

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

Annual Report 2009



MISSISSIPPI STATE
UNIVERSITY



A collaborative effort between
Mississippi State University's
Geosystems Research Institute
and the U.S. Geological Survey
and National Biological Information Infrastructure

GRI Publication #5039

Preface

The research and outreach programs described in the following report are the result of an ongoing partnership between the U.S. Geological Survey Biological Resources Discipline, the National Biological Information Infrastructure, and Mississippi State University. Funding for these programs was provided by an award from USGS BRD to MSU under cooperative agreements 04HQAG0135 and 08HQAG0139. The MSU program was managed by the Geosystems Research Institute. The USGS BRD Invasive Species Program manager was Sharon Gross, the NBII Invasive Species Information Node manager was Annie Simpson, and Randy Westbrook of USGS BRD worked with MSU on virtually every task.

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Introduction

Invasive species are a widespread and increasing 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 Geosystems

Research 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, developing a National Early Detection and Rapid Response webpage, and the renegade biocontrol agent, cactus moth (*Cactoblastis cactorum*). For each area, a program of extension and outreach has been developed to deliver the information from our research to those who can best make use of the results, both through traditional



Figure 2. Underwater photo of Eurasian watermilfoil (*Myriophyllum spicatum*) in Noxon Reservoir, Montana. Geosystems Research Institute staff assisted the Sanders County (MT) Eurasian watermilfoil Task Force, under the guidance of the U.S. Army Engineer Research and Development Center, with a demonstration control project during the summer and fall of 2009. Photo by John Madsen.



Figure 1. Ryan Wersal (left) and Dr. David Shaw (right) discuss invasive plant management while sampling on Noxon Reservoir, Montana. Dr. Shaw, at that time Director of GRI, came to participate in a demonstration project of controlling Eurasian watermilfoil in Noxon Reservoir. Dr. Shaw is now Vice President of Research and Economic Development at Mississippi State University. Photo by John Madsen.

printed information and web-based information solutions. Our current webpage effort, the Cactus Moth Detection and Monitoring Network (www.gri.msstate.edu/cactus_moth), has been operating for four years and garnered significant attention as the one source for pricklypear cactus and cactus moth location information nationwide. Our newest webpage is the Invasive Plant Atlas of the Mid-South (IPAMS) which is currently available at www.gri.msstate.edu/ipams. While USDA CSREES (now NIFA) is funding the initial program, we have listed USGS BRD and NBII as partners in the effort.

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

Clifton Abbott, Research Associate, Geosystems Research Institute
Richard L. Brown, Professor, Entomology and Plant Pathology
Gary N. Ervin, Associate Professor, Biological Sciences
Victor Maddox, Postdoctoral Associate, Geosystems Research Institute
John D. Madsen, Associate Professor, Geosystems Research Institute
David R. Shaw, Professor and Director, Geosystems Research Institute (now Vice President of Research and Economic Development)

Student Involvement

Graduate Students

Joshua Cheshier, MS, MSU Department of Plant and Soil Sciences
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Steven Hughes, M.S. student, MSU Department of Biological Sciences
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Edda Martinez, PhD, MSU Department of Entomology
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Undergraduate Students

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Angel Frame, Biological Sciences B.S. student
Jessica McClure, Biological Sciences B.S. student
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Collaborators

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James Carpenter, USDA-ARS
Eric D. Dibble, Department of Wildlife and Fisheries, Mississippi State University
Joel Floyd, USDA APHIS PPQ
Pam Fuller, U.S. Geological Survey, Caribbean Science Center
Kurt D. Getsinger, US Army Engineer Research and Development Center
Sharon Gross, USGS BRD
Stephen Hight, USDA-ARS
Sang Mi Lee, Entomology and Plant Pathology, Mississippi State University
Guillermo Logarzo, USDA-ARS
Travis Marisco, Biological Sciences, Mississippi State University
Les Mehrhoff, IPANE
Thomas Simonsen, Natural History Museum, London
Annie Simpson, NBII
John C. Stewart, USDA APHIS PPQ
Laura Varone, USDA-ARS
Lisa Wallace, Assistant Professor, Biological Sciences, Mississippi State University
Mark Welch, Assistant Professor, Biological Sciences, Mississippi State University
Randy Westbrook, USGS NWRC

Task 1. Aquatic Plants



Figure 1. Hydrilla (*Hydrilla verticillata*) was found by a golf course superintendent at a golf course pond in southern Mississippi, reported to their aquatic plant management contractor, who in turn asked GRI to verify the identity. We confirmed the identity, and gave the applicator a recommendation for control. Early detection and rapid response in action. GRI photo.



Figure 2. Flowering rush (*Butomus umbellatus*) is a lesser-known invasive aquatic plant that is becoming a significant nuisance in the Columbia River system, Flathead Lake in Montana, and lakes in northwestern Minnesota. GRI has been involved in discussions concerning control of this species in Idaho, Montana, and Minnesota. This photo is from Noxon Reservoir, MT by John Madsen.

Task 1.1. Growth of Common Salvinia (*Salvinia minima*) and Waterhyacinth (*Eichhornia crassipes*) as Regulated by Loading Rates of Water Column Nitrogen and Phosphorus

PI: John Madsen

Collaborators: Randy Westbrooks, USGS

Life History and Starch Allocation of Common Reed (*Phragmites australis*)

Joshua C. Cheshier and John D. Madsen

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 29 haplotypes, 13 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. An understanding of

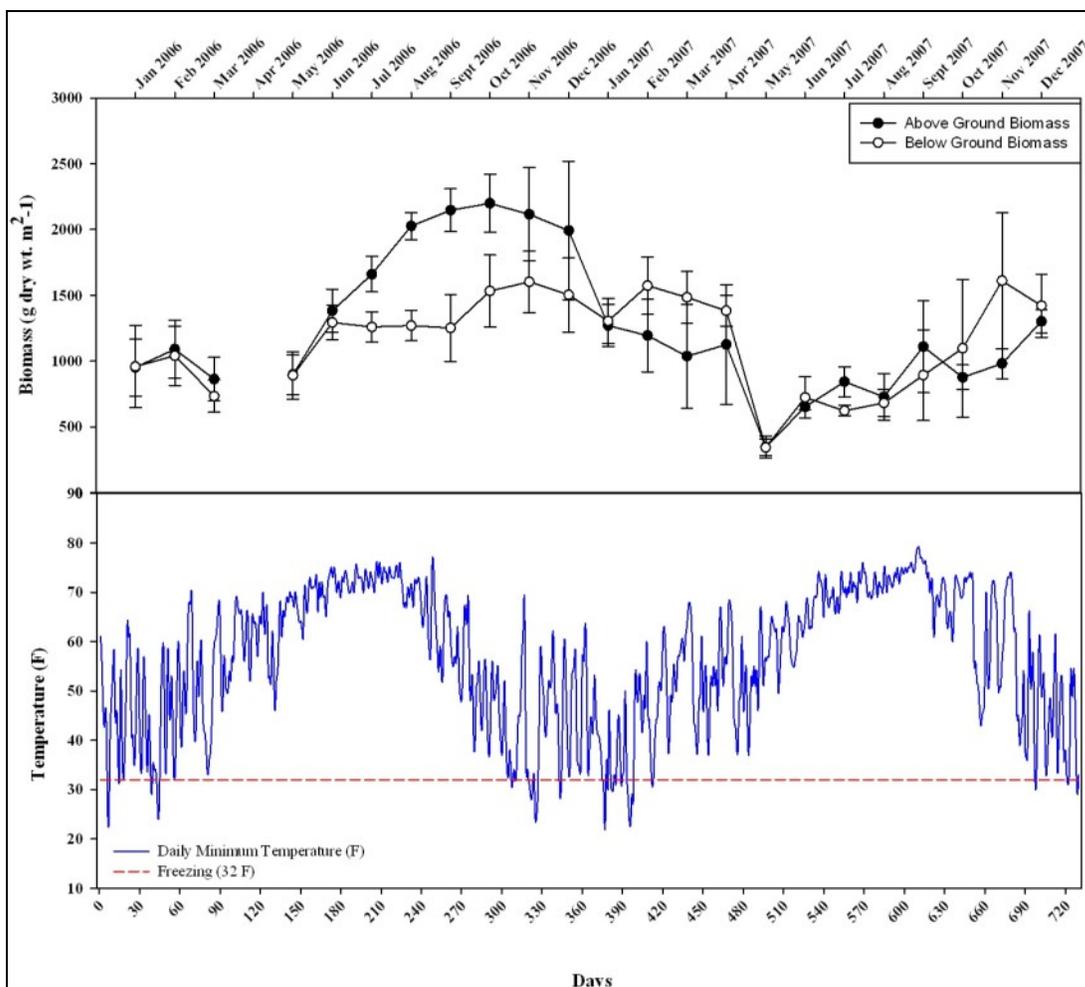


Figure 1. Average biomass allocation of above and below ground tissues of common reed in the Mobile River Delta.

common reed life history and starch allocation can be used as a predictive tool in management regimes and wetland planning and restoration. Our objectives were to measure the biomass and starch allocation of common reed over a two year period to get identify trends in the growth of common reed.

Life History

Common reed was sampled every month for two years beginning in January 2006 and ending in December 2007. 48, 1 m² samples were taken from the Mobile River Delta in southern Alabama each month and separated to above and below ground tissues, then dried at 70°C for 72 hrs to obtain a constant weight. Biomass were analyzed using a mixed model procedure in SAS and differences were assessed at P<0.05 level of significance. Above ground biomass peaked from June to December, below ground biomass peaked in December and both above and below ground biomass declined with freezing temperatures (Figure 1).



Starch Analysis

Starch samples were prepared by grinding the life history tissue samples in a cyclone mill and filtering them through a 40 mesh screen. Starch analyses were conducted using the STA20 Starch Assay Kit and methodology developed by Sigma Aldrich (Figure 2). Above ground starch peaked in August of 2006 ($107.5 \pm 0.8 \text{ g starch}^{-1} \text{ m}^2$) and in September of 2007 ($95.5 \pm 1.0 \text{ g starch}^{-1} \text{ m}^2$) (Figure 3). Below ground biomass peaked in December of 2006 and November of 2007 with $239.5 \pm 1.6 \text{ g starch}^{-1} \text{ m}^2$ and $330.6 \pm 0.51 \text{ g starch}^{-1} \text{ m}^2$ respectively (Figure 3).

Figure 2. Common reed (*Phragmites australis*) starch analysis study at Mississippi State University.

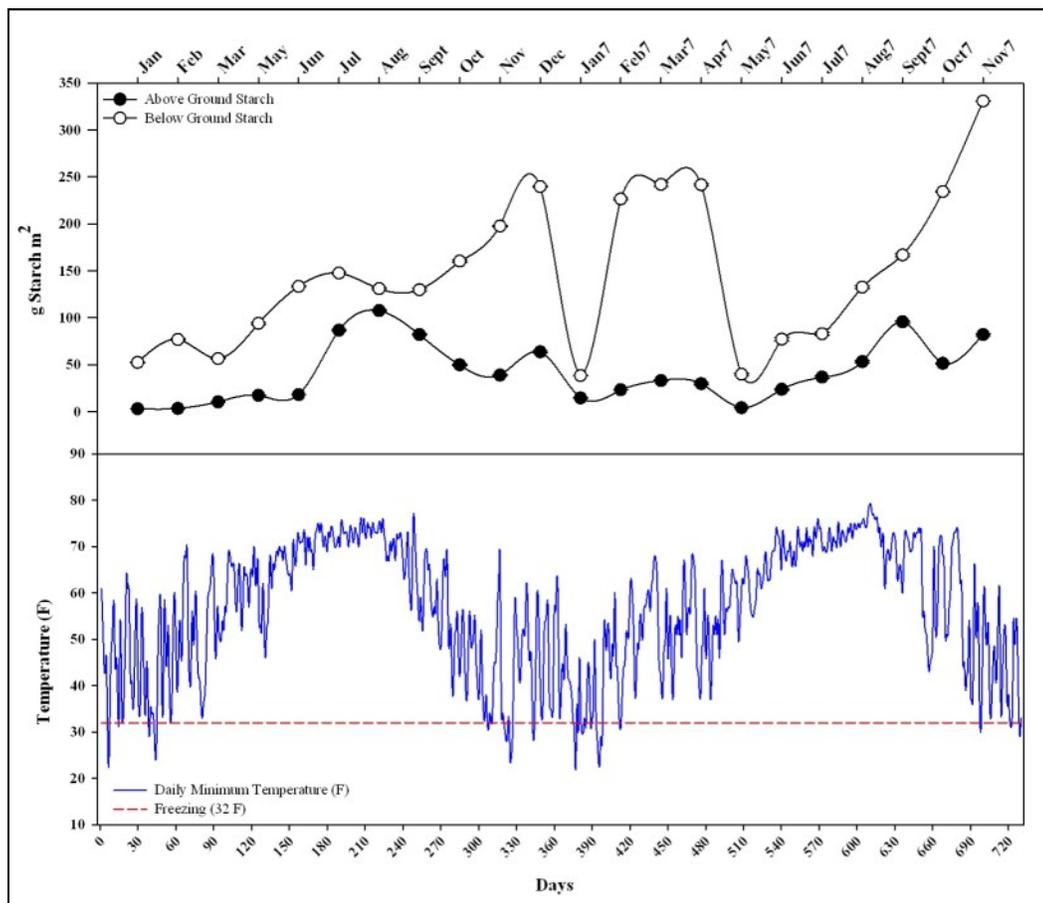


Figure 3. Average starch of above and below ground tissues of common reed in the Mobile River Delta.

Effects of Hydrologic Variations on the Growth of Parrotfeather (*Myriophyllum aquaticum*)

Ryan Wersal and John D. Madsen

Photo 1. Parrotfeather grown at the 0 cm depth for 12 weeks.



Photo 2. Parrotfeather regrowth after a 12 week winter drawdown.

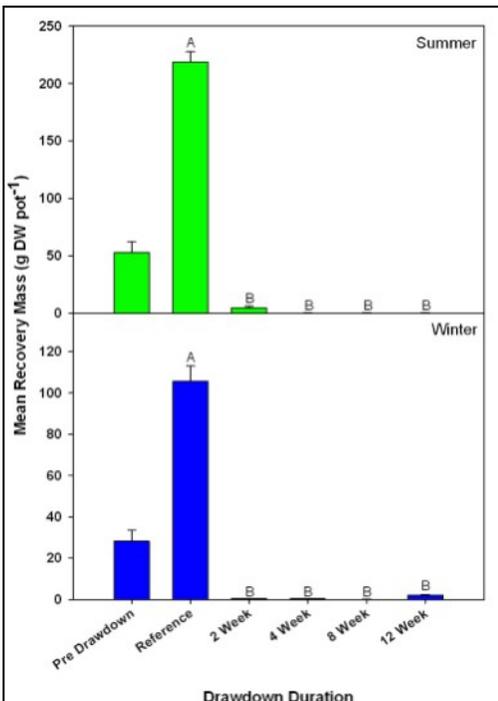


Figure 2. Mean (± 1 SE) biomass of parrotfeather after a winter (bottom) and summer (drawdown) with durations of 0, 2, 4, 8, and 12 weeks.

Parrotfeather [*Myriophyllum aquaticum* (Vell.) Verdc] is a nonnative aquatic plant from South America that is becoming increasingly problematic across the Southeastern United States. Currently, little is known regarding basic biological and ecological processes that impact the growth of this species. Understanding these processes can result in the utilization of the most effective control techniques to maximize management, and can result in the development of predictive tools to identify susceptible habitats for species invasions.

In an effort to quantify parrotfeather growth under different hydrologic regimes three controlled mesocosm studies were conducted. A water depth manipulation study was conducted in 28, 1900 L tanks in 2008 and 2009. Platforms were suspended within each tank to achieve a water depth of 0 (< 2 cm), 37, 57, 77, 97, 117, and 138 cm (4 repetitions per water depth). Six pots of planted parrotfeather were placed on the platforms and allowed to grow for 12 weeks. At the conclusion of 12 weeks all pots were harvested, plants dried, and weighed to assess treatment biomass. Additionally, winter and summer drawdown studies were conducted to determine plant response in the absence of water. Studies were conducted in 20, 1100 L tanks from September 2008 to May 2009 (winter drawdown), and February 2009 to September 2009 (summer drawdown). Pots of planted parrotfeather were placed into tanks designated as 0

weeks (reference), 2, 4, 8, and 12 week drawdown duration. A 4 month growth period was allowed prior to drawdown to ensure a mature plant stand. The winter drawdown was initiated on January 16, 2009 followed by the summer drawdown on June 15, 2009. At these times the wa-

ter in each tank was drained and the plants exposed for the designated time period. After the drawdown duration had lapsed, the designated tanks were refilled with water and a 4 week recovery period was used to monitor plant regrowth. At the conclusion of the recovery period, pots with live parrotfeather were harvested, plants dried, weighed, and compared to the reference plants to assess drawdown efficacy. Biomass data for all studies were analyzed using Mixed Procedures models in SAS[®] to determine the effects of water depth on parrotfeather growth as well as differences in a winter vs. summer drawdown and drawdown duration. Treatment means for all studies were separated using the LSD method and bars sharing the same letters are not different at a $p = 0.05$ level of significance.

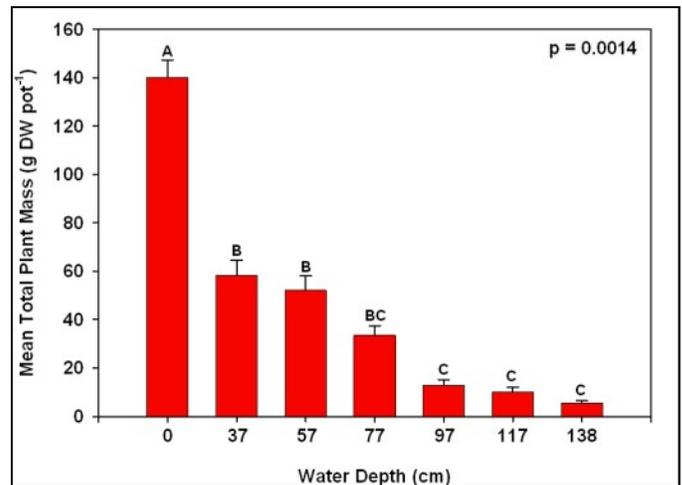


Figure 1. Mean (± 1 SE) biomass of parrotfeather grown at different water depths for 12 weeks.

Task 1.2. Nonindigenous Aquatic Plant Database Plant Observation Entry

PI: John Madsen

Collaborator: Pam Fuller, USGS Caribbean Science Center

Hydrilla and Giant Salvinia Survey in Mississippi for 2009

Michael C. Cox, John D. Madsen and Ryan M. Wersal

Water bodies in Mississippi provide recreational opportunities, fishing, transportation, municipal and drinking supply, and wildlife habitat. Invasive aquatic plant species negatively affect all of these when introduced to water bodies. Hydrilla [*Hydrilla verticillata* (L.f.) Royle] and giant salvinia (*Salvinia molesta* D. S. Mitchell) are two aquatic plants that are non-native and present in Mississippi waterbodies. Hydrilla is a submersed aquatic plant native to warmer areas of Asia and has become a serious nuisance plant in the United States (Langeland 1996). The specialized growth habit, reproduction, and physiological properties of hydrilla make it superior to neighboring plant species in the gathering of light, nutrients, and oxygen. For this reason, hydrilla has the well-deserved nickname “the perfect aquatic weed”. Although both dioecious and monoecious biotypes of hydrilla exist in the United States, only the dioecious biotype occurs in Mississippi. Hydrilla can reproduce by fragmentation and through the production of turions and tubers (subterranean turions). Giant salvinia is a free-floating aquatic fern native to southeastern Brazil. It primarily reproduces asexually (daughter plants arising from buds on stolons) and may double in leaf number in less than 8 days (McFarland et al. 2004). The rapid growth rate and proficient reproduction methods of giant salvinia make it an extreme nuisance and competitor in aquatic environments.

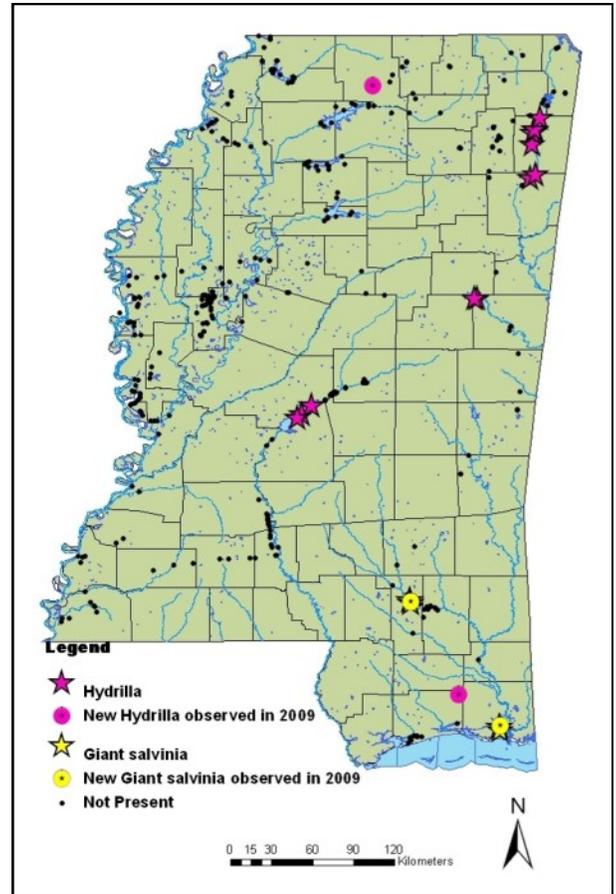


Figure 1. Locations of hydrilla and giant salvinia distribution in Mississippi. Included are points surveyed from 2005 to 2009.

Methodology

Surveys to detect the presence or absence of hydrilla and giant salvinia have been conducted across Mississippi since 2005. Locations surveyed in 2009 were previously non-surveyed areas, while the Ross Barnett Reservoir, Wedgeworth Creek, and Pascagoula River Delta were revisited for an update on hydrilla or giant salvinia occurrence after they were detected in previous surveys. A Hewlett-Packard model 2110 iPAQ handheld computer with Global Positioning System (GPS) capabilities via a Holux GPS model GR-271 receiver was used to obtain geographic locations at approximately 3 m position accuracy. All data was collected and reported in latitude and longitude under datum WGS 84. Location maps with present points were produced using ArcGIS-ArcMap, version 9.2.



Figure 2. Giant salvinia population in Wedgeworth Creek, Forrest County, MS, during May 2007. GRI Photo.

Hydrilla and Giant Salvinia Status

Presence and absence of giant salvinia and hydrilla from 2009 in the state of Mississippi is shown in Figure 1.

Persisting hydrilla populations in the Ross Barnett Reservoir, Tennessee-Tombigbee Waterway, and Bluff Lake suggest that control methods should be continued or initiated in these areas. New populations found at Fallen Oak and Wall Doxey Lake should be treated and monitored, as they will likely spread if ignored. The Ross Barnett Reservoir and Fallen Oak Golf Course are currently the only locations under active management for hydrilla with herbicides. Aggressive control for hydrilla is imperative for all infested sites indicated to prevent future establishment and spread to neighboring locations.

The giant salvinia population in Wedgeworth Creek still persists. The salvinia weevil has not been effective in eradicating giant salvinia from this location. Therefore, more aggressive control techniques should be used to completely remove surviving plants before future spread occurs. The giant salvinia population in the Pascagoula River delta is currently under active management by the Mississippi Department of Marine Resources. This area should continue to be monitored and managed for the possible reoccurrence and spread of giant salvinia populations.

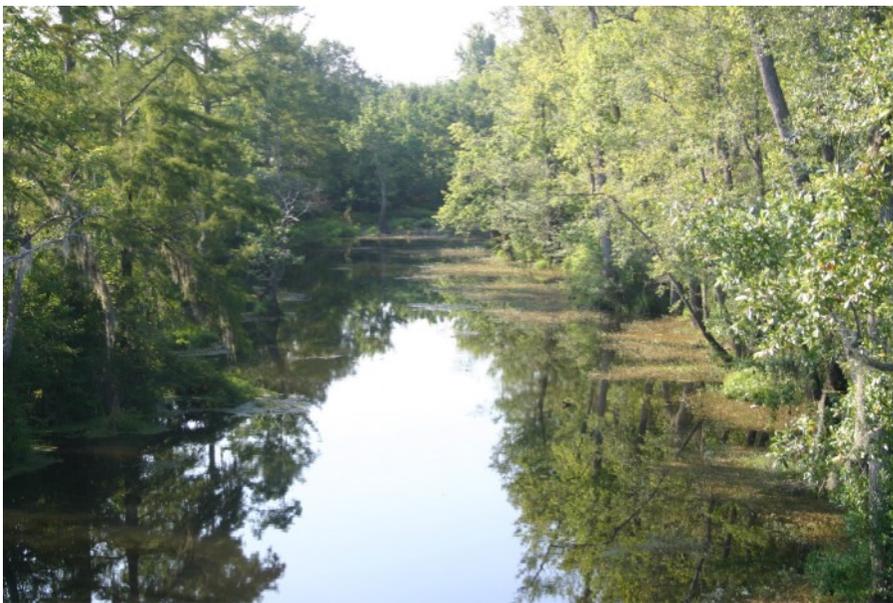


Figure 3. Giant salvinia population in Wedgeworth Creek, Forrest County, MS, during August 2009. GRI Photo.

Literature Cited

Langeland, K. A. 1996. *Hydrilla verticillata* (L. F.) Royle (Hydrocharitaceae), "The perfect aquatic weed". *Castanea* **61**: 293-304.

McFarland, D. G., L. S. Nelson, M. J. Grodowitz, R. M. Smart, and C. S. Owens. 2004. *Salvinia molesta* D. S. Mitchell (Giant Salvinia) in the United States: A review of species ecology and approaches to management. *APCRP Technical Notes Collection (ERDC/EL SR-04-2)*, U.S. Army Engineer Research and Development Center, Vicksburg, MS. 33pp. June 2004.

Task 2. National Early Detection and Rapid Response Webpage Development



Figure 1. Identification of invasive species is the first step in early detection and rapid response. Yellow flag iris (*iris pseudocolor*) is on numerous state noxious weed lists. GRI Photo.



Figure 2. Early detection of cactus moth may involve being able to identify the distinctive egg stick. Photo by Randy Westbrook, USGS.

Task 2.1. National Early Detection and Rapid Response Toolbox Development

PI: John Madsen

Co-PI: Victor Maddox

Cooperator: Elizabeth Sellers, NBII, Randy Westbrook, USGS NWRC, and Annie Simpson, USGS National Headquarters (NBII), Pam Fuller, USGS Caribbean Science Center, and Les Mehrhoff, University of Connecticut (IPANE)



The Use of Early Detection and Rapid Response Protocol for the Control of Water lettuce (*Pistia stratiotes* L.) in Powe Pond, Starkville, MS

Ryan M. Wersal and John D. Madsen

Water lettuce is a free-floating aquatic plant that is not native to the United States. The floating growth habit and rapid reproduction allows water lettuce to cover large expanses of water in short periods of time. Dense infestations reduce access and use of waterways, navigation, hydroelectric generation, and recreation. Ecologically, dense infestations of water lettuce can cause reductions in dissolved oxygen which may lead to fish mortality; these infestations can also shade native submersed aquatic plants reducing the spatial heterogeneity and habitat for aquatic invertebrates.

On August 12, 2008, water lettuce was identified growing in a small area of a 1.75 acre impoundment located in the Thad Cochran Research, Technology, and Economic Development Park, Starkville, MS. The water lettuce has escaped the pond via a water control structure to a creek that transects the Research Park for several miles. The creek empties into Sand Creek (North East of the pond) which ultimately empties into the Tennessee Tombigbee Waterway 20 miles to the east. Therefore, the objectives of this study were to 1) eradicate the water lettuce population in the pond, and 2) survey and eradicate any plants that have escaped into the outflow creek using aquatic labeled herbicides.

Figure 1. Aerial imagery of Powe Pond in August 2007 indicating no water lettuce present.

Methods



Figure 2. Aerial imagery of Powe Pond in June 2008 shows small scattered patches along the northern shoreline.

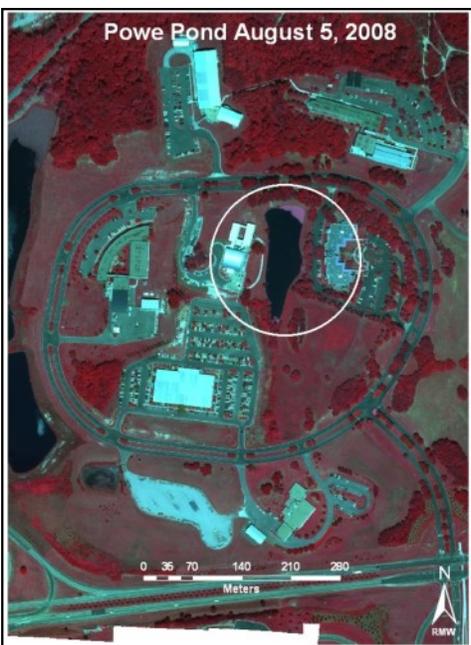


Figure 3. Aerial imagery of Powe Pond in August 2008 shows a substantial increase in water lettuce coverage.

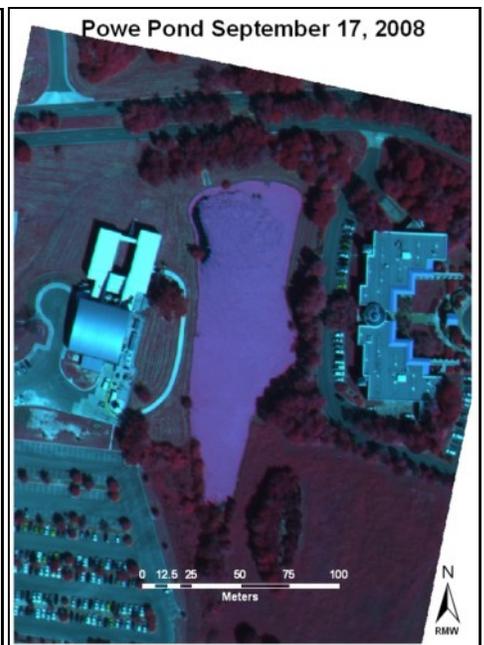


Figure 4. Aerial imagery of Powe Pond in Sept. 2008 showing complete water surface coverage by water lettuce.

Powe Pond: Aerial imagery was used to calculate the spread rate of water lettuce by analyzing imagery from May, June, and August 2008. Similar imagery was flown on September 19, 2008 prior to herbicide applications. On September 22, 2008 the aquatic herbicide penoxsulam (Galleon[™]) was applied to the water column from a boat using a weighted hose system to obtain an herbicide concentration of 50 µg L⁻¹ (ppb). Penoxsulam is a low use rate, slow acting systemic herbicide that inhibits branched chain amino acid production. Initial herbicide symptoms may take 4-6 weeks to appear, however growth inhibition is rapid. Following the initial herbicide application, three water samples were collected from the pond and shipped to the SePRO Research and Technology Campus in Whitakers, NC for herbicide residue determinations. Water samples were collected at 3, 14, 17, and 30 days after treatment (DAT). The water samples documented the herbicide concentration in the pond, ensured adequate exposure of the plants to the herbicide, and allowed for monitoring the herbicide concentration over time to determine if supplemental applications were needed to maintain the desired herbicide concentration. Photographs were taken weekly for 9 weeks after treatment (WAT) and then 1 year post treatment to document herbicide injury and overall control.



Photo 1. Powe Pond in September 2008 prior to herbicide application.

Outflow Creek: The creek was surveyed to identify how far the plants had moved from the pond and to apply the aquatic herbicide imazamox (Clearcast[™]) to plants growing in the creek. Imazamox was applied as a foliar application using a 3% by volume concentration. The surfactant DyneAmic[™] was added to the spray solution at 1% v:v. Additional surveys were conducted in October 2008, May 2009, and September 2009 to ensure herbicide efficacy and water lettuce eradication in the creek.

Table 1. Mean herbicide concentrations in Powe Pond following herbicide applications.

Herbicide (ppb)	3 DAT	14 DAT ^a	17 DAT ^b	30 DAT
Penoxsulam	50.03	38.7	26.2	66.1

^aHeavy rain following this sample date

^bApplied a follow up application on Oct. 20, 2008 of 30 ppb of penoxsulam to maintain 50 ppb concentration in the pond

Results and Discussion



Photo 2. Chlorosis of water lettuce tissue following exposure to the herbicide penoxsulam.

day⁻¹ from June 2008 to September 2008.

Water lettuce Introduction and Growth: Historic aerial imagery indicates that there was no water lettuce in Powe Pond in August 2007 (Figure 1). Using similar imagery, it was observed that water lettuce may have been introduced into the pond in June 2008 where it infested approximately 0.02 acres (Figure 2). However, by August 2008 water lettuce occupied large areas of the pond and by September 2008 the entire pond surface was covered by water lettuce, and subsequently reported to the Geosystems Research Institute (Figures 3 and 4; Photo 1). The water lettuce infestation expanded approximately 0.03 acres



Photo 3. Herbicide injury 2 WAT showing the deterioration of the outer leaves and chlorosis beginning in the center of the rosette.

Herbicide Efficacy and Monitoring: Herbicide residues in the water column indicate that sufficient concentrations of penoxsulam were maintained in the pond for at least 30 days (Table 1).



Photo 4. Powe Pond 6 WAT where plants are showing severe chlorosis and areas of dead (brown) plants.

applications made in the fall, September and October, were also aided by frost in late November that killed any remaining plants.

Water lettuce in the outflow creek was also treated on September 22, 2008 along a 1 mile segment. This treatment consisted of spot spraying individual plants or small collections of plants within the creek or along the creek bank. The creek was further surveyed during this time as it

Photo 6. Powe Pond at 8 WAT where the water lettuce mat is breaking up.



Photo 7. Necrotic water lettuce at 9 WAT.

emptied into a larger creek that traversed the R.R. Foil Plant Research Center, at Mississippi State University; however no more plants were observed and therefore the spread of water lettuce was stopped in the outflow creek. The outflow creek was surveyed again approximately 4 WAT (October 2008), and the water lettuce was necrotic or dead during at this time. Additional surveys conducted in May September 2009 found no remaining water lettuce in the outflow creek. Additionally there have been no reports of water lettuce in the Tennessee Tombigbee Waterway downstream of the Powe Pond infestation.

By employing an Early Detection Rapid Response protocol the water lettuce infestation was identified, and ultimately eradicated before it could spread further.

Herbicide injury was noted on plants as early as 1 WAT by severe chlorosis and reddening of the outer leaves of water lettuce (Photo 2). At 2 WAT the outer leaves began to deteriorate and chlorosis was observed in the center of plant rosettes (Photo 3). By 6 WAT plants were mostly chlorotic and areas of necrotic (brown) and dead plants were beginning to form (Photo 4). Severe rosette injury was observed at 7 WAT where the apical portions of the rosette necrotic and beginning to deteriorate (Photo 5). During this assessment period it was noted that small openings in the plant mat were beginning to form. At 8 WAT plants were severely chlorotic/necrotic with large holes beginning to form in the plant mat (Photo 6). By 9 WAT plants were completely necrotic, deteriorating, and sinking in the water column (Photo 7). A follow up assessment 1 year after treatment found Powe Pond to be completely free of water lettuce (Photo 8).

Water lettuce was sensitive to the concentration of penoxsulam maintained in the water column as indicated by the early injury signs. Herbicide

Photo 5. Water lettuce 7 WAT with penoxsulam, the center of the rosettes beginning to show signs of necrosis.



Photo 8. Powe Pond approximately 1 year after treatment with the herbicide penoxsulam.



Task 3. Invasive Insects:

Cactus Moth

Cactoblastis cactorum



Figure 1. Post-doctoral researcher Travis Marsico (left) and undergraduate Jeffery Cannon prepare plants for a growth chamber experiment to evaluate responses of two native North American cacti to feeding by *C. cactorum* and a native moth, *Melitara prodenialis*. The prep work here was conducted in our live *Opuntia* greenhouse collection, representing plants from throughout the southeastern US. Photo by Gary Ervin.

Figure 2. Joe Bravata with USDA-APHIS in Louisiana inspecting *Opuntia engelmannii* Salm-Dyck ex Engelm. for cactus moth while Maurice Duffel with USDA-APHIS in Florida records the GPS location. USDA-APHIS representatives from Texas participated in the survey as training for activities in Texas. (Image by Victor Maddox, MSU-GRI).



Task 3.1. Early Detection and Reporting of Cactus Moth

PI: Richard L. Brown

Co-PI: John Madsen, Victor Maddox

Collaborators: Randy Westbrooks, USGS NWRC; Joel Floyd, USDA APHIS PPQ; John C. Stewart, USDA APHIS PPQ, Thomas Simonsen, Natural History Museum, London; Sangmi Lee, MSU

Establishment of Quarantine Facility for Rearing Cactus Moths

Richard L. Brown

Research on cactus moths, *Cactoblastis cactorum*, and their biology and interactions with host species of cactus required the establishment of quarantine facility for rearing this species at Mississippi State University. Space for this quarantine rearing center was obtained at the Insect Rearing Facility in the Department of Entomology and Plant Pathology at MSU, where three of the six environmentally controlled rooms were dedicated towards rearing cactus moths. In order to obtain a permit as a quarantine facility, a Standard Operation Procedure (SOP) was developed to address criteria required for ensuring the security of the containment area. The application for the permit with the SOP was followed by an on-site inspection by USDA-APHIS personnel to ensure that all criteria had been met.

The rearing rooms have a unique keyed lock with keys made available for only the Directors of the facility, Drs. John Schneider and Frank Davis, the Containment Director and author of the SOP, Dr. Richard Brown, and Cactus Moth Rearing Officer, Dr. Travis Marisco. The Rearing Facility has two HVAC systems for a closed air system that flows through filters that occlude particles larger than 5 microns. The outside vent for fresh is covered with an 8-mesh screen. The rearing rooms are controlled and monitored by a Johnson Control, Inc., direct digital control system running under a LON computer network protocol. All cactus moths are reared in cages on species of *Opuntia* cactus native to Mississippi. All specimens are confined in cages to prevent escape (Figure 1). All materials used for rearing cactus moths are autoclaved before removal from the rearing facility.



Figure 1. One of three rearing rooms in the Quarantine Facility with cages holding cactus moths used in research by Gary Ervin and Travis Marsico.

Research in the facility by Drs. Gary Ervin and Travis Marsico on the comparative fitness of *Cactoblastis cactorum* and *Melitara prodenialis* has provided secondary benefits in collaboration with Richard Brown. Two species of parasitoids of *Melitara prodenialis*, a tachinid fly (*Acantholespia constocki*) and an ichneumonid wasp (*Telemucha sinuata*) (Figure 2), and the fungus *Beauveria bassiana*

have been identified as causing mortality to *Melitara prodenialis*, but none of these were found to attack *Cactoblastis cactorum*.



Figure 2. *Telemucha sinuata* (Ichneumonidae), a parasitoid reared from *Melitara prodenialis*.

Evolution of Host Preferences in Cactus-Feeding Pyralidae

Thomas Simonsen and Richard Brown

The use of cactus as larval hosts has been most developed in genera of Pyralidae, specifically the Phycitinae. Surveys of the cactus moth, *Cactoblastis cactorum*, have concentrated on surveys of prickly pear cacti in the genus *Opuntia* (subgenus *Platyopuntia*). However, other genera of cacti, e.g., *Cylindropuntia* and *Consolea*, which were formerly regarded as subgenera of *Opuntia*, also have been recorded as hosts of the cactus moth. In order to determine the ancestral host of *Cactoblastis*, the evolution of larval hosts in these genera were analysis. The analysis was made with Mesquite 2.71, a modular system for evolutionary analysis (Maddison & Maddison 2009), based on the phylogeny presented by Simonsen (2008).

The results of our analysis of the evolution of cactus feeding in Pyralidae are shown in Figure 1. Cactus-feeding has evolved once in the Pyralidae and subsequently was lost in the genus *Rhagea*, which has switched to feeding on plants in the family Crassulaceae (live-forever). The two basal lineages within the cactus-feeding clade, *Cactobrosis* and *Echinocereta*, feed on two genera of barrel-like cacti, *Ferrocactus* and *Echinocerus* respectively. However, our analysis indicates that the last common ancestor of the remaining cactus-feeders fed on an “Opuntoid” cactus. The genus *Opuntia* s.l. has recently been split into several smaller genera of which cactus-feeding phycitines feed on three: *Opuntia* s.s. (= *Platyopuntia*), *Cylindropuntia*, and *Consolea*. When these three genera are treated as ‘*Opuntia* s.l.’ in the analysis, *Opuntia* s.l. feeding appears to have a single origin. Though *Opuntia* s.l. feeding has been lost independently in the genera *Eremberga*, *Sigelgaita* and *Yosemiteia*, this scenario opens up for the intriguing possibility that the ancestor of the *Opuntia* s.l. feeders fed on the last common ancestor of *Opuntia* s.l., and that the two clades subsequently have co-evolved. Of the three non-*Opuntia* s.l. feeders in this clade, *Eremberga* and *Sigelgaita* are both restricted to a few genera of barrel-like or rod-like cacti (*Echinocerus*, *Echinopsis*, and *Eulychina*). However, the small genus *Yosemiteia* feeds on a wide variety of barrel-like cacti.

It is uncertain if the ancestral “Opuntoid” host was a member of *Platyopuntia* or *Cylindropuntia* because both genera are used as hosts by the basal genera, *Nanaia* and *Alberada* on *Cylindropuntia* and *Melitaria* on *Platyopuntia*. However, the basal genera in the clade containing *Cactoblastis* feed on *Platyopuntia*, suggesting that this was the ancestral host in *Cactoblastis*.

Predacious larvae feeding on scale insects have evolved independently in the non cactus-feeders *Laetilia* and *Baphala*, and the cactus-feeder *Salembona*. *Laetilia* and *Baphala* are apparently primarily predacious in all life stages (Neunzig 1997). However, in *Salembona* the larvae feed on flowers, fruit and shoots of *Opuntia* s.s. in the spring, but switch to mealy bugs on *Opuntia* later in the year (Mann 1969).

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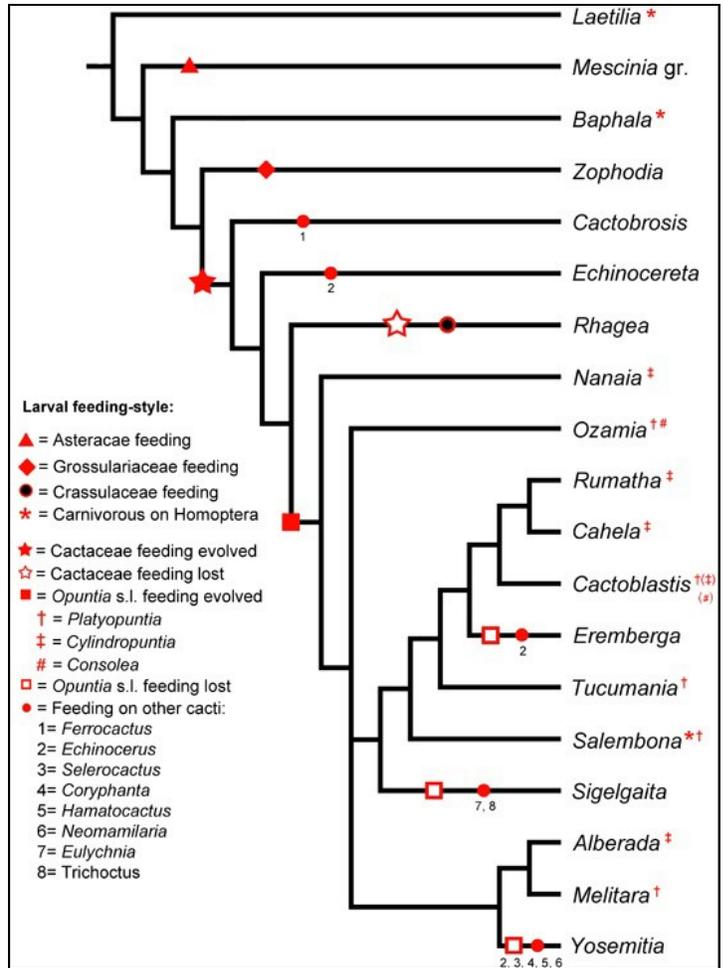


Figure 1. Phylogenetic tree of cactus feeding Pyralidae and their relatives with evolution of host preferences.

Sensory Structures on the Antennae of the Cactus Moth

Richard L. Brown and Sang Mi Lee

Typical of all Lepidoptera, the antennae of cactus moths, *Cactoblastis cactorum*, have sensory structures for detecting pheromones, locating host plants, and detecting environmental conditions. Six types of antennal sensillae are ubiquitous in Lepidoptera: 1) Sensillum trichodeum (pheromone receptors in males, plant volatile receptors in females), 2) Sensillum basiconicum (plant volatile receptors in females); 3) Sensillum auricillicum (plant volatile receptors in females); 4) Sensillum coeloconicum (olfactory); 5) Sensillum chaeticum (taste and mechanoreceptors); and 6) Sensillum styloconicum (temperature and humidity sensors). Although previous research has documented the response of various cactus moth sensilla to plant volatiles, no information is available on the types, distribution, and relative abundance of the various antennal sensilla in the cactus moth.

Research is in progress on the sensilla of female and male antennae of the cactus moth to determine the types of sensilla present, their relative abundance, and their distribution on the individual antennal subsegment (flagellomere). Scanning electron microscopy (SEM) has been combined with microscope slide preparations of de-scaled antennae to obtain diversity and distribution of sensilla. Some sensilla, e.g., coeloconica and chaetica, are easily identified with a compound microscope, but others require use of the SEM for identification.

The number of flagellomeres (“segments”) were counted in the antennae from five individuals of each sex of the cactus moth. The number of flagellomeres range from 60 to 89 ($\bar{x} = 76$) in males and 67-79 in females ($\bar{x} = 73$) in females. Variation in number of flagellomeres was correlated with the forewing length.

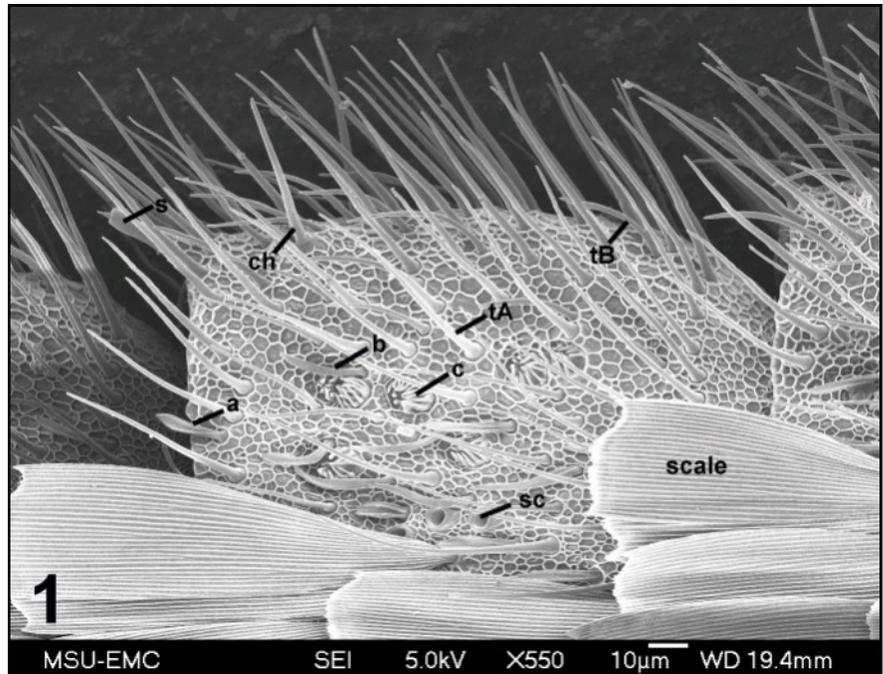


Figure 1. Sensilla on flagellomere near middle of female antenna of cactus moth, a – auricillicum, b – basiconicum, c – coeloconicum, ch – chaeticum, sc - socket of scale, t – trichodeum, types A and B.

Cactus moth males and females have all six types of antennal sensilla, with sensilla trichodea represented by two types, A and B (Fig. 1). Examinations of SEM images and slide mounts have revealed that sensilla are restricted to the ventral half of each flagellomere whereas the remainder is covered by scales (Fig. 1). Examinations of slide mounts revealed that a female antenna averaged 3.6 sensilla coeloconica for each of 68 flagellomeres, whereas a male antenna averaged 4.9 sensilla coeloconica for each of 69 flagellomeres. These data suggest that this sensillum in the male is a more important receptor for olfaction of chemicals than in the female. Sensilla chaetica, which are known to be gustatory receptors, are present in almost equal numbers (either one or two present on each flagellomere) among males and females. In females the sensilla chaetica are positioned at the apical end of the ventral surface of each flagellomeres. In males, these sensilla are irregular in position, sometimes occurring on the dorsal surface intermixed with scales. Sensilla styloconica, which respond to temperature and humidity, are present on the apical margin of each flagellomeres of the apical two-thirds of the antenna in each sex.

Additional antennae need to be examined to determine variation in distribution and number of sensilla. Additional scanning electron microscopy is needed to differentiate sensilla trichodea and sensilla basiconica. These data on diversity, abundance, and distribution of sensilla in the cactus moth will be compared with those for the native cactus moth, *Melitara prodenialis* to determine any differences between the two species for host location.

Task 3.2 Distribution of *Opuntia* in the Region

PI: Victor Maddox

Co-PI: John Madsen, Richard Brown

Collaborators: Randy Westbrooks, USGS NWRC; Joel Floyd, USDA APHIS PPQ; John C. Stewart, USDA APHIS PPQ

Distribution of Pricklypear Cactus

Victor Maddox

Much of the host mapping activity in 2009 was focused along the Gulf Coast due to the discovery of cactus moth in southern Louisiana (Figure 1), although host mapping did occur elsewhere. Host data from 18 states was collected in 2009, including four new states, bringing the total number of states with host data in the CMDMN database to 36 (as of 14 Dec 2009). In 2009, 1399 host data reports were collected and entered into the Cactus Moth Detection and Monitoring Network (CMDMN) database. The largest number of reports entered in 2009 were negative host reports at 1292 compared to 107 positive host reports for the same period as of 14 December 2009. On 14 December 2009, there were 10,030 reports in the CMDMN database with 2,678 positive host reports and 7,352 negative reports.

There is still a need for additional host mapping along the Gulf Coast which, in addition to visual cactus moth surveys in known infested areas and volunteer sentinel site activity, will be the focus of near-future project activities as funding permits in 2010. The entry of numerous negative reports from the northwestern United States continues and is expected to be completed in early 2010, adding data from new areas like the Great Basin Desert and Fish Lake National Forest (Figure 2).

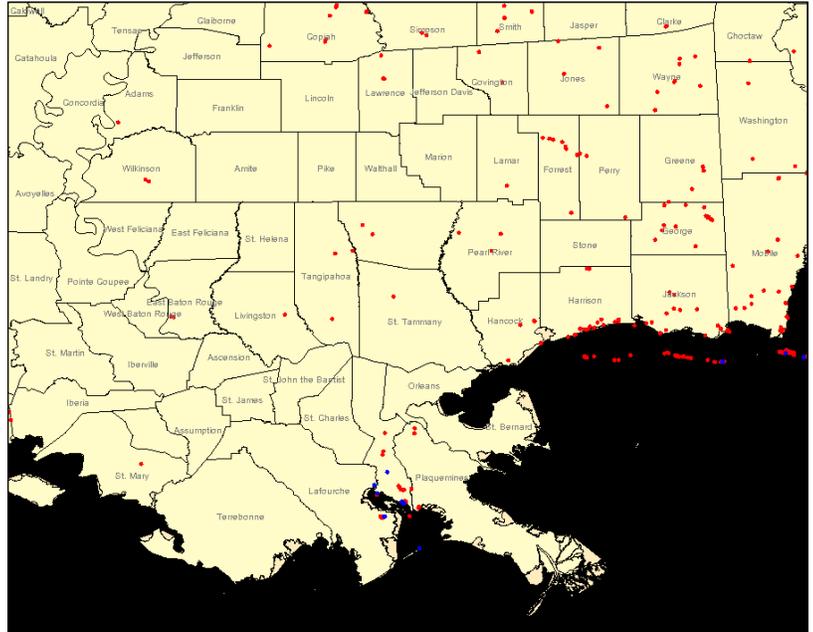


Figure 1. Cactus moth was discovered in the southern Louisiana bayous in Mid-2009. The blue dots on the CMDMN database map south of New Orleans indicate the location of the infestation. Red dots indicate locations with cactus but without the moth. This discovery has prompted increase activity in southern Louisiana.



Figure 2. The entry of numerous negative reports from the northwestern United States is expected to be completed in early 2010 and will eventually add data from new areas like the Great Basin Desert in Nevada (left) and Fish Lake National Forest (right) in Utah.

Task 3.3. *Opuntia* and *Cactoblastis* Habitat Models and Population Genetics

PI: Gary N. Ervin

Co-PI: John Madsen, Richard Brown

Collaborators: Chris Brooks, Lisa Wallace, and Mark Welch; MSU Biological Sciences

Modeling of Pricklypear Cactus and Cactus Moth Habitat

Gary N. Ervin

Our proposed work for 2009-2010 encompasses three major areas of research – experimental studies of growth performance of *C. cactorum* and native US cactus moths on native southeastern US *Opuntia* species, genetic studies of *Opuntia* and cactophagous moths, and *C. cactorum* habitat modeling efforts.

Experimental studies

Growth chamber experiments continue, as of December 2009, with both *C. cactorum* and *Melitara prodenialis* nearing the ends of their life cycles (Figure 1). Preliminary analyses suggest differential performance of these moths on the native Florida cacti (*O. humifusa* and *O. stricta*), and those data are being used as the basis for an NSF grant proposal to be submitting in January 2010. That proposal aims to fund molecular genetic work to identify mechanisms of interaction between moths and host plants. The proposal submission will involve collaborative work with Dr. Travis Marsico of Arkansas State University; Marsico was a post-doc sponsored on this research.

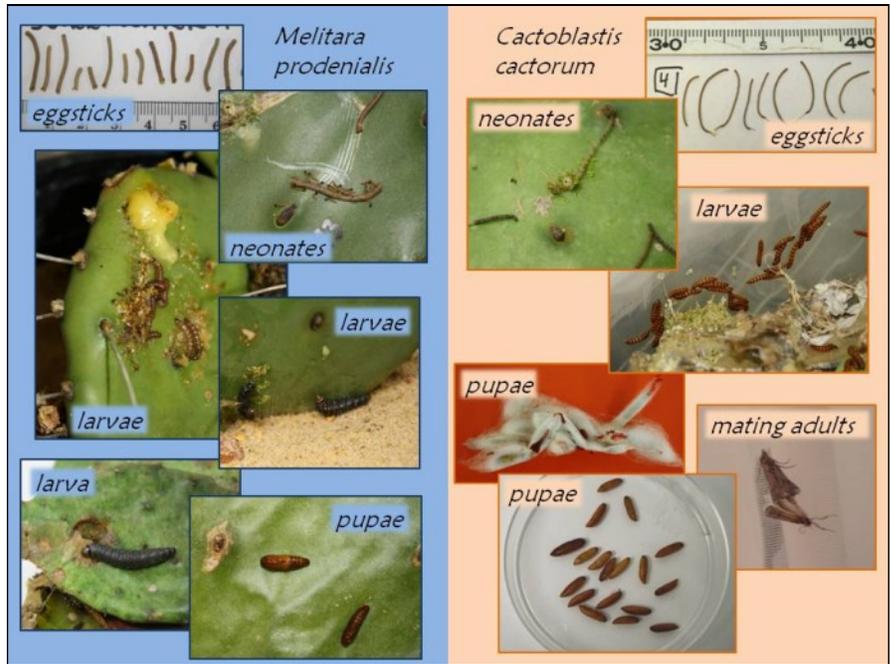


Figure 1. Life history stages of *Melitara prodenialis* (left) and *Cactoblastis cactorum* (right). All images taken in MSU growth chamber facility (an APHIS-approved quarantine facility).

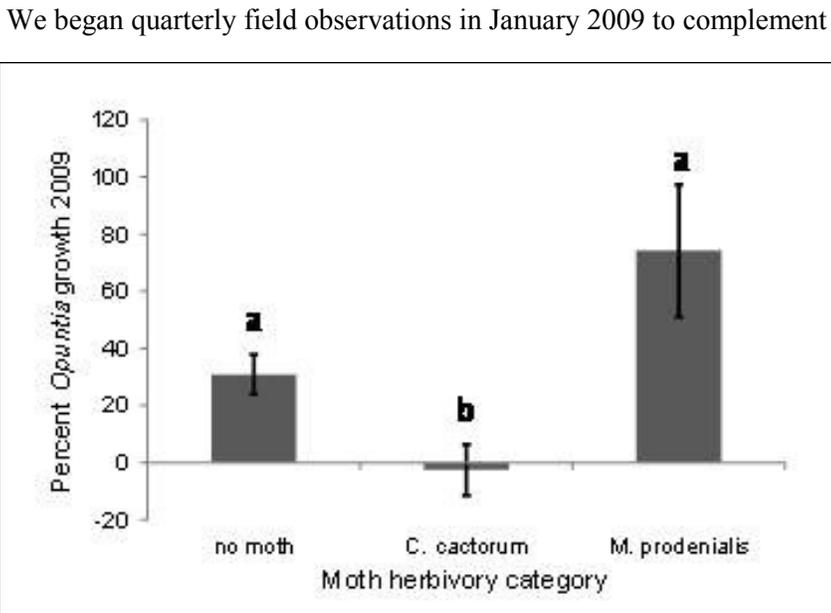


Figure 2. Changes in *Opuntia* host plant size from field-monitored individuals in Florida, between January and October 2009. Growth measured as number of cladodes per plant for plants with no feeding from moths (left), feeding by *C. cactorum* (center), or feeding by *M. prodenialis* (right). Different letters above bars indicate significant difference, based on one-way ANOVA and a Tamhane post-hoc test to determine significant differences at $p < 0.05$.

We began quarterly field observations in January 2009 to complement the growth chamber studies. The objectives were to determine patterns and outcomes of *M. prodenialis* and *C. cactorum* feeding on *O. humifusa* and *O. stricta*. Of the ninety-three *O. humifusa* plants observed, only one was fed upon by *C. cactorum* alone, one was fed upon by both *C. cactorum* and *M. prodenialis*, but *M. prodenialis* fed upon eighteen plants by itself. Of forty-nine *O. stricta* plants observed, *C. cactorum* fed upon twenty. On average, *Opuntia* plants without moth herbivory or with herbivory from the native *M. prodenialis* grew during the study (Figure 2). In contrast, plants with *C. cactorum* herbivory decreased in size because plant growth did not compensate for losses due to moth herbivory.

Genetic analyses

Our first series of genetic analyses for *C. cactorum* in its native range in Argentina, its invasive range in Florida, and for *Melitara prodenialis* across its native Floridian range were completed during the first half of 2009. These analyses have shown that *C. cactorum* has considerable

geographically structured genetic diversity in its native range, similar to *M. prodenialis* in its native range. As expected, *Cactoblastis cactorum* in Florida has far reduced genetic diversity relative to its native range (5 vs. 55 cytochrome oxidase I [COI] haplotypes); however, this diversity was geographically structured, with a Gulf Coast clade, an Atlantic Coast Clade, and a more widespread clade overlapping these other two. The data supported published inferences of multiple introductions to Florida, but only from the nearby Caribbean range.

We have submitted a manuscript based on these genetic analyses, and we are beginning the work of integrating the results into our environmental modeling work. The genetic results also form the basis for continued collaborations with the USDA ARS scientists at Tifton and Buenos Aires, Argentina, as well as one or more subsequent journal manuscripts.

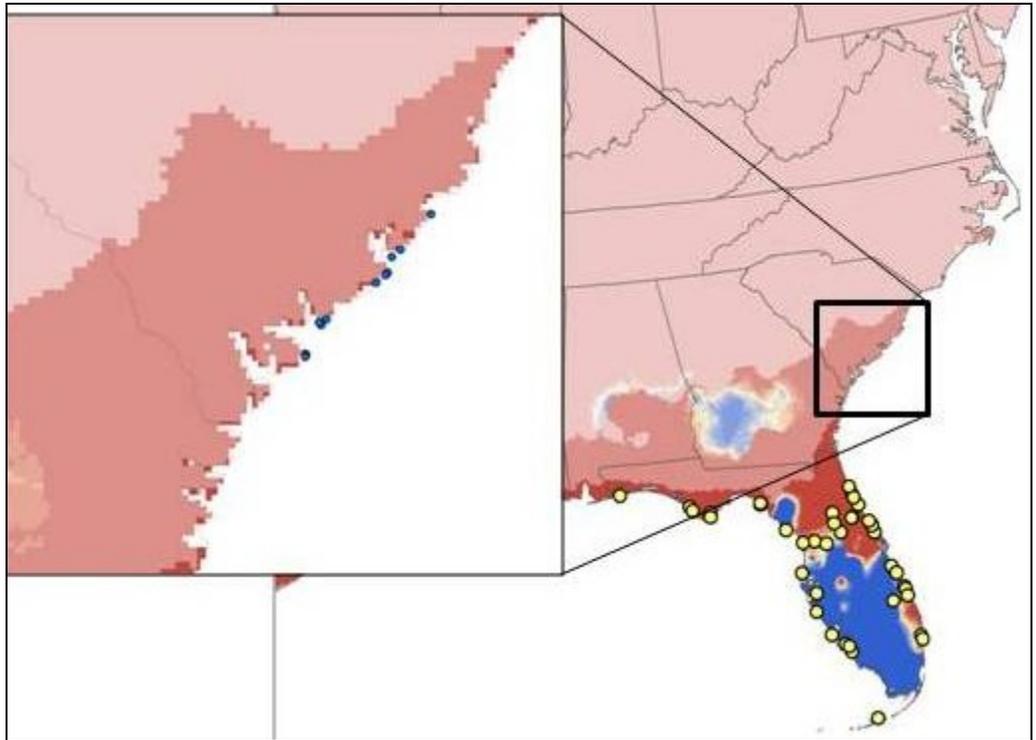


Figure 3. Preliminary map of expected environmental envelope of *Cactoblastis cactorum* in southeastern US, based on environmental data for research conducted in Argentina. Expanded inset shows overlap of most likely habitat (darkest red color) with known locations in South Carolina (blue dots). Large yellow dots indicate some of the known *C. cactorum* locations from Florida.

Environmental tolerance models for *Cactoblastis*

We have begun comparative habitat modeling approaches aimed at testing hypotheses regarding factors influencing the distribution of *C. cactorum* across Florida and other areas. This work, and a field study completed during summer 2008, suggest the moth's distribution is strongly influenced by the presence of its preferred host species (or that the two are mutually influenced by one or more environmental factors). We presently are expanding this work to evaluate potential habitat for the moth in areas of the Gulf Coast beyond the Florida-Alabama distribution (Figure 3). Thus far, models agree closely with known distribution of the moth, but we are now engaged in comparing modeling approaches prior to submitting manuscripts on these studies.

We also have begun work to integrate habitat modeling studies with results we have obtained to date from our genetic analyses (i.e., modeling habitat for specific genotypes). We have two manuscripts in development based on this habitat modeling work, and a third is in the planning stages; all will specifically address the roles of environment and genetics on distribution of *C. cactorum*. We also will be using these findings to help direct the collaborative work with USDA ARS scientists. Initial manuscript submission is targeted for January 2010; grant proposal submission is targeted for July 2010.

Task 3.4. Webpage: Cactus Moth Detection and Monitoring Network

PI: Clifton F. Abbott

Co-PI: Richard Brown, Victor Maddox, John Madsen

Collaborators: Randy Westbrook, USGS NWRC, Joel Floyd, USGS APHIS PPQ, John C. Stewart, USDA APHIS PPQ, and Annie Simpson, USGS National Headquarters (NBII)

Cactus Moth Detection and Monitoring Network

Clifton F. Abbott

The year 2009 has been busy for the cactus moth. The cactus moth, either by natural flight or by storm winds, has come across the Mississippi Sound and has invaded Southeast Louisiana. The Cactus Moth Detection and Monitoring Network (CMDMN) provided cactus population information to aid in an extensive search and eradication effort led by USDA APHIS.

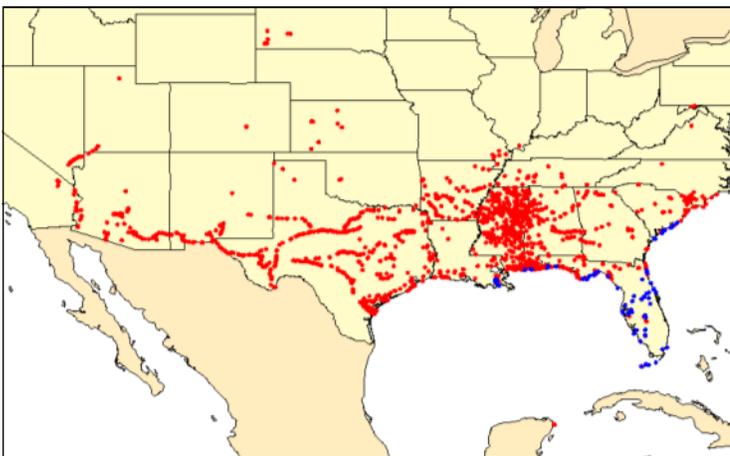


Figure 1. Pricklypear cactus locations (red) and the cactus moth's locations (blue), indicating new locations across the Gulf Coast.

As a result of the on-going fight against the cactus moth, the CMDMN now houses 10,050 pricklypear surveys spanning across the nation and Mexico. Of these, 2,678 cactus populations are identified in 24 states and Mexico. Currently, six U.S. states are positive for the cactus moth. The online maps show the leading edge of the moth infestation along the Gulf Coast is Southeast Louisiana, while the Atlantic Coast edge is holding in the northern part of South Carolina. Seventy-six sentinel sites across the nation are being monitored by volunteers to provide an early detection “network” to detect the moth’s movements into a new area.

The CMDMN is also tracking locations where cacti are known not to be found. These negative locations are used in prediction models that will be used to predict the locations of pricklypear cactus locations. Currently there are 7,372 surveys reporting negative cactus locations.

GRI has been planning software and hardware upgrades to the servers that house the Cactus Moth Detection and Monitoring Network. These upgrades have been plagued with problems with both the software and the hardware throughout the year. Progress in this area was made in the latter part of 2009. Upgrades are planned to be complete in early 2010.

The Cactus Moth Detection and Monitoring Network can be visited at http://www.gri.msstate.edu/cactus_moth. If you would like to help with this effort, volunteer information can be found at the CMDMN website.

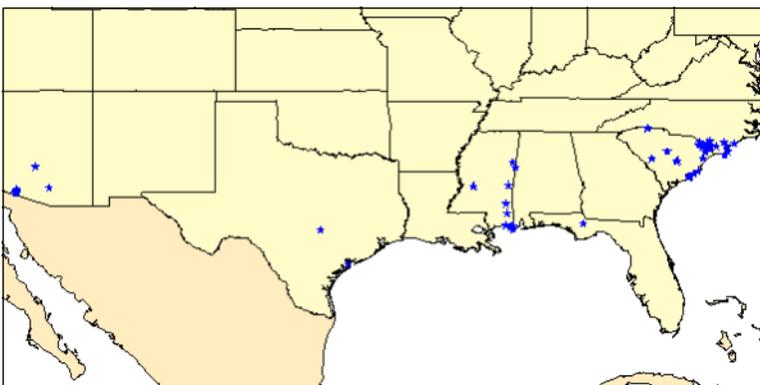


Figure 2. Sentinel plots mapped on the Cactus Moth Detection and Monitoring Network.

Task 4. Invasive Plant Atlas



Figure 1. Japanese honeysuckle (*Lonicera japonica*) is one of the forty species included in the IPAMS training. Photo by Victor Maddox



Figure 2. John Madsen training utility employees and contractors at an IPAMS workshop held with the Mississippi Vegetation Management Association at Lake Tiak O'Khata in November 2009. GRI Photo.

Task 4. Web-based Database of Invasive Plant Species Locations (IPAMS)

PI: John Madsen

Co-PI: Gary Ervin, Clifton Abbott, David Shaw, and John Byrd

Collaborators: Randy Westbrooks, USGS NWRC, Annie Simpson, USGS National Headquarters (NBII), and Les Merhroff, University of Connecticut (IPANE)

An Update to the Invasive Plant Atlas of the MidSouth Project

John D. Madsen and Gary N. Ervin



Figure 1. Cogongrass, *Imperata cylindrica*. Photo by Debbie McBride.

Invasive weedy plants are a widespread problem throughout the United States. Their growth is often widely dispersed, with little scientific ability to predict why they occur in a given location. In addition, historical human activities such as urbanization, agriculture, and forestry have a marked effect on the distribution and spread of invasives. This project will quantify relationships of weed distribution and spread with land use, then use that information directly in educating agriculture stakeholders, natural resources managers, and other interested parties on potential human-induced opportunities for invasive species spread. The Invasive Plant Atlas of the Mid-South (IPAMS) is an integrated research and extension project to develop an invasive plant program for the Mid-South states of Alabama, Arkansas, Louisiana, Mississippi, and Tennessee. Research activities include conducting systematic regional vegetation surveys to assess the distribution of key invasive plants, developing models for predicting the occurrence of target species based on land use and cover, and evaluating the relative effectiveness of professional versus volunteer surveys.

For the research component of this project, we have surveyed over 470 points throughout the state of Mississippi, providing data on more than 800 plant species, including more than 70 not native to the region. Initial analyses of these data have demonstrated a strong correlation of land use/cover with the presence of exotic plant species, especially key invaders such as the grass *Imperata cylindrica* (cogongrass, Figure 1). Outreach and extension activities include developing training programs for volunteers to identify and report invasive species using IPAMS, developing an efficient Early Detection and Rapid Response (EDRR) system for invasive plants, developing best management information, and developing an online mapping system. To date, we have trained numerous individuals in identification of our target forty species. We are in the process of developing management information for these species. Our webpage (www.gri.msstate.edu/ipams) is operational, with over 8700 records of 136 species from 29 states, entered and many more observations completed but not entered into the database.

Introduction

Invasive plants are a global problem battled at the local level, by individual landowners and consumers. The problem is dispersed across the landscape, and largely borne by individual landowners or resource agencies. Government agencies have neither the resources nor personnel to survey the entire landscape and manage all infestations of these problematic species, and the number of species is too large for a simple public awareness campaign.

Our project is aimed at quantifying relationships of weed distribution and spread with land use, and then using that information directly in educating agriculture stakeholders, natural resources managers, informed citizen groups, and other interested parties on potential anthropogenically induced opportunities for invasive species spread.

The long-term goal of the proposed work is the development of a regional invasive species database, similar to that developed for the Invasive Plant Atlas of New England (IPANE). The resulting internet portal, named the Invasive Plant Atlas of the Mid-South (IPAMS – www.gri.msstate.edu/ipams) provides information on the biology, ecology, distribution, and best management practices for forty of the most economically and ecologically significant invasive weeds in the mid-south.

A supporting effort of the IPAMS project is training of lay volunteers to identify species in our list of forty invasive weeds of the Mid-South, and to provide them the resources to report results of their surveys via a centralized web-based database. This will provide location data to federal and state natural resource agencies for rapid action, as well as generating data to develop predictive models to further refine searches, surveys, and rapid response efforts to control invasive weeds in the Mid-South.

Extension and Outreach

We have developed a training manual and a field identification guide, and have trained 70 volunteers in 2009 using these materials (Figure 2). We plan on holding ten workshops in 2010 to train volunteers in each of the five Mid-South states.

In addition, we have trained three hundred volunteers to identify the forty species listed in our training guide through Master Gardener and Extension Service training workshops (Table 1).

We are also developing collaborative training opportunities through the Mississippi Cooperative Weed Management Area partnership, which includes federal and state agencies with the mission of managing invasive plants.



Figure 2. Volunteers receiving IPAMS training at a workshop in Biloxi, MS on Dec. 4, 2009. Photo by John Madsen.

Research

We have conducted systematic regional vegetation surveys to assess the distribution of key invasive plants in agroecosystems, and quantified recent changes in land use and land cover at each survey point based on existing geospatial databases, including the USGS GAP layer. Survey sites were stratified by ecoregion and land use type. Points were randomly selected in each land use type, but within public lands when possible. For instance, points collected in 2006-2008 were distributed across a continuum of increasing deforestation that was the result of hurricanes in 2004-2006. At each point, species presence and cover was collected along with disturbance type, proximity to roads, catastrophic deforestation, forest community type, and soil parameters.

Using these data, we have developed probabilistic models for predicting the occurrence of target species. For instance, the relationship for cogongrass indicated a relationship to proximity to a road, localized disturbance, and percent sand in the soil. Statistically, no relationship was found that landscape scale plant community composition or damage associated with Hurricane Katrina had an effect on the distribution of *Imperata cylindrica*. Strong support was found that disturbance will facilitate invasion by this species regardless of forest community type.

Future work will include comparing the professional stratified-random data collected in research to the volunteer-generated survey data as the basis for predictive plant distribution models.

Table 1. Species selected for extension and outreach training and webpage tracking.

Scientific Name	Common Name(s)	Primary Habitat
<i>Commelina benghalensis</i> L.	Benghal dayflower (tropical spiderwort)	Row Crop
<i>Crotalaria spectabilis</i> Roth	showy rattlebox	Row Crop
<i>Digitaria ciliaris</i> (Retz.) Koel.	Southern Crabgrass	Row Crop
<i>Digitaria sanguinalis</i> (L.) Scop.	Large Crabgrass	Row Crop
<i>Galinsoga quadriradiata</i> Cav.	shaggy-soldier (hairy galinsoga)	Row Crop
<i>Sorghum halepense</i> (L.) Pers.	Johnsongrass	Row Crop
<i>Xanthium spinosum</i> L.	spiny cocklebur	Row Crop
<i>Carduus nutans</i> L.	nodding plumeless thistle (musk thistle)	Pasture
<i>Imperata cylindrica</i> (L.) Beauv.	cogongrass	Pasture
<i>Rosa multiflora</i> Thunb. Ex Murr.	multiflora rose	Pasture
<i>Solanum viarum</i> Dunal	tropical soda apple	Pasture
<i>Sporobolus indicus</i> (L.) R. Br.	smut grass	Pasture
<i>Alliaria petiolata</i> (Bieb.) Cavara & Grande	garlic mustard	Managed Forests
<i>Elaeagnus pungens</i> Thunb.	thorny olive	Managed Forests
<i>Hedera helix</i> L.	English ivy	Managed Forests
<i>Lonicera maackii</i> (Rupr.) Herder	Amur honeysuckle	Managed Forests
<i>Lygodium japonicum</i> (Thunb. ex Murr.) Sw.	Japanese climbing fern	Managed Forests
<i>Mimosa pigra</i> L.	black mimosa	Managed Forests
<i>Nandina domestica</i> Thunb.	sacred bamboo	Managed Forests
<i>Pueraria montana</i> (Lour.) Merr.	kudzu	Managed Forests
<i>Wisteria sinensis</i> (Sims) DC.	Chinese wisteria	Managed Forests
<i>Ailanthus altissima</i> (P. Mill.) Swingle	tree of heaven	Rights of Way
<i>Albizia julibrissin</i> Durazz.	silktree (mimosa)	Rights of Way
<i>Ligustrum japonicum</i> Thunb.	Japanese privet	Rights of Way
<i>Ligustrum sinense</i> Lour.	Chinese privet	Rights of Way
<i>Rottboellia cochinchinensis</i> (Lour.) W.D. Clayton	itchgrass	Rights of Way
<i>Triadica sebifera</i> (L.) Small	Chinese tallowtree	Rights of Way
<i>Arundo donax</i> L.	giant reed	Wildland
<i>Cayratia japonica</i> (Thunb.) Gagnepain	bushkiller	Wildland
<i>Lonicera japonica</i> Thunb.	Japanese honeysuckle	Wildland
<i>Microstegium vimineum</i> (Trin.) A. Camus	Nepalese browntop (stiltgrass)	Wildland
<i>Vitex rotundifolia</i> L. f.	roundleaf chastetree (beach vitex)	Wildland
<i>Alternanthera philoxeroides</i> (Mart.) Griseb.	alligatorweed	Aquatic
<i>Eichhornia crassipes</i> (Mart.) Solms	common water hyacinth	Aquatic
<i>Hydrilla verticillata</i> L.f. Royle	waterhyme (hydrilla)	Aquatic
<i>Myriophyllum aquaticum</i> (Vell.) Verdc.	parrotfeather	Aquatic
<i>Lythrum salicaria</i> L.	purple loosestrife	Aquatic
<i>Myriophyllum spicatum</i> L.	spike watermilfoil (Eurasian watermilfoil)	Aquatic
<i>Rotala rotundifolia</i> (Buch.-Ham. ex Roxb.) Koehne	roundleaf toothcup	Aquatic
<i>Salvinia molesta</i> Mitchell	kariba-weed (giant salvinia)	Aquatic

IPAMS Web Portal

We have developed a web-based database (www.gri.msstate.edu/ipams) for location data entry, similar to that designed by IPANE. Our basic data requirements follow the NAWMA standards (NAWMA 2002) to ensure broad compatibility of the database. The combination of an ArcIMS server to map data provides immediate quality assurance checks on the data entered, and provides up-to-the minute information on the distribution of target invasive plants. The database is being used to generate improved predicted distributions of the forty selected species. Maps of those predictions will be

available as layers to advise volunteers and professionals in their surveys, to target rapid response efforts. Predicted distributions will be based on models developed research section, thus integrating research into the extension and outreach effort.

Our database will be available for data entry to anyone willing to register as a user, providing contact information to clarify observations and track by whom data has been entered. A reward system for new finds or most locations for each year will be developed to encourage participants. Our data will be freely available to others interested in distribution data. We will develop generators in which users can select species of concern and download data in a specified format. Also, we will develop data exchange relationships with the USDA PLANTS database and the appropriate NBII ISIN and SAIN nodes. Lastly, we will contact the appropriate CAPS coordinator in each state if federal or regulated noxious weeds are found, so that the information can be entered into NAPIS.

Our database currently holds 8786 records for 136 species from 29 US states, with a backlog of several thousand records to be entered.

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North American Weed Management Association (NAWMA). 2002. North American Invasive Plant Mapping Standards. Granby, CO. May 2002. 34pp.

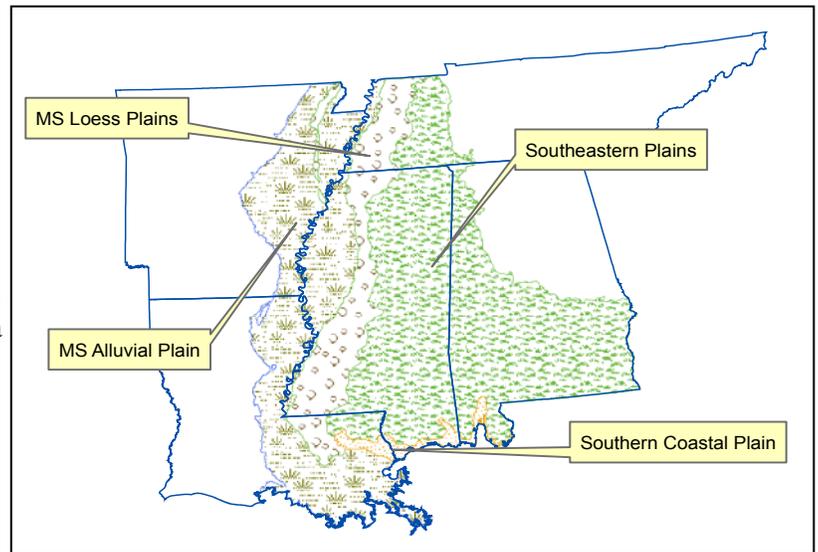


Figure 3. Target geographic region for the Invasive Plant Atlas of the Mid-South (IPAMS). Shaded portions indicate initial focus of habitat modeling efforts.

Task 5. Regional Coordination



Figure 1. *Cactoblastis* workgroup at USDA-ARS Crop Protection and Management Research Laboratory, Tifton, GA, August 2009. From left: Christopher Brooks, Travis Marsico, Gary Ervin, James Carpenter, Guillermo Logarzo, Stephen Hight, Laura Varone.

Figure 2. Boat Survey for cactus moth and hosts in southern Louisiana with USDA-APHIS representatives from LA, FL, and TX. MSU-GRI participated in this survey to collect host and pest data for the Cactus Moth Detection and Monitoring Network (Image by Victor Maddox, MSU-GRI).



Task 5. Coordination

PI: David Shaw

Co-PI: John Madsen

Coordination Tasks During 2009

Richard Brown and Thomas Simonsen, systematist at the Natural History Museum in London, have been collaborating during the past year on developing a web site for the cactus moth and all cactus feeding relatives. Dr. Simonsen worked with Dr. Brown at Mississippi State University during December 6-10 to complete the web site.

Richard Brown and Sangmi Lee, Research Associate in the Mississippi Entomological Museum, collaborated on a comparative study of antennal sensilla of the cactus moth and the native *Melitara prodentialis* using the scanning electron microscope.

Gary Ervin and Travis Marsico were invited to visit the USDA Agricultural Research Service's Crop Protection and Management Research Laboratory in Tifton, GA to participate in research collaborations related to the South American cactus moth research program (Figure 4). Also in attendance were Christopher Brooks (MSU Biological Sciences), James Carpenter (USDA ARS, Tifton) and Stephen Hight (USDA ARS, Tallahassee, FL), and Guillermo Logarzo and Laura Varone (USDA ARS South American Biological Control Research Laboratory in Buenos Aires, Argentina).

The goal of these collaborations is the design of studies to examine the degree and mechanism of isolation among Argentinean *Cactoblastis cactorum* genotypes identified through ongoing genetic research at MSU.



Figure 1. Cactus moth was identified and removed on eradication trips to Mississippi's Horn and Petit Bois Islands. Partial Horn Island survey team pictured while visually surveying for cactus moth. Pictured are Randal St. Louis (front) (USDA-APHIS), Maurice Duffel (middle) (USDA-APHIS), and Victor Maddox (back) (MSU-GRI) (Image by Kimberly Sargent, USDA-APHIS, Pensacola, FL).



Figure 2. Technical Working Group inspecting *Opuntia engelmannii* Salm-Dyck ex Engelm. for cactus moth in southern Louisiana during a meeting in New Orleans to discuss potential USDA cactus moth strategic plans. MSU-GRI was one of several groups that participated at the meeting. Two of the three survey boats are pictured (Image by Victor Maddox, MSU-GRI).

Travis Marsico, a post-doctoral scientist supported on this research, has recently begun a tenure-track faculty position at the University of Arkansas at Jonesboro. We plan continued collaborations with him and will be submitting a grant proposal to the National Science Foundation in January 2010 as part of these joint efforts.

Victor Maddox made five survey trips with USDA-APHIS in Mississippi and Louisiana in 2009. USDA-APHIS is currently negotiating a contract with MSU for Victor to perform additional surveys in Louisiana and Texas. During the week of November 16th, USDA-APHIS, USDA-ARS, and MSU-GRI conducted a cactus moth visual survey on Horn and Petit Bois Islands off the coast of Mississippi (Figure 1). Cactus moth was found on both islands, but the infestation did not appear to be heavy and most of the host populations were free of cactus moth. Another visual survey of the islands will be conducted in early 2010.

Victor Maddox as invited to participate in the Cactus Moth Technical Working Group Meeting hosted by USDA, 1-3 Dec 2009, in New Orleans, LA. During the first week of December, USDA hosted a Cactus Moth Technical Working Group (TWG) meeting in New Orleans, Louisiana to address



Figure 3. John Madsen sampling post-treatment biomass on the Noxon Reservoir, Montana, in September 2009. Photo by Celestine Duncan.

issues regarding the recent discovery of cactus moth in southern Louisiana and potential future strategies. The meeting was by invitation only, and attendees participating represented Barataria Terrebonne National Estuary Program, MSU-GRI, National Park Service (Arizona), SAGARPA (Mexico), Southeastern Louisiana University, Texas A&M University, The Nature Conservancy, USDA-APHIS, USDA-ARS, and USDA-PPQ. The first day included an on-site inspection of the infested area in the Louisiana marsh (Figure 2). The remainder of the meeting was a facilitated, roundtable meeting, where after two intense days of discussion the group generated 5 strategic plans. Each plan represented a different level of activity intensity and addressed the positive and negative sides of each plan. These plans will be utilized by USDA for near-future decision-making in regard to cactus moth.

John Madsen participated in the National Biological Information Infrastructure conference on content, the first such conference since 2005. The Conference was held 3-5 February 2009 in Baltimore, MD.

John Madsen attended the 10th National Invasive Weeds Awareness Week (NIWAW 10), February 22-27, 2009, in Washington, DC, and presented a poster on the MSU/USGS/NBII collaboration.

John Madsen represented the Weed Science Society of America on the National Invasive Species Awareness Week organizing committee. The first NISAW meeting was held January 11-14 2010, but the organizing committee met monthly by teleconference from February 2009 to January 2010.

John Madsen, Victor Maddox, and Richard Brown cooperated with the Mississippi Department of Agriculture on invasive species issues as part of the Cooperative Agricultural Pest Survey, a program of USDA APHIS.

John Madsen, Victor Maddox, and Gary Ervin have participated in the new Mississippi Cooperative Weed Management Area program. Victor has been selected to be the new coordinator, on a part-time contract with MSU GRI.

John Madsen, Ryan Wersal and Michael Cox have been working with the Pearl River Valley Water Supply District to monitor invasive plants and assess management on the Ross Barnett Reservoir near Jackson, MS.

John Madsen and Ryan Wersal worked with Kurt Getsinger of the US Army Engineer Research and Development Center on a demonstration project to control Eurasian watermilfoil in the Noxon Reservoir, Montana (Figure 3).

John Madsen and Ryan Wersal participated with Angela Poovey of the US Army Engineer Research and Development Center on a ring test for macrophyte aquatic toxicology, under the Aquatic Macrophyte Ecotoxicology Group of the Society for Environmental Toxicology and Chemistry (SETAC).



Figure 4. Laura Varone (left) and Guillermo Logarzo (right), both of USDA ARS, Buenos Aires, checking out Mississippi pitcher plants (*Sarracenia alata*) at Sandhill Crane NWR.

Accomplishments

Book or Book Chapter

Wersal, R. M., & Getsinger, K. D. 2009. Chapter 3: Impact of Invasive Aquatic Plants on Waterfowl pp. 19-23. In: Biology and control of aquatic plants: A best management practices handbook. (Gettys, L.A., W.T. Haller, and M. Bellaud, eds.). Aquatic Ecosystem Restoration Foundation, Marietta, GA. 210.

Madsen, J. D. 2009. Chapter 1: Impacts of invasive aquatic plants on aquatic biology, pp. 1-8. In: Biology and control of aquatic plants: A best management practices handbook. (Gettys, L.A., W.T. Haller, and M. Bellaud, eds.). Marietta, GA: Aquatic Ecosystem Restoration Foundation.. 210.

Madsen, J. D. 2009. Chapter 13.2: Eurasian watermilfoil, pp. 95-98. In: Biology and control of aquatic plants: A best management practices handbook. (Gettys, L.A., W.T. Haller, and M. Bellaud, eds.). Marietta, GA: Aquatic Ecosystem Restoration Foundation.. 210.

Madsen, J. D. 2009. Appendix D: Developing a lake management plan, pp. 167-172. In: Biology and control of aquatic plants: A best management practices handbook. (Gettys, L.A., W.T. Haller, and M. Bellaud, eds.). Marietta, GA: Aquatic Ecosystem Restoration Foundation.. 210.

Peer-Reviewed Journals

Holly, D. C., Ervin, G. N., Jackson, C. R., Diehl, S. V., & Kirker, G. T. 2009. Effect of an invasive grass on ambient rates of decomposition and microbial community structure: A search for causality. *Biological Invasions*. DOI: 10.1007/s10530-008-9364-5. 11(1855), 1868.

Simpson, A., Jarnevich, C., Madsen, J. D., Westbrooks, R., Fournier, C., Mehrhoff, L., Browne, M., Graham, J., & Sellers, E. 2009. Invasive species information networks: collaboration at multiple levels for prevention, early detection, and rapid response to invasive alien species. *Biodiversity*. 10(2), 5-13.

Ervin, G. N. 2009. Distribution, habitat characteristics, and new county-level records of *Baccharis halimifolia* L. on a portion of its present US range boundary. *Southeastern Naturalist*. 8, 293–304.

Ervin, G. N. 2009. Using GAP data in invasive plant ecology and management. *US Geological Survey Gap Analysis Bulletin*. 16, 34-41.

Dibble, E. D., & Kovalenko, K. 2009. Ecological Impact of Grass Carp: A Review of the Available Data. *Journal of Aquatic Plant Management*. 47, 1-15.

Wersal, R. M., & Madsen, J. D. 2009. Combinations of diquat and a methylated seed oil surfactant for control of common duckweed and watermeal. *Journal of Aquatic Plant Management*. 47(1), 59-62.

Presentations

Maddox, V. L., Abbott, C. F., Byrd, J., & Thompson, D. 2009. State Department of Transportation Vegetation Inventory Protocol Project. 12th AASHTO-TRB Maintenance Management Conference. Loews Annapolis Hotel, Annapolis, MD.

Cheshier, J., Madsen, J. D., & Kaminski, R. M. 2009. Selective Herbicides for Managing Moist-Soil Wetlands in the Mississippi Alluvial Valley. 5th North American Duck Symposium. Toronto, Ontario, Canada.

Madsen, J. D., Wersal, R. M., & Woolf, T. E. 2009. Eurasian Watermilfoil Monitoring and Management Assessment in the Pend Oreille Lake and River System, Idaho. Western Aquatic Plant Management Society Annual Meeting. Honolulu, HI: 30 March - 1 April 2009.

- Madsen, J. D., & Wersal, R. M.** 2009. Efficacy of Combinations of Endothall with 2,4-D and Triclopyr For Enhanced Control of Eurasian Watermilfoil with Low Contact Time. Western Aquatic Plant Management Society Annual Meeting. Honolulu, HI: 30 March - 1 April 2009.
- Madsen, J. D., Wersal, R. M., & Getsinger, K.** 2009. Efficacy of combinations of endothall with 2,4-D and triclopyr for enhanced control of Eurasian watermilfoil with low contact time. Midwest Aquatic Plant Management Society 29th Annual Meeting, March 1-4, 2009. Chicago, IL.
- Madsen, J. D., & Ervin, G. N.** 2009. The Invasive Plant Atlas of the Mid-South. Weed Science Society of America 2009 Annual Meeting. Orlando, FL.
- Madsen, J. D., Wersal, R. M., & Getsinger, K.** 2009. Efficacy of Combinations of Endothall with 2,4-D and Triclopyr For Enhanced Control of Eurasian Watermilfoil with Low Contact Time. Northeast Aquatic Plant Management Society 10th Annual Meeting, January 19-21, 2009. Saratoga Springs, NY.
- Madsen, J. D., Wersal, R. M., & Tagert, M. L.** 2009. Littoral Zone Survey of the Ross Barnett Reservoir (MS) for Invasive Species Management. Souther Division of the American Fisheries Society Spring Meeting, 15-18 January 2009. New Orleans, LA.
- Madsen, J. D.** 2009. Aquatic weed control in the MidSouth. Mississippi Vegetation Management Association. Lake Tiak O'Khata, MS, Novmeber 12-13, 2009.
- Madsen, J. D.** 2009. Identification and management of milfoils (*Myriophyllum*). Southeast Herbicide Applicators Conference. Panama City Beach, FL.
- Maddox, V. L., Abbott, C. F., Madsen, J. D., & Westbrook, R.** 2009. New Developments with the Cactus Moth (*Cactoblastis cactorum* Berg.) Detection and Monitoring Network Efforts. 36th Natural Areas Conference. Vancouver, WA.
- Wersal, R. M., & Madsen, J. D.** 2009. Combinations of penoxsulam and diquat as foliar applications for control of waterhyacinth and common salvinia: Evidence of herbicide antagonism. 28th Annual Meeting of the MidSouth Aquatic Plant Management Society. Guntersville, AL.
- Wersal, R. M., & Madsen, J. D.** 2009. Growth of parrotfeather (*Myriophyllum aquaticum* Vell. Verc.) as regulated by water depth. 28th Annual Meeting of the MidSouth Aquatic Plant management Society. Guntersville, AL.
- Madsen, J. D., & Ervin, G. N.** 2009. The Invasive Plant Atlas of the MidSouth. MidSouth Aquatic Plant Management Society Annual Meeting. Guntersville, AL.
- Madsen, J. D., Wersal, R. M., & Getsinger, K. D.** 2009. Combinations of endothall with 2,4-D and triclopyr for enhanced control of Eurasian watermilfoil with short contact times. MidSouth Aquatic Plant Management Society Annual Meeting. Guntersville, AL.
- Prince, J. M., Madsen, J. D., Shaw, D. R., Brooks, C. P., & Martin, J.** 2009. Modeling Eurasian Watermilfoil (*Myriophyllum spicatum*) with Geographic Information Systems. Midsouth Aquatic Plant Management Society Conference. Lake Guntersville State Park, AL.
- Madsen, J. D.** 2009. Major Aquatic Weed Problems in the MidSouth: Identification and Specific Recommendations for Management. MidSouth Aquatic Plant Management Society Annual Meeting. Guntersville, AL.
- Cheshier, J., & Madsen, J. D.** 2009. The Use of Aquatic Herbicides to Control Common Reed: *Phragmites australis* (Cav.) Trin. Ex. Steud. Midsouth Aquatic Plant Management Sociey, 27th Annual Meeting. Guntersville, AL.
- Cox, M. C., Wersal, R. M., & Madsen, J. D.** 2009. Distribution and Management of Invasive Plant Species in the Ross Barnett Reservoir. Mid-South Aquatic Plant Management Society Annual Meeting. Guntersville, AL.

Wersal, R. M., & Madsen, J. D. 2009. Effects of Water Depth on the Growth of Parrotfeather (*Myriophyllum aquaticum* Vell. Verc.). 49th Annual Meeting of the Aquatic Plant Management Society. Milwaukee, WI.

Cheshier, J., & Madsen, J. D. 2009. The Use of Aquatic Herbicides to Control Common Reed: *Phragmites australis* (Cav.) Trin. Ex. Steud. Aquatic Plant Management Society 49th Annual Meeting. Milwaukee, WI.

Madsen, J. D., Wersal, R. M., & Getsinger, K. D. 2009. Efficacy of combinations of endothall with 2,4-D and triclopyr for enhanced control of Eurasian watermilfoil with low contact time. Aquatic Plant Management Society Annual Meeting. Milwaukee, WI.

Madsen, J. D., & Ervin, G. N. 2009. Update on the Invasive Plant Atlas of the MidSouth. Mississippi Exotic Pest Plant Council. Jackson, MS.

Cannon, J. B., & Ervin, G. N. 2009. Soil texture effects on *Opuntia pusilla* morphology. Mississippi State University Undergraduate Research Symposium. Mississippi State University.

Wersal, R. M., & Madsen, J. D. 2009. Comparison of Subsurface and Foliar Herbicide Applications for Control of Parrotfeather (*Myriophyllum aquaticum*). Weed Science Society of America 49th Annual Meeting. Orlando, FL.

Madsen, J. D. 2009. Introduction to the Symposium: Invasive Plant Web-Accessible Databases and Volunteer Monitoring Programs. Weed Science Society of America 2009 Annual Meeting. Orlando, FL.

Prince, J. M., Shaw, D. R., Madsen, J. D., Harvill, J. L., Ervin, G. N., Samson, S., & Martin, J. 2009. Local-scale GIS Modeling of Eurasian Watermilfoil. Proceedings Southern Weed Science Society /Weed Science Society of America Abstracts. Orlando, FL.

Cheshier, J., & Madsen, J. D. 2009. Flowering Rush (*Butomus umbellatus* L.): a New Invader to the Northwest. Aquatic Plant Management Society 49th Annual Meeting. Milwaukee, WI.

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Lucardi, R. D., Wallace, L., & Ervin, G. N. 2009. Genetic diversity of cogongrass (*Imperata cylindrica*) populations and the genus *Imperata* in the Southern United States: Impacts on invasion dynamics and evolutionary potential. Southeastern Ecology and Evolution Conference. Gainesville, FL.

Cheshier, J., & Madsen, J. D. 2009. Common Reed: *Phragmites australis* Cav. Trin. Ex Steud: Life History in the Mobile River Delta, Alabama. Weed Science Society of America. Orlando, FL.

In-House

Madsen, J. D., & Maddox, V. L. 2009. Invasive Plant Atlas of the MidSouth Training Workshop Manual. Mississippi State University: Geosystems Research Institute.

Madsen, J. D., Maddox, V. L., Ervin, G. N., Byrd, J. D., McBride, D. W., Madsen, N., & Stroud, B. 2009. Invasive Species Field Identification Guide. Mississippi State University: Geosystems Research Institute. 82.

Madsen, J. D., & Robles, W. 2009. Waterhyacinth [*Eichhornia crassipes* (Mart.) Solms]. Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.

Madsen, J. D. 2009. Alligatorweed [*Alternanthera philoxeroides* (Mart.) Griseb.]. Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.

Maddox, V. L., Randy,, Westbrooks, & John,, D. Byrd Jr. 2009. Amur honeysuckle [*Lonicera maackii* (Rupr.) Herder]. Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.

- Maddox, V. L., Westbrook, R., Byrd, J.D., & Brabson, Betsy.** 2009. Beach Vitex (*Vitex rotundifolia* L.f.). Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.
- Maddox, V. L., Westbrook, R., & Byrd, J.D.** 2009. Benghal Dayflower [*Commelina benghalensis* (L.) Small]. Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.
- Maddox, V. L., Westbrook, R., & Byrd, J. D.** 2009. Catclaw Mimosa (*Mimosa pigra* L., Syn. *Mimosa pellita* Kunch ex Willd.). Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute.
- Maddox, V. L., Byrd, J. D., & Westbrook, R.** 2009. Bushkiller [*Cayratia japonica* (Thunb.) Gagnepain]. Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute.
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- Maddox, V. L., Bryson, C. T., & Byrd, J. D.** 2009. Cogongrass [*Imperata cylindrica* (L.) Beauv.]. Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.
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- Madsen, J. D.** 2009. Eurasian watermilfoil (*Myriophyllum spicatum* L.). Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.
- Madsen, J. D., & Wersal, R. M.** 2009. Giant Salvinia, Kariba-weed (*Salvinia molesta* Marshall). Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.
- Madsen, J. D., & Robles, W.** 2009. Hydrilla [*Hydrilla verticillata* (L.F.) Royle]. Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.
- Maddox, V. L., Westbrook, R., & Byrd, J. D.** 2009. Itchgrass [*Rottboellia cochinchinensis* (Lour.) W.D. Clayton]. Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.
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- Byrd, J. D., Maddox, V. L., & Westbrook, R.** 2009. Kudzu [*Pueraria montana* (Lour.) Merr.]. Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.
- Maddox, V. L., Westbrook, R., & Byrd, J. D.** 2009. Multiflora Rose (*Rosa multiflora* Thunb. ex Murr.). Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.
- Madsen, J. D., & Wersal, R. M.** 2009. Parrotfeather [*Myriophyllum aquaticum* (Vellozo) Verdecourt]. Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.
- Madsen, J. D., & Wersal, R. M.** 2009. Purple Loosestrife (*Lythrum salicaria* L.). Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.
- Ervin, G. N., & Madsen, J. D.** 2009. Roundleaf toothcup [*Rotala rotundifolia* (Roxb.) Koehne]. Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.

Maddox, V. L., Byrd, J. D., & Westbrooks, R. 2009. Sacred Bamboo (*Nandina domestica* Thunb.). Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.

Maddox, V. L., Westbrooks, R., & Byrd, J. D. 2009. Showy Rattlebox (*Crotalaria spectabilis*, Roth). Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.

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Maddox, V. L., Westbrooks, R., & Byrd, J. D. 2009. Thorny olive (*Elaeagnus pungens* Thunb.). Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.

Bryson, C. T., Byrd, J. D., Westbrooks, R., & Maddox, V. L. 2009. Tropical Soda Apple (*Solanum viarum* Dunal). Invasive Plant Atlas of the MidSouth Fact Sheet. Mississippi State University: Geosystems Research Institute. 2.

Maddox, V. L., Abbott, C. F., Byrd, J., Thompson, D. G., & Harper-Lore, B. L. 2009. State Department of Transportation Inventory Protocol Project - Training Manual. Mississippi State University: Geosystems Research Institute.

Madsen, J. D., Cheshier, J., Phuntumart, V., Thum, R., & Welch, M. 2009. Eurasian Watermilfoil Survey Of Three Reservoirs In The Lower Clarks Fork River, Montana: II. Taxonomic Analysis Of Native And Nonnative Watermilfoils. Geosystems Research Institute Report 5035. Mississippi State University: Geosystems Research Institute.

Madsen, J. D., & Cheshier, J. 2009. Eurasian Watermilfoil Survey of Three Reservoirs in the Lower Clarks Fork River, Montana: I. Results of the Field Vegetation Survey. GRI Report #5033. Mississippi State University: Geosystems Research Institute.

Madsen, J. D., Brown, R., Ervin, G. N., Shaw, D. R., Abbott, C. F., Maddox, V. L., Wersal, R. M., McBride, D. W., & Madsen, N. 2009. Research to Support Integrated Management Systems of Aquatic and Terrestrial Invasive Species: Annual Report 2008. GRI Report #5030. Mississippi State University: Geosystems Research Institute.

Maddox, V. L., & Kelly, L. S. 2009. Ornamental grasses for the Midsouth landscape. www.msucares.com. Mississippi State, MS; Mississippi State University: Mississippi State University Extension Service, Mississippi State University. P2532.

Madsen, J. D., & Wersal, R. M. 2009. Aquatic Plant Community and Eurasian watermilfoil (*Myriophyllum spicatum* L.) Management Assessment in Lake Pend Oreille, Idaho for 2008. GRI Report #5032. Mississippi State University: Geosystems Research Institute.

Wersal, R. M., Madsen, J. D., & Tagert, M. L. 2009. Littoral Zone Aquatic Plant Community Assessment of the Ross Barnett Reservoir, MS in 2008: A Four Year Evaluation. GRI Report #5031. Mississippi State University: Geosystems Research Institute.

Byrd, J. D., Jr., Maddox, V. L., & Westbrooks, R. 2009. Kudzu [*Pueraria montana* (Lour.) Merr.]. www.gri.msstate.edu. Mississippi State, MS; Mississippi State University: Geosystems Research Institute. NSL

Professional Presentations

Maddox, V. L. 2009. Identifying the IPAMS species, part 1. Invasive Plant Atlas of the MidSouth - Volunteer Workshop, University of Southern Mississippi, Long Beach, MS.

Maddox, V. L. 2009. Identifying the IPAMS species, part 2. Invasive Plant Atlas of the MidSouth - Volunteer Workshop, University of Southern Mississippi, Long Beach, MS.

Madsen, J. D., & Maddox, V. L. 2009. Invasive Plant Atlas of the MidSouth Volunteer Training Workshop. University of Southern Mississippi Gulf Coast, Biloxi, MS.

- Maddox, V. L.** 2009. Host distribution. Cactus Moth Technical Working Group Meeting, Maison Dupuy, New Orleans, LA.
- Maddox, V. L., Abbott, C. F., Byrd, J. D., & Thompson, D.** 2009. Invasive species on the right of way: Vegetation inventory protocol project. Mississippi Vegetation Management Association Meeting, Lake Tiak-O'Khata, Louisville, MS.
- Maddox, V. L.** 2009. Invasive plant species training. Mississippi Vegetation Management Association, Lake Tiak-O'Khata, Louisville, MS.
- Maddox, V. L.** 2009. CWMA: Pulling together for Mississippi and beyond,. Mississippi Cooperative Weed Management Area Meeting, Lake Tiak-O'Khata, Louisville, MS.
- Madsen, J. D., & Maddox, V. L.** 2009. Invasive Plant Atlas of the MidSouth Volunteer Training Workshop. Mississippi Vegetation Management Association. Lake Tiak O'Khata, MS.
- Madsen, J. D.** 2009. How the CWMA can develop an aquatic plant program. Mississippi Cooperative Weed Management Area Annual Meeting. Louisville, MS..
- Maddox, V. L.** 2009. Invasive weeds on the radar. Bureau of Plant Industry Inspector Training, Mississippi Agricultural and Forestry Museum, Jackson, MS.
- Maddox, V. L., Abbott, C. F., Byrd, J. D., & Thompson, D.** 2009. IPAMS Invasive Plant Species Training Workshop. High Performance Computing Collaboratory, Mississippi State University, Starkville, MS.
- Ervin, G. N., Marsico, T. D., & Brooks, C. P.** 2009. Reassessing expectations for *Cactoblastis cactorum* (Berg) spread in North America. Research Collaboration Workshop. USDA ARS Crop Protection and Management Research Laboratory, Tifton, GA.
- Marsico, T. D., & Ervin, G. N.** 2009. Chew 'em up and spit 'em out: Prickly pear defenses elicited from native but not invasive moths. Research Collaboration Workshop. USDA ARS Crop Protection and Management Research Laboratory, Tifton, GA.
- Madsen, J. D., Brown, R. L., Ervin, G. N., Maddox, V. L., & Abbott, C. F.** 2009. Update on the GRI Cactus Moth Detection Network. Invasive Species Working Group. Teleconference: National Biological Information Infrastructure, Invasive Species Information Node.
- Madsen, J. D.** 2009. Evaluating Environmental Impacts of Aquatic Plant Management Techniques: Examining Direct and Indirect Effects. Aquatic Vegetation Control; Balancing Habitat and Nuisance. Elkhart, IN: St. Joseph River Basin Commission and Aquatic Ecosystem Restoration Foundation.
- Madsen, J. D., Wersal, R. M., & Tagert, M. L.** 2009. Survey of the Ross Barnett Reservoir (MS) for Invasive Species Management. Pearl River Valley Water Supply District Board of Directors Meeting. Jackson, MS.
- Maddox, V. L.** 2009. Invasive Species Identification and Management. Agriculture Club Meeting, Oktibbeha County Extension Office, Starkville, MS.
- Wersal, R. M.** 2009. An Overview of Invasion Ecology. Lecture for Weed Biology and Ecology PSS 4633/6633.
- Fleming, J. P.** 2009. Aquatic Biodiversity and Invasive Species. 2009 Alabama State Envirothon. 4H Center, Columbiana, AL.
- Maddox, V. L.** 2009. Invasive species information and plant identification. 2009 Hattiesburg Garden and Patio Show, 27-29 Mar 2009, Hattiesburg Convention Center, Hattiesburg, MS.

Maddox, V. L. 2009. Invasive Plant Species. Master Gardener Training, 26 March 2009, Bost Extension Center (videoconference), Mississippi State University, Mississippi State, MS. Presentation (2 hrs).

Maddox, V. L. 2009. Plant identification and invasive species information. 12th Annual Jackson Garden and Patio Show, 13-15 Mar 2009, Mississippi Trade Mart, Jackson, MS.

Wersal, R. M., & Madsen, J. D. 2009. GIS in Aquatic Plant Management. Applications of Spatial Technology in Wildlife and Fisheries Management (WF 4253/6253), Mississippi State University.

Maddox, V. L. 2009. IPAMS – Invasive plant species. Weed Biology and Ecology, 10 Mar 2009, 152 Dorman Hall, Mississippi State University, MS.

Maddox, V. L. 2009. Identification of invasive and other plant species. 2009 Gulf Coast Garden and Patio Show, 27-28 Feb – 1 Mar 2009, Mississippi Coast Coliseum, Biloxi, MS.

Maddox, V. L. 2009. Invasive Plant Species Problematic to Golf Courses and the IPAMS Database. Turf Seminar, 128 Dorman Hall, Mississippi State University, MS.

Madsen, J. D. 2009. Aquatic Weed Control in the Mid-South. Weed Science Current Topics, PSS 8711, Mississippi State University, Invited Speaker.

Awards and Recognitions

Cox, M. C. 2009. MidSouth Aquatic Plant Management Society Graduate Student Scholarship. Mid-South Aquatic Plant Management Society Annual Meeting. Guntersville, AL. October 2009.

Cheshier, J. 2009. Awarded 2nd Place in the Student Paper Contest. Aquatic Plant Management Society 49th Annual Meeting. Milwaukee, WI.

Ervin, G. N. 2009. Doug Wilcox Award for Outstanding Associate Editor for the journal Wetlands. Society of Wetland Scientists International Conference, Madison, WI.

Ervin, G. N. 2009. College of Arts & Sciences Faculty Research Award. Mississippi State University.

Collaborating Partners

