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Effects of pH on Growth of *Salvinia molesta* Mitchell

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ABSTRACT

Growth of giant salvinia (*Salvinia molesta* Mitchell) under different pH regimes was examined at the Lewisville Aquatic Ecosystem Research Facility (LAERF) in Lewisville, Texas. Giant salvinia grew to completely cover a research pond over a 15-week period when pH was less than 7.5. Growth was reduced in a second pond maintained at a higher pH ranging from 8.5 to 10.00. Tank studies found that significantly greater giant salvinia biomass was produced, over a 2-fold increase, at the lower pH (less than 7.5 units). Additionally, water chemistry of tanks changed, especially pH and dissolved oxygen, when completely covered by the resultant mat.

Key words: pH, nutrient availability, giant salvinia, distribution.

INTRODUCTION

Giant salvinia is a floating aquatic fern native to southeastern Brazil and occurs between latitudes 24 and 32 degrees (Forno and Harley 1979). The plant is currently found in subtropical and tropical regions but has been reported in more than 20 countries, where it typically was introduced as an aquarium or water garden species (Room et al. 1981). Giant salvinia was first discovered and subsequently eradicated from North Carolina in the mid 1990s and was later found in 1997 in a Houston, Texas schoolyard pond (USGS 2004). In 1998, giant salvinia was reported in Toledo Bend Reservoir and by year 2000, had been found in 3 additional reservoirs (Conroe, Sheldon, and Texana), 5 rivers (or streams) and 20 ponds in Texas. It has also been reported in eleven other states, including AL, AZ, CA, FL, GA, HI, LA, MS, NC, SC and VA (USGS 2004).

Temperature is probably the greatest factor limiting giant salvinia growth, survival and spread (Owens et al. 2004, Whiteman and Room 1991, Harley and Mitchell 1981). Giant salvinia has a distinct northern boundary corresponding to low (below freezing) winter temperature, and appears to be incapable of survival in locations where ice forms for extended periods (Owens et al. 2004, Whiteman and Room 1991, Harley and Mitchell 1981).

Giant salvinia has invaded several aquatic systems in southern, southwest and Gulf coastal states of the United States where it has exhibited persistent and explosive growth (USGS 2004). Dense mats of giant salvinia can impede transportation, irrigation, hydroelectric production, flood and mosquito control, destroy habitats, degrade water quality, and hinder endeavors such as rice cultivation and fishing (Mitchell 1979, Holm et al. 1977). An aggressive aquatic species under ideal conditions, giant salvinia can completely cover water surfaces and form mats up to 1 m thick (Thomas and Room 1986).

Because giant salvinia is a free-floating plant, nutrients must be obtained from the water column via the modified third leaf, which resembles roots. Nutrients such as phosphorus, manganese and iron can become bound in sediments under certain conditions, such as high pH or elevated dissolved oxygen concentrations, and are thus unavailable for floating plant uptake (Wetzel 1983). These nutrients are essential for healthy plant growth as they are important for photosynthesis, chlorophyll synthesis, enzymatic activity, etc. (Raven et al. 1981), thus availability is necessary for plant growth and survival. When pH and dissolved oxygen concentrations decline, many sediment bound nutrients, such as

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iron, manganese and phosphorus may be released into the water column (Riemer 1984, Wetzel 1983). Cary and Weerts (1984) found that greatest dry weights were obtained from giant salvinia plants grown in nutrient solution at a pH of 6.0 over plants grown at a pH of 7.0 or greater.

The objectives of this study were to 1) document giant salvinia growth in relation to different pH regimes under natural (pond) conditions; 2) determine pH effects on giant salvinia growth; and 3) determine impacts of giant salvinia mats on water chemistry in tank studies. This knowledge might be utilized to predict distributional limits of giant salvinia based on water chemistry or to evaluate the probability of a new infestation reaching problematic proportions.

MATERIALS AN D METHODS

Pond Study

During 2001, three ponds at the LAERF were manipulated to achieve different pH or water levels. The ponds used were earthen, clay-lined, rectangular, and ranged in size from 0.25 to 0.32 hectares. When full, most ponds are approximately 2.0 m at the deepest end and average about 1.0 m deep overall (Smart et al. 1995). The first two ponds were used to compare growth rates of giant salvinia colonies under high and low pH. Pond one (hereafter referred to as low pH, deep) received approximately 120 L of muriatic acid (HCl) to reduce alkalinity and lower the pH to below 7.5. This was followed by the addition of 25 bales of hay to provide longer-term pH amendment through organic decomposition, CO_2 production and organic acid accumulation. The second pond (hereafter referred to as high pH, deep) was unamended and the water chemistry was typical of LAERF ponds in which pH ranges from 8-10.5 depending on time of day, season and submersed plant community (Smart et al. 1995). The depth of these 2 ponds was maintained at approximately 1.5 m at the deep end. A third pond (hereafter referred to as high pH, shallow) was unamended, but depth was held at approximately 0.3 m. This pond had a corresponding smaller surface area than other treatments and was included to simulate shallow backwater areas to evaluate early growth under unamended pH conditions with the roots in close proximity to the sediments.

Six 114-L containers of giant salvinia were added to each pond during August 2001. Water was periodically added to each pond to replace evaporative losses. Hydrolab DataSondes® (Hydrolab Corp., Austin, TX) were deployed at a depth of 25 cm to record hourly pH (units), temperature (C), dissolved oxygen (mg/L) and conductivity (µs/cm) for each of the deeper ponds. After 15 weeks of growth, the ponds were surveyed using GPS (Trimble TSC1, Sunnyvale, CA) and analyzed using GIS (ArcView 3.1, ESRI, Redlands, CA) to demonstrate the extent of giant salvinia growth under each treatment. No water chemistry was collected on the shallow pond due to inability of the DataSonde to record in shallow water.

Tank Studies

In the first study, water chemistry effects on giant salvinia growth were determined over a 6-week period in 2002 using outdoor tanks. To ensure adequate nutrients were available, approximately 5.1 cm of LAERF pond sediment was added to the bottom of eighteen 416-L plastic tanks (Toter Incorp., Statesville, NC). Tanks were then filled with LAERF pond water. Nine tanks received unamended LAERF pond water (high pH) and nine tanks received amended LAERF pond water. Low pH (low pH: 7.0-6.0) was maintained by adding 19 L of Canadian peat moss directly to the tanks at the beginning of the study. Five 5-leaf pairs of giant salvinia were added to each tank at a total average biomass (g dry weight) of 0.45 g. Biomass was harvested from three tanks of each treatment every two weeks, dried at 65 C in a convection-drying oven and weighed. Surface area (cm^2) coverage was also measured. Additionally, a DataSonde was used to record pH, temperature and dissolved oxygen in each tank at least once every third day.

In a second tank study, giant salvinia effects on water chemistry were investigated. Eighteen 416-L outdoor plastic tanks were filled with approximately 5.1 cm depth of LAERF pond sediment followed by LAERF pond water. No amendments were made to alter the water chemistry. Treatments included six tanks with 100% giant salvinia coverage, six tanks with 25% giant salvinia surface area coverage, and six tanks containing no giant salvinia (control). DataSondes were distributed into one tank of each treatment to record hourly pH, temperature and dissolved oxygen. Additionally, discrete water chemistry data for the same parameters were collected at least every three days from all tanks. This study was conducted over a two-week period.

RESULTS AND DISCUSSION

GPS (Geographic Positioning Systems) data collected from treatment ponds revealed substantial differences between giant salvinia populations. After 15 weeks of growth, most of the low pH, deep pond was covered with giant salvinia (Figure 1). Additionally, the dominant growth form was the erect leaf mat-forming stage. pH was generally maintained below 7.5 and dissolved oxygen fell to well below 5.0

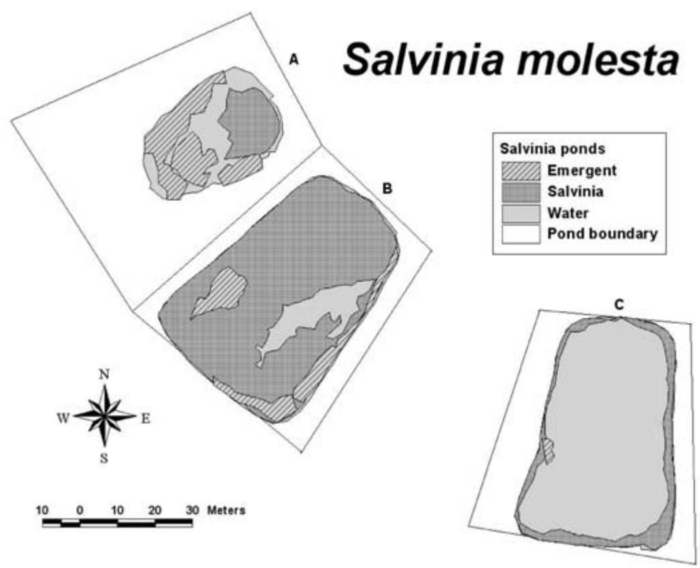

Figure 1. GIS map showing extent of surface coverage of giant salvinia after 15-weeks during summer 2001 in the 3 treatment LAERF ponds. The treatments were A) high pH (natural LAERF water chemistry), shallow, B) low pH, (amended with hay and muriatic acid), deep, and C) high pH (natural LAERF water chemistry), deep. Ponds are actual GPS locations.

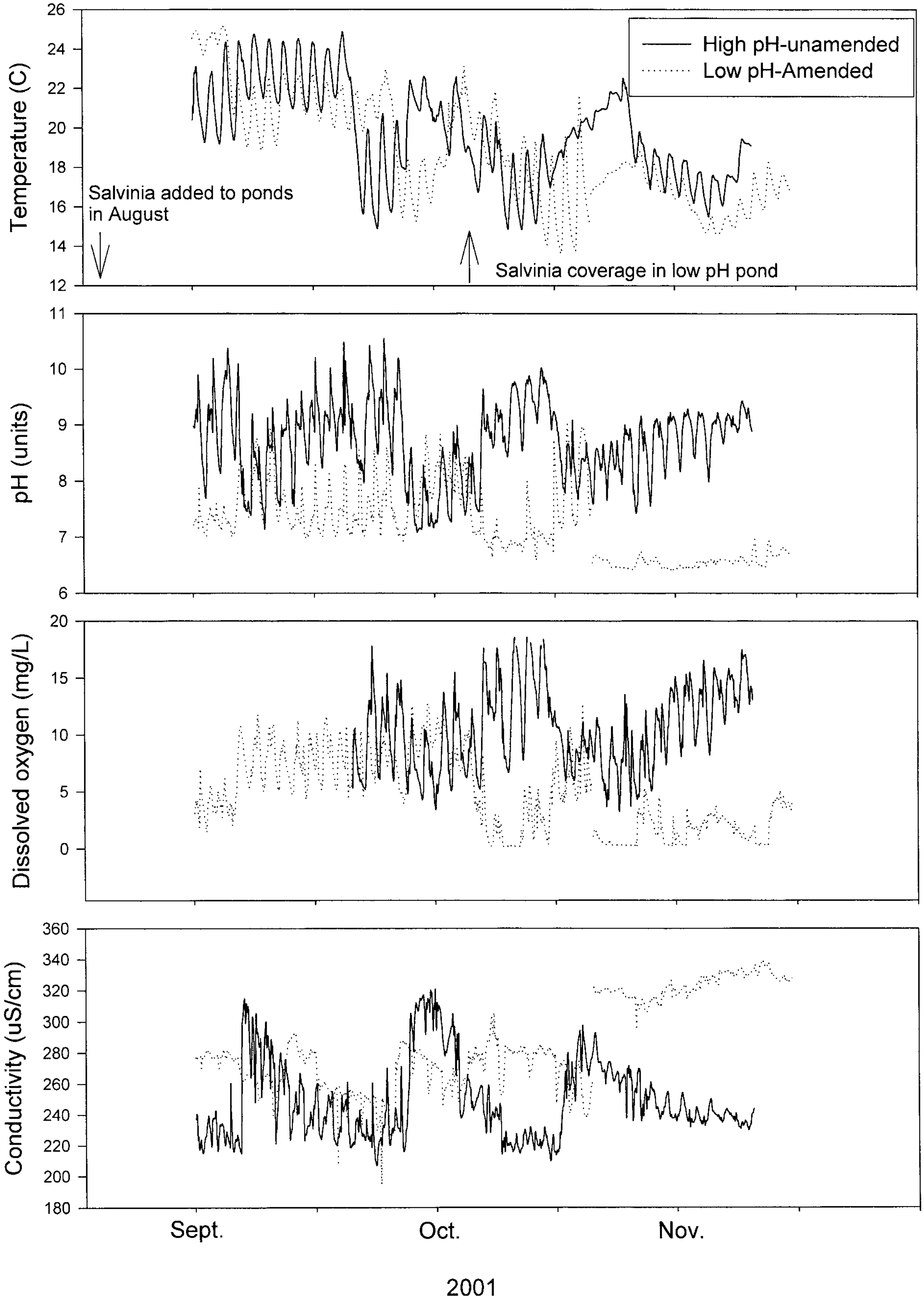

Figure 2. Water chemistry data for the 2 deep giant salvinia ponds showing hourly recorded data for temperature, pH, and dissolved oxygen for the 15-week study period. Treatments were high pH (natural LAERF water chemistry) and low pH (amended with hay and muriatic acid).

mg/L toward the middle of the study period, as the giant salvinia canopy began to completely cover the pond (Figure 2). Although not measured, it is speculated that nutrients such as iron and phosphorus became more readily available under lower pH conditions, perhaps reducing growth limitations on giant salvinia. As a floating plant, giant salvinia does not have access to nutrients via the sediments and is therefore dependent upon nutrient availability in the water column. Neither of the high pH ponds was completely covered; giant salvinia rimmed the edge of the high pH, deep pond and formed a mat of erect leaves in the center of the high pH, shallow pond (Figure 1). Giant salvinia in the low pH, deep pond covered ca. 90% of the pond surface while both the high pH ponds were found to have ca. 15% coverage of the total or flooded part of the pond. It should be noted that these growth differences based on the pH of the ponds have been observed over several years although data was only collected during this growing season (Owens, pers. obs.).

In the first tank study, significant biomass and surface area coverage differences occurred between the plants growing under low and high pH. By week four, giant salvinia had grown to cover the surface of low pH tank; however, this did not occur in the high pH tanks throughout the entire 6-week study. In addition to differences in surface area coverage between low and high pH treatments, significant differences were detected by ANOVA between week 2 and weeks 4 and 6 at low pH (Figure 3A), but not between any weeks at high pH, indicating more rapid colony growth rate at low pH.

Biomass in low pH tanks exhibited significant increases for each sampling period; however, this did not occur in high pH tanks (Figure 3B). During the study period, pH in low pH tanks was generally maintained at 7.0 or less while high pH tanks were typically above 8.0 (Figure 4). Dissolved oxygen was generally lower in the low pH tank and there were no observable differences in temperature. This study indicated that pH might be a critical factor in growth of giant salvinia following invasion.

Giant salvinia had a decided impact on water chemistry in the second tank study. Tanks with 100% giant salvinia coverage exhibited lower dissolved oxygen readings by day 2 and pH began to decline by day 4 (Figure 5); no differences were observed in control or partly covered tanks. Both declines were most likely due, in part, to reduction of algal photosynthesis, caused by light blockage by the giant salvinia canopy (Smart pers comm.). Generally, photosynthesis removes carbon dioxide from the water column while decomposition consumes oxygen and drives pH down; at the same time, photosynthesis produces oxygen as a by-product. Reduction of photosynthesis due to low light limits oxygen production, and dissolved oxygen concentrations will decline without alternate sources of replenishment (e.g., atmospheric oxygen). In addition to blocking light and reducing photosynthetically produced oxygen, the giant salvinia canopy also serves as a

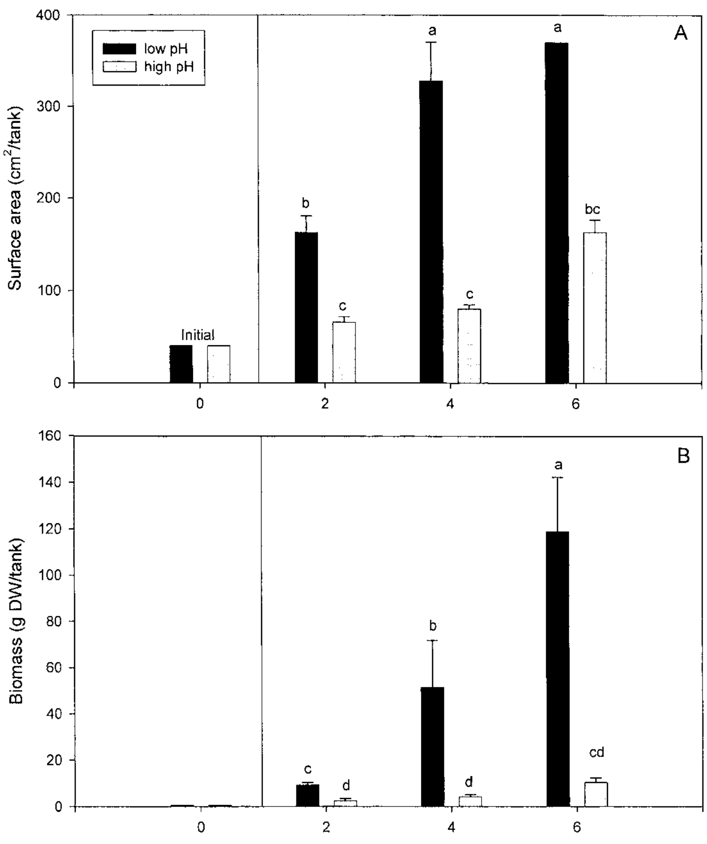

Figure 3. A) Measurements of giant salvinia 0, 2, 4, 6, weeks after treatment. Bars represent means of replicates and standard error bars. Treatments coded with same letter are not different at p = 0.05. A) Surface area (cm²/tank), and B) Biomass (g DW/tank).

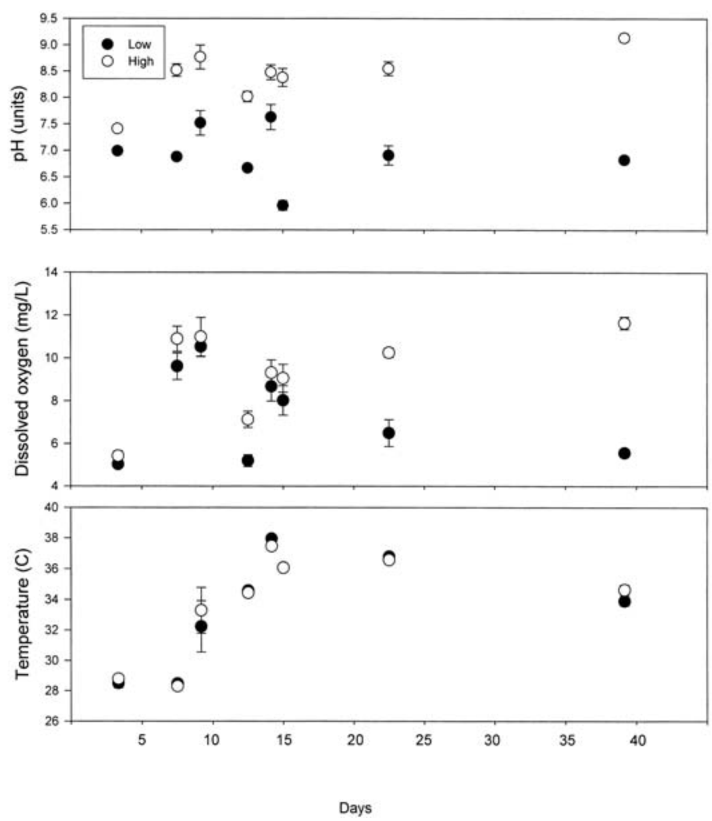

Figure 4. Temperature, pH, and dissolved oxygen in experimental tanks during the 6-week study period. Treatments were higher pH (natural LAERF water chemistry) and lower pH (amended with peat moss).

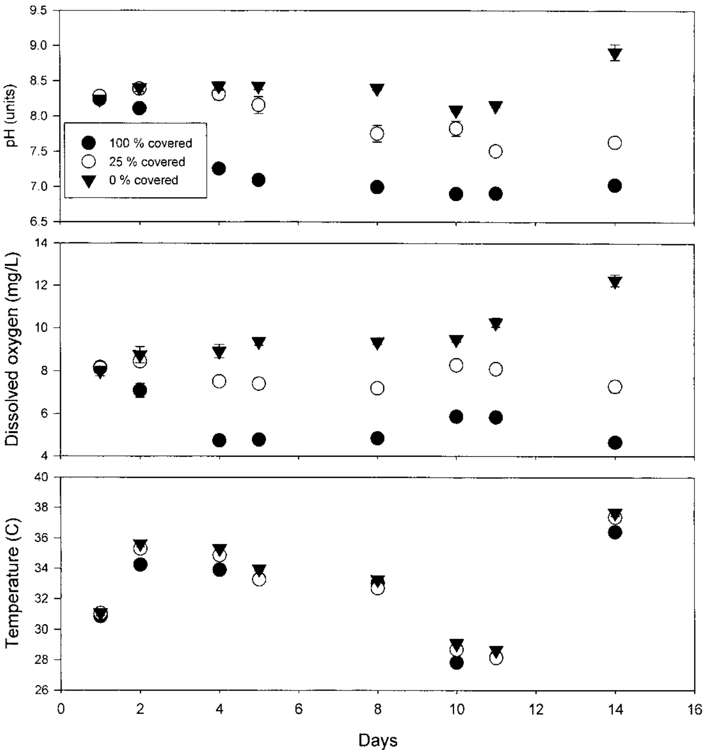

Figure 5. Temperature, pH, and dissolved oxygen in experimental tanks during giant salvinia effects study over a 14 day period. Treatments were 100% coverage, 25% coverage and control (no salvinia).

physical barrier between atmospheric and water column gas exchange, further reducing dissolved oxygen concentrations and potentially increasing carbon dioxide concentrations and decreasing pH. Giant salvinia may therefore cause shifts in pH and subsequent release of substrate nutrients (Wetzel 1983), making the environment more suitable to its growth. No differences were observed in temperature (Figure 5).

Giant salvinia has been in the United States for several years and is now a major detrimental factor in many lakes (ex. Lake Wilson, HI) and wetland systems (ex. Toledo Bend, TX) throughout states where low temperature limits are not an issue (USGS 2004). This paper suggests the important effect of pH on the explosive growth potential of giant salvinia; and how this information could be used to identify potential areas (low pH, high nutrients) where giant salvinia could become a problem. Additionally, more research needs to be conducted to study the relationships between pH and nutrient dynamics relative to giant salvinia and to investigate the effects of other water chemistry parameters such as conductivity and salinity.

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