Littoral Zone Aquatic Plant Community Assessment of the Ross Barnett Reservoir, MS for 2007

American lotus (*Nelumbo lutea*)

An Annual Report to the Pearl River Valley Water Supply District

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INTRODUCTION

Non-native plants affect aesthetics, drainage, fishing, water quality, fish and wildlife habitat, flood control, human and animal health, hydropower generation, irrigation, navigation, recreation, and ultimately land values (Pimentel et al. 2000, Rockwell 2003). The fraction of non-native plants that are harmful does not have to be large to inflict significant damage to an ecosystem (Pimentel et al. 2000). As the threat of non-native plant species increases, the development and refining of methods to rapidly detect, monitor and ultimately control these species to mitigate negative impacts is critical. Three non-native aquatic plant species that have caused major problems throughout the United States are waterhyacinth (*Eichhornia crassipes*) alligatorweed (*Alternanthera philoxeroides*), and hydrilla (*Hydrilla verticillata*). In Mississippi, all three of these species can be found in the Ross Barnett Reservoir. This is of concern because this reservoir is not only the largest reservoir in the state (33,000 acres), but it also supplies the City of Jackson with potable water. Waterhyacinth and alligatorweed have been under active management for almost a decade, primarily through the use of systemic herbicides. Hydrilla was first observed in the Reservoir in 2005 and has since undergone aggressive management through the use of the systemic herbicide fluridone and the contact herbicide endothall. To ensure that these management techniques are successful, we conducted a survey of the littoral zone plant community to monitor and record changes in the occurrence of plant species as well as to assess management techniques. Regular assessment of management effectiveness is a significant component of successful long-term maintenance management programs (Madsen 2007).

OBJECTIVES

Our objectives were to 1) continue monitoring the aquatic plant community in the Ross Barnett Reservoir by mapping the distribution of aquatic plants in the littoral zone (water depths ≤ 10 feet; 2) continue to monitor and assess the current hydrilla populations as well as document the presence of new populations; and 3) assess control techniques for waterhyacinth and alligatorweed. The results of this assessment are included in detail in this report.

MATERIALS AND METHODS

Vegetation Survey

Aquatic plant distribution was evaluated using a point intercept survey method using a 300 meter grid in July 2007 (Madsen 1999). Only those points occurring in water depths of ≤ 10 feet were sampled. Sampling points in this manner allowed for a more rigorous survey of the littoral zone, the portion of the reservoir most likely to be inhabited with aquatic plants (Figure 1). There were still areas within the littoral zone that were inaccessible by boat due to low water levels at the time of the survey. Points that were located in those areas were not sampled. The southern portion of the Reservoir was excluded due to greater water depths and the low likelihood of observing plant growth. For the purposes of recording sampling data, the Reservoir was divided into seven sections: Upper Reservoir, Middle Reservoir 5, Middle Reservoir 4, Lower Reservoir 3, Lower Reservoir 2, Lower Reservoir 1, and Pelahatchie Bay.

A hand-held personal digital assistant (PDA) outfitted with a global positioning systems (GPS) receiver was used to navigate to each point. Spatial data were directly recorded in the hand-held computer using Farm Works® Farm Site Mate software (Wersal et al. 2006a, Wersal et al. 2007). Data were recorded in database templates using specific pick lists constructed exclusively for this project. The software provides an environment for displaying geographic and attribute data and enables navigation to the specific points of this survey. A total of 423 points were sampled during the survey by deploying a rake to determine the presence or absence of aquatic plant species at these points (Figure 1). Water depth was also recorded at each point during the survey.

Percent frequency of occurrence was calculated for each species by dividing the number of detections for that species by the total number of points sampled. Estimated total acreage for commonly occurring aquatic plant species was also calculated by using the total number of points at which a given species was observed and multiplying that number by 22.2 (the acreage represented by one survey point). The change in occurrence of plant species was determined using McNemar's Test to account for repeated measures (sampling the same points in multiple years) in the sampling design (Stokes et al. 2000, Wersal et al. 2006b). A pairwise comparison of species occurrences was made between years using the Cochran-Mantel-Haenszel statistic (Stokes et al. 2000, Wersal et al. 2006b).

References and comparisons to the 2005 survey were done using only the littoral zone sample points that correspond to the surveys conducted in 2006 and 2007.

Invasive Species Management

Waterhyacinth and Alligatorweed Assessment: Management assessments of these plant species were made at the Reservoir scale using data obtained from the point intercept surveys. These data will allow for a quantitative comparison of changes in the frequency of occurrence of each species between years.

Hydrilla Assessment: A survey of hydrilla sites 1 through 4 and other possible observations was conducted in April 2007 (Figure 12). Surveys were conducted from a boat by deploying a plant rake to determine the presence or absence of hydrilla at these locations. If hydrilla was present, the GPS locations were recorded using a handheld computer. Approximately 228 acres were surveyed during this time for the presence of hydrilla.

Following the survey in April, another survey was conducted during May 2007 at sites 1 through 4 to quantitatively assess fluridone treatments one year after treatment. At each site, 30 regularly spaced points were sampled for hydrilla presence by deploying a plant rake. Hydrilla populations were assessed by recording hydrilla presence or absence, if hydrilla was at the water surface (topped out), and assigning a nuisance rating (1 to 4) at each point (Madsen 2005, Madsen 2007) (Table 1). Additionally, site 5 was surveyed in the same fashion to assess the presence of hydrilla prior to fluridone applications.

Table. 1 Hydrilla nuisance ratings (Madsen 2005).

Rating	Description
1	Poor control, extensive nuisance problems with hydrilla at the surface
3	Fair control, abundant hydrilla but not to the surface
3	Good control, hydrilla present but sparse
4	Excellent control, only sprigs of hydrilla observed, or no hydrilla

An additional hydrilla survey encompassing approximately 190 acres was conducted in August 2007 with the Reservoir applicator. The survey was used to verify observations and locations of new hydrilla infestations found in areas not covered during the littoral survey. A plant rake was deployed at regular intervals throughout the survey, and any presence of hydrilla at the surface was recorded.

Hydrilla tuber surveys were conducted following the spring and summer surveys. A tuber survey of the initial four hydrilla populations and site 5 was conducted in February and December of 2007 to assess the density of the tuber bank. Additionally, site 6 was surveyed in December. Thirty core samples were collected within each hydrilla site using a PVC (0.018 m^2) coring device (Madsen et al. 2007). Core samples were washed in a pail with a 0.25 m^2 wire mesh bottom to separate plant material (tubers) from the sediment. Plant material was placed into 1 gallon Ziploc® bags for transport back to Mississippi State University. Samples were sorted, dried to a constant mass, and weighed to assess tuber biomass and density.

RESULTS AND DISCUSSION

Vegetation Survey

The survey of the Ross Barnett Reservoir yielded 19 aquatic and riparian plant species (Table 2). The dominant species was the native plant American lotus with a percent frequency of occurrence of 21%, followed by white waterlily at 5% (Figures 2 and 3). Other native plant species included coontail (4%) and American pondweed (2%) (Figures 4 and 5). The occurrence of all non-native species was below 5%, with alligatorweed observed most often (4%) (Figure 6). Hydrilla had a frequency of occurrence of 1%, followed by waterhyacinth (Figures 7 and 8). Hydrilla was observed at 5 locations during the littoral zone survey in July 2007, resulting in the 1% frequency of occurrence; the points depicted in Figure 7 are all of the sites that are known to have hydrilla and were not necessarily observed during the July survey or used in analyses. Brittle naiad (*Najas minor*), a non-native plant from Europe, had a frequency of occurrence of 2% and was observed for the first time during the survey in July of 2007 (Figure 9). It is unclear; however, how problematic it will become due to the presence of other submersed species such as hydrilla, the shading caused by American lotus, and stresses associated with fluctuating water levels. Brittle naiad does not typically cause the widespread nuisance problems of the other nonnative species, but it should be monitored in the future. The low water levels of the past two years may contribute to increased abundance of brittle naiad which, as an annual, is favored by this type of disturbance.

Water depths during the time of this survey were significantly lower than in 2005 ($p \leq 0.01$) (Figure 10). The lower depths may have favored species that could tolerate the stresses associated with low water. Also, some shallow water areas were not accessible and therefore were not sampled, possibly resulting in some species being missed, which may be a plausible explanation for an overall reduction in species richness in 2006 and 2007 (Figure 11). Submersed plant species growing in what were shallow areas in 2005 were likely killed as the water receded in 2006 and 2007 and bottom sediments were exposed to air. Typically, draw-downs favor the establishment of mud-flat annuals and emergent species in areas that were previously dominated by aquatic species (van der Valk 1981). Species such as American lotus reproduce vegetatively via rhizomes and also through the production of large seeds. The production of seeds represents a mechanism for survival of adverse conditions or a mechanism for spread during times of low water (Sculthorpe 1967). The frequency of occurrence of American lotus increased from 2005 to 2007, although the increase was not significant ($p = 0.08$). The frequency of occurrence for the native species white waterlily, American pondweed, and coontail did not change from 2005 to 2007 ($p = 0.44$, $p = 0.92$, and $p = 0.58$, respectively). White waterlily and American pondweed are floating leaved species and may be tolerant of water level fluctuations. Indeed, there was not significant relation found between floating plant species and drawdown (Van Geest et al. 2005). However, coontail is a submersed species and much more sensitive to water depth than the floating species. The fact that the occurrence of coontail did not change between 2005 and 2007 may suggest that it occurs in the deeper portions of the littoral zone, sheltering it from water fluctuations.

While we are confident of the estimates of floating and submersed plant distributions, we are concerned that alligatorweed and other emergent plants may be under-sampled. Alligatorweed may grow in very shallow water or even in moist soil. We propose using remote sensing (either aerial photography or satellite imagery) to validate our estimates of alligatorweed distribution from point sampling and determine areas of existence beyond the shoreline of the Reservoir.

Invasive Species Management

Waterhyacinth and Alligatorweed Assessment: The frequency of occurrence for both waterhyacinth and alligatorweed decreased significantly ($p \leq 0.01$) from 2005 to 2007. The frequency of occurrence for waterhyacinth in 2005 was 4.9% and declined to 2.9% and 1.2% in 2006 and 2007, respectively (Table 2). The occurrence of alligatorweed was reduced from 21.1% in 2005 to 3.9% in 2006 and to 4.0% in 2007; almost an 80% reduction in occurrence. These reductions in species occurrence may be attributed to the use of systemic herbicides 2,4-D for waterhyacinth and 2,4-D and Imazapyr for alligatorweed. The occurrence of American lotus, white waterlily, American pondweed, and coontail did not significantly change between years, indicating that waterhyacinth and alligatorweed are being selectively removed with little impact on native plant species or species richness. Our surveys suggest that the aggressive management of waterhyacinth and alligatorweed has been successful in reducing these weeds in the Ross Barnett Reservoir. If the survey team had better information on the locations of management activities in the Reservoir, a more direct approach at assessing management of these two species could be achieved and would provide more definitive information.

Hydrilla Assessment: Hydrilla was not observed at any of the four sites in April 2007 that were previously treated with fluridone (Figure 12). Some dead shoots were found at Site 1. However, since no viable shoots were found, it is uncertain if these dead shoots were from the herbicide application in the previous year or if they were fragments that did not establish and subsequently died. Viable hydrilla was observed at Site 5, where both fragments and rooted plants were found. A follow up survey of sites 1 through 4 was conducted in May 2007 (one year after treatment) and resulted in no hydrilla being observed; a nuisance rating of 4 was assigned at all points. The fluridone treatments in April 2006 have resulted in excellent control of hydrilla one year after treatment. A pretreatment survey of Site 5 in May 2007 resulted in no hydrilla observed and nuisance ratings of 4 being assigned at each point. Therefore, hydrilla densities at this site are considered to be low, and fluridone treatments at this location should offer excellent control.

The littoral survey in July 2007 resulted in no observations of hydrilla in Site 5 approximately 60 days after the fluridone treatment. Overall, the occurrence of hydrilla has significantly increased ($p \leq 0.01$) from 2005 to 2007. The increase can be attributed to the finding of 3 new infestations (Sites 6, 7, and 8) during the July 2007 littoral survey and an additional three sites (9, 10, and 11) in August 2007 (Figure 13). Site 6 is the largest of the 11 sites and encompasses approximately 178.8 acres. Hydrilla was not observed throughout this entire area; however, it was seen at regular intervals throughout the site. Hydrilla in sites 6, 7, 8 was showing fluridone symptoms from a treatment made in late July. Additionally, there was no evidence of hydrilla growth in sites 1 through 5; however, repeated monitoring should continue to ensure hydrilla was eradicated from these areas. Although fluridone treatments appear to be successful, repeated surveys and intensive monitoring should continue in known hydrilla locations (Figure 14) to ensure herbicide efficacy on hydrilla biomass, tuber production and identification of new populations.

To date, very few hydrilla tubers have been harvested during regular tuber surveys. Tuber production is thought to be a photoperiodic response, meaning, as day length shortens tuber production should increase (Van et al. 1978). Therefore, the optimal time to survey for hydrilla tubers would be in late fall (December) and winter (February). There were no tubers harvested in February 2007 at Sites 1 through 5 or in December 2007 at Sites 1 through 6 (Table 4). However, there were young hydrilla plants harvested in Site 6 during the December tuber survey. The paucity of hydrilla tubers in the Reservoir could be due to very low densities, the use of fluridone, or a combination of these. Fluridone applied at rates of 5.0 to 50.0 parts per billion (ppb) inhibited the growth and reproduction (tubers and turion formation) of hydrilla (MacDonald et al. 1993). The effect was more pronounced on young plants due to their dependence on active photosynthesis for growth and a subsequent lack of carbohydrates for tuber production (MacDonald et al. 1993). Fluridone treatments may have inhibited tuber production in Ross Barnett Reservoir.

The hydrilla in the Ross Barnett Reservoir represents a new or young infestation, as tuber densities have not reached levels observed in other studies or geographic regions (Netherland

1997, Madsen and Owens 1998). The use of fluridone has resulted in reductions in the presence of hydrilla in Sites 1 through 5, although the occurrence of hydrilla lakewide has increased since 2005, likely due to the establishment of viable fragments. The early detection of hydrilla and rapid response has likely resulted in reduced tuber production and the subsequent low densities observed. Year to year recruitment of hydrilla from tubers is thought to be minimal, as tubers or plants have not been found in Sites 1 through 5 after successive fluridone treatments. Aggressive management of hydrilla has been successful in minimizing the growth and spread of this weed and, more importantly, preventing the production of tubers. While managing the weed is expensive, the cost is much less than the potential cost if hydrilla were to spread in the Ross Barnett Reservoir.

RECOMMENDATIONS

- Apply fluridone to Sites 6, 7, 10, and 11 in May 2008.
- Use a contact herbicide such as endothall, copper, or diquat in sites 8 and 9 due to the small area and reduced presence of hydrilla as compared to other sites.
- Monitor Sites 1 through 5 and use a contact herbicide if hydrilla is observed.
- Continue herbicide applications to waterhyacinth and alligatorweed.

FUTURE WORK

- Continued monitoring of plant distribution to assess changes and spread in nuisance species populations.
- Continued monitoring of hydrilla populations and herbicide treatments.
- Assess herbicide treatments on other nuisance species.
- Assess techniques to control the new hydrilla populations located in 2007.
- Assess techniques to control nuisance species and promote the growth of more desirable native plants.
- Accurately estimate coverage of nuisance aquatic plant species (particularly waterhyacinth and alligatorweed) using remote sensing (e.g., aerial or satellite imaging) technology.

ACKNOWLEDGEMENTS

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Table 2. Percent frequency of occurrence for aquatic or riparian plant species observed in the littoral zone during the Ross Barnett Reservoir Survey, July 2007 (n=423). The percent frequency of occurrence reported for the 2005 data (n=677) and 2006 data (n=508) are from those points that where sampled in 10 feet of water or less during the time of that survey.

Species Name	**Common Name**	**Native (N) or Exotic (E), Invasive (I)**	**2005 % Frequency**	**2006 % Frequency**	**2007 % Frequency**	**Significance[1] Value p = 0.05**
Alternanthera philoxeroides	alligatorweed	E I	21.1	3.9	4.0	< 0.01
Azolla caroliniana	mosquito fern	N	0.0	0.2	0.4	
Cabomba caroliniana	fanwort	N	2.2	0.0	0.5	
Ceratophyllum demersum	coontail	N	4.4	4.9	3.5	0.58
Colocasia esculenta	wild taro	E I	0.0	0.9	0.7	
Eichhornia crassipes	waterhyacinth	E I	4.9	2.9	1.2	< 0.01
Hydrilla verticillata	hydrilla	E I	0.0	0.7	1.4	< 0.01
Hydrocotyle ranunculoides	pennywort	N	6.4	0.5	1.4	
Lemna minor	common duckweed	N	3.1	2.5	1.9	
Limnobium spongia	American frogbit	N	1.5	0.7	0.7	
Ludwigia peploides	waterprimrose	N	4.9	7.4	4.3	
Myriophyllum aquaticum	parrotfeather	E I	0.7	0.0	0.2	
Najas minor	brittle naiad	EI	0.0	0.0	1.9	
Nelumbo lutea	American lotus	N	17.1	17.7	21.2	0.20
Nitella sp.	stonewort	N	0.1	0.0	0.0	
Nymphaea *odorata*	white waterlily	N	4.4	3.4	4.9	0.44
Potamogeton nodosus	American pondweed	N	2.7	2.7	2.4	0.92
Sagittaria latifolia	arrowhead	N	1.0	1.2	0.0	
Sagittaria platyphylla	arrowhead	N	0.0	1.8	0.8	
Scirpus validus	softstem bulrush	N	1.2	0.2	0.0	
Typha sp.	cattail	N	1.3	2.4	0.7	
Utricularia vulgaris	bladderwort	N	0.0	0.4	0.0	
Zizaniopsis miliacea	giant cutgrass	N I	1.5	3.5	1.9	

[1]Analyses were only conducted on the commonly occurring species, or the species most often growing in association with waterhyacinth, alligatorweed, and hydrilla that may be impacted by control techniques.

Table 3. Estimated acreage of the commonly occurring aquatic plants in the littoral zone during the Ross Barnett Reservoir Survey, July 2007.

Species Name	**Common Name**	**Native (N) or Exotic (E), Invasive (I)**	**Estimated Acreage[1]**
Alternanthera philoxeroides	alligatorweed	E I	377
Eichhornia crassipes	waterhyacinth	E I	111
Hydrilla verticillata	hydrilla	E I	111
Najas minor	Brittle naiad	EI	178
Ceratophyllum demersum	coontail	N	333
Lemna minor	common duckweed	N	178
Ludwigia peploides	waterprimrose	N	400
Nelumbo lutea	American lotus	N	1998
Nymphaea *odorata*	white waterlily	N	466
Potamogeton nodosus	American pondweed	N	222

[1]Acreage was calculated based on the total number of points for which a given species was observed. Each point of the survey represents approximately 22.2 acres.

Table 4. Mean tuber number (± 1 SE), mean tuber density (± 1 SE), mean tuber biomass (± 1 SE), and mean shoot biomass (± 1 SE) of hydrilla found during the tuber surveys conducted in February and December of 2007.

New Site Name	**Tuber Number**	**Tuber Density ($n\ m^{-2}$)**	**Tuber Biomass ($g\ m^{-2}$)**	**Shoot Biomass ($g\ m^{-2}$)**
February				
Site 1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Site 2	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Site 3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Site 4	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Site 5	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Site 6	Not Sampled	Not Sampled	Not Sampled	Not Sampled
December				
Site 1	0.0± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Site 2	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Site 3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Site 4	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Site 5	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
Site 6	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.2

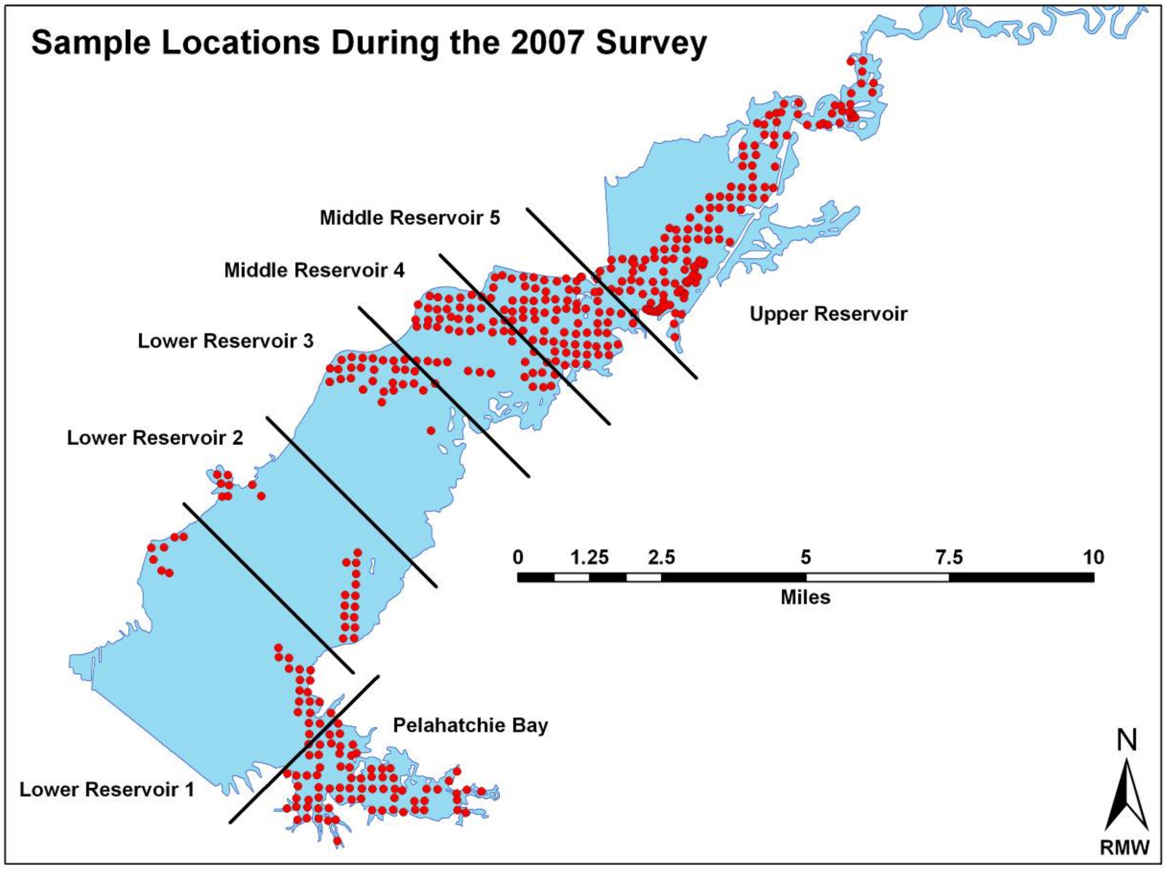

Figure 1. Points sampled during the littoral survey in July 2007.

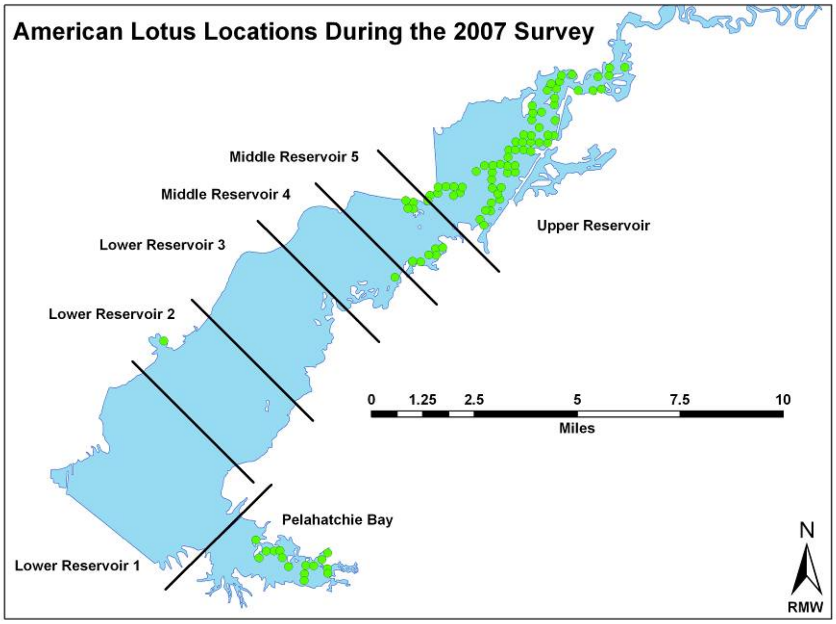

Figure 2. Locations of American lotus in July 2007.

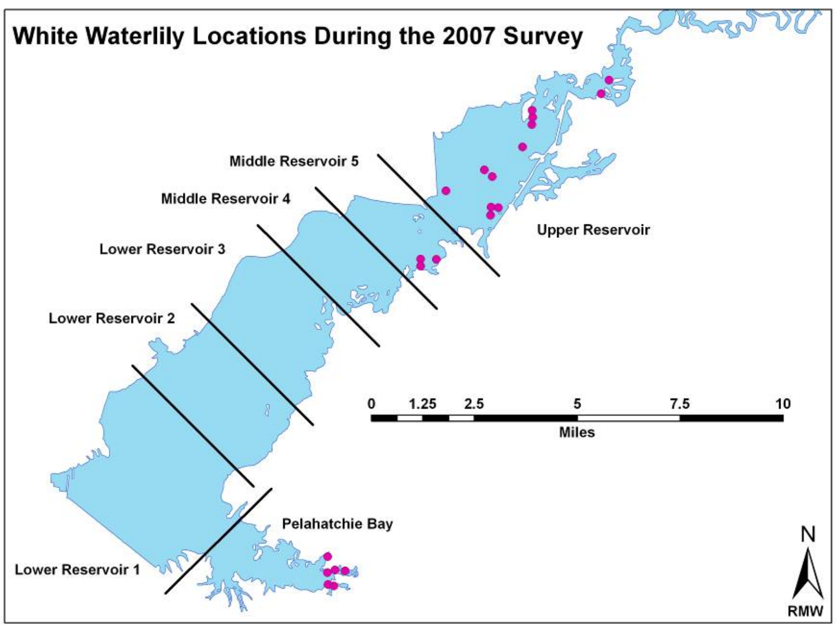

Figure 3. Locations of white waterlily in July 2007.

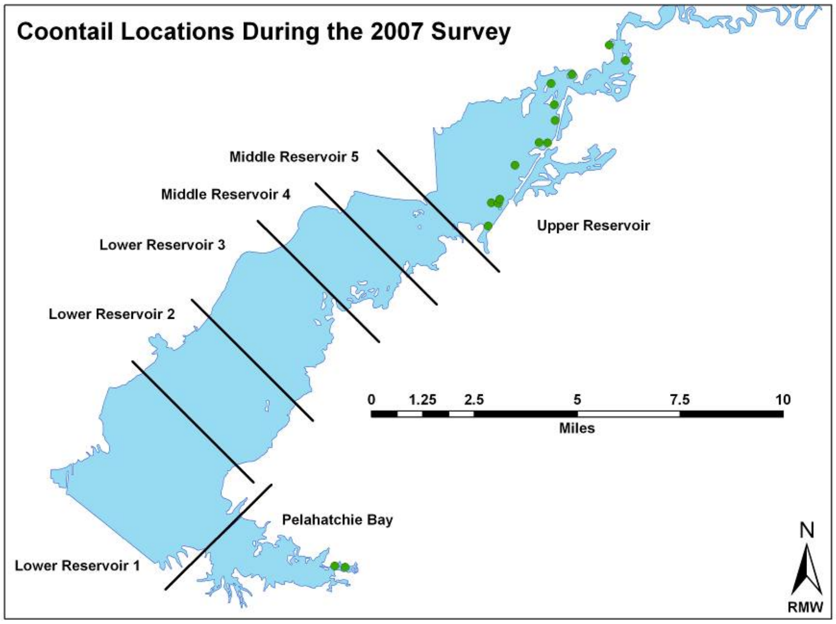

Figure 4. Locations of coontail in July 2007.

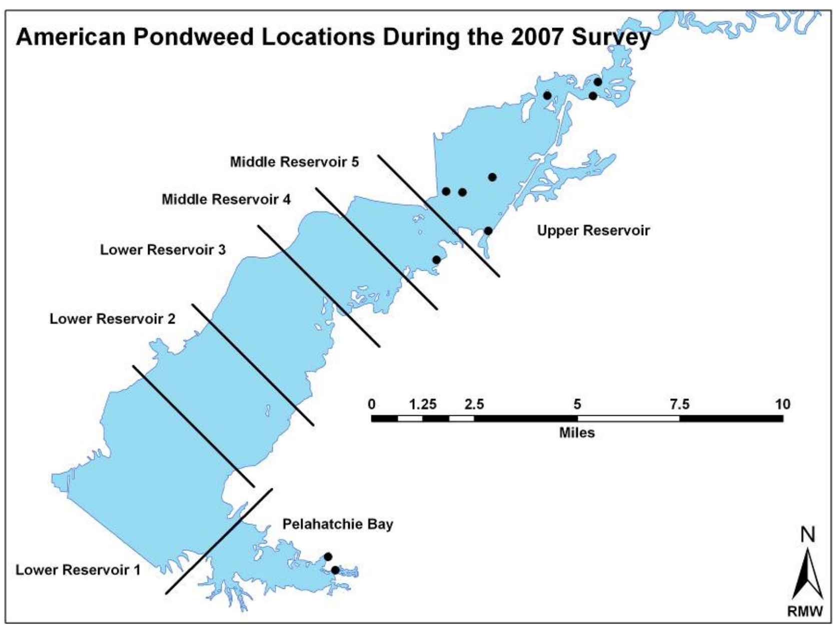

Figure 5. Locations of American pondweed in July 2007.

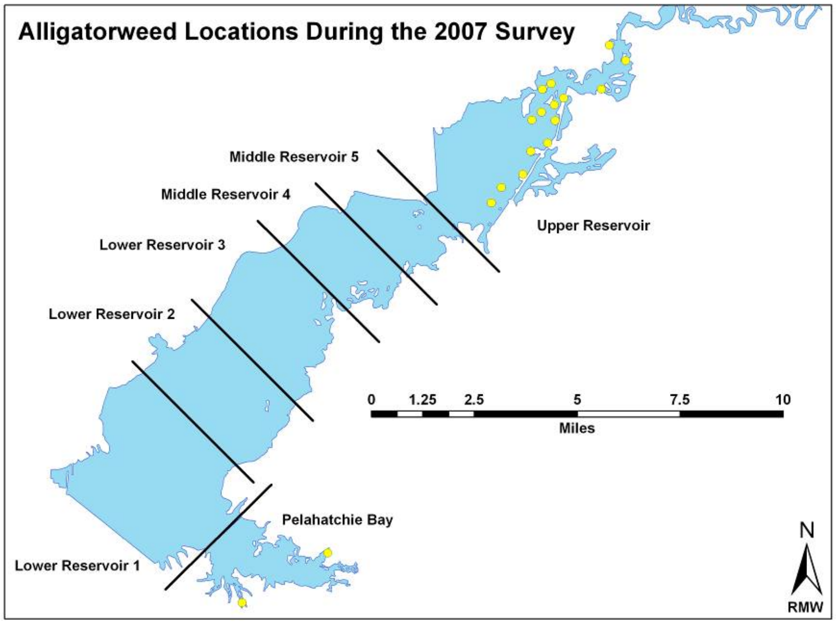

Figure 6. Locations of alligatorweed in July 2007.

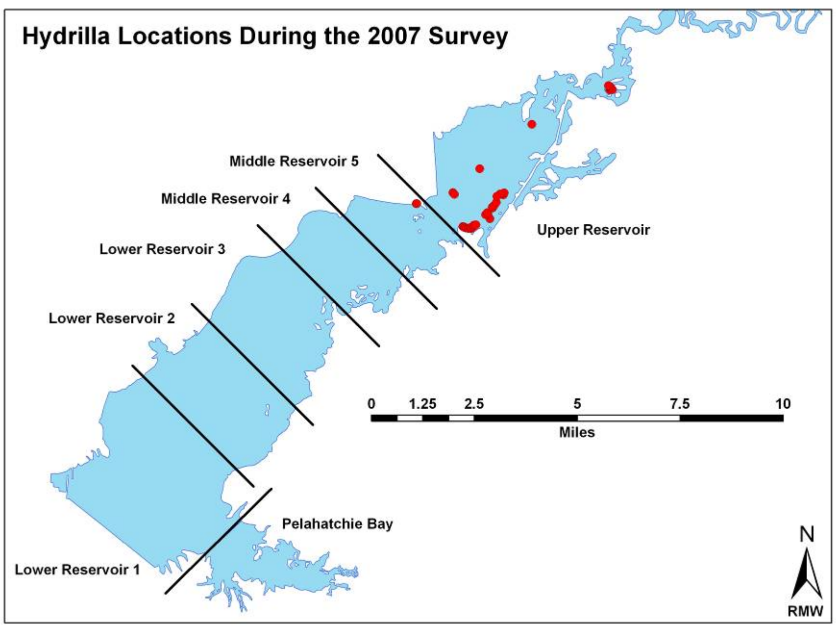

Figure 7. Locations of hydrilla in July 2007.

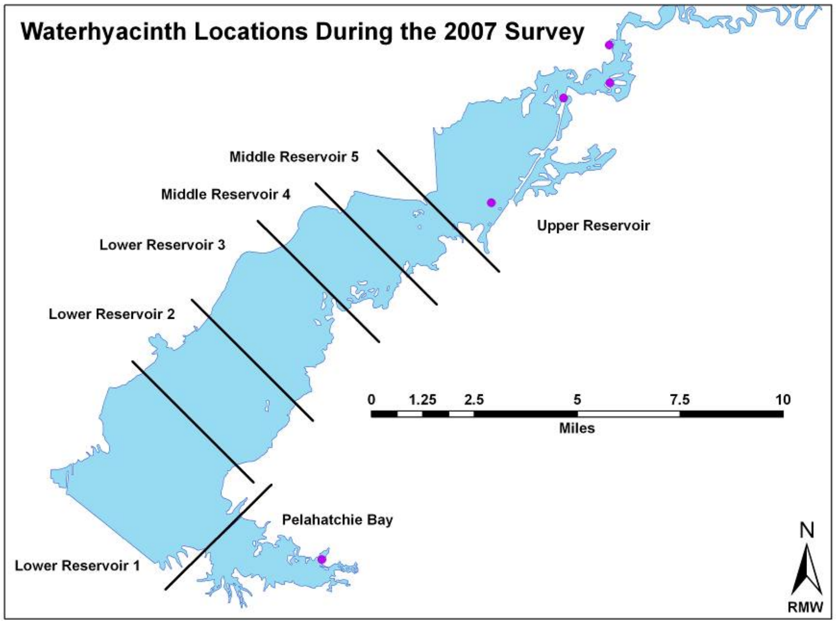

Figure 8. Locations of waterhyacinth in July 2007.

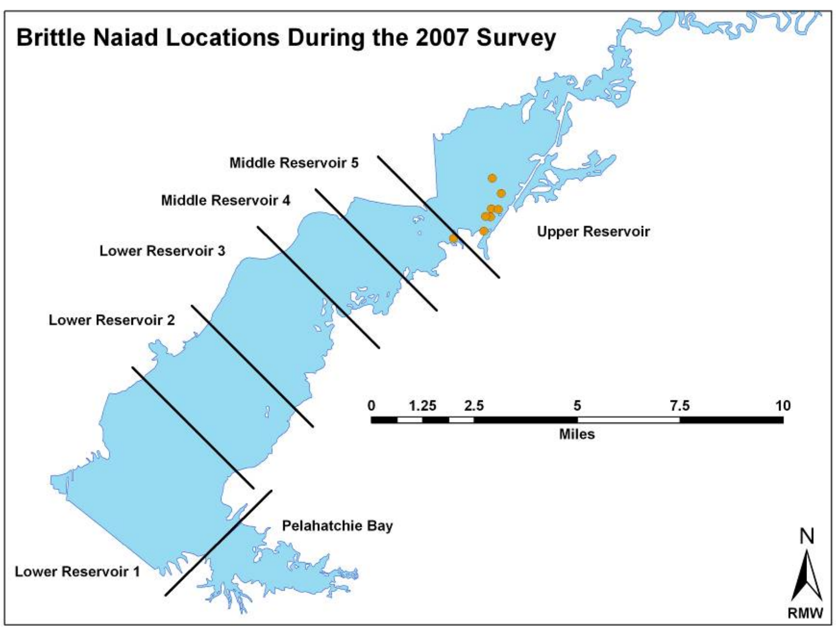

Figure 9. Locations of brittle naiad in July 2007.

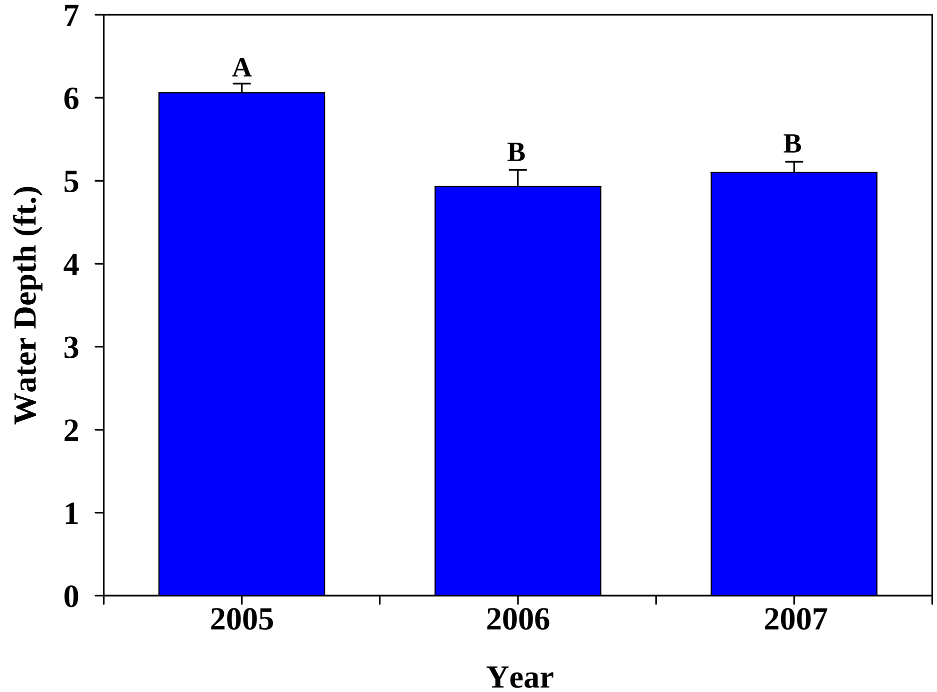

Figure 10. Mean (± 1 SE) water depth for surveys conducted between 2005 and 2007.

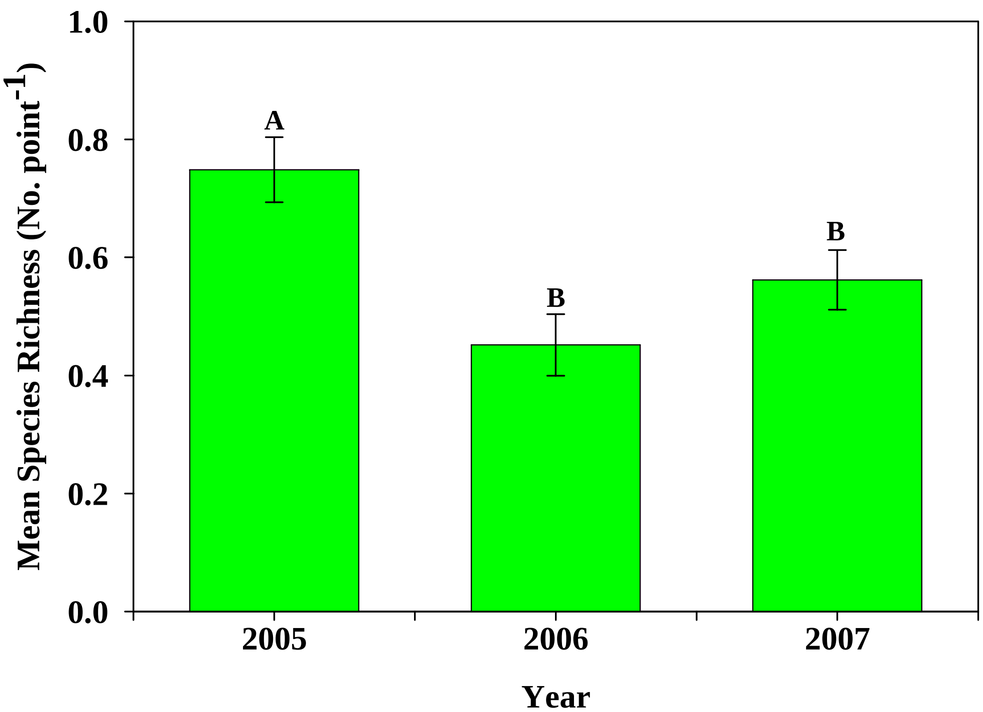

Figure 11. Mean (± 1 SE) species richness during surveys conducted between 2005 and 2007.

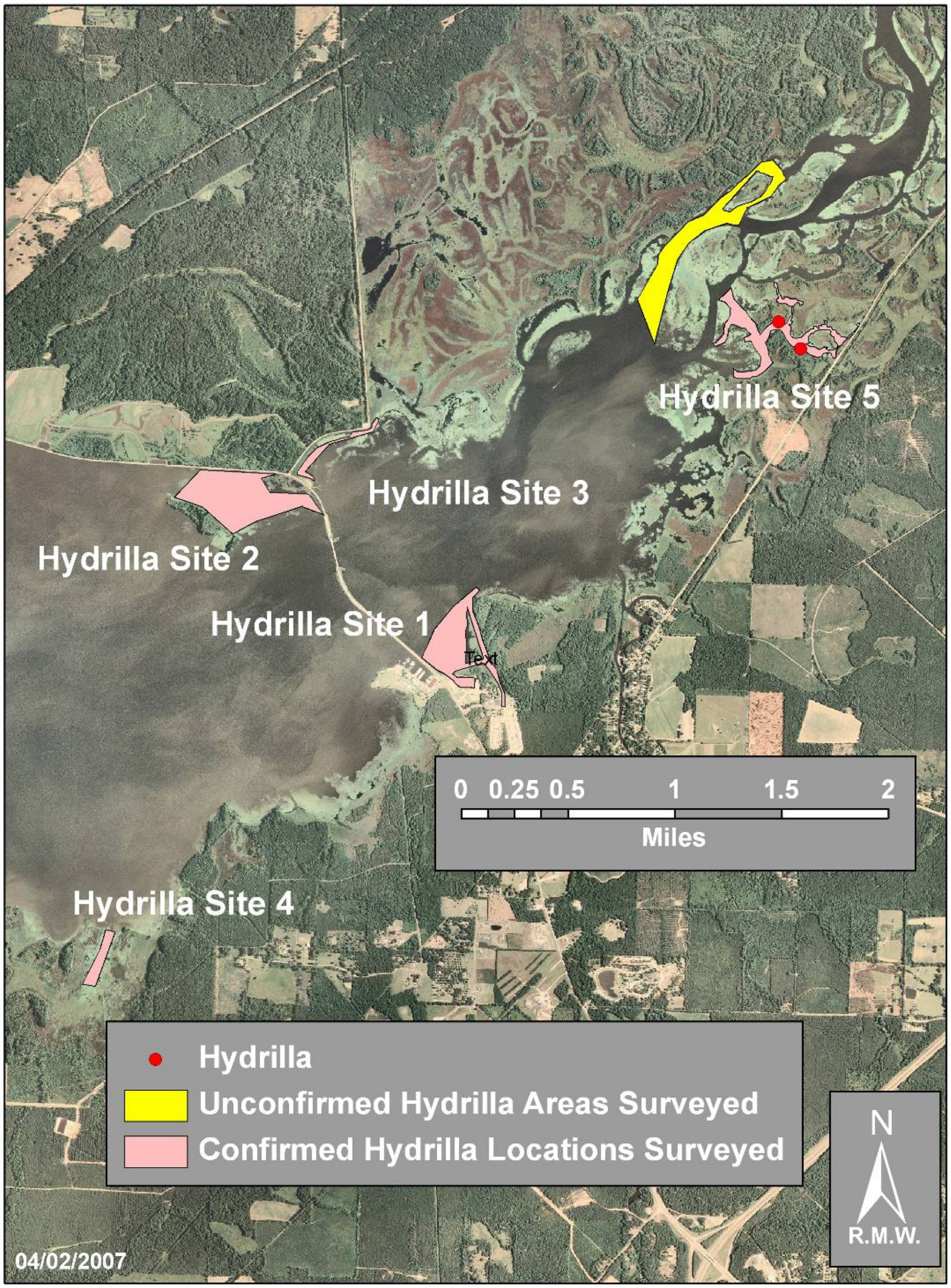

Figure 12. Hydrilla locations during the survey conducted in April 2007.

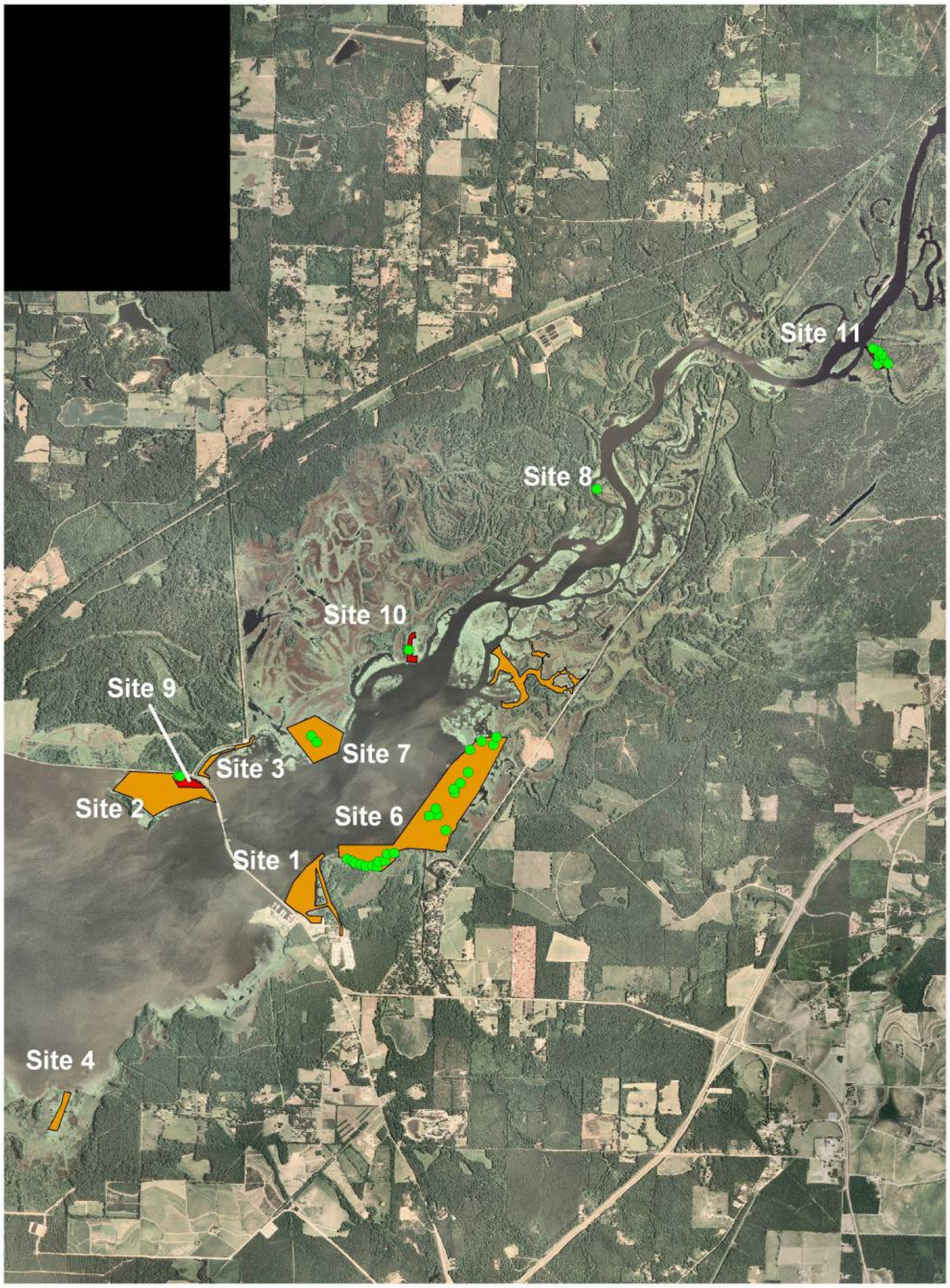

Figure 13. Hydrilla sites in the Ross Barnett Reservoir as of August 22, 2007. Green points are locations of hydrilla growth.

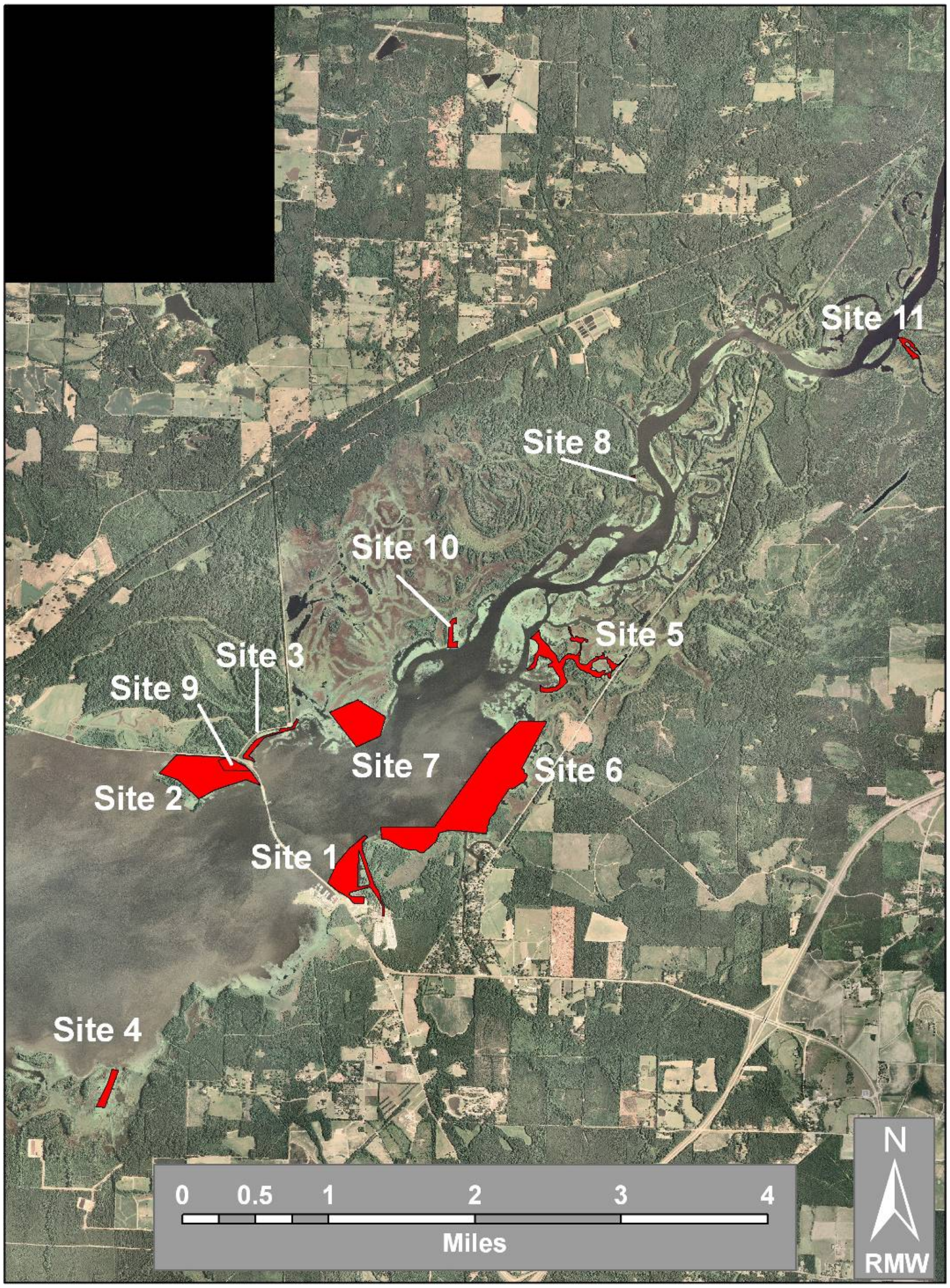

Figure 14. Hydrilla sites in the Ross Barnett Reservoir as of December 2007.