibited 60% more mean bouts, and recognized 38% more food items in native mixed habitat versus a hydrilla dominated habitat. We suggest a hydrilla dominated habitat disrupts predator-prey interactions by directly altering native habitat complexity, thus decreasing predator foraging success and prey recognition.

Abstract submitted for the Aquatic Plant Management Society 36th Annual Meeting 13-16 July 2006, Portland, OR.

Task 1.4B. The Effects of Non-Native Macrophyte Invasion on Juvenile Largemouth Bass *(Micropterus salmoides)*

Authors: Alexander J. Perret, and Eric D. Dibble, Department of Wildlife and Fisheries, Mississippi State University

Non-native macrophyte infestations in lakes and waterways of the United States in recent years have become a cause for concern. Research is needed to better understand the ecological impact on aquatic communities, and how a shift from native plants to invasive exotics affect aquatic habitat. Little is known about how fish habitat is impacted when a homogeneous plant bed replaces a heterogeneous bed of native vegetation. Changes in this structure within habitat can potentially impact growth, condition, and foraging ability of juvenile fish. We investigated the hypothesis that exotic invasive plants alter juvenile largemouth bass (*Micropterus salmoides*) growth, condition, and foraging ability when diverse native plant beds are overgrown by exotic plant growth. We conducted two experiments: 1) in ponds we measured for differences in largemouth bass growth and condition between treatments of diverse native plants (*Nymphaea odorata*, *Brasenia schreberi*, *Ceratophyllum demersum*, and *Potamogeton nodosus*) and invasive hydrilla (*Hydrilla verticillata*), and 2) in aquaria where foraging ability of juvenile largemouth bass was quantified at different stages of hydrilla invasion. Level of invasion was manipulated within the aquaria by increasing intervals (n=4) of introduced hydrilla (25% per treatment) from a 100% diverse native plant treatment to 100% hydrilla. We observed differences in the growth and condition of fish across pond treatments and foraging appeared to be altered within the aquaria experiment. These data provide insight into effects that invasive macrophytes have on largemouth bass habitat.

Abstract submitted for NALMS: 15th Annual Southeastern Lake and Watershed Management Conference. March 8-10, 2006. Columbus, GA.

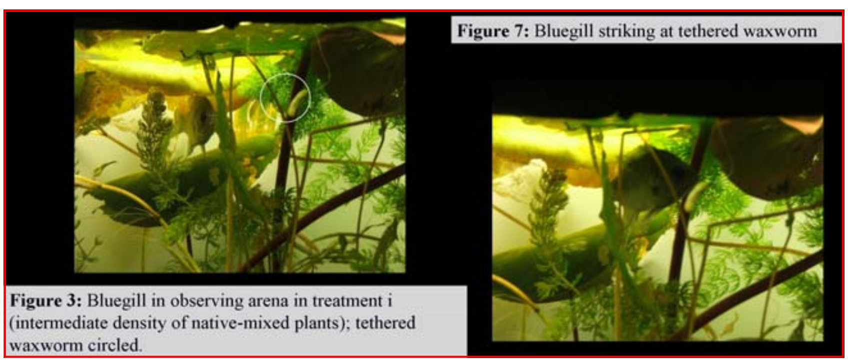


Figure 7: Bluegill striking at tethered waxworm

Figure 3: Bluegill in observing arena in treatment i (intermediate density of native-mixed plants); tethered waxworm circled.

Task 1.5. Survey for Hydrilla and Giant Salvinia in Mississippi

PI: John Madsen, Co-PI: Victor Maddox, Wilfredo Robles

Introduction

Invasive aquatic plant species are a significant threat to the water resources and wetlands of the nation, including the mid-south. For instance, invasive aquatic plants disrupt many bodies of water affecting the ecological interactions, disrupting water-supply, and impeding boat traffic. Two species in particular, hydrilla (*Hydrilla verticillata*) and giant salvinia (*Salvinia molesta*) are considered invasive aquatic plants worldwide. Both, hydrilla and giant salvinia are present in the Mid-South. However, little information still exists on the number of water bodies impacted and county records with the presence of these two species.

Methods and Materials

An extensive survey was conducted in 2006 in the state of Mississippi and western region of Alabama to detect the presence and absence of giant salvinia and hydrilla. A total of 19 counties were surveyed including reservoirs, waterways and major rivers. A handheld computer with Global Position System (GPS) capabilities was used to obtain geographic coordinates of surveyed locations. For hydrilla, we developed and extend potential sites by contacting natural resource agencies in the state, as well as encountering hydrilla infestations as part of our other research activities. For giant salvinia, surveys at known sites were performed including southern Mississippi counties after Hurricane Katrina. Current sites were widely surveyed to detect giant salvinia presence and its potential spread to related water bodies.

Results and Discussion

Current presence of hydrilla and giant salvinia in the state of Mississippi is presented in Figure 1.Giant salvinia was found at the Wedgeworth Creek located northeast of Leaf River near Petal in Forrest County, MS. To date, giant salvinia has not escaped into the Leaf River. The biocontrol agent *Cyrtobagous salviniae* has been released at this site; however, no suppression and damage was noticed on the giant salvinia population. Hydrilla has been found in Lake Aberdeen, Columbus Lake, Aliceville Lake, Gainesville Lake, Ross Barnett Reservoir, and Loakfoma Lake on the Noxubee National Wildlife Refuge (NWR). Management practices have been addressed for hydrilla control in the Ross Barnett Reservoir and Noxubee NWR. However, Lake Aberdeen, Aliceville Lake, Gainesville Lake, and Columbus Lake are not currently under active management. Further surveys should be conducted to track giant salvinia and hydrilla spread over the reported sites as well as examine their presence in other of mid-south water bodies.

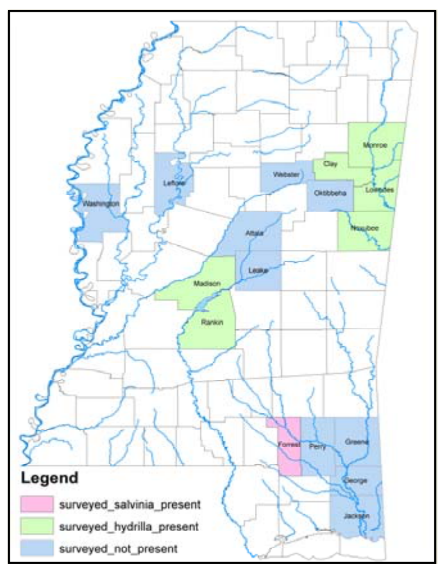


Figure 1. Occurrence of hydrilla and giant salvinia in Mississippi.

Revised from an abstract submitted for the Mid-South Aquatic Plant Management Society 25th Annual Meeting, October 24 – 26, 2006. Orange Beach, AL.

Task 2.
Terrestrial Plants

Task 2.1A. Habitat Invasibility Models

PI: Gary Ervin, Co-PIs: John Madsen, John Byrd

Cogongrass presence & absence data collected by MSU researchers (Figure 2.1A-1) have been used in developing habitat modeling approaches to complement search and management efforts for this species in the region. The initial modeling effort used the State Soil Geographic Database (STATSGO; USDA NRCS 1994), to provide representative environmental predictor variables for cogongrass distribution within Mississippi. Model variables used as regressors on cogongrass presence-absence data included available soil water content, bulk density, CEC, clay content, organic matter content, permeability, and pH, each calculated as the minimum & maximum value for each soil mapping unit across MS. Analyses involved binary logistic regression models of soil factors correlation with cogongrass presence-absence, followed by information-theoretic analyses to compare resulting models. Information-theoretic analyses used the Akaike Information Criterion (AIC) to rank the resulting logistic regression models and indicate which provided the best fit to cogongrass occurrence across the state. The resulting best model was incorporated into an ArcMap GIS to generate a layer indicating probabilities of occurrence of cogongrass, based on statewide soil characteristics (Figure 2.1A-2).

As mentioned in Task 1.2.1A, we developed a stratified, randomly selected set of sample points to be visited beginning in the 2006 field season. Data from these points will be used in subsequent modeling efforts to better understand the distribution of exotic plants in the region (versus data collected simply from roadside census). During summer 2006, we collected data at 69 of those points (Figure 2.1A-3) on plant species present and microhabitat characteristics (using a modification of the Beyond NAWMA guidelines [Stohlgren et al. 2003] including detailed soil analyses). We will augment those data with geospatial information, such as climatic data, land use/cover, soil associations, and proximity to such features as urban areas and transportation corridors in order to develop predictive statistical models that utilize data from both the local and landscape scales. During data collection, we encountered two major difficulties. First was a clumped distribution of points in certain land use categories, such as the thirty-three highly aggregated herbaceous wetland points in the brackish marshes of Alabama (Figure 1.2.1A-1). This is problematic because it is an inadequate representation of the landscape in which we are interested. The second major obstacle was that many points occurred on private, rather than federal lands. This was the result of the nature of the federal lands GIS data layer, which was simply a coarse-scale boundary in which all federally-owned lands of a given unit fell. The boundaries available included all federal lands, but also included numerous private landholdings intermingled with public lands. The result was that approximately half the points to which we drove in some federal land units were not available for sampling; this seriously decreased the efficiency of sampling. Because of these difficulties, a new set of points will be generated with more care applied in the manner with which points are stratified across the landscape and among land use categories.

Despite logistical difficulties, we do now have a set of data from 69 random points located across twelve land cover categories (LCC), with an average of six points per LCC. The first use of this dataset will be to combine soils data from a random subset of our points with data collected by Dr. Charles Bryson (USDA Southern Weed Science Research Unit, Stoneville, MS) at points across Mississippi that were occupied by cogongrass (*Imperata cylindrica*). Soils information from this presence-absence dataset will be used to evaluate whether and which soil characteristics appear to influence the colonization success of cogongrass in Mississippi. These analyses will be presented at the WSSA Conference in San Antonio, TX, in February 2007.

In addition to the projects discussed in the following sections (Tasks 2.1B-2.1C), we currently are completing a study on the effects of cogongrass on litter decomposition in natural plant assemblages, versus invaded areas, and we are in the midst of an 18-mo study on the roles of native vegetation, nutrients, and soil fungi in permitting or resisting cogongrass invasion in the Black Prairie region of Mississippi. We expect both studies to increase understanding of the reciprocal effects of natural vegetation and cogongrass on one another during the invasion process.

Using *Imperata cylindrica* as a model organism, the decomposition study will address some of the hypotheses that arise out of the current invasive species literature. For instance, *I. cylindrica* is a dominant exotic perennial grass species whose decomposition rates have not been studied alongside those of a dominant native perennial grass. That is, there are no available data to indicate whether monotypic *I. cylindrica* colonies alter the decomposition rates of native vegetation. Similarly, it is not well known whether the ability to alter the composition of soil microbial communities is a strong mechanistic factor that leads to regional dominance of a particular invasive plant. The current Black Prairie study is using *Imperata cylindrica* as a model organism to test several hypotheses about this potential competitive mechanism. The study aims to determine if *Imperata cylindrica* possess the ability, through a hypothesized belowground-release of chemicals, to alter the natural occurrence and frequency of symbiotic mycorrhizae. Further, the study will address whether this phenomenon is influenced by local plant species richness and diversity. The decomposition study will terminate during Spring 2007, and the Black Prairie study will continue through the 2007 growing season. The whole of these projects will enable us to interpret the landscape models through detailed understanding of local-scale ecological processes.

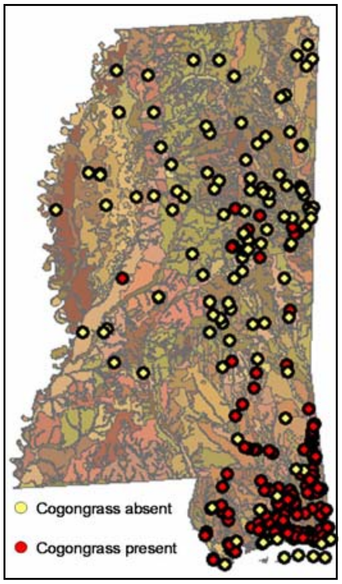


Figure 2.1A-1. Points used for cogongrass presence (red points) and absence (yellow), courtesy of J. Byrd.

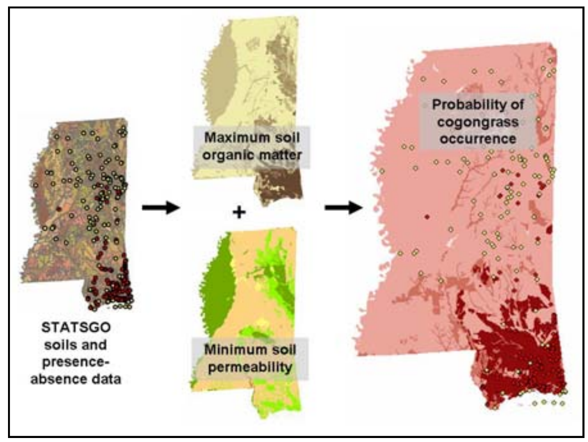


Figure 2.1A-2. Presence-absence data (Figure 2.1A-1) were combined with environmental predictor variables (left) to derive best-fit models, which were combinations of a subset of predictors (center). The best statistical model then was used to project estimated occurrence probabilities across the landscape (right).

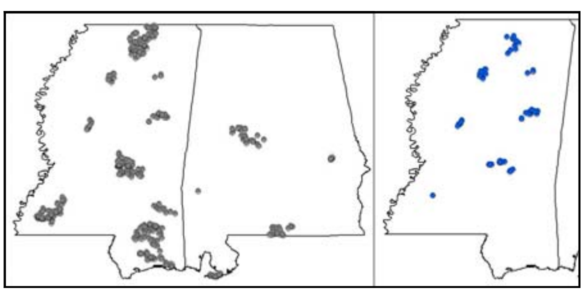


Figure 2.1A-3. Map of random points generated (left, in gray) and the 69 points actually sampled during 2006 (right, in blue – all were in Mississippi).

References:
Stohlgren, T. J., D. T. Barnett, and S. E. Simonson. 2003. Beyond North American Weed Management Standards. Available at: http://www.nawma.org/documents/Mapping%20Standards/ BEYOND%20NAWMA%20STANDARDS.pdf

United States Department of Agriculture, Natural Resources Conservation Service. 1994. State Soil Geographic (STATSGO) Database for MS. Accessed January 2006 through: http://www.ncgc.nrcs.usda.gov/products/datasets/statsgo/index.html.

Task 2.1B. Effects of Intraspecific Seedling Density, Soil Type, and Light Availability upon Growth and Biomass Allocation in Cogongrass, *Imperata cylindrica*

D. Christopher Holly and Gary N. Ervin

Imperata cylindrica is a prolific seed producer, but the importance of this vector of invasion has been inadequately addressed, despite growing support in the ecological literature that propagule pressure plays a key role in many successful invasions. The relative importance of propagule pressure across environmental gradients is an area of research that is quickly becoming important in understanding invasion success. The present study was conducted in order to test the effects of varying propagule pressure upon the ability of *I. cylindrica* to grow and establish across experimentally manipulated light and soil gradients. The results point out several biologically significant trends in the establishment and growth of *I. cylindrica* seedlings in the experimental environments. Seedlings growing in high nutrient soils performed the best regardless of the amount of available light, but overall biomass was always greatest in high light environments (Table 2.1B-1). *Imperata cylindrica* showed a very strong trend in biomass allocation, with seedlings in reduced light environments always partitioning more biomass to aboveground tissue (Figure 2.1B-1). The data provided no evidence that initial propagule density affected the growth and establishment of *I. cylindrica* seedlings, but realized propagule pressure (number of surviving seedlings) had a positive effect on growth and biomass production in Black Prairie and Pontotoc Ridge soils (Figure 2.1B-2).

Table 2.1B-1. Treatment Factors and Relative Effects Upon Plant Performance. No effect is indicative of a *P*-value > 0.05, + effects are significant at a level ≤ 0.05.

Experiment	***Factor***	***Effect on Plant Growth Parameters***
100% Light	Soil Type	+ with increasing nutrient concentration
	Initial Propagule Density	no effect
	Final Propagule Density	no effect
27% Light	Soil Type	+ with increasing nutrient concentration
	Initial Propagule Density	no effect
	Final Propagule Density	+ with increasing seedling density
14% Light	Soil Type	+ with increasing nutrient concentration
	Initial Propagule Density	no effect
	Final Propagule Density	+ with increasing seedling density

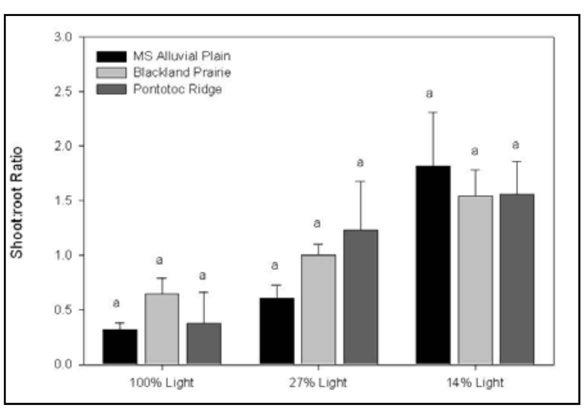


Figure 2.1B-1. The effect of soil type on mean shoot:root ratio per plant (± 1SE) in 70-d-old cogongrass seedlings. Data illustrate the soil effects on shoot:root ratio across three levels of available light (PAR). For each soil, within each light level, values sharing the same letter do not differ significantly according to Scheffé's multiple comparison procedure (*P* ≤ 0.01).

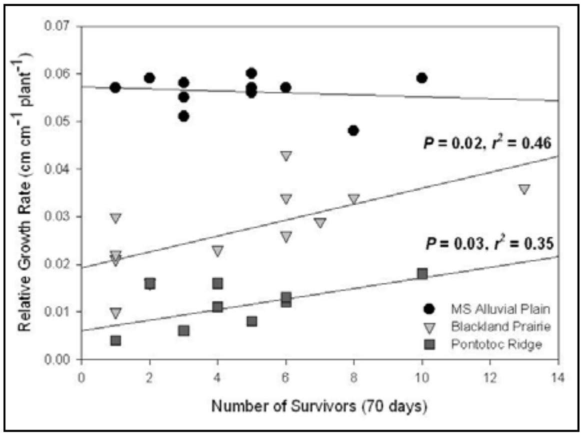


Figure 2.1B-2. The effect of number of surviving seedlings (at 70 days) on the relative growth rate of cogongrass across all three soil types in the 27% available PAR experiment. Associated *P*-values are given for significant regression lines ($P \leq 0.05$).

Modified from a manuscript submitted to *Journal of Applied Ecology*:
Holly, D. Christopher and G.N. Ervin. 2006. Effects of propagule pressure, soil type, and light availability upon growth and biomass allocation in an invasive perennial grass species, *Imperata cylindrica*. *Weed Technology*, In review.

Task 2.1C. Regional distribution of eastern baccharis, *Baccharis halimifolia*

Gary N. Ervin

Baccharis halimifolia, although native to the Gulf and Atlantic Coastal Plains, exhibits numerous traits of highly invasive species. Examples of these traits are: *Baccharis* is a prolific producer of small, wind dispersed achenes, reaches reproductive age in about three years, and capitalizes on disturbed habitats such as roadsides, fallow fields, and cutover timber lands. Although *Baccharis* is highly abundant in central Mississippi, it recently was reported that this species has been recorded in only two localities in Tennessee (Estes, D. 2006. The vascular flora of Giles County, Tennessee. *Sida* 21:2343-2388). As part of our efforts to model the invasion process, patches of *Baccharis* have been mapped in 38 counties of northeast Mississippi and western Tennessee (Figure 2.1C-1). The results of this exercise indicate that MSU is situated very near the present northern limits of this species across at least part of its range, making *Baccharis* a potentially useful tool for monitoring range expansion as part of the invasion process. Initial examination of data collected further suggests different patterns of land use occupancy in the northern limits of *Baccharis'* range, compared with the southernmost counties surveyed (Table 2.1C-1).

Table 2.1C-1. Comparison of distribution of *Baccharis halimifolia* in ten Tennessee counties, versus the three southernmost Mississippi counties that were mapped (Clay – Oktibbeha - Webster). Asterisks indicate percent of all patches located in the most frequently occupied land use types (upper ~50% of all patches), boldface italicized land use classes are those occupied only in Mississippi.

	Mississippi (Clay – Oktibbeha - Webster)	Tennessee (ten counties)
Number of patches mapped	208	52
Max. estimated patch size (km^2)	2.7	0.1
Habitat types occupied	10	10
Land Cover (LC) types occupied	11	8
% of all patches in		
cultivated land use class	2	6
low-intensity developed	3	13
med- intensity developed (primarily rights-of-way)	***16*	***31*
high-intensity developed	2	0
evergreen	11	6
grassland	8	4
pasture	12	0
mixed forest (primarily edge)	11	**23*
scrub-shrub (fallow or cutover)	**33*	13
wetland – herbaceous	< 1	0
wetland – woody	1	4

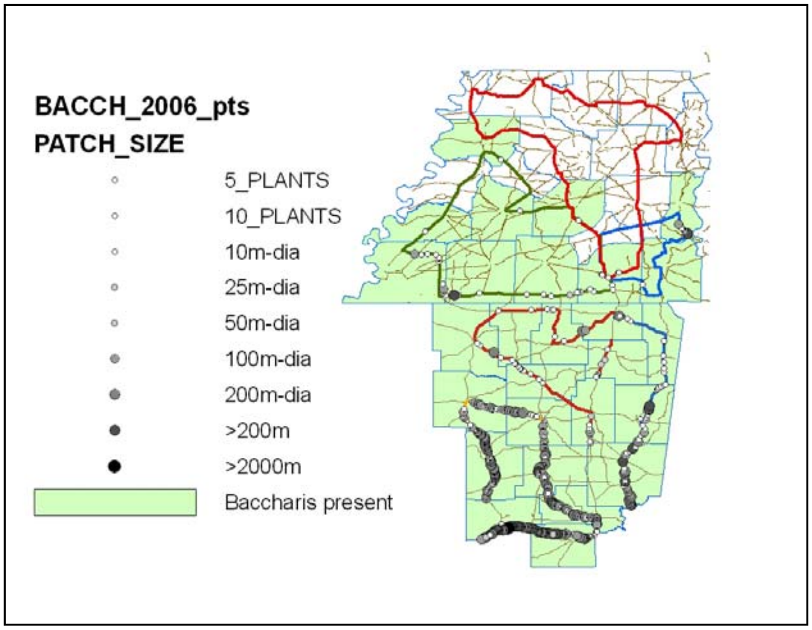


Figure 2.1C-1. Mapped patches of *Baccharis halimifolia* in the study region. A total of 634 patches were mapped and 22 putative new county-level records were made, ten in Tennessee and twelve in Mississippi. Colored lines represent the route that was surveyed during November 23 to December 07, 2006.

Task 2.2. Assessment of Terrestrial Plants

PI: John Byrd, Randy Westbrooks

Seed Germination in Ornamental Varieties of Nonnative Grasses

Victor Maddox[1], John Madsen[1], John Byrd[2], and Randy Westbrooks[3]

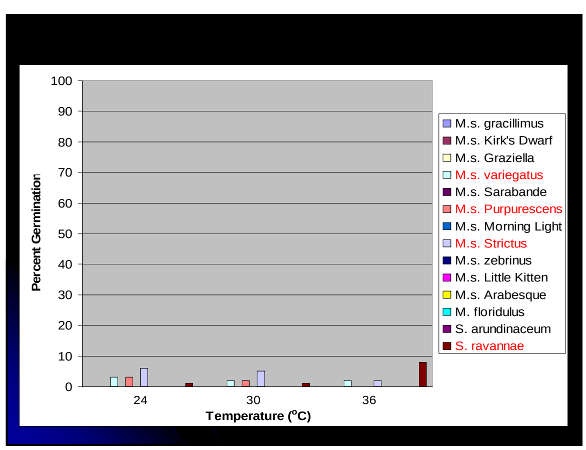
[1]GeoResources Institute, Mississippi State University; [2]Plant and Soil Sciences Department, Mississippi State University; [3]National Wetland Research Center, U.S. Geological Survey

Thousands of exotic species have been introduced to the United States. Many times the invasibility or risk of these species is unknown. Determining risk associated with introduced species could be of great benefit in the prevention or early detection of invasions. Multifaceted efforts on selected species are underway. Efforts conducted in 2006 with certain grasses are presented in this summary. Grasses are numerous in scope and continue to be introduced into the United States, mostly as forages or ornamentals.

This study focuses on four species of grasses, *Miscanthus floridulus* (Labill.) Warb., *Miscanthus sinensis* Anderss. (cultivars and varieties), *Saccharum arundinaceum* Retz., and *Saccharum ravennae* (L.) L. Aside from these four species, *Miscanthus sinensis* cultivars and varieties studied were 'Arabescue', *gracillimus* Hitchc., 'Graziella', 'Kirk's Dwarf', 'Little Kitten', 'Morning Light', 'Purpurescens', 'Sarabande', 'Strictus', *variegatus* Beal, and *zebrinus* Beal. *Miscanthus sinensis* and *Saccharum ravennae* are widely cultivated as ornamental. Though not common at present in the southeast, there are reports of both escaping cultivation. Little is known about *Saccharum arundinaceum*, but its rapid growth, large size (Figure 1), and wind desimminated seed may pose problems if invasion where to occur. The purpose of this study was to determine which species and/or cultivars pose a risk of invasion, suitable temperatures for seed germination, and if *Miscanthus sinensis* cultivars and/or varieties pose a greater risk when outcrossing is possible.

Two replications of 100 seeds collected in the fall from field plants were placed petri plated on wet germination paper in a curtain germinator under continuous lighting and at constant temperatures of 12^{o}C, 18^{o}C, 24^{o}C, 30^{o}C, and 36^{o}C. Separate runs were conducted at each temperature. Percent germination was recorded for each grass at each temperature.

Current results indicate that *Miscanthus sinensis* 'Purpurescens', *Miscanthus sinensis* 'Strictus', *Miscanthus sinensis variegatus*, and *Saccharum ravennae* all produce some viable seed and may pose a risk of invasion. Although percent germination was low (Table 1), seed production on these grasses is very high. No germination was observed at 18^{o}C or below. All but one germinated at temperatures of 24^{o}C, 30^{o}C, and 36^{o}C, except *Miscanthus sinensis* 'Purpurescens' which showed no germination at 36^{o}C. Germination at these higher temperature may not be surprising since all are warm-season, C_4 grasses.



Research objectives for 2007 are to: repeat the 2006 study, isolate *Miscanthus sinensis* cultivars and varieties which had viable seed in 2006 to determine if outcrossing is an issue, and continue monitoring and mapping efforts.

Task 2.3. Cultivation Intensity for Cogongrass Eradication

PI: John Byrd, Jr.

Mowing or Burning before chemical applications

Analysis of cogongrass foliage biomass dry weight data indicated that the removal of aboveground biomass before chemical treatments increased herbicide efficacy by 60 to 80%. Mowing with no herbicide application reduced above-ground biomass 40% while burning with no herbicide treatment reduced cogongrass biomass 60%. All treatments that included biomass removal before herbicide application reduced cogongrass biomass 55 to 96% compared to chemical treatment alone. Chemical treatments alone provided only 9 to 40% biomass reduction. Visual control data indicated almost all treatments provided satisfactory control (above 70%), however glyphosate with no foliage removal, mowing or burning with no herbicide treatments provided only 40 to 50% control.

Tillage Frequency

First year results indicate rotary tillage provided the best control (above 90%) 30, 60 and 90 days after first tillage (DA1T). Moldboard plowing provided 80% control 30 DA1T, but control decreased to 57% 60 DA1T and 28% 90 DA1T. Disking provided 77% control 30 DA1T and decreased to 51% 60 DA1T and 25% 90 DA1T. A second tillage was conducted 120 after first tillage and control once again increased for all three tillage implements. Rotary tillage provided the best control and remained over 85% control for the rest of the growing season. Disking was the second best control but did not remain above 70% control for the rest of the growing season. Moldboard plow provided the least amount to control after the second tillage and dropped after 30 days. A third tillage was implemented in the winter of 2005 to end tillage for the season. Second year results are similar to the first year except control lasted longer throughout the growing season. Plots that were tilled three times the year before with the rotary tiller remained almost void of any cogongrass, and remained bare throughout the growing season once tillage occurred. Rotary tilled plots that were tilled twice the previous season had minimal cogongrass regrowth, but were absent of cogongrass after the first tillage operation was completed and remained that way for the rest of the growing season. Rotary tilled plots that were tilled once the prior season prior did not show but a 20% reduction from the original infestation. Overall rotary tilled plots provided the best control which lasted the longest. Disking plots that were tilled once the year prior showed no reduction from the original population. These plots showed 80-85% control 30 DA1T but decreased to only 10% control by120 DA1T and to 0% control by the end of the growing season. Plots that were disked twice the year prior showed a 15% decrease from original population density. The only difference between these plots and the ones disked once is that after the second tillage control increased to 80% after this second tillage and remained above 65% throughout the growing season. Plots that were disked three times the previous season showed a 25% reduction from the original infestation. These plots provided 80-85% control 30 DA1T and decreased 20% by the time the second tillage of the year occurred and decreased little by the third tillage. Moldboard plots that were tilled once the year prior showed little to no reduction from that original stand. The plots moldboard plowed once provided 85% control 30 DA1T, but deceased to 15% control 120 DA1T, then dropped to 0% by the end of the growing season. Plots that were moldboard plowed twice the year prior showed about a 35% reduction from the original stand. These plots had similar results to the plots tilled once but control increased after the second tillage and remained above 50% throughout

the rest of the growing season. Moldboard plots that were tilled three times the year prior showed a 40% reduction from the original population. These plots provided 85-90% control 30 DA1T and remained above 70% control throughout the growing season because of the second and third tillage. Overall the plots that were tilled three times a year provided the best control with rotary tillage providing the best control, moldboard second and disking third.

Tillage followed by Spraying

All plots that had a tillage operation performed before chemical applications provided excellent control. After cogongrass greened up this spring, the plots that were rotary tilled followed by the chemical combinations (Arsenal, Roundup and Mix) contained almost no cogongrass. The rotary tilled plot that was not sprayed provided only 15% control after greenup, but the plots that were sprayed the prior fall all provided 90% control or above. A similar trend existed with other tillage methods. All plots that were tilled, regardless of the implement prior to chemical application, provided 85% or better throughout the growing season. When these treatments were repeated in 2006 most of the treatments were applied to almost bare ground. The plots that were only tilled and not followed by an application exhibited little to no control. Similar results were seen in plots that received only herbicide application with no tillage. The mix of Arsenal and Roundup provided the best cogongrass control, followed by Arsenal and then Roundup.

Task 3.
Invasive Insects

Task 3.1. Early Detection and Reporting of Cactus Moth: Protocols for Identification of Exotic and Native Cactus Moths

PI: Richard L. Brown, Department of Entomology & Plant Path., Mississippi State University
Co-PI: John Madsen, GeoResources Institute, Mississippi State University
Collaborators: Randy Westbrooks, USGS National Wetland Center

Introduction

Survey and detection programs for the exotic cactus moth, *Cactoblastis cactorum* (Berg) (Pyralidae) are dependent on visual inspections of cactus for presence of larvae and use of pheromone traps for detection of adults. These survey programs across a wide geographical area are dependent upon a large number of individuals who may be employed by private, state or federal agencies or who may be volunteers, e.g., Master Gardeners in Mississippi. The ability to recognize larvae and adults of the cactus moth is essential for individuals involved in the survey program.

In southeastern United States the cactus moth caterpillar can be easily distinguished from caterpillars of native cactus moths and all other Lepidoptera by the distinctive red and black color; however, the range in color of western species of cactus feeding caterpillars is still unresolved. Identification of adult cactus moths in pheromone traps is more problematic, in part because the specimens may be in poor condition without complete wing patterns. In addition, adults of native cactus moths in the genus *Melitara* are superficially similar in wing pattern and color to the exotic *Cactoblastis* (Figs. 1-2). The pheromone lure is not specific to *Cactoblastis cactorum*, and many other species of moths are also trapped.

The objectives of this task have been the following: 1) develop protocols for identifying adults of cactus moths in pheromone traps, and 2) develop protocols for identifying larvae infesting cladoles of *Opuntia* cactus. These objectives required: 1) examination of pheromone traps operated in various geographic localities to determine which species of Lepidoptera are attracted to the cactus moth pheromone lure and which species might be confused with the cactus moth, and 2) collection and rearing of larvae infesting *Opuntia* cladoles in western U.S. to obtain diagnostic characters for distinguishing larvae of the exotic cactus moth from larvae of native species in the western states.

Materials and Methods

Pheromone traps were operated in Alabama, Mississippi, Louisiana, Texas, New Mexico, Arizona, and California during 2005 and in Puerto Rico, South Carolina, Mississippi, Texas, and Arizona during 2006. Traps were operated in 2006 by personnel in national parks and wildlife refuges in Mississippi (Grand Bay Savannah National Wildlife Refuge) and Texas (Padre Island National Seashore) and by personnel of USDA-APHIS and CAPS (Cooperative Agricultural Pest Survey) in Puerto Rico, South Carolina, Mississippi, Texas and Arizona. Depending on the state, traps were operated during a period from May through the end of November. All trap samples were mailed to Richard Brown for identification. Results of all traps operated in 2005 and traps operated on federal lands during 2006 are reported here; results of trap samples operated by APHIS and CAPS personnel during 2006 will be reported in the future. All moths from traps operated in South Carolina, Mississippi, and Texas were identified to genus or species when possible and counted. Moths from Arizona that were similar in size to *Cactoblastis* were identified to species when possible, but no attempt was made to identify the small sized moths (less than ½ inch in length) below family level. Because small Pyralidae dominated the trap catches in Arizona, counts were estimated by counting number of specimens in three rows of squares (both ends and middle), multiplying by three to account for the nine rows, and rounding the number to nearest five.

Larvae infesting *Opuntia* in western Texas were collected by Greg Christoloudou and JoVonn Hill during June, 2006. Additional collections of *Opuntia* were made in New Mexico by Victor Maddox. All cacti suspected to be infested by larvae were photographed for subsequent identification by Victor Maddox, and infested or damaged cladoles were held for rearing and identification. Cladoles with signs of damage or infestation were dissected to determine if larvae were present. Detected larvae in cladoles were removed for photography, after which they were returned to the cladole they had infested to complete development. Pupated larvae currently are being held in the Department of Entomology Insect Rearing facility at 70°F, 12 hours light:12 hours dark, and 50% RH over the winter to obtain emergence of moths for identification in 2007.

Results

During 2006 surveys in five states and Puerto Rico resulted in 319 samples (sticky trap bottoms) for which moths were identified and counted. These traps yielded 5,909 moths, of which most were small pyralids collected in Arizona. Forty-seven species or genera in various families of moths were identified from the pheromone traps. *Cactoblastis cactorum* moths were identified in traps only from South Carolina and Puerto Rico, where they have been established.

The most frequently collected non-target species in pheromone traps during 2005 and 2006 federal lands included the following, in decreasing number of individuals: 1) *Plodia interpunctella* (AZ), 2) *Spodoptera exigua* (all states), 3) *Melitara* spp. (AZ), 4) *Platynota flavedana* (eastern U.S.), and 5) *Ptycholoma peritana* (eastern U.S.). Among the most common, non-target species, *Spodoptera exigua* and *Melitara* species are the only taxa that exceed one-half inch in length from the head to tip of the wings. However, several other species were collected in smaller numbers that are near the size range of *Cactoblastis*. These larger species include the following: *Spodoptera dolichos*, *Spodoptera frugiperda*, *Acrolophus* species, *Elasmopalpus lignisellus*, *Crambus quinquareatus,* A*delphia petrella*, and *Pseudoplusia includens* (Table 1; Figs. 3-16).

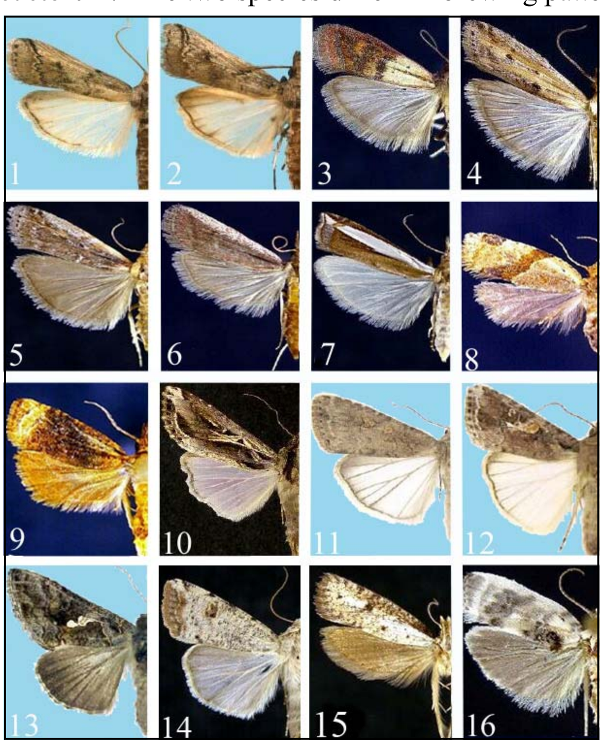
Larvae of three native species of cactus moths were collected in western Texas. Two are species of *Melitara* and one species has been identified by Dr. Don Davis, Smithsonian Institution, as *Dyotopasta yumaella* Kft. (Tineidae), a species for which the caterpillar has not been described. This tineid caterpillar, which exceeds one inch in length and is whitish in color, feeds gregariously in the cladole, similar to *Cactoblastis*. Caterpillars of all native species in Texas differ from those of *Cactoblastis* in having whitish, blue or gray coloration.

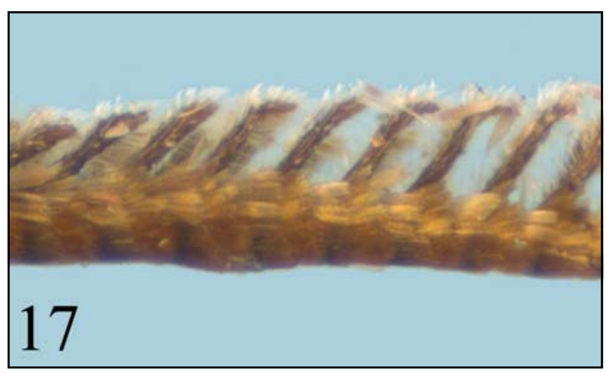
Identification of Moths in Pheromone Traps

Cactoblastis cactorum is most similar in wing pattern and color to the seven species of *Melitara* in the United States, all of which are native cactus feeders (Neunzig, 1997). Both genera are members of the family Pyralidae. Most species of Pyralidae have adults with relatively long labial palpi that extend from near the base of the proboscis to beyond the front of the head. However, length of labial palpi varies in many families and between sexes, and this character alone cannot be used to identify members of the Pyralidae. Intact specimens of *Cactoblastis* (Fig. 1) and *Melitara* (Fig. 2) can be distinguished from most of the other specimens of moths that are commonly collected in pheromone traps (Figures 3 - 16) by their grayish brown color with a whitish to light gray area on the leading edge (costa) of the wing and the zig-zag line that crosses the wing before the wing tip.

Males of *Melitara* are usually larger than those of *Cactoblastis*, but because their wing pattern are so similar, their antennae should be examined to differentiate the two genera. Males of *Melitara* have a bipectinate antenna, in which the antennal shaft has short projections on each segment, whereas males of *Cactoblastis* do not have a bipectinate antenna (Figs. 17-18).

Spodoptera exigua is the most common non-target species in pheromone traps that is similar in size to *Cactoblastis cactorum*. The two species differ in forewing pattern, most no-





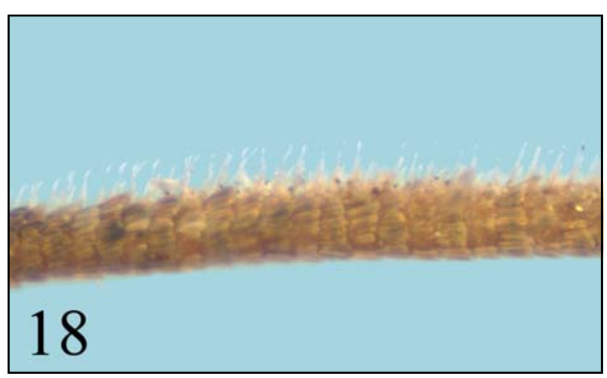
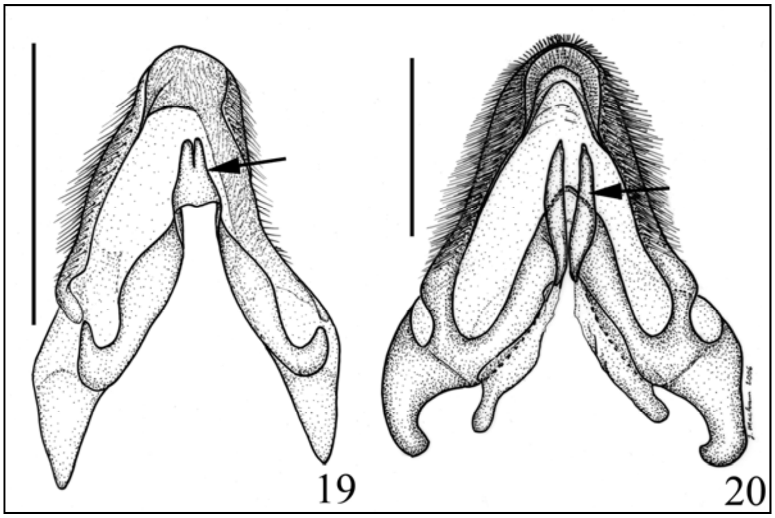


Table 1. Lepidoptera collected in *Cactoblastis cactorum* pheromone traps for all states in 2005 and for Grand Bay Savannah N.W.R., Mississippi and Padre Islands Nat. Seashore, Texas in 2006. Species in bold type are illustrated in figs. 1-16.

Taxa	AL	MS	MS	TX	TX	AZ	CA	Totals
	2005	2005	2006	2005	2006	2005	2005	
Phycitinae	0	0	1	2	0	9329	832	10164
Plodia interpunctella	0	0	6	1	0	1122	0	1129
Spodoptera exigua	69	36	279	53	102	5	162	706
Unidentified Microlepidoptera	11	8	57	6	9	0	4	95
Unidentified Noctuidae	2	3	4	50	1	2	0	62
Unidentified Gelechiidae	0	0	2	0	0	0	24	26
Melitara spp.	0	0	0	1	0	18	1	20
Cactoblastis cactorum	16	0	0	0	0	0	0	16
Platynota flavedana	11	0	0	1	0	0	0	12
Ptycholoma peritana	9	2	0	0	0	0	0	11
Unidentified Pyralidae	6	1	0	4	0	0	0	11
Eucosma sp.	0	0	0	6	0	0	0	6
Unidentified Crambidae	2	0	0	4	0	0	0	6
Unidentified Tineidae	2	0	3	0	0	0	1	6
Unidentified Torticidae	4	0	0	1	0	1	0	6
Blastobasinae	4	0	1	0	0	0	0	5
Spodoptera frugiperda	0	0	4	1	0	0	0	5
Dicymolomia opuntialis	0	0	0	1	0	0	3	4
Spodoptera dolichos	0	0	0	4	0	0	0	4
Unidentified Geometridae	1	1	1	1	0	0	0	4
Harrisina americana	1	0	0	2	0	0	0	3
Platynota sp.	0	0	0	0	0	0	3	3
Unidentified Hesperiidae	0	1	2	0	0	0	0	3
***Acrolophus* sp.**	1	1	0	0	0	0	0	2
Atascosa glareosella	2	0	0	0	0	0	0	2
Atteva punctella	0	0	0	2	0	0	0	2
Cosmopterix sp.	2	0	0	0	0	0	0	2
Crambus quinquareatus	2	0	0	0	0	0	0	2
Elasmopalpus lignosellus	0	0	0	2	0	0	0	2
Hypena scabra	0	0	0	2	0	0	0	2
Pseudoplusia includens	0	0	2	0	0	0	0	2
Spodoptera sp.	0	0	0	2	0	0	0	2
Unidentified. Moth	2	0	0	0	0	0	0	2
Adelphia petrella	1	0	0	0	0	0	0	1
Anicla infecta	0	1	0	0	0	0	0	1
Antaeotricha lucillana	0	0	1	0	0	0	0	1
Argyrogramma verruca	0	0	1	0	0	0	0	1
Aristotelia sp.	0	0	1	0	0	0	0	1
Cisseps fulvicollis	0	0	1	0	0	0	0	1
Cycnia sp.	0	0	0	1	0	0	0	1
Cydia sp.	1	0	0	0	0	0	0	1
Diacme elealis	0	0	0	1	0	0	0	1
Donacaula sp.	1	0	0	0	0	0	0	1
Dyseriocrania griseocapitella	1	0	0	0	0	0	0	1
Endothenia hebesana	1	0	0	0	0	0	0	1
Ethmia sp.	0	0	0	0	0	0	1	1
Eucosmini	1	0	0	0	0	0	0	1
Fissicrambus profanellus	0	0	0	1	0	0	0	1
Gretchena sp	1	0	0	0	0	0	0	1
Helicoverpa zea	0	0	0	0	1	0	0	1
Heliothis virescens	0	0	1	0	0	0	0	1
Hellula rogatalis	0	0	0	0	0	0	1	1
Idia aemula	0	1	0	0	0	0	0	1
Idia sp.	0	0	0	1	0	0	0	1
Leptostales crossii	1	0	0	0	0	0	0	1
Lineodes integra	0	0	0	1	0	0	0	1
Marasmia cochrusalis	0	0	0	1	0	0	0	1
Nomophila nearctica	0	0	1	0	0	0	0	1
Olethreutes sp.	0	0	0	1	0	0	0	1
Peoriini	1	0	0	0	0	0	0	1
Plutella xylostella	1	0	0	0	0	0	0	1
Ptycholoma virescana	0	0	1	0	0	0	0	1
Schinia sp.	0	0	0	1	0	0	0	1
Sparganothis sp.	0	1	0	0	0	0	0	1
Sparganothis sulfureana	1	0	0	0	0	0	0	1
Spoladea recurvalis	0	0	1	0	0	0	0	1
Stegesta bosqueella	1	0	0	0	0	0	0	1
Strepsicrates indentanus	0	0	1	0	0	0	0	1
Tinea apicimaculella	1	0	0	0	0	0	0	1
Unidentified Nymphalidae	0	0	1	0	0	0	0	1
Xylostella maculipennis	0	0	0	0	0	0	1	1
	160	56	372	154	113	10477	1033	12365

ticeable by the yellowish brown, circular spot in the middle of the wing in *S. exigua*. In addition to the wing pattern, *Cactoblastis* and *Melitara* have a black, diagonal band across the apical third of the middle leg, but this black band is absent on the middle leg of *Spodoptera*. If the wing pattern or leg color cannot be discerned, the *Spodoptera* can be easily identified by the bundles of long hair-like scales (hair pencils) associated with the genitalia at the tip of the abdomen. These hair pencils can be easily seen when the abdomen is placed in a small dish of alcohol and the tip of the abdomen is teased apart with forceps.

Species that exceed one-half inch in length from head to tip of the forewings and that do not have intact wing patterns or are greasy from the sticky trap might be confused with *Cactoblastis*. These can be identified by genitalia, although shape of wings and length of labial palpi also can be used with experience in identification. Species of *Melitara* or *Cactoblastis* that lack antennae also require examination of genitalia. Abdomens of moths in pheromone traps can be placed directly in alcohol for two or more hours to allow softening of the structures. The genitalia at the tip of the abdomen can be teased apart for examination with a microscope. *Cactoblastis* are distinctive by the form of the dorsal structures of the genitalia with a gnathos that has a short cleft at its apex (Fig. 19). No other species of Lepidoptera has similar genitalia, except those in *Melitara*. However, species in the latter genus have a gnathos that is deeply divided and expanded apically (Fig. 20).



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Acknowledgements

Photographs and drawings of *Cactoblastis* and *Melitara* were made by Joe MacGown. Photographs of other Lepidoptera were obtained from the Moth Photographers Group site of the Mississippi Entomological Museum at: http://mothphotographersgroup.msstate.edu/MainMenu.shtml

JoVonn Hill was responsible for data management, preparation of species lists, and preparation of the plate of imago photographs Greg Christoloudou and JoVonn Hill collected larvae in Texas.

Literature Cited

Neunzig, H. H. 1997. Pyraloidea, Pyralidae (Part). In Dominick, R. B., et al., The Moths of America North of Mexico, fasc. 15.4. Allen Presss, Lawrence, KS. 157 pp.

Task 3.2 Distribution of *Opuntia* in the Region

Victor Maddox, John Madsen, Gary Ervin, John Byrd, Richard Brown, and Randy Westbrooks

Pricklypear (*Opuntia* spp.) mapping and data collection was conducted over a large geographic area of the eastern and southern United States by the senior author in 2006 (Figure 1). The data presented in this summary only reflects mapping and data collection conducted by the senior author, although other mapping and data collection was conducted by the GeoResources Institute and its partners during 2006.

The greatest concentration of mapping and data collection work was conducted in Alabama and Mississippi, which are along the western leading edge of the cactus moth. However, there was an increase in mapping and data collection activity in the southwestern and northeastern United States in 2006. Despite this increase in activity, trips to states outside Alabama and Mississippi were generally limited to less than five. Individual mapping trips ranged from just a few miles to over 5000 road miles. During this period, many pricklypear dataforms were taken. Due to constraints with private land, much of the work was conducted from highway rights-of-way. However, pricklypear populations were mapped on federal, state, and privates lands during this period. During these trips, data from negative locations were also identified.

During a round-trip to Arizona in September (Figure 2), dollarjoint pricklypear (*Opuntia chlorotica* Engelm. & Bigelow) was found in Pecos County, TX growing with cactus apple (*O. engelmannii* Salm-Dyck ex Engelm.) and black-spined pricklypear (*O. macrocentra* Engelm.). It is unclear if this was an escape from cultivation or part of an eastern disjunct population. Also during this trip, samples containing native cactus moth were collected from several *Cylindropuntia* and *Opuntia* spp. These samples were returned to Richard Brown, Mississippi State University, for further study. A poster on the project was presented at the 33rd Annual Natural Areas Conference in Flagstaff during this same trip.

In 2006 the furthest east and north *Opuntia* identified was in Maryland and the furthest west was Pima County, AZ. Nueces County, TX was the furthest point south. Some negative data were collected further east and north of this range, including Maine, New Hampshire, and Vermont. Most 2006 pricklypear dataforms have been entered into the Cactus Moth Detection and Monitoring Database. Entry completion of the remaining data is expected by early January 2007.

Goals for 2007 related to this task will include continued mapping, data collection and entry, develop additional sentinel sites, monitor existing sentinel sites, collaboration with volunteers and agencies, and increased focus on *Opuntia* and cactus moth distribution in Florida. This latter goal should assist USDA-APHIS with eradication efforts in Florida. As of 14 December, only 128 reports from Florida were in the database compared to 632 reports from Mississippi. This number is expected to be much higher for Florida. In addition, most positive reports of cactus moth in Florida are from coastal areas. More *Opuntia* and cactus moth data are needed from Florida's interior.
List of Figures.

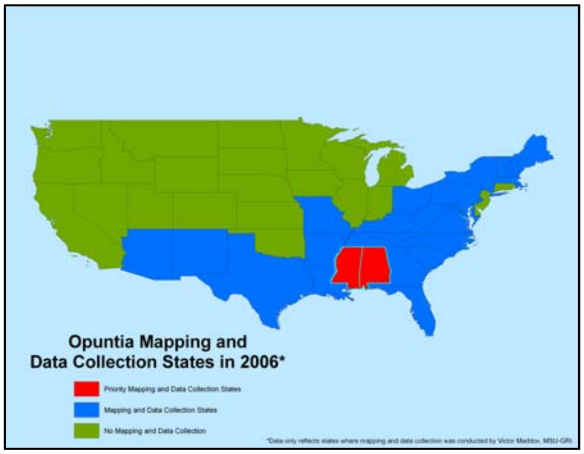

Figure 1. United States map showing states where active invasive species mapping was conducted in 2006. Areas most aggressively mapped are displayed in red.

Figure 2. Mapping and data collection was conducted in the Sonoran Desert in Southern Arizona by Victor Maddox (pictured with *Opuntia engelmannii* Salm-Dyck ex Engelm. on right and *Cylindropuntia* spp.), MSU-GRI, in September, 2006.

Task 3.3A. *Opuntia* Habitat Models

PI: Gary Ervin, Co-PIs: John Madsen, John Byrd
Collaborator: Lucas Majure, MSU Biological Sciences

Work to date on characterizing habitat of southeastern *Opuntia* species has taken place on two scales. Plot-scale work has focused on edaphic characteristics and associate plant species and has utilized study plots throughout Mississippi and in southwestern Alabama, and is reported in the following sections (Tasks 3.3B & D).

At the regional scale, data from the cactus mapping project (Figure 3.3A-1) have been used in developing habitat modeling approaches to complement search efforts and potential remote sensing applications for locating *Opuntia* populations near new cactus moth outbreaks. The initial modeling effort used the State Soil Geographic Database (STATSGO; USDA NRCS 1994), to provide representative environmental predictor variables for prickly pear distribution within Mississippi (Figure 3.3A-2). Model variables used as regressors on prickly pear presence-absence data included available soil water content, bulk density, CEC, clay content, organic matter content, permeability, and pH, each calculated as the minimum & maximum value for each soil mapping unit across MS. Analyses involved binary logistic regression models of soil factors on prickly pear presence-absence, followed by information-theoretic analyses to compare resulting models. Information-theoretic analyses used the corrected Akaike Information Criterion (because of small sample size, relative to estimated parameters in the models) to rank the resulting logistic regression models and indicate which provided the best fit to prickly pear occurrence across the state. The resulting best model was incorporated into an ArcMap GIS to generate a layer indicating probabilities of occurrence of prickly pear, based on statewide soil characteristics (Figure 3.3A-2). This model is far from complete, but represents a first cut at developing the methods by which statistical modeling will be combined with geospatial technologies to produce materials to guide targeted management efforts for invasive species.

We now are in the process of preparing current data from the CMDMN, along with data from our random survey points, for a second iteration of prickly pear habitat models. We presently have 125 data points from natural populations of *Opuntia stricta*, *O. humifusa*, *O. pusilla*, *O.* aff. *grandiflora* and (probable) *O. macrorhiza*, in addition to 69 random data points with no cactus present at all. As with the modeling exercise above, we plan to use soil characteristics as one set of environmental data in developing and testing this second set of models. Additional data will include land cover from the new SE GAP program (which are to be available in early 2007), as well as canopy cover, impervious surfaces, and other geospatial data that could influence cactus distribution over the relatively small spatial scales at which we are initially working.

Additional research under this Task area includes morphological and genetic analyses of the Mississippi *Opuntia* and reporting of other interesting taxonomic finds. With respect to the latter, the most recent find is a population of the ant, *Pogonomyrmex badius*, which had been considered extirpated from inland Mississippi based on a period of 70 years passing since it was sighted in the state. This ant, typically found in xeric, sandy habitats, was rediscovered in a xeric community in Smith County, along with a population of *Opuntia pusilla*.

Regarding the current status of *Opuntia* species inhabiting the state of Mississippi and the eastern United States, it is well known that these are a complex group that have been a problem taxonomically for close to 200 years. As they are extremely morphologically plastic (e.g., Task 3.3C), are poorly studied taxonomically and ecologically, and are difficult to preserve correctly, the *Opuntia* of the eastern United States have remained misunderstood by most plant taxonomists. Present work in this area deals with the ecology, morphological variation, and taxonomy of the group for Mississippi. As a flora for Mississippi has not been completed, this work also will provide a guide to the Mississippi Cactaceae for the project as well as distribution information for the species present.

Opuntia species also are renowned for their ability to hybridize. In many cases, interspecific hybrids show higher rates of growth and reproduction than their parental taxa due to "hybrid vigor." Subsequently, populations become overwhelmed by the hybrid "species" and the parental taxa are extirpated from an area. Populations of *Opuntia* appearing intermediate between *O. humifusa* and *O. pusilla* were found in various areas within the state of Mississippi. However, parental taxa did not appear to be present at those sites. We are testing these populations using RAPD and automated ISSR molecular analyses in order to determine whether they represent true hybrids, distinct species, or are simply morphological variants of one of the proposed parental species.

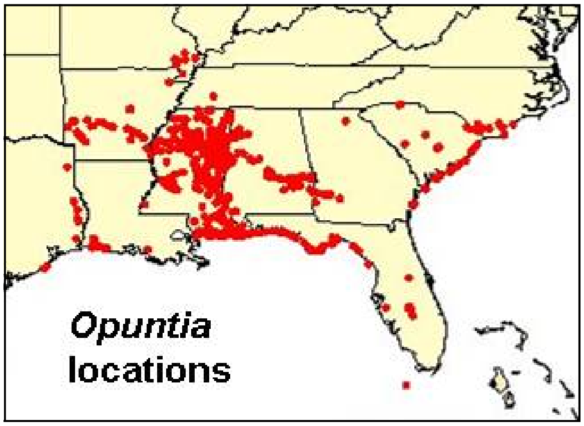

Figure 3.3A-1. Locations of prickly pear cactus from the Cactus Moth Detection and Monitoring Network, as of January 2006.

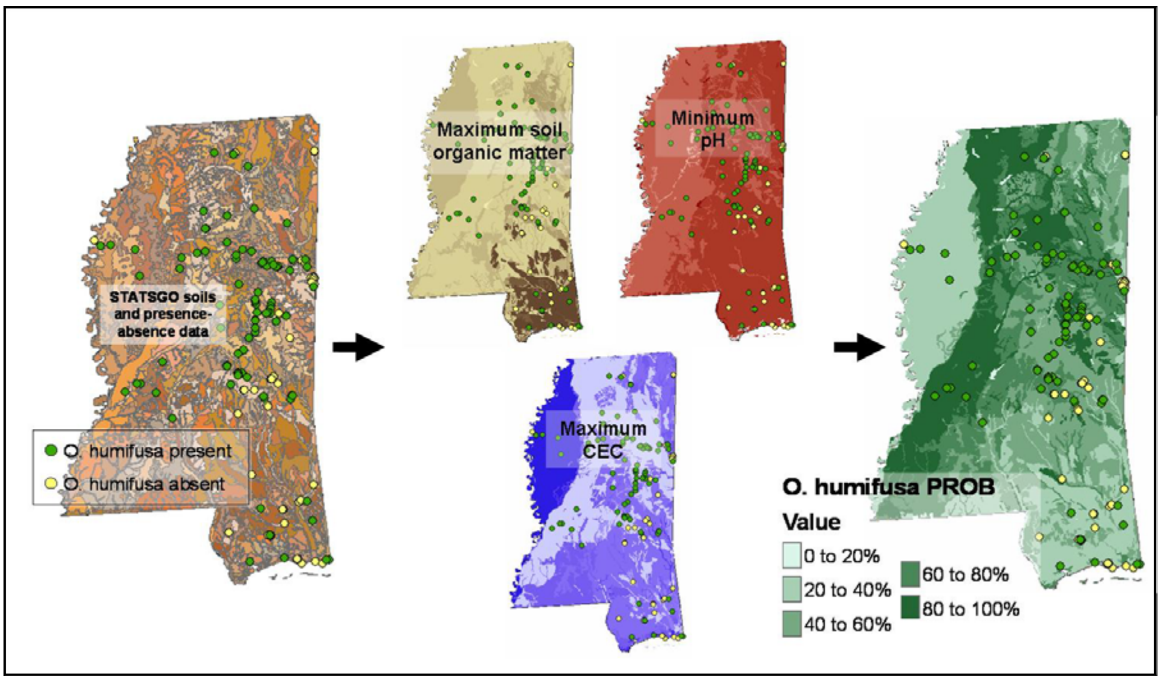

Figure 3.3A-2. Presence-absence data from the CMDMN were combined with environmental predictor variables (soils, left) to derive best-fit models, which are combinations of a subset of predictors (center). The best model then was used to project estimated occurrence probabilities across the landscape (right).

References:

United States Department of Agriculture, Natural Resources Conservation Service. 1994. State Soil Geographic (STATSGO) Database for MS. Accessed January 2006 through: http://www.ncgc.nrcs.usda.gov/products/datasets/statsgo/index.html.

Task 3.3B. Assessing Habitat Requirements for Host Plants (*Opuntia* spp.) of *Cactoblastis cactorum* in the Southeastern United States

Lucas Majure[1], Gary N. Ervin[1], John D. Madsen[2], Randy Westbrooks[3], Annie Simpson[4], and Elizabeth Sellers[4]

[1] MSU Department of Biological Sciences, [2] ***MSU GeoResources Institute,*** [3] ***National Wetland Research Center, U.S. Geological Survey Biological Resources Discipline, Whiteville, NC,*** [4] ***National Biological Information Infrastructure, Invasive Species Information Node, U.S. Geological Survey, Reston, VA***

Cactoblastis cactorum Berg. (cactus moth), one of the world's most effective biological control agents, is now threatening cacti in their native habitats throughout parts of the southeastern United States. Since being found in the Florida keys in 1989, the moth has migrated rapidly up the east coast to South Carolina and is also moving west through the gulf states where it has been found as far west as Dauphin Island, in southwest Alabama. In order to better predict what westward route this invasive insect might use to continue its spread, it is essential to understand the basic ecology and distribution of *Opuntia* (prickly pear cactus), the host plants for *Cactoblastis*. Habitat descriptions including vegetation types, soil structure and pH are necessary components for delimiting areas in which these cacti might be found. These and other parameters were evaluated in sixteen sites located in Mississippi and Alabama where natural populations of *Opuntia pusilla* (Haw.) Nutt. and *Opuntia humifusa* (Raf.) Raf. were established. A putative hybrid between the two species also was studied. Data suggested that *Opuntia* were located predominantly on acidic, well-drained soils, with clear associate species that varied to some degree with the regional physiography. This information should help guide future efforts at locating potential host sites for *Cactoblastis* by indicating areas with the highest potential for sustaining populations of these cacti.

Abstract from a poster given at the Ecological Society of America International Meeting, Merida, Mexico:
Majure, Ervin, Madsen, Westbrooks, Simpson, and Sellers. 2006. Assessing habitat requirements for host plants (*Opuntia* spp.) of *Cactoblastis cactorum* in the Southeastern United States. Ecological Society of America International Meeting, January 2006, Merida, Mexico.

Task 3.3C. Environmentally-induced Morphological Plasticity in *Opuntia pusilla* (Haw.) Haw.

Lucas Majure and Gary N. Ervin

Opuntia species (pricklypear cacti) show a high degree of morphological variation in natural populations due to naturally applied pressures from abiotic factors. In this study, light and shade treatments were used in a greenhouse to test the differences in overall phenotypic changes exhibited by *O. pusilla*. Spines were clipped from half of the cladodes (pads) used in this experiment, whereas the other half were left with spines intact. It was hypothesized that those cladodes without spines would produce more biomass as opposed to those with spines among both treatments. It also was thought that cladodes planted within the shade treatments would produce fewer spines on new cladodes due to lower temperatures and produce larger size cladodes for higher light uptake. In contrast, those grown in full light were hypothesized to produce more spines for thermoregulation and produce smaller and fewer cladodes, therefore lowering the productivity of the plant. As hypothesized, cladodes of plants in the full light treatment produced a higher number of spines than those within the shade treatments where lower temperatures were observed (Figure 3.3C-1). Initial results also showed that there were differences in the growth rates between the two treatments (Figure 3.3C-2). Those planted in the shade treatments produced a higher number of cladodes and were less spiny than those planted in full light. Also, those cladodes that were left with spines produced less biomass than those cladodes that were spine free in the full light treatment. This study helps demonstrate the plasticity in morphological characteristics exhibited by *O. pusilla*. Understanding such easily inducible changes helps to support the idea that spines are not only used as deterrents against herbivores and as dispersal mechanisms, but also may serve in thermoregulation.

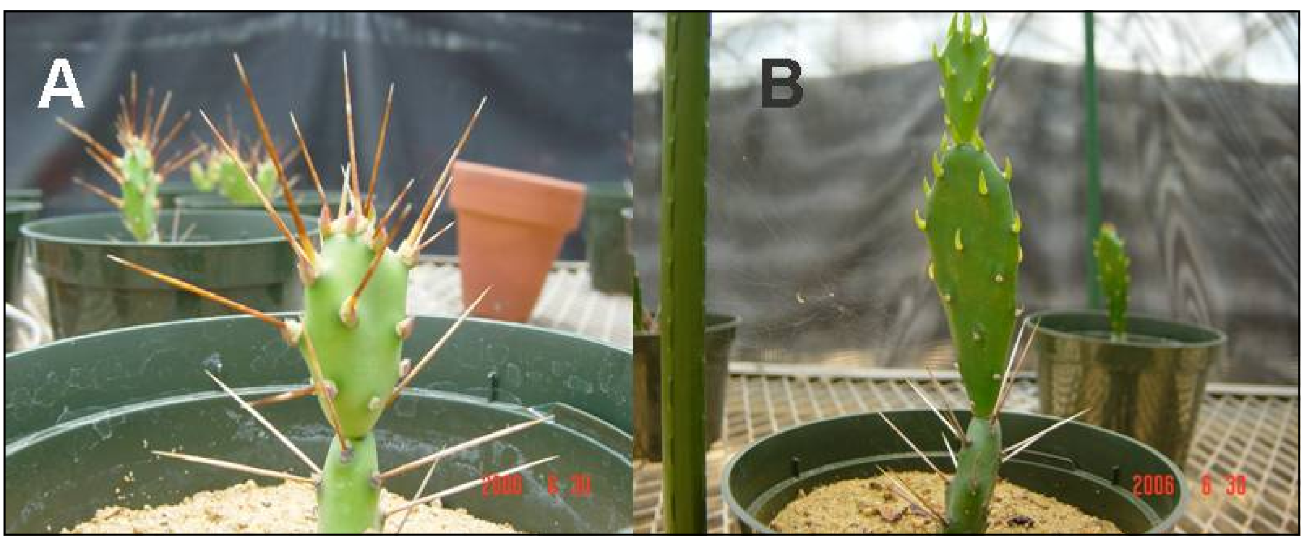

Figure 3.3C-1. Copious spine production in plants exposed to sun (A), in comparison with those grown under shade cloth (B).

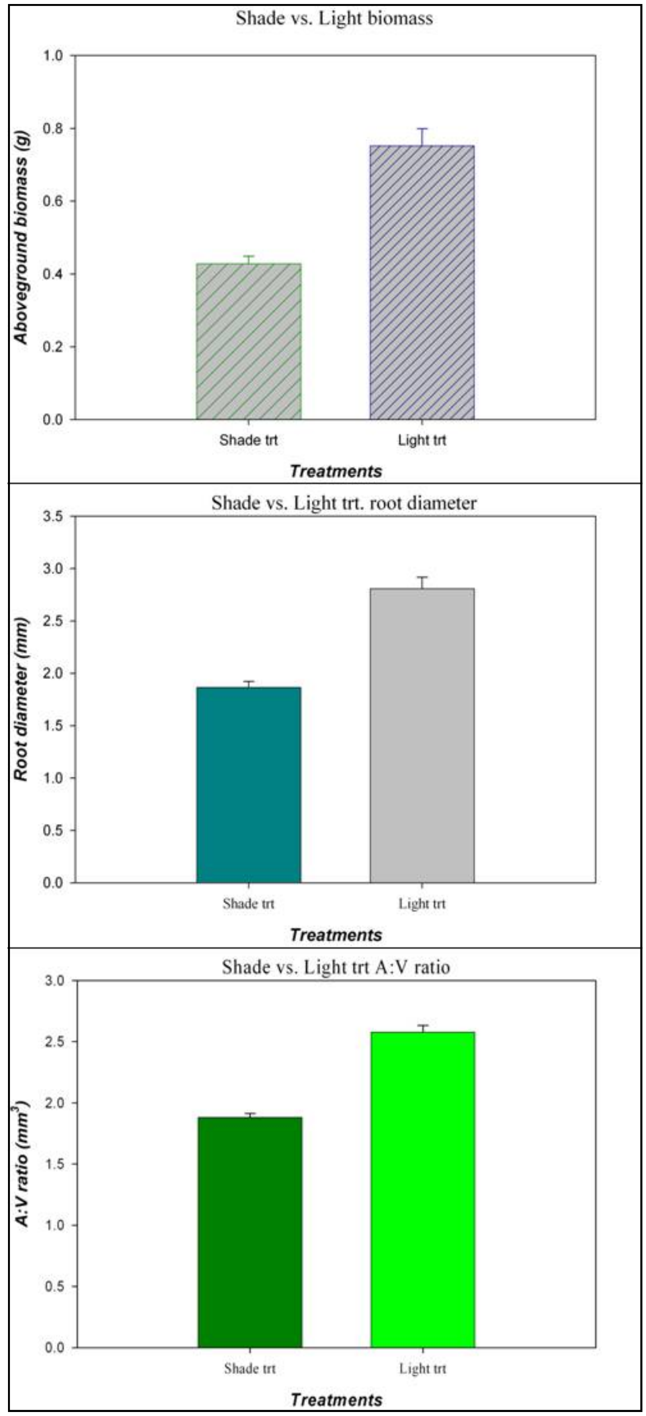

Figure 3.3C-2. Aboveground biomass (top), root diameter (center), and cladode area to volume ratio (bottom) all were significantly greater in the full light treatment.

Modified from a poster given at the Ecological Society of America 91st Annual Conference:
Majure and Ervin. 2006. The morphological plasticity of *Opuntia pusilla* (Haw.) Nutt. induced by differentiations in environmental variables. Ecological Society of America 91st Annual Conference, August 2006, Memphis, TN.

Task 3.3D. Associate Plant Species for the *Opuntia* of Mississippi

Lucas Majure and Gary N. Ervin

The *Opuntia* of Mississippi have been understudied ecologically and taxonomically. With *Cactoblastis cactorum* now potentially threatening populations of various species in the state, it is essential that this group of enigmatic xerophytes be heavily studied. Using herbarium data to gather enough information on possible locations, several populations of four different species were surveyed and ecological data were obtained. There is a distinct separation in habitat type of the recently recorded *Opuntia* affinis *grandiflora,* as compared to the other species. Among the other species, *O. humifusa, O. pusilla*, and *O. stricta*, there is a degree of sympatry in coastal communities. However, inland populations generally consist of only *O. humifusa* or *O. pusilla*.

Using Indicator species analysis (PcOrd, version 4), associate plant species were quantitatively determined for Mississippi *Opuntia* species. *Opuntia humifusa* and *O. pusilla* had more associate species in common, as might be expected with their more similar habitat requirements. It should be noted that these results can be misleading as certain species are sympatric and will have similar associate species, despite the quantitative differentiation among species associations in these analyses.

Opuntia **affinis** ***grandiflora*** was found to associate with *Schedonorus phoenix, Carex cherokeensis, Centrosema virginiana, Chamaechrista fascicularis, Cynodon dactylon, Dichanthelium acuminatum subsp. lindheimeri, Dichondra carolinensis, Helenium amarum, Iva annua, Juncus tenuis, Juniperus virginiana, Medicago lupulina, Pyrus communis, Ranunculus sardous, Salvia lyrata, Trifolium repens,* and *Verbena brasiliensis.*

Opuntia humifusa was found to associate with *Carex tenax, Dichanthelium sphaerocarpon var. sphaerocarpon, Krigia virginica, Lonicera japonica, Quercus falcata, Pinus palustris, Serenoa repens, Stenotaphrum secundatum, Vaccinium elliottii,* and *Wahlenbergia marginata.*

Opuntia pusilla was found to associate with *Asistida dichotoma var. curtissii, Asistida tuberculosa, Chrysopsis mariana, Croptilon divaricatum, Dichanthelium oligosanthes, Diodia teres, Hypericum gentianoides, Oenothera laciniata, Stipulicida setacea,* and *Triplasis americana.*

Opuntia stricta was found to associate with *Baccharis halimifolia, Campsis radicans, Conradina canescens, Cynanchum palustre, Galium hirsutum, Hydrocotyle bonariensis, Ipomoea sagittata, Panicum repens, Polygonella sp., Rubus trivialis, Smilax bona-nox, Solidago sempervirens,* and *Tradescanthia roseolens.*

Associate species common to all ***Opuntia*** species include: *Cynodon dactylon, Juniperus virginiana* and *Smilax bona-nox.*

Opuntia **affinis** ***grandiflora***, ***O. humifusa*** and ***O. pusilla*** all were found associated with: *Diospyros virginiana, Ilex decidua, Liquidambar styraciflua, Lonicera japonica, Oxalis stricta, Quercus hemisphaerica, Quercus falcata, Quercus nigra Vaccinium arboretum, Vitis rotundifolia* and *Vulpia myuros.*

Opuntia humifusa and ***O. pusilla*** were both found associated with: *Acalypha gracilens*, *Albizia julibrissin, Andropogon virginicus,Bulbostylis ciliatifolia, Clitoria mariana, commelina erecta, Conyza canadensis, Croptilon divaricatum,Dichanthelium meridionale, Dichanthelium sphaerocarpon var. sphaerocarpon, Diodia teres, Gelsemium sempervirens, Hypericum gentianoides, Ilex vomitoria, Krigia virginica, Lechea minor, Lechea mucronata, Lonicera japonica, Nuttalanthus canadensis,Paspalum notatum, Pinus palustris, Plantago virginica, Prunus serotina, Pseudognaphalium obtusum, Quercus incana, Quercus laevis, margarrettiae, Quercus virginiana, Rumex hastatulus, Smilax auriculata, Stylisma humistrata, Stylisma pickeringii, Toxicodendron pubescens, Triodanis perfoliata,Vaccinium arboreum, Vaccinium elliottii, Vaccinium stamineum,* and *Vulpia octoflora.*

Opuntia* affinis *grandiflora and ***O. humifusa*** were both found with *Carex muhlenbergii, Carya pallida, Carya tomentosa, Centrosema virginiana, Cerastium glomeratum,Cercis canadensis, Dichondra carolinensis, Erigeron anuus, Euphorbia corollata, Fraxinus americanus, Quercus alba, Quercus falcata, Q. pagoda, Q. stellata, Quercus velutina, Schedonorus phoenix, Solidago odora, Symphyotrichum patens, Trifolium campestre* and *Vicia sativa.*

Opuntia humifusa and *O. pusilla* share many more species in common than they do with *O.* aff. *grandiflora.* This likely results from differential habitat characteristics of *O.* aff. *grandiflora*, relative to features of habitats commonly occupied by *O. humifusa* and *O. pusilla*.

Task 3.3E. Noteworthy Plant Species Collections in Mississippi

Lucas Majure and Gary N. Ervin

During surveys for unrecorded populations of *Opuntia* in Mississippi, numerous noteworthy plant species sightings have been recorded. Three such sightings are reported here. These are reported in more detail by Majure (2007).

Anemone quinquefolia Linnaeus var. *quinquefolia* (Ranunculaceae) was observed in Newton County off of Huey Road, ca. 7 mi NE of Decatur along tributary of Chunky Creek, 32.4843˚N, 89.0608˚W (10 Apr 2005, *L. Majure 838,* deposited in MISSA and MMNS). This site was in an alluvial plain bordering a small tributary of Chunky Creek. This collection represents a significant range extension of the species to the southwest and is a new record for Newton County, which is located in east central Mississippi. According to collections from MISS, MISSA and MMNS, *A. quinquefolia* var. *quinquefolia* was known previously only from Tishomingo County, which is located in the extreme northeastern portion of Mississippi. The Newton County population is disjunct from previous collections in Tishomingo County by approximately 260 km. The Mississippi Natural Heritage Program state rank for this species is S1-S2 (MNHP 2006), therefore, this is an important record for the state.

Sanguinaria canadensis Linnaeus (Papaveraceae) was recorded in Noxubee County, Noxubee River ca. 13 mi E of Shuqualak, 33.02180°N 88.45762°W (26 March 2006, *L. Majure 1307*, MMNS). Although *S. canadensis* has been heavily collected in Mississippi from numerous counties, as evidenced by collections in various herbaria (MISS, MISSA, MMNS, USMS), no specimens were seen for the Flora of North America. Subsequently, it was not recorded for the state but only reported as occurring within the state (Kiger 1997). *Sanguinaria canadensis* has been reported for the state numerous times (e.g., Lowe 1921; Simmons 1968; Morgan 1979; Morris et al. 1993; MacDonald 1996; Leidolf et al. 2002), so this collection is intended merely to confirm the presence of *S. canadensis* within Mississippi.

Stipulicida setacea Michaux var. *setacea* (Caryophyllaceae) was recorded in Forrest County in the vicinity of Hattiesburg off of Edwards St., 31.3120°N, 89.2774°W (26 May 2005, *L. Majure 989,* MISSA, MMNS). *Stipulicida* also was commonly associated with: *A. tuberculosa, Asclepias humistrata, Carex tenax, Ilex vomitoria, Pinus palustris, Quercus hemisphaerica, Q. incana, Q. laevis, Q. virginiana, Stylisma humistrata*, and *Vaccinium arboreum.* Thousands of plants of *Stipulicida* were seen in flower and fruit at the time of collection. The site where *Stipulicida* was collected contains several large pits, which are currently two large bodies of water and one city dumping area. However, there are also large sand dunes presumably created from “pit construction.” Many of the plant species within the area are native taxa typically found in sandy, xeric areas, suggesting that those species were already established at this site. Therefore, the sand dune system may be somewhat historical instead of completely manmade. While there are inland populations of *Stipulicida* in Alabama, Georgia, North and South Carolina (USDA 2006), this find represents the most northerly population of *Stipulicida setacea* and the only inland population known within the state of Mississippi, according to collections from MISS and MISSA. This population is within the vicinity of the Pascagoula River system (i.e., within 0.3 km of the Leaf River), so a direct link to the Gulf Coast exists. However, all other records in Mississippi are from barrier islands in Harrison and Jackson Counties (Deer, Horn, and Ship islands), which are disjunct by approximately 200 km. Although *Stipulicida* is not on the Mississippi Natural Heritage Program tracking or watch list, several of its associate species within the Forrest County site are ((e.g., *Aristida condensata* (S3-S4), *Aristida tuberculosa* (S3-S4), *Carex tenax* (S2) and *Stylisma pickeringii* (S1) MNHP, 2006)). Therefore, this site also is significant for its rare plant assemblage.

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Task 3.3F. Microscopic features of *Opuntia* species based on Scanning Electron Microscopy

Lucas Majure and Gary N. Ervin

Using standard scanning electron microscopy (SEM) techniques, the morphological differences among several species of *Opuntia* were studied. Slight differences were seen in the retrorse barbs of *Opuntia* affinis *grandiflora*, as compared to *O. humifusa* and *O. pusilla.* Aperture or quantity of pores and areoles on pollen surfaces were substantially greater in *O.*aff. *grandiflora* than in *O. humifusa*, *O. pusilla*, or a putative hybrid of the two (Figures 3.3F-1 through 3.3F-3). Minor differences in seed topology also were noticed among species. The arrangement of glochids produced from stem areoles was not readily distinguishable among species. It is anticipated that some of these microcharacteristics will prove useful in delimiting species of *Opuntia*.

Fig. 3.3F-1. *Opuntia pusilla* pollen at 750´ magnification.

Fig. 3.3F-2. *Opuntia* affinis *grandiflora* pollen at 811´ magnification.

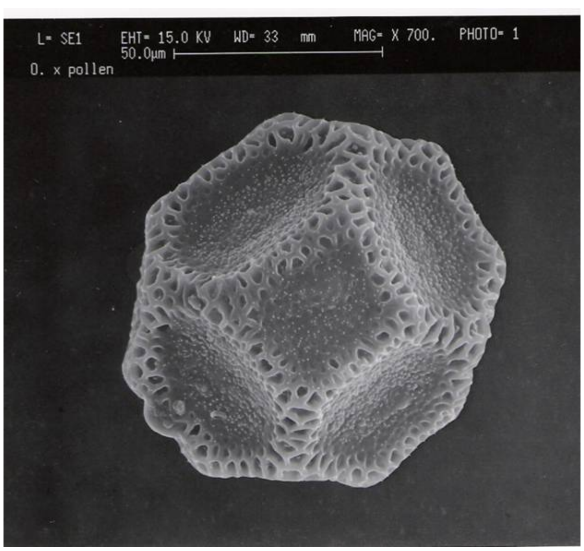

Fig. 3.3F-3. *Opuntia humifusa ´ O. pusilla* "hybrid" pollen at 700´ magnification.

Task 4.
Extension and Outreach

Task 4.1. Aquatic Plant Extension Information

PI: John Madsen, Collaborators: USACE (ERDC; Kurt Getsinger), Vicksburg, MS;

Invasive Aquatic Plant Extension Products

John D. Madsen, GeoResources Institute, Mississippi State University

One aspect of managing invasive plants that is often overlooked is to provide pertinent and up-to-date information to the public on managing the problem species. Many fact sheets that are available may provide information about the plant, but neglect to mention how to effectively manage them in a safe and economical manner. To address this lack of public information, a series of fact sheets is being developed on nationally important invasive aquatic plants that include specific information on management techniques.

Our current plan is to develop fact sheets on the twenty-two aquatic plants listed in Table 1. Due to the lag in time of completing a draft act sheet and publication by MSU Agricultural Publishing, we have developed draft fact sheets that are currently posted on the GRI webpage at http://www.gri.msstate.edu/information/pubs.php. Currently, four species-specific fact sheets are available at this site.

Table 1. Invasive aquatic plant information product status page

Common Name	Scientific Name	Status
Alligatorweed	*Alternanthera philoxeroides*	Planned
American Frogbit	*Limnobium spongia*	Planned
American Lotus	*Nelumbo lutea*	Planned
Cabomba	*Cabomba caroliniana*	Planned
Chinese Tallow	*Triadica sebifera*	Planned
Curlyleaf pondweed	*Potamogeton crispus*	In press
Egeria	*Egeria densa*	Planned
Eurasian watermilfoil	*Myriophyllum spicatum*	GRI Webpage
Fragrant waterlily	*Nymphaea odorata*	Planned
Giant cutgrass	*Zizaniopsis miliaceae*	Planned
Giant salvinia	*Salvinia molesta*	GRI Webpage
Hydrilla	*Hydrilla verticillata*	In preparation
Parrotfeather	*Myriophyllum aquaticum*	GRI Webpage
Phragmites	*Phragmites australis*	In preparation
Purple loosestrife	*Lythrum salicaria*	GRI Webpage
Roundleaf toothcup	*Rotala rotundifolia*	Planned
Torpedograss	*Panicum repens*	Planned
Variable-leaf watermilfoil	*Myriophyllum heterophyllum*	Planned
Water primrose	*Ludwigia grandiflora*	Planned
Waterchestnut	*Trapa natans*	Planned
Waterhyacinth	*Eichhornia crassipes*	In preparation
Waterlettuce	*Pistia stratiotes*	Planned

In addition, the Mississippi Weed Science Consortium revises their weed control recommendations each year, and GRI is involved with this group to provide current recommendations for aquatic weeds. These recommendations are available at http://msucares.com/pubs/publications/p1532.html, and include aquatic weeds.

Managing invasive aquatic weeds in large water bodies are a process, and should begin with identifying the problem plants and developing a lake management plan. Three conference proceedings papers follow the process from identifying invasive aquatic plants, developing a lake management plan, and selecting aquatic plant management techniques. These papers, published in the proceedings of the Mississippi Water Resources Conference over three successive years, are available at the GRI webpage:

Madsen, J. D. 2004. Invasive Aquatic Plants: A Threat to Mississippi Water Resources. 2004 Proceedings, Mississippi Water Resources Conference. CDRom. 122-134.

Madsen, J. D. 2005. Developing Plans for Managing Invasive Aquatic Plants in Mississippi Water Resources. Proceedings, Mississippi Water Resources Conference, Jackson, MS. Vol. 35. 143-151.

Madsen, J. D. 2006. Techniques for Managing Invasive Aquatic Plants in Mississippi Water Resources. Proceedings of the 36th Annual Mississippi Water Resources Conference. Vol. 36. 42-51.

In the future, we will complete additional invasive plant fact sheets and develop an aquatic plant management page to allow easier access to information relevant to managing nuisance aquatic plants.

Cabomba (*Cabomba caroliniana*), a native of the southeastern United States, is becoming a nuisance invasive plant to midwestern and northeastern United States and southeastern Canada. Little is known about the life history or management of this plant.

Waterchestnut (*Trapa natans*), a native of eastern Asia, has been an invasive aquatic of significant concern to the northeastern and mid-Atlantic United States for many decades. Despite this, little research has been done on life history or management.

Task 4.2. Terrestrial Grass Extension Information

Victor Maddox and John Byrd

Grasses belong to a large family (Poaceae) consisting of 785 genera and approximately 10,000 species. Most are terrestrial and as a group are similar in appearance, which can make identification challenging. In Mississippi, 18 % of introduced vascular plants are grasses. Approximately 30% of grasses in Mississippi are introduced. Roughly 11 % of the grass species in the United States are introduced (~156 species). Not surprisingly, many grasses tend to be invasive. Cogongrass [*Imperata cylindrica* (L.) Beauv.] and itchgrass [*Roettboellia cochinchinensis* (Lour.) W.D. Clayton] are two examples of problematic grasses in the Mid-south. However, invasive grasses also include crabgrasses (*Digitaria* spp.), johnsongrass [*Sorghum halepense* (L.) Pers.] and others. In addition to existing non-native grasses, species continue to be introduced into the United States and mid-south region making invasion by grasses an ongoing issue. Additionally, some invasive grasses, like cogongrass and itchgrass, are federal and/or state regulated while others are not. In either case, there is a need to assist federal, state, and public stakeholders with issues related to terrestrial grass recognition and control.

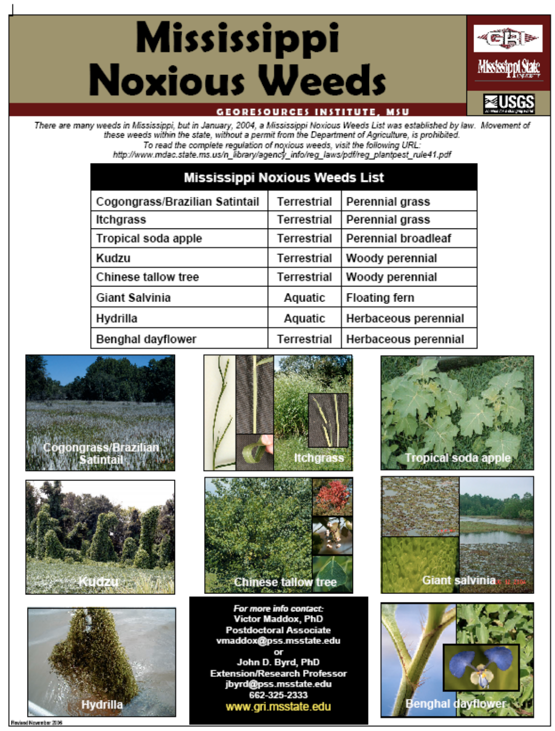

Figure 2. A flyer on invasive species is one example of several forms of extension information provided at public meetings in 2006. This information assists with plant identification and provides contacts toclientele needing additional extension information.

In 2006, numerous federal, state, and local meetings were attended to present information on terrestrial grasses to stakeholders. Extension information ranged from formal presentations (Figure 1) to flyers (Figure 2) handed out at garden and patio shows. The scope of clientele ranged from federal land managers to public landowners. The majority of this activity occurred within the Mid-south, but was not confined to this region. Since clientele attending individual meetings ranged from a handful to just under 10,000 people, the number of people contacted verbally or through literature handed out in 2006 is estimated in the thousands.

Mapping and monitoring efforts were conducted to assist stakeholders, like the department of transportation (DOT) and Tennessee Valley Authority (TVA), by providing geographic locations of known invasions. In addition, numerous grass identifications and control recommendations were made during 2006 for a wide range of clientele.

Figure 1. Dr. John Byrd giving a presentation on cogongrass [*Imperata cylindrica* (L.) Beauv.] to stakeholders in George County, MS.

A continuation of efforts similar to 2006 is planned for 2007, including numerous meeting presentations and other activities designed to reach stakeholders. Additionally, we plan to assist with the training of public volunteers on how to identify invasive grasses and report information. We plan to continue active monitoring and mapping and provide this invasive terrestrial grass information to clientele via a new invasive species database (IPAMS) in 2007. Active monitoring and mapping efforts will assist with ED/RR efforts, as well. Grasses continue to escape from cultivation, such as maidengrass (*Miscanthus sinensis* Anderss.) and others, and related research and extension information will be needed to support ED/RR efforts with clientele.

Task 4.3. Cactus and Cactus Moth Extension Information

PI: John Madsen , Co-PI: Richard Brown, John Byrd, Victor Maddox, Clifton Abbott
Collaborators: Randy Westbrooks, Annie Simpson

Cactus and Cactus Moth Information Resources

John D. Madsen, GeoResources Institute, Mississippi State University.

Introduction

The potential spread of the cactus moth in North America from Florida to the southwestern US and Mexico is an issue of great economic and ecological concern. We have developed web-based information to aid in the identification of cactus and the cactus moth, provide an avenue for reporting suspected locations on the web, and web GIS database to display the movement of the moth and locations of natural cactus populations. The products generated will inform the general public of the cactus moth issue, and assist in building and training volunteers for monitoring sites.

We have developed a cactus moth database webpage (http://www.gri.msstate.edu/cactus_moth) for use with monitors, and have used this site as well for disseminating information on cactus moth. Cactus moth information is also available at the GRI invasive species webpage (http://www.gri.msstate.edu/lwa/invspec.php) with links to other useful sites (http://www.gri.msstate.edu/lwa/invspec/cactus_moth.php). Due to the time lag between submitting draft publications to MSU Extension Service publishing and final availability, all of our products are now available on the cactus moth webpages or the GRI webpage in draft form. Currently, we have developed ten print items, in addition to the webpages, that provide information on pricklypear cactus and cactus moth (Table 1).

Just recently, we handed out the last of our first printing of the MSU cactus moth brochure. We have passed out 5000 brochures in two years, mostly to members of the general public.

Dr. John Byrd discusses the danger of cactus moth to the native cactus with Becky Stowe, The Nature Conservancy's resource manager at Charles Deaton Nature Preserve in southern Mississippi.

Task 4.4. Cactus Moth Detection and Monitoring Network Website

John D. Madsen, Clifton F. Abbott, GeoResources Institute, Mississippi State University

The cactus moth (*Cactoblastis cactorum* Berg.) is a widely used biological control agent of pricklypear cactus in Australia and South Africa. The cactus moth appeared in the Florida Keys in 1989, spreading as far as South Carolina and Alabama. The cactus moth quickly destroys a stand of pricklypear, and is a threat to natural biodiversity, horticulture, and forage in the southwestern United States and Mexico. USGS, USDA-APHIS, and Mississippi State University have formed the National Cactus Moth Detection and Monitoring Network, composed of volunteer monitors from public and private land management units, garden clubs and Master Gardeners to monitor the spread of the moth. Volunteers will report observations using a web-based database available from the network's website at http://www.gri.msstate.edu/cactus_moth. All data are entered by registered users and all users are individually approved, to prevent false data entry. Anyone can register from the website to become a volunteer.

The Cactus Moth Detection and Monitoring Network, online since 2005, has 43 registered users reporting a total of 1,386 pricklypear reports. Of those reports, 1,280 are positive cactus locations leaving 106 negative locations. These reports come from 15 different collectors spanning 11 states and locating 21 different *Opuntia* species. The network has 56 positive reports for the invasive cactus moth, none of which are new for 2006. The reports that are submitted to the system are being used to model cactus locations in an effort to help predict where cacti are likely to be located. Using this information, collectors can identify areas that have high potential in containing cactus and possibly the cactus moth.

The network's website has taken on a new face in 2006 to become the one-stop-shop for information on the cactus moth (Figure 1). A visitor can find the history of the moth, biology information, see what king of threat it poses, and find information on it hosts, identification, and controls. There is a description on how to help as well as valuable resources for someone just interested in the subject or someone interested in being a volunteer. There are real-time maps embedded within the website to give a quick assessment of mapping efforts. A GIS map tracking tool is also available and provides multiple maps for viewing cactus locations, moth locations, and sentinel site locations (Figure 2). The tracking map provides a visual representation of the detection and monitoring system, which may be used by collectors to identify areas in which there are gaps in the survey. Collectors are then able to plan survey trips into those areas that are lacking observations. The map is also being used to identify potential sentinel site locations on or around the leading edge of the moth's progression.

The GIS map has become useful for other reasons as well. County boundaries, zip code boundaries, roads, and urban areas are displayed to help collectors find routes to certain areas, or to find their way to a certain cactus location. These data layers are also used for reports that have poor descriptions on their locations. Better, or more complete, location descriptions can be obtained. Areas can be zoomed into, maps can be made for printing or publication purposes, and reports can be queried to provide certain survey information on that location.

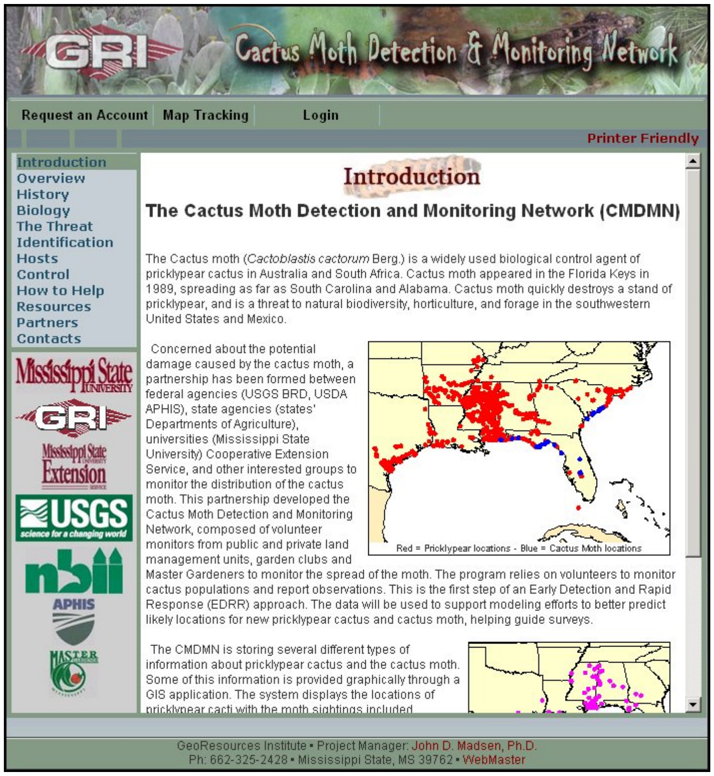

Figure 1. Cactus Moth Detection and Monitoring Network Website

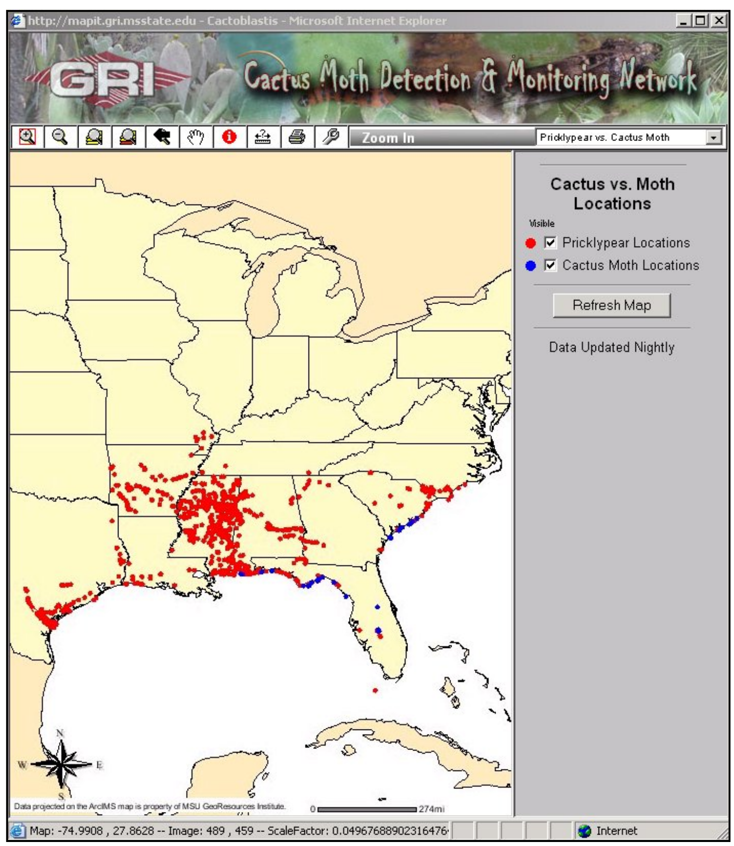

Figure 2. GIS Map Tracking

Task 4.5. Web-based Database of Invasive Plant Species Locations (IPAMS)

John D. Madsen[1], Clifton F. Abbott GeoResources Institute, Mississippi State University

Despite the widespread occurrence of weedy plants, adequate assessment of coarse-scale landscape factors influencing their distribution is lacking for most species. Such information is potentially more useful to land managers and other concerned parties than are plot-scale factors on which most studies of invasive species are focused. The Invasive Plant Atlas of the Mid-South (IPAMS), in an effort to quantify relationships of weed distribution and spread with land use and educate people on potential human-induced opportunities for invasive species to spread, will provide a centralized invasive species database modeled after the Invasive Plant Atlas of New England (IPANE). IPAMS will provide information on the biology, ecology, distribution, and best management practices for an initial suite of forty of the most economically and ecologically significant invasive weeds in the mid-south. Development and implementation of this database will involve intensive outreach/extension and research activities, and will support the USDA NRI's stated goals of enhancing protection of US agriculture and protecting the nation's natural and environmental resources.

An initial web presence for IPAMS has been created at http://www.gri.msstate.edu/ipams and database has been developed (Figure 1). An interface providing in-house access has been provided, however, the database and website has not been publicly released. Future plans include working on the website's appearance and functionality and to launch IPAMS in 2007.

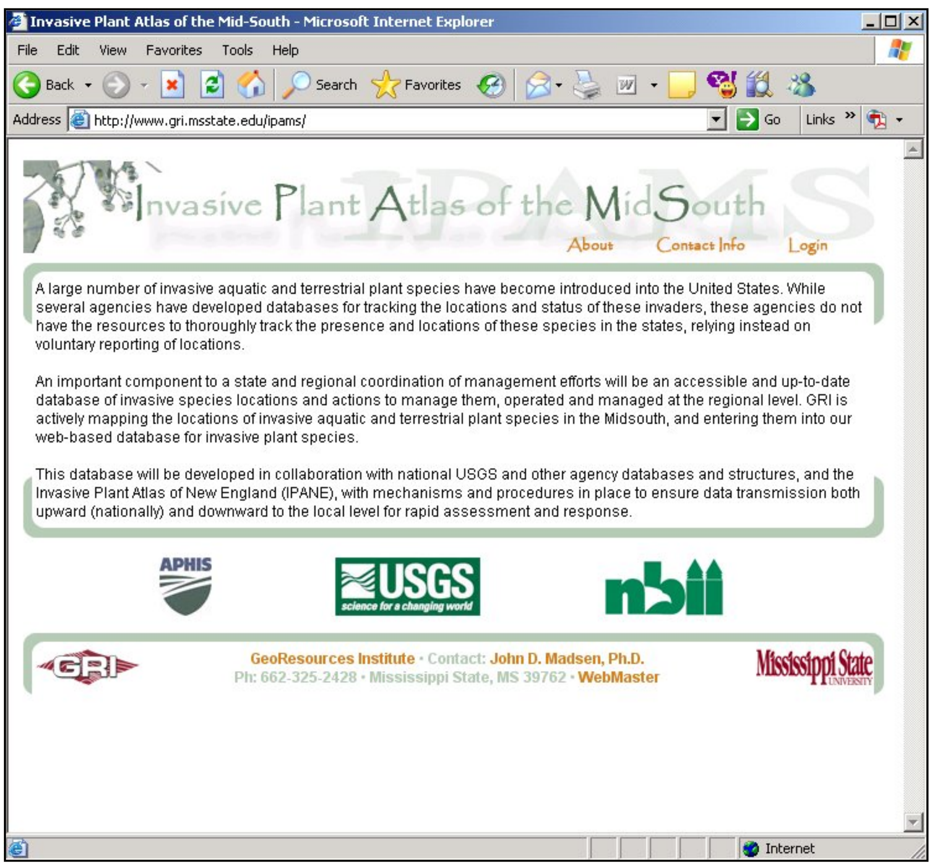

Figure 1. Invasive Plant Atlas of the Mid-South (IPAMS) Web Presence

Task 5.
Regional Coordination

Task 5.1. State ISA formation

PI: David Shaw, Co-PI: John Byrd, John Madsen

Collaboration on the Mississippi Aquatic Invasive Species Plan

John D. Madsen, GeoResources Institute, Mississippi State University, Mississippi State, MS.

The Mississippi Aquatic Invasive Species Task Force has been meeting since October 2004,chaired by the Mississippi Department of Environmental Quality. Representation includes state agencies (DEQ, WFPD, DAC), federal agency representatives within the state, colleges and universities, private industry, and nongovernmental organizations (The Nature Conservancy). Early on, the AIS Task Force contracted with the Tulane University Center for Bioenvironmental Research to assist with the development of the plan. The CBR was instrumental in developing the State of Louisiana Aquatic Invasive Species Plan.

The National Invasive Species Act of 1996 authorizes expenditures to assist a state or group of states in developing aquatic invasive species management plans, through the U.S. Fish and Wildlife Service. The goal of these plans is to identify how a state may more efficiently prevent aquatic invasive species or detect and control new populations early in the infestation cycle. One major goal of most invasive species plans is to develop education and outreach materials to increase public awareness and prevention.

John Madsen of GRI was appointed to the task force in 2004, and has been working with numerous others on the development of the plan. Other individuals have also represented Mississippi State University from research and extension, including aquaculture research and development.

The Mississippi Aquatic Invasive Species Plan is nearing completion, with a final draft anticipated early in 2007.

Grass carp (*Ctenopharyngodon idella*) is one species of Asian carp discussed in the draft Mississippi Aquatic Invasive Species Plan.

Wilfredo Robles samples hydrilla from Aberdeen Lake. In the background are some floating clumps of dead waterhyacinth. Hydrilla and waterhyacinth are two of the problematic aquatic plants discussed in the draft Mississippi Aquatic Invasive Species Plan.

Task 5.2 MidSouth ISA formation

PI: David Shaw, Co-PI: John Byrd, John Madsen

Progress toward interstate regional cooperation on invasive species issues has been limited, largely due to the disruption experienced by everyone in the Mid-South states due to Hurricane Katrina and resistance within some key states toward a mult-state cooperative approach. As a result of the latter, we are now exploring a realignment of states in the Southeast that are interested in such an approach, and expect to make substantial progress in the coming year.

Appendices

Apendix A. Aquathol K Study

Combinations of Endothall with 2,4-D and Triclopyr for Control of Eurasian Watermilfoil

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Eurasian watermilfoil (*Myriophyllum spicatum* L.) is a widespread submersed aquatic plant that causes nuisance problems in each of the continental United States. While both contact and systemic herbicides are available to control Eurasian watermilfoil, each class of herbicide has its drawbacks. Contact herbicides are fast acting, relieving nuisance problems quickly, but may allow grow-back of nuisance plants and may not kill the entire plant. Systemic herbicides will often kill the entire plant, but are slower acting and limited by short contact times. We examined whether combinations of contact and systemic herbicides might exploit the strengths of each herbicide class, and minimize their weaknesses. Eurasian watermilfoil was treated with combinations of endothall (Aquathol-K) with either 2,4-D or triclopyr. Our goal is to determine if there is a potential additive or synergistic effect with these two compounds, or screen for potential interference. The liquid formulation of endothall (Aquathol-K) was evaluated alone (at either 1.5 or 1 ppm for 24 hour expostura) and in combination with 2,4-D or triclopyr at a rate of 1 ppm Aquathol-K with 0.5 ppm of 2,4-D or triclopyr at both 12 and 24 hours of exposure. Each treatment, and a reference, were replicated in four tanks, for a total of 36 - 100 gallon tanks. Each tank will have seven 1-gallon pots with "supersoil" growth medium. Each pot will be planted with two sprigs of Eurasian watermilfoil. Plants were allowed to grow for four weeks before treatment. One pot per tank will be harvested for pretreatment biomass values. Each week, tanks were rated for percent control on a 0-100% scale. Four weeks after treatment, plants were harvested and sorted to shoot biomass. Plants were dried at 70C and weighed for biomass determination. After four weeks, all treatments showed equal control of plant shoot mass, based on a one-way analysis of variance. Analysis of visual ratings indicated that endothall alone provided control the first week after treatment, but percent control was rated at 60% (Figure 1).

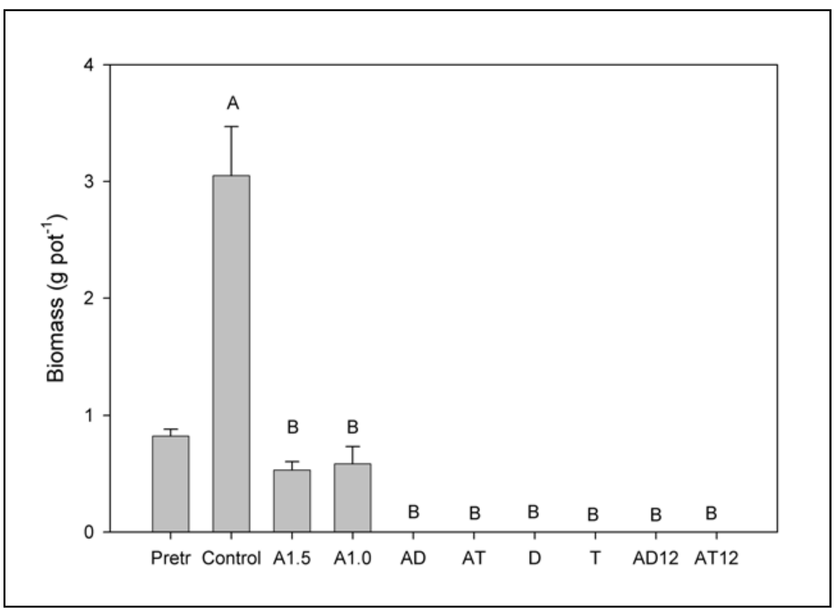

Figure 1. Eurasian watermilfoil mass per pot harvested 4 WAT.

Triclopyr and 2,4-D alone provided 100% control after two to three weeks, but initial control was less than 20%. All treatments with endothall and a systemic herbicide provided at least 50% control in the first week of treatment, and 100% control after four weeks. Combinations of endothall with either 2,4-D or triclopyr provided the benefits of immediate action in the short run and complete control within four weeks (Figure 2).

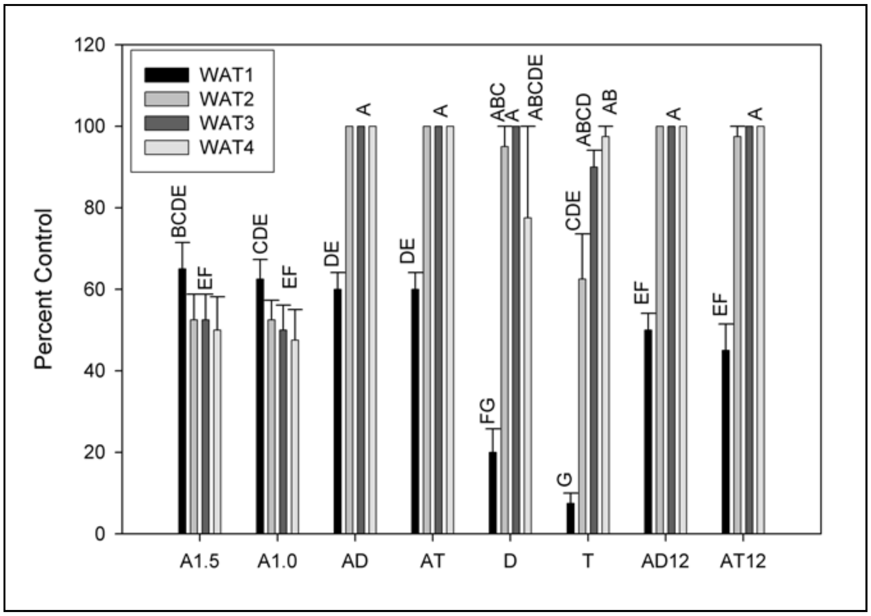

Figure 2. Weekly ratings (1, 2, 3, and 4 WAT) for treatments. A is Aquathol. D is 2,4-D. T is triclopyr. 1.5 and 1.0 are concentrations of Aquathol alone. AD 12 and AT12 are twelve hour exposures of those two combinations. All other treatments are for 24 hours.

Photo. Underwater photo of Eurasian watermilfoil (*Myriophyllum spicatum*) shoots.

Revised from an abstract for the Midsouth Aquatic Plant Management Society 25th Annual Meeting, 24-26 October 2006, Perdido Beach, AL.

Apendix B. Sensitivity of Wild Rice (*Zizania aquatica* L.) to the Aquatic Herbicide Triclopyr

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A primary goal of managing invasive aquatic plants is to selectively control the target plant without impacting desirable native plant species. Aquatic herbicides can often be employed to manage invasive weeds without negative impacts to native plant communities. One common invasive species to northern waters is Eurasian watermilfoil (*Myriophyllum spicatum* L.), which often infests the littoral zone of lakes, even into the emergent plant zone. An emergent plant of special concern in these littoral areas is wild rice (*Zizania aquatica* L.). Wild rice is not only an excellent habitat for fish and wildlife and an outstanding food source for migratory waterfowl, but humans also exploit it as a food source. Natural resource agencies are especially concerned not to adversely affect this species while managing invasive Eurasian watermilfoil. Pursuant to this goal, we examined the sensitivity of wild rice to the herbicide triclopyr, which can be efficacious on Eurasian watermilfoil at application rates as low as 0.25 mg L^{-1}. Three life stages of wild rice were evaluated: seedling (floating leaf stage), young (an emergent culm with one leaf), and mature (flowering head beginning to form). For each stage, we had four treatments: 0.0, 0.75, 1.5, and 2.5 mg L^{-1} aqeuous concentrations of triclopyr (Renovate 3). For each life stage and treatment, we replicated the treatment in four tanks, and each tank had fourteen 3.8L pots, with each pot containing one plant. Each treatment was exposed for 72 hours, then the herbicide treated water was replaced with untreated water, and plants were allowed to grow for four weeks. Plants in all tanks were visually rated for percent injury using 0-100% scale each week after treatment. At four weeks post treatment all plants were harvested, measured for height (cm), and the number of seedheads and tillers, and dried to a constant mass to determine biomass. Within two weeks of treatment, seedling stage plants exhibited statistically significant herbicide damage at the 1.5 and 2.5 mg L^{-1} rates, but not at the lowest rate (Figure 1). By four weeks after treatment, seedlings under the highest concentration of herbicide exhibited 80% herbicide damage, and at the second highest rate herbicide damage was almost 60% (Figure 1). While herbicidal damage was statistically significant for the two highest rates in both young and mature stage plants, in all cases damage ratings were less than 20%. After four weeks, plants at all life stages exposed to the highest rate of herbicide exhibited reduced height, mass, seedhead production, and tiller formation (Figure 2). However, plants exposed to only the lowest rate of triclopyr did not exhibit significantly reduced height, biomass, seedhead density, or tiller formation (Figure 2). From this study, the seedling stage of wild rice exhibited the greatest sensitivity to triclopyr, while other stages were much less sensitive. At all stages, the lowest concentration (0.75 mg L^{-1}) had no significant impact, and the intermediate rate (1.5 mg L^{-1}) had minimal response to the herbicide at the young and mature stages (Photo 1).

Photo 1. Triclopyr effects on mature wild rice at 0.75 ppm (left), 1.5 ppm (center), and 2.5 (right).

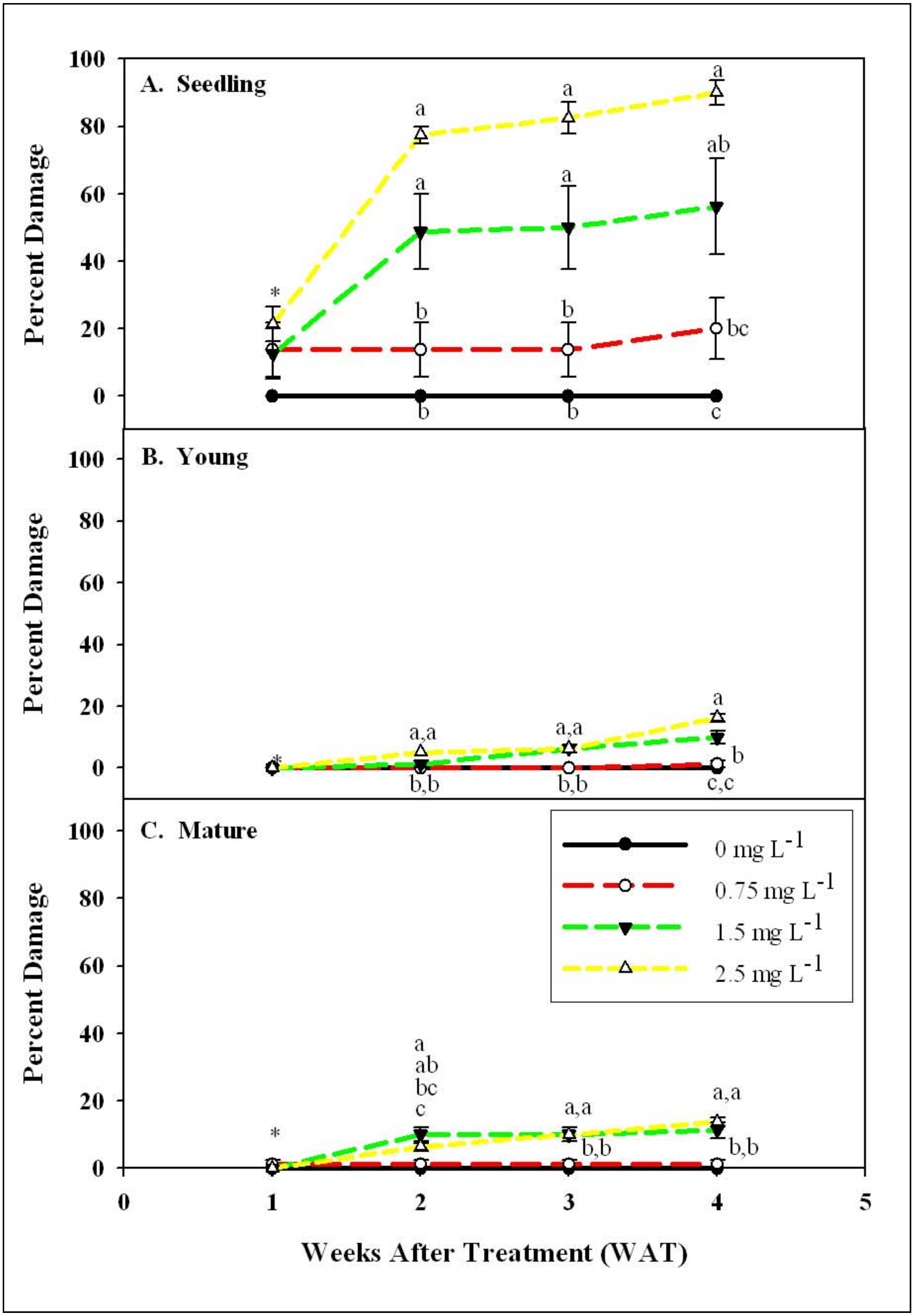

Figure 1. Percent injury ratings of wild rice during the seedling stage (A), young stage (B), and mature stage (C) for 4 weeks after treatment. Bars sharing the same letter are not statistically different.

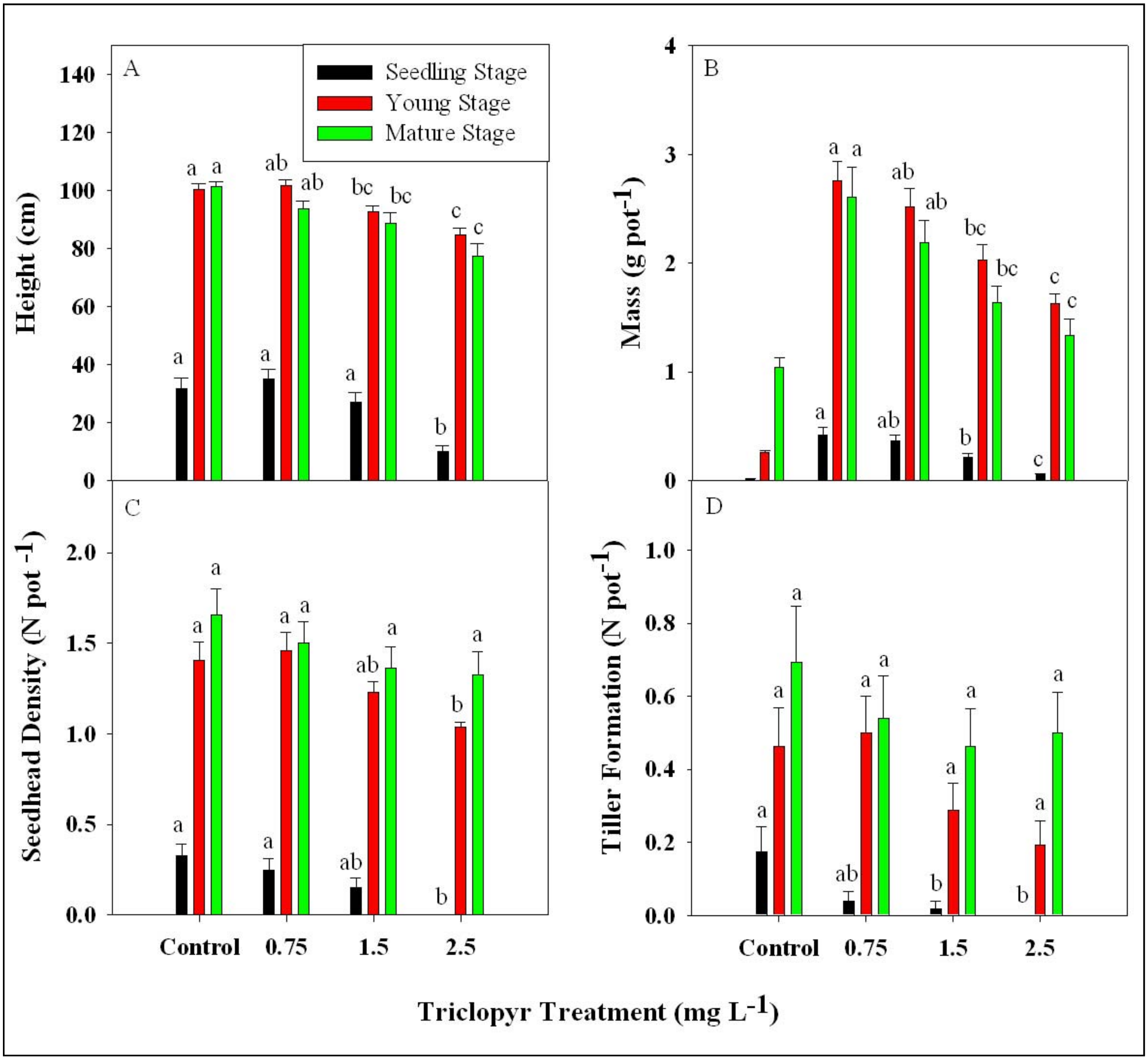

Figure 2. Triclopyr effects on wild rice height (A), mass (B), seedhead formation (C), and tiller formation (D) for all three growth stages. Bars sharing the same letter within each figure window are not statistically different.

Apendix C. Comparison of Imazapyr and Imazamox for Control of Parrotfeather (*Myriophyllum aquaticum* (Vellozo) Verdecourt)

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Parrotfeather (*Myriophyllum aquaticum* Vellozo Verdecourt) is a non-native aquatic plant from South America that grows rapidly and can persist as a submersed plant or as an emergent stoloniferous perennial. It is the emergent growth that has caused major problems in water-bodies in the United States. The emergent growth enables parrotfeather to cover large expanses in a short period of time impeding navigation, stream flow, and runoff resulting in increases in flooding frequency and intensity. Parrotfeather is difficult to control and once it is established it usually persists in spite of variations in the environment and the deployment of management techniques. To date, chemical control has been the most effective in controlling parrotfeather. Contact herbicides such as glyphosate, diquat, and endothall have been evaluated and are effective short term, but significant regrowth of parrotfeather occurs and multiple applications are necessary. Therefore, the use of a systemic herbicide may be more effective in controlling this species. Imazapyr is a relatively new systemic herbicide labeled for aquatic use. Imazamox is a new herbicide currently under experimental use and being evaluated for use in aquatic systems. To date, there has been no published data on the use of imazapyr for control of parrotfeather and no published data on the use of imazamox for control of aquatic plants in general. The objective of this study was to evaluate the efficacy of three application rates of imazapyr and imazamox herbicides for control of parrotfeather. The study was conducted in an outdoor mesocosm facility at the R.R. Foil Plant Research Station, Mississippi State University, Starkville, Mississippi for 14 weeks beginning in August 2006 and ending November 2006. Three rates of Imazapyr (1.123, 0.584, 0.281 kg ai ha^{-1}), three rates of Imazamox (0.561, 0.281, 0.140 kg ai ha^{-1}), and an untreated reference were evaluated. A non-ionic surfactant was added to the spray mixture at a 0.25% v:v ratio per herbicide label. Each rate was replicated three times in 21-378 L tanks. Parrotfeather was cultured from greenhouse stock in 3.78 L plastic pots. Pots were filled with super soil potting medium and amended with 2 g/L of Osmocote® fertilizer. Four pots were placed into every tank for a total of 84 pots. Parrotfeather was allowed to grow in the tanks for four weeks until the emergent growth covered the water surface. After four weeks, one pot from every tank was removed, the parrotfeather harvested at the sediment surface and dried to a constant mass to assess pre-treatment biomass. Following the four week growth period, foliar applications of imazapyr and imazamox were made to parrotfeather using a CO_2-pressurized sprayer at a spray volume of 187 L ha^{-1}. Visual injury ratings of percent control (0 – 100%) were recorded weekly after treatment for ten weeks. At the conclusion of ten weeks all remaining pots were removed from the tanks and viable parrotfeather was harvested, dried to a constant mass, weighed, and compared to the control to assess treatment efficacy. At the conclusion of 10 weeks parrotfeather treated with rates of 1.123 and 0.584 kg ai ha^{-1} had percent control ratings of 100.0 percent. Parrotfeather treated with rates of 0.561 and 0.281 kg ai ha^{-1} had ratings of 53.3 and 46.7 percent respectively. Parrotfeather biomass was significantly reduced when treated with rates of 1.123 and 0.584 kg ai ha^{-1} of imazapyr and 0.561 and 0.281 kg ai ha^{-1} rates of imazamox as determined by Analysis of Variance with a Fischer's LSD post hoc analysis (Figure 1). There was a significant reduction in biomass between the imazapyr and imazamox treatments with imazapyr having a greater reduction in biomass (Figure 1 and Photo 1). Our study indicates that imazapyr was most effective at controlling and maintaining control of parrotfeather after 10 weeks. Imazamox was effective at controlling parrotfeather however, regrowth was observed.

Photo 1. Visual comparison of the untreated reference (left), Imazamox 0.561kg ai ha^{-1} (center), and Imazapyr 1.1230 kg ai ha^{-1} (right).

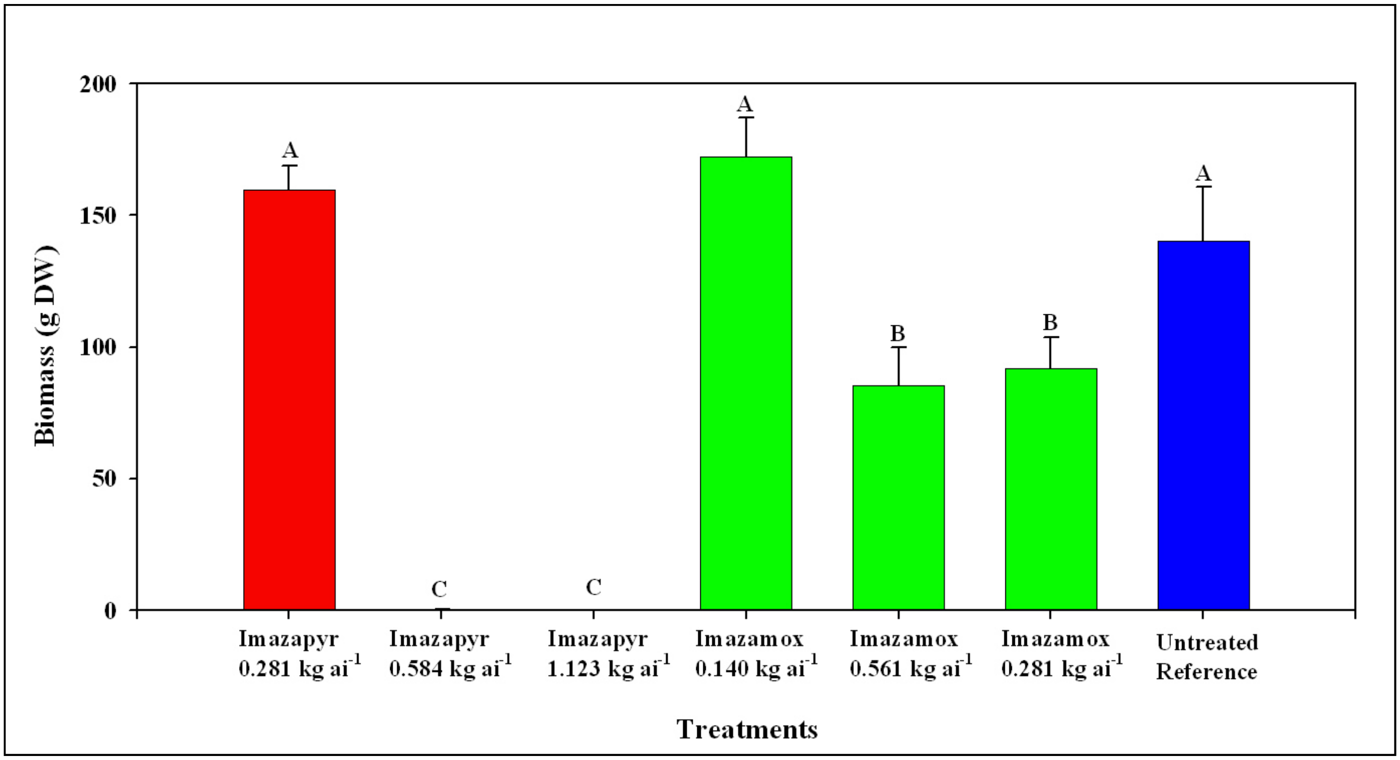

Figure 1. Mean (± SE) biomass of parrotfeather 10 weeks after treatment with imazapyr and imazamox herbicides. Bars sharing the same letter do no differ significantly.

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