Aquatic Plant Community and Invasive Plant Management Assessment of the Ross Barnett Reservoir, MS in 2013

A Report to the Pearl River Valley Water Supply District

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EXECUTIVE SUMMARY

Summary

- The coverage of target plants alligatorweed, waterhyacinth, and hydrilla has remained low in the reservoir, indicating that the ongoing maintenance management has been effective in containing the spread of these three species.
- While hydrilla has been found at new sites, management of hydrilla has been successful in completely controlling hydrilla in a number of sites in which it was previously found.
- 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.
- Continue current management approaches for alligatorweed and waterhyacinth.
- For 2013, 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 were 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.
- Aggressively treat any new invasive species, such as the Cuban bulrush, waterlettuce, 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, 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 both 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 (*Alteranthera 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 evoked the Pearl River Valley Water Supply District to create a long term management plan in order to suppress their spread by monitoring and evaluating control techniques. During 2012, glyphosate was used at 3 quarts (qt) per acre in combination with 1 qt non-ionic surfactant for alligatorweed and waterhyacinth 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 contacts provided control in some areas, it typically takes multiple contact herbicide treatments annually and re-growth occurs soon after treatments. During 2013, fluridone treatments were once again used in areas with minimal water exchange in order to gain more long term control.

Other non-native aquatic plants that have been sighted and caused concerns are waterlettuce (*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).

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 ≤ 10 feet);
2) Monitor and assess the current hydrilla populations; as well as document the occurrence and establishment of other invasive plant populations; and
3) Gauge the efficiency of hydrilla management techniques within the Ross Barnett Reservoir, as well as the effectiveness of management of other species. The results of this assessment are included in this report.

MATERIALS AND METHODS

Vegetation Survey

A point-intercept survey was conducted on a 300 meter grid (Madsen 1999), in June of 2013 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 seven years were surveyed. The sampling of points located within the littoral zone (water depths ≤ 10 feet) allows for a more effective survey to be conducted in areas more prone to aquatic plant growth (Figure 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 665 points were sampled in 2013 (Figure 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.

Invasive Species Management

Waterhyacinth 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.

In addition to the surveys within hydrilla sites, nine hydrilla sites were chosen that have had hydrilla growth in the past two years and received multiple treatments since 2012. Data was collected through a series of point intercept surveys within the nine selected sites. These data were then used to assess the effectiveness of hydrilla control within the selected areas. In order to compare changes in plant occurrence between years, presence/absence data collected within the nine selected sites during September 2012 and September 2013 was subjected to a McNemar's statistical test that tested for a statistical change in occurrence from one year to the next. Due to limited occurrence by many plant species only the most frequently occurring plant species were used in the analysis. These consisted of: alligatorweed (*Alternanthera philoxeroides* (Mart). Griseb), fanwort (*Cabomba caroliniana* A. Gray), coontail (*Ceratophyllum demersum* L), hydrilla, waterprimrose (*Ludwigia peploides* (Kunth) P.H. Raven), American lotus, (*Nelumbo lutea* Willd), and white waterlily, (*Nymphaceae odorata* Aiton).

Hydrilla Tuber Bank Analysis: In order to assess the current density of hydrilla tubers in the Ross Barnett Reservoir, tuber surveys were conducted in March and May of 2012 and 2013. Four sites were sampled for hydrilla tubers each year. A PVC coring device was used to collect 20 sediment cores within these four sites (Madsen et al. 2007). The sediment collected was sieved through a pail with a wire mesh bottom to separate sediment from any hydrilla tubers and/or plant matter. Any tubers and/or above ground biomass found was collected and transported to Mississippi State University where it was sorted, dried, and weighed in order to obtain tuber number, biomass, density and above ground biomass (g/m^2).

***Other Non-natives of Concern*:** Giant salvinia, Cuban bulrush, torpedograss, and waterlettuce 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

The 2013 Ross Barnett Reservoir Littoral Survey yielded a total of 19 aquatic plant or riparian plant species. Since 2005, 29 different plant species have been documented in the Ross Barnett Reservoir (Appendix A, B). American lotus, a native emergent plant, was the most documented plant in the 2013 survey (17.4%) and has been the most dominant species since the survey began in 2005 (Table 1, Appendix A, B). Other commonly occurring native species were white waterlily at 5.4% and waterprimrose at 7.4% occurrence (Table 1). Due to the unusual spring weather, cooler temperatures, and increased rainfall several plant species occurred less often than years past. Mean species richness, or the average number of species found at a survey point not significantly different from 2012 (Figure 2). American lotus occurrence was not significantly different from 2012 to 2013 (Table 1).

The occurrence of all non-native plant species was less than 1 %, excluding alligatorweed (5.9%, Table 1, Figure 3). Alligatorweed populations have been reduced from 11.6% in 2010 to 4.6% in 2011, but is statistically unchanged since then (3.6% in 2012, 5.9% during 2013;Table 1, Figures 4-6, Appendix A, B). Hydrilla occurrence has remained stable from 2012 (0.5%) to 2013 (0.5%) (Table 1). Waterhyacinth populations have also been controlled and only having an occurrence of 0.5% during the 2013 survey, which is down from 2.1% in 2012 (Table 1, Figures 4-7, Appendix A, B). The only other nonnative species observed in the survey included brittle naiad (*Najas minor* All.) (0.3%). Cuban bulrush (*Oxycaryum cubense* (Poepp. & Kunth) Lye), waterlettuce (*Pistia stratiotes* L.), and parrotfeather (*Myriophyllum aquaticum* (Vell.) Verdc.) have all been recorded in previous years, but were not recorded at any survey points during the 2013 littoral survey. Although they were not recorded they were documented growing in parts of the reservoir during other surveying trips.

Invasive Species Management

Waterhyacinth and Alligatorweed Assessment: Alligatorweed increased during 2013 when compared to 2012 (Figure 3, 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); 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 (Cox et al. 2011).

Waterhyacinth populations have been reduced dramatically since 2009, and during the 2013 survey waterhyacinth was only found at three sampling points (Figure 7). The increased occurrence of waterhyacinth in 2012 is more than likely due to the mild winter experienced in Mississippi during 2011-2012 where temperatures dropped below freezing 27 days between November and February as opposed to 49 days in 2010-2011 (NOAA 2012). Moderate winters typically result in higher overwintering survival and increased waterhyacinth populations the following growing season (Owens and Madsen 1995). Both alligatorweed (Figure 3) and waterhyacinth (Figure 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 waterlettuce populations were first observed in 2009 in Pelahatchie Bay. Waterlettuce had not been seen since 2009 until 2012 (Appendix A, B). Before 2012, both species had been controlled using combinations of 2, 4-D and diquat, but during 2012 and 2013 glyphosate and 2,4-D have been utilized depending on spraying location (near golf courses, residences, etc.) and target plant type (2,4-D is not active on waterlettuce). 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 this year (Figure 8). Both forms are present throughout the southern United States, and both forms have been documented in areas of Mississippi (Fernandez personal communication 2013). All waterlettuce populations were treated with glyphosate during 2013.

Torpedo grass has been recently seen in various portions of the Ross Barnett Reservoir. Although none was reported during the 2013 Littoral Survey, several plants were seen during other trips in 2013. Populations of torpedo grass have been reported in Pelahatchie Bay and above highway 43. All torpedo grass populations were treated with glyphosate during 2013.

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, no giant salvinia was reported during any aquatic plant surveys.

***Hydrilla Assessment**:* Hydrilla was only found in existing hydrilla sites 5b, 15, and between existing sites 21 and 12 during the 2013 littoral survey (Figures 9 and 10). During 2012, there were 28 existing hydrilla sites, and an additional 5 sites were discovered in 2013 totaling 33 known sites (Figure 11). The new sites were found both above and below MS highway 43 and are located close to previously existing sites. During hydrilla site surveys in September, hydrilla was found in sites: 22, 15, 7, 10, 20, and 11 (Figure 11). Four hydrilla treatments were performed during 2013, the first round of treatments began in June, the second in July, the third in October, and a fourth in November (Figure 12). Fortunately, the new sites were treated during the November treatment. The discovery of several new hydrilla populations above/below highway 43 and in Pelahatchie Bay shows how efficiently hydrilla is being spread through the Ross Barnett Reservoir. Until 2012 hydrilla had only been discovered about as far south as mile marker 7, but has since made its way to Pelahatchie Bay. The discovery of the new hydrilla site in Pelahatchie Bay is most likely the result of hydrilla fragments being transported by water craft. Hydrilla has been successfully extending its growth outside of existing sites, and showing up in new areas. Many of the sites along the Rankin county shoreline have been expanding. 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 find and treat new areas.

The results of the point intercept surveys within the nine selected hydrilla sites concluded that out of the seven major species present within each site, only three (two of which are non-native) were significantly reduced from September 2012 to September 2013 (Table 2). Alligatorweed, fanwort, and the target species, hydrilla were these species. Water primrose, American lotus, and white water lily were the most frequently recorded species accounting for greater than 30% occurrence each year (Table 2). Native species richness within hydrilla sites did not differ between years and followed a similar trend each month, significantly increasing as the growing season progressed (Figure 13). Although native species richness appeared lower during 2013, differences were not statistically significant between years. The slight decrease in richness from 2012 to 2013 is most likely attributed to the wet spring where turbid water conditions and excess current limited plant growth early in the year. These results are beneficial in showing that native plant richness is not declining due to invasion of hydrilla and/or application of herbicides.

***Tuber Survey**:* Tuber surveys have been conducted since 2005 and have accounted for very few hydrilla tubers being found. During 2006, site 4 showed the presence of hydrilla tubers, but that is the only record of tubers being found since 2005 (Sartain et al. 2012). The recovery of hydrilla

tubers in 2006 explains the repeated occurrence of hydrilla each year within site 4. Although site 4 was also sampled for tubers in 2011, 2012 (Sartain et al. 2012), and 2013 very few were found. During 2012 and 2013, hydrilla sites 4, 5, 11, 12, and 13 (site 13 was chosen due to limited access to site 12 in 2013) were sampled for hydrilla tubers during March and May. During March 2012, site 4 was the only site where tubers were found, but during May 2012 and 2013, sites 5, 11, and 13 showed the presence of hydrilla tubers. Based off the core sampling, sites 4 and 5 could be showing very little tuber production, and re-growth may be due to the overwintering of plants and re-growing from healthy root crowns (Sartain et al. 2012). In addition both sites have been treated with fluridone in the past. Herbicide treatments of fluridone have been shown to reduce biomass as well as inhibit tuber production (MacDonald et al. 1993). The Ross Barnett core sampling data collected was compared to a non-managed hydrilla infestation (Gainesville, Tenn-Tom Waterway) on the Tenn-Tom Waterway in order to see variations in tuber banks between managed and un-managed hydrilla infestations. The data showed significantly higher above ground biomass, tuber biomass, tuber weight, and tuber density in the Tenn-Tom when compared to Ross Barnett (Sartain 2014; Table 1). Herbicide treatments during the summer and fall at the Ross Barnett Reservoir may be preventing tuber production by reducing plants available for tuber production. These data suggest from a management perspective, that management of the tuber bank will lead to a reduction in year to year recruitment of hydrilla (Sartain 2014).

Hydrilla Treatments: The Mississippi Department of wildlife, fisheries, and parks treated hydrilla at the sites indicated in Table 5 at four separate time periods: early summer (June), mid-summer (July), mid-autumn (October), and late-autumn (November). Most treatments in 2013 were done using contact herbicides; namely, a tank-mix of diquat (Reward) and copper (Harpoon), a granular form of copper was also utilized in the November treatments. Fluridone (Sonar) was also utilized to treat areas with minimal water exchange. Time of treatment, total acres treated, and amount of product used is available in Table 4.

Conclusions

The three most prevalent exotics species in the Ross Barnett Reservoir are Alligatorweed, Waterhyacinth, and Hydrilla (Table 1). Alligatorweed has declined in prevalence from 2005 – 2013, however it has risen in percent frequency in the last year (Figure 14). Waterhyacinth has declined in prevalence from 5 % to 0.5 % between 2005 and 2013 (Figure 14). Hydrilla prevalence has remained relatively stable between 2005 and 2013 (Figure 14).

The three most common native species in the Ross Barnett Reservoir are American lotus, waterprimrose, and white waterlily (Table 1). Lotus prevalence in 2013 was 17.4 %; approximately what it was 2005 (Figure 14, Appendix A and B). However, it increased in prevalence in 2009 to almost 27 % (Figure 14, Appendix A, B). Waterprimrose, a native species,

has increased in prevalence from 4.9 % in 2005 to 7.4 % in 2013; however, it was most widespread in 2009 at 14.8 % (Appendix A, B). Prevalence of white water lily, another native species of concern, has remained relatively constant from 2005 to 2013 (Appendix A, B).

The coverage of target plants alligatorweed, waterhyacinth, and hydrilla has remained low in the reservoir, indicating that the ongoing maintenance management has been effective in maintaining low numbers of these species (Table 1, Appendix A and B). While hydrilla has been found at new sites, management of hydrilla has been successful in completely controlling it in a number of sites in which it was previously found.

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

Current management approaches for alligatorweed and waterhyacinth should be continued. 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 were 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. Aggressively treat any new invasive species, such as the Cuban bulrush, waterlettuce, 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.

Monitoring of lake-wide plant populations and assessing plant management activity should continue to ensure that invasive plants are being controlled and native plant richness and prevalence aren’t being significantly reduced by control efforts.

Acknowledgements

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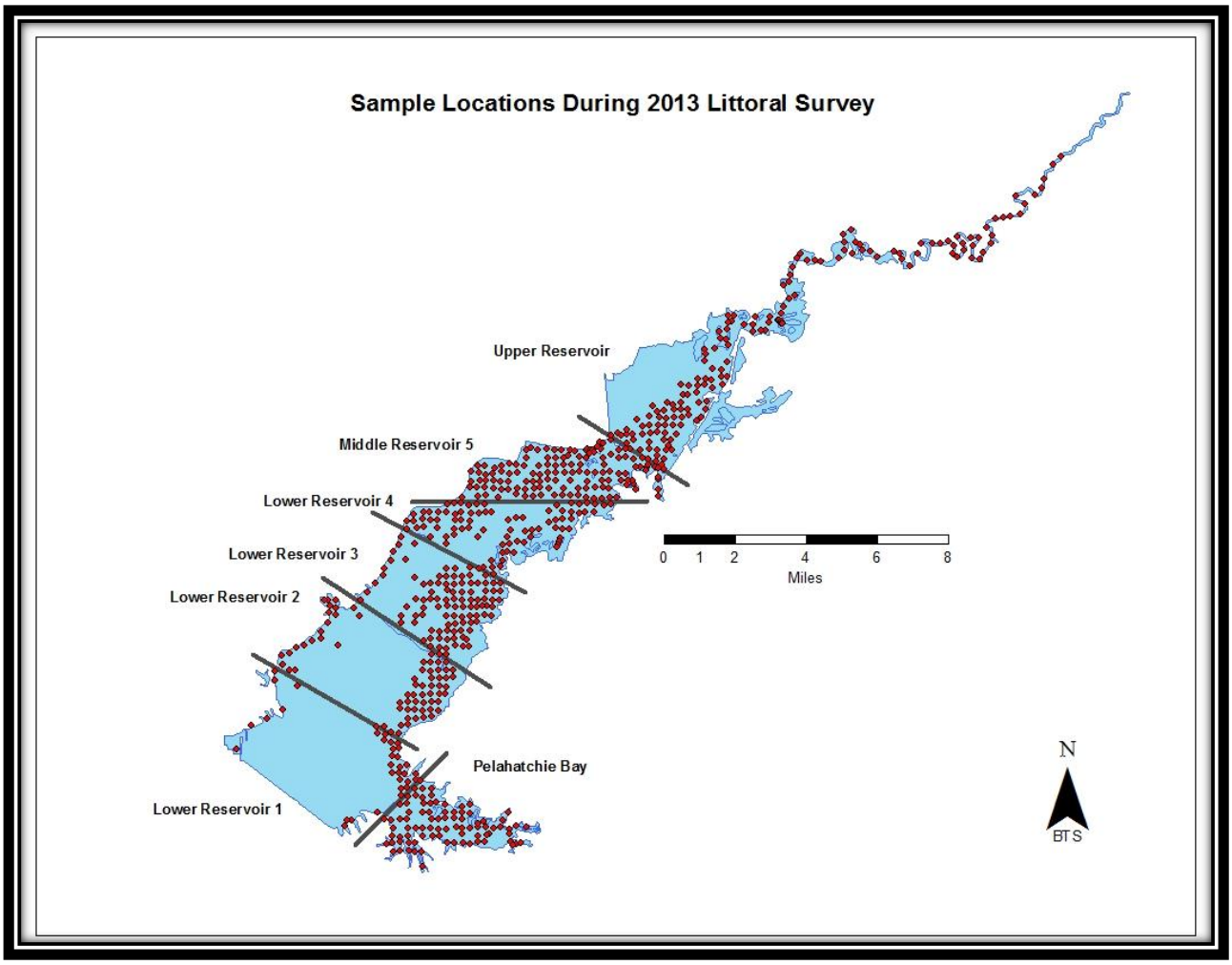

Figure 1. Points surveyed during the 2013 Ross Barnett Reservoir littoral survey (n = 665).

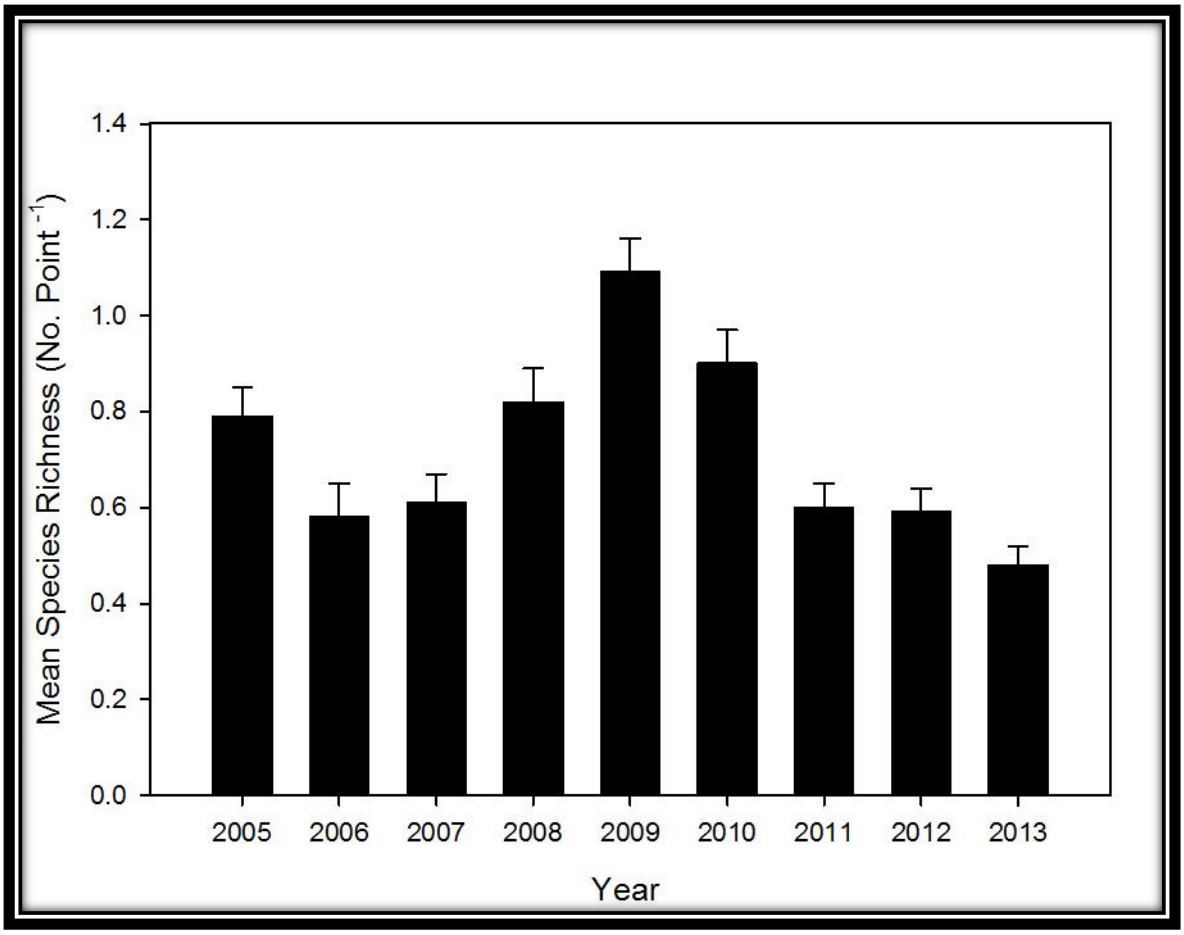

Figure 2. Mean species richness of plant occurrence from 2005-2013 during the Ross Barnett Reservoir littoral survey.

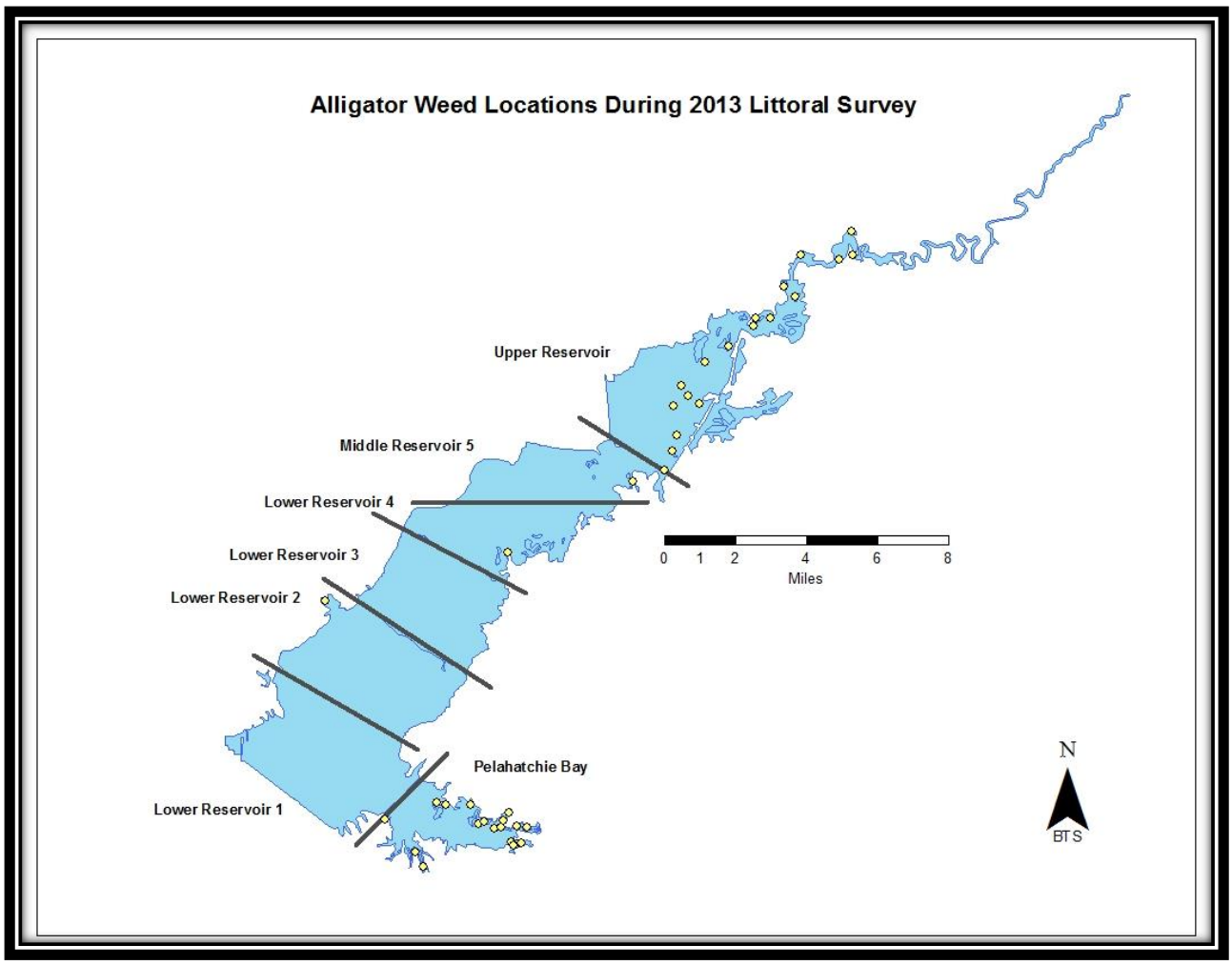

Figure 3. Alligatorweed locations during the 2013 Ross Barnett Reservoir littoral survey.

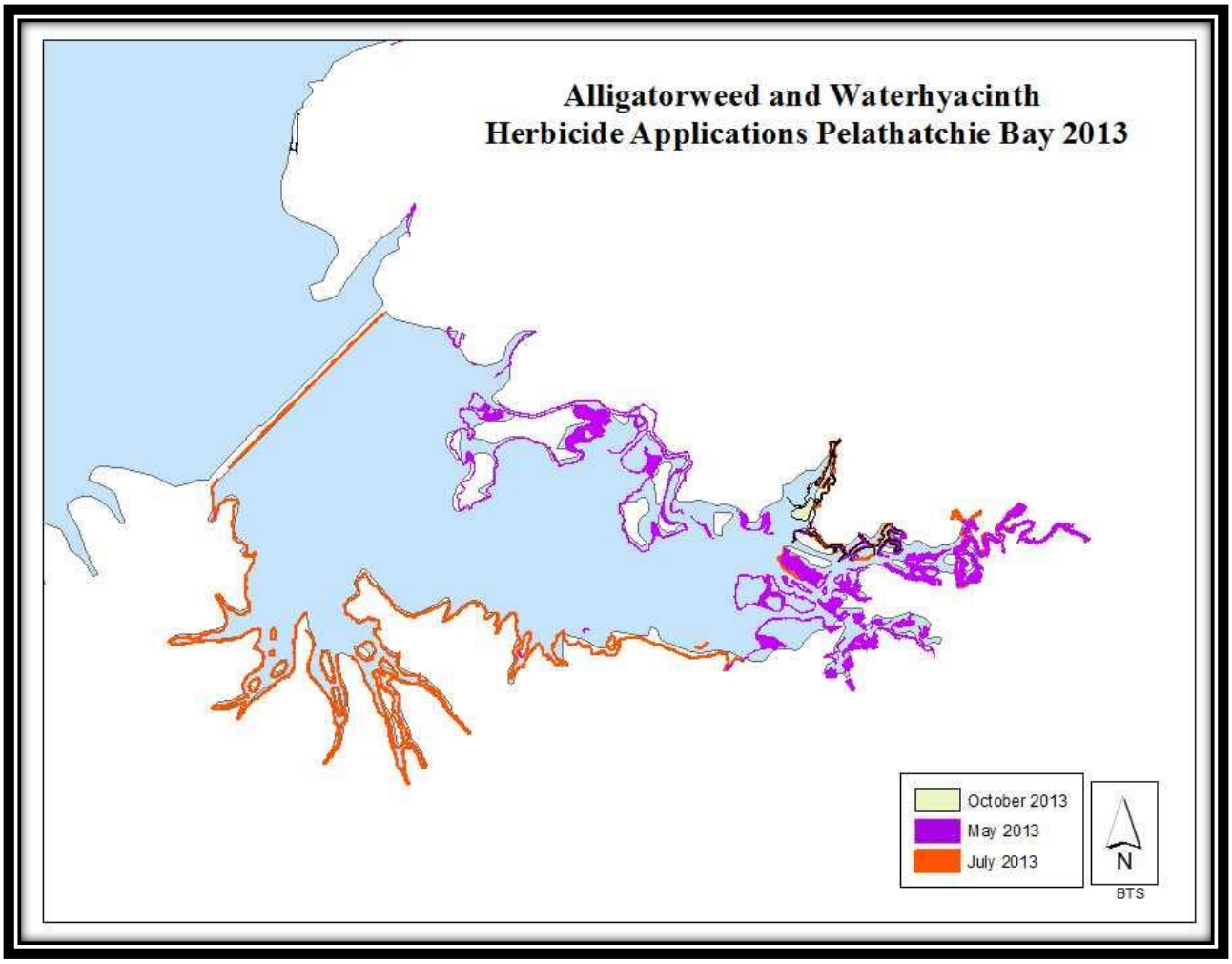

Figure 4. Alligatorweed and waterhyacinth herbicide applications from May to October 2013 in Pelahatchie Bay, Ross Barnett Reservoir.

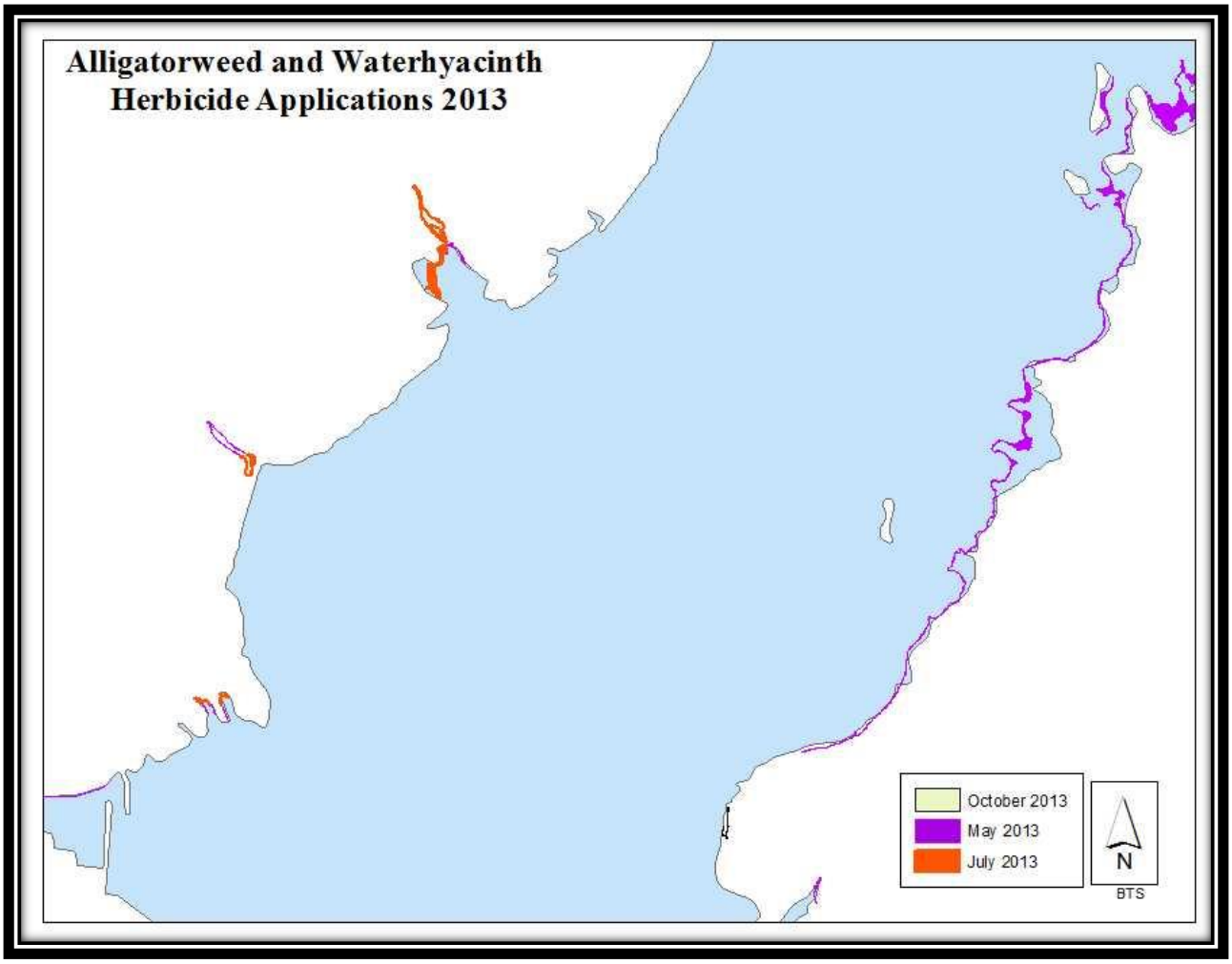

Figure 5. Alligatorweed and waterhyacinth herbicide applications from May to October 2013 in the Lower Main Lake, Ross Barnett Reservoir .

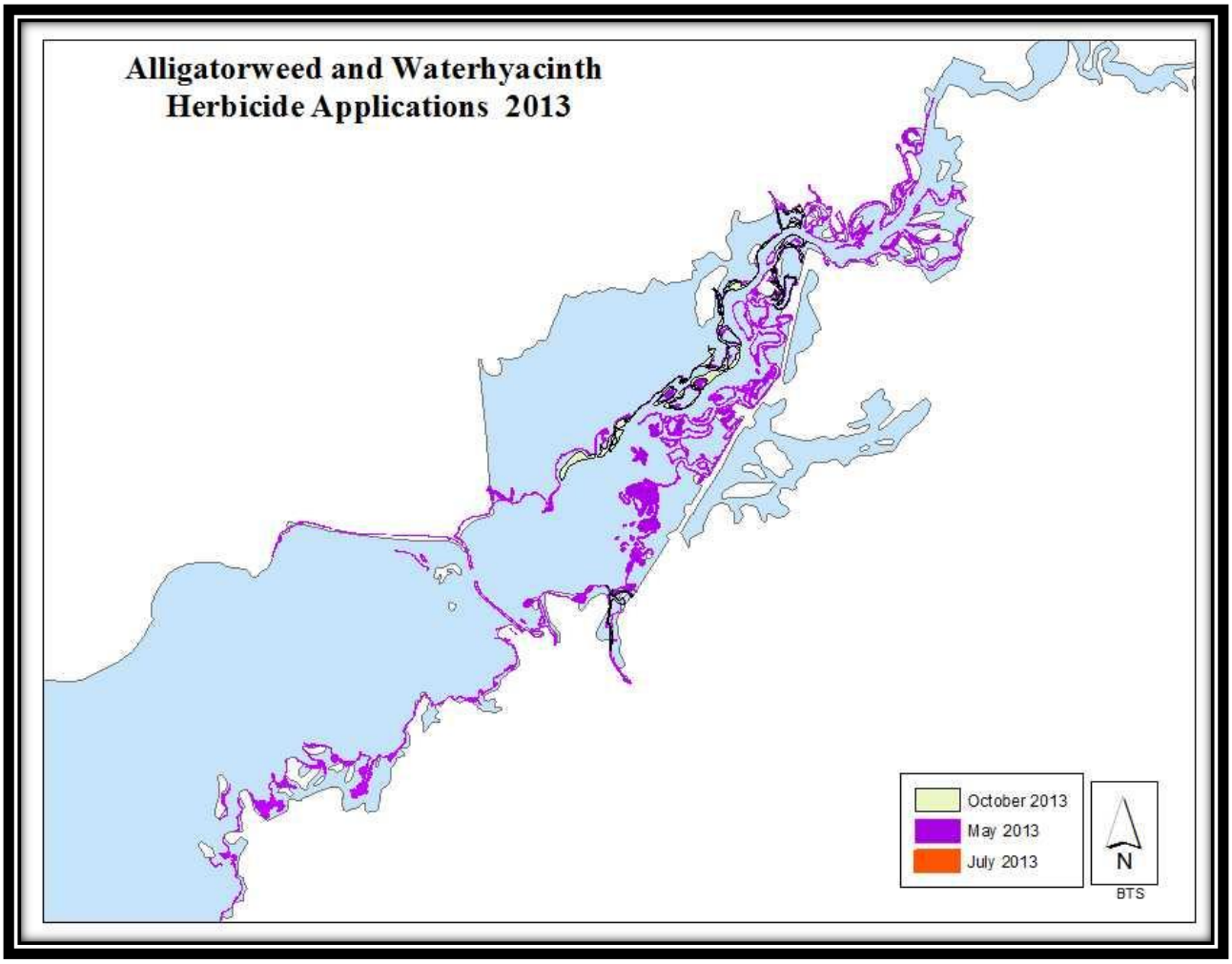

Figure 6. Alligatorweed and waterhyacinth herbicide applications from May to October 2013 in the Upper Main Lake and above MS Highway 43, Ross Barnett Reservoir.

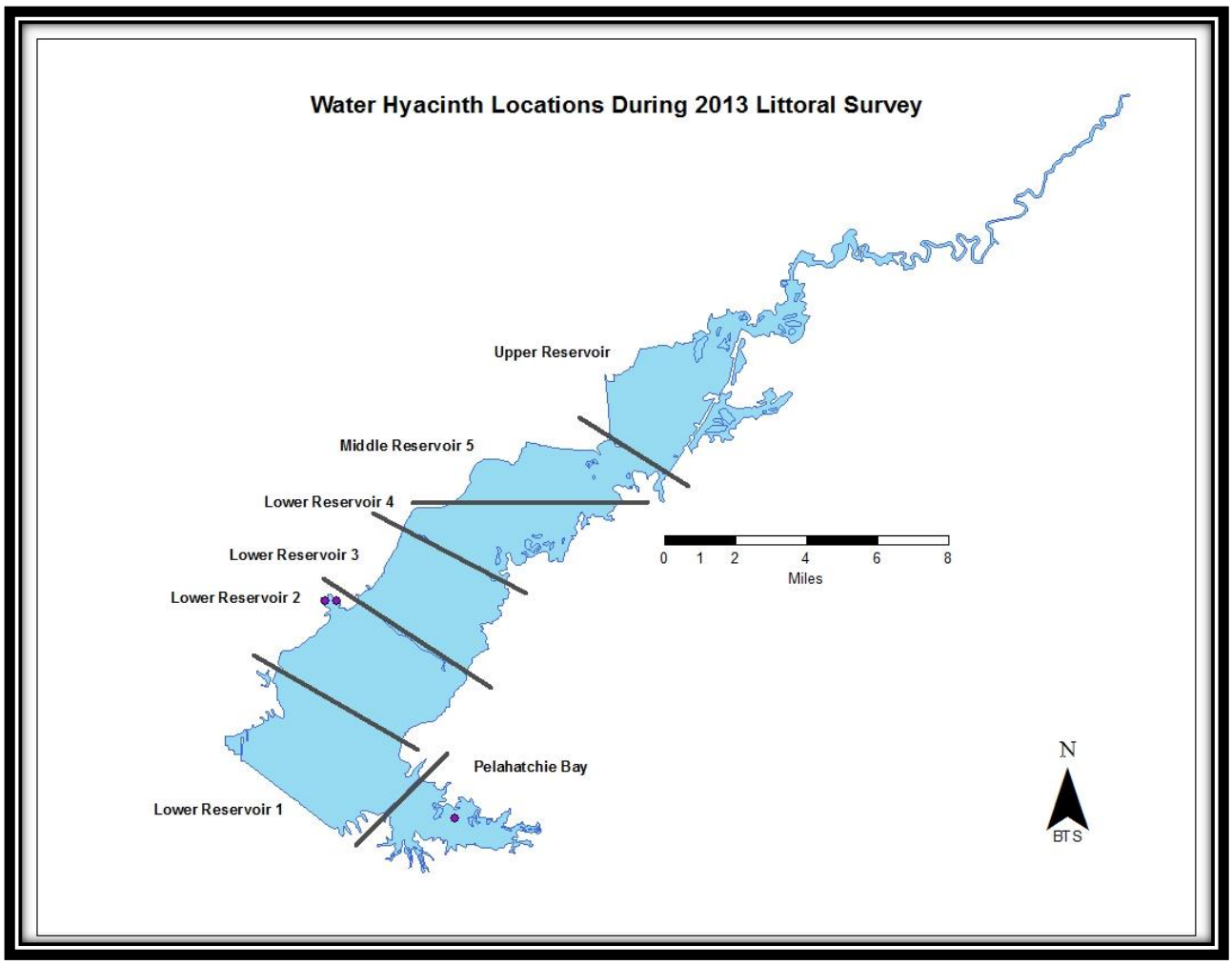

Figure 7. Waterhyacinth locations during the 2013 Ross Barnett Reservoir littoral survey.

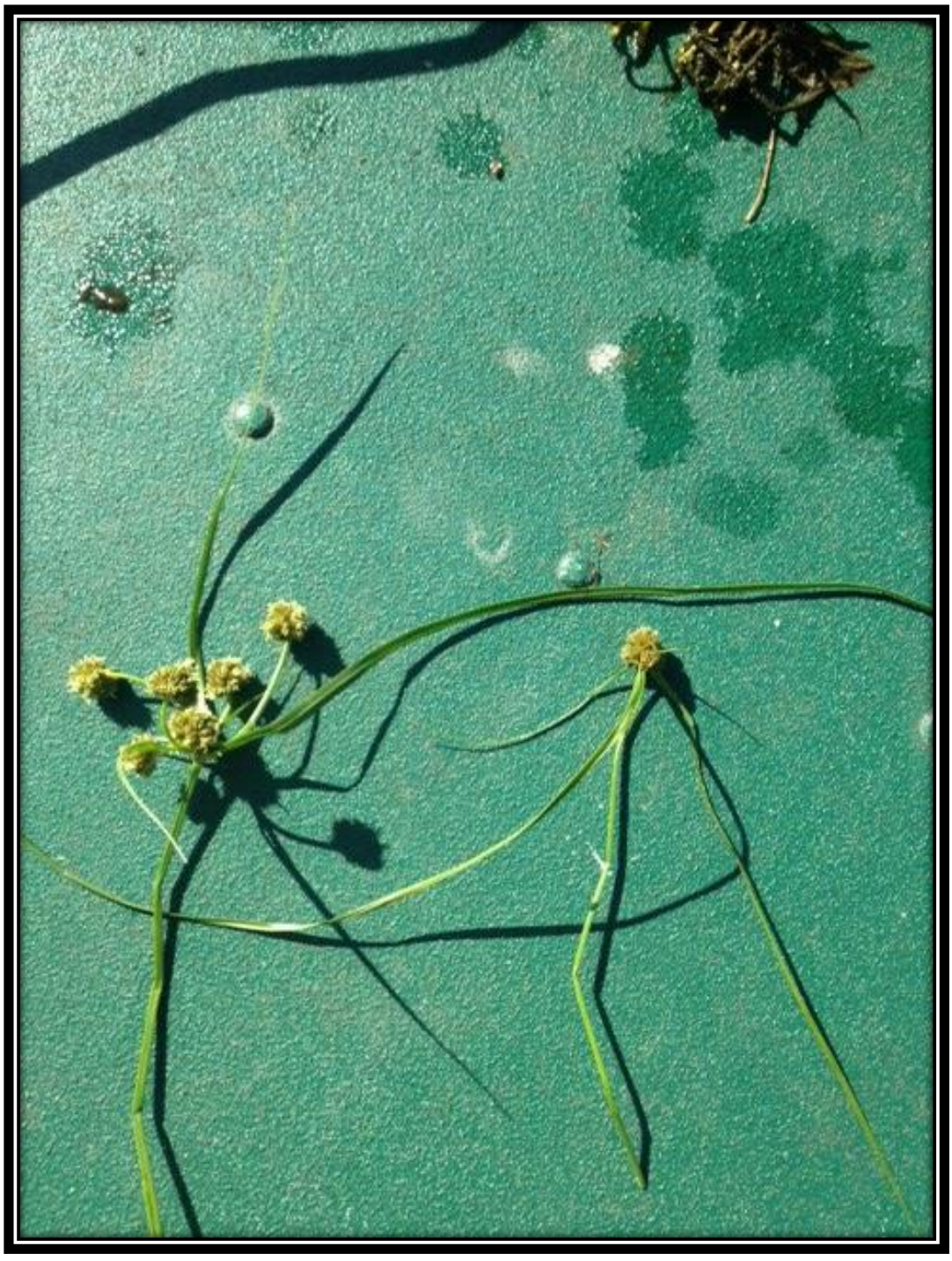

Figure 8. Two variations of Cuban bulrush collected during July 2013 at the Ross Barnett Reservoir. Left is the umbellate type (*O. cubense cubense*) Right is the monocephalous type (*O. cubense paraguayense)*

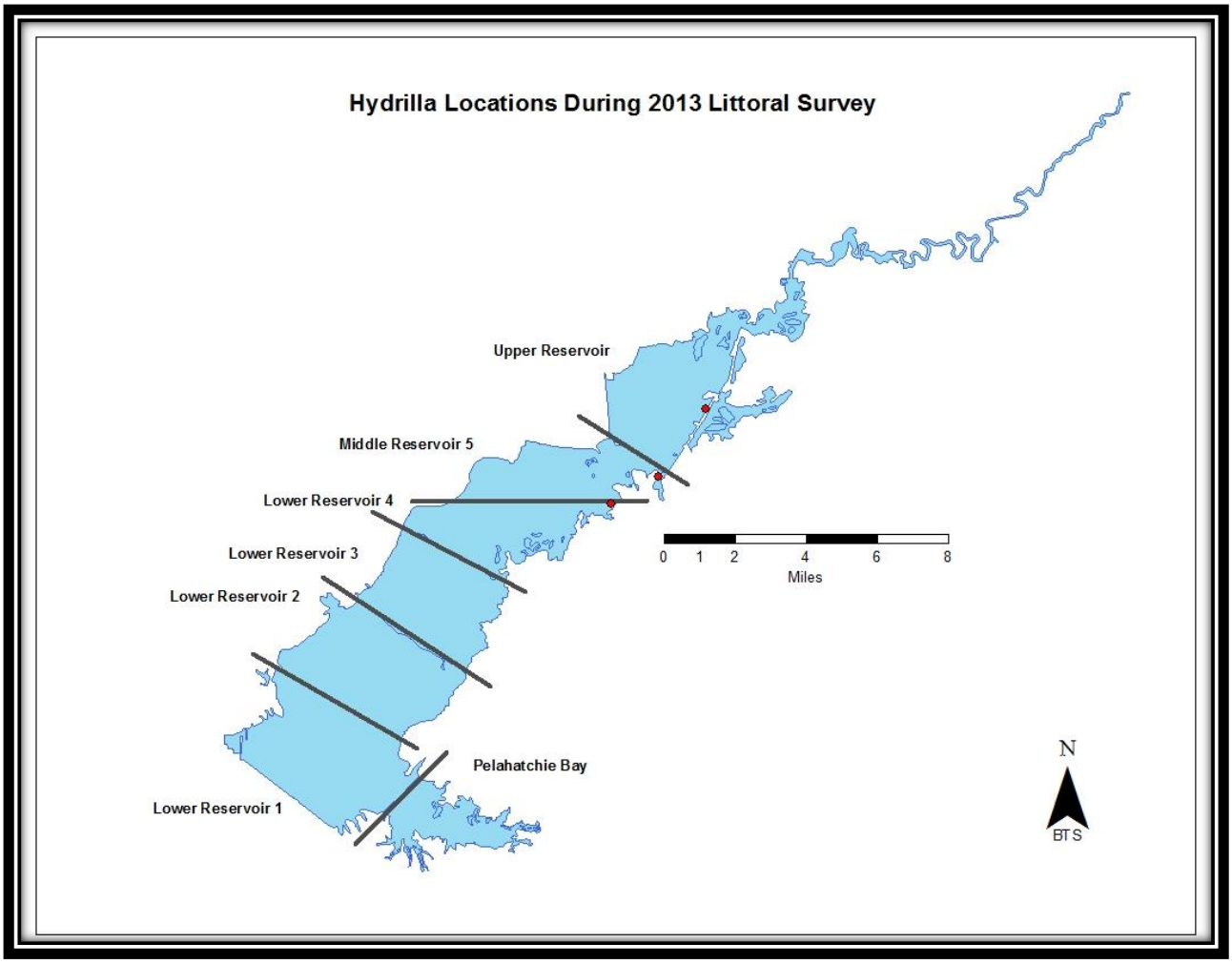

Figure 9. Hydrilla locations during the 2013 Ross Barnett Reservoir littoral survey.

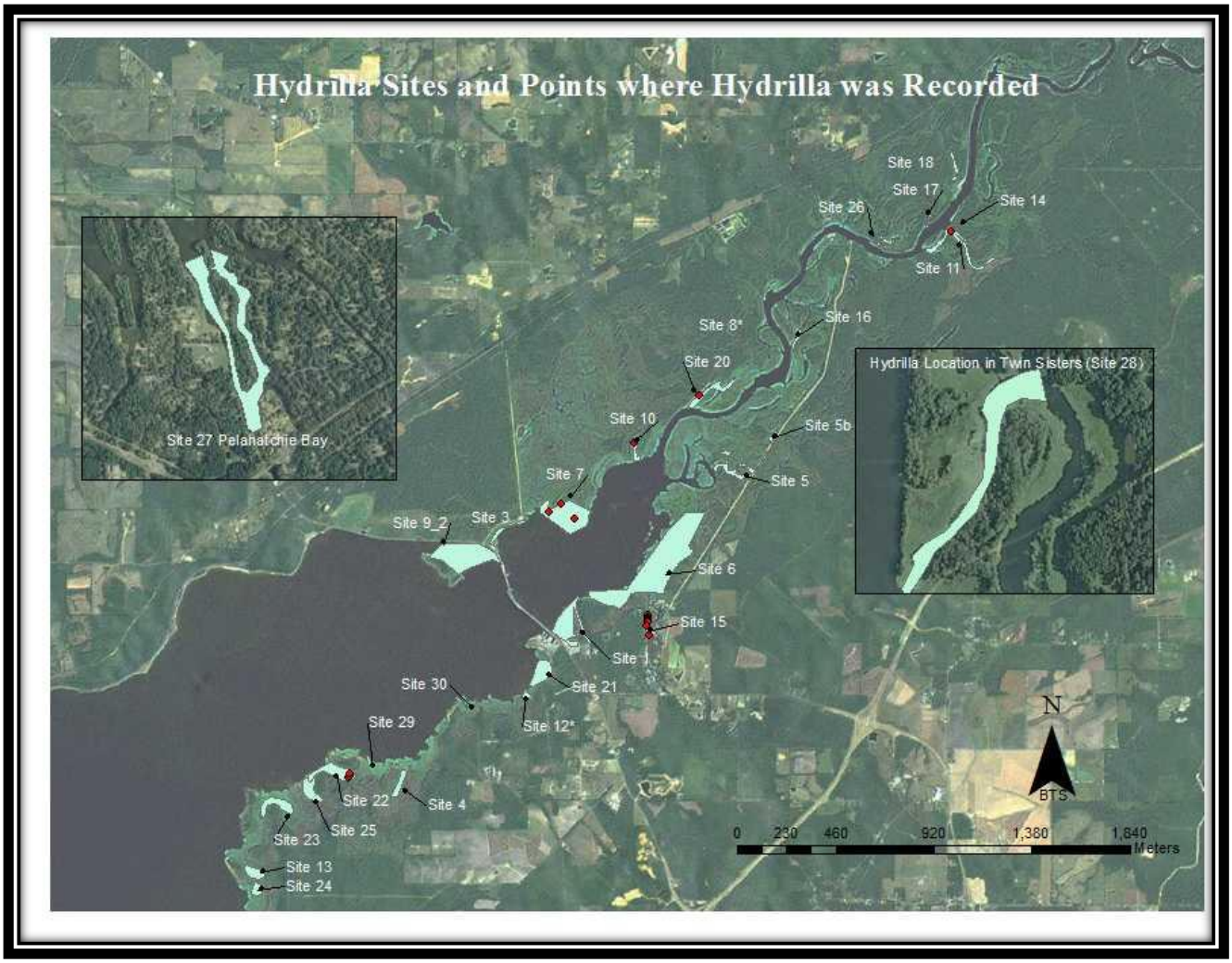

Figure 10. Hydrilla locations during the September 2013 Ross Barnett Reservoir hydrilla sites survey

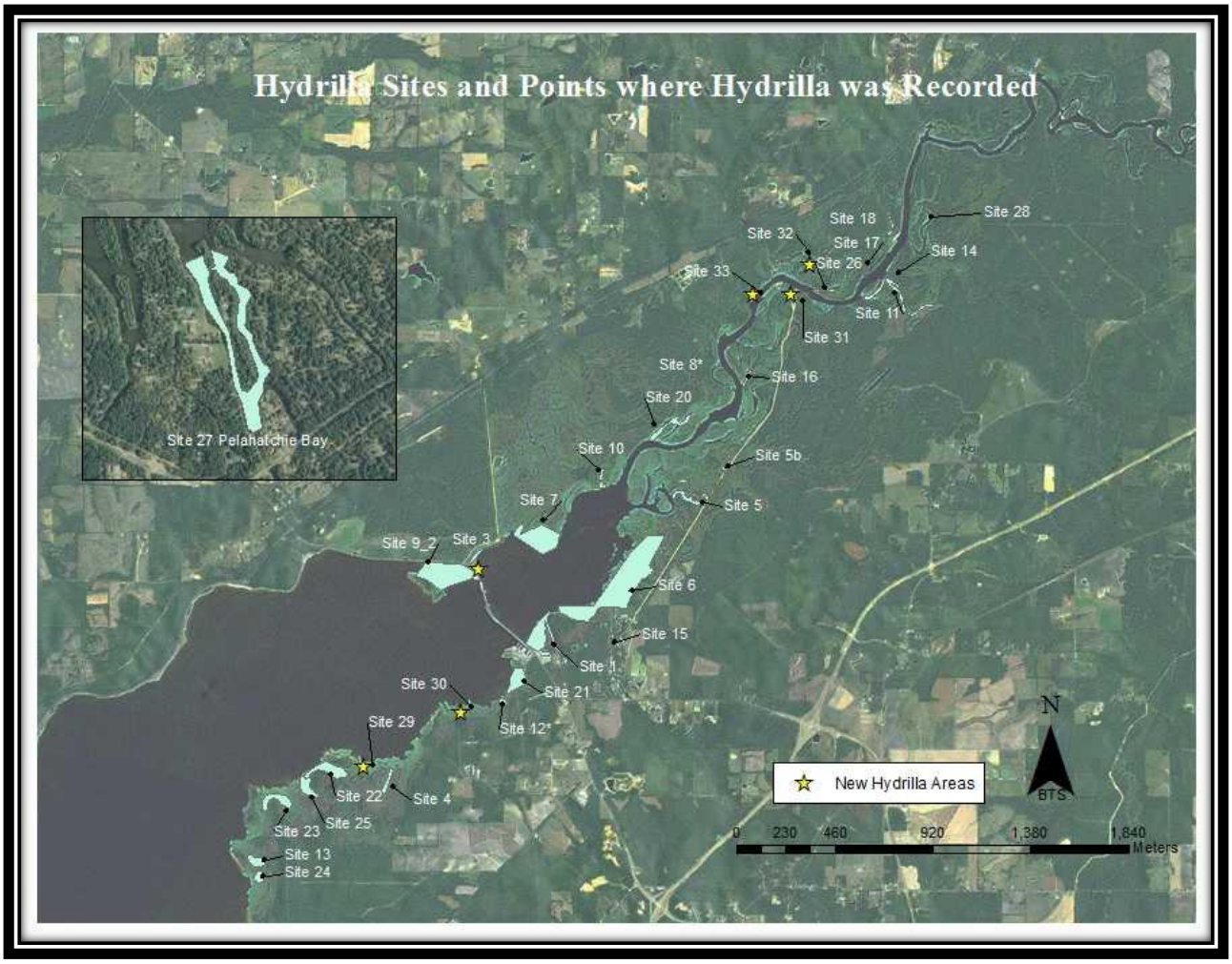

Figure 11. Hydrilla sites at the Ross Barnett Reservoir during 2013 with the addition of the newly discovered hydrilla sites

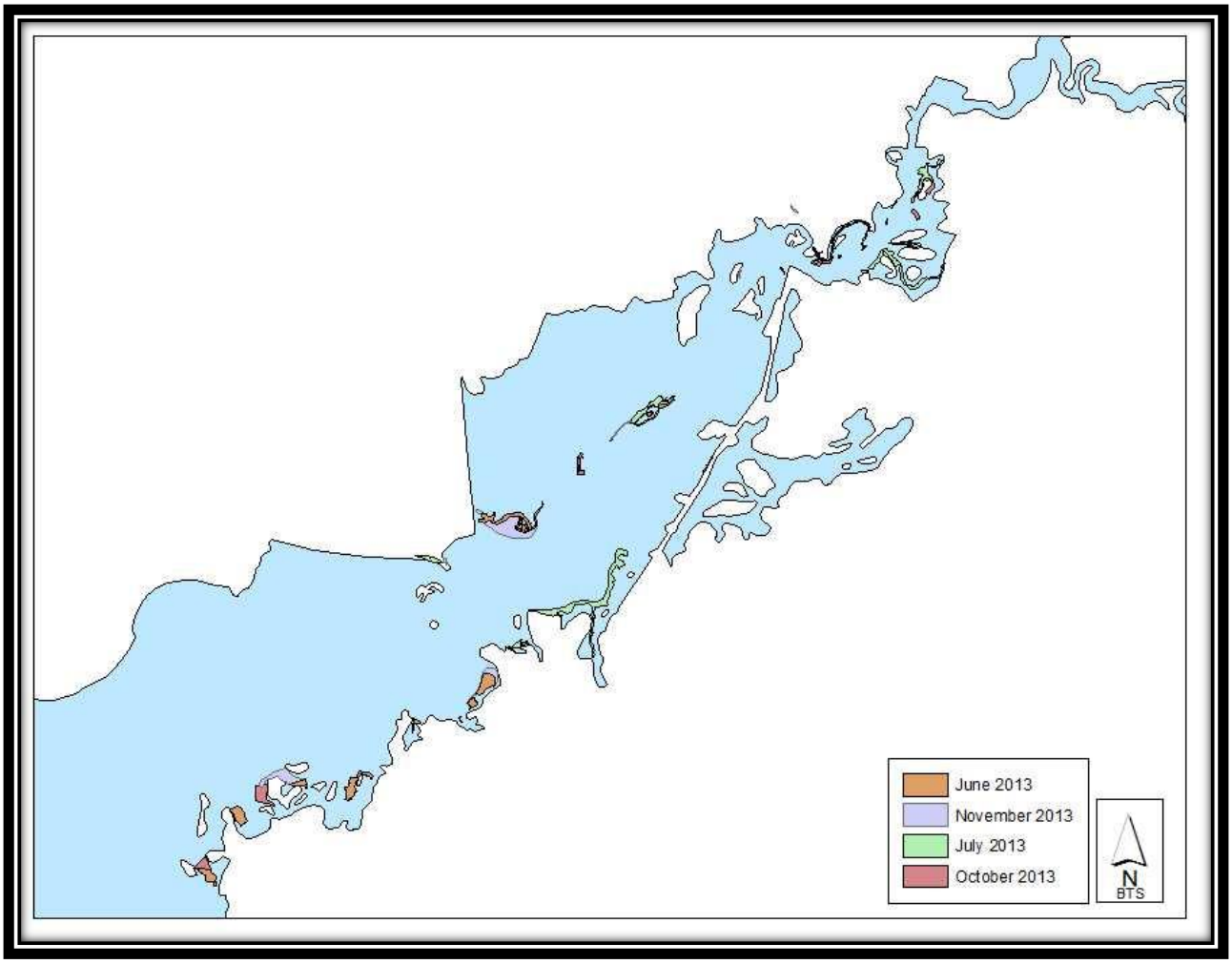

Figure 12. Areas treated for hydrilla during 2013 at the Ross Barnett Reservoir, MS

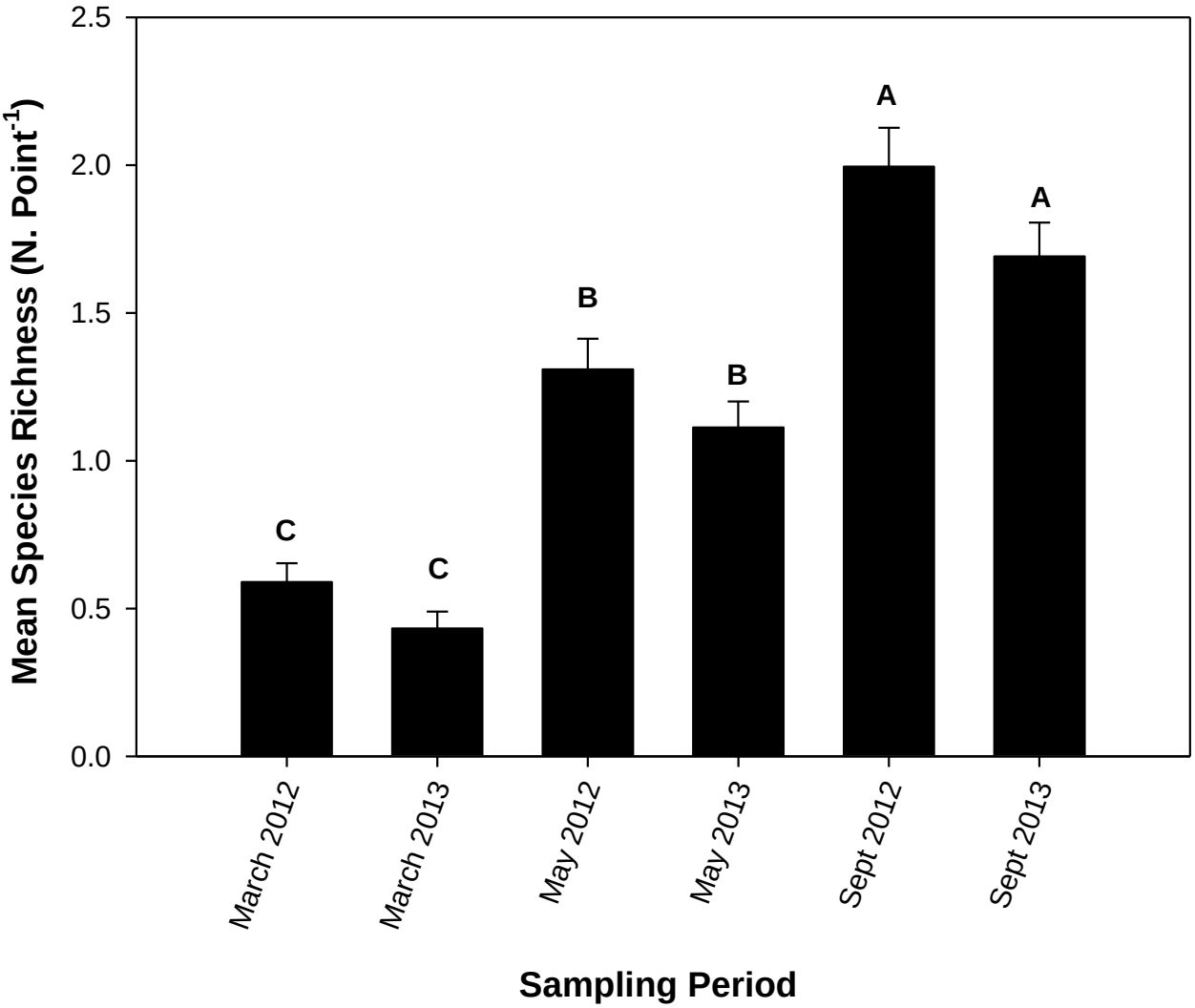

Figure 13. Mean native plant species (number of species observed per point) at each sampled location on the Ross Barnett Reservoir from March 2012 – September 2013 (Sartain 2014, Thesis).

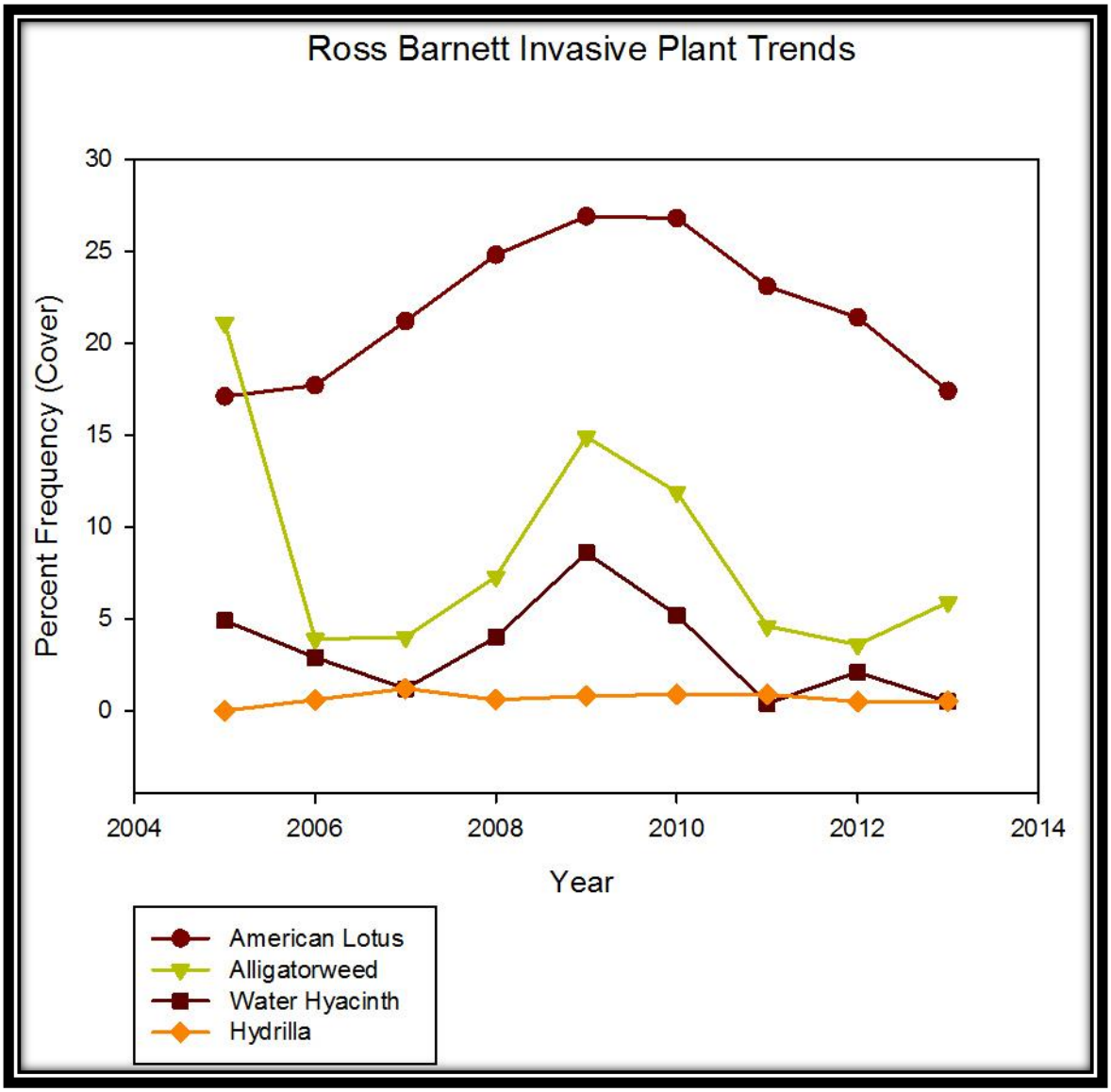

Figure 14. Percent frequency of American lotus and three invasive plant species from annual point intercept surveys, 2005 through 2013.

Table 1. The percent frequency of occurrence for aquatic plant species observed in the littoral zone (<10 ft.) during the Ross Barnett Reservoir Surveys 2012-2013. 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=0.05 level using a chi-square test. No species were significantly different between these two years.

Species	Common Name	2012 % Frequency (n=665)	2013 % Frequency (n=665)
Alternanthera philoxeroides	alligatorweed	3.6	5.9
Azolla carolininia	mosquito fern	0.0	0.0
Brasenia schreberi	watershield	0.1	0.0
Cabomba carolininia	fanwort	1.7	0.8
Ceratophyllum demersum	coontail	4.2	3.3
Colocasia esculenta	wild taro	0.5	0.3
Eichhornia crassipes	waterhyacinth	2.1	0.5
Hydrilla verticillata	hydrilla	0.5	0.5
Hydrocotyle umbellata	pennywort	0.9	0.3
Juncus effusus	common rush	0.0	0.0
Lemna minor	common duckweed	0.8	0.2
Limnobium spongia	American frog's bit	0.3	0.0
Ludwigia peploide	waterprimrose	8.3	7.4
Myriophyllum aquaticum	parrotfeather	0.0	0.0
Najas minor	brittle naiad	1.1	0.3
Nelumbo lutea	American lotus	21.4	17.4
Nitella sp.	nitella	0.8	0.0
Nymphaea odorata	white waterlily	5.7	5.4
Oxycaryum cubense	Cuban bulrush	0.6	0.0
Pistia stratiotes	waterlettuce	0.2	0.0
Potamageton foliosus	leafy pondweed	0.0	0.0
Potamageton nodosus	American pondweed	2.0	1.8
Sagittaria latifoli	broadleaf arrowhead	0.5	0.2
Sagittaria platyphylla	delta leaf arrowhead	0.9	0.3
Scirpus validus	softstem bulrush	0.3	0.5
Spirodella polyrhiza	giant duckweed	0.0	0.0
Typha sp.	cattail	1.5	0.6
Utricularia vulgaris	bladderwort	0.6	0.3
Zizaniopsis miliacea	giant cutgrass	2.0	2.6

Table 2. Percent frequency of occurrence for seven frequently observed plant species within known hydrilla sites of the Ross Barnett Reservoir during September 2012 and September 2013. The letter "n" refers to the total number of points sampled, an "*" indicates a statistically significant change in frequency of occurrence for the previous year for the indicated plant species (Sartain, 2014; in revision).

Species Name	Common Name	September 2012 % Frequency (n=177)	September 2013 % Frequency (n=177)
Alternanthera philoxeroides	Alligatorweed	5.6	0.6*
Cabomba caroliniana	Fanwort	14.1	6.8*
Ceratophyllum demersum	Coontail	11.9	14.7
Hydrilla verticillata	Hydrilla	14.1	6.8*
Ludwigia peploides	Waterprimrose	44.1	40.1
Nelumbo lutea	American lotus	32.2	37.9
Nymphaea odorata	White waterlily	37.9	30.5

Table 3. Tuber weight, tuber biomass, tuber density, and aboveground hydrilla biomass (g/m^2) from ANOVA of Ross Barnett Reservoir vs. Tenn-Tom Waterway hydrilla sites. Means with the same letter within the same column are not significantly different at the p=0.05 level.

Waterbody	Season	Tuber wt. (g DW/ tuber)	Tuber Biomass (gDW/m^2)	Tuber Density ($number/m^2$)	Aboveground Biomass (gDW/m^2)
Tenn-Tom Waterway	Winter (2007)	0.06 B	3.20 B	31.48 B	420.00 A
	Spring (2007)	0.38 A	21.34 A	140.74 A	146.11 B
Ross Barnett Reservoir	Winter (2012-2013)	0.00 C	0.03 C	1.04 C	0.00 C
	Spring (2012-2013)	0.01 BC	0.51 BC	6.94 C	0.09 C

Table 4. Dates of hydrilla treatment, total acreage treated, and total amount of formulated product used for hydrilla treatments in the Ross Barnett Reservoir in 2013.

Treatment/Date	Total Acres Treated	Product Used
Treatment #1 June	80	Reward-112.5 gallons Harpoon-70 gallons Sonar-568 lbs
Treatment #2 July	117.2	Reward-1,081 gallons Komeen-1,758 gallons
Treatment #3 October	74	Reward-109 gallons Komeen-1,411 gallons
Treatment #4 November	102	Reward-108 gallons Harpoon-1,425 gallons Granular Harpoon-40 lbs

Table 5. Treatment record by month and product (F, fluridone; C, contact), for hydrilla sites during 2005-2013, a (1) indicates that hydrilla was present during treatment.

		Treatment Records								
Hydrilla Site	Year Discovered	2005	2006	2007	2008	2009	2010	2011	2012	2013
1	2005	1	1-F (April)	1-F	1	1-FC	C (Jun, Aug, & Oct)	1-C (Jun, August)	1-C (Jun, Aug)	1-C(Jun, July)
2	2005	1	1-F (April)	F						1-C(July)
3	2006		1-F (April)	F						1-C(Nov)
4	2006		1-F (April)	1-F	1	F		1-C (Aug, Sept)	1-C (Jun, Aug, Oct)	1-F(Jun)
5	2006		1-F (April)	F	?	1-FC	1-C (Jun, Aug, & Oct)	1-FC (Jun, Aug)	1-C (Jun, Aug, Oct)	1-F(Jun)
6	2007			1-F	?	1	1-C (Jun, Aug, &Oct)	C (Jun, Aug, Sept)	1-C(Oct)	1-C(July)
7	2007			1	?	F		C (Sept)	1-C (June, Aug, Oct)	1-F(Jun, Nov)
8	2007			1	?					
9	2007			1	?					
10	2007			1	?			1-C (Sept)	1-C (Oct)	1-F(Jun, Oct)
11	2007			1-F	1-F	1-F	C (Jun, Aug, & Oct)	1-C (Jun, Aug)	1-C (Jun, Aug, Oct)	1-C(July)
12	2009					1	F (June)	FC (Jun, Aug, Sept)	1-C (Jun, Aug)	1-F(Jun, Nov)
13	2009					1	F (June)	1-FC (Jun, Aug, Sept)	1-C (Jun, Aug)	1-FC(Jun, Oct)
14	2010						1-C (Aug & Oct)	1-C (Jun, Aug)	1-C (Jun, Aug, Oct)	1-C(July)
15	2010						1-C (August)	1-F (Jun)	1-C (Jun, Aug, Oct)	
16	2010						1	C (Jun)		
17	2011							1-C (Aug, Sept)	1-C (Aug, Oct)	1-C(July)
18	2011							1-C (Aug, Sept)	1-C (Jun, Aug)	
19	2011							1-C (Aug, Sept)	1-C (Jun, Aug)	
20	2011							1-C (Sept)	1-C (Jun, Aug, Oct)	1-FC(Jun, July, Oct,Nov
21	2011							1-C (Sept)		1-F(Jun, Nov)
22	2011								1-C (Jun, Aug, Oct)	1-F(Jun, Nov)
23	2011								1-C (Jun, Aug)	1-F(Jun)
24	2011								1-C (Jun, Aug)	
25*	2012								1-C (Jun, Aug, Oct)	1-C(Oct)
26*	2012								1-C (Oct)	1-C(July, Oct)
27*	2012								1-C (Oct)	1-C(July)
28*	2012								1-C (Oct)	1-C(July, Oct)
29	2013									1-F(Jun)
30	2013									1-C(Nov)
31	2013									1-C(Oct)
32	2013									1-C(Nov)
33	2013									1-C(Nov)

Appendix A. The percent frequency of occurrence for 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 percent frequency from the previous year, at a p=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)
Alternanthera philoxeroides	alligatorweed	I	21.1	3.9	4	7.3	14.9*
Azolla caroliniana	mosquito fern	N	0	0.2	0.4	0	0.5
Brasenia schreberi	watershield	N	-	-	-	-	-
Cabomba caroliniana	fanwort	N	2.2	0	0.5	1.3*	0.6
Ceratophyllum demersum	coontail	N	4.4	4.9	3.5	7.6*	3.6*
Colocasia esculenta	wild taro	I	0	0.9	0.7	2.4*	2.4
Eichhornia crassipes	waterhyacinth	I	4.9	2.9	1.2	4.0*	8.6*
Hydrilla verticillata	hydrilla	I	0	0.6*	1.2*	0.6*	0.8
Hydrocotyle ranunculoides	pennywort	N	6.4	0.5	1.4	2.8*	1.3*
Juncus effusus	common rush	N	0	0	0	0.2	1.7
Lemna minor	common duckweed	N	3.1	2.5	1.9	1.4*	1.3
Limnobium spongia	American frogsbit	N	1.5	0.8	0.7	1.3	0.3
Ludwigia peploides	waterprimrose	N	4.9	7.4	4.3	10.2*	14.8*
Myriophyllum aquaticum	parrotfeather	I	0.7	0	0.2	1.0*	0.4
Najas minor	brittle naiad	I	0	0	1.9*	1.0*	0.3
Nelumbo lutea	american lotus	N	17.1	17.7	21.2	24.8*	26.9
Nitella sp.	stonewort	N	0.1	0	0	0	0
Nymphaea odorata	white waterlily	N	4.4	3.4	4.9	5.4	5.9
Oxycaryum cubense	Cuban bulrush	I	-	-	-	-	-
Pistia stratiotes	waterlettuce	I	-	-	-	-	-
Potamageton foliosus	leafy pondweed	N	0	0	0	0.6	0
Potamageton nodosus	American pondweed	N	2.7	2.7	2.4	3	2.9
Sagittaria latifolia	broadleaf arrowhead	N	1	1.2	0.0*	0.5	1.3
Sagittaria platyphylla	delta leaf arrowhead	N	0	1.8	0.8	0.3*	2.3*
Scirpus validus	softstem bulrush	N	1.2	0.2	0	0	0
Spirodella polyrhiza	giant duckweed	N	0	0	0	0.16	0.7
Typha sp.	cattail	N	1.3	2.4*	0.7	1.1	7.1*
Utricularia vulgaris	bladderwort	N	0	0.4	0	0.5	0.1
Zizaniopsis miliacea	giant cutgrass	I	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=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)
Alternanthera philoxeroides	alligatorweed	I	14.9*	11.9	4.6	3.6	5.9
Azolla caroliniana	mosquito fern	N	0.5	0	0.2	0	0
Brasenia schreberi	watershield	N	-	-	-	0.1	0
Cabomba caroliniana	fanwort	N	0.6	0	0.5	1.7	0.8
Ceratophyllum demersum	coontail	N	3.6*	3.9	5.8	4.2	3.3
Colocasia esculenta	wild taro	I	2.4	2.1	0.7	0.5	0.3
Eichhornia crassipes	waterhyacinth	I	8.6*	5.2*	0.4	2.1	0.5
Hydrilla verticillata	hydrilla	I	0.8	0.9	0.9	0.5	0.5
Hydrocotyle ranunculoides	pennywort	N	1.3*	0.3	0.1	0.9	0.3
Juncus effusus	common rush	N	1.7	1.6	0.1	0	0
Lemna minor	common duckweed	N	1.3	1.5	3.1	0.8	0.2
Limnobium spongia	American frogsbit	N	0.3	0.3	0.4	0.3	0
Ludwigia peploides	waterprimrose	N	14.8*	11.9	5.5	8.3	7.4
Myriophyllum aquaticum	parrotfeather	I	0.4	0.2	0	0	0
Najas minor	brittle naiad	I	0.3	0.2	0.9	1.1	0.3
Nelumbo lutea	American lotus	N	26.9	26.8	23.1	21.4	17.4
Nitella sp.	stonewort	N	0	0	0.3	0.8	0
Nymphaea odorata	white waterlily	N	5.9	5.3	4.8	5.7	5.4
Oxycaryum cubense	Cuban bulrush	I	-	0	0.3	0.6	0
Pistia stratiotes	waterlettuce	I	-	0	0	0.2	0
Potamageton foliosus	leafy pondweed	N	0	0.3	0	0	0
Potamageton nodosus	American pondweed	N	2.9	1.1	1.2	2	1.8
Sagittaria latifolia	broadleaf arrowhead	N	1.3	1	1.2	0.5	0.2
Sagittaria platyphylla	delta leaf arrowhead	N	2.3*	1.1	0.1	0.9	0.3
Scirpus validus	softstem bulrush	N	0	0	0	0.3	0.5
Spirodella polyrhiza	giant duckweed	N	0.7	0.5	0.6	0	0
Typha sp.	cattail	N	7.1*	5.5	2.4	1.5	0.6
Utricularia vulgaris	bladderwort	N	0.1	0	1.2	0.6	0.3
Zizaniopsis miliacea	giant cutgrass	N	10.4*	8.5	0.9	2	2.6