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

Annual Report 2010

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

MISSISSIPPI STATE UNIVERSITY

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nbii

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 08HQAG0139 and G10AC00404, a Gulf Coast Cooperative Ecosystem Studies Unit Cooperative and Joint Venture Agreement. The MSU program was managed by the Geosystems Research Institute. The USGS BRD Invasive Species Program manager was Sharon Gross and NBII Invasive Species Information Node manager was Annie Simpson.

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For comments or questions, contact Dr. John D. Madsen at jmadsen@gri.msstate.edu.

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Introduction

Figure 1. Casey Olson, undergraduate student at Concordia College in Moorhead, MN, drills through the ice to sample for the invasive plant flowering rush on the Detroit Lakes in December 2010. Photo by Joshua Cheshier.

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 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 six years and garnered significant attention as the one source for pricklypear cactus and cactus moth location information nationwide. The Invasive Plant Atlas of the Mid-South (IPAMS), a national database with a regional focus, is 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. For 2010, we have also added program elements that are more oriented to biodiversity and visualization.

Figure 2. GRI's John Madsen (left) with Dr. David Spencer (right) of USDA ARS in Davis, CA; examining a stalk of phragmites as part of a joint experimental study on the growth patterns of this invasive plant.

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

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Kurt D. Getsinger, *US Army Engineer Research and Development Center*
Sharon Gross, *USGS BRD, Invasive Species Program*
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Travis Marsico, *Arkansas State University*
Les Mehrhoff, *IPANE*
Thomas Naberhaus, *Big Sky Institute*
Michael Netherland, *US Army Engineer Research and Development Center*
John Pickering, *Discover Life and University of Georgia*
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Ron Weeks, *USDA APHIS PPQ*
Randy Westbrooks, *USGS National Wetlands Research Center*
Tom Woolf, *Idaho State Department of Agriculture*

Task 1. Aquatic Plants

South American spongeplant (*Limnobium laevigatum*) is a new invasive aquatic to the Sacramento River delta of California. With the assistance of Pat Akers, California Department of Food and Agriculture, GRI placed the points of infestation on the USGS NAS database and added a fact sheet to that system for this new species. Photo by Pat Akers.

Yellow flag iris (*Iris pseudacoris)* is a widespread invasive plant along the shorelines of rivers and lakes in the northwestern part of the U.S. This photo was taken along the shore of Pend Oreille Lake, but GRI has mapped the presence of this species in Washington, Montana, and Idaho. Photo by John Madsen.

Task 1.1. GIS Model of Invasive Aquatic Plant Distribution and Abundance Based on Watershed Nutrient Loading Rates

PI: John Madsen
Collaborators: Randy Westbrooks, USGS

GIS Model of Invasive Aquatic Plant Distribution and Abundance
Based on Watershed Nutrient Loading Rates
Louis Wasson

Mapping the spatial distribution of nutrient gradients based on a water quality stream gage dataset resulted in a nutrient surface across much of Mississippi for nitrates and phosphorous. The primary focus in this initial step was to locate sources of water quality data that can be used in the project. Next steps are developing a Workflow that will result in an Invasive Species Suitability Model (Figure. 1). The following bullets illustrate the workflow being used in the project.

- Prepare the data for analysis by building a project database and getting the data ready for analysis.
- Next, analyze the data. Specifically, use geoprocessing to model potential habitat. This will involve multiple stages of refinement.
- Finally, document work with metadata and helpful instructions.

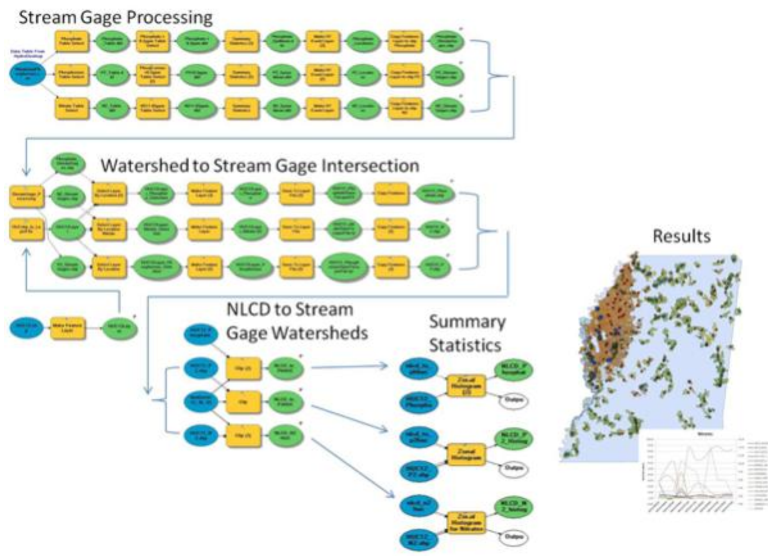


Figure 1. GIS Model of invasive aquatic plant distribution and abundance based on Watershed Nutrient Loading Rates

The following datasets are used in the project database and more will be added as the model is refined. Geostatisics will be conducted in the model on the spatial datasets to understand the relative relationships in the environment that lead to suitable habitat for aquatic invasives.

Dataset	Purpose
Water quality stream gages	Used to determine stream nutrient concentrations
National Hydrography Dataset (NHD)	Geographic dataset of all surface water in study region
National Land Cover Dataset (NLCD)	Understand land use around surface waters

Shapefiles from the initial map are five year water quality stream gage means for nitrate and phosphorous. The nutrient gradient raster surface was generated from these two shapefiles.

Shapefiles
Nitrate_5yr_site_means.shp
Phosphorous_5yr_site_means.shp

Generated rasters
N_5yr_idw (Inverse Distance Weighted gradient surface raster for nitrates)
P_5yr_idw (Inverse Distance Weighted gradient surface raster for phosphorous)

As the geodatabase is developed and populated with data the suitability model will be refined by incorporating these new datasets and analytical processes. The suitability maps produced by the model will be analyzed for patterns and ground truthed by field teams to check the accuracy of the model.

Task 1.2. Nonindigenous Aquatic Plant Database Plant Observation Entry

PI: John Madsen
Collaborator: Pam Fuller, USGS Caribbean Science Center

Using Bioinformatics and Online Spatial Technologies to Track and Monitor the Spread of Invasive Aquatic Plants

Ryan M. Wersal

In March 2010, the Geosystems Research Institute (GRI) received training and began coordinating the entry of invasive aquatic plant data into the USGS Non-indigenous Aquatic Species (NAS) database http://nas.er.usgs.gov. The GRI is responsible for adding new aquatic plant location records, sending aquatic plant alerts through the NAS Alert System, creating factsheets for aquatic plant species, updating and adding aquatic plant photos to the database, adding and maintaining plant references in the NAS reference database, and answering questions regarding aquatic plants that the NAS program receives.

Figure 1. A cove on Columbus Lake, MS, which is part of the Tennessee Tombigbee Waterway that is covered with waterhyacinth. Photo by Wilfredo Robles.

To date, the GRI has entered 312 species locations from a variety of sources. A total of 95 entries were from literature sources such as journal articles or agency reports, 100 entries from plant database sources, 33 entries from personal communications such as emails, and 84 entries from internet website sources. The 312 species entries also resulted in 21 national species alerts comprising 9 different invasive aquatic plant species. Species alerts were generated within the NAS system and emailed to over 100 individuals nationwide. Also, 19 emails with questions regarding aquatic plant locations or identifications specific to the NAS database were answered since the GRI has been coordinating the aquatic plant information.

Figure 2. The same cove one year later after Cuban bulrush had taken over waterhyacinth. Photo by Wilfredo Robles.

Pursuant to the data entry and tracking of invasive aquatic plants, Cuban bulrush or Cuban club-rush [*Oxycaryum cubense* (Poepp. & Kunth) Palla] was added to the NAS database as a new species of concern in 2010. There are currently five specimen records in the database from Mississippi, Alabama, and Louisiana, though a new population was recently observed in the Ross Barnett Reservoir, MS. Cuban bulrush is overtaking waterhyacinth in many locations in Columbus Lake, MS (Figures 1 and 2). Given the areas that Cuban bulrush now inhabits, its epiphytic growth habit, floating propagules, and rapid growth it has the potential to be a widespread nuisance throughout the southeastern United States.

Task 1.2. Nonindigenous Aquatic Plant Database Plant Observation Entry (Cont.)

Another invasive aquatic plant that we are now tracking closely is the South American sponge plant [*Limnobium laevigatum*) (Humb. & Bonpl. ex Willd.) Heine] (Photo 3). The plant is a floating aquatic plant that can be easily confused with the native plant frogsbit (*Limnobium spongia*). South American sponge was first found in the San Joaquin River by the California Department of Food and Agriculture, and the United States Department of Agriculture in 2007, and has spread downstream into the San Joaquin Delta since then. The plant is a popular component in water gardens and the aquarium industry, thus it is widely available and easily transported. Seedlings float, are very small, and can be confused with duckweed species (Photo 4). The GRI is in the process of developing factsheets for both Cuban bulrush and South American sponge plant. The factsheets will be published on the NAS website along with current location information. Both factsheets should be available in early 2011.

Figure 3. South American sponge plant. Photo by Pat Akers.

Figure 4. Seedling South American sponge plants inter-mixed with duckweed species. Photo by Lars Anderson.

We have also had several requests regarding the use of NAS data, as the database contains the most recent and easily accessible data regarding species locations. The most notable of these requests was from the US Army Corps. Engineers Environmental Laboratory in Vicksburg, MS. Researchers wanted to develop a time series map of the introduction of Eurasian watermilfoil into all 50 United States. We used the NAS database to query Eurasian watermilfoil (*Myriophyllum spicatum* L.) to access data on the first year of observation within all states and used these data in combination with existing data at the GRI to create a temporal and spatial map of Eurasian watermilfoil spread by decade of introduction (Figure 5).

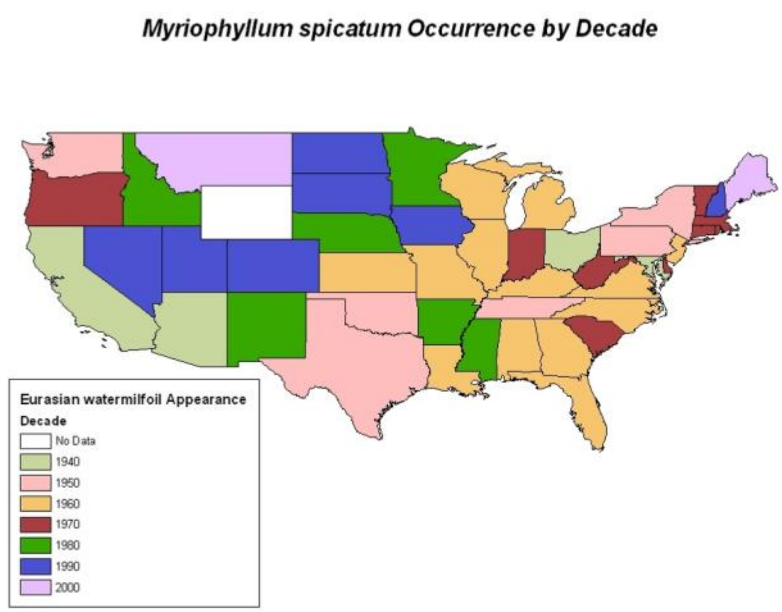


Figure 5. The spread of Eurasian watermilfoil across the United States by decade of introduction.

In order to better facilitate data entry and training of personnel we are developing a NAS Training Manual for distribution during training exercises. The GRI is working closely with Pam Fuller with the USGS/BRD Nonindigenous Aquatic Species Program, Southeast Ecological Science Center, Gainesville, FL in developing this manual. The NAS Training Manual should be available in early 2011 for printing and distribution.

Task 2. National Early Detection and Rapid Response Toolbox Development

The key to early detection and rapid response is trained volunteers, such as these volunteers on Waites Island in South Carolina, trained by Randy Westbrooks. Photo by Randy Westbrooks.

Dr. Kurt Getsinger, U.S. Army Engineer Research and Development Center, Vicksburg, MS, is one of our collaborators. Dr. Getsinger and John Madsen presented at a workshop in Petersborough, Ontario, Canada, to train volunteers and natural resource agency personnel on the identification and management of fanwort (*Cabomba caroliniana*), an invasive plant to Ontario waters. Fanwort is widely distributed in the aquarium pet trade. Photo by John Madsen.

Task 2.1. National Early Detection and Rapid Response Toolbox Development

PI: John Madsen
Co-PI: Victor Maddox
Collaborators: Elizabeth Sellers, NBII, Randy Westbrooks, USGS NWRC, and Annie Simpson, USGS National Headquarters (NBII), Pam Fuller, USGS Caribbean Science Center, and Les Mehrhoff, University of Connecticut (IPANE)

Early Detection and Rapid Response Toolbox
John D. Madsen

Our task for the Early Detection and Rapid Response Toolbox is to develop at least fifty linked publications for use in the National EDRR toolbox.

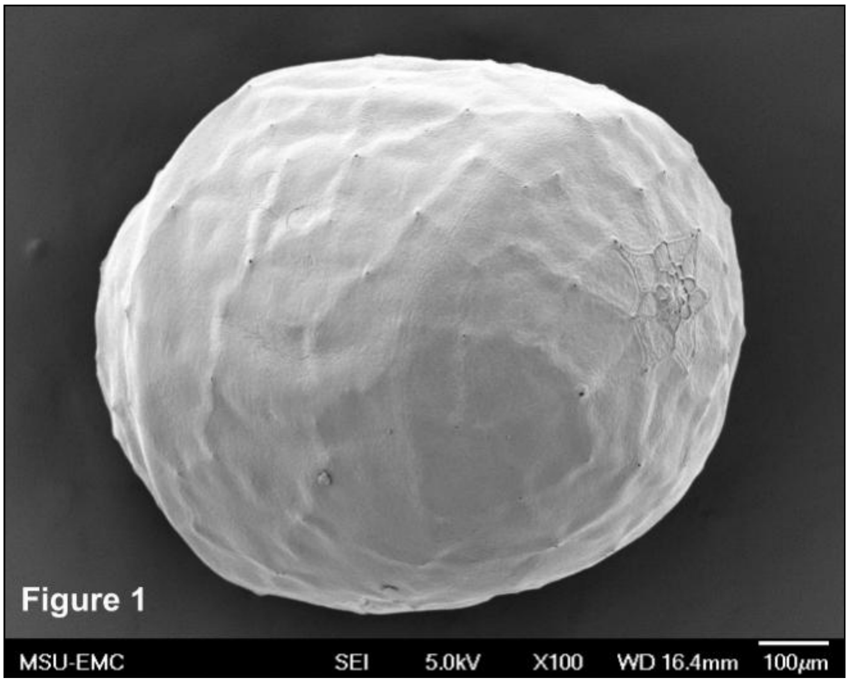
The current Geosystems Research Institute publication database has over two hundred citations on invasive species projects; 52 of these publications are in-house reports and fact sheets that are available in full text online.

These range from the forty two-page fact sheets included with the Invasive Plant Atlas of the MidSouth training course, to training manuals and project reports. We have eleven peer-reviewed journal publications, nine of which are available online at the GRI publication site.

During the spring of 2011, these publication links will be organized into an online catalog.

Eric Dibble works on waterlettuce control in Powe Pond, Starkville, MS, as part of an early detection and rapid response project.

Task 3. Invasive Insects: Cactus Moth *Cactoblastis cactorum*



Egg of the cactus moth (*Cactoblastis cactorum).*

Two of the *Opuntia* growth forms found in south Texas. Note the low habit and green cladode form (left) compared to the upright habit and gray cladode form (right); growing approximately 30 m apart. Other growth forms were also observed during the surveys. Image by Victor Maddox.

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

Sensory Structures on the Ovipositor and Tarsi of the Cactus Moth

Richard L. Brown, Sangmi Lee and Gerald T. Baker

Many complex insect behaviors, including host selection and oviposition, are mediated by chemical senses. Previous research on sensory structures of the antenna of the cactus moth has been supplemented during the past year by examination of the types of sensilla on two other areas of the female body of the moth that area critical for sensing and identifying the host plant. Oviposition is usually induced by specific key chemicals in the host plant, and these chemicals are detected by chemoreceptors on both the tarsi of the legs and the ovipositor. Both sensilla trichodea and sensilla chaetica are contact chemoreceptors, although they also can function as mechanoreceptors, but these sensilla have never been described for the cactus moth. Sensilla on the middle (mesothoracic) leg were studied with a combination of scanning electron microscopy, compound microscopy, and stereomicroscope, with the latter having an ocular micrometer for measurements. The mesothoracic tarsus has five tarsomeres, I-V from base to apex, with lengths as follows: I (2.12 mm), II (1.04 mm), III (0.72 mm), IV (0.44 mm), and V (0.40 mm) for a total length of about 4.7 mm. All tarsomeres have sensilla trichodea (Fig. 1, st.) and larger sensilla chaetica (Fig. 2, sc). The numbers of sensilla for each tarsomere are as follows: I (22 st, 15 sc), II (8 st, 10 sc), III (6 st, 10 sc), IV (10 st, 8 st), and V (12 st, 6 sc). Although the sensilla chaetica are larger and conspicuous, the sensilla are more numerous. The differing functions of these two types of mechano-chemosensory sensilla are unknown.

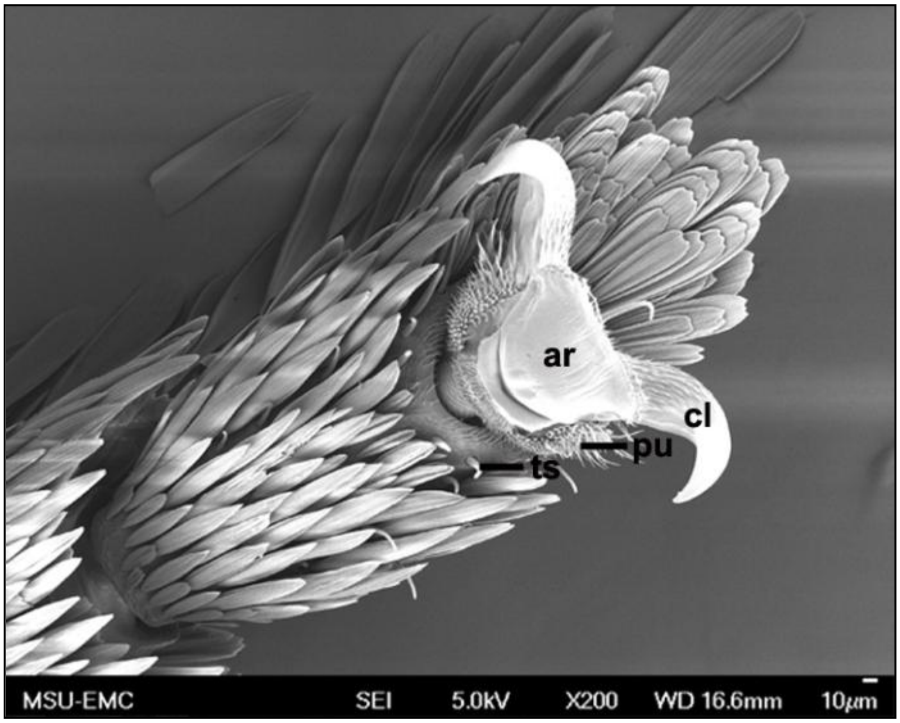


Figure 1. Tarsomere V of the mesothoracic tarsus and pretarsus of *Cactoblastis cactorum*, ar – arolium, cl – claw, pu – pulvinus, st – sensillum trichodea.

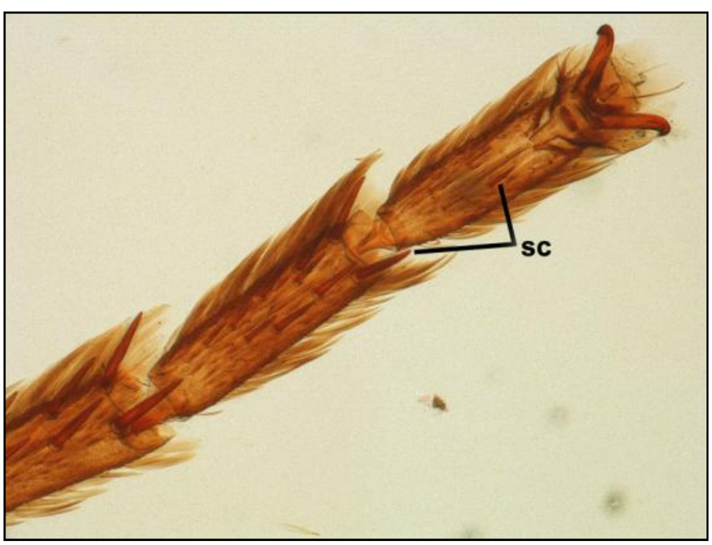


Figure 2. Tarsomeres IV and V of *Cactoblastis cactorum*, sc – sensilla chaetica.

The pretarsus (Fig. 1) is considered a separate leg segment from the tarsus and includes a pair of claws (cl), pair of pulvilli (pu), an arolium (ar), and a pseudempodial bristle arising from between the base of the claws. These structures are involved in grasping a substrate, and their form differs greatly among different species. Although unsocketed microtrichia are present on the pulvilli and bases of claws, no sensilla were detected.

Task 3.1. Early Detection and Reporting of Cactus Moth (Cont.)

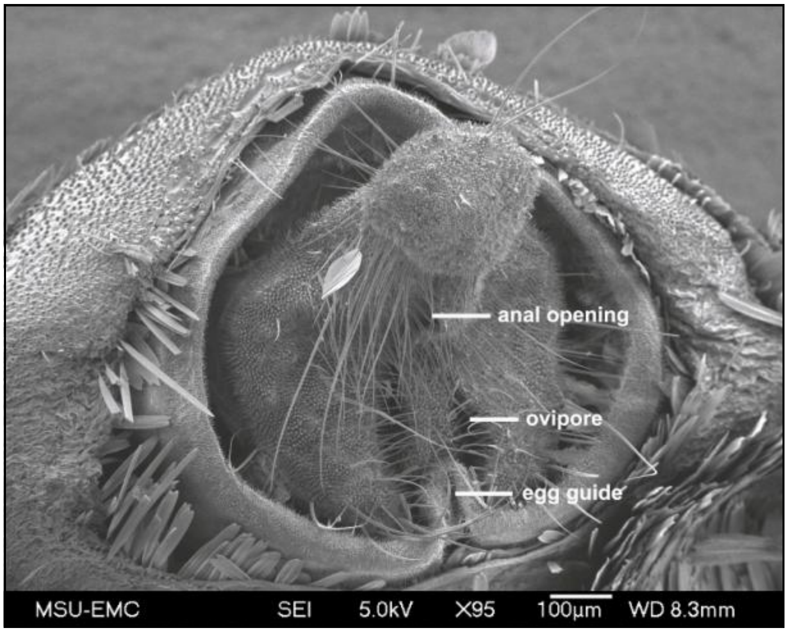


Figure 3. Ventral view of ovipositor of *Cactoblastis cactorum.*

The ovipositor of the cactus moth includes papillae anales (ovipositor pads) that are narrowed posteriorly, enclosing the anal opening (Fig. 3), and are narrowed posteriorly (Fig. 4). The ovipore is medially covered by a projection of the papillae anales, such that two openings appear to be present. The function of this projection covering the ovipore is unknown, although it may be involved in aligning the eggs that are released by the female. A similar structure has not been seen in other Lepidoptera. The ventral margin of the eighth segment is invaginated to form a groove that is interpreted to serve as an egg guide for placing the eggs on top of each other. This modification of the eighth segment has not been seen in other Lepidoptera examined previous to this study.

The papillae anales are covered with a large number of sensilla chaetica that vary in length. High magnifications of an individual sensillum reveal a smooth wall, a pore at the tip for allowing entry of volatiles, and in sensilla that have been broken, a hollow interior. The antennae of cactus moths also have sensilla chaetica, as well as three other types of sensilla. However, only sensilla chaetica are present on the ovipositor and in greater numbers that are present on the antenna.

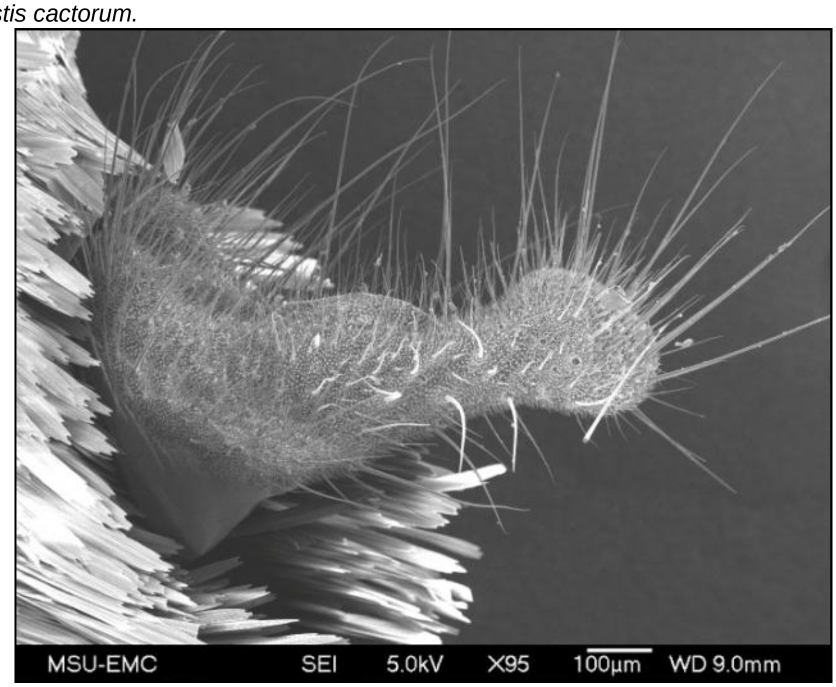


Figure 4. Lateral view of ovipositor of *Cactoblastis cactorum.*

Eggs of Exotic and Native Species of Cactus Moths

Gerry T. Baker and Richard L. Brown

During research on the internal anatomy of the cactus moth, mature eggs in the ovariole of females of the cactus moth were discovered. Although much basic information on the cactus moth has been obtained during the past 80 years, an individual egg of *C. cactorum* has never been photographed nor compared with eggs of other cactus feeding species, in part because the eggs are deposited as an egg stick that is covered with secretions from the colleterial gland. Because it has been impossible to remove all these secretions from the eggs for adequate imaging, several females of both *C. cactorum* and *M. prodenialis* were dissected in Ringer's solution to remove the first egg (the most mature) from each ovariole. The extracted eggs were then processed and critically point dried for scanning electron microscopy.

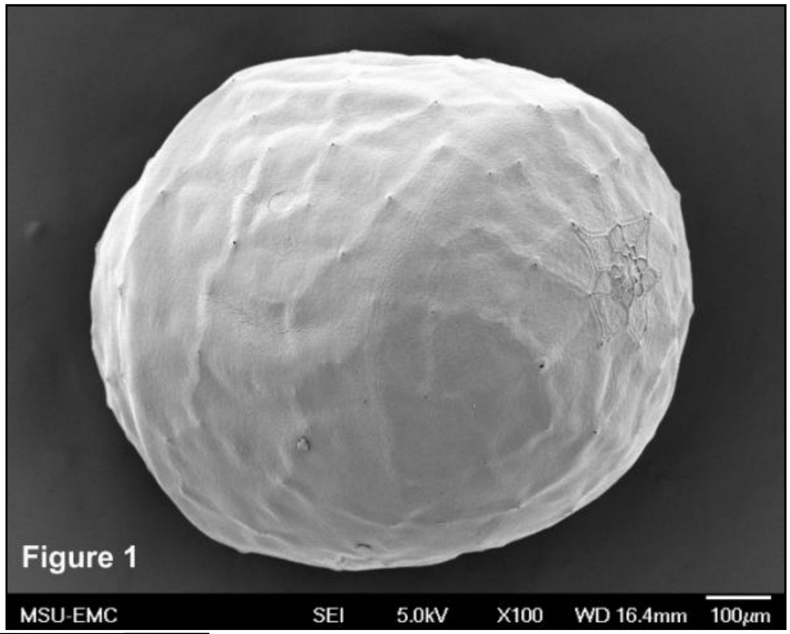


Figure 1. Egg of *Cactoblastis cactorum*.

The eggs of *C. cactorum* and *M. prodenialis* are globular and slightly flattened, but less so than after being oviposited in the egg stick. The ridges on the surface of C. cactorum eggs are not as distinct as those on *M. prodenialis*, and the chorionic surface of both species have many aeropyles for respiration. At high magnifications the surface of the chorion of both specis has a rugose appearance. The most distinct differences in the chorion of the two species occurs in the micropylar region where sperm enter the egg. The primary cells around the micropyle are delineated by very distinct carinae. The primary cells around the micropyle of *C. cactorum* are short, angular cells, whereas the cells of *M. prodenialis* are long and looping. The carinae fade and form the secondary cells around the primary ones in both species. A major difference with the secondary cells between the two species, besides their shape, is the presence of aeropyles on the raised areas of the apices of the cells.

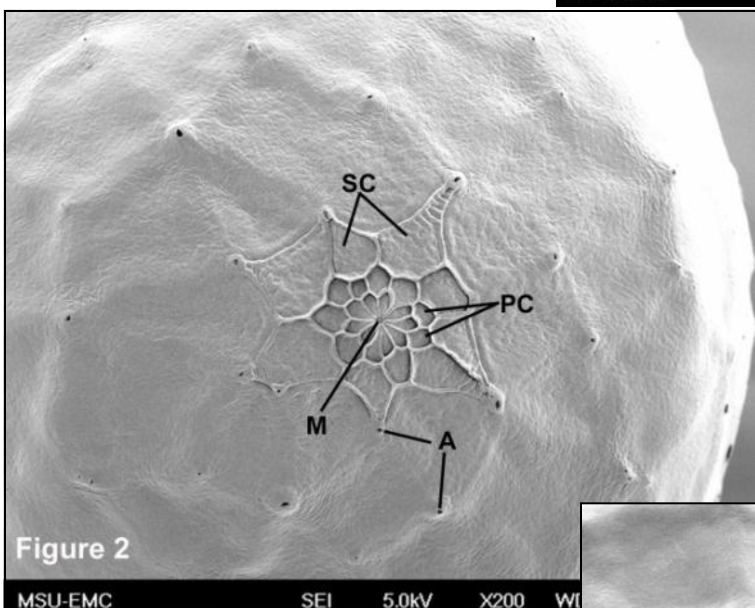


Figure 2. Micropylar area of *Cactoblastis cactorum* egg, A—aeropyles; M—micropyles; PC—primary cells; SC—secondary cells.

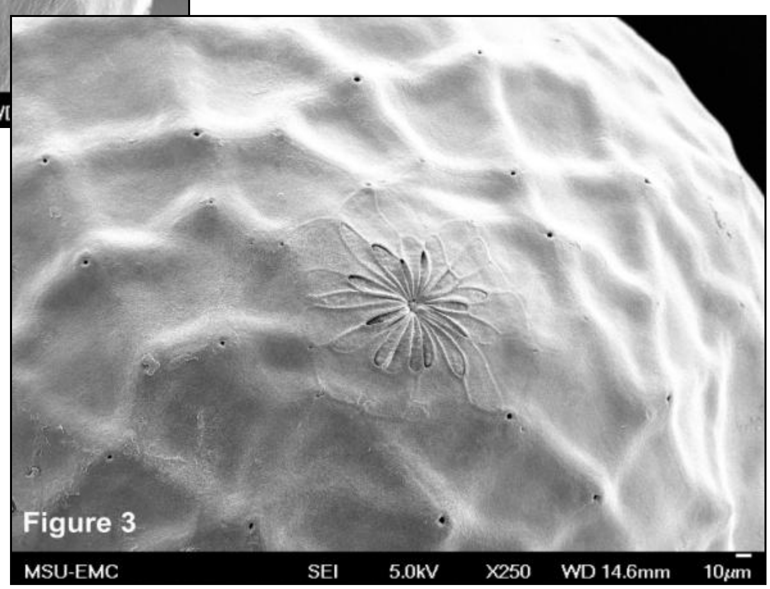


Figure 3. Micropylar area of *Melitara prodenialis* egg.

Task 3.2. Distribution of *Opuntia* in the Region

Figure 1. Highway 90 in west Texas is an example of one of the many roads surveyed (and mapped) during the 2010 cactus moth host and pest surveys. Photo by Victor Maddox.

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

Major Cactus Moth Host and Pest Data Collection and Collaboration Efforts Launched in 2010

Victor Maddox, Robyn Rose and Ken Bloem

Hundreds of thousands of cactus moth host plants (*Opuntia* spp.) on thousands of acres were mapped during thousands of miles of surveys (Fig. 1) from Mississippi to western Texas in 2010. In addition, thousands of plants were visually inspected for cactus moth during these surveys. In reality, the actual number of host plants in Texas would probably be closer to millions, but surveys are based upon what is actually visible from the highway. This is based upon the fact that in a few places during the surveys, host plants could be seen for long distances, even across the border into Mexico (Fig. 2).

Figure 2. View south toward the Rio Grande River and Mexico from Eagle Pass Road in Texas showing thousands of acres of pricklypear habitat. Photo Victor Maddox.

Five survey trips were made to Texas and comprise most of the nearly 1200 positive host reports collected in 2010. Nearly as many negative host reports were also collected during the surveys from western Texas north to western Missouri across to Tennessee and south to the Alabama coast. Mapping was conducted along the entire Texas coast from LA to Brownsville (Las Palomas Wildlife Management Area-Boca Chica Unit) and the Mexico-Texas border from Brownsville to Sanderson, TX (Fig. 3). Most of the data was reported to USDA-APHIS daily during the surveys, particularly those in Texas, as part of collaboration efforts.

Survey host species included *Opuntia atrispina* Griffiths, *O. cochenillifera* (L.) Mill. [Syn. *Nopalea cochenillifera* (L.) Salm-Dyck], *O. ellisiana* Griffiths, *O. engelmannii* Salm-Dyck ex Engelm., *O. ficus-indica* (L.) Mill., *O. humifusa* (Raf.) Raf. and *O. leucotricha* DC., *O. macrocentra* Engelm., *O. macrorhiza* Engelm., *O. microdasys* (Lehm.) N.E. Pfeiffer, *O. phaeacantha* Engelm., *O. pusilla* (Haw.) Haw., *O. stricta* (Haw.) Haw., *O. strigil* Engelm. but *Opuntia engelmannii* (Fig. 1) was the most prevalent both wild and in cultivation. Various growth forms of *Opuntia engelmannii* including possible hybrids were also observed during the surveys. New CMDMN host counties were added to the CMDMN database during these surveys.

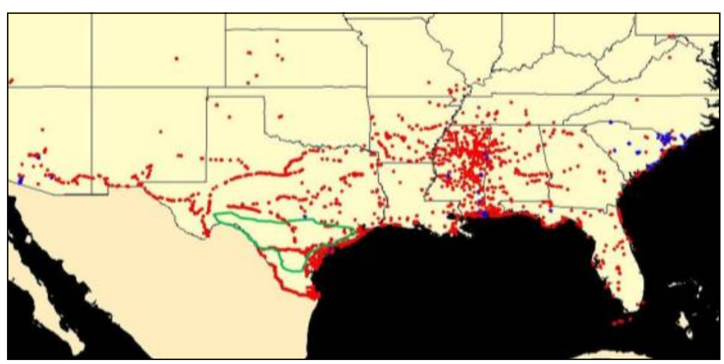


Figure 3. Host maps of Nov. 28, 2010, from the Cactus Moth Detection and Monitoring Network showing georeferenced host data from points in southern Texas. Area circled in green indicates where data has been collected, but is still being entered.

During the surveys, host population connectivity was studied in an effort to identify areas where coastal host populations connect to inland host populations. If cactus moth progressed along the coast into Texas, these areas could pose potential problems by allowing the pest to move inland and impact large host populations. Host population connectivity issues are still being studied and will be presented to USDA-APHIS in 2011.

Task 3.3. Environmental-based Habitat Models for Invasive Species

PI: Gary N. Ervin
Co-PI: John Madsen, Richard Brown
Collaborators: Chris Brooks, Lisa Wallace, and Mark Welch; MSU Biological Sciences

Environmental-basd Habitat Models for Invasive Species

Gary N. Ervin and Chris Brooks

Expected Results and Deliverables:

1. Spatially-explicit environmental data layers formatted for multiple habitat modeling approaches to be used by our group will be made available through the NBII Web pages.

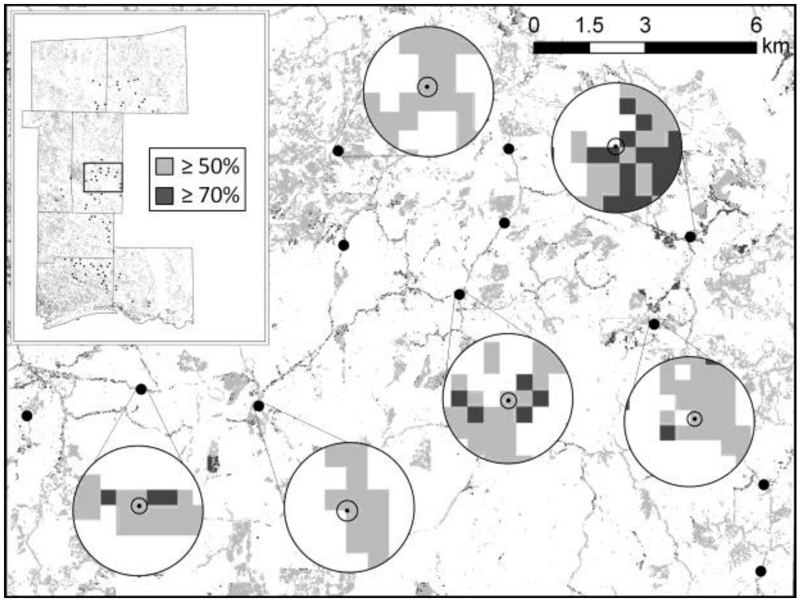


Figure 1. Maximum entropy habitat suitability model (Philips et al. 2006) for cogongrass (*I. cylindrica*) in seven southern Mississippi counties, showing close-ups of areas around six cogongrass locations that were used as training points for the model. Detailed map represents that boxed area near the center of the seven-county area; sample points are indicated by circled dot at center of circular insets, and pixels are 30m x 30m. Darkest gray indicates areas with at least 70% predicted probability of suitability for cogongrass; lighter gray areas have at least 50% likelihood of suitability.

In order to develop a series of data layers that are for modeling the habitat of various species, it is critical to consider the spatial grain and extent at which the target organism interacts with the landscape (Brooks 2003, 2006). That is, some studies need finer scale model resolution, which may require use of a different environmental layer than in a model that examines even that same species at a different spatial scale. For example, if one were interested in specific sites where a species might establish and successfully expand its local distribution, data layers with a grain or resolution of 1m, 10m, or perhaps 30m would be appropriate. However, if one were interested in the potential North American range of that same species, the spatial grain might expand to a few hundred meters. Thus, no one format of data would be applicable to all modeling uses.

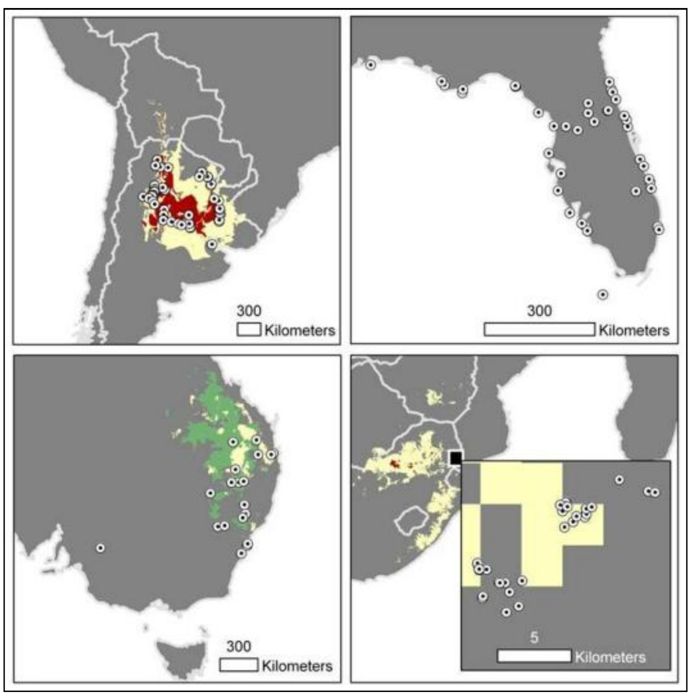


Figure 2. Maximum entropy habitat suitability models for *C. cactorum* fitted using native range points as training data. Light yellow indicates that the probability of the designated area being suitable habitat is at least 0.50, while dark red areas have a probability of suitability at least 0.75. Areas modeled, clockwise from upper left, are: Argentina and surrounding countries, Florida (USA), South Africa and surrounding countries, and eastern Australia. The dark green area in the lower left panel shows the extent of moderate and heavy *Opuntia* infestation in Australia, as mapped by Dodd (1927).

We have begun development of an Invasive Species Resources web page that will be hosted through the Geosystems Research Institute. This page will include links to and brief descriptions of the sources for original data layers that are being used in our work or that may be of interest in other modeling efforts. Our Habitat Modeling Web Tutorial pages also will link through this Resources page and will include information on the data layer manipulations that we have carried out in formatting environmental data for our modeling activities. This will permit future users to replicate our data formatting activities or to conduct their own formatting for their specific data and modeling needs.

Task 3.3. Environmental-based Habitat Models for Invasive Species (Cont.)

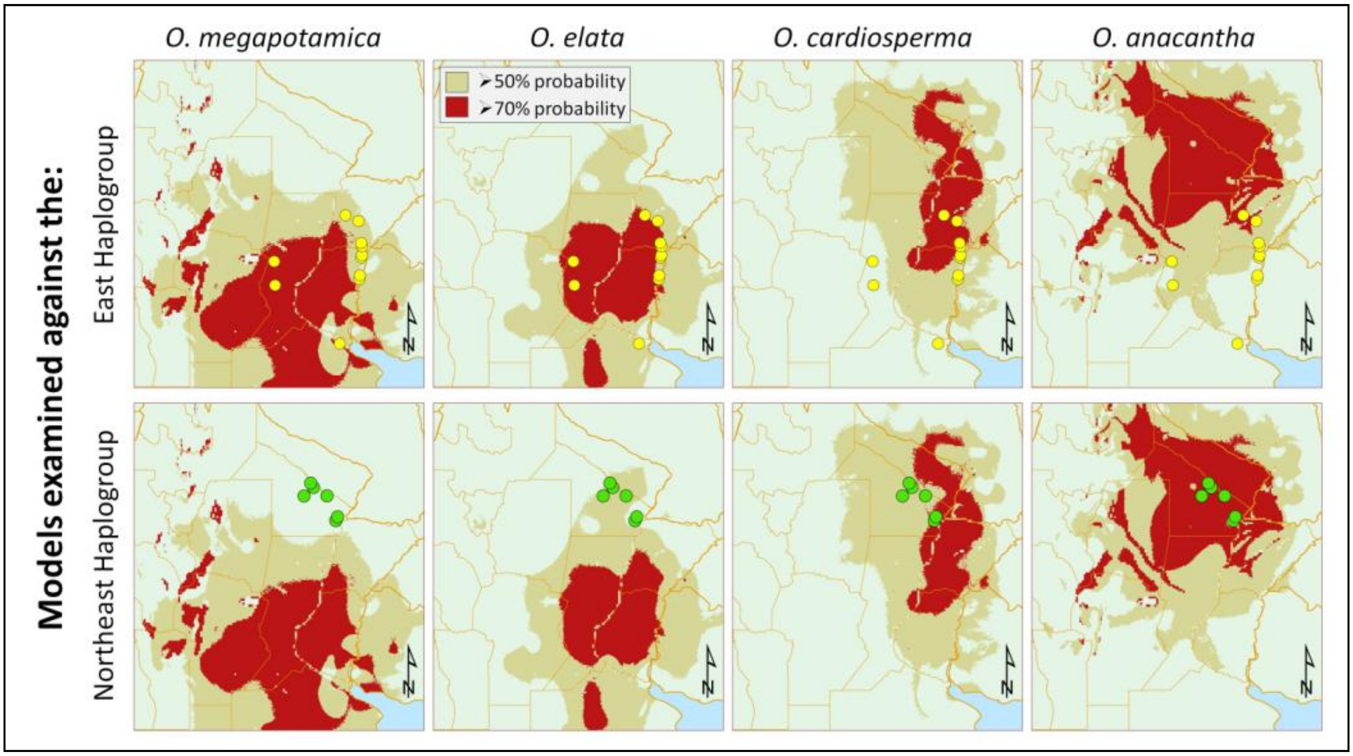


Figure 3. Habitat suitability models for four native-range *C. cactorum* hosts (*Opuntia* species) provided a reasonable fit to their respective *C. cactorum* mitochondrial haplotype groups (Marisco et al. 2010), in the native range (Table 1). The East haplotype group (haplogroup) can be found commonly on *O. megapotamica, O. elata,* or *O. cardiosperma*, depending on geography. The Northeast group is most commonly encountered on *O. anacantha, O. cardiosperma,* and *O. elata*. Red areas have predicted likelihood of suitable habitat ≥ 0.70, tan areas ≥ 0.50.

2. Environmental tolerance models for a few key North American invasive species.

Habitat models have been developed for *Imperata cylindrica* and for *Cactoblastis cactorum*. These modeling studies will be used as case study examples in the Habitat Modeling Web Tutorial. Environmental data formatting is underway for another plant species that is not invasive but is of conservation importance in the southeastern U.S. (*Arundinaria gigantea*, rivercane). Results of the first two modeling studies provided some interesting insight into the modeling process, which will be incorporated into the Habitat Modeling Workshop proposed for the Ecological Society of America Conference (assuming our proposal is accepted).

With respect to *I. cylindrica*, we found relatively high predictive ability of models within the region of the training data (our data collections in southern Mississippi; Fig. 1), but those models had poor transferability to data from Alabama (provided by Scotch Lumber Company in Fulton, Alabama). Analysis of the Alabama data, via additional habitat model development, indicated distribution of the Alabama cogongrass locations was much more strongly correlated with soil variables than was the case in Mississippi, where model training and test points were most strongly correlated with tree canopy cover. Results suggested that transferability of models was influenced strongly by: 1) data collection methods, 2) landscape context of the survey data, and 3) variations in qualitative aspects of environmental data used in model development.

Table 1. Percent of east and northeast haplotype group occurrences that were correctly predicted correctly by the four *host species* models (Fig. 3). Probability of presence in these models = 0.5; numbers in parentheses indicate number of occurrences predicted correctly.

Haplotype group	*O. megapotamica*	*O. elata*	*O. cardiosperma*	*O. anacantha*
East	100% (12/12)	92% (11/12)	67% (8/12)	58% (7/12)
Northeast	0% (0/6)	67% (4/6)	100% (6/6)	100% (6/6)

Task 3.3. Environmental-based Habitat Models for Invasive Species (Cont.)

With *C. cactorum*, we found that environmental variables expected to be correlated with distribution of the moth and/or its hosts yielded strong predictive power in the native range, but again here, models did not transfer well at all to known invaded regions of the globe (Fig. 2). Further model development based on locations of host plants in the native range suggested that interrelationships between environment and hosts may be informative in future modeling efforts (Fig. 3, Table 1). However, this will require additional information on susceptible host species from potential areas of invasion.

3. Refined environmental tolerance model for *C. cactorum* that incorporates new data from across the eastern portion of its native range, along with additional genetic data.

We have just completed, during 02-09 December 2010, a research expedition to Argentina and Uruguay to collect samples for this work (Fig. 4). Egg and larvae samples of *Cactoblastis* were collected from *Opuntia* species at seven locations in Uruguay and eight locations in Argentina, most in the vicinity of Salto, Uruguay and Concordia, Argentina. These samples should be processed during Spring 2011 to obtain genetic data for our current native range dataset (Marsico et al. 2010). In addition to *Cactoblastis* sampling, we collected tissues from *Opuntia* species encountered on this trip for submission to Lucas Majure (University of Florida) to aid in determining the host species from which our samples were collected. *Opuntia* taxonomy is quite complicated, owing to high levels of plasticity and hybridization. Although we know roughly the species that are present in this moth's native range, the importance of hosts that has been indicated by our studies (Fig. 3, Table 1) and those of our collaborators in Argentina requires we be as certain as possible as to host identities. Genetic analyses provided by Majure should help in this respect.

Once we have genetic data from the moth samples, we should be able to quickly produce new environmental models to determine whether the expanded sampling improves prediction quality outside the native range. One note is that the USDA South American Biological Control Laboratory (SABCL) currently is processing permit renewal applications that will be required for shipment of tissue samples to our laboratory at MSU. We have received word from SABCL scientist Laura Varone that permits should be in place around March 2011.

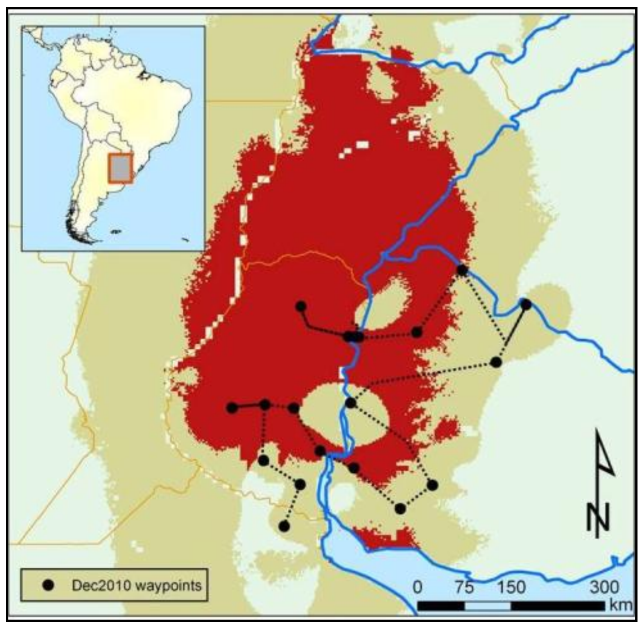


Figure 4. Map of December 2010 *C. cactorum* sampling trip in Argentina and Uruguay. Points represent cities and major intersections along our route. Shading represents predicted habitat suitability for the East haplotype group of *C. cactorum*; red areas have predicted likelihood of suitable habitat ≥ 0.70, tan areas ≥ 0.50. We focused our sampling effort at defining the easternmost area of *C. cactorum* habitat and on increasing our genetic information for the eastern genetic haplotype group. Locator map indicates the portion of Argentina and Uruguay represented in the larger map.

References

Brooks, C.P. 2003. A scalar analysis of landscape connectivity. Oikos 102(2):433-9.

Brooks, C.P. 2006. Quantifying population substructure: extending the graph-theoretic approach. Ecology 87 (4):864-72.

Dodd, A.P. 1927. The biological control of prickly pear in Australia. Council for Scientific and Industrial Research Bull No. 34. Melbourne, 53pp.

Marsico, T. D., L. E. Wallace, G. N. Ervin, C. P. Brooks, J. E. McClure, and M. E. Welch. 2010. Geographic patterns of genetic diversity from the native range of *Cactoblastis cactorum* (Berg) support the documented history of invasion and multiple introductions for invasive populations. *Biological Invasions*, In press. DOI: 10.1007/s10530-010-9874-9

Task 3.4. Habitat modeling of and susceptibility to *C. cactorum* among west Gulf Coast *Opuntia* species

PI: Gary Ervin
Co-PI: John Madsen
Collaborators: Chris Brooks, MSU Biological Sciences

Habitat Modeling of *Opuntia* Species
Gary Ervin and Chris Brooks

1. Habitat models for *Opuntia* species not yet encountered by *C. cactorum* in Louisiana and Texas.

During Summer 2010, we collected pads of *Opuntia* species from southwestern Louisiana and along the Texas Gulf Coast, and these have been potted in our greenhouse for use in growth chamber studies during Spring and Summer 2011 (Fig. 1). *Opuntia* specimens were collected for these studies from 43 locations along the Gulf Coast from Morgan City, LA to Corpus Christi, TX, north to Kerrville, TX. We plan to use the results of these growth chamber studies to inform habitat models for *Opuntia* attack risk, by combining relative larval performance with habitat models of the plant species themselves.

We plan to obtain C. cactorum eggsticks in Spring 2011 for use in these experiments, which will be conducted in a permitted, quarantined rearing facility at Mississippi State University (permit number **P526P-09-01017**).

2. Analysis and interpretation of the above described growth chamber studies.

This will be accomplished after the above experiments are completed.

3. Maps and analyses would be used to develop a report for dissemination to all parties involved in *C. cactorum* control efforts along the Gulf Coast. These materials also would be posted to the Cactus Moth Detection and Monitoring Network Web pages.

This will be accomplished after the experiments and modeling described above are completed.

Figure 1. *Opuntia* collections from Louisiana and Texas that will be used in growth chambers studies during 2011. Plants are allowed to grow in the greenhouse for several months in order to provide healthy, potted plants for studies, as experiments using excised pads have provided results inconsistent with those using intact, rooted plants.

Task 3.5. Cactus Moth Detection and Monitoring Network (CMDMN)

PI: Clifton Abbott
Co-PI: Richard Brown, Victor Maddox, John Madsen
Collaborators: Randy Westbrooks, USGS NWRC; Joel Floyd, USGS APHIS PPQ; Ron Weeks, USDA APHIS PPQ, and Annie Simpson, NBII

Detecting and Monitoring Cactus Moth Distributions
Clifton Abbott

Figure 1. The Cactus Moth Detection and Monitoring Network helps survey participants identify cactus moth hosts.

Cactoblastis cactorum is a very destructive cactus moth wreaking havoc across the gulf coast on cactus populations. The Cactus Moth Detection and Monitoring Network (CMDMN) has been identifying cactus populations throughout the coastal states and monitoring the spread of the destructive moth. The leading edge of the moth's progression across the gulf coast is still in south Louisiana. Efforts are to keep the moth from progressing any further.

The CMDMN system currently contains 11,677 prickly-pear surveys. 3,444 of these surveys are actual cactus populations with the remaining surveys being areas where cactus populations are not found. Cactus populations have been surveyed in 25 states and Mexico. Six states are positive for the cactus moth. A host of sentinel sites in six states are being monitored by volunteers to detect the moth's movement into new areas.

Recently, we were notified of potentially large cactus populations along the Pearl River in south Louisiana and plans are being made to survey more extensively in that area in early 2011. Extensive surveying has been ongoing in Texas and cactus populations are estimated to be in the hundreds of thousands throughout Texas. More surveying is planned for 2011.

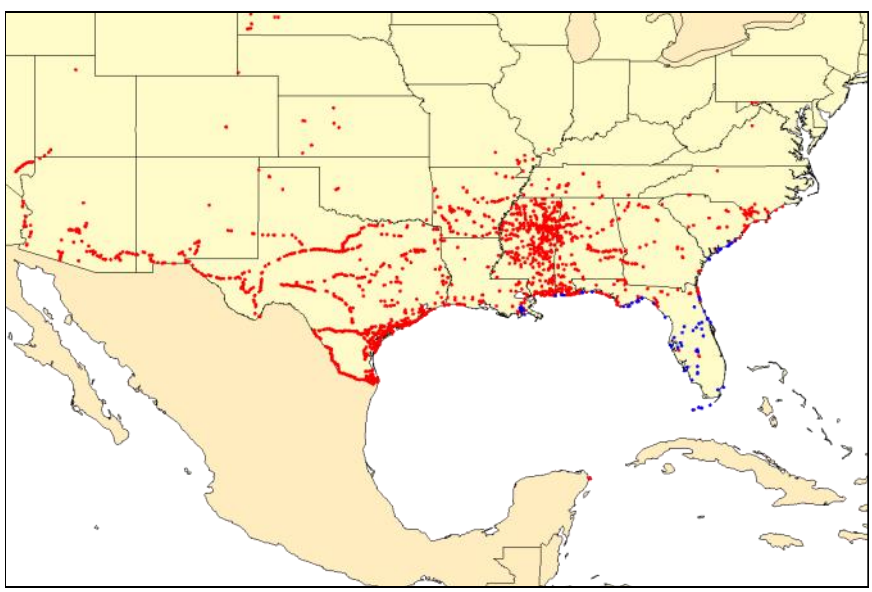


Figure 2. The Cactus Moth Detection and Monitoring Network shows cactus population (red) with moth locations (blue).

The CMDMN online system has been in place for a few years now and has served the needs quite well. However, in an effort to keep up with current technology plans are being made for an overhaul of the underlying system and the website. Plans for a more robust user account module, mapping module, and database interface are being planned.

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.

Task 3.6. Adapt Cactus Moth Detection and Monitoring Network (CMDMN) Web Page for Web-Enabled Mobile Devices

PI: Clifton Abbott
Co-PI: John Madsen
Collaborators: Annie Simpson, NBII, and John Pickering, Discover Life, University of Georgia

Cactus Moth Detection and Monitoring Network on the Move
Clifton Abbott

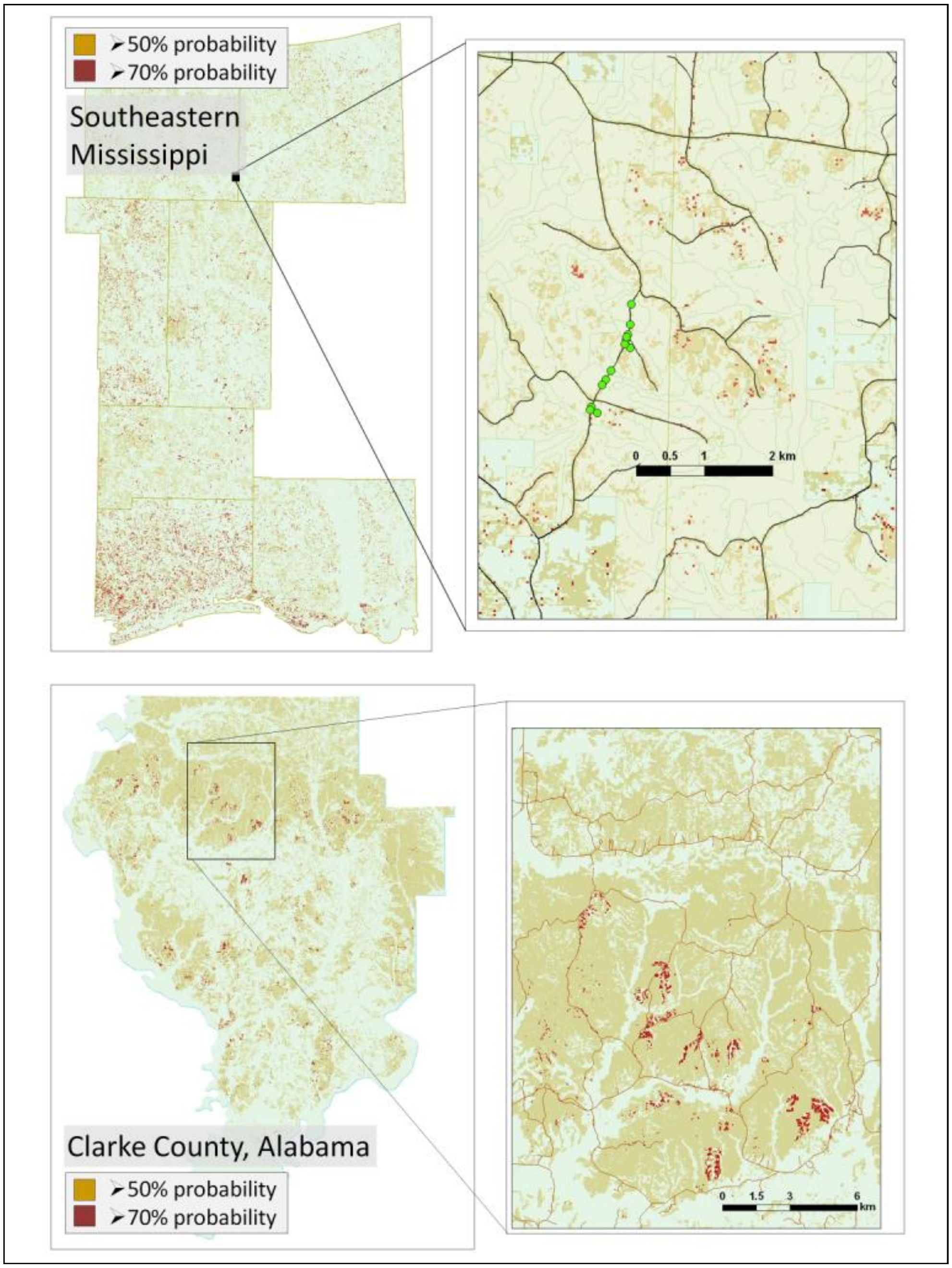
More and more of today's web access is from a mobile device. Many websites are adapting their pages to more mobile-friendly pages in order to tap into that customer-base. The Cactus Moth Detection and Monitoring Network is no exception. Many people have mobile devices that capable of taking pictures and grabbing GPS coordinates. This is a volunteer-base that can be a great asset in finding cactus locations and for monitoring the cactus moth.

Efforts are underway in identifying the methods at which we can utilize the mobile device in the effort to fight the cactus moth. Among these methods is adapting the website to be more mobile-friendly. The CMDMN website provides a lot of cactus and moth information, not to mention the survey system as well. We are currently researching the best way to provide all of that information to the mobile device in a way that will the volunteer to identify the cactus species, and possibility the moth larvae, as well as submit surveys to the system.

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 1. A smartphone shows cactus locations on the Cactus Moth Detection and Monitoring Network.

Task 4. Habitat Modeling for Species of Interest



Habitat models for cogongrass (*Imperata cylindrica*) in southeastern Mississippi (upper) and Clarke County, Alabama (lower). Green dots in the expanded area of the MS model indicate actual cogongrass patches encountered during the field surveys. Brown and red shading indicate predicted probabilities of suitable habitat, based on Maximum Entropy models. The MS model was based primarily on the relationship of tree canopy coverage and soil silt content on cogongrass distribution. The AL model was influenced most strongly by soil cation exchange capacity and tree canopy coverage. Points are not shown for Alabama because of a data sharing agreement with data providers.

Task 4.1. Habitat Modeling Workshop and Web Tutorial

PI: Gary Ervin
Co-PI: Chris Brooks

Habitat Modeling Workshop and Web Tutorial
Gary N. Ervin and Chris Brooks

Expected Results and Deliverables:

1. Directory of data sources, made available through the NBII Web pages.

We have begun development of an Invasive Species Resources web page that will be hosted through the Geosystems Research Institute. This page will include links to and brief descriptions of the sources for original data layers that are being used in our work or that may be of interest in other modeling efforts. This Resources page will be linked with the NBII Invasive Species Information Node web site (or other appropriate pages).

2. Annotated comparison of select modeling approaches, as a Web tutorial to be posted on the NBII Web pages.

Our Habitat Modeling Web Tutorial also will link through the GRI Invasive Species Resources web page and will include the following information to permit future users to replicate our habitat modeling activities or to conduct their own analyses. Annotations for each element would consist of a paragraph or so describing each tool, method, or database.

A. ***Methods* -** An annotated overview of methods currently in use for habitat modeling.
B. ***Modeling tools*** - Individual overviews of the various tools available for habitat modeling.
C. ***Data* -** An annotated directory of data repositories for environmental and biological collection data. These would be primarily environmental data, but one or two global species databases will be included.
D. ***Examples* -** Examples using partial data sets or hypothetical data sets, with notes on application of tools and methods.
E. ***Case studies* -** Specific examples, including notes on derivation and assessment of the models. This would be provided as studies are published (and subject to any copyright restrictions).
F. ***Publications and presentations* -** Bibliography, with PDFs where appropriate, of recent habitat modeling studies and presentations.

3. Habitat modeling workshop at 2011 Ecological Society of America meeting in Austin, TX, with all workshop materials hosted through the NBII Web pages.

We submitted the following workshop proposal for this ESA conference. Proposers are scheduled to receive notification of acceptance by 13 Jan 2011.

Title: Hypothesis-Driven Habitat Modeling: Workshop and Web Tutorial

Description: Habitat modeling has application for predicting expected distributions of invasive species, species responding to climate change, or other species of interest, but there may be other important benefits for ecologists and other scientists. An often overlooked utility of habitat modeling is the use of resulting models as hypotheses for gaining a deeper understanding of mechanisms influencing species distribution. This workshop will be targeted towards this latter function of habitat modeling. We propose a workshop that would illustrate some of the most accessible and commonly used habitat modeling approaches, while simultaneously focusing on the habitat modeling process as a means to formulate and test hypotheses at multiple scales. The workshop materials would be designed primarily to benefit those desiring to use habitat modeling approaches for the first time, although others are welcome. We will make use of accompanying web resources that will be hosted by or linked to through the Mississippi State University Geosystems Research Institute, in partnership with the US Geological Survey National Biological Information Infrastructure's Invasive Species Information Node.

Environmental and species data sets will be provided, along with instructions for preparatory work that may be

Task 4.1. Habitat Modeling Workshop and Web Tutorial (Cont.)

completed prior to the conference. Participants will be responsible for their own computers, and it will be assumed that at least some preparation is conducted before arrival. Workshop discussions will focus on analyses of the data provided, but participants are encouraged to bring questions regarding their own study systems.

Summary: We will use common habitat modeling methodologies to direct discussion on the utility of environmental niche modeling as a tool for exploring species distribution hypotheses. Aspects of the modeling process to be discussed include: niche concepts, hypothesis formulation and environmental variable selection, and insight to be gained from model "failure."

Task 4.2. Landscape Genetic Habitat Modeling for Invasive Species

PI: Gary Ervin
Co-PI: John Madsen
Collaborators: Chris Brooks, Lisa Wallace, Mark Welch – MSU Biological Sciences; Charles Bryson, USDA-ARS, Stoneville, MS

Landscape Genetic Habitat Modeling for Invasive Species

Gary Ervin, Chris Brooks, Lisa Wallace and Mark Welch

Expected Results and Deliverables:

1. Genetic analyses (AFLP results) from across the invasive range of *I. cylindrica*.

Three main objectives are addressed by this project: to asses genetic diversity and population genetic structure in *I. cylindrica* across the invasive range in the U.S., detect if distinctive genotypes exist, and conduct spatial and landscape-level genetic analyses. These objectives facilitate the overarching aim of determining the interactions between the genome and successful invasion of *I. cylindrica* in North America. We are utilizing population genetic tools based on measures of genetic diversity and population structure and attempting to identify candidate loci correlated with physical space and ecological habitat variables.

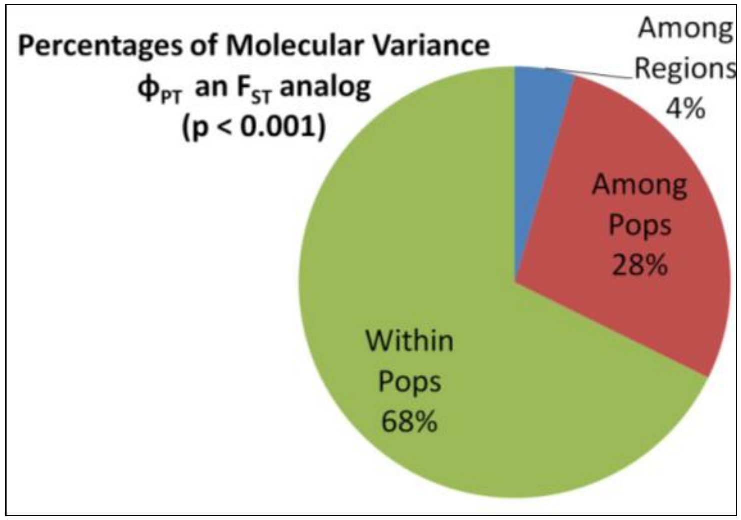


Figure 1. Partitioning of genetic variance using an F_{ST} analog for dominant markers (AFLPs) for *I. cylindrica* in populations in Mississippi, Alabama, Iraq. Individual populations contain considerably more genetic variation than expected.

Amplified Fragment Length Polymorphism (AFLP) analyses are being conducted for populations sampled from Mississippi, Alabama, Texas, Louisiana, Georgia, South Carolina, and Florida. At this time, over 50% of all sampled tissues collected have been analyzed, primarily from Mississippi, Alabama, and Iraq. Iraqi samples were obtained from accessions in the collection of Dr. Charles Bryson, USDA-ARS, Stoneville, MS. The Iraqi samples represent 12 samples from approx. 800 km of each of the Tigris and Euphrates river basins (Al-Jaboory and Hassawy 1980).

Using an F_{ST} analog (φ_{PT}), 68% of the total AFLP-based genetic variance can be resolved within populations (N=207), 28% among populations (n=19), and 4% among regions (n=3), with a p-value <0.001 (Fig. 1). Genetic data from *I. cylindrica* populations sampled from Mississippi and Alabama demonstrated high within population genetic diversity with 2-5% heterozygosity, and 79-254 polymorphisms per population (Fig. 2). Unique ("private") polymorphisms are those that only occur in one population and no other. As many as 71 unique polymorphisms were found in one population in Mississippi and 72 such polymorphisms in one Alabama population.

Together, these data suggest that there may be a spatial component for genetic partitioning that can result in geographic genetic structure in *I. cylindrica*. In addition, the high number of unique polymorphisms occurring in few, but not all populations may also suggest intraspecific hybridization between introduced populations that were previously isolated between Mississippi and Alabama, combining material from the separate historical introductions into McNeil, MS, and Grand Bay, AL (Tabor 1949, 1952).

2. Grouping of *I. cylindrica* into distinct genotypes.

Data collection for genetic assays of the full set of collections (AL, FL, GA, LA, MS, SC, TX) is 70% complete, and the remaining genetic data collection should be completed by February 2011. Spatial and landscape genetic analyses, as well as further relatedness analyses to identify *I. cylindrica* genetic 'groups' will be conducted throughout 2011, following collection of genetic data. Distinctiveness of AFLP-based genotypes will be deter-

Task 4.2. Landscape Genetic Habitat Modeling for Invasive Species (cont.)

mined by the amount of variation exhibited across the full dataset, thus, it remains to be determined how many actual "groups" will be present, or what the geographic range of each may be.

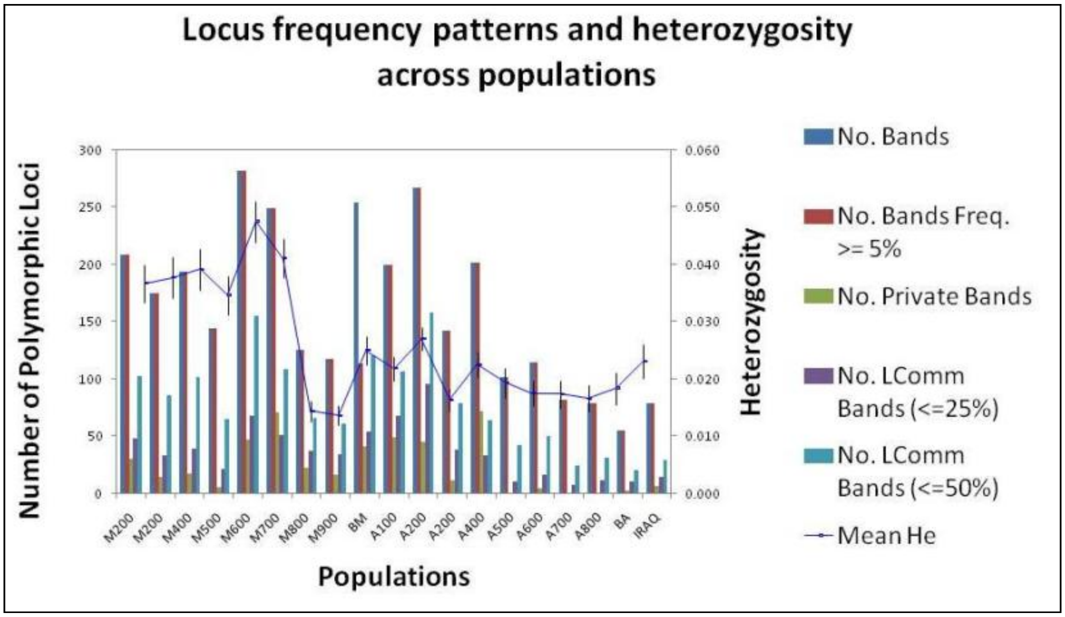


Figure 2. Locus frequency pattern and heterozygosity across Mississippi & Alabama populations of *I. cylindrica*, compared with samples from Iraq. Population labels indicate whether samples were collected from Mississippi (M), Alabama (A), or Charles Bryson accessions (BM, BA, IRAQ). Note that samples from Mississippi exhibit generally higher levels of genetic diversity than those from Alabama, although comparisons between the two states account for a small level of total genetic diversity (4%).

3. Spatial and landscape genetic analyses of *I. cylindrica*.

These analyses will follow the above analyses to determine genetic groups and a planned evaluation of AFLP band patterns across the southeastern US. It is possible that particular AFLP markers may show geographic variation that can be used to explore for correlations with ecological landscape features, such as land cover or transportation corridors.

4. Spatial and landscape genetic analyses of *C. cactorum*.
See description of results under Task 3.3 above.

5. Assessment of potential population genetic tools for *C. cactorum*.
This work has not yet begun. We have published genetic analyses at the regional scale, using mitochondrial markers, but these markers are insufficient for smaller-scale population genetic analyses. We are planning analyses of data from our mitochondrial markers, in conjunction with ecological data from a previous study in Florida, to determine the potential for population-level genetics to contribute to understanding patterns of spread for *C. cactorum* in the U.S. Results of those analyses will help inform next steps with respect to genetic studies in this species.

6. "Applying genetics to management of invasive species" section to be added to NBII's Ecological Topics – Genetic Diversity and Ecological Topics – Invasive Species sections.
We have begun development of an Invasive Species Resources web page that will be hosted through the Geosystems Research Institute. This page will include information on genetic analyses of a number of the invasive species being studied in GRI research programs, such as *Cactoblastis cactorum*, *Imperata cylindrica*, and *Phragmites australis*.

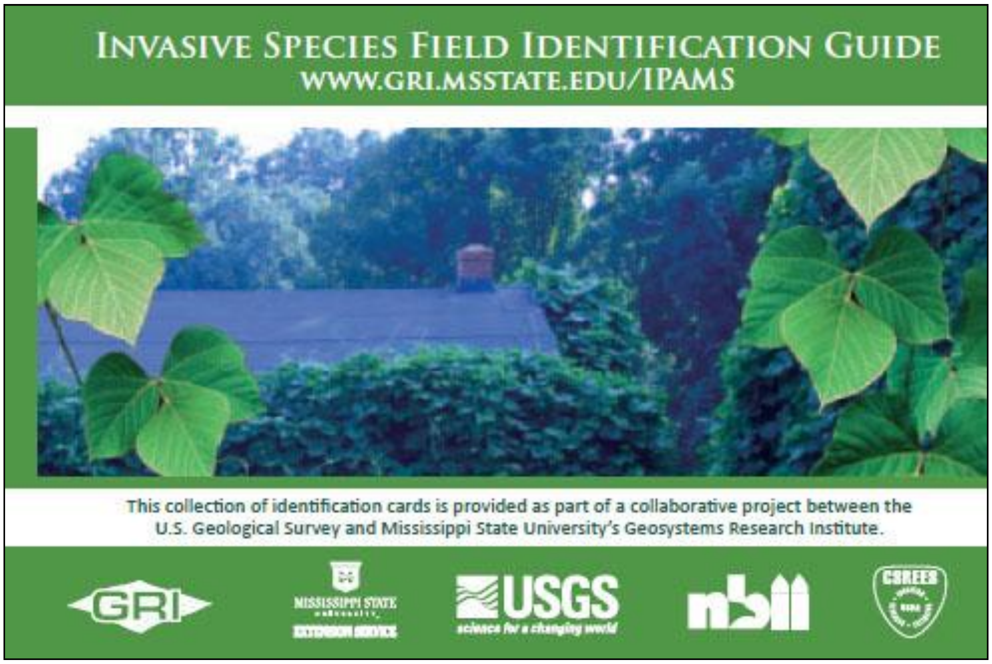
References

Al-Jaboory, B.A., G.S. Hassawy. 1980. Comparative morphological development of Cogongrass (*Imperata cylindrica*) in Iraq. Weed Science. 28:324-326.

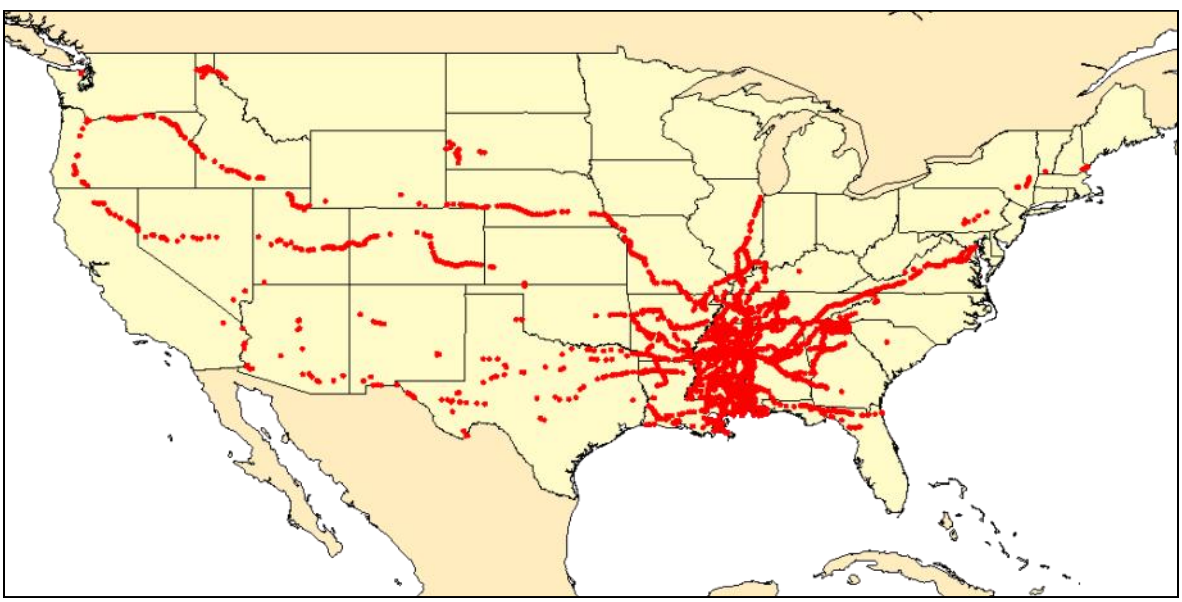
Tabor, P. 1949. Cogongrass, *Imperata cylindrica* (L) Beauv., in the southeastern United States. Agronomy Journal 41:270.

Tabor, P. 1952. Cogongrass in Mobile County, Alabama. Agronomy Journal 44:50.

Task 5. Invasive Plant Atlas of the Mid-South (IPAMS)



Our IPAMS field identification manual provides a photo or photos of one of the forty species on the front, and a description of the plant on the back. The manual is produced from heavy stock, and sealed for partial protection from the elements. It is available to participants in our training workshops.



The map of observations in the IPAMS database grows over time – we now have over 10,000 points from coast to coast, and points being added for Hawaii and Puerto Rico (not shown).

Task 5.1. Web-based Database of Invasive Plant Species Locations

PI: John Madsen
Co-PI: Gary Ervin, Clifton Abbott, and Victor Maddox
Collaborators: John Byrd, MSU; Randy Westbrooks, USGS NRWC; Annie Simpson, NBII, and Les Mehrhoff, University of Connecticut (IPANE)

Invasive Plant Atlas of the Mid-South (IPAMS)
John D. Madsen and Gary N. Ervin

The Invasive Plant Atlas of the Mid-South (IPAMS) is an integrated research and extension project to develop an invasive plant awareness program for the Mid-South states of Alabama, Arkansas, Louisiana, Mississippi, and Tennessee. This project aims to 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.

Figure 1. Volunteers attending an IPAMS training session in November 2010 in Hattiesburg, MS.

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. As part of these research activities, we have surveyed over 470 points throughout the state of Mississippi, providing data on more than 800 plant species, including more than 70 species that are not native to the region. Initial analyses of these data have demonstrated a strong correlation of land use and cover with the presence of exotic plant species, especially key invaders such as the grass *Imperata cylindrica* (cogongrass).

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 weed species, and we are in the process of developing management information for these species.

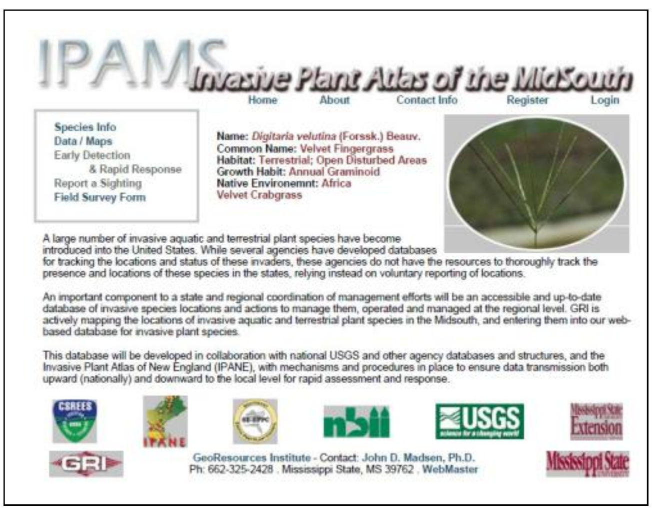


Figure 2. Invasive Plant Atlas of the MidSouth webpage, at http://www.gri.msstate.edu/IPAMS. We will be launching a newly designed page in the near future.

We have completed both our training manual and our identification guide, and these are available in PDF format both through the GRI webpage and on the IPAMS page, as well as from the first author with an e-mail request.

This past year, we held a workshop to train volunteers at the Mississippi Department of Transportation office in Hattiesburg, MS, in association with the Mississippi Exotic Pest Plant Council. Twelve volunteers attended the event (Figure 1).

Our webpage (www.gri.msstate.edu/ipams) is operational, with over 10,000 records entered for 134 species from over 30 states and many more observations completed but not entered into the database (Figure 2).

Task 5.2. IPAMS Web Site Enhancement for Accessibility by Mobile Devices

PI: Clifton Abbott
Co-PI: John Madsen, Gary Ervin
Collaborators: Annie Simpson, NBII

Invasive Plant Atlas of the Mid-South on the Move
Clifton Abbott

More and more of today's web access is from a mobile device. Many websites are adapting their pages to more mobile-friendly pages in order to tap into that customer-base. Invasive Plant Atlas of the MidSouth is no exception. Many people have mobile devices that capable of taking pictures and grabbing gps coordinates. This is a volunteer-base that can be a great asset in finding and mapping invasive plants.

Efforts are underway in identifying the methods at which we can utilize the mobile device in the effort to control and manage invasive plants. Among these methods is adapting the website to be more mobile-friendly. The IPAMS website provides a lot of plant information, not to mention the survey system as well. We are currently researching the best way to provide all of that information to the mobile device in a way that will the volunteer to identify the plant species, as well as submit surveys to the system.

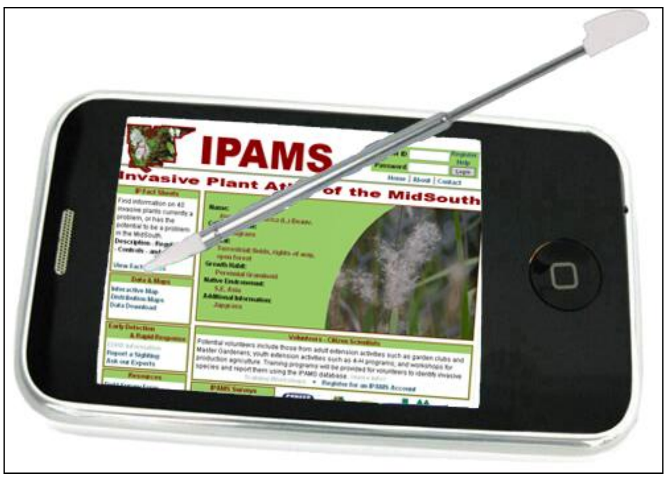


Figure 1. A smartphone display showing the IPAMS adapted webpage.

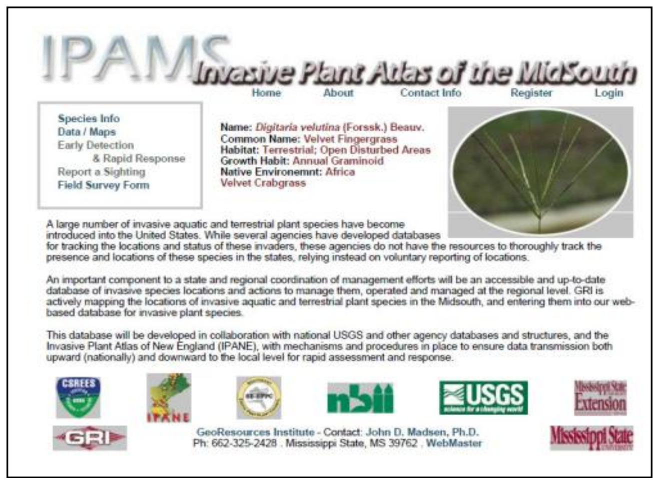


Figure 2. Invasive Plant Atlas of the MidSouth webpage, at http://www.gri.msstate.edu/IPAMS. We will be launching a newly designed page in the near future.

Task 6. Bioinformatics and Biodiversity

Thomas Naberhaus (right) showing the newest version of BAMONA database to Richard Brown (left) and Sangmi Lee at Big Sky Institute in July.

Dr. Gregory Bohach (left), Vice President of the Division of Agriculture, Forestry, and Veterinary Medicine, and Dr. Mark Keenum (right), President of Mississippi State University, at the Mississippi Entomological Museum insect rearing facility. Biodiversity studies and collections are important at Mississippi State University. Photo by Kat Lawrence, MSU Ag Communications.

Task 6.1. Collaboration with the Intgrated Taxonomic Information System (ITIS) and Bioinformatics of Butterflies and Moths of North America (BAMONA)

PI: Richard Brown
Co-PI: John Madsen, Clifton Abbott, Sangmi Lee
Collaborators: Thomas Naberhaus, Big Sky Institute, Bozeman, MT; Elizabeth Sllers, NBII, and Jen Carlino, NBII

Bioinformatics: Lepidoptera data for BAMONA and Nomenclature for ITIS
Richard L. Brown

The proposed work for 2010-2011 includes the export of data for 45,000 specimens of moths to the Big Sky Institute at Montana State University for incorporation into distribution maps of the Butterflies and Moths of North America (BAMONA) website and to up-date the nomenclature of Lepidoptera in the database of the Integrated Taxonomic Information System (ITIS). Objectives include the capture and formatting of specimen data for 60,000 specimens for BAMONA and updating the nomenclature for 12 superfamilies of moths.

Figure 1. Sangmi Lee (left) receiving training from David Nicolson, ITIS, in using the TWB software.

Specimen data has been captured for more than 40,000 specimens and are currently being re-formatted following standards provided by Thomas Naberhaus at Big Sky Institute. Data have been exported for 1,826 specimens of Limacodidae from 123 counties in 20 states, 218 specimens of Zygaenidae from 47 counties in 12 states, and 296 specimens of Megalopygidae from 56 counties in 11 states. An additional 11,000 records of Gelechiidae have been formatted and are currently being proofed for accuracy.

During November 15-18 Sangmi Lee received training at the Smithsonian Institution from David Nicolson, Data Develop Coordinator for ITIS, to learn the Taxonomic Workbench (TWB) software (Fig. 1). To date 2,192 species names for four families of Gelechioidea have been formatted, proofed with Text editor softeare, and imported into the TWB. After merging with data downloaded from the ITIS online database, duplications will be eliminated and all mandatory required data fields will by checked by several query tools. For each of the 2,192 names provided to date, the following data fields have provided: author and date of name, taxonomic rank, current nomenclatorial standing, parent scientific name, associated synonyms, any available vernacular names, a unique taxonomic serial number, data source information (publications, taxonomic experts, etc), geographical distribution, and data quality indicators. The original publication for each published name has been checked to verify the accuracy of spelling, title of article, and page number.

Task 7. Visualization and Biological Informatics

Virtual bluegill swim through a virtual bed of mixed water celery and Eurasian watermilfoil in our virtual reality simulation of the littoral zone.

Photo of the VERTEX, a virtual reality projection booth at Mississippi State University's Geosystems Research Institute, High Performance Computing Collaboratory.

Task 7.1. Visualization of Invasive and Native Aquatic Plant Structure in the Littoral Zone Environment

PI: Eric Dibble (Ecology), Phil Amburn (Computation)
Co-PI: John Madsen

Waterscape—A Virtual Environment for Invasive and Native Aquatic Plant Structure

Eric Dibble, Phil Amburn, Rachel Schultz and Derek Irby, Department of Wildlife, Fisheries and Aquaculture and Geosystems Research Institute

Figure 1. Rachel Schultz records a digital image of plants.

A team from the Geosystems Research Institute (GRI) and the Department of Wildlife, Fisheries and Aquaculture (WFA) at Mississippi State University has been working on incorporating a scientific basis for the 3D model of a waterscape. These models allow us to predict potential impacts that invasive plant species may have on the habitat of native aquatic organisms. To create a realistic waterscape, we reviewed and synthesized information regarding plant community dynamics (i.e., assemblage, structure, temporal changes, etc.) in reservoirs using over 30 peer-reviewed publications. The team then designed a waterscape with realistic density and distribution of native aquatic plants in a notional southern reservoir. To characterize a biological invasion, we chose a common plant invader of southern reservoirs, *Hydrilla verticillata* (hereafter hydrilla), and compiled published data on its modes of introduction, rates of spread, and monoculture density. Then, in a virtual environment, we are using this data to create a realistic, time-dependent simulation of the introduction hydrilla and the subsequent invasion of the native plant community. This all sets the stage to address the impact of invasive plants on fish. Again, using a review of published data, we demonstrate corresponding changes to fish (e.g., bluegill and bass) populations as the plant community is invaded. It will soon be possible to quickly review the changes in the waterscape through the use of DVD-like controls for simulated time so that several simulated months can be reviewed in just a few minutes of wall clock time.

Figure 2. Plant density based on water depth and a Gaussian distribution.

Figures 1 and 2 show the visual presentation available in the MSU Virtual Environment for Real-Time Exploration (VERTEX), which we use for the Virtual Environment. The density of vegetation in a realistic scenario required a level-of-detail (LOD) approach to limit the number of plants (represented as texture-mapped polygons) that were rendered in any single frame. We used the straightforward approach of distance from the virtual camera to filter which plants to draw in an individual scene. The discrete LOD works well and enables us to maintain an acceptable interactive frame rate of approximately 15 frames per second at a minimum. Screen shots such as the ones below and short video segments will be captured and placed on the project web page. Near-term efforts will continue to use subject-matter expertise and collected data to improve the realism of habitat complexity and incorporate plant changes and fish movement.

Task 7.1. Visualization of Invasive and Native Aquatic Plant Structure in the Littoral Zone Environment (Cont.)

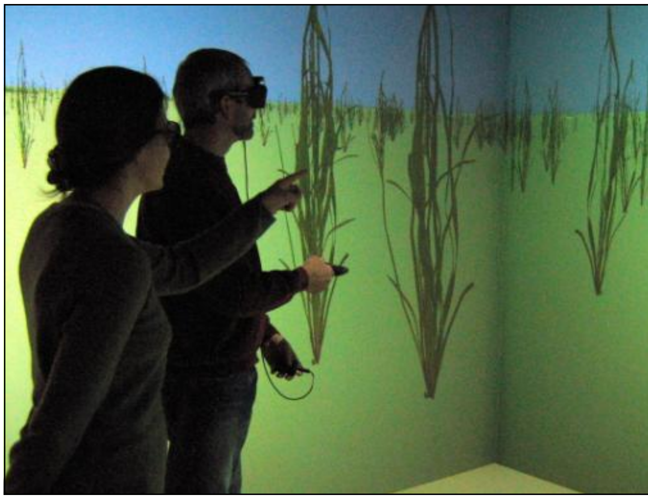


Figure 3. Researchers show plant life in the VERTEX, virtual environment facility.

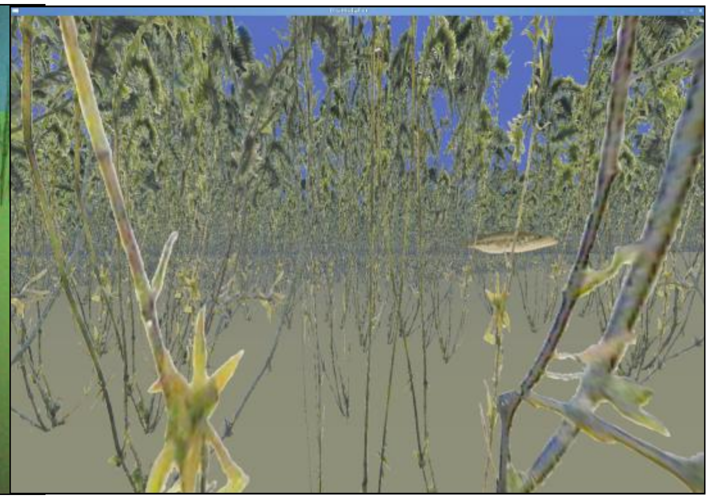


Figure 4. Representative image of an early version of the 3D waterscape (mature hydrilla infestation) in the VERTEX.

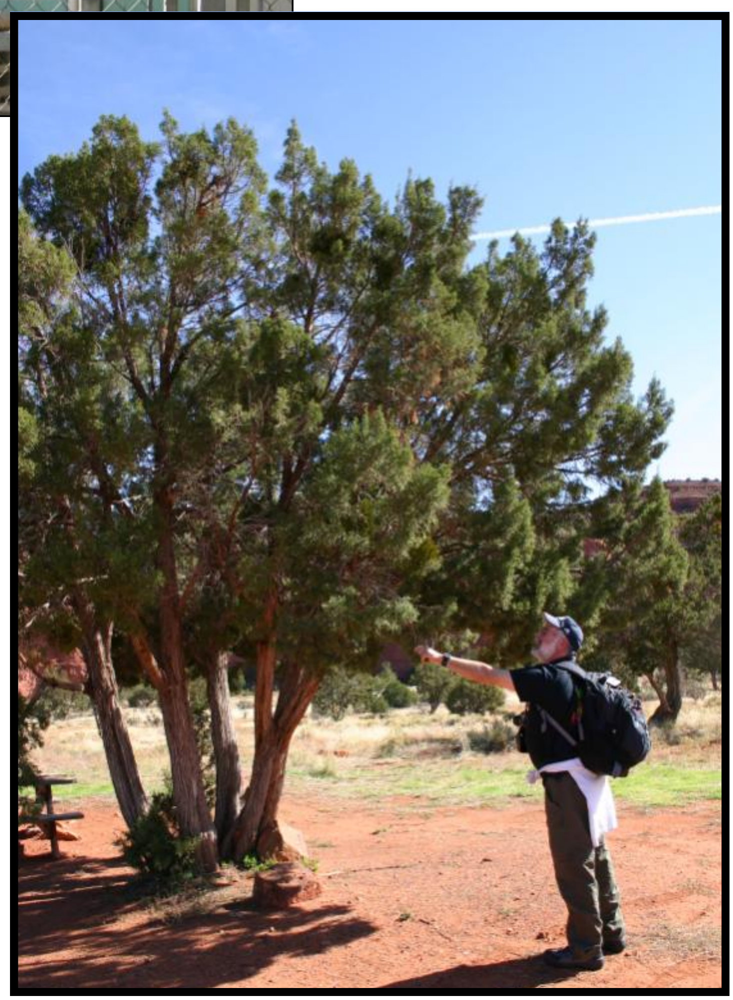
Table 1. Estimated plant density (number of plants per m^2) for a native plant community (green) and a mature hydrilla infestation (yellow) by water depth and growth form in a southern reservoir. *Ceratophyllum demersum* (coontail), *Potamogeton nodous* (American pondweed), *Najas sp*. (water najad), and *Vallisneria americana* (water celery) were identified from the literature as abundant, native species in southern reservoirs. *Hydrilla verticillata* is the primary invader of these systems.

		Native macrophyte community					Mature hydrilla infestation
		Ceratophyllum	*Potamogeton*	*Najas*	Vallisneria (ribbon)	*Vallisneria* (rosette)	*Hydrilla*
Water depth	**Growth form[1]**	**# of plants per m^2**					
0-1 m	Canopied	50	0	0	0	0	300
0-1 m	Topped-out	50	50	0	0	0	0
0-1 m	Submerged	0	0	10	0	0	0
1-3 m	Canopied	20	0	0	0	0	360
1-3 m	Topped-out	160	40	0	0	0	90
1-3 m	Submerged	20	10	150	250	0	0
3-6 m	Canopied	0	0	0	0	0	0
3-6 m	Topped-out	0	0	0	0	0	320
3-6 m	Submerged	50	50	400	250	250	80
> 6 m	Canopied	0	0	0	0	0	0
> 6 m	Topped-out	0	0	0	0	0	0
> 6 m	Submerged	0	0	10	0	10	50

[1]Growth form refers to plant biomass in the water column, “canopied” = plant reaches the top of the water and spreads laterally, “topped-out” = plant just reaches top of water, and “submerged” = plant does not reach water surface.

Task 8. Regional and National Collaboration

Dr. Wilfredo Robles, a graduate of Mississippi State University and participant in this research collaboration, is now an assistant professor at University of Puerto Rico-Mayaguez in weed science. Dr. Robles is collaborating with our group on several research projects. Photo by John Madsen.



Dr. Les Mehrhoff examining a juniper during a field trip in New Mexico in conjunction with an NBII all-node meeting in 2005. It is with great sadness that we reflect on the passing of our good friend and colleague during 2010. Les will be missed for his enthusiasm and dedication to the conservation of plant biodiversity and management of invasive plants.

Task 8.1. Collaborations

PI: Wes Burger
Co-PI: John Madsen, David Shaw

Collaboration Means Helping Others
John D. Madsen

When I was with the federal government, we would often use the phrase "I'm from the Government … and I'm here to help." While it was true, it was also such a cliché that many citizens grew skeptical.

Well, within the Geosystems Research Institute, we are from Mississippi State University, and whether it is working in research or extension, we are working to improve the management of invasive species. Usually, that means we are helping others with a specific project, while learning techniques or demonstrating procedures that are more widely applicable in the national effort to manage invasive species.

Figure 1. **Left**: Ervin, Varone, and Zamudio collecting *Opuntia* tissue near Ceibas, Agentina. **Center**: Brooks inspecting *C. cactorum* damage on a pad of *O. ficus-indica* collected near Concordia, Argentina. **Right**: Ervin found the cactus moth queen emerging form a cactus pad in downtown Buenos Aires.

I want to highlight some activities in the invasive species program in which Mississippi State University is helping federal, state, and local government agencies, nongovernment entities, and private citizens manage invasive species.

Figure 2. Participants in the desert plants field trip organized as part of the *Cactoblastis* symposium at the Entomological Society conference, San Diego, CA. From left: Stephen Hight (USDA-ARS), Rebecca Lee (NAPPO), Gary Ervin (MSU), Juan Cibrian Tovar (Colegio de Post-graduados, Mexico), Richard Brown (MSU), John Rebman (SDNHM), Christopher Brooks (MSU), James Carpenter (USDA-ARS), Guillermo Logarzo (USDA-ARS), Rebeca Gutiérrez Moreno (SENASICA-DGSV), Laura Varone (USDA-ARS), Faith Campbell (TNC).

International. Gary Ervin and Christopher Brooks traveled to Argentina and Uruguay during December 2010 to collection additional samples and information on geographic distribution and host associations of *C. cactorum*. They were guided on this trip by USDA-ARS scientist Laura Varone (South American Biological Control Lab, Argentina) and accompanied by Ph.D. student Paula Zamudio from the National University of Tucuman, Argentina (Figure 1). Zamudio is working on a comprehensive morphological study of the genus *Cactoblastis*, and Varone is the primary scientist investigating *C. cactorum* biology in its native range.

Gary Ervin, Christopher Brooks, and Richard Brown were invited participants in a symposium on *Cactoblastis cactorum* during the 2010 conference of the Entomological Society of America, in San Diego, CA. The symposium was organized by USDA-ARS scientists and included papers from scientists in MS, FL, GA, CA, and MD, as well as Canada, Mexico, Guatemala, and Argentina (Figure 2).

Task 8.1. Collaborations (Cont.)

Figure 3. Victor Maddox assisting USDA APHIS PPQ in surveying an old fort at the mouth of the Lower Pearl River in Louisiana, for prickly pear cactus and cactus moth. Photo by Maurice Duffel, USDA APHIS PPQ.

Federal. Throughout 2010, Dr. Victor Maddox assisted both Eastern and Western Regional staff of the USDA APHIS PPQ to survey for pricklypear cactus and cactus moth, ranging from the offshore islands of Mississippi to the marshlands of Louisiana and coastline of Texas (Figure 3). As part of that effort, he performed two workshops in Texas to train natural resource professionals to identify the cactus moth. If frequent driver miles were handed out to MSU employees, Victor would be platinum. Victor has been working with Maurice Duffel of USDA APHIS PPQ in the eastern region, and Robyn Rose and Ken Bloem of the western region. Richard Brown of the Department of Entomology has also been assisting APHIS with identifications of insect samples collected from traps throughout the eastern and western regions.

Figure 4. Sangmi Lee (left) receiving training from David Nicolson, Data Development Coordinator for ITIS, in using the TWB software.

Collaboration with the Butterflies and Moths of North America (BAMONA) project has resulted in export of data for 11,917 specimens to Thomas Naberhaus at the Big Sky Institute in Bozeman, Montana. These data of specimens in the Mississippi Entomological Museum represent distributions and dates of collection for specimens from 38 states and 188 counties. The sharing of specimen level data to BAMONA was complemented with a revision of the nomenclature of selected families of moths for the Integrated Taxonomic Information System (ITIS). Nomenclaturial names were edited and verified for all mandatory data fields for 3,434 species in eight families of Gelechioidea. Revised nomenclatorial data and data source information were exported to David Nicolson, Data Development Coordinator for ITIS (Figure 4).

Figure 5. Sangmi Lee (left) and Richard Brown with their demonstration of identification methods for exotic species at the CAPS Conference.

Dr. Richard Brown and Dr. Sangmi Lee (Figure 5) provided demonstrations and identification aids for the cactus moth and other exotic species of Lepidoptera at the National Conference of the Cooperative Agricultural Pests Survey (CAPS). More than 200 attendees from all states attended this conference.

State. While we worked during 2010 with state governments in Alabama, Louisiana, Minnesota, Mississippi, Montana, and others, our project with Idaho State Department of Idaho is typical. Idaho State Department of Agriculture (ISDA) is responsible for noxious weeds in all environments of the state.

Task 8.1. Collaborations (Cont.)

Idaho was facing a new invader, flowering rush, for which no use patterns and control programs have been demonstrated to be successful. We collaborated with ISDA to develop a scientifically-valid management study so they would qualify for ARRA funds available through the U.S. Army Corps of Engineers. Our proposal was successful, and GRI is now assisting ISDA in developing and testing some appropriate management approaches for this novel weed (Figure 6).

Figure 6. John Madsen applying herbicides to bare ground plots of flowering rush rhizomes at Pend Oreille Lake, Idaho in March 2011, with PJ Tabert of Idaho State Department of Agriculture (ISDA). Photo by Thomas Woolf, ISDA.

Local. Flowering rush (*Butomus umbellatus*) has been a significant nuisance to Detroit Lakes, Minnesota since the mid-1970's. As yet, they have not found a successful management approach. GRI researcher John Madsen is working with the Pelican River Watershed District, coordinated by Executive Director Tera Guetter, to better understand the ecology of flowering rush in the Detroit Lakes, and evaluate possible management techniques. We are partnering in our research with Dr. Michelle Marko of Concordia College, Moorhead, MN, and John Skogerboe of the U.S. Army Engineer Research and Development Center; and interacting with Minnesota Department of Natural Resources personnel in developing research and management plans (Figure 7).

Nongovernment Organization. John Madsen and Ryan Wersal of GRI work with a significant number of the manufacturers and distributors of aquatic herbicides to develop the use of their products for selective control of invasive plants (Figure 8). Over the past several years, GRI has worked with companies such as Applied Biochemists, BASF, Diversified Waterscapes, Inc., FMC, Helena, SePRO, Syngenta, United Phosphorus, Inc., and Valent. Most result in peer-reviewed papers, presentations, and reports; all result in a better understanding of the tools used to manage invasive aquatic plants. Many of these studies are performed through a Memorandum of Agreement with the Aquatic Ecosystem Restoration Foundation.

Figure 7. (Left) Kristine Williams, undergraduate student at Concordia College, Moorhead, MN, taking sediment samples during our survey of the Detroit Lakes, MN, in 2010.

Figure 8. (Right) Ryan Wersal planting a study on the tolerance of a native plant to aquatic herbicides. If our goal is to selectively manage invasive aquatic plants, we need to know not only the efficacy of the herbicide on the target plant, but the tolerance of desirable and/or significant native plants to the herbi-

Task 9. Coordination and Reporting

Big Bend region of Texas has both invasive plants, giant reed (*Arundo donax*) along the Rio Grande River, and pricklypear cactus in the foreground, the host of the cactus moth. GRI has been working with volunteers and professionals in Texas on both issues. Photo by Victor Maddox.

Ryan Wersal (left) being quizzed on his poster presentation by an unidentified participant at a regional Southeast Exotic Pest Plant Council conference. Photo by John Madsen.

Task 9.1. Coordination

Cliff Abbott provided a short presentation to the Organization of Fish and Wildlife Information Managers, Cadiz, KY on Oct 19, 2010.

Cliff Abbott attended training on the Global Invasive Species Information Network at the NAISN Meeting, Boise, ID on Nov 15-17, 2010.

Richard Brown and **Sangmi Lee** attended the Cooperative Agricultural Pests Survey (CAPS) National Conference, December 1-3, 2010 and provided demonstrations and identification aids for the cactus moth and other exotic species of Lepidoptera. More than 200 attendees from all states attended this conference

Sangmi Lee (left) and Richard Brown with their demonstration of identification methods for exotic species at the CAPS Conference.

Richard Brown collaborated with Maurice Duffel, USDA-APHIS, to provide identifications of cactus moths captured after initiation of SIT trials on Barrier Islands of Mississippi.

Collaborative Research: Molecular mechanisms of reciprocal recognition and response in plant-herbivore interactions - defense and counterdefense in cactus-cactus moth systems
NSF Symbiosis, Defense, and Self-recognition Program (BIO)
G. N. Ervin, B. A. Counterman, **M. E. Welch**, **L. E. Wallace**, and **C. P. Brooks**.
This proposal was a collaboration with T. D. Marsico at Arkansas State University. It was not funded.

Collaborative Research: Magnolia grandiFLORA: A digital herbarium of collections in Mississippi
NSF Improvements to Biological Research Collections (BRC)
Wallace, L. E., G. N. Ervin, C. P. Brooks.
This proposal is a collaboration with the director of the Mississippi State University herbarium, and several other herbaria throughout Mississippi. The project would result in a publicly available database of herbarium collections across the state, including digital photographs and a single interface that would provide access to all eight major collections.

Assessing local adaptation and reproductive isolation among phylogenetic groups of *Cactoblastis cactorum* in northern Argentina
NSF Population and Community Ecology Program (DEB)
Brooks, C. P. and **G. N. Ervin**. $540,877.
This proposal is a collaboration with USDA-ARS scientists in Tifton, GA, Tallahassee, FL, and Buenos Aires, Argentina. The project would result in experimental work to identify factors responsible for observed genetic population structure in the native range of the invasive cactus moth.

Gary Ervin, **Christopher Brooks**, and **Richard Brown** were invited participants in a symposium on *Cactoblastis cactorum* during the 2010 conference of the Entomological Society of America, in San Diego, CA. The symposium was organized by USDA-ARS scientists and included papers from scientists in MS, FL, GA, CA, and MD, as well as Canada, Mexico, Guatemala, and Argentina.

Gary Ervin and **Christopher Brooks** traveled to Argentina and Uruguay during December 2010 to collect additional samples and information on geographic distribution and host associations of *C. cactorum*. They were guided on this trip by USDA-ARS scientist Laura Varone (South American Biological Control Lab, Argentina) and accompanied by Ph.D. student Paula Zamudio from the National University of Tucuman, Argentina. Za-

Task 9.1. Coordination (Cont.)

Seeing double, or deploying the fleet? Two boats from Mississippi State University were in use at Detroit Lake, Minnesota for sampling in association with the flowering rush research project. Students from Concordia College, Moorhead, MN assisted staff of Mississippi State University in this study.

mudio is working on a comprehensive morphological study of the genus *Cactoblastis*, and Varone is the primary scientist investigating *C. cactorum* biology in its native range.

Victor Maddox attended the Tennessee Invasive Plant Steering (TIPS) meeting. 14 Jan 2010. Ed Jones Auditorium, Ellington Agricultural Center, Nashville, TN.

Victor Maddox attended the Southern Weeds Sciences meeting (Weed ID committee). 24-27 Jan 2010. The Peabody Little Rock, Little Rock, AR.

Victor Maddox participated in cactus moth survey with USDA-APHIS on Mississippi Barrier Islands, 1-3 Feb 2010.

Victor Maddox attended the Mississippi Cooperative Weed Management Area Board Meeting, 10 Feb 2010, MS Farm Bureau Board Room, Jackson, MS.

Victor Maddox participated in cactus moth survey with USDA-APHIS on Mississippi Barrier Islands, 9-12 Mar 2010.

Victor Maddox attended the Mississippi Cooperative Weed Management Area Board Meeting, 15 Apr 2010, MS Farm Bureau Board Room, Jackson, MS.

Victor Maddox attended the Alabama Invasive Plant Conference (ALIPC). 20-22 Apr 2010. Auburn Hotel, Auburn, AL.

Victor Maddox participated in Cogongrass Teleconference between Southeastern States to develop a white paper. 12 May 2010. Bureau of Plant Industry Building, Mississippi State, MS.

Victor Maddox participated in Cooperative Agricultural Pest Survey meeting. 20 May 2010. Bureau of Plant Industry Building, Mississippi State, MS.

Victor Maddox provided a five-minute MSU cactus moth project update during a USDA teleconference hosted by USDA-APHIS on 24 May 2010 for the United States and Mexico.

Victor Maddox attended Mississippi Exotic Pest Plant Council meeting. 2 June 2010. Engineer Research and Development Center, Vicksburg, MS.

Victor Maddox provided MSU cactus moth survey update for USDA-APHIS, Pensacola, FL, for 5-9 July 2010 Cactus Moth Program weekly activity report.

Victor Maddox provided MSU cactus moth survey update for USDA-APHIS, Pensacola, FL, for 9-13 July 2010 Cactus Moth Program weekly activity report.

Victor Maddox attended the MS Cooperative Weed Management Area (CWMA) Board Meeting, 15 July 2010, MS Farm Bureau Board Room, Jackson, MS.

Victor Maddox provided a short workshop on the Cactus Moth Detection and Monitoring Network for the Fish

Task 9.1. Coordination (Cont.)

and Wildlife Service in Austwell, TX on 20 July 2010.

Victor Maddox provided a five-minute MSU cactus moth project update during a USDA teleconference hosted by USDA-APHIS on 4 August 2010.

Victor Maddox "How big is pricklypear in Texas." Article invited and provided to USDA-APHIS, Pensacola, FL, for the 9-13 August 2010 Cactus Moth Program weekly activity report.

Victor Maddox provided MSU cactus moth survey update for USDA-APHIS, Pensacola, FL, for 30 August to 3 September 2010 Cactus Moth Program weekly activity report.

Victor Maddox participated in cactus moth survey with USDA-APHIS on Mississippi Barrier Islands, 13-15 September 2010.

Victor Maddox exhibited a MS CWMA booth at the Southeastern Association of RC&D Councils meeting, September 22-25, 2010, at the Beau Rivage, Biloxi, Mississippi.

Victor Maddox provided a five-minute MSU cactus moth project update during a USDA teleconference hosted by USDA-APHIS on 5 Oct 2010.

Victor Maddox attended the Mississippi Cooperative Weed Management Area Board Meeting, 21 Oct 2010, MS Farm Bureau Board Room, Jackson, MS.

Victor Maddox attended the Fall Mississippi Exotic Pest Plant Council Meeting. 3 Nov 2010. Mississippi Department of Transportation Office, Hattiesburg, MS.

Poppy Welch (left, ISDA), Joshua Cheshier (center, GRI), and Tom Woolf (right, ISDA) look at flowering rush colonies in Pend Oreille Lake, Idaho, as part of an ARRA research project.

Victor Maddox provided a workshop on the Cactus Moth Detection and Monitoring Network for the Texas Parks and Wildlife Department in La Grange, TX on 2 Dec 2010.

Victor Maddox provided a workshop on the Cactus Moth Detection and Monitoring Network for the Texas Parks and Wildlife Department in Pleasanton, TX on 3 Dec 2010.

John Madsen represented the Aquatic Plant Management Society on the Board of Representatives of the Council for Agricultural Science and Technology, and was chair of the Plant Science and Environment working group through October 2010.

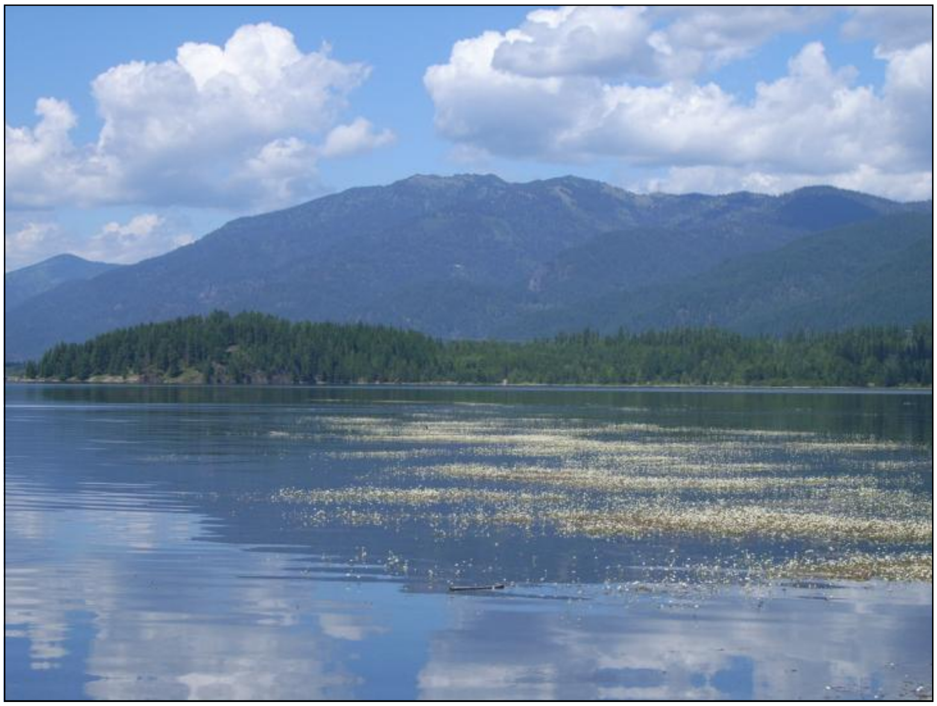
John Madsen attended a working group meeting on the ecology and control of flowering rush at the Minnesota Department of Natural Resources offices in St. Paul, MN from January 27-29, 2010.

Task 9.1. Coordination (Cont.)

John Madsen was on the evaluation panel for 2010 TSTAR proposals, for the USDA TSTAR program and the University of Florida.

John Madsen served on the Lake Gaston (VA and NC) Weed Control Technical Advisory Committee, chaired by Robert Richardson of North Carolina State University.

John Madsen, Victor Maddox, Cliff Abbott, and **Gary Ervin** participated (in turn) on the Invasive Species Working Group teleconferences.



The native plant white watercrowfoot flowers in 2010, where Eurasian watermilfoil dominated in 2009 before a control demonstration project on Noxon Rapids Reservoir, Montana.

John Madsen and **Ryan Wersal** have been working with the Pearl River Valley Water Supply District in assessing their invasive plant program on Ross Barnett Reservoir near Jackson, MS.

John Madsen and **Joshua Cheshier** worked with the Pelican River Watershed District in developing an ecology and management study of flowering rush on the Detroit Lakes system, in conjunction with Dr. Michelle Marko and her students of Concordia College, Moorhead, MN. They have been working with Tera Guetter of the PRWD.

John Madsen, Ryan Wersal, and **Joshua Cheshier** have been working with Thomas Woolf of the Idaho State Department of Agriculture on a USACE-funded ARRA project to control flowering rush in Pend Oreille Lake, ID (Fig 3).

John Madsen and **Ryan Wersal** have been working with John Halpop and Sanders County, MT on a USACE-funded ARRA project on the control of Eurasian watermilfoil in western Montana.

John Madsen and **Ryan Wersal** have been working with Dr. Kurt Getsinger of the US Army Engineer Research and Development Center (Vicksburg, MS) on a Eurasian watermilfoil management program for Noxon Rapids Reservoir, Idaho; in conjunction with the Eurasian watermilfoil Task Force and Brian Burky of Avista.

John Madsen and **Ryan Wersal**, along with several other experts, presented at an extension and outreach workshop sponsored by the Eurasian watermilfoil task force and Montana State University Extension Service at Trout Creek, MT on July 26, 2010.

John Madsen provided a presentation to the Central Arizona Project on aquatic weed control for Lake Havasu, AZ/CA.

John Madsen is representing Mississippi State University and the Geosystems Research Institute on the board of the North American Invasive Species Network.

Publications

Peer-Reviewed Journals

Bried, J. T. and **G. N. Ervin.** 2010. Randomized intervention analysis for detecting non-random change and management impact: Dragonfly examples. Ecological Indicators 11: 535-539.

Robles, W., Madsen, J. D., & **Wersal, R. M.** (2010). Potential for Remote Sensing to Detect and Predict Herbicide Injury on Waterhyacinth (*Eichhornia crassipes*). Invasive Plant Science and Management. 3, 440-450.

Bryson, C. T., Krutz, L. J., **Ervin, G. N.,** Reddy, K. N., & **Byrd, J. D., Jr**. (2010). Ecotype Variability and Edaphic Characteristics for Cogongrass (*Imperata cylindrica*) Populations in Mississippi. Invasive Plant Science and Management. 3, 199-207.

Marsico, T. D., **L. E. Wallace, G. N. Ervin, C. P. Brooks**, J. E. McClure, and **M. E. Welch.** 2010. Geographic patterns of genetic diversity from the native range of *Cactoblastis cactorum* (Berg) support the documented history of invasion and multiple introductions for invasive populations. Biological Invasions DOI: 10.1007/s10530-010-9874-9

Wersal, R. M., Madsen, J. D., Woolf, T. E., & Eckberg, N. (2010). Assessment of herbicide efficacy on Eurasian watermilfoil and impacts to the native submersed plant community in Hayden Lake, Idaho, USA. Journal of Aquatic Plant Management. 48, 5-11.

Wersal, R. M., & Madsen, J. D. (2010). Combinations of penoxsulam and diquat as foliar applications for control of waterhyacinth and common salvinia: Evidence of herbicide antagonism. Journal of Aquatic Plant Management. 48, 21-25.

Wersal, R. M., Madsen, J. D., Massey, J. H., **Robles, W.,** & **Cheshier, J.** (2010). Comparison of daytime and night-time applications of diquat and carfentrazone-ethyl for control of parrotfeather and Eurasian watermilfoil. Journal of Aquatic Plant Management. 48, 56-58.

Maddox, V. L., Byrd, J., & Serviss, B. 2010. Identification and Control of Invasive Privets (*Ligustrum* spp.) in the Middle Southern United States. Invasive Plant Science and Management. 3, 482-488.

Presentations

Ervin, G. N. 2010. Patrones en la diversidad de especies exóticas y aplicaciones para programas de monitoreo. 31st Congress of the Mexican Weed Science Association, Cancún, México, November 10, 2010. (presentation given in Spanish)

Brooks, C., & Ervin, G. N. (2010). Genetic Diversity of *Cactoblastis cactorum* in the Moth's Native Range and Implications for Future Spread. Entomological Society of America Annual Conference. San Diego, CA.

Brown, R.L & Lee, S. Adult Lepidoptera Screening & Identification. National Cooperative Agricultual Pest Survey (CAPS) Conference. Kansas City, MO.

Simonsen, T., **Brown, R.,** & Sperling, F. Evolution of cactus feeding in Pyralidae and phylogeography of Cactoblastis cactorum in the southeastern United States. 58th Annual Meeting of the Entomological Society of America. San Diego, CA.

Maddox, V. L., & Byrd, J. D. (2010). Shoot Control of Running Bamboos using Glyphosate. Natural Areas Association Conference. Tan-Tar-A Resort, Osage Beach, MO: Natural Areas Association.

Abbott, C. F. (2010). The Invasive Plant Atlas of the MidSouth and the Cactus Moth Detection and Monitoring Network: Keeping Up With Technology. The Organization of Fish and Wildlife Information Managers 2010 Conference. Cadiz, KY: The Organization of Fish and Wildlife Information Managers.

Madsen, J. D. (2010). Site-specific management of aquatic weeds. Weed Science Society of America and the Society of Range Management Joint Meeting. Denver, CO.

Madsen, J. D., & Ervin, G. N. (2010). An update on the Invasive Species Atlas of the MidSouth. Weed Science Society of America and the Society of Range Management Joint Meeting. Denver, CO.

Prince, J. M., **Madsen, J. D., Shaw, D. R., & Brooks, C. P.** (2010). Predicting Habitat for Eurasian Watermilfoil with Mahalanobis Distance Methods. Weed Science Society of America Abstracts. Denver, CO.

Prince, J. M., **Madsen, J. D., Shaw, D. R., & Brooks, C. P.** (2010). Presence-only Methods for Predication of Eurasian Watermilfoil Habitat. Proceedings of the Southern Weed Science Society. Little Rock, AR.

Madsen, J. D., & Ervin, G. N. (2010). An update on the Invasive Plant Atlas of the MidSouth project. Southern Weed Science Society Annual Meeting. Little Rock, AR.

Madsen, J. D., Cheshier, J., Marko, M., & Guetter, T. (2010). Ecology and Management of Flowering Rush in the Detroit Lakes Chain. 2010 Minnesota-Wisconsin Invasive Species Conference. St. Paul, MN.

Fleming, J. P., Madsen, J. D., & Dibble, E. D. (2010). Using Deductive GIS Modeling Tools to Locate Suitable Macrophyte Habitat for Re-establishment Projects. Midsouth Aquatic Plant Management Society 29th Annual Meeting. Guntersville, AL.

Brooks, C. P., & **Ervin, G. N.** (2010). The global invasion of *Cactoblastis cactorum* (Berg). Ecological Society of America annual conference. Pittsburg, PA.

Marsico, T. D., Woodard, A. M., & **Ervin, G. N.** (2010). Novel defenses in invasion resistance: Potential eavesdropping may cue inducible defenses against an invasive herbivore. Ecological Society of America annual conference. Pittsburg, PA.

Cox, M. C., Wersal, R. M., & Madsen, J. D. (2010). Evaluation of Alligatorweed (*Alternanthera philoxeroides* [Mart.] Griseb.) Control with Nine Different Herbicides. Aquatic Plant Management Society 50th Annual Meeting. Bonita Springs, FL.

Madsen, J. D., Cheshier, J., Phuntumart, V. P., Thum, R. A., & **Welch, M. E.** (2010). Morphological and Genetic Taxonomic Analysis of Native and Nonnative Watermilfoil in Reservoirs of the Lower Clark Fork River System. Aquatic Plant Management Society 50th Annual Meeting. Bonita Springs, FL.

Fleming, J. P., Madsen, J. D., & Dibble, E. D. (2010). Using Deductive GIS Modeling Tools to Locate Suitable Macrophyte Habitat for Re-establishment Projects. Aquatic Plant Management Society 50th Annual Meeting. Bonita Springs, FL.

Madsen, J. D. (2010). What Challenges Lie Ahead for Hydrilla Management? Aquatic Plant Management Society 50th Annual Meeting. Bonita Springs, FL.

Cox, M. C., Madsen, J. D., & Wersal, R. M. (2010). Hydrilla and Giant Salvinia Survey in Mississippi for 2009. Aquatic Plant Management Society 50th Annual Meeting. Bonita Springs, FL.

Fleming, J. P., Madsen, J. D., & Dibble, E. D. (2010). Establishing Aquatic Macrophytes as Self-renewing Fish Habitat in Little Bear Creek Reservoir, Alabama. Southern Division of the American Fisheries Society 2010 Meeting. Asheville, NC.

Ervin, G. N., Brooks, C. P., & Alarcon, V. J. (2010). Exploring biologically relevant buffer zones for aquatic and wetland ecosystems in northern Mississippi. Proceedings of the Mississippi Water Resources Conference. Tunica, MS.

Fleming, J. P., Madsen, J. D., & Dibble, E. D. (2010). Identifying Macrophyte Habitat with Deductive GIS Modeling: A Tool for Aquatic Resource Managers. Mississippi Chapter of the American Fisheries Society 36th Annual Meeting. Vicksburg, MS.

Marsico, T. D., **Woodard, A. M., & Ervin, G. N.** (2010). Potential Eavesdropping May Cue Inducible Defenses Against an Invasive Herbivore. Entomological Society of America Annual Conference. San Diego, CA.

Madsen, J. D., & Ervin, G. N. (2010). An update on the Invasive Plant Atlas of the MidSouth. Weeds Across Borders 2010. Sheperdstown, WV.

Ervin, G. N. (2010). Mississippi's noteworthy exotic plant species: Final draft list for comment. Southeastern Exotic Pest Plant Council - Southeastern chapter of the Society for Ecological Restoration, International, Joint Conference. Chattanooga, TN.

Articles in Trade Journals and Popular Press

Maddox, V. L. (2010). How Big is Pricklypear in Texas? August 2010 Cactus Moth Program Weekly Activity Report. USDA-APHIS, Pensacola, FL.

Maddox, V. L. (2010). Prioritizing invasive weeds on Mississippi and Louisiana golf courses. Tee to Green. Louisiana-Mississippi Chapter of the GCSAA. Spring 2010, 10.

Maddox, V. L. (2010). Cooperative Weed Management Area (CWMA). Tee to Green. Louisiana-Mississippi Chapter of the GCSAA. Spring 2010, 3.

Ervin, G. N. (2010). Anthropogenic dispersal corridors override large-scale natural disturbance in determining distribution of a widespread invasive grass (*Imperata cylindrica*). Weeds Across Borders. National conservation Training Center, Shepherdstown, WV.

Lucardi, R. L., Bryson, C. T., Wallace, L. E., & Ervin, G. N. (2010). Assessing genetic diversity in a model invasive species: cogongrass (*Imperata cylindrica*) in the southeastern U.S. Southeastern Exotic Pest Plant Council - Southeastern chapter of the Society for Ecological Restoration, International, Joint Conference. Chattanooga, TN.

Ervin, G. N. (2010). Getting the jump on invasives: Considerations during habitat management and restoration. Southeastern Exotic Pest Plant Council - Southeastern chapter of the Society for Ecological Restoration, International, Joint Conference. Chattanooga, TN.

In-House

Wersal, R. M., Madsen, J. D., & Cheshier, J. (2010). Aquatic Plant Monitoring In Noxon Rapids Reservoir and Cabinet Gorge Reservoir for 2010. Mississippi State University: Geosystems Research Institute Report 5042. 18.

Cox, M. C., & Madsen, J. D. (2010). 2010 Mississippi Survey for Hydrilla and Giant Salvinia. GRI Report # 5043. Mississippi State University: Geosystems Research Institute. 12.

Madsen, J. D., Brown, R. L., Ervin, G. N., Shaw, D. R., Abbott, C. F., Maddox, V. L., Wersal, R. M., McBride, D. W., & Madsen, N. (2010). Research to Support Integrated Management Systems of Aquatic and Terrestrial Invasive Species. GRI#5039. Mississippi State University: Geosystems Research Institute. 41.

Cox, M. C., Madsen, J. D., & Wersal, R. M. (2010). Aquatic Plant Community Assessment within the Littoral Zone of the Ross Barnett Reservoir, MS in 2009: A Five Year Evaluation. GRI Report 5038. Mississippi State University: Geosystems Research Institute.

Cox, M. C., Madsen, J. D., & Wersal, R. M. (2010). Hydrilla and Giant Salvinia Survey in Mississippi for 2009. GRI Report 5037. Mississippi State University: Geosystems Research Institute. 13.

Fleming, J. P., Madsen, J. D., & Dibble, E. D. (2010). Establishment of Submersed Aquatic Vegetation in Little Bear Creek Reservoir 2007-2009. Geosystems Research Institute Report 4007. Mississippi State University: Geosystems Research Institute. 15.

Technical Report

Maddox, V. L., & Kelly, L. S. (2010). Selecting Landscape Shrubs with Special Comments on Native and Invasive Plants. Mississippi State University: MSU Extension Service.

Madsen, J. D., Wersal, R. M., Getsinger, K. D., & Skogerboe, J. G. (2010). Combinations of Endothall with 2,4-D and Triclopyr for Eurasian Watermilfoil Control. APCRP Technical Notes Collection (ERDC/TN APCRP -CC-14). Vicksburg, MS: U.S. Army Engineer Research and Development Center.

Professional Presentations

Maddox, V. L. (2010). Cactus Moth Detection and Monitoring Network Workshop: Texas Parks and Wildlife Department. Texas Parks and Wildlife Department Office, Pleasanton, TX.

Maddox, V. L. (2010). Cactus Moth Detection and Monitoring Network. Texas Parks and Wildlife Department Office, La Grange, TX.

Wersal, R. M. (2010). Aquatic weed control research update. Mississippi Vegetation Management Association Annual Meeting. Jackson, MS.

Maddox, V. L. (2010). Identifying the IPAMS Species: Part 1 and Part 2. Mississippi Department of Transportation Office. Hattiesburg, MS: Fall Mississippi Exotic Pest Plant Council Meeting.

Maddox, V. L. (2010). Plant Identification and Invasive Species Information. Truck Crops Branch Experiment Station, Crystal Springs, MS: 32nd Annual Fall Flower and Garden and Flower Fest.

Ervin, G. N. (2010). North Meets South Meets North Again: A Global Series of Species Introductions. Department of Biological Sciences, University of Alabama, Tuscaloosa, AL..

Ervin, G. N. (2010). Ecological genetics of the cactus moth *Cactoblastis cactorum* at home and abroad. US Geological Survey National Biological Information Infrastructure Invasive Species Working Group teleconference.

Maddox, V. L. (2010). Cactus Moth Detection and Monitoring Network Workshop: Fish and Wildlife Service. Aransas National Wildlife Refuge, Austwell, TX.

Maddox, V. L. (2010). Southwest Mississippi Invasive Plant Species. Master Gardener Meeting, Pike County Fairgrounds, McComb, MS.

Maddox, V. L. (2010). Southwest Mississippi Invasive Plant Species. Pike County Landowners Meeting, Pike County Fairgrounds, McComb, MS.

Madsen, J. D. (2010). The Invasive Plant Atlas of the MidSouth Project. Greater Noxubee Wildlife Management Cooperative Meeting. Noxubee National Wildlife Refuge, MS.

Woodard, A. M., Marsico, T. D., **& Ervin, G. N.** (2010). Evaluating Differential Defense Response In Two Native Cactus Species. Mississippi State University Biology Undergraduate Research Symposium. Mississippi State University.

Madsen, J. D. (2010). Aquatic Plant Assessment of the Ross Barnett Reservoir in 2009: A Five Year Evaluation. Board of Directors Meeting, Pearl River Water Supply District. Jackson, MS.

Maddox, V. L. (2010). Invasive weeds of turf and ornamentals in the MidSouth. BWI Turf and Landscape Seminar, Whispering Woods Hotel and Conference Center, Southaven, MS.

Maddox, V. L. (2010). Invasive Plant Atlas of the MidSouth Volunteer Training Workshop. Lafayette County Extension Office, Oxford, Biloxi, MS.

Madsen, J. D. (2010). Invasive species programs at the Geosystems Research Institute. Mississippi State University: Geosystems Research Institute Seminar Series.

Maddox, V. L. (2010). Invasive Plant Atlas of the MidSouth Volunteer Training Workshop (Videoconference). Bost Extension Center, Mississippi State, MS.

Madsen, J. D., & Ervin, G. N. (2010). An Update on the Invasive Plant Atlas of the MidSouth Project. Invasive Species Working Group Teleconference. National Biological Information Infrastructure: Invasive Species Information Node.]

Ervin, G. N. (2010). Invasive species research at Mississippi State University. Soil and Water Conservation Society, MSU Chapter. Mississippi State University.

Maddox, V. L. (2010). Plant identification and invasive species information.. Mississippi Trade Mart. Jackson, MS: 13th Annual Jackson Garden and Patio Show.

Maddox, V. L. (2010). Invasive species information and plant identification.. Lake Terrace Convention Center, Hattiesburg, MS: 5th Hattiesburg Garden and Patio Show.

Maddox, V. L. (2010). IPAMS Invasive plant species. Mississippi State University. Starkville, MS: Weed Biology and Ecology Greenhouse 104.

Maddox, V. L. (2010). Invasive Species Identification and Management... Mississippi Horse Park, Starkville, MS: Everything Garden Expo.

Maddox, V. L. (2010). Identification of invasive and other plant species. Mississippi Coast Coliseum, Biloxi, MS: 2010 Gulf Coast Garden and Patio Show.

Marsico, T. D., **Ervin, G. N., Brooks, C. P.,** Counterman, B. A., **Wallace, L. E., & Welch, M. E.** (2010). Using next-generation sequencing approaches to investigate reciprocal recognition and response in plant-herbivore interactions. MidSouth Computational Biology and Bioinformatics Society, 7th annual conference. Arkansas State University, Jonesboro, AR.

Madsen, J. D. (2010). Council for Agricultural Science and Technology. Current Topics. Mississippi State University: Plant and Soil Science Department.

Madsen, J. D. (2010). Considerations of the use of herbicides to control the emergent and submersed phases of flowering rush. Flowering Rush Workshop. St Paul, MN: Minnesota Department of Natural Resources.

Madsen, J. D. (2010). Developing GIS-based invasive species programs: From red-necks to remote sensing, terabyte servers, and parallel computing. National Biological Information Infrastructure, Biogeospatial Working Group Seminar,. U.S. Geological Survey, Reston, VA..

Maddox, V. L. (2010). Invasive plant species affecting golf courses. Louisiana-Mississippi Golf Course Superintendents Association of America, Brookhaven Country Club, Brookhaven, MS.

Awards and Recognitions

Wersal, R. M. 2010 Centers and Institutes Research Support Staff Award. Mississippi State University.

Fleming, J. P. (2010). Ernest A. Gluesing Memorial Award for Outstanding Graduate Student. Department of Wildlife, Fisheries and Aquaculture. Mississippi State University.

Fleming, J. P. (2010). Identifying Macrophyte Habitat with Deductive GIS Modeling: A Tool for Aquatic Resource Managers. 2nd Place Student Presentation Award. Vicksburg, MS: Mississippi Chapter of the American Fisheries Society 36th Annual Meeting.

Thesis and Dissertation

Cheshier, J.C. (2010). The Biology, Ecology and Management of Common Reed [*Phragmites australis* (Cav.) Trin. Ex. Steudel]. Master's Thesis. Mississippi State University: Department of Plant and Soil Science.

Fleming, J. P. (2010). Macrophyte Re-establishment and deductive GIS modeling to identify planting locations for fish habitat enhancement projects. Master's Thesis. Mississippi State University: Department of Wildlife, Fisheries and Aquaculture.

Hughes, S. C. (2011). Analysis of conservation practices in the Blackland Prairie region of Mississippi and construction of a predictor for locating new sites for conservation efforts. Master’s thesis, accepted December 2010.

Wersal, R. M. (2010). The Conceptual Ecology and Management of Parrotfeather (*Myriophyllum aquaticum* (Vell.) Verdc.). Starkville, MS: Mississippi State University.