Estimation of Alligatorweed (*Alternanthera philoxeroides* (Mart.) Griseb.) and Waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) Distribution in the Ross Barnett Reservoir using Remote Sensing Techniques

A Report to the Pearl River Valley Water Supply District

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Geosystems Research Institute Report 5045
February 7, 2011

MISSISSIPPI STATE UNIVERSITY

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INTRODUCTION

Nonindigenous plant species introduced into aquatic and riparian systems can reduce water quality, hinder navigation and recreational uses, clog irrigation canals, reduce species diversity, harbor pathogen-carrying insects, and decrease property values (Pimentel et al. 2004, Rockwell 2003). Alligatorweed (*Alternanthera philoxeroides* (Mart.) Griseb.) is an emergent, aquatic plant native to South America (Vogt et al. 1979). Hollow stems that produce adventitious roots at the node allow this plant to form extensive, floating mats of vegetation along shorelines that may extend several meters out into waterways. Alligatorweed may disperse great distances via fragmentation of vegetative structures or from mats of stems that have broken away from parent populations and floated downstream to establish in available substrate material (Spencer and Coulson 1976). Waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) is a floating, aquatic plant also native to South America. It is a nuisance plant in subtropical and tropical regions around the world where it may double its population size in under a month due to its vigorous growth habit (Madsen et al. 1993). It reproduces by the production of stolons that give rise to rametes, or daughter plants (Owens and Madsen 1995).

Remote sensing techniques are a useful tool in assessing and managing aquatic and riparian areas (Carter 1982, Tiner 1997). In order to properly manage-eradicate invasive plant species, an early detection and rapid response program is an absolute priority (Madsen 2007, Westbrook 2003). Previous experiments have utilized aerial photography to distinguish plant species and populations in wetland ecosystems (Seher and Tueller 1973, Howland 1980, Carter 1982, Martyn 1985). Everitt and others (1999) used aerial videography and global positioning systems (GPS) to map the distribution of waterhyacinth and hydrilla (*Hydrilla verticillata* L.f. Royle) in waterways of southern Texas. Similar techniques were also utilized to estimate waterhyacinth distribution and assess management strategies in Lake Victoria, Africa (Albright et al. 2004).

OBJECTIVE

The objective was to 1) estimate the coverage of alligatorweed and waterhyacinth in the Ross Barnett Reservoir using aerial or satellite imagery.

MATERIALS AND METHODS

National Agriculture Imagery Program (NAIP) aerial acquired imagery, with a 1 meter (m) spatial resolution, was utilized to conduct this study. A Digital Ortho Quarter Quad (DOQQ) of the Ross Barnett Reservoir near Jackson, MS was obtained from archives containing

2007 and 2009 data. The spectral resolution of the acquired imagery was natural color, or RGB. The DOQQ was imported into ArcMap™ Version 9.3.1 (ESRI, Redlands, CA 92373-8100) and overlaid with point-intercept survey (Madsen 1999) data taken in the summers of 2007 (Wersal et al. 2008) and 2009 (Cox et al. 2010) on a 300 m grid system at the Ross Barnett Reservoir. This point-intercept data was recorded in Farm Works® Site Mate software version 11.4 (Farm Works, Hamilton, Indiana 46742) by creating a pick-list of all aquatic plant species in the Reservoir and indicating their presence with a "1" or absence with a "0" at each point. A 300 m grid was created in ArcMap™ and laid on top of the NAIP imagery for identifying and grouping the pixels using a supervised classification method based on similar reflectance and visual color. Any pixel containing a ground-truth point from a point intercept survey was labeled according to the species recorded as present at that location. Each surveyed point covers approximately 9 hectares (ha) based on the calculation that each point covers one pixel on the 300 meter grid (90,000 m^2 or 9 ha). Due to variables that alter surveying abilities such as scattered and hidden populations of plants, water depth, and dense plant populations, the assumption was made that a pixel contains more individual plants than just at the surveyed location.

Seven classes were created to classify the imagery pixels based on plant species or land use cover: **AW Mix** – alligatorweed mix; **AW/WH Mix** – alligatorweed/waterhyacinth mix; **WH Mix** – waterhyacinth mix; **FES Mix** –floating, emergent, and/or submersed species mix; **LOT** – American lotus; **OW** – open water; and **LM** – land mass (Table 1).

RESULTS AND DISCUSSION

The open water (OW) class had the highest frequency of occurrence (total number of pixels) or surface area coverage in 2007 and 2009; which is consistent with the observation that the largest portion of the Ross Barnett Reservoir is the middle lake and is predominately deeper water (depths of > 3 m) that is not favorable for plant growth. In 2007, all classes yielded the following pixel occurrences in order from highest to lowest: open water (OW) – 972 (8732 ha), land mass (LM) – 239 (2147 ha), floating/emergent/submersed mix (FES Mix) – 200 (1797 ha), American lotus (LOT) – 153 (1375 ha), alligatorweed mix (AW Mix) – 15 (135 ha), waterhyacinth mix (WH Mix) – 6 (54 ha), and alligatorweed/waterhyacinth mix (AW/WH Mix) – 3 (27 ha) (Table 1, Figure 1). In 2009, the data was as follows: open water (OW) – 972 (8732 ha), land mass (LM) – 251 (2255 ha), floating/emergent/submersed mix (FES Mix) – 201 (1806 ha), American lotus (LOT) – 154 (1384 ha), alligatorweed mix (AW Mix) – 24 (216 ha), alligatorweed/waterhyacinth mix (AW/WH Mix) – 11 (99 ha), and waterhyacinth mix (WH Mix) – 8 (72 ha) (Table 1, Figure 2).

According to this method of estimation, most of the areas inaccessible by boat contain a mixture of floating, emergent, and submersed aquatic plant species. Most of these locations are along the perimeter of the Reservoir where the water level is low, boat traffic and disturbance is low, and environmental conditions are optimal for plant growth. These areas were somewhat obvious to classify in that they exhibited a brownish-red response color (Figure 3). This color indicates a mixture of shallow water, sediment, and the presence of some submersed aquatic

plant species such as coontail (*Ceratophyllum demersum* L.) and hydrilla (*Hydrilla verticillata* (L. f.) Royle).

Differentiating alligatorweed and waterhyacinth from other species was difficult other than at the ground-truth surveyed locations. At the given spatial resolution, alligatorweed and waterhyacinth did not have any reflectance characteristic making differentiation between them or any other similar floating and emergent plant species apparent. However, a dark shade of green color did indicate that floating and/or emergent plant species similar in growth habit and physiological structure to alligatorweed and/or waterhyacinth were present at those locations (Figure 4). An assumption that one or both species is present in adjacent pixels to the surveyed point is all that can be made due to high plant species diversity and a majority of mixed color pixels. Pixels displaying the dark green color that are adjacent to ground-truth points indicating alligatorweed and/or waterhyacinth's presence were classified as alligatorweed mix (AW Mix), waterhyacinth mix (WH Mix), or alligatorweed/waterhyacinth mix (AW/WH Mix). These classifications indicate that alligatorweed, waterhyacinth, or both species are present in the pixel(s), but other floating and/or emergent plant species may be present as well. This classification method did indicate that alligatorweed and waterhyacinth coverage increased on the Reservoir from 2007 and 2009.

American lotus (LOT) classified pixels were fairly simple to differentiate because of the light green color response exhibited from the surface of these monotypic populations (Figure 5). These dense stands may, however, hide small populations of alligatorweed, waterhyacinth, and other plant species of concern. If no dark green areas were visible in the pixel, indicating other floating and/or emergent species, the pixel was classified as specifically LOT. American lotus coverage did not differ from 2007 to 2009.

The pixels classified as open water (OW) and land mass (LM) were obvious and very simple to differentiate from plant-inhabited areas. A solid, dark blue color image response indicated open water with evidence supported from surveyed points. A very dark green color image response with visible tree canopies indicated wooded terrain or islands. These areas along with pixels comprised mainly of shoreline or residential/commercial developments were classified as LM.

Due to the high diversity of aquatic plant species in the Ross Barnett Reservoir, this method of estimating specific plant species coverage is not accurate. Most areas in the Reservoir that contain alligatorweed and/or waterhyacinth also contain waterprimrose (*Ludwigia peploides* (Kunth) Raven), white waterlily (*Nymphaea odorata* Ait.), giant cutgrass (*Zizaniopsis miliacea* (Michx.) Döll & Asch.), and other similar floating and/or emergent plant species. Without a precise color or reflectance signature indicative of the specific species, no absolute prediction can be made. Nevertheless, an estimation of American lotus, alligatorweed, waterhyacinth, and areas containing floating, emergent, and/or submersed plants were made based on slight color differentiations between pixels and ground-truth points. This estimation technique does not produce hard evidence of specific plant species occurrence, but it does provide a more organized perspective of the Ross Barnett Reservoir based on plant species of concern and their distribution size between years that may enable better aquatic plant management schemes and control efforts, and allows distribution estimates in areas inaccessible by boat.

RECOMMENDED FUTURE WORK

- Estimate coverage of nuisance aquatic species in the Reservoir using high spatial resolution satellite imagery (e.g. QuickBird, IKONOS, etc.)

ACKNOWLEDGEMENTS

We would like to thank the Pearl River Valley Water Supply District for funding this project. We also thank Wade Givens and Cheryl McLaurin for assistance with collection of imagery.

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Table 1. Surface area coverage of the seven land cover classes within the Ross Barnett Reservoir in 2007 and 2009.

Class	Species/Vegetation/Land Use Present	Surface Coverage (ha)	
		2007	2009
AW Mix	alligatorweed and other floating/emergent species	135	216
AW/WH Mix	alligatorweed and waterhyacinth with other floating/emergent species	27	99
WH Mix	waterhyacinth and other floating/emergent species	54	72
FES Mix	diverse compilation of floating, emergent, and/or submersed species	1797	1806
LOT	American lotus only	1375	1384
OW	open water; no vegetation	8732	8732
LM	solid land, residential or commercial development, or wooded terrain	2147	2255

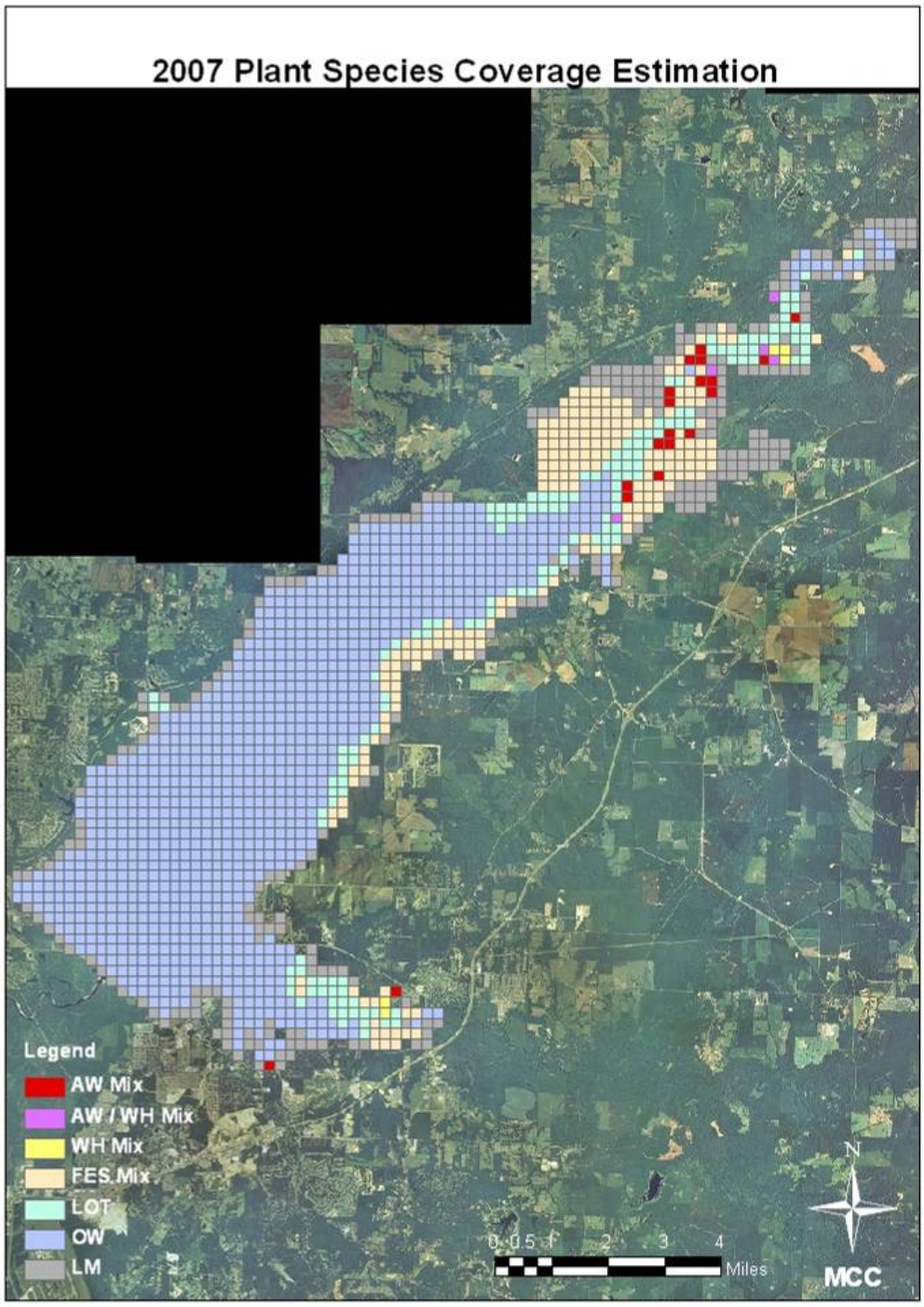

Figure 1. An estimation of plant species coverage on the Ross Barnett Reservoir in 2007.

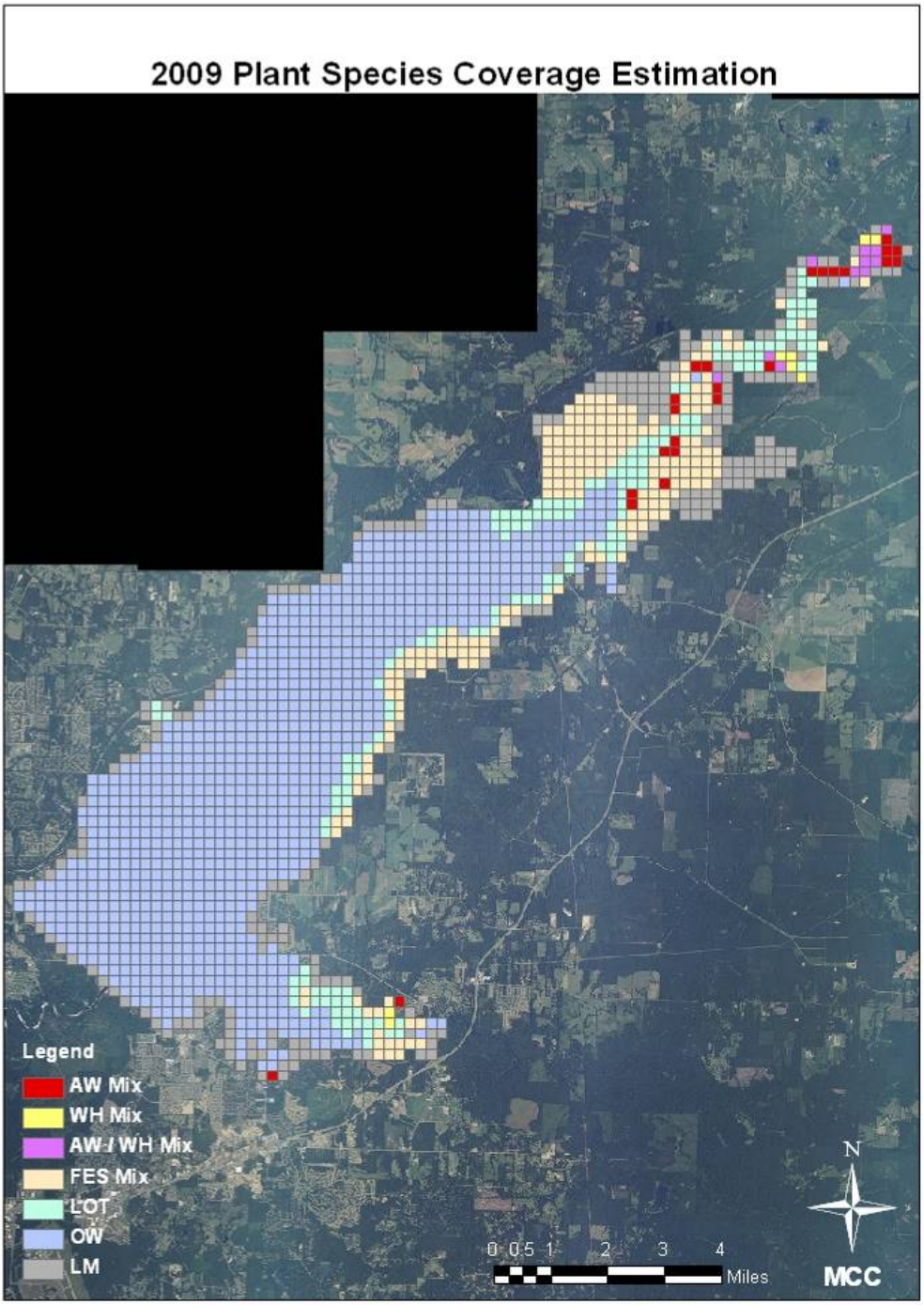

Figure 2. An estimation of plant species coverage on the Ross Barnett Reservoir in 2009.

Figure 3. Aerial imagery showing the brownish-red color indicative of submersed vegetation and/or sediment in shallow water areas. The orange dot is a ground-truth point indicating the occurrence of coontail, a submersed aquatic plant.

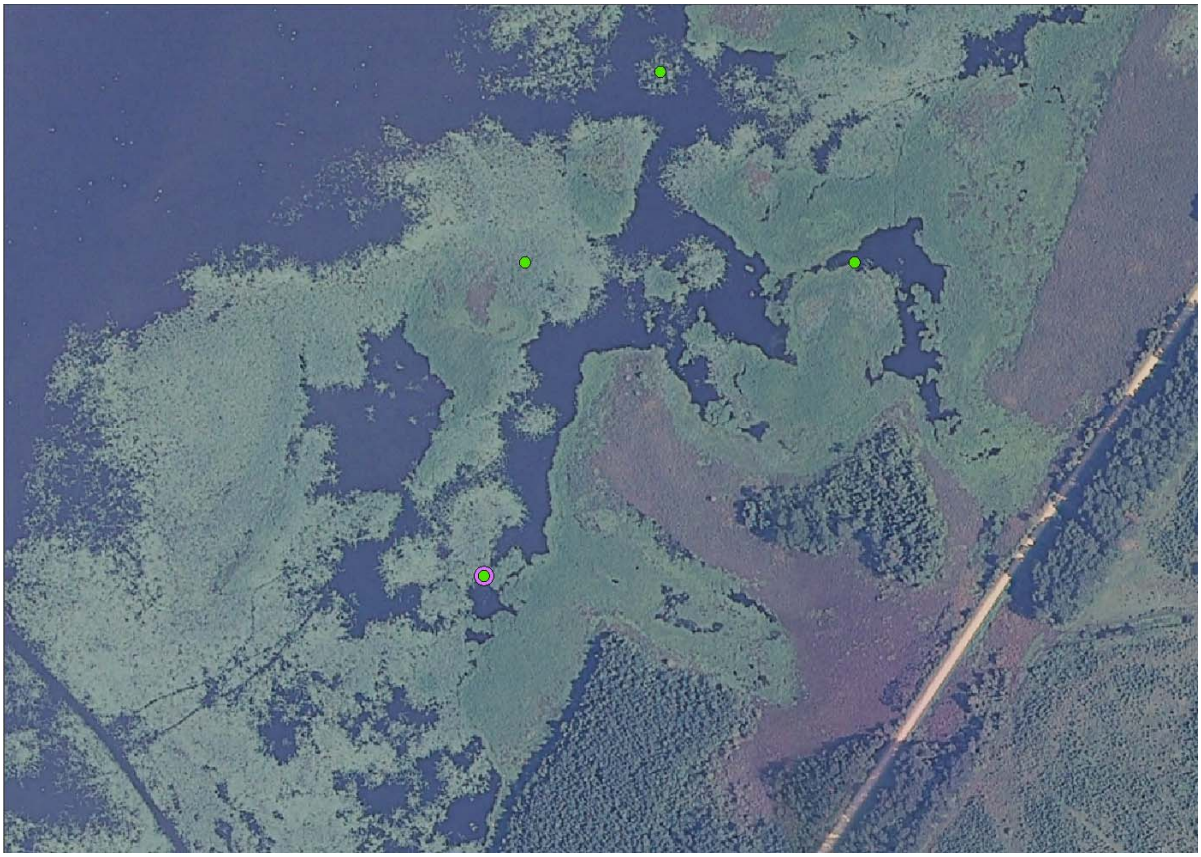

Figure 4. 2009 aerial imagery showing the dark green color indicative of alligatorweed, waterhyacinth, and other similar floating and/or emergent plant species' reflectance. The green dots are ground-truth points indicating alligatorweed occurrence, and the purple dots indicate waterhyacinth occurrence.

Figure 5. 2007 aerial imagery showing the light green color indicative of American lotus light reflectance. The yellow dots are ground-truth points indicating American lotus occurrence.