Assessing the Aquatic Plant Community within the Ross Barnett Reservoir, Mississippi

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Alligatorweed, waterhyacinth, and hydrilla are three nonnative aquatic species of concern in the Ross Barnett Reservoir near Jackson, MS. Point-intercept surveys were conducted on the reservoir from 2005 to 2010 to monitor native and nonnative species' distributions and assess herbicide treatment efficacy across the reservoir. Foliar applications of 2,4-D, glyphosate, imazapyr, and diquat were made during summer months for emergent and free-floating vegetation, whereas submersed applications of liquid copper and granular fluridone were applied in spring and late summer for subsurface hydrilla populations. American lotus is the native species that has been observed the most throughout the survey years, with occurrence frequencies averaging between 17 and 27%. Alligatorweed populations significantly decreased from 21% in 2005 to 4% in 2006; however, they consistently increased in the next 4 yr to 12% occurrence in 2010. Waterhyacinth occurrence has remained relatively constant over the study period, averaging below 10% occurrence. Hydrilla was discovered in the reservoir in late 2005 and has remained below 2% in frequency of occurrence since 2006. Suppression of these nonnative species has been attributed to rigorous monitoring and herbicide applications conducted on the reservoir since 2005. A logistic regression model indicated that as native species richness increased, the likelihood of a nonnative species occurring also increased.

Nomenclature: Alligatorweed, *Alternanthera philoxeroides* (Mart.) Griseb.; American lotus, *Nelumbo lutea* Willd.; hydrilla, *Hydrilla verticillata* (L. f.) Royle; waterhyacinth, *Eichhornia crassipes* (Mart.) Solms.

Key words: Distribution, herbicide, invasive, littoral zone, management.

The Ross Barnett Reservoir, located near Jackson, MS, is the state's largest surface water impoundment and considered one of the most substantial watersheds in the state. This 13,355 ha (33,000 ac) water body provides the capital city of Jackson with potable water, fishing, recreational opportunities, essential wildlife habitat, and a basis for economic expansion (Rezonate Mississippi 2012). The introduction of nonnative plant species in the reservoir has threatened its biodiversity and natural processes (Madsen 2004). Not only can multiple nonnative plants do extreme harm to an area, but just one exotic species can alter an entire ecosystem if not controlled properly (Pimental et al. 2000). The exotic, invasive plant hydrilla [*Hydrilla verticillata* (L. f.) Royle] was observed in the reservoir in 2005 (Wersal et al. 2006). This submersed aquatic plant is on the state and federal noxious weed lists and has been nicknamed "the perfect aquatic weed" due to its aggressive growth habit and adaptive morphological characteristics (Langeland 1996). Alligatorweed [*Alternanthera philoxeroides* (Mart.) Griseb.], and waterhyacinth [*Eichhornia crassipes* (Mart.) Solms] are also species of concern that have spread to a large degree and have negatively impacted the reservoir's services and available recreational opportunities. Impacts from these plant species, as well as from other aquatic invasives, prompted the Pearl River Valley Water Supply District to create a long-term management plan to strategically monitor these plants and assess control methods to suppress their spread.

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Management Implications

This research was conducted over a 6-yr time span to assess long-term management techniques for tracking the distribution and monitoring the control of several invasive aquatic plant species. In addition, this research was designed to determine the impact on the composition of the native plant community within this reservoir. A point-intercept survey of the entire Ross Barnett Reservoir was conducted each year using point locations at 300-m intervals within a grid system established by geographic information system (GIS) across the reservoir. Each year (2005 to 2010), these locations were surveyed for all plant species present. Aquatic herbicides were the primary method used for nonnative plant management in the reservoir over the previous 6 yr. By comparing how often each plant species occurred over consecutive years, we determined how effective our management program was. A logistic model was also utilized to decipher the effects of native species richness on the likelihood of nonnative species invasion. This model showed that a greater native species richness favored nonnative species establishment. We concluded that our herbicide applications were effective in reducing nonnative plant coverage; however, source plant populations upstream of the reservoir were likely supplying propagules capable of producing future populations throughout the reservoir. Employing an Early Detection and Rapid Response program based on results gathered from the logistics model could significantly reduce nonnative plant establishment by defining locations that are more favorable or susceptible to invasion, based on native species richness at that particular location. Integrating a prevention program in addition to effective postestablishment practices such as herbicide applications is the most effective way to reduce invasive plant establishment and spread.

Systemic herbicide applications have primarily been the management technique used for alligatorweed and waterhyacinth over the last decade (Wersal et al. 2009). Hydrilla has been managed in the reservoir over the last 6 yr by the combinations of the contact herbicides copper (Komeen®; SePRO Corporation, Carmel, IN 46032) and diquat (Reward®; Syngenta Crop Protection, Inc., Greensboro, NC 27419) and granular formulations of the systemic herbicide fluridone (Sonar®; SePRO Corporation). Applications of fluridone have proven successful, greatly reducing the populations of hydrilla in some areas of the reservoir. However, fragmentation of hydrilla and water movement aid in dispersing this species and allow new populations to develop. Alligatorweed and waterhyacinth populations have been greatly suppressed by applications of glyphosate and 2,4-D since 2005; however, fluctuating water levels and varying plant densities throughout the reservoir have made treatment efforts difficult at times. To ensure that the current management techniques are effective, intensive surveying and regular assessments are imperative to the success of any long-term management maintenance program (Madsen 2007). The objectives of this study were to: (1) quantify changes in the aquatic plant community composition over time; (2) identify major factors that influence changes in plant community composition; (3) develop a simple model to predict areas within the reservoir that are more likely to promote the growth of hydrilla, alligatorweed, and waterhyacinth based on total species richness throughout the reservoir; and (4) assess the management strategies that are ongoing in the Ross Barnett Reservoir with respect to hydrilla, waterhyacinth, and alligatorweed.

Materials and Methods

Vegetation Survey. Surveys were conducted using a 300 m (984 ft) grid of points (Madsen 1999; Wersal et al. 2009) in June 2005, October 2006, July 2007, July 2008, July 2009, and September 2010 to evaluate aquatic plant distribution in the reservoir. Only points located in the littoral zone (water depths of 3 m or less) were surveyed. Light extinction coefficients were utilized to determine the optimal water depth(s) for rooted submersed macrophyte growth in the reservoir (Wersal et al. 2006). The maximum depth of macrophyte colonization in the reservoir was estimated to be 2.2 m; therefore, the littoral zone was assigned depths of 3 m or less to ensure efficiency of sampling. Sampling of the littoral zone allowed for a more rigorous survey on the reservoir at locations most favorable for plant growth (Figure 1). Sampling of the same points from 2005 to 2010 allowed changes in the plant community to be statistically quantified over time.

Survey accuracy of 1 to 3 m was achieved by using a Trimble AgGPS106™ receiver (Trimble, 935 Stewart Drive, Sunnyvale, California 94085) coupled with a Panasonic C-29 Toughbook™ computer (Panasonic, One Panasonic Way, Secaucus, New Jersey 07094). A total of 677, 508, 423, 627, 695, and 260 points were surveyed in 2005, 2006, 2007, 2008, and 2010, respectively. At each survey point, a weighted plant rake with an attached rope was deployed and pulled in to determine the presence or absence of plant species. Depth was recorded at each point with a Lowrance LCX-28C depth finder (Lowrance, 12000 East Skelly Drive, Tulsa, Oklahoma 74128) or with a sounding rod at depths less than 3 m. Navigation to survey points, the display and collection of geographic and attribute data while afield, and spatial data were recorded electronically using FarmWorks Site Mate® software version 11.4 (Farm Works, 6795 South SR1, Hamilton, Indiana 46742) using templates and pick lists created for this project. Collecting survey in this manner decreased the likelihood of errors in data entry and postprocessing time.

Nonnative Species Assessment. Data obtained from the point intercept surveys conducted on the reservoir were used to assess management efficacy on hydrilla, waterhyacinth, and alligatorweed. A quantitative comparison was then made by the analysis of changes in the frequency of occurrence of

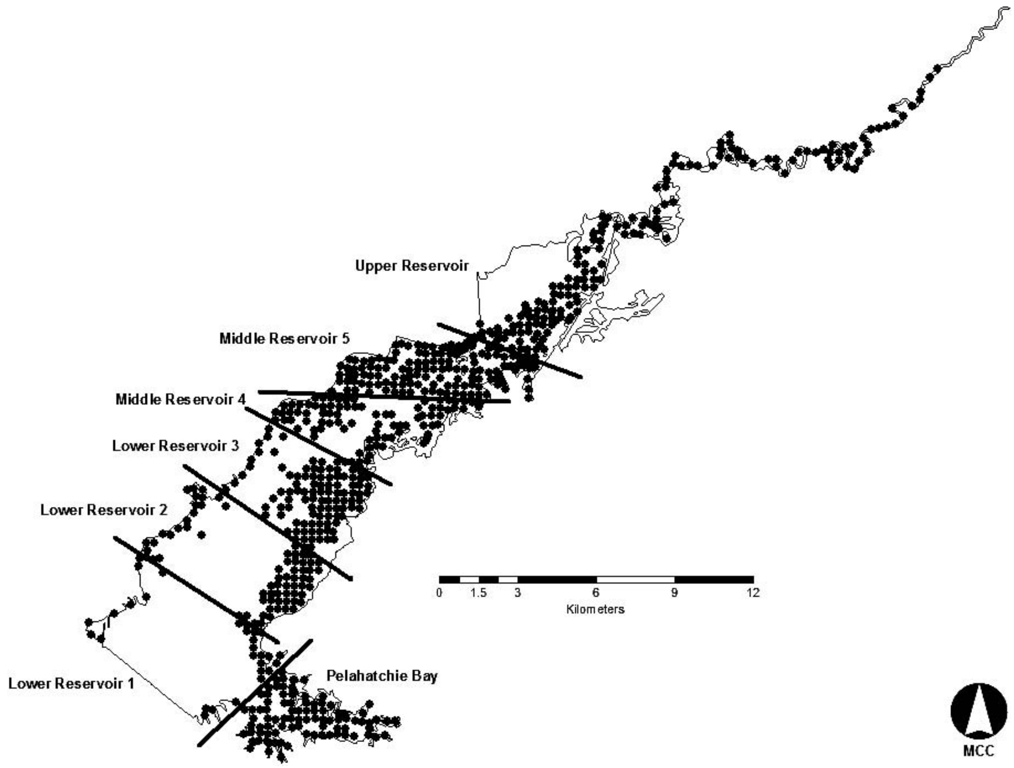

Figure 1. Total surveyed locations on the Ross Barnett Reservoir from 2005 to 2010.

each species between years. Applications of the herbicide fluridone and combinations of chelated copper and diquat were implemented for hydrilla management on the reservoir from 2005 to 2010.

Tuber surveys were conducted in the early springs of 2006 to 2010 to assess the current density of hydrilla tubers in the Ross Barnett Reservoir. Sampling the sediment for tubers in areas of known hydrilla occurrence allows for estimation of future hydrilla populations. A polyvinyl chloride (PVC) coring device was used to collect 20 sediment samples at each site (Madsen et al. 2007). The sediment was sieved through a pail with a wire mesh bottom to separate the sediment from any plant material. Any tubers found were transported to Mississippi State University where they were sorted, dried, and weighed to calculate tuber biomass and density.

Foliar applications of the herbicides glyphosate (Touchdown® Pro; Syngenta Crop Protection, Inc.), 2,4-D (DMA® IV; Dow Agrosciences LLC, Zionsville Road, Indianapolis, IN 46268), or imazapyr (Habitat®; BASF Corporation, Research Triangle Park, NC 27709) were applied to waterhyacinth and alligatorweed populations in the reservoir from 2005 to 2010. Cuban club-rush [*Oxycaryum cubense* (Poepp. & Kunth) Lye] was treated with combination applications of 2,4-D and diquat in 2009 and 2010. The small population of waterlettuce (*Pistia stratiotes* L.) observed in 2009 was also treated with a combination of 2,4-D and diquat in the fall of that year and has not been observed in the reservoir since that time. All herbicides were applied by licensed applicators in compliance with Mississippi State University and federal regulations; the authors of this paper did not apply any herbicides in this study.

Data Analysis. Plant species presence was averaged over all points sampled and multiplied by 100 to obtain percent frequency. Total species richness was calculated and presented as the mean ($\pm$ 1 SE) of all species observed at each point. Mean species richness was compared between years using a general linear model (GLM). Changes in the occurrence of plant species was determined using McNemar's Test for dichotomous response variables that assesses differences in the correlated proportions within a given data set between variables that are not independent (Stokes et al. 2000; Wersal et al. 2006, 2008). A pairwise comparison of species occurrences was made between years using the Chi Square test due to differences in total number of sampled locations between years (Plackett 1983). All analyses were conducted at $\alpha = 0.05$ significance level.

Logistic Model. A logistic regression model was developed using SAS® to determine the relationship between the presence of nonnative species and increasing native species

Table 1. Percent frequency (%) of occurrence for aquatic plant species observed in the littoral zone during the Ross Barnett Reservoir surveys 2005–2010. The letter "n" refers to the total number of points sampled in a given year. Letters in a row for a given species denotes a significant difference among years at a p = 0.05 level of significance.

Species name	2005 (n = 677)	2006 (n = 508)	2007 (n = 423)	2008 (n = 627)	2009 (n = 695)	2010 (n = 620)
	% Frequency					
Alternanthera philoxeroides[a]	21.1	3.9	4.0	7.3	14.9 a	11.9
Azolla caroliniana Willd.	0.0	0.2	0.4	0.0	0.5	0.0
Cabomba caroliniana Gray	2.2	0.0	0.5	1.3 a	0.6	0.0
Ceratophyllum demersum	4.4	4.9	3.5	7.6 a	3.6 a	3.9
Colocasia esculenta (L.) Schott[a]	0	0.9	0.7	2.4 a	2.4	2.1
Eichhornia crassipes[a]	4.9	2.9	1.2	4.0 a	8.6 a	5.2 a
Hydrilla verticillata[a]	0.0	0.6 a	1.2 a	0.6 a	0.8	0.9
Hydrocotyle ranunculoides L. f.	6.4	0.5	1.4	2.8 a	1.3 a	0.3
Juncus effusus L.	0.0	0.0	0.0	0.2	1.7	1.6
Lemna minor L.	3.1	2.5	1.9	1.4 a	1.3	1.5
Limnobium spongia (Boac.) Steud.	1.5	0.8	0.7	1.3	0.3	0.3
Ludwigia peploides	4.9	7.4	4.3	10.2 a	14.8 a	11.9
Myriophyllum aquaticum[a]	0.7	0.0	0.2	1.0 a	0.4	0.2
Najas minor[a]	0.0	0.0	1.9 a	1.0 a	0.3	0.2
Nelumbo lutea	17.1	17.7	21.2	24.8 a	26.9	26.8
Nitella sp.	0.1	0.0	0.0	0.0	0.0	0.0
Nymphaea odorata	4.4	3.4	4.9	5.4	5.9	5.3
Oxycaryum cubense[a]	—	—	—	—	—	0.0
Pistia stratiotes[a]	—	—	—	—	—	0.0
Potamogeton foliosus Raf.	0.0	0.0	0.0	0.6	0.0	0.3
Potamogeton nodosus Poir.	2.7	2.7	2.4	3.0	2.9	1.1
Sagittaria latifolia Willd.	1.0	1.2	0.0 a	0.5	1.3	1.0
Sagittaria platyphylla (Engelm.) J. G. Sm.	0	1.8	0.8	0.3 a	2.3 a	1.1
Scirpus validus Vahl	1.2	0.2	0.0	0.0	0.0	0.0
Spirodela polyrrhiza (L.) Schleid.	0.0	0.0	0.0	0.16	0.7	0.5
Typha sp.	1.3	2.4 a	0.7	1.1	7.1 a	5.5
Utricularia macrorhiza Leconte	0.0	0.4	0.0	0.5	0.1	0.0
Zizaniopsis miliacea	1.5	3.5	1.9 a	4.1	10.4 a	8.5

[a] Indicates a nonnative species.

richness (Stokes et al. 2000). Only native species richness values recorded with more than 30 locations were used in the model, therefore, values ranged from one to five. The predictor variable (Native Species Richness) was transformed using the X + 1 procedure to eliminate zeros in the data range (Quinn and Keough 2002). The natural log was then calculated for the new range of values to reduce variability within the model. Logistic regression estimates the probability that a defined set of variables accurately predicts dichotomous or categorical variables (Buchan and Padilla 2000; Trexler and Travis 1993). The use of logistic regression is useful because it provides a measure of association (Buchan and Padilla 2000); in the case of this study, it was used to approximate the probability of observing a nonnative species or alligatorweed alone given increasing native species richness. A similar model was used to determine the probability of observing alligatorweed as native species richness increases. Although data were transformed for analysis purposes, nontransformed probabilities are given for ease of interpretation when comparing to vegetation survey frequencies for a given species.

Results

Vegetation Survey. Surveys conducted on the Ross Barnett Reservoir from 2005 to 2010 recorded a total of 26 aquatic or riparian plant species (Table 1). The native plant American lotus (*Nelumbo lutea* Willd.) was the most abundant species across all years. American lotus increased in occurrence from 17% in 2005 to 27% in 2010

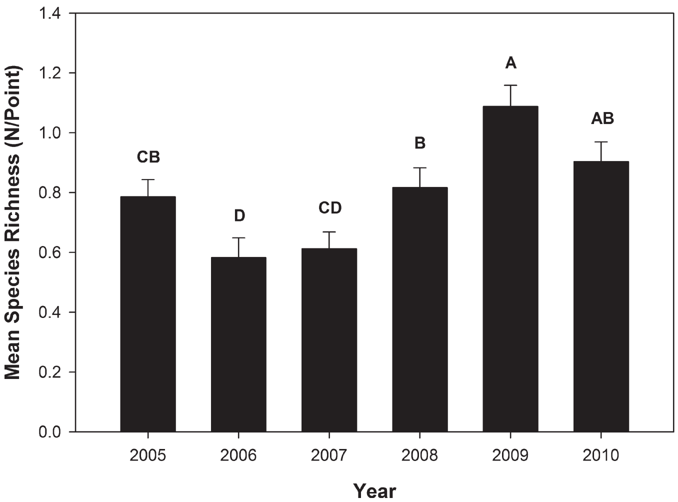

Figure 2. Mean plant species (number of species observed per point) at each sampled location on the Ross Barnett Reservoir from 2005 to 2010. Mean species richness was compared across years and significant differences indicated by a different letter.

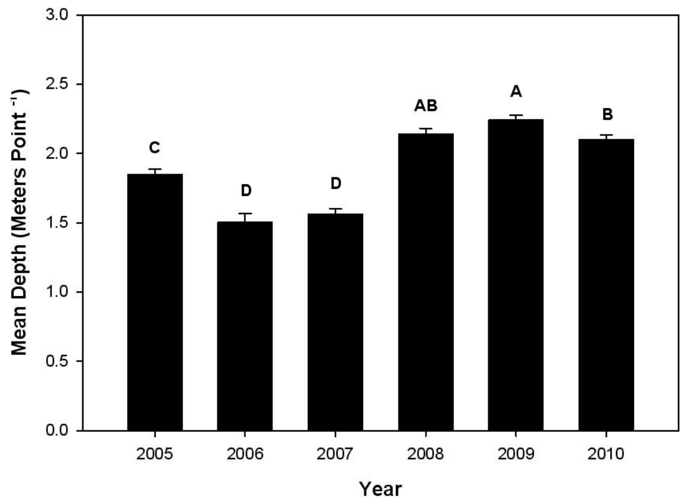

Figure 3. Mean water depth (meters per point) at each sampled location on the Ross Barnett Reservoir from 2005 to 2010. Mean depth was compared across years and significant differences indicated by a different letter.

(Table 1). The presence of fragrant waterlily (*Nymphaea odorata* Ait.) remained constant over time, whereas coontail (*Ceratophyllum demersum* L.) significantly decreased from 7.6% in 2008 to 3.9% in 2010. Other native species that commonly occurred were creeping waterprimrose [*Ludwigia peploides* (Kunth) Raven] and giant cutgrass [*Zizaniopsis miliacea* (Michx.) Döll & Asch.]. Species richness was significantly greater in 2009 than in 2008, where on average, one plant species was observed per point (Figure 2). Species richness was lower in 2006 than all other years with approximately 0.6 plant species observed per point. Water depth was a key determinant in species richness at each point during the year of the survey (Table 2). Low water levels in 2005, 2006, and 2007 likely resulted in lower plant species occurrence per point due to inaccessibility of many predefined survey locations that showed high species richness values in previous survey years. Conversely, increased water depth in 2008, 2009, and 2010 resulted in higher species richness per point. (Figure 3).

Nonnative Species Assessment. Hydrilla and waterhyacinth had occurrences below 10% for all survey years (Table 1). The frequency of occurrence for alligatorweed decreased significantly ($p \leq 0.01$) from 21.1% in 2005 to 7.3% in 2008, increased to 14.9% in 2009, and decreased to 11.9%

Table 2. Monthly mean lake level readings (m above sea level) from 2005 to 2010 for the Ross Barnett Reservoir, Mississippi.

	2005	2006	2007	2008	2009	2010
January	90.3	90.3	90.3	90.3	90.3	90.3
February	90.3	90.3	90.3	90.3	90.3	90.3
March	90.4	90.4	90.5	90.6	90.6	90.5
April	90.7	90.8	90.5	90.7	90.7	90.7
May	90.7	90.7	90.3	90.7	90.7	90.7
June	90.7	90.6	90.5	90.6	90.6	90.7
July	90.7	90.5	90.6	90.7	90.7	90.7
August	90.3	90.3	90.4	90.7	90.7	90.6
September	90.2	90.3	90.2	90.7	90.6	90.3
October	90.2	90.4	90.1	90.4	90.4	90.3
November	90.3	90.3	90.1	90.3	90.3	90.3
December	90.3	90.3	90.3	90.3	90.3	—
[a]Yearly Avg. (May–October)	90.5	90.5	90.3	90.6	90.6	90.6

[a] Annual surveys were conducted during the growing season in Mississippi, which is approximately May through October.

Table 3. Estimated and treated surface hectares of nonnative plant species in the Ross Barnett Reservoir (Mississippi) from 2005 to 2010.

	2005	2006	2007	2008	2008	2009	2009	2010	2010
Species	Estimated	Estimated	Estimated	Estimated	Treated[a]	Estimated	Treated[a]	Estimated	Treated[a]
	ha								
Alligatorweed	1,285	179	153	413	137	934	124	665	263
Brittleleaf naiad	0	0	72	45	—	18	—	9	—
Hydrilla	49	27	45	36	111	54	63	54	32
Parrotfeather	45	45	9	54	—	27	—	9	—
Waterhyacinth	297	135	45	225	68	539	227	287	166
Waterlettuce	—	—	—	—	—	—	2[b]	0	0.2
Cuban club-rush	—	—	—	—	—	—	21[b]	9	53

[a] Hectares treated refers to the total surface area of water treated, not necessarily to the point of plant infestation.

[b] Denotes first observation in 2009 of the indicated plant species.

in 2010. Waterhyacinth decreased in frequency of occurrence from 2005 to 2007, then significantly increased from 1.2% in 2007 to 4.0% in 2008 and 8.6% in 2009. Alligatorweed was the nonnative species observed most often in all years, followed by waterhyacinth, hydrilla, brittleleaf naiad (*Najas minor* All.), and parrotfeather [*Myriophyllum aquaticum* (Vell.) Verdc.] (Table 1). To date, a total of 16 hydrilla populations have been observed throughout the reservoir; however, many of these populations have been greatly reduced by herbicide treatments and are still being monitored (Table 3). Likewise, these herbicide treatments have proven effective on reducing hydrilla tuber production and preventing future populations (MacDonald et al. 1993) as shown by the reduction in tuber occurrence in the reservoir. Generally, the occurrence of all aquatic plant species was in Pelahatchie Bay and the northern portion of the reservoir where water depths are generally lower, and light penetration through the water column reaches the sediment floor and favors submersed, emergent, and floating–emergent plant growth.

Waterlettuce was not found during the 2010 survey after being observed in September 2009 along a small channel in Pelahatchie Bay (Figure 1). Several small pockets (< 0.10 hectares) of waterlettuce were discovered in the early fall of 2009 after the survey was completed and included into the management scheme of the reservoir. It appears that the early detection and immediate combination applications of 2,4-D and diquat were successful at eradicating this species. Cuban club-rush was also discovered in Pelahatchie Bay in the fall of 2009 after the annual survey was completed and is still well established. Combination applications of 2,4-D and diquat were made to Cuban club-rush in 2009 and 2010; however, data recorded from surveys conducted in 2011 and 2012 show an increasing trend in frequency of occurrence (Sartain et al. 2013) since those treatments in 2009 and 2010. Treated hectare amounts given in Table 3 often exceeded estimated amounts because estimated hectares are based solely on survey data and not areas outside of the survey points within the reservoir. The private applicator treated areas of weed infestation within the entire reservoir, not just surveyed locations.

Logistic Model. This model was tested against the conceptual idea that greater native species richness inhibits nonnative species occurrence and establishment (Hobbs and Huenneke 1992). We developed a logistic regression model to determine the relationship of increasing native species richness (i.e., increased growth) to observation of nonnative plant species (i.e., resisting invasion), and to predict the probability of observing a nonnative species or alligatorweed alone at a given point. Alligatorweed was chosen as a favorable species for modeling in the Ross Barnett Reservoir based on nonnative species frequency of occurrence for all years of the survey. Our model found a significant positive relationship ($P < 0.01$) between the presence of a nonnative species (or specifically alligatorweed) and increasing native species richness. Based on our model, as species richness increases there is a greater likelihood of invasion by nonnative species, and in particular alligatorweed for the purpose of the model. For example, when one native species was present at a sample point, there was a probability of 0.14 of observing a nonnative species (Figure 4). However, as species richness increased to five (the maximum richness observed in this lake) the probability of observing a nonnative species increased to 0.88. Similar to these results, the probability of observing alligatorweed at a sample point when native species were present at mean richness values of one and five were 0.10 and 0.81, respectively (Figure 5).

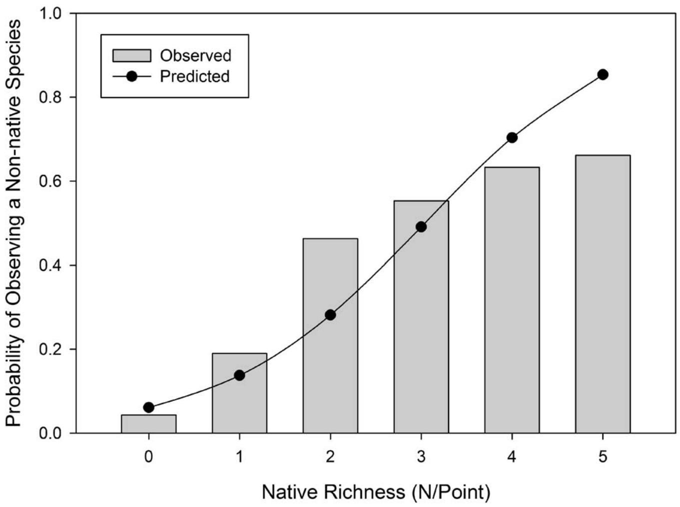

Figure 4. The estimated probability of observing a nonnative species (line) and the observed frequency of nonnative species (bar) vs. the native species richness (number of native species per point, or N/Point) on the Ross Barnett Reservoir, based on all point data collected from 2005 to 2010.

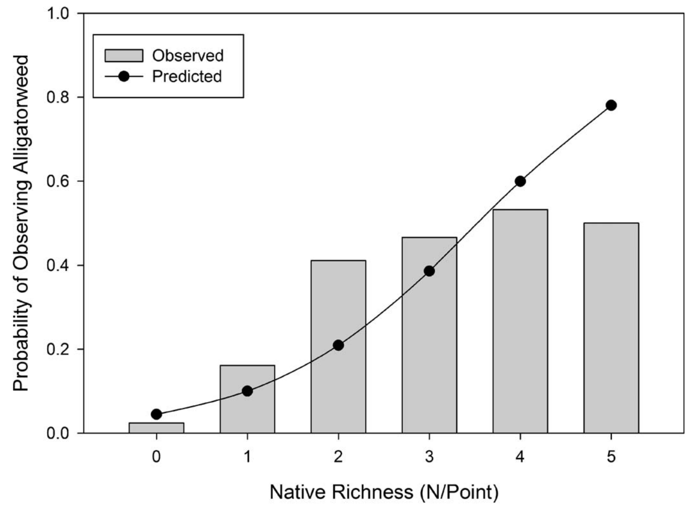

Figure 5. The estimated probability of observing alligatorweed (line) and the observed frequency of alligatorweed (bar) vs. the native species richness (number of native species per point, or N/Point) on the Ross Barnett Reservoir, based on all point data collected from 2005 to 2010.

Discussion

Vegetation Survey. *Nonnative Species Assessment.* The estimated coverage of alligatorweed had more than doubled from 2008 to 2009, according to survey data from 2009 (Table 1). This tremendous increase in occurrence might be attributed to the increase in water level, allowing for better boat access to survey locations and plant movement throughout the reservoir in 2009. The addition of approximately 25 locations of alligatorweed observed up the Pearl River that were not surveyed in 2008 and cover an estimated 225 ha (8.9 ha $point^{-1}$) were also additional sources to the higher frequency of occurrence in 2009. The estimated coverage of alligatorweed for 2010 decreased by approximately 283 ha; this reduction is attributed to rigorous herbicide applications (Table 3), as well as increased plant population densities hindering access to previously surveyed locations, which led to a fluctuation in the number of surveyed locations between years. Small, existing alligatorweed populations along the river are likely responsible for supplying propagules and establishing new populations in the reservoir. Dense pockets and pools of vegetation that are not accessible by boat might also provide plant propagules to the reservoir. The significant increase in occurrence is most likely due to higher water levels and the ability to access more of the survey points to find these populations. Although the alligatorweed flea beetle [*Agasicles hygrophila* (Selman and Vogt)] has proven successful at controlling alligatorweed in many areas throughout the southeastern United States, the flea beetle has a more limited survival zone than alligatorweed due to climate (temperature and altitude) restrictions (Buckingham et al. 1983; Spencer and Coulson 1976). Small numbers of flea beetles were observed in the reservoir during the length of the study, but significant herbivore damage on alligatorweed was not. This lack of alligatorweed control by the flea beetle could be attributed to the average yearly temperature of the reservoir being unsuitable for flea beetle overwintering and establishment. The significant decrease in waterhyacinth from 2009 to 2010 could likely be attributed to successful herbicide applications (Table 3) and densely populated areas that were previously surveyed in earlier years of the study but now inaccessible by boat. ‘‘Hidden’’ plants among dense stands of other plant species also make surveying and treatment difficult at times.

Hydrilla Assessment. The suppression of hydrilla distribution in the reservoir over the last 6 yr is attributed to intensive management strategies (Table 3). Approximately 5 of 16 total hydrilla populations have been greatly reduced on the reservoir since 2005. Some of these populations have just recently been discovered; therefore, herbicide treatments have not had adequate time to become effective. Despite rigorous herbicide applications, three hydrilla populations have remained. These reoccurrences might be attributed to the inhibition of herbicidal activity on hydrilla due to water movement limiting chemical–plant contact times in these particular locations. Still, hydrilla has consistently reoccurred throughout the reservoir in untreated locations. Fragmentation and transportation of hydrilla by mechanical boat parts is likely the cause of these new populations sporadically occurring throughout the reservoir.

Subterranean turions, or tubers, produced by hydrilla are vital to the life cycle of this plant and can remain viable in undisturbed sediment for up to 4 yr (Netherland 1997). Tuber surveys conducted on the Ross Barnett Reservoir since 2006 have yielded very few hydrilla tubers. Tubers were found in one location in the reservoir in 2006, which explained the presence of new hydrilla plants in that location in 2008. Although no other tubers have been found, it is possible that hydrilla plants might be overwintering and regrowing from healthy root crowns with very little tuber production. Low tuber densities might decrease the year-to-year recruitment of hydrilla and possibly the number of herbicide treatments necessary for eradication. Fluridone treatments at 5.0 to 50 parts per billion have been documented to inhibit tuber production as well as remove standing biomass (MacDonald et al. 1993). If herbicide treatments are reduced, minimizing fragmentation and transport of hydrilla within the reservoir would become more critical.

Logistic Model. The logistic regression approach to predicting invasion success has been used for nonnative species in lakes in Connecticut and Wisconsin (Buchan and Padilla 2000; Capers et al. 2007). Buchan and Padilla (2000) utilized water quality data to predict the invasion of Wisconsin lakes by Eurasian watermilfoil (*Myriophyllum spicatum* L.). Our data corroborates those reported by Capers et al. (2007) where increasing native species richness did not resist invasion by nonnative species as spatial scales increase. In most of the lakes, the authors found a positive relationship, thus indicating that native and nonnative species have an affinity for the same abiotic resources. Although studies on invasibility and invasion success are variable in their conclusions, data from this study supports the claim that the ''rich get richer'' (Stohlgren et al. 1999, 2003). The ''rich get richer'' means that areas that have high initial native species diversity are more likely to be areas for invasive plants to establish and thrive, and, at least over short time periods, have a net increase in total species richness.

Although native species richness does not impede invasion, native plant density was shown to have a negative effect on the presence of nonnative species (Capers et al. 2007). Dense native plant beds are presumably better able to prevent the colonization and establishment of nonnative propagules, thus reducing the invasibility of nonnative species (Capers et al. 2007). This typically only occurs at very high plant densities, and high densities might not be achievable due to reoccurring disturbance (Capers et al. 2007; Shea and Chesson 2002) or frequent reintroduction of nonnative propagules by humans. There are many factors that determine the invasibility of a habitat, such as species richness, plant density, inter- and intraspecific interactions, habitat complexity, resource availability, and abiotic factors; many of these are interconnected and difficult to separate their direct influences.

The use of the point intercept survey facilitated the quantitative assessment of a lake-wide nonnative plant control program for the Ross Barnett Reservoir. The use of herbicides resulted in the suppression of hydrilla, alligatorweed, and waterhyacinth with no significant long-term impact to the native plant community. Our logistic regression model indicated that areas of high species richness could be used to predict the probability of invasion by nonnative species. Therefore, existing mixed-plant species communities are more likely to be invaded by nonnative plants than areas without native plants. The addition of other environmental variables in the model would increase the predictive power and aid in further identifying specific areas of the lake that are more susceptible to invasion. Monitoring can then be focused more intensely in these areas making early detection and rapid response feasible.

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