Aquatic Plant Survey within the Littoral Zone of the Ross Barnett Reservoir for 2006

An Annual Report to the Pearl River Valley Water Supply District

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INTRODUCTION

The Ross Barnett Reservoir is a 13,400 hectare (33,000 acre) freshwater impoundment that is located just north of Jackson, Mississippi's capital city. The reservoir is the largest surface water impoundment in Mississippi and serves as the primary drinking water supply for the City of Jackson. The reservoir is surrounded by over 4,600 homes and provides recreation in the form of fishing, boating, camping, and trail systems along the shoreline. In recent years, invasive plant species have become an increasing problem by clogging navigation channels, reducing recreational fishing opportunities, and reducing access for users of the reservoir (Madsen 2004). Dense mats of vegetation may also affect water quality by increasing the pH and water temperature and causing decreases in oxygen under the mats. Dense mats of vegetation may stagnate water, resulting in good breeding grounds for mosquitoes. In 2005, hydrilla (*Hydrilla verticillata* L.f. Royle) was discovered at four locations within the Reservoir (Wersal et al. 2006a). Hydrilla is an invasive submersed aquatic plant that was introduced into the United States in the 1960's by the aquaria market (Blackburn et al. 1969). Hydrilla can be spread by asexual reproduction via tubers (produced below the sediment), turions (produced in leaf axils), and fragmentation of stems. These reproductive structures can remain viable for several days out of water, remain in the sediment up to four years, survive the ingestion and regurgitation of waterfowl, and survive herbicide applications (Langeland 1996). Hydrilla has been called "the perfect aquatic weed" as a result of its reproductive mechanisms and its resiliency to survive under adverse environmental conditions (Langeland 1996). As a result of the 2005 survey, it was estimated that hydrilla could encompass over 2,800 hectares (7,000 acres) of the Ross Barnett Reservoir if control techniques and continued assessments are not implemented (Wersal et al. 2006a).

OBJECTIVES

Our primary objective was to continue monitoring the aquatic plant community in the Ross Barnett Reservoir by mapping the distribution of aquatic plants throughout the littoral zone (water depths $\leq$ 10 feet). We also continued to monitor and assess the current hydrilla populations as well as document the presence of new populations. The results of this assessment are included in detail in this report.

METHODS AND MATERIALS

Vegetation Survey

Aquatic plant distribution was evaluated using a point intercept survey method using a 300 meter grid in October 2006 (Madsen 1999). The grid of points for the current survey was

modified from the 2005 survey to include only those points occurring in water depths of ≤ 10 feet (Wersal et al. 2006a). 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 experienced 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. 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 508 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). 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 for the end point analyses. Estimated total acreage for commonly occurring aquatic plant species was also calculated by using the total number of points that a given species was observed at and multiplying that number by 22.2 (the acreage represented by one survey point).

Hydrilla Population Assessment

After fluridone treatments to the four hydrilla populations [Goshen Springs boat landing (Site 1), Refuge (Site 2), Pipeline (Site 3), and Site 4] in April 2006, water samples were collected from each location at 30 days and 60 days after treatment. Water samples were sent to SePro for herbicide residue analysis to assess concentrations (ppb) of fluridone in the water column. During each water sample collection period, approximately 25 plant rake tosses were performed in each of the four hydrilla populations. Also, at the 30 day water sampling event, a survey of the shoreline between hydrilla Site 4 and the Goshen Springs boat landing (Site 1) was conducted. The plant rake was deployed every 300 ft during this survey.

A tuber survey of the four hydrilla populations was conducted in February and December of 2006 to assess the density of the tuber bank. The tuber bank is an indication of possible hydrilla recruitment for the following growing season. Thirty core samples were collected within each hydrilla site using a PVC 0.018 m^2) coring device (Case and Madsen 2004, Wersal et al. 2006b). 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.

Environmental Monitoring

Environmental parameters (e.g. depth, turbidity, dissolved oxygen, pH, and water temperature) were recorded using a Manta multi-probe (Eureka Environmental Laboratories) in Pelahatchie Bay, Lower Reservoir 1, 2, and 3, Middle Reservoir 4 and 5, and the Upper Reservoir. Water transparency was estimated using a secchi disk at the seven sites within the Reservoir. Light intensity was also recorded at the seven sites using a LiCor light meter enabled with a submersible photosynthetically active radiation (PAR, 400-700 nm) sensor as well as an incident PAR sensor. All measurements were taken in 10 inch intervals from the water surface to the Reservoir bottom. Light extinction coefficients (K_d) were calculated for each site as an index of how rapidly light is attenuated, or decreases in intensity with respect to distance traveled, through the water column.

$$K_d = [\ln (I_{z1}) - \ln (I_{z2})] / (z_2 - z_1) \quad (1)$$

Where z = the water depth at a given point and I = the light intensity at that point. The greater the coefficient indicates the more rapidly light is attenuated.

Also, the maximum depth of plant colonization (Z_c) (Vant et al. 1986) was calculated using the light extinction coefficients (K_d) for each site.

$$Z_c = 4.34/K_d \quad (2)$$

RESULTS

Vegetation Survey

A total of 19 species of aquatic or riparian plants were observed during the survey. Of the 19 species, 15 are strictly aquatic species (Table 1). Alligatorweed was the exotic invasive aquatic plant species observed most often, followed by waterhyacinth and hydrilla. The distributions of these invasive species were located primarily in the Upper Reservoir and in Pelahatchie Bay (Figures 2 through 4). Other native species found during the survey include American lotus, coontail, fragrant waterlily, American pondweed, duckweed, frog's bit, cattail, soft-stem bulrush, two species of arrowhead, and bladderwort (Table 1). American lotus was the most common native plant species observed, followed by waterprimrose and coontail (Figures 5 through 7). American lotus was observed throughout the Reservoir, with increased occurrence in the Upper Reservoir and Pelahatchie Bay. Bladderwort, a native submersed plant species, was observed in the Reservoir for the first time (Figure 8). In general, the occurrence of aquatic plants was greatest in the Upper Reservoir and Pelahatchie Bay. Species occurrence was low in parts of the Middle Reservoir sites and the majority of the Lower Reservoir where water depths are too great to support aquatic plant growth.

The estimated acreages for the commonly occurring native and non-native aquatic plant species are shown in Table 2. Native species occupied the greatest area, with American lotus occupying the largest area (1998 acres), followed by waterprimrose (844 acres), and coontail (555 acres). The non-native alligatorweed occupied approximately 444 acres followed by waterhyacinth (333

acres), and hydrilla (67 acres). Based on these acreage estimates, native plant species occupy the greatest area and non-native aquatic plant species occupy less than 2.5% of the total Reservoir area. These estimates are derived from the point survey, in which each point of occurrence represents 22.2 acres. There were approximately 125 acres of hydrilla treated in 2006 resulting in a 54% reduction based on the estimates from the survey. For accurate mapping of waterhyacinth and alligatorweed, we may have to utilize remote sensing, since we cannot access all areas where these two species are found.

Hydrilla Population Assessment

Hydrilla was observed growing at the four locations treated with fluridone during the water sample collection at 30 and 60 days after treatment (Table 3). Although plants were found, they exhibited symptoms typical of exposure to fluridone with the majority of hydrilla tissue being necrotic (Photos 1 and 2). Hydrilla was not located during the survey of the shoreline between Site 1 and Site 4. In October, hydrilla was growing in Site 1 and Site 2 (Figure 2). Hydrilla was also observed growing in a previously unreported area near a boat landing along Pipeline Road on the eastern side of the Upper Reservoir (UTM Zone 16, WGS 1984, 227539.10 N 3602813.29 E). The hydrilla observed at these sites was green, healthy, and exhibited no herbicide symptoms. There was no hydrilla observed at Site 3 on the western side of the Reservoir. Hydrilla Site 4 was not sampled due to low water depths and the inaccessibility by boat to these points. Based on the October survey and the finding of a new hydrilla population, the Ross Barnett Reservoir now has five separate locations where hydrilla has been observed growing.

Hydrilla is typically a prolific producer of tubers, however no tubers were found at any of the hydrilla sites surveyed in February of 2006. During a similar survey of the same four sites in December 2006, only two tubers were found. These tubers were found in Site 4 and appeared unviable (Table 4). A single small shoot of hydrilla was also found in Site 1 and appeared to be health and viable.

Environmental Monitoring

The maximum depth of plant colonization indicated that plants should not occur in water depths greater than 10 feet throughout the reservoir. Maximum depth of macrophyte colonization was greatest in the Lower Reservoir 2 and Lower Reservoir 3 (Table 5). However, plants currently growing at these locations are primarily limited to the eastern shoreline where water depths are shallow. These areas also had a high occurrence of American lotus and waterprimrose, species able to overcome light deficiencies (Figures 5 and 6). Light intensity, as shown by the percent of surface light transmitted though the water column, decreased rapidly at each site (Figure 10). Light intensities were generally reduced to less than 20 percent of surface light intensity within the upper 3 feet of the water column, which is similar to data collected in 2005 (Wersal et al. 2006a). Water transparency in areas of highest plant occurrence (Upper Reservoir, Pelahatchie Bay, and the eastern shore of the Middle Reservoir sites) was less than 3 feet (Table 5). Turbidity levels are expressed in nephelometric turbidity units (NTU) and presented along with other environmental factors in Table 6.

DISCUSSION

Aquatic plant growth in the Ross Barnett Reservoir appears to be limited to the Upper Reservoir, Pelahatchie Bay, and the eastern shoreline of the Reservoir. Species that are able to overcome deficiencies in light availability were observed most often. These species included American lotus, alligatorweed, waterprimrose, and waterhyacinth, species with an emergent or floating growth habit. Light profiles from seven sites within the Reservoir indicate that light transmittance is less than 20% in the upper 3 ft of the water column. The limitation of light in deeper water areas excludes submersed plant species from inhabiting these areas and forces colonization to shallower water depths where greater than 21% of surface light reaches the bottom sediments (Chambers and Kalff 1985). However, species such as coontail and hydrilla are well adapted to survive in low light environments and have mechanisms to overcome the stresses associated with light limitations, which may explain their dominance as submersed species in the Reservoir. Under low light availability, hydrilla can increase its shoot length to reach the water surface rapidly where it forms a dense canopy to overcome deficiencies in light availability (Barko and Smart 1981). The elongation of shoots under low light availability may allow hydrilla to expand its depth distribution more so than other species (Barko and Smart 1981). Furthermore, the ability of hydrilla to increase shoot elongation confers a competitive advantage over other species in waterbodies of limited transparency, such as the Ross Barnett Reservoir (Barko and Smart 1981).

Intensive management efforts have been deployed to control the hydrilla populations in the Reservoir. These include herbicide applications of endothall in the fall of 2005 to control actively growing hydrilla prior to tuber formation, followed by spring to early summer herbicide applications of fluridone in 2006 to offer greater control of new germination of hydrilla. The granular formulations of fluridone (Sonar Q, Sonar PR, and Sonar SRP) were used in the hydrilla treatments, and this accounts for the low concentrations of fluridone detected in the water samples 30 days and 60 days after treatment. Sonar PR and SRP granules release fluridone into the water column as the granules break down at the sediment surface. These two formulations release fluridone slowly to maintain an effective fluridone concentration in the water column over a longer period of time. The slower release combined with the collection of water samples at 16 inches under the surface accounted for the low detection of fluridone in the water samples. Intensive monitoring was conducted in and around the hydrilla populations following the fluridone applications. To date, only two tubers have been collected, indicating that the tuber bank is small and year-to-year recruitment is from over-wintering of individual plants or from fragmentation of live stems. The potential small size of the tuber bank may be a good indicator of how long hydrilla has been growing in the reservoir and also a good indicator of the potential for eradication. The longevity of hydrilla tubers is unknown, but field evidence suggests that there has been a decrease in tuber numbers over time following fluridone treatments. However, it has also been noted that hydrilla tubers can remain viable for up to three years following an application (Netherland 1997). The tubers found during the December survey were soft, white, and appeared non-viable, likely a result of the fluridone treatments. Long-term monitoring and repeated herbicide applications to hydrilla populations need to continue to allow for effective control and eradication of hydrilla from the Reservoir.

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.
- Implement techniques to control the new hydrilla populations located in 2006.
- Implement and assess techniques to control nuisance species and promote the growth of more desirable native plants.
- Accurately estimate aerial coverage of nuisance aquatic plant species using remote sensing technology.

ACKNOWLEDGEMENTS

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Table 1. Percent frequency of occurrence for aquatic or riparian plant species observed in the littoral zone during the Ross Barnett Reservoir Survey, October 2006 (n=508). The percent frequency of occurrence reported for the 2005 data (n=677) 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[1] % Frequency**	**2006 % Frequency**
Alternanthera philoxeroides	alligatorweed	E I	21.10	3.94
Azolla caroliniana	mosquito fern	N	0.00	0.20
Cabomba caroliniana	fanwort	N	2.20	0.00
Ceratophyllum demersum	coontail	N	4.40	4.92
Colocasia esculenta	wild taro	E I	0.00	0.98
Eichhornia crassipes	waterhyacinth	E I	4.90	2.95
Hydrilla verticillata	hydrilla	E I	0.00	0.79
Hydrocotyle ranunculoides	pennywort	N	6.40	0.59
Lemna minor	common duckweed	N	3.10	2.56
Limnobium spongia	American frogbit	N	1.50	0.79
Ludwigia peploides	waterprimrose	N	4.90	7.48
Myriophyllum aquaticum	parrotfeather	E I	0.70	0.00
Nelumbo lutea	American lotus	N	17.10	17.72
Nitella sp.	stonewort	N	0.10	0.00
Nuphar odorata	fragrant waterlily	N	4.40	3.35
Potamogeton nodosus	American pondweed	N	2.70	2.76
Sagittaria latifolia	arrowhead	N	1.00	1.18
Sagittaria platyphylla	arrowhead	N	0.00	1.77
Scirpus validus	softstem bulrush	N	1.20	0.20
Typha sp.	cattail	N	1.30	2.36
Utricularia vulgaris	bladderwort	N	0.00	0.39
Zizaniopsis miliacea	giant cutgrass	N I	1.50	3.54

[1]A direct comparison between years is not valid due to the different times of the year that the 2005 and 2006 surveys were conducted. The difference in time likely introduced seasonal effects on the growth of aquatic plant species such as different water temperatures, water depths, light intensities, etc., and does not allow for a comparison between years.

Table 2. Estimated acreage of the commonly occurring aquatic plants in the littoral zone during the Ross Barnett Reservoir Survey, October 2006.

Species Name	**Common Name**	**Native (N) or Exotic (E), Invasive (I)**	**Estimated Acreage[1]**
Alternanthera philoxeroides	alligatorweed	E I	444
Eichhornia crassipes	waterhyacinth	E I	333
Hydrilla verticillata	hydrilla	E I	67
Ceratophyllum demersum	coontail	N	555
Lemna minor	common duckweed	N	289
Ludwigia peploides	waterprimrose	N	844
Nelumbo lutea	American lotus	N	1998
Nuphar odorata	fragrant waterlily	N	377
Potamogeton nodosus	American pondweed	N	311

[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 39.5 acres.

Table 3. Results from the fluridone FasTEST analysis 30 days and 60 days after treatment. Results reflect the detected fluridone concentration (parts per billion) in the water column. A reading of no detect is represented by ND.

		Days After Treatment	
		30	**60**
Site	**New Site Name**		
Goshen Springs	Site 1	< 1.00	ND
Boat Landing			
Refuge	Site 2	ND	ND
Pipeline	Site 3	< 1.00	ND
Site 4	Site 4	1.60	< 1.00

Table 4. Mean tuber number (± 1 standard error (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 2006.

Site	New Site Name	Tuber Number	Tuber Density (n m^{-2})	Tuber Biomass (g m^{-2})	Shoot Biomass (g m^{-2})
February					
Goshen Springs Boat Landing	Site 1	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Refuge	Site 2	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Pipeline	Site 3	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Site 4	Site 4	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
December					
Goshen Springs Boat Landing	Site 1	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.03 ± 0.03
Refuge	Site 2	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Pipeline	Site 3	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
Site 4	Site 4	0.06 ± 0.04	3.70 ± 2.57	0.11 ± 0.09	0.00 ± 0.00

Table 5. Light extinction coefficients (K_d), estimated maximum depth of plant colonization (Z_c), and secchi depth observed in the Ross Barnett Reservoir, October 2006.

Site	Kd	Zc (ft)	Secchi Depth (ft)
Pelahatchie Bay	1.99	7.15	1.60
Lower Reservoir (1)	1.80	8.03	3.50
Lower Reservoir (2)	1.38	10.30	3.34
Lower Reservoir (3)	1.41	10.10	2.85
Middle Reservoir (4)	1.71	8.33	2.13
Middle Reservoir (5)	2.83	5.01	2.65
Upper Reservoir	2.10	6.79	2.65

Table 6. Mean (± 1 SE) environmental data collected from seven sites in the Ross Barnett Reservoir, December 2006.

Site	Temperature °C	Dissolved Oxygen (mg/L)	Turbidity nephelometric turbidity units (NTU)	Depth (ft)
Pelahatchie Bay	10.83 ± 0.21	12.26 ± 0.06	13.41 ± 0.21	5.54 ± 0.91
Lower Reservoir 1	10.53 ± 0.123	12.94 ± 0.03	5.40 ± 0.11	3.28 ± 0.68
Lower Reservoir 2	9.67 ± 0.09	12.35 ± 0.07	14.72 ± 8.53	7.18 ± 1.08
Lower Reservoir 3	10.13 ± 0.03	12.94 ± 0.05	9.45 ± 1.96	5.28 ± 0.91
Middle Reservoir 4	11.09 ± 0.11	14.18 ± 0.14	7.94 ± 1.24	2.85 ± 0.49
Middle Reservoir 5	11.22 ± 0.10	13.04 ± 0.20	7.91 ± 0.23	5.05 ± 0.85
Upper Reservoir	12.08 ± 0.21	12.24 ± 0.20	6.30 ± 0.16	2.88 ± 0.59

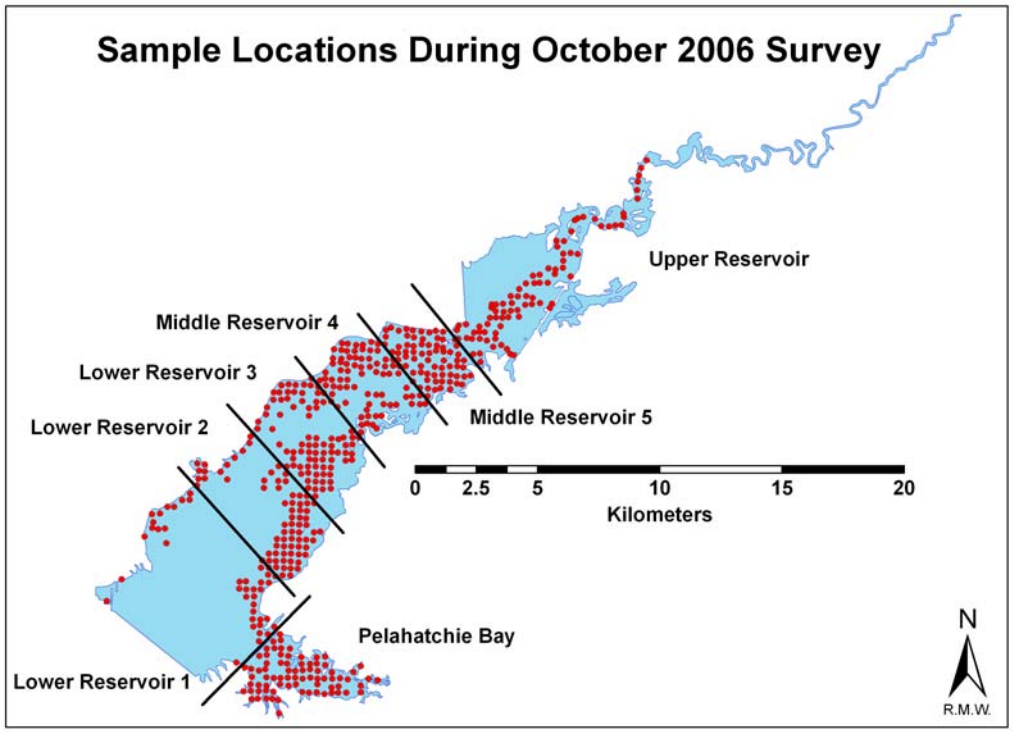

Figure 1. Points sampled within the littoral zone of the Ross Barnett Reservoir during the survey conducted in October 2006.

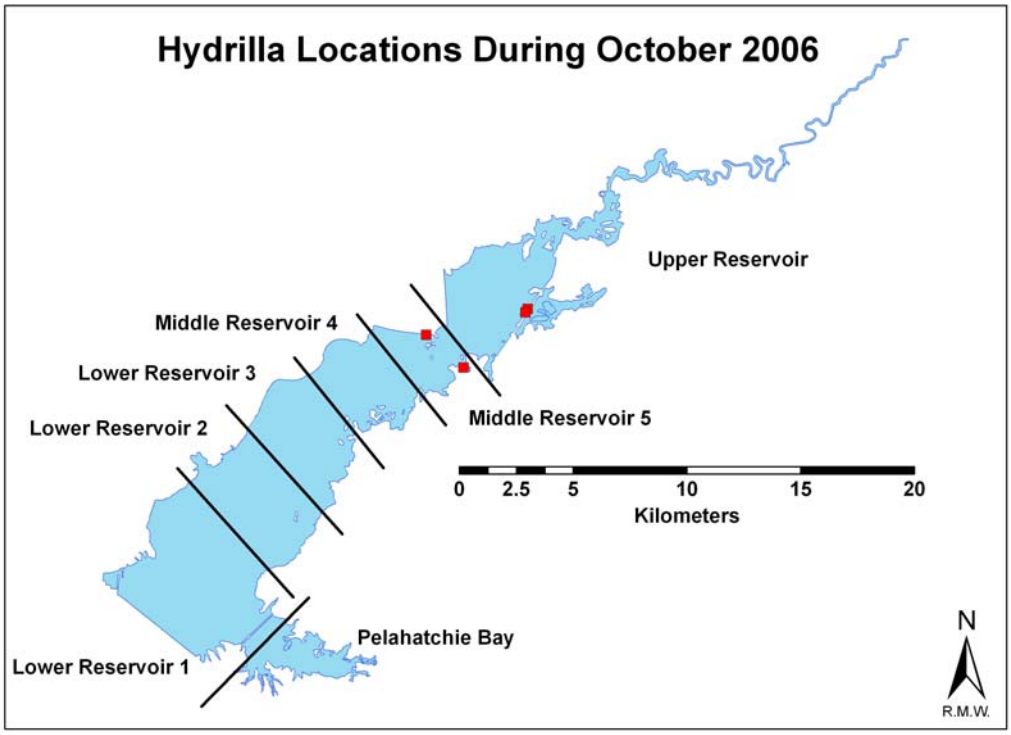

Figure 2. Locations of hydrilla in the Ross Barnett Reservoir, October 2006.

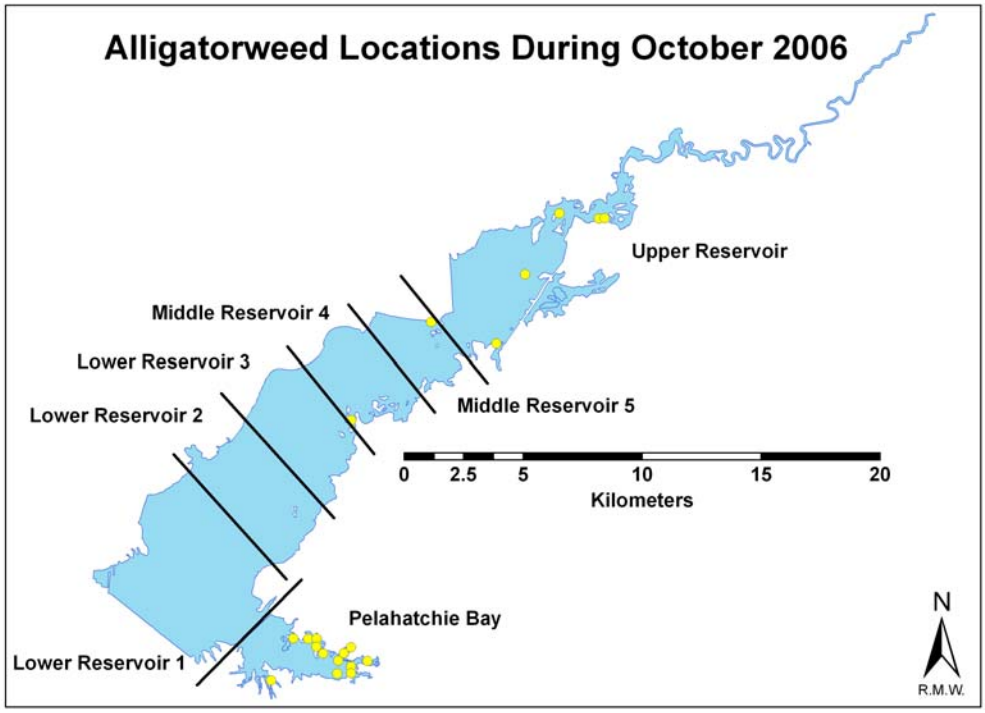

Figure 3. Locations of alligatorweed in the Ross Barnett Reservoir, October 2006.

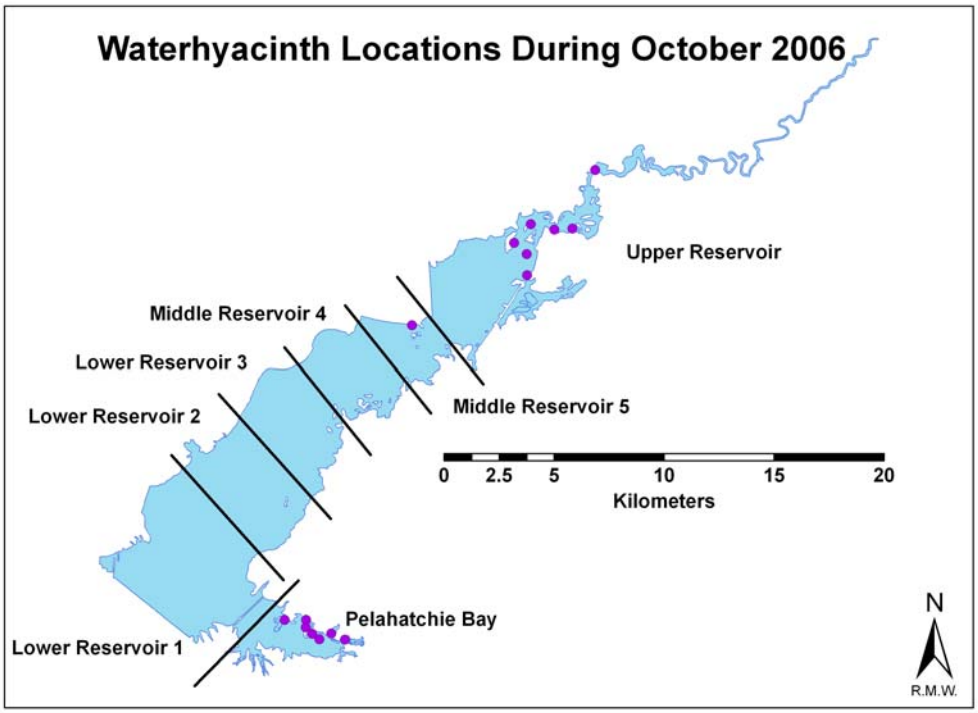

Figure 4. Locations of waterhyacinth in the Ross Barnett Reservoir, October 2006.

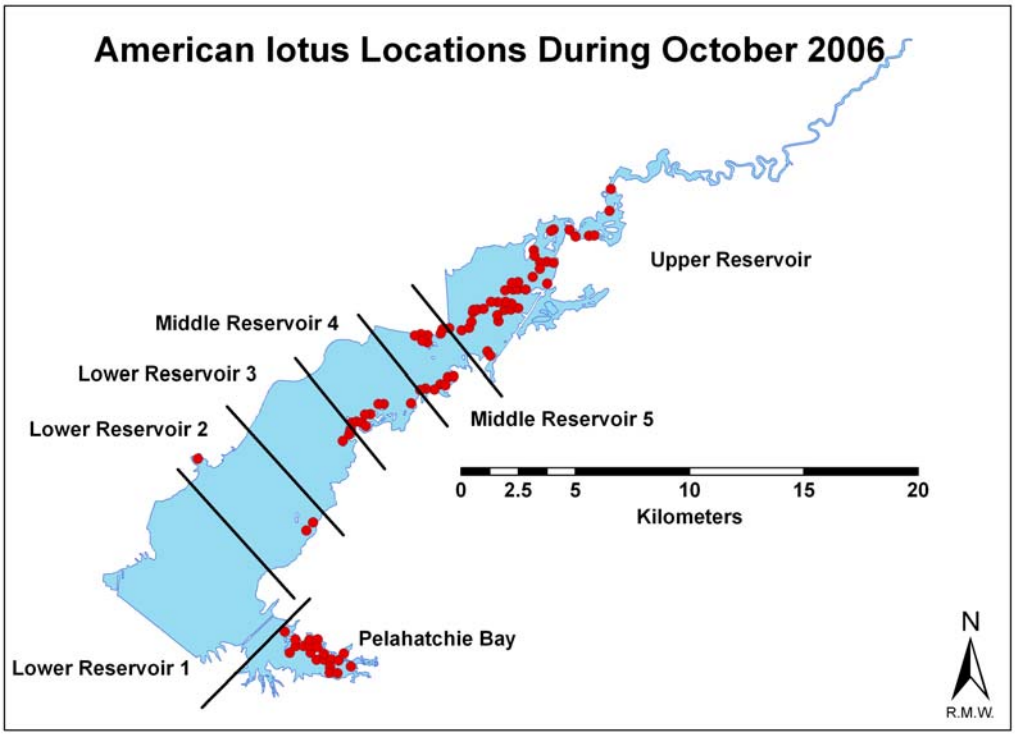

Figure 5. Locations of American lotus in the Ross Barnett Reservoir, October 2006.

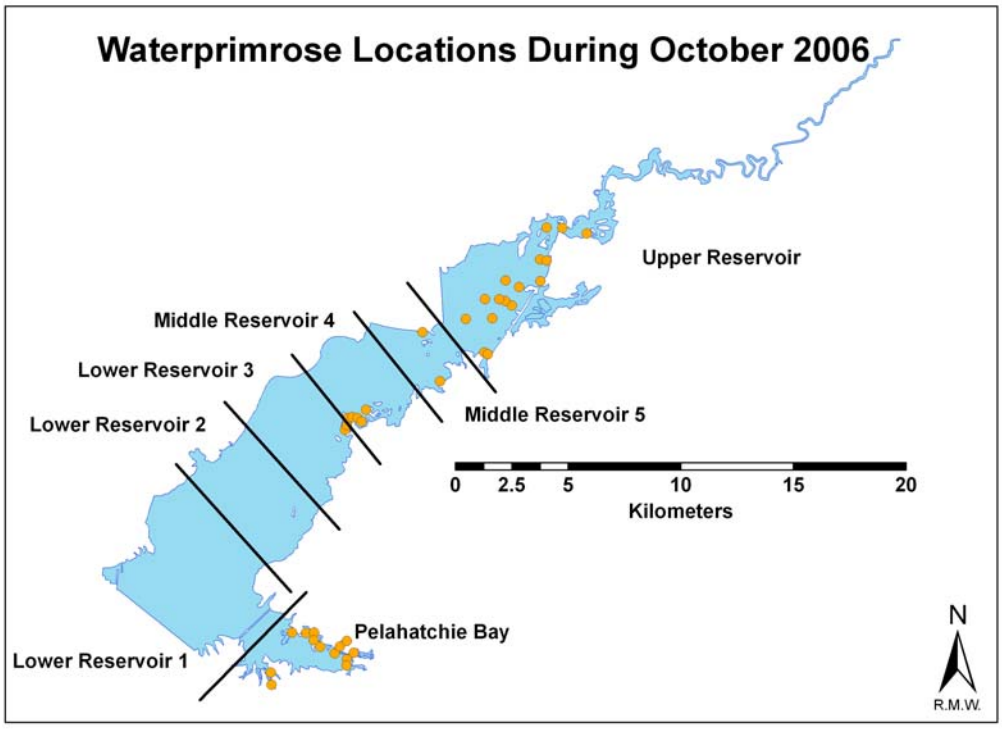

Figure 6. Locations of waterprimrose in the Ross Barnett Reservoir, October 2006.

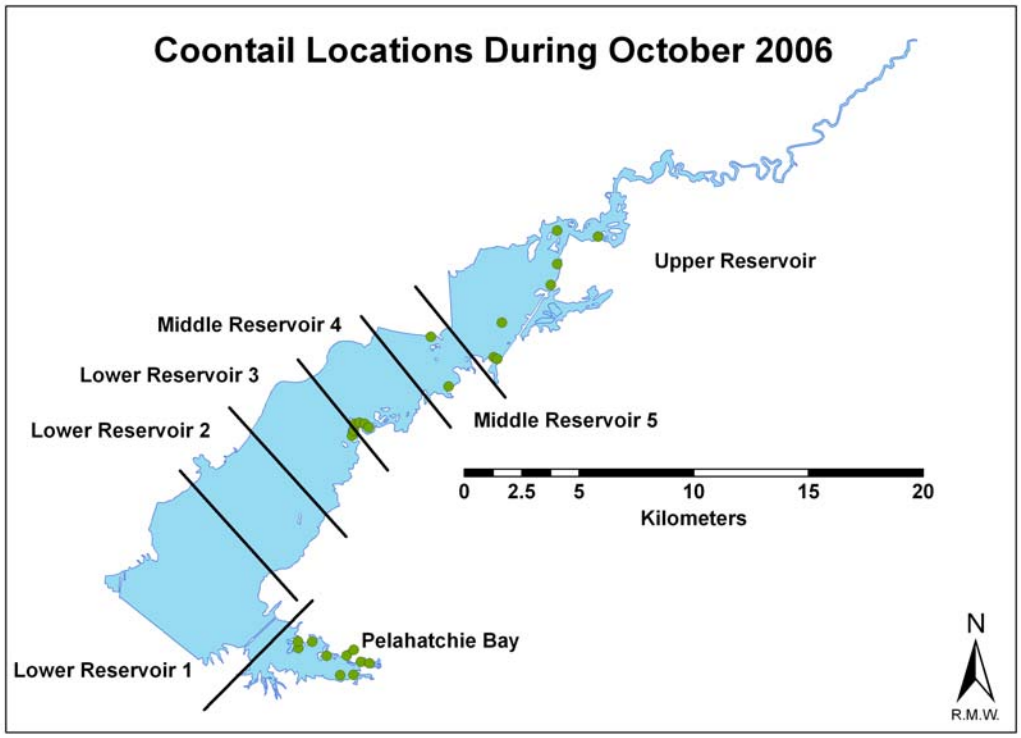

Figure 7. Locations of coontail in the Ross Barnett Reservoir, October 2006.

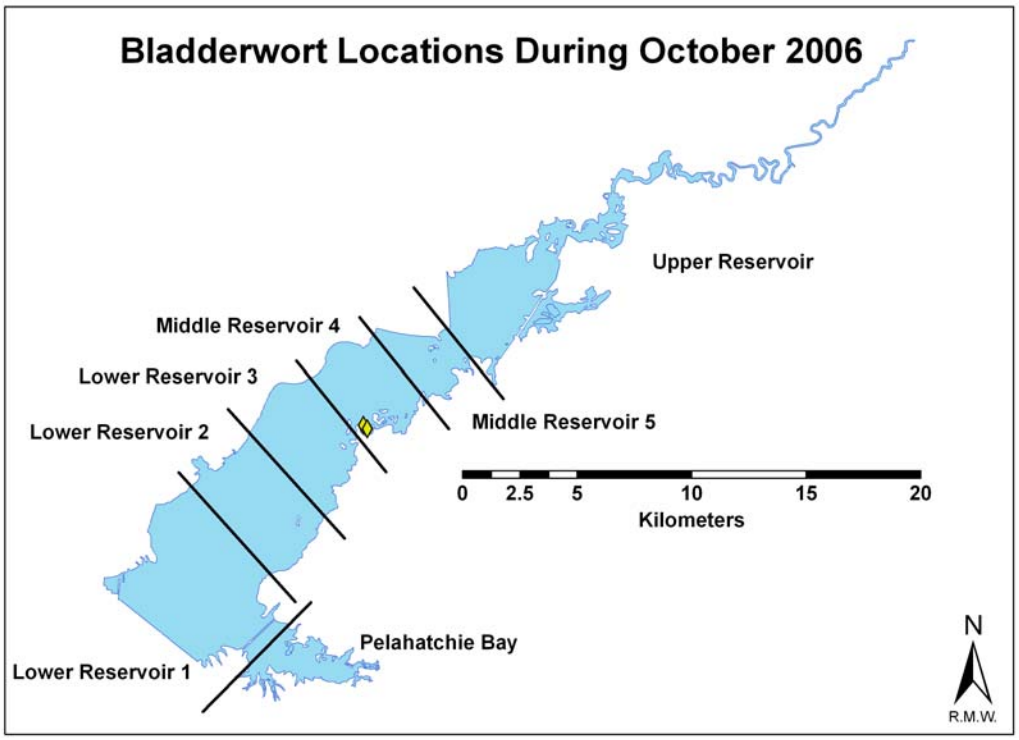

Figure 8. Locations of bladderwort in the Ross Barnett Reservoir, October 2006.

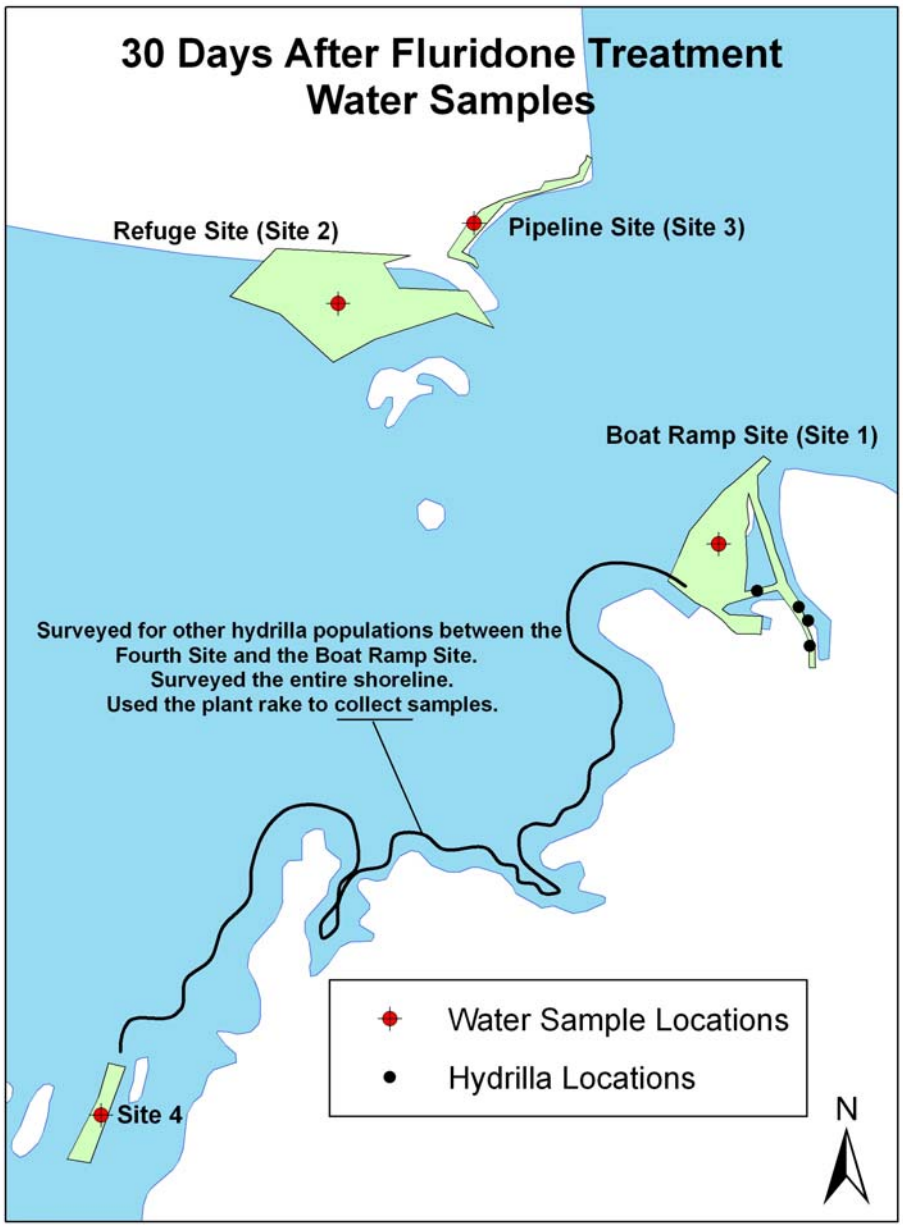

Figure 9. Hydrilla monitoring 30 days after the April fluridone treatment. Water samples were collected for herbicide residue analysis; also the presence or absence of hydrilla was sampled using a plant rake.

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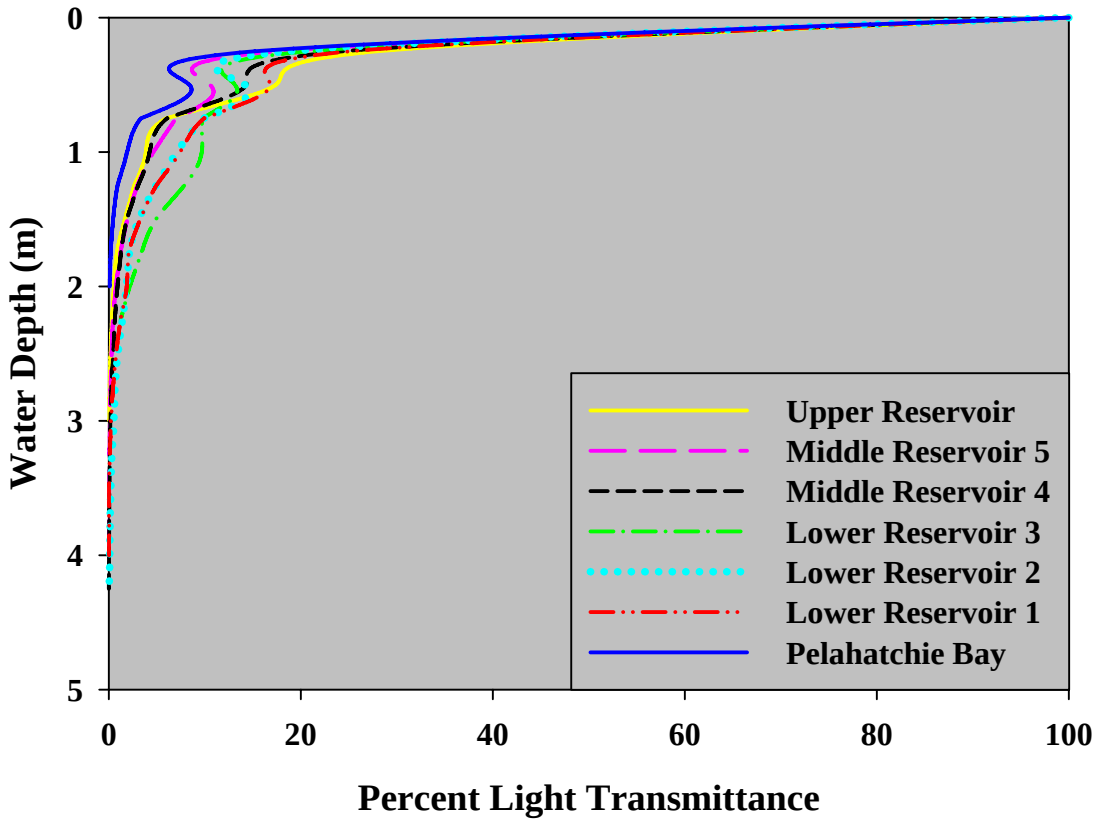

Figure 10. Light profiles for seven sites in the Ross Barnett Reservoir, October 2006.

Photo 1. Hydrilla found during the 60 days after treatment survey.

Photo 2. Hydrilla found during the 60 days after treatment survey. The majority of the plant is necrotic and symptomatic of fluridone exposure.