

# **Aquatic Plant Community Assessment of the Ross Barnett Reservoir, MS in 2014**



**A Report to the Pearl River Water Supply District**

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## **EXECUTIVE SUMMARY**

### **Summary**

- The coverage of target plants water hyacinth and hydrilla have remained low in the reservoir, indicating that the ongoing maintenance management has been effective in containing the spread of these species.
- The increase in prevalence of the exotic invasive plants alligatorweed, wild taro, and Cuban bulrush should be of concern to future maintenance management efforts.
- Native species diversity remains similar to previous years; native plant coverage still far exceeds that of the target invasive plants.
- The introduction of new invasive plants is an ongoing concern.

### **Recommendations**

- Continue monitoring of lake-wide plant populations and assessing plant management activity to maintain compliance with National Pollutant Discharge Elimination System (NPDES) permitting guidelines.
- Continue current management approaches for water hyacinth and hydrilla.
- A more aggressive treatment regime should be used when targeting alligatorweed, wild taro, and Cuban bulrush. Glyphosate, triclopyr, imazapyr, or 2,4-D herbicides should be used when targeting alligatorweed. Glyphosate, triclopyr, or 2,4-D should be used to control wild taro. Glyphosate, triclopyr, or diquat should be utilized when targeting Cuban bulrush. A non-ionic surfactant should be used in all foliar herbicide applications in aquatic environments.
- Continue to approach hydrilla management using the contact herbicide mixture of diquat and chelated copper, treating each site twice as needed and implement fluridone treatments in sites where water exchange is minimal. In addition, we suggest a demonstration project to evaluate using chelated copper alone at some sites to reduce off-target effects on American lotus.
- Install signage at popular boat ramps regarding the spread of aquatic invasive plants to educate users on the importance of checking and cleaning plants from motors, trailers, and hulls both before launching and after retrieving boats.

## INTRODUCTION

The Ross Barnett Reservoir, located in central Mississippi, is a 33,000 acre water supply reservoir that was constructed in the early 1960's. The Ross Barnett Reservoir is the largest surface water impoundment within the state, and is a popular recreation area for boaters, water skiers, anglers, campers, and other users. In addition to recreation, it also provides shoreline commercial and residential land developments, as well as, a vast expanse of wildlife habitat (Cox et al. 2010). The Ross Barnett Reservoir is home to a variety of emergent and submersed aquatic plants. The introduction of non-native aquatic plants has threatened biodiversity and natural processes within the Ross Barnett Reservoir. Management and control efforts have been implemented since 2006 in order to prevent the spreading of invasive non-native plant populations within the reservoir and throughout the state of Mississippi. Nuisance aquatic plant species can cause many negative effects, such as, altering ecological relationships among aquatic species, disruption of nutrient cycling, constricting navigation canals, lowering property values, and declined recreational use of rivers and lakes (Madsen 2004, Pimentel et al. 2000).

In 2005, the exotic weed hydrilla (*Hydrilla verticillata* (L.f.) Royle) was observed in the Ross Barnett Reservoir (Wersal et al. 2006). Hydrilla is a submersed plant species that is listed on the State and Federal Noxious Weed Lists, and due to its growth and reproduction habits hydrilla has been referred to as "the perfect aquatic weed" (Langeland 1996). It can grow in both static and flowing water and anywhere from several centimeters to 15 meters in depth (Yeo 1984).

Waterhyacinth (*Eichhornia crassipes* (Mart.) Solms) and alligatorweed (*Alternanthera philoxeroides* (Mart) Griseb.) are also exotic plant species that are causing problems within the Ross Barnett Reservoir. The ability of these plants to spread quickly and negatively impact services and recreational opportunities provided by the Ross Barnett Reservoir prompted the Pearl River Valley Water Supply District to create a long term management plan in order to suppress their spread. During 2012, glyphosate was used at 3 quarts (qt) per acre in combination with 1 qt. non-ionic surfactant for alligatorweed and water hyacinth control. Hydrilla treatments from 2006-2011 have consisted of the systemic herbicide fluridone, as well as, combinations of copper and diquat. Although fluridone has led to adequate control in some areas, diquat and copper combinations were used exclusively in 2012 pending the outcome of water exchange studies. The contact herbicide treatments provided control in several areas, reducing hydrilla biomass substantially. Although the contact herbicides provided control in some areas, it typically takes multiple contact herbicide treatments annually, with re-growth occurring soon after treatment. During 2013, fluridone treatments were once again used in areas with minimal water exchange in order to gain longer control.

Other non-native aquatic plants that have been sighted and caused concerns are water lettuce (*Pistia stratiotes*), giant salvinia (*Salvinia molesta*), Cuban bulrush (*Oxycaryum cubense*), and torpedo grass (*Panicum repens*). An assessment for each is included in this report. To ensure the success of any long-term management plan, regular assessments and intensive surveying are required to ensure current management strategies are sufficient (Madsen 2007) and meet National Pollutant Discharge Elimination System (NPDES) permit requirements.

An NPDES permit requires that action thresholds (usually based on quantitative species prevalence data) be established for invasive plant species being treated with a pesticide in any

waters of the U.S. These thresholds are to be established in a Pesticide Discharge Management Plan (PDMP) to be submitted when applying for an NPDES permit (National Pollutant Discharge Elimination System 2014). These thresholds determine if prevalence of an invasive aquatic plant is such that management efforts need to be implemented in order to control the abundance and spread of the invasive. Continuance of monitoring efforts help to ensure that these thresholds are up to date and that invasive aquatic plants are not exceeding established prevalence standards of the PDMP.

## Objectives

- 1) Monitor the aquatic plant communities within the Ross Barnett Reservoir by mapping the location and distribution of aquatic plants in the littoral zone (water depths  $\leq 10$  feet);
- 2) Monitor and assess the current aquatic invasive plant populations.

## **MATERIALS AND METHODS**

### **Vegetation Survey**

A point-intercept survey was conducted on a 300 meter grid (Madsen 1999), in June of 2014 in order to assess the distribution of aquatic plant communities within the Ross Barnett Reservoir. Points located in the littoral zone at locations previously sampled from the past ten years were surveyed. The sampling of points located within the littoral zone (water depths  $\leq 10$  feet) allows for a more effective survey to be conducted in areas more prone to aquatic plant growth (Fig 1). Some sampling points were inaccessible by boat due to low water and/or high vegetation density. These points were either not sampled or a new point in close relation to the inaccessible point was created. Annual point-intercept surveys are beneficial by showing differences in aquatic plant communities that can be statistically quantified over time.

A Trimble Yuma™ (Sunnyvale, California) tablet computer, with an internal global positioning system (GPS), was used to navigate to each point. A total of 669 points were sampled in 2014 (Fig 1). Presence and absence of plant species was collected by deploying and pulling in a weighted plant sampling rake attached to a rope and by visual observations at each survey point. Depth was also recorded at each point by a Lowrance LCX-28C depth finder (Tulsa, Oklahoma) or sounding rod. Spatial data were directly recorded into the tablet computer using FarmWorks Site Mate® software version 11.4 (Hamilton, Indiana). The software enables navigation to specific points and displays attribute and geographic data for this survey. Data was recorded in database templates with pick lists created specifically for this project (Cox et al. 2011).

Presence and absence of plant species was averaged over all points sampled and multiplied by 100 in order to obtain percent frequency. Percent frequency was calculated in order to assess control techniques. Mean species richness was also calculated and compared to previous years using a general linear model. Statistical differences were tested at the  $p \leq 0.05$  level of significance.

### **Invasive Species Management**

***Water hyacinth and Alligatorweed Assessment:*** Data collected from the point intercept surveys conducted on the Ross Barnett Reservoir were used to assess the effectiveness of management techniques on these two species. An analysis of changes in the frequency of occurrence for each species between years allows for a quantitative comparison to be made.

***Hydrilla Assessment:*** A point intercept survey within known hydrilla sites on the Ross Barnett Reservoir was conducted during March, May, and September of 2012 and 2013 in order to evaluate hydrilla management and aquatic plant distribution. Surveys were conducted by overlaying known hydrilla sites with a grid of points, created in ArcMap10®, Arc GIS computer software, and surveying each point located within that site.

***Other Non-natives of Concern:*** Giant salvinia, wild taro, Cuban bulrush, torpedograss, and water lettuce have all been observed in the reservoir in the past. Data collected from the point

intercept surveys conducted on the Ross Barnett Reservoir were used to assess the spread of these species.

## RESULTS AND DISCUSSION

### Littoral Survey

A total of 669 points were surveyed in 2014 (Fig 1). Of these, 188 (28 %) were vegetated (Fig 2). The 2014 Ross Barnett Reservoir Littoral Survey yielded a total of 24 aquatic plant or riparian plant species (Table 1). Since 2005, 29 different plant species have been documented in the Ross Barnett Reservoir (Appendix A, B, and C). American lotus, a native emergent plant, was the most documented plant in the 2014 survey (23.6%) and has been the most dominant species since the survey began in 2005 (Fig 3, Fig 5, Table 1, Appendix A, B). Other commonly occurring native species were white waterlily at 7.8% and water primrose at 9.7% occurrence (Table 1). Mean species richness, or the average number of species found at a survey point is significantly different from 2013 (Fig 4). American lotus, the most prevalent aquatic plant in the Ross Barnett Reservoir, has significantly increased from 2013 to 2014 (Fig 5, Table 1).

The occurrence of all non-native plant species has increased from 2013 to 2014 (Table 1). Alligatorweed populations were reduced from 2010 to 2011 and remained unchanged through 2013. In 2014, alligatorweed significantly increased from 2013 to near 2010 levels (Fig 5, Table 1, Appendix A, B, and C). Hydrilla occurrence is not significantly different from 2013 (0.5%) to 2014 (0.6%) (Fig 5, Table 1). Water hyacinth also are not significantly different from the 2013 survey (Fig 5, Table 1, Appendix A, B, and C). The only other nonnative species observed in the survey were brittle naiad (*Najas minor* All.), Cuban bulrush (*Oxycaryum cubense* (Poepp. & Kunth) Lye), and wild taro (*Colocasia esculenta*). Of these three species, Cuban bulrush and wild taro have significantly increased from years past (Table 1, Appendix A, B, and C) and are at their highest recorded prevalence in the Ross Barnett Reservoir. Water lettuce (*Pistia stratiotes* L.) and parrot feather (*Myriophyllum aquaticum* (Vell.) Verdc.) were both recorded in previous years, but were not recorded at any survey points during the 2014 littoral survey.

### Invasive Species Management

**Alligatorweed and Water Hyacinth Assessment:** Alligatorweed increased from 2013 to 2014 (Fig 5 and 6, Table 1). Fluctuations in occurrence are not uncommon when looking at the previous sampling years (2005-2013); these fluctuations are most likely due to environmental variables such as water level, temperature, and flow rate (Appendix A, B, and C); all of which can affect alligatorweed growth, distribution, and available habitat for establishment. Alligatorweed occurrence more than doubled between 2008 (7.3%) and 2009 (14.9%) (Sartain et al. 2012, Appendix A). These results are likely a cause of the high water levels in 2009 and the addition of 25 new alligatorweed locations that were not surveyed in 2008 but were found in 2013 and 2014 (Cox et al. 2011).

Water hyacinth populations have been reduced dramatically since 2009, and during the 2014 survey water hyacinth was found at nine sampling points (Fig 7). This is not a significant change from 2013 levels.

Both alligatorweed (Fig 6) and waterhyacinth (Fig 7) populations are capable of spreading through fragmentation and small floating mats are most likely responsible for establishing new populations.

**Cuban Bulrush, Waterlettuce, and Torpedograss Assessment:** Cuban bulrush and water lettuce populations were first observed in 2009 in Pelahatchie Bay. Before 2012, both species had been

controlled using various combinations of herbicides labeled for aquatic use. The herbicide used depended on the target species and the locale of the infestation (near golf courses, residences, etc.). Cuban bulrush has spread to various parts of the Ross Barnett Reservoir since its introduction in 2009, no Cuban bulrush was recorded during the 2013 survey, but large populations were seen during surveys in July 2013, often growing on top of other emergent plants such as alligatorweed and water primrose. Prior to 2013, only the umbellate type of Cuban bulrush (*Oxycaryum cubense cubense*) was seen in the Ross Barnett Reservoir, but the monocephalous type (*Oxycaryum cubense paraguayense*) was discovered in 2013. Both forms are present throughout the southern United States, and both forms have been documented in areas of Mississippi (Sartain et al. 2014). In 2014, Cuban Bulrush was recorded at 8 sites in the Ross Barnett Reservoir (Fig 8). This is the highest recorded prevalence of Cuban bulrush since it was found in 2009 (Table 1, Appendix A, B, and C).

Water lettuce (*Pistia stratiotes*) had not been seen since 2009 until 2012 (Appendix A, B). It was not recorded in the 2013 or 2014 littoral surveys (Appendix A, B, and C).

Torpedo grass has been recently seen in various portions of the Ross Barnett Reservoir. Although none was recorded at survey sites in 2014, several plants were seen while traveling between sites. Populations of torpedo grass have been reported in Pelahatchie Bay and above highway 43.

**Wild Taro:** Wild taro (*Colocasia esculenta*) is mostly seen along shorelines (very common on the Northwestern shoreline along the Natchez Trace Parkway). Prevalence in 2013 was 0.3 % and in 2014 had significantly increased to 1.3 % (Fig 9, Table 1, Appendix B and C). This plant has large underground structures for storing nutrients making it very difficult to control. Due to this, repeat applications of herbicide are almost always necessary. The plant was seen in all parts of the reservoir suggesting that it may be spreading. Monitoring of wild taro should be included in all future surveys to track any changes in the population.

**Giant Salvinia:** Giant salvinia (*Salvinia molesta* Mitchell) is native to South America and considered extremely invasive. It has currently been established in over 20 countries and is considered one of the world's worst weeds (Nelson 2009). It has the ability to form large, dense mats that can lead to a multitude of problems. On October 20, 2012, it was reported that giant salvinia had been discovered near the marina at Tommy's Trading post. Upon further investigation it was confirmed by Mississippi State University botanist, Dr. Victor Maddox that the plants seen were in fact giant salvinia. On October 25, 2012 Aqua Services employees and Dennis Reicke from the Mississippi Department of Wildlife Fisheries and Parks removed the giant salvinia from the boat ramp area and extensively surveyed the surrounding areas. Aqua Services employees also treated the shoreline with a diquat application. During 2013 and 2014, no giant salvinia was reported during any aquatic plant surveys.

**Hydrilla Assessment:** Hydrilla was found in four sites in 2014 (Fig 10, Table 1, Appendix C). The sites were found both above and below MS highway 43 and are located close to previously existing sites (Fig 10). Four hydrilla treatments were performed during 2013, the first in June, the second in July, the third in October, and a fourth in November. While not present at any survey sites in Pelahatchie Bay, Hydrilla was observed while traveling between sites in the bay and between sites in other parts of the reservoir. The fact that hydrilla is still prevalent at survey sites in 2014 shows how difficult it is to control and how efficiently it can spread. Due to the dense

plant growth and shallow water it is difficult to spot hydrilla plants growing close to the shoreline, thus making it difficult to treat in some areas.

## **Conclusions**

The three most prevalent exotic species in the Ross Barnett Reservoir are alligatorweed, water hyacinth, and wild taro (Table 1). Alligatorweed has declined in prevalence from 2005 – 2013, however it has risen in percent frequency over the last two years (Fig 5). Water hyacinth has decreased in prevalence from 5 % to 1.3 % between 2005 and 2014 (Fig 5). Wild Taro prevalence has significantly increased 0.3 to 1.3 % between 2013 and 2014 (Table 1).

The four most common native species in the Ross Barnett Reservoir are American lotus, water primrose, white water lily, and cattail (Table 1). Lotus (Fig 3) prevalence in 2014 was 23.6 %; approximately what it was 2011 (Appendix B and C). Water primrose, which can become problematic, increased slightly from 7.4 % in 2013 to 9.7 % in 2014 (Fig 11, Table 1, Appendix B and C). Prevalence of White water lily, another native species of concern, has remained relatively constant from 2005 to 2014 (Fig 12, Table 1, Appendix A, B, and C). Cattail, which can form large monotypic stands that impede recreational activities, increased in prevalence from 0.6 % in 2013 to 6.7 % in 2014 (Fig 13, Table 1, Appendix B and C).

The coverage of target plants alligatorweed, water hyacinth, and hydrilla has increased from 2013 levels but is still relatively low in the reservoir. Most of this increase can be attributed to the increase in the alligatorweed population in the reservoir as the prevalence of the other two species has remained relatively unchanged from the previous year (Fig 5, Table 1, Appendix B and C.).

Native species diversity remains similar to previous years and native plant coverage still exceeds that of the target invasive plants.

Current management approaches for water hyacinth should be continued. Management approaches to alligatorweed, wild taro, and Cuban bulrush control should become more aggressive as all three species have significantly increased in prevalence from 2013 to 2014. Control of alligatorweed should utilize multiple glyphosate, triclopyr, imazapyr, or 2,4-D (all are systemic herbicides) applications within a growing season. Wild taro control should utilize the herbicides 2,4-D, triclopyr, or glyphosate (Nelson and Getsinger 2000). While little is known about Cuban bulrush control, a mesocosm study conducted at Mississippi State University achieved adequate (>80%) control using the herbicides glyphosate and triclopyr and the contact herbicide diquat (Fernandez 2013). Diquat is commonly used for a quick burn down application and then followed up with a systemic herbicide application when any surviving plants start to regrow. All foliar applications should be supplemented with a non-ionic surfactant. If possible, Cuban bulrush applications should be made pre-flowering (March-April) but can also be utilized post flowering (Fernandez 2013). All treated sites for alligatorweed, wild taro, and Cuban bulrush will need to be revisited after treatments are made. Any remaining plants will need to be retreated.

Continue to approach hydrilla management using the contact herbicide mixture of diquat and chelated copper, treating each site twice as needed and implement fluridone treatments in sites where water exchange is minimal (Sartain 2014). In addition, we suggest a demonstration project to evaluate using chelated copper alone at some sites to reduce off-target effects on American lotus (Turnage et al. 2015). Treatment options for wild taro should be assessed and treatment protocols put in place to stop the further spread of this species. Aggressively treat any new invasive species, such



as the Cuban bulrush, water lettuce, torpedo grass, and giant salvinia, in order to prevent the establishment of new species in the reservoir. Install signage at popular boat ramps regarding the spread of aquatic invasive plants to educate users on the importance of checking and cleaning plants from motors, trailers, bilge water, and hulls both before launching and after retrieving boats.

Action thresholds are based on year to year observations in the Ross Barnett Reservoir. Quantifiable data is provided in this and previous littoral survey reports (Cox et al. 2010, 2011; Sartain et al. 2012, 2014) and would be useful in establishing quantifiable thresholds for future management activities of aquatic invasive plant species.

Monitoring of lake-wide plant populations and assessing plant management activity should continue to ensure that invasive plants are being controlled within limits established in the PDMP and to ensure native plant richness and prevalence are not being significantly reduced by control efforts.

### **Acknowledgements**

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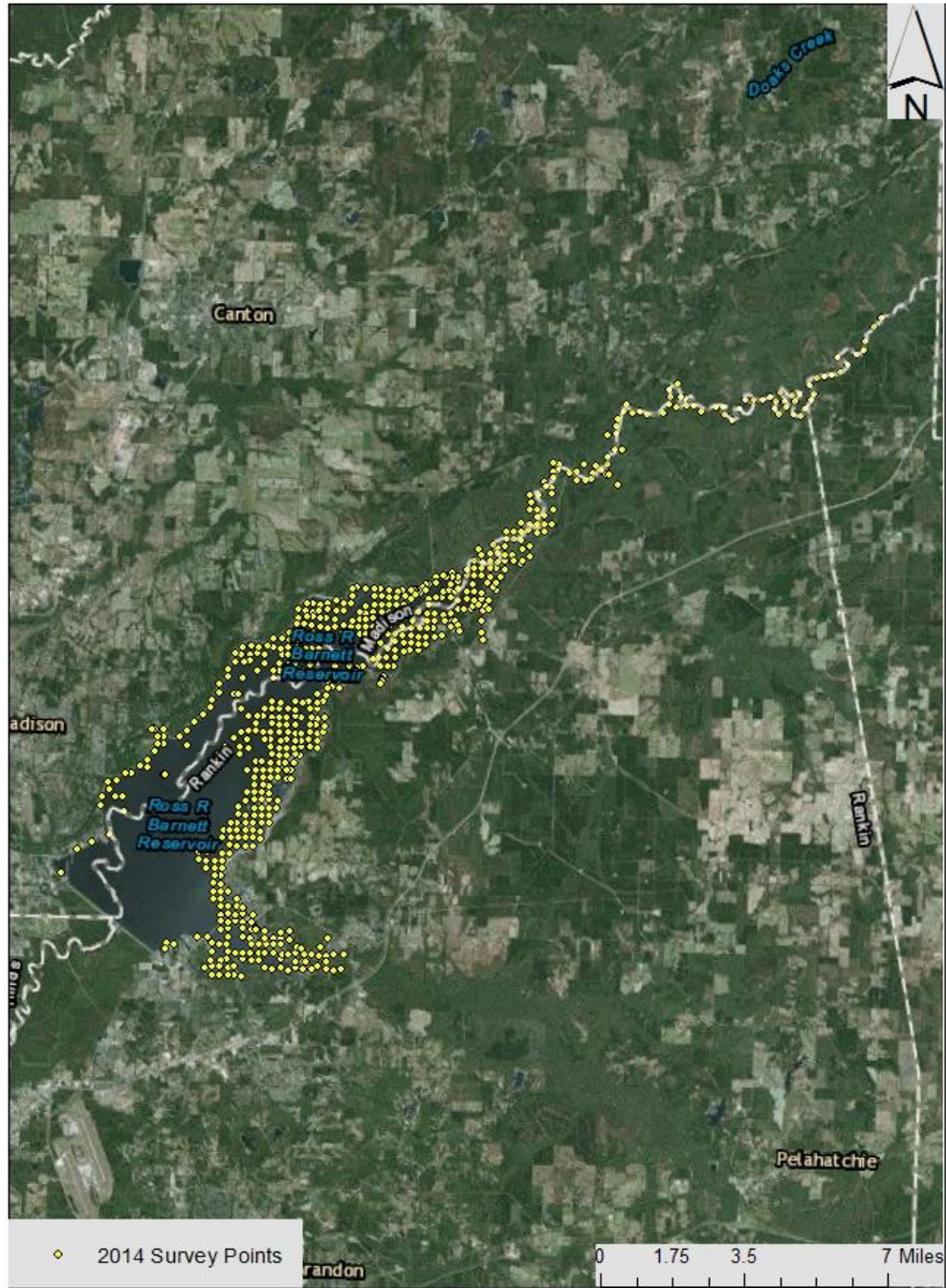
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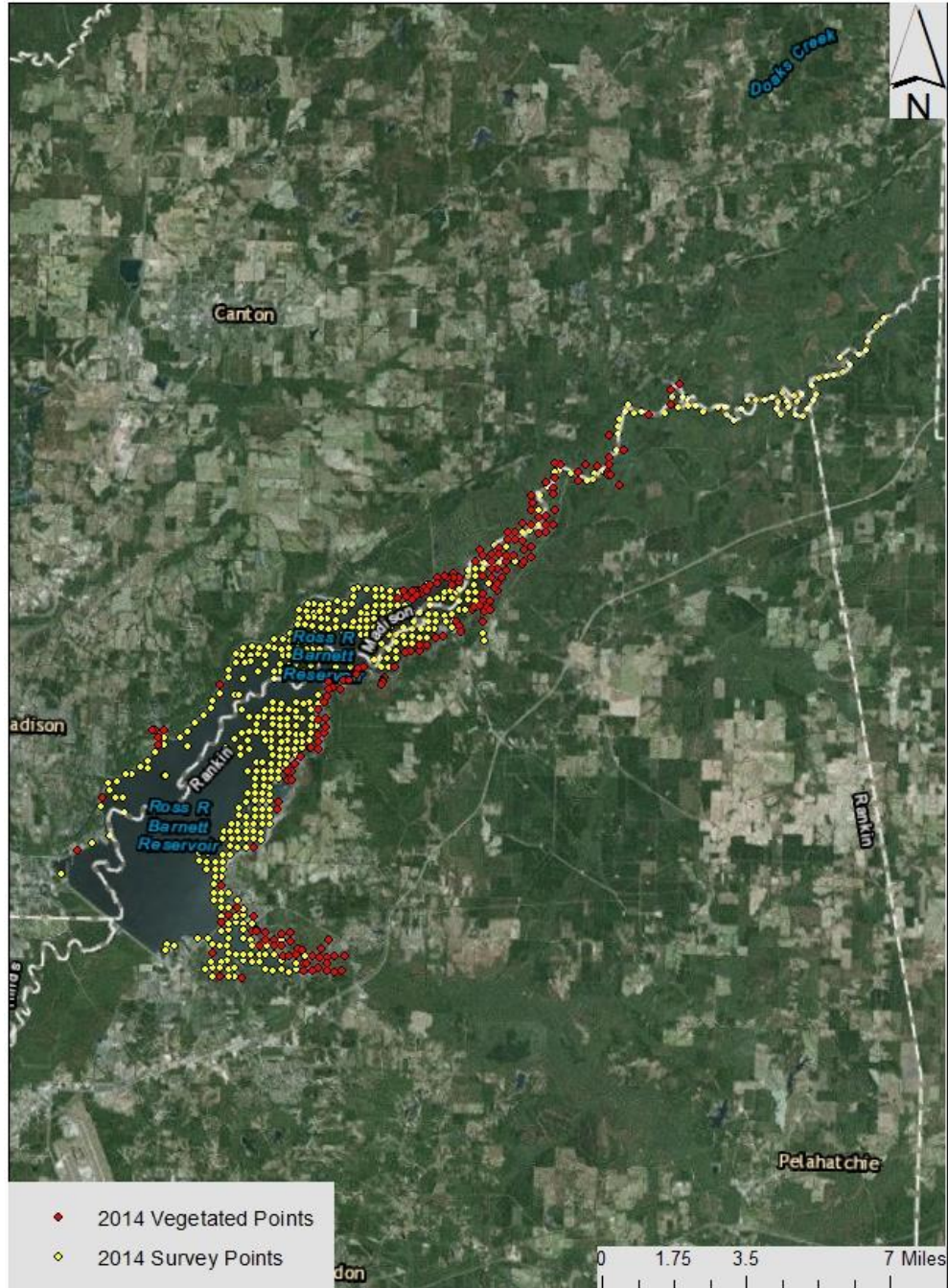
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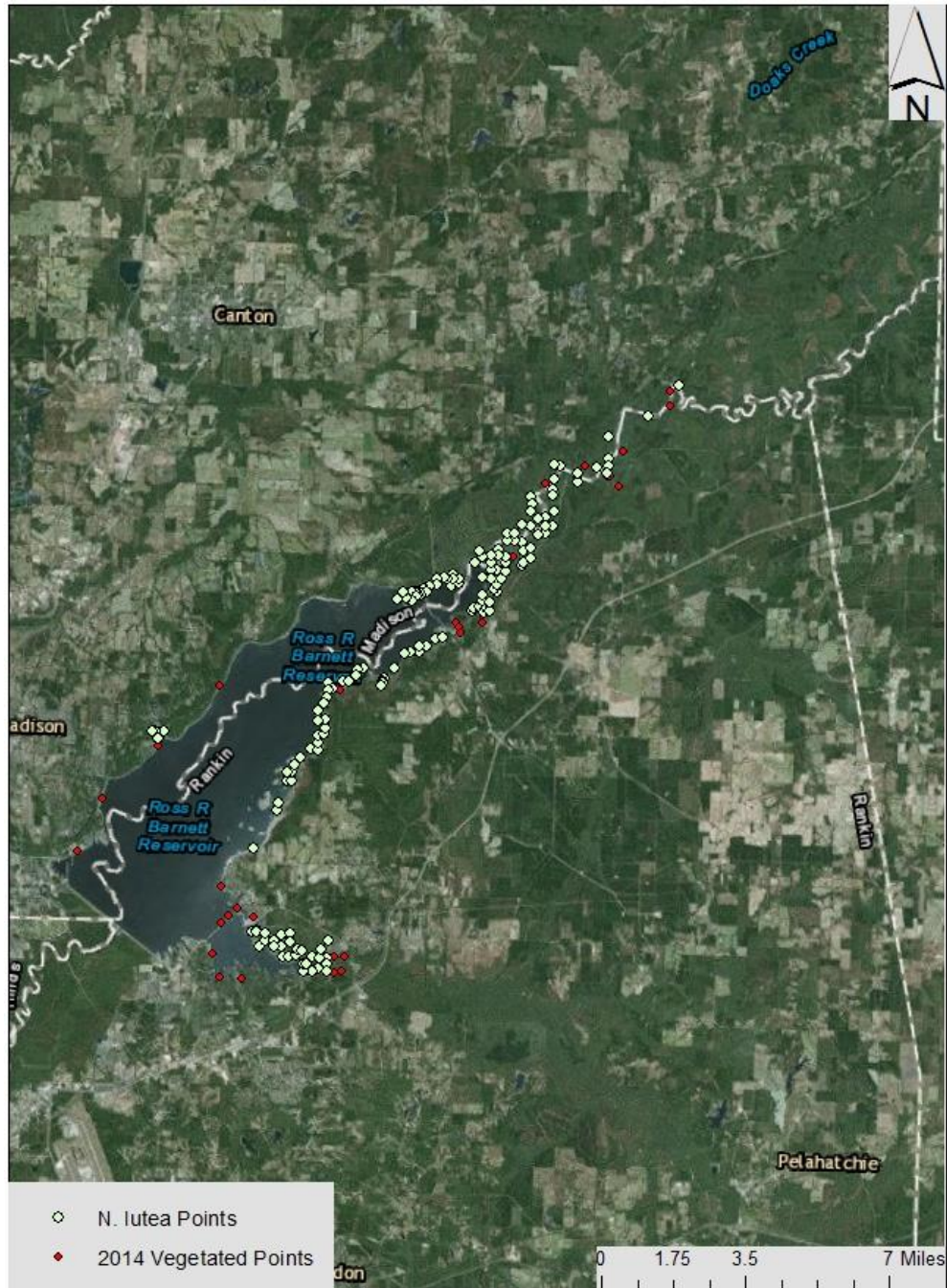
## Figures and Tables



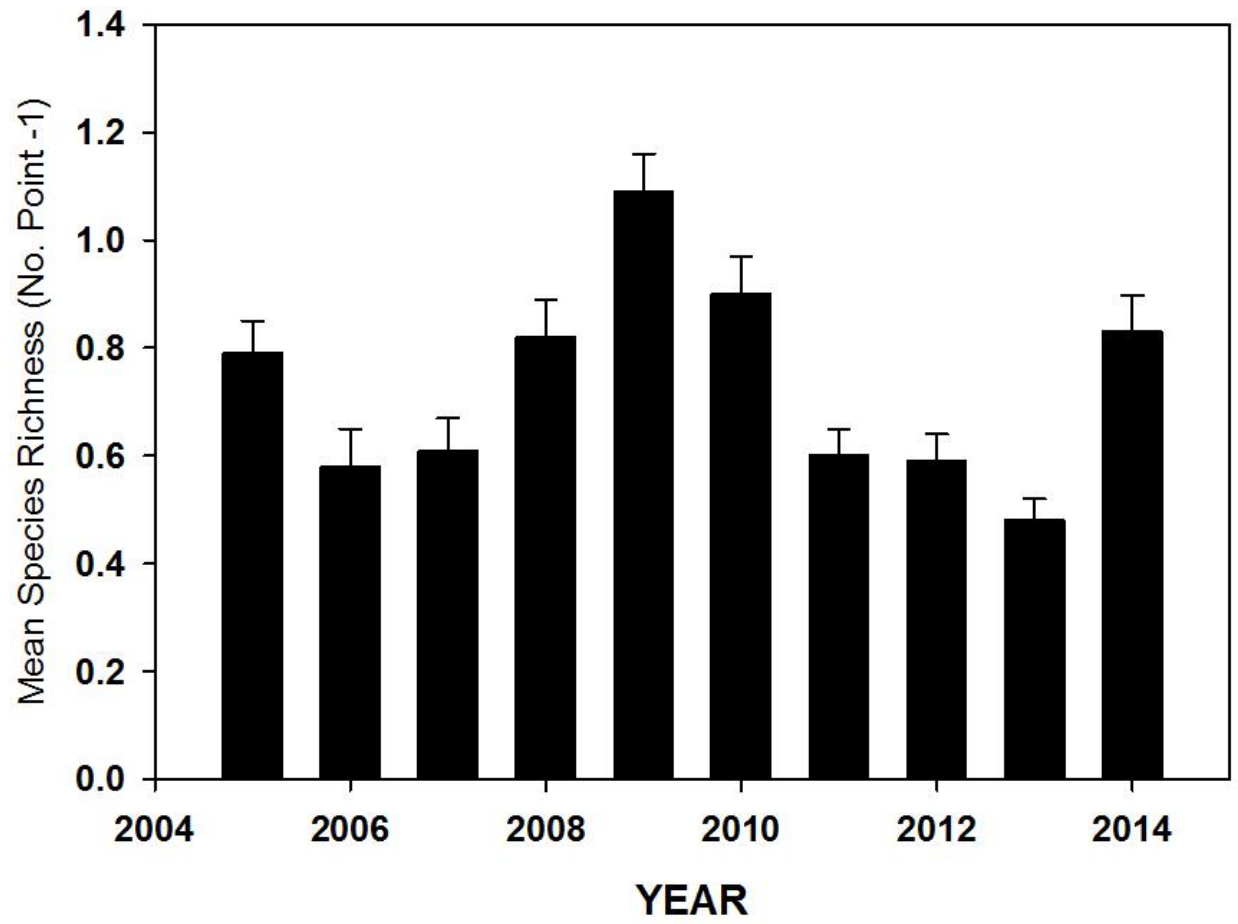
**Figure 1.** Points surveyed during the 2014 Ross Barnett Reservoir littoral survey (n=669).



**Figure 2.** Vegetated points (red) surveyed during the 2014 Ross Barnett Reservoir littoral survey (n=188).

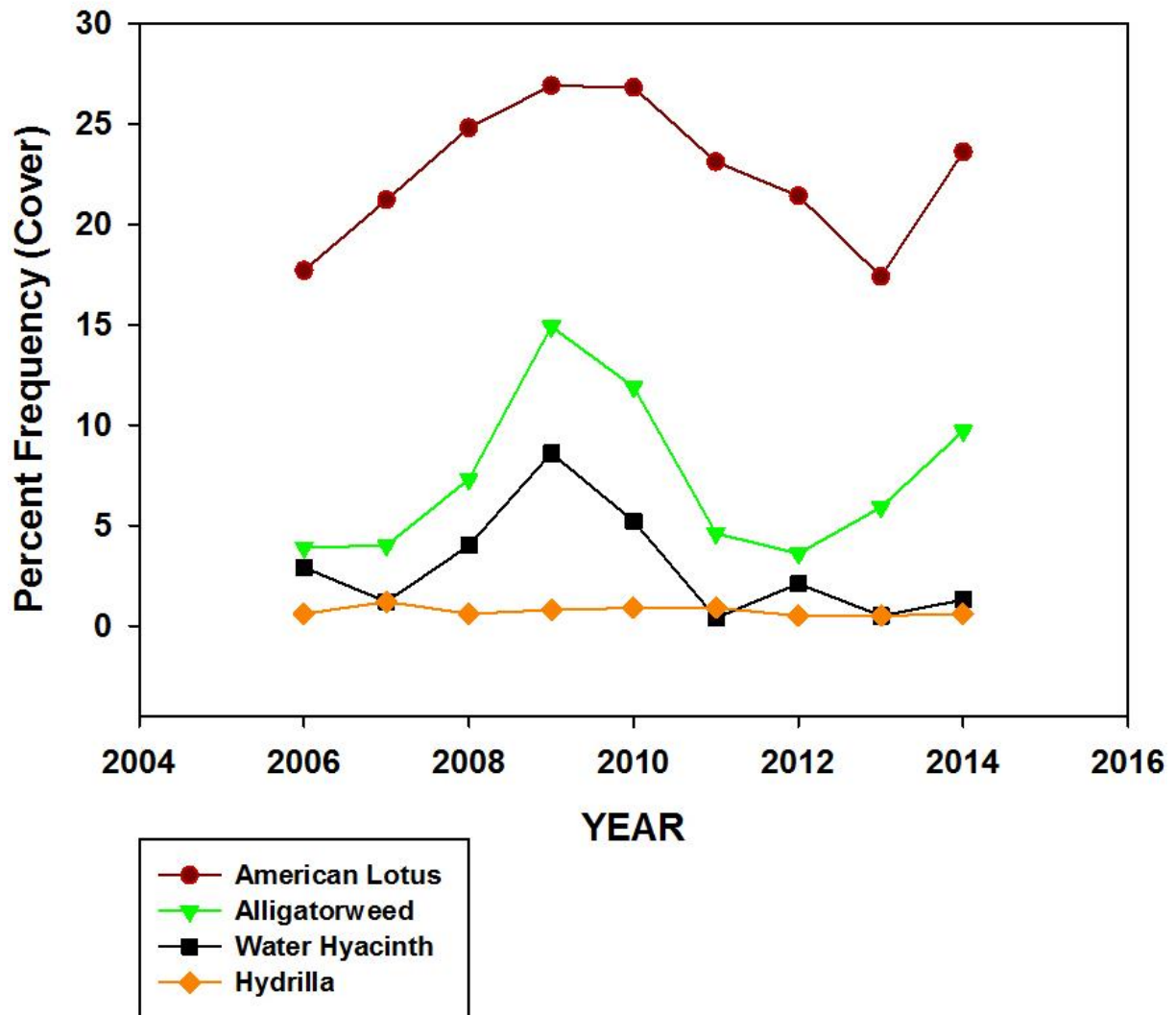


**Figure 3.** American lotus (*Nelumbo lutea*) points surveyed during the 2014 Ross Barnett Reservoir littoral survey (n=158).



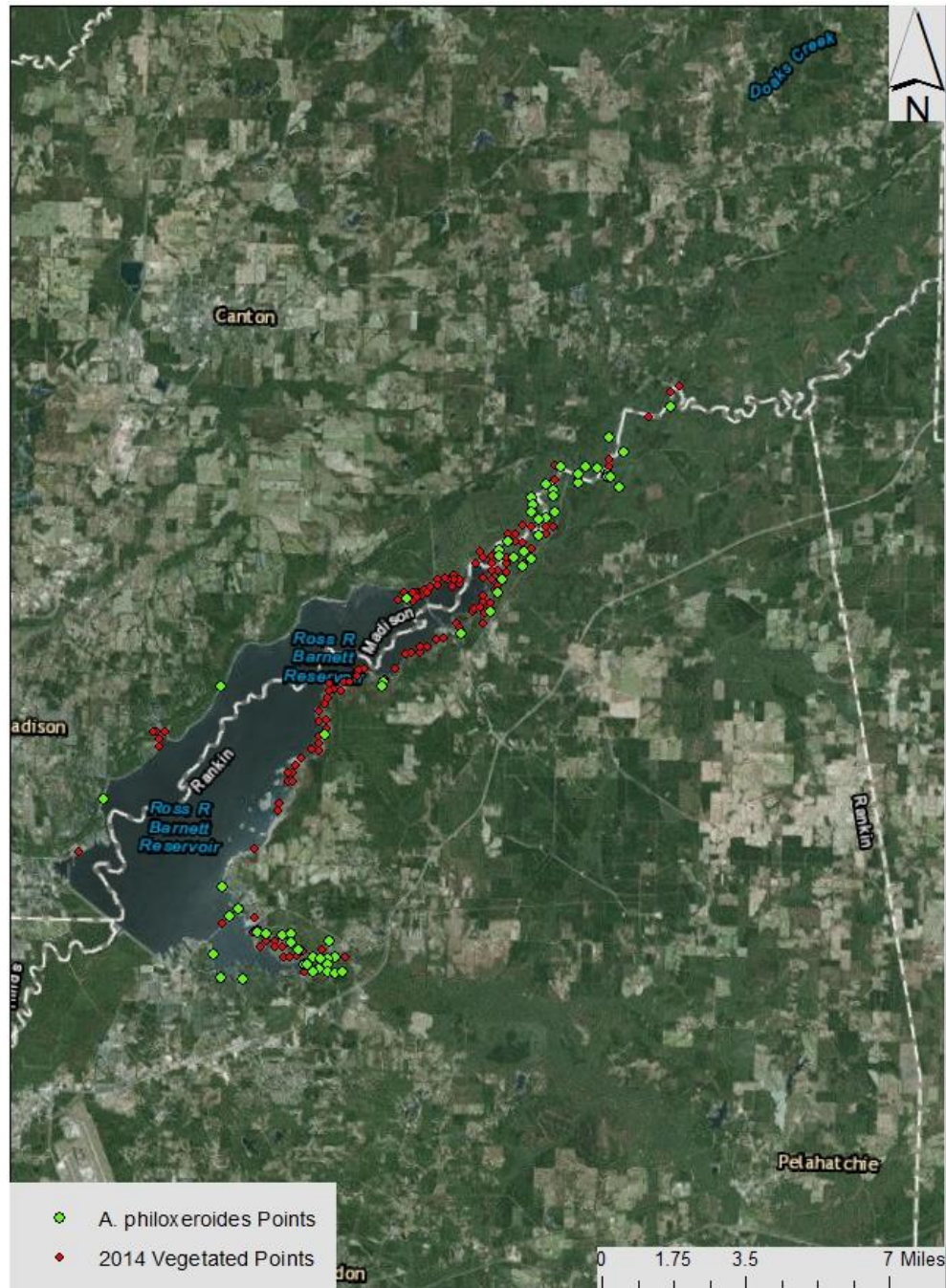
**Figure 4.** Mean species richness of plant occurrence from 2005-2014 during the Ross Barnett Reservoir littoral survey.

## Ross Barnett Invasive Plant Trends

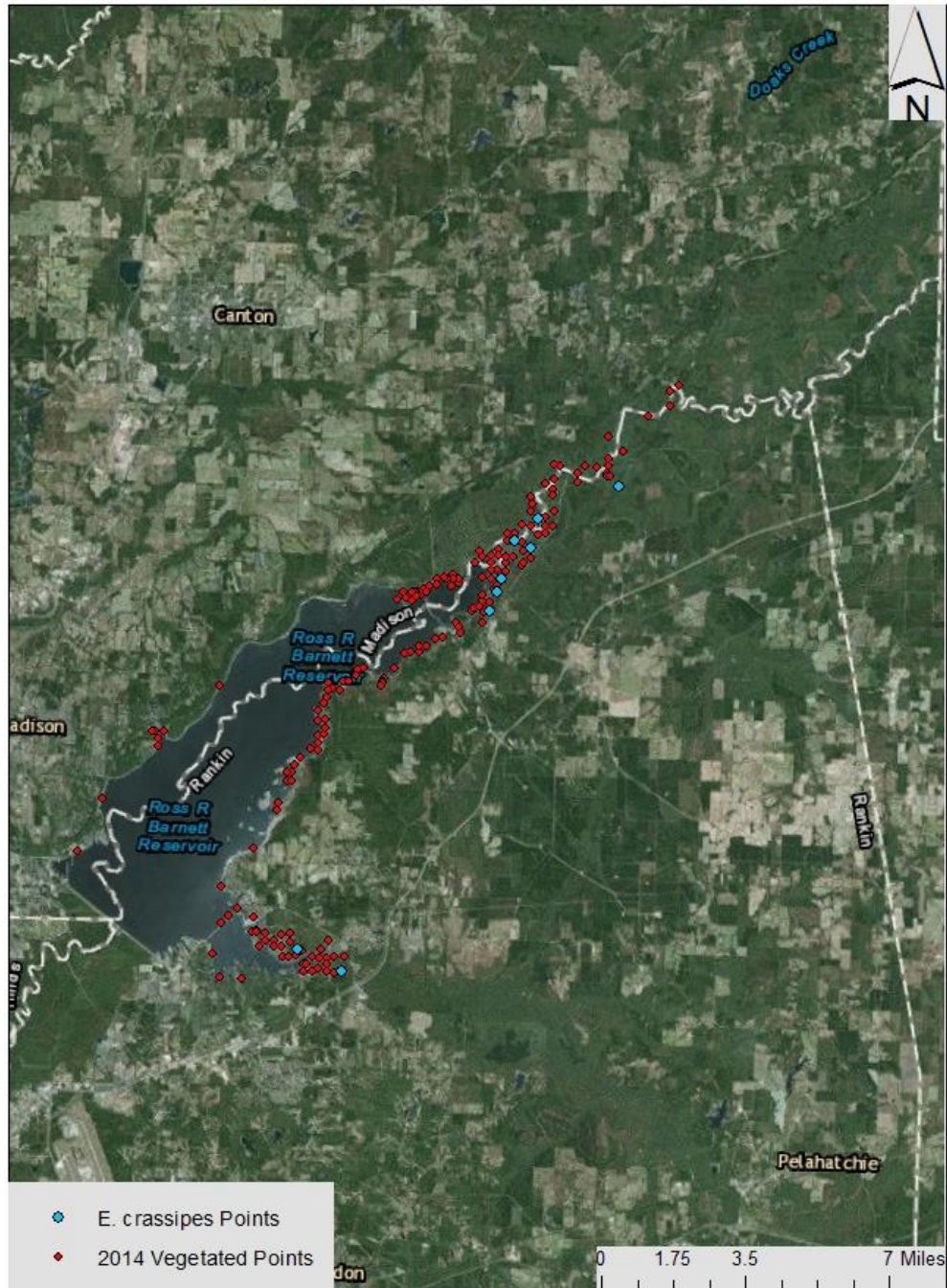


**Figure 5.** Percent frequency of American lotus and three invasive plant species from annual point intercept surveys, 2005 through 2014.

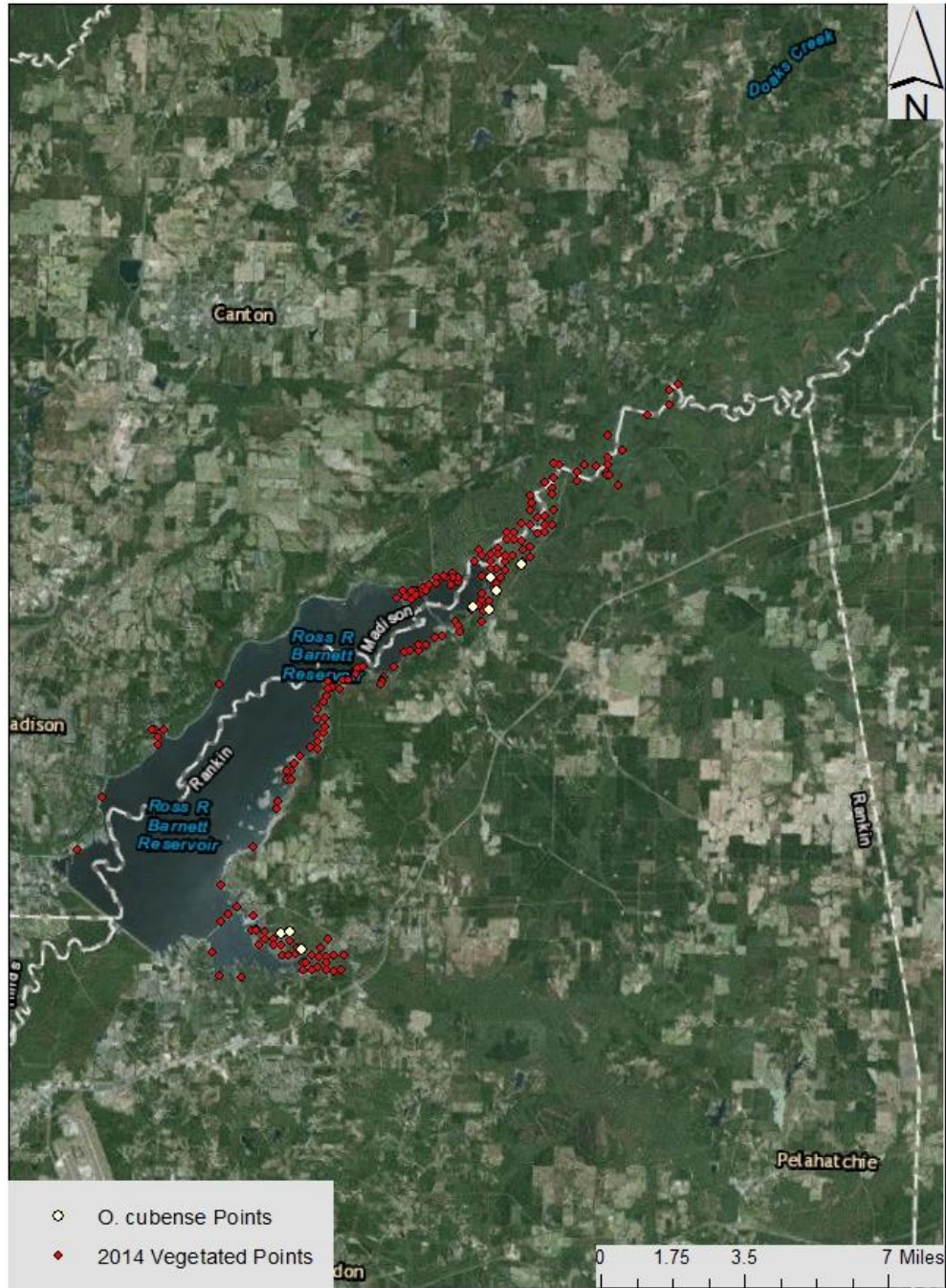




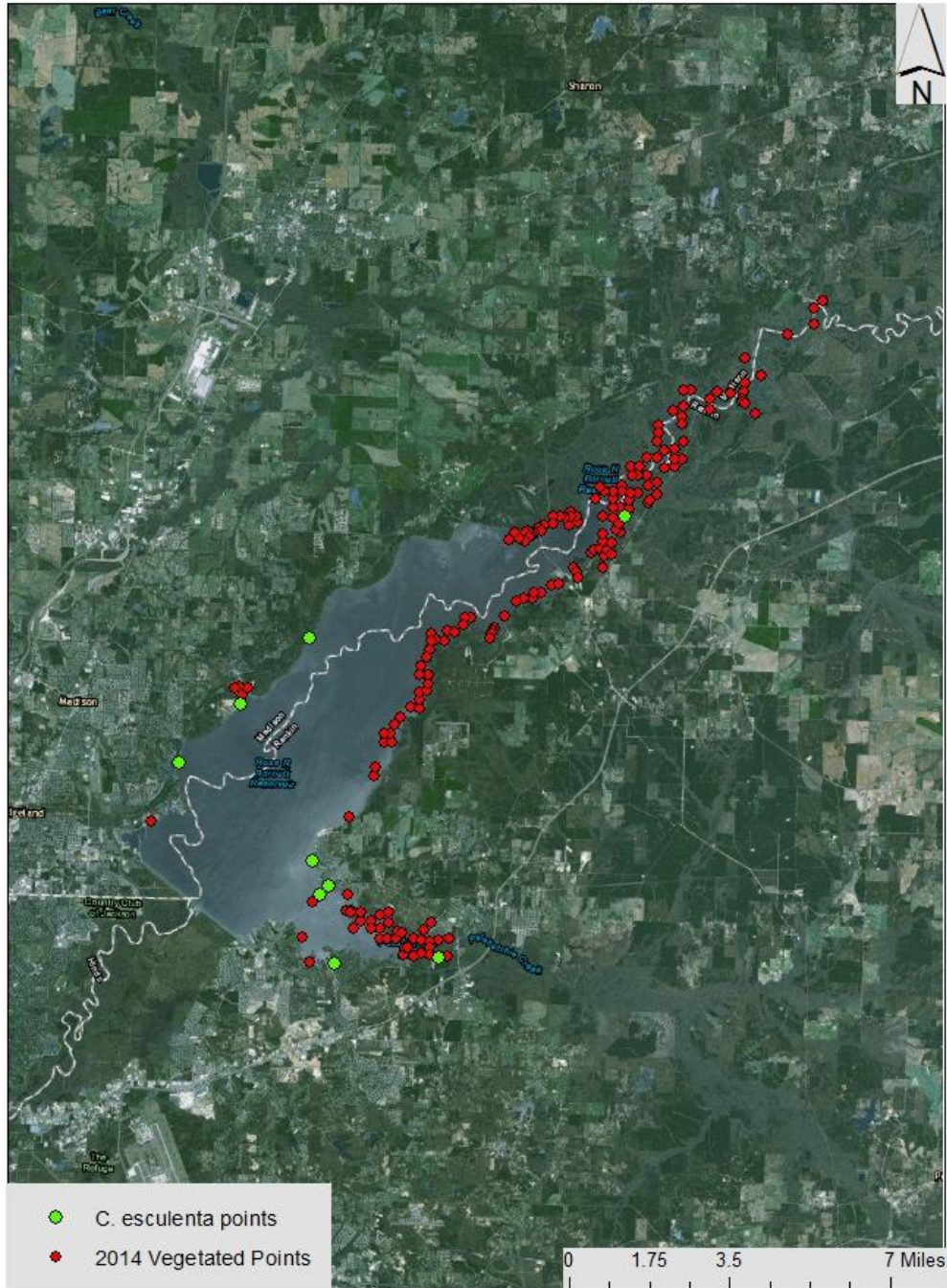
**Figure 6.** Alligatorweed (*Alteranthera philoxeroides*) points surveyed during the 2014 Ross Barnett Reservoir littoral survey (n=65).



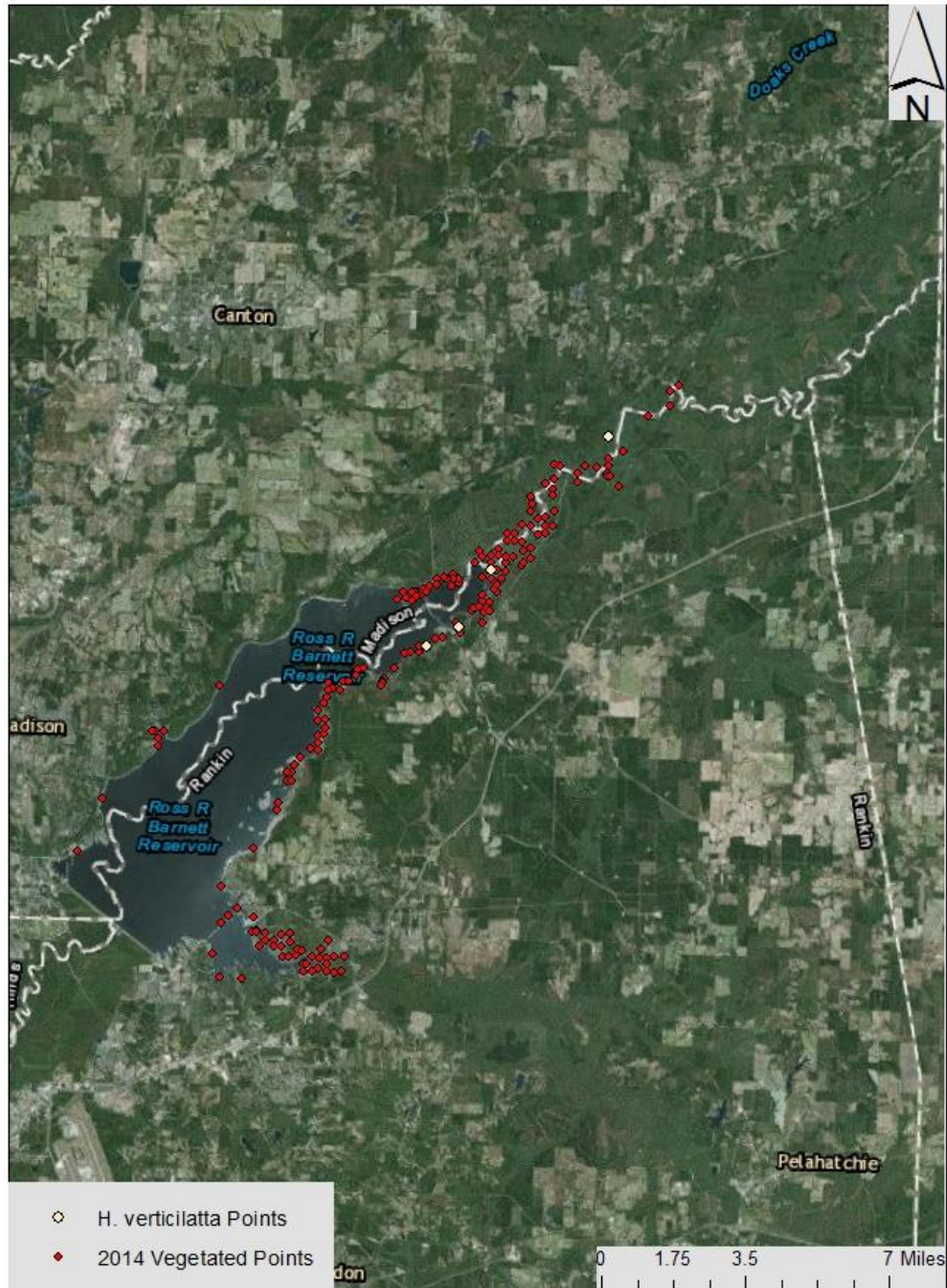
**Figure 7.** Water Hyacinth (*Eichhornia crassipes*) points surveyed during the 2014 Ross Barnett Reservoir littoral survey (n=9).



**Figure 8.** Cuban Bulrush (*Oxycarum cubense*) points surveyed during the 2014 Ross Barnett Reservoir littoral survey (n=8).



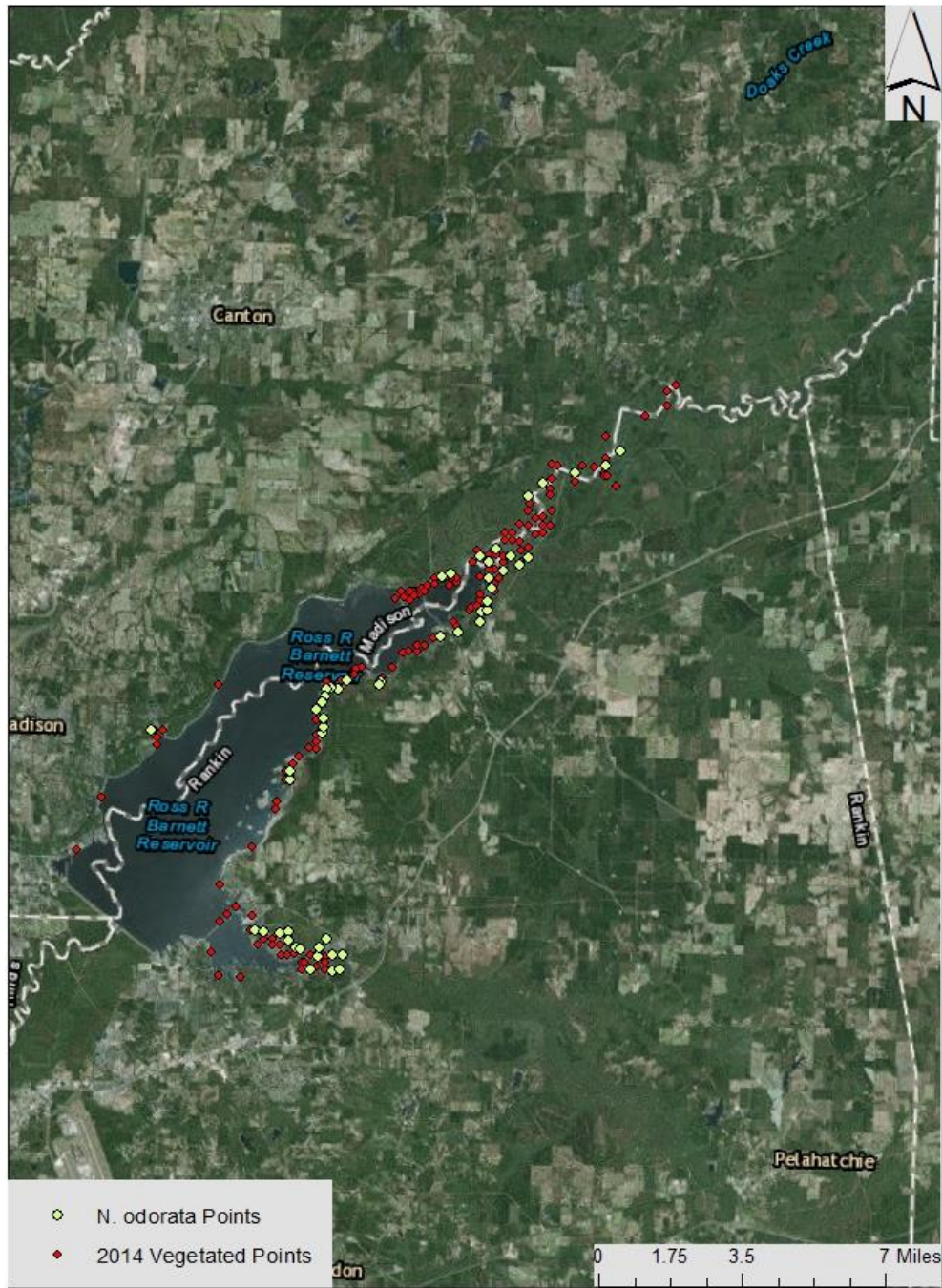
**Figure 9.** Wild Taro (*Colocasia esculenta*) points surveyed during the 2014 Ross Barnett Reservoir littoral survey (n=9).



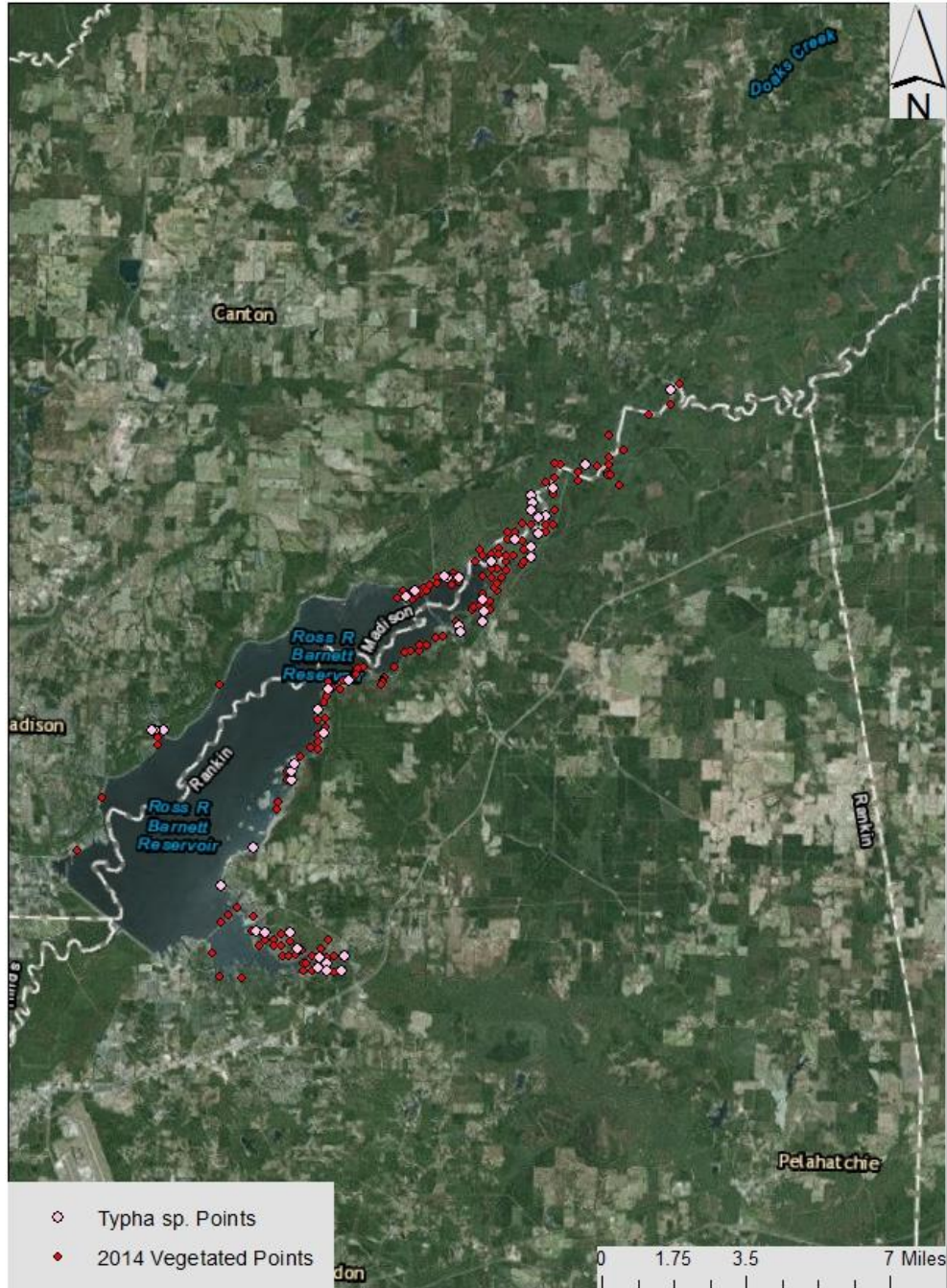
**Figure 10.** Hydrilla (*Hydrilla verticillata*) points surveyed during the 2014 Ross Barnett Reservoir littoral survey (n=4).



**Figure 11.** Water primrose (*Ludwigia peploides*) points surveyed during the 2014 Ross Barnett Reservoir littoral survey (n=65).



**Figure 12.** White water lily (*Nymphaea odorata*) points surveyed during the 2014 Ross Barnett Reservoir littoral survey (n=52).



**Figure 13.** Cattail (*Typha* sp.) points surveyed during the 2014 Ross Barnett Reservoir littoral survey (n=45).



**Table 1.** The percent frequency of occurrence for aquatic plant species observed in the littoral zone (<10 ft.) during the Ross Barnett Reservoir Surveys 2013 – 2014. The letter n represents the total number of points sampled. An ‘\*’ represents a significant change in percent frequency from the previous year, at a  $p \leq 0.05$  level using a chi-square test. A total of seven species were significantly different between these two years.

Species Name	Common Name	Native (N) or Exotic (E), or Invasive (I)	2013	2014
			% Frequency (n=665)	% Frequency (n=669)
<i>Alternanthera philoxeroides</i>	alligatorweed	EI	5.9	9.7*
<i>Azolla caroliniana</i>	mosquito fern	N	0	0
<i>Brasenia schreberi</i>	water shield	N	0	0.3
<i>Cabomba Caroliniana</i>	fanwort	N	0.8	0.6
<i>Ceratophyllum demersum</i>	coontail	N	3.3	4.8
<i>Colocasia esculenta</i>	wild taro	EI	0.3	1.3*
<i>Eichhornia crassipes</i>	water hyacinth	EI	0.5	1.3
<i>Hydrilla verticillata</i>	hydrilla	EI	0.5	0.6
<i>Hydrocotyle ranunculoides</i>	pennywort	N	0.3	0.9
<i>Juncus effusus</i>	common rush	N	0	1.9*
<i>Lemna minor</i>	common duckweed	N	0.2	2.4*
<i>Limnobium spongia</i>	American frogbit	N	0	0.4
<i>Ludwigia peploides</i>	waterprimrose	N	7.4	9.7
<i>Myriophyllum aquaticum</i>	parrotfeather	EI	0	0
<i>Najas minor</i>	brittle naiad	EI	0.3	0.4
<i>Nelumbo lutea</i>	American Lotus	N	17.4	23.6*
<i>Nitella sp.</i>	stonewort	N	0	0.1
<i>Nymphaea odorata</i>	white waterlily	N	5.4	7.8
<i>Oxycaryum cubense</i>	Cuban bulrush	EI	0	1.2*
<i>Pistia stratiotes</i>	water lettuce	EI	0	0
<i>Potamogeton foliosus</i>	leafy pondweed	N	0	0
<i>Potamogeton nodosus</i>	American pondweed	N	1.8	1.6
<i>Sagittaria latifolia</i>	broadleaf arrowhead	N	0.2	0.4
<i>Sagittaria platyphylla</i>	deltaleaf arrowhead	N	0.3	1.3*
<i>Scirpus validus</i>	softstem bulrush	N	0.5	0.6
<i>Spirodella polyrhiza</i>	giant duckweed	N	0	0
<i>Typha sp.</i>	cattail	N	0.6	6.7*
<i>Utricularia vulgaris</i>	bladderwort	N	0.3	7.5
<i>Zizaniopsis miliacea</i>	giant cutgrass	NI	2.6	4.2

**Appendix A.** The percent frequency of occurrence form aquatic plant species observed in the littoral zone (<10 ft.) during the Ross Barnett Reservoir Surveys 2005-2009. The letter n represents the total number of points sampled. An ‘\*’ represents a significant change in the percent frequency from the previous year, at a  $p \leq 0.05$  level using a Chi-square test.

Species Name	Common Name	Native (N) or Invasive (I)	2005 % Frequency (n=677)	2006 % Frequency (n=508)	2007 % Frequency (n=423)	2008 % Frequency (n=627)	2009 % Frequency (n=695)
<i>Alternanthera philoxeroides</i>	alligatorweed	I	21.1	3.9	4	7.3	14.9*
<i>Azolla caroliniana</i>	mosquito fern	N	0	0.2	0.4	0	0.5
<i>Brasenia schreberi</i>	water shield	N	-	-	-	-	-
<i>Cabomba caroliniana</i>	fanwort	N	2.2	0	0.5	1.3*	0.6
<i>Ceratophyllum demersum</i>	coontail	N	4.4	4.9	3.5	7.6*	3.6*
<i>Colocasia esculenta</i>	wild taro	I	0	0.9	0.7	2.4*	2.4
<i>Eichhornia crassipes</i>	water hyacinth	I	4.9	2.9	1.2	4.0*	8.6*
<i>Hydrilla verticillata</i>	hydrilla	I	0	0.6*	1.2*	0.6*	0.8
<i>Hydrocotyle ranunculoides</i>	pennywort	N	6.4	0.5	1.4	2.8*	1.3*
<i>Juncus effusus</i>	common rush	N	0	0	0	0.2	1.7
<i>Lemna minor</i>	common duckweed	N	3.1	2.5	1.9	1.4*	1.3
<i>Limnobium spongia</i>	American frogbit	N	1.5	0.8	0.7	1.3	0.3
<i>Ludwigia peploides</i>	waterprimrose	N	4.9	7.4	4.3	10.2*	14.8*
<i>Myriophyllum aquaticum</i>	parrotfeather	I	0.7	0	0.2	1.0*	0.4
<i>Najas minor</i>	brittle naiad	I	0	0	1.9*	1.0*	0.3
<i>Nelumbo lutea</i>	American Lotus	N	17.1	17.7	21.2	24.8*	26.9
<i>Nitella sp.</i>	stonewort	N	0.1	0	0	0	0
<i>Nymphaea odorata</i>	white waterlily	N	4.4	3.4	4.9	5.4	5.9
<i>Oxycaryum cubense</i>	Cuban bulrush	I	-	-	-	-	-
<i>Pistia stratiotes</i>	water lettuce	I	-	-	-	-	-
<i>Potamogeton foliosus</i>	leafy pondweed	N	0	0	0	0.6	0
<i>Potamogeton nodosus</i>	American pondweed	N	2.7	2.7	2.4	3	2.9
<i>Sagittaria latifolia</i>	broadleaf arrowhead	N	1	1.2	0.0*	0.5	1.3
<i>Sagittaria platyphylla</i>	deltaleaf arrowhead	N	0	1.8	0.8	0.3*	2.3*
<i>Scirpus validus</i>	softstem bulrush	N	1.2	0.2	0	0	0
<i>Spirodella polyrhiza</i>	giant duckweed	N	0	0	0	0.16	0.7
<i>Typha sp.</i>	cattail	N	1.3	2.4*	0.7	1.1	7.1*
<i>Utricularia vulgaris</i>	bladderwort	N	0	0.4	0	0.5	0.1
<i>Zizaniopsis miliacea</i>	giant cutgrass	N	1.5	3.5	1.9*	4.1	10.4*

**Appendix B.** The percent frequency of occurrence for aquatic plant species observed in the littoral zone (<10 ft.) during the Ross Barnett Reservoir Surveys 2009 - 2013. The letter n represents the total number of points sampled. An ‘\*’ represents a significant change in percent frequency from the previous year, at a  $p \leq 0.05$  level using a chi-square test.

Species Name	Common Name	Native (N) or Invasive (I)	2009 % Frequency (n=695)	2010 % Frequency (n=620)	2011 % Frequency (n=665)	2012 % Frequency (n=665)	2013 % Frequency (n=665)
<i>Alternanthera philoxeroides</i>	alligatorweed	I	14.9*	11.9	4.6	3.6	5.9
<i>Azolla caroliniana</i>	mosquito fern	N	0.5	0	0.2	0	0
<i>Brasenia schreberi</i>	water shield	N	-	-	-	0.1	0
<i>Cabomba caroliniana</i>	fanwort	N	0.6	0	0.5	1.7	0.8
<i>Ceratophyllum demersum</i>	coontail	N	3.6*	3.9	5.8	4.2	3.3
<i>Colocasia esculenta</i>	wild taro	I	2.4	2.1	0.7	0.5	0.3
<i>Eichhornia crassipes</i>	water hyacinth	I	8.6*	5.2*	0.4	2.1	0.5
<i>Hydrilla verticillata</i>	hydrilla	I	0.8	0.9	0.9	0.5	0.5
<i>Hydrocotyle ranunculoides</i>	pennywort	N	1.3*	0.3	0.1	0.9	0.3
<i>Juncus effusus</i>	common rush	N	1.7	1.6	0.1	0	0
<i>Lemna minor</i>	common duckweed	N	1.3	1.5	3.1	0.8	0.2
<i>Limnobium spongia</i>	American frogbit	N	0.3	0.3	0.4	0.3	0
<i>Ludwigia peploides</i>	waterprimrose	N	14.8*	11.9	5.5	8.3	7.4
<i>Myriophyllum aquaticum</i>	parrotfeather	I	0.4	0.2	0	0	0
<i>Najas minor</i>	brittle naiad	I	0.3	0.2	0.9	1.1	0.3
<i>Nelumbo lutea</i>	American Lotus	N	26.9	26.8	23.1	21.4	17.4
<i>Nitella sp.</i>	stonewort	N	0	0	0.3	0.8	0
<i>Nymphaea odorata</i>	white waterlily	N	5.9	5.3	4.8	5.7	5.4
<i>Oxycaryum cubense</i>	Cuban bulrush	I	-	0	0.3	0.6	0
<i>Pistia stratiotes</i>	water lettuce	I	-	0	0	0.2	0
<i>Potamogeton foliosus</i>	leafy pondweed	N	0	0.3	0	0	0
<i>Potamogeton nodosus</i>	American pondweed	N	2.9	1.1	1.2	2	1.8
<i>Sagittaria latifolia</i>	broadleaf arrowhead	N	1.3	1	1.2	0.5	0.2
<i>Sagittaria platyphylla</i>	deltaleaf arrowhead	N	2.3*	1.1	0.1	0.9	0.3
<i>Scirpus validus</i>	softstem bulrush	N	0	0	0	0.3	0.5
<i>Spirodella polyrhiza</i>	giant duckweed	N	0.7	0.5	0.6	0	0
<i>Typha sp.</i>	cattail	N	7.1*	5.5	2.4	1.5	0.6
<i>Utricularia vulgaris</i>	bladderwort	N	0.1	0	1.2	0.6	0.3
<i>Zizaniopsis miliacea</i>	giant cutgrass	N	10.4*	8.5	0.9	2	2.6

**Appendix C.** The Percent frequency of occurrence for aquatic plant species observed in the littoral zone (<10 ft.) during the Ross Barnett Reservoir Survey 2014. The letter n represents the total number of points sampled. An ‘\*’ represents a significant change in percent frequency from the previous year, at a  $p \leq 0.05$  level using a Chi-square test.

Species Name	Common Name	Native (N) or Invasive (I)	2014 % Frequency (n=669)
<i>Alternanthera philoxeroides</i>	alligatorweed	I	9.7*
<i>Azolla caroliniana</i>	mosquito fern	N	0
<i>Brasenia schreberi</i>	water shield	N	0.3
<i>Cabomba caroliniana</i>	fanwort	N	0.6
<i>Ceratophyllum demersum</i>	coontail	N	4.8
<i>Colocasia esculenta</i>	wild taro	I	1.3*
<i>Eichhornia crassipes</i>	water hyacinth	I	1.3
<i>Hydrilla verticillata</i>	hydrilla	I	0.6
<i>Hydrocotyle ranunculoides</i>	pennywort	N	0.9
<i>Juncus effusus</i>	common rush	N	1.9*
<i>Lemna minor</i>	common duckweed	N	2.4*
<i>Limnobium spongia</i>	American frogbit	N	0.4
<i>Ludwigia peploides</i>	waterprimrose	N	9.7
<i>Myriophyllum aquaticum</i>	parrotfeather	I	0
<i>Najas minor</i>	brittle naiad	I	0.4
<i>Nelumbo lutea</i>	American Lotus	N	23.6*
<i>Nitella sp.</i>	stonewort	N	0.1
<i>Nymphaea odorata</i>	white waterlily	N	7.8
<i>Oxycaryum cubense</i>	Cuban bulrush	I	1.2*
<i>Pistia stratiotes</i>	water lettuce	I	0
<i>Potamogeton foliosus</i>	leafy pondweed	N	0
<i>Potamogeton nodosus</i>	American pondweed	N	1.6
<i>Sagittaria latifolia</i>	broadleaf arrowhead	N	0.4
<i>Sagittaria platyphylla</i>	deltaleaf arrowhead	N	1.3*
<i>Scirpus validus</i>	softstem bulrush	N	0.6
<i>Spirodella polyrhiza</i>	giant duckweed	N	0
<i>Typha sp.</i>	cattail	N	6.7*
<i>Utricularia vulgaris</i>	bladderwort	N	7.5
<i>Zizaniopsis miliacea</i>	giant cutgrass	N	4.2