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Comparison of Experimental Strategies to Control Torpedograss

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ABSTRACT

Studies were conducted to evaluate whether the herbicide imazapyr or a combination of imazapyr and fluridone could be used effectively to control torpedograss (*Panicum repens* L.), an exotic perennial plant that has replaced more than 6,000 ha of native vegetation and degraded quality wildlife habitat in Lake Okeechobee, Florida. Torpedograss was controlled for more than one year in some areas following a single aerial treatment using 0.56, 0.84, or 1.12 kg acid equivalents (ae) imazapyr/ha. Combining imazapyr and fluridone did not increase the level of torpedograss control. In areas where plant biomass was reduced by fire prior to being treated with 0.84 or 1.12 kg ae imazapyr/ha, torpedograss was controlled for more than two years and native plant species, including duck potato (*Sagittaria lancifolia* L.) and pickerelweed (*Pontederia cordata* L.) became the dominant vegetation in less than one year. Although torpedograss was controlled in some areas, little or no long-term control was observed at 16 of the 26 treatment locations. To reduce the uncertainty associated with predicting long-term treatment affects, additional studies are needed to determine whether environmental factors such as periphyton mats, plant thatch, hydroperiod and water depth affect treatment efficacy.

Key words: *Panicum repens*, herbicide, imazapyr, fluridone, Lake Okeechobee, burning.

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INTRODUCTION

Many species of animals use the plant communities found in Lake Okeechobee's littoral zone for nesting, foraging, and shelter (Aumen et al. 1995, Havens et al. 1996). However, due to the rapid spread of exotic vegetation that has occurred in the lake during the past 25 years, thousands of hectares of valuable wildlife habitat has been lost.

One of the most invasive and detrimental exotic plants is torpedograss (*Panicum repens* L.), which has replaced about 6,000 ha of native plants in Lake Okeechobee's 40,000 ha littoral zone (Schardt 1994). Once established, torpedograss often grows as a dense monospecific stand. Heavily impacted areas are considered poor habitat for sport fish because high stem densities form tangled mats that inhibit the movement of fish, and mid-day dissolved oxygen concentrations often are less than 2 mg/L beneath the vegetative mats.

Torpedograss can tolerate a wide range of environmental conditions making it a problematic invader in aquatic and terrestrial habitats. Torpedograss thrives on moist sandy or organic soils but also can withstand several meters of flooding (Holm et al. 1977) or dry conditions (Hodges and Jones 1950). Torpedograss is thought to reproduce primarily by fragmentation or underground rhizomes (Wilcut et al. 1988) that contain numerous axillary buds. Some of these buds are dormant while active buds produce numerous aerial stems. To control a rhizomatous species such as torpedograss for a relatively long period of time, the rhizome and axillary buds must be destroyed (Sutton 1996, Smith et al. 1993, Chandrasena 1990).

Torpedograss is continuing to spread and threaten new areas of Lake Okeechobee's littoral zone. Many of the areas being impacted are dominated by native spikerush (*Eleocharis* spp.), water lily (*Nymphaea* spp.), and open-water habitats, which are frequently utilized by sport fish (Bull et al. 1991).

Until a management strategy to control the growth and spread of torpedograss is developed and implemented, the lake's multi-million dollar recreational sport fishery (Bell 1987) will be threatened, as will the quality and diversity of habitat for other wildlife.

The purpose of this investigation was to evaluate whether the herbicides imazapyr and fluridone could effectively be used to reduce torpedograss coverage in Lake Okeechobee's littoral zone. Studies were conducted to determine whether one or two herbicide treatments applied during a two year period could provide control and whether a pre-treatment burn could increase treatment efficacy.

MATERIALS AND METHODS

Experiments were conducted at three locations in Lake Okeechobee's littoral zone: Pierce Canal, Moore Haven Canal, and Indian Prairie Canal (Figure 1). All study sites had dense stands of torpedograss that averaged about 1 m in height. Applications of the systemic herbicides imazapyr and fluridone were made using the commercial formulations Arsenal and Sonar, respectively. Herbicide was applied to each plot by helicopter using a total mix volume of 187 L/ha (20 gal/acre). Four different rates and two combinations of imazapyr and fluridone were evaluated. Treatment efficacy was visually evaluated as percent control every one to eight months during each study period. Control ratings were based on the estimated amount of dead plant material observed above and below the water line and on the amount of regrowth that occurred following each treatment. In addition, pre and post-treatment biomass data were collected from the Pierce Canal plots, and stem density data were collected from the Indian Prairie and Moore Haven Canal plots.

Pierce Canal

Eight treatment plots and two control plots were located north of Pierce Canal. Four treatment plots and one control plot were located south of the canal. The 0.4 ha treatment plots were treated in July 1995 with 0.56 or 0.84 kg acid equivalents (ae) imazapyr/ha (32 or 48 oz Arsenal/acre), or with 0.56 or 0.84 kg ae imazapyr/ha combined with 0.43 kg fluridone/ha (12 oz Sonar/acre) (see Table 1 for assigned plots). Kenetic, a nonionic surfactant, also was applied with each treatment at a 0.5% rate. Each treatment was replicated three times. The plots were retreated in June 1996 using the same herbicide and surfactant rates as in the initial treatment. Treatment efficacy was evaluated nine times at 4 to 31 week intervals during a 24 month period.

Pre-treatment biomass samples were obtained in June 1995. Three 0.25 m^2 quadrats were randomly selected within each plot, and all above ground plant material inside the quadrats was collected. Samples were placed in paper bags, dried 96 hours at 70C, and weighed. Final post-treatment biomass samples were obtained in July 1997 using the same methods.

Moore Haven Canal

In June 1996, six 1.2 ha treatment plots and four control plots were established west of the Moore Haven Canal. Three plots were treated with 0.84 kg ae imazapyr/ha and 0.5% nonionic surfactant; three others were treated with 0.84 kg ae imazapyr/ha combined with 0.43 kg fluridone/ha and 0.5% nonionic surfactant. Treatment efficacy was visually evaluated five times during a 20 month period. Stem density was quantified at three random locations inside the treatment and control plots in January 1999 (30 months post-treatment) using 0.25 m^2 quadrats.

Indian Prairie Canal

In February 1997, a wildfire burned approximately 2,500 ha of the littoral zone north of Indian Prairie Canal. About six weeks after the fire (April 1997), four 2 ha plots were treated in the burned area 1 km north of Indian Prairie Canal. Four additional 2 ha plots were treated in an unburned area located 0.5 km south of the canal. At the time of treatment, torpedograss had regrown to an average height of 20 cm in the burned area. Paired plots, one burned (north of the canal) and one unburned (south of the canal), each were treated with 0.28, 0.56, 0.84, or 1.12 kg ae imazapyr/ha and a 0.5% nonionic surfactant. About three weeks after the herbicide treatment, a second wildfire unexpectedly burned the plots south of the canal. No additional herbicides treatments were made after the second fire.

Treatment efficacy was visually evaluated six times during the 29 month study period. In addition, torpedograss stem densities were quantified at three random locations inside each plot using a 0.25 m^2 quadrat. Stem densities were determined prior to treatment and 16 months post-treatment.

Statistical Analysis

Repeated measures (RM) analysis of variance (ANOVA) was used to test for significant treatment, location, and temporal effects at the Pierce Canal and Moore Haven plots where treatments were replicated. All statistical analyses were performed using the general linear models (GLM) procedures in SAS (1989).

RESULTS

Pierce Canal

During year one, there was a highly significant location and time effect ($p < 0.05$) and a marginally significant treatment effect ($0.05 < p < 0.1$). In year two, there was a highly significant location and time/location interaction effect ($p < 0.05$) but no significant treatment effect.

One year after the initial herbicide treatment, 80 to 99 percent of torpedograss was killed in 5 of the 8 treatment plots located north of Pierce Canal while virtually no control was observed in plots south of the canal. One year after the second herbicide treatment, 80 to 100 percent control of torpedograss was obtained in all plots north of the canal. However, once again, little or no control was observed in the plots south of the canal (Table 1).

By the end of the study, torpedograss biomass was greatly reduced in all control and treatment plots north of Pierce Canal. Although plant biomass declined by 2.9 kg/m^2 (72 percent) and 3.1 kg/m^2 (80 percent) in control plots 1 and

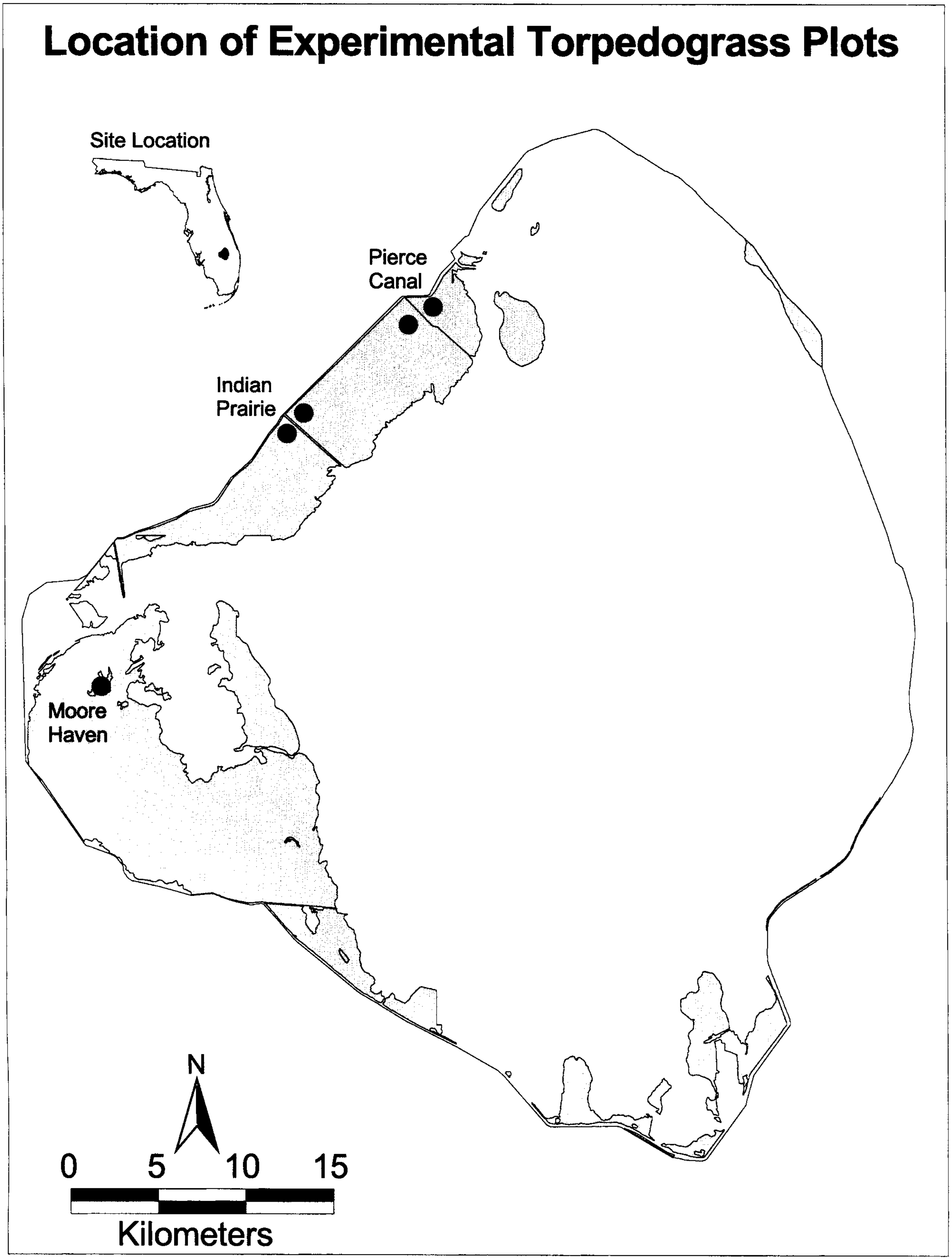

Figure 1. The location of Lake Okeechobee's littoral zone (gray region) and the approximate location of the Pierce Canal, Moore Haven, and Indian Prairie Canal study sites. Inset map shows the Lake Okeechobee's location in Florida, USA.

TABLE 1. PERCENT CONTROL OF TORPEDOGRASS FOLLOWING A JULY 95 AND JUNE 96 HERBICIDE TREATMENT NEAR PIERCE CANAL. A RATING OF 100% INDICATES NO TORPEDOGRASS WAS OBSERVED IN THE PLOT. EVALUATION DATES ARE SHOWN AS WEEKS AFTER THE INITIAL TREATMENT. PLOTS 1 TO 4 AND 5 TO12 WERE LOCATED SOUTH AND NORTH OF PIERCE CANAL, RESPECTIVELY.

		Weeks After Treatment									
Treatment rate	Plot	4	8	18	23	33	48	2nd treat Jun-96	58	70	101
0.56 kg ae imazapyr/ha	1*	85	80	80	20	0	0		25	0	0
	6	85	95	85	95	20	10		60	70	80
	9	95	90	100	95	95	99		100	99	100
0.84 kg ae irnazapyr/ ha	2 e	90	75	60	60	0	0		25	10	0
	5	85	95	90	70	70	25		70	60	80
	8	85	100	100	95	9*	95		95	99	100
0.56 kg ae imazapyr/ha and 0.43 kgfluridone/ha	3 e	70	80	60	60	0	0		30	25	10
	7	85	95	90	95	80	85		80	75	80
	12	85	100	100	95	95	60		70	85	90
0.84 kg ae imazapyr/ha and 0.43 kg fluridone/ha	4*	90	90	95	80	0	10		35	35	20
	10	90	100	100	95	99	95		95	99	100
	11	85	100	95	95	99	80		90	99	90

*Located south of Pierce Canal.

2, respectively, torpedograss still covered more than 90 percent of both plots (Figures 2a-b). In comparison, torpedograss biomass was reduced by 92 to 100 percent in the treated plots north of Pierce Canal and the percent of the plots covered by torpedograss was reduced by 80 to 100 percent (Figure 2a-b).

South of Pierce Canal, torpedograss biomass was reduced by 16 to 25 percent in two treatment plots but increased by 8 to 12 percent in three plots (Figure 2a). Torpedograss remained the dominant plant south of the canal covering 80 to 100 percent of each plot (Figure 2b).

Moore Haven Canal

Long-term control was not achieved in any of the Moore Haven plots. There was a highly significant time effect ($p < 0.0001$) but no treatment effect. Eleven weeks after treatment, 80 to 85 percent control of torpedograss was obtained in the six treatment plots (Table 2). By sixteen weeks, control had increased to 95 percent in three plots. Control began to decrease after 24 weeks. By week 86, control levels ranged from 10 to 15 percent. Although control was not achieved and torpedograss covered nearly 100 percent of all plots 125 weeks post-treatment, a treatment effect was evident. There was an average of 43 percent fewer stems inside the treated plots (528 stems m^2) when compared to the untreated plots (928 stems m^2) (Figure 3).

Indian Prairie Canal

Treatment efficacy was enhanced in the plots that were burned prior to being treated with herbicide when compared to the plots that burned about three weeks after the treatment. Twelve weeks post-treatment (July 1997), control ranged from 70 to 90 percent in the pre-treatment burn plots and from 25 to 70 percent in the plots that burned after the herbicide treatment (Table 3). After 26 weeks, control ranged from 80 to 95 percent in the pre-treatment burned plots while only 5 to 30 percent control was obtained in the plots south of the canal. After 68 weeks, control levels in the pre-treatment burn plots that were treated with 0.84 or 1.12 kg ae imazapyr/ha ranged from 90 to 95, respectively, while control ranged from 0 to 10 percent in the other six plots. After more than two years (118 weeks post-treatment), control was maintained at 90 percent in the pre-treatment burn plots that were treated with 0.84 or 1.12 kg ae imazapyr/ha. No long-term control was observed in the other six plots.

In addition to evaluating treatment efficacy, stem density counts also were recorded at 68 weeks post-treatment. Because of low water levels, a helicopter was used to access the plots. The helicopter was able to land only in or near the plots north of the Indian Prairie Canal where plant biomass was reduced. Therefore, post-treatment stem density counts were recorded only in the four plots that were burned prior to the herbicide treatment. There were large reductions in stem density in the plots that were treated with the two highest rates of imazapyr (Figure 4). No torpedograss stems were observed in the plot that was treated with 0.84 kg ae imazapyr/ha and only 2 stems were observed in the plot treated with 1.12 kg ae imazapyr/ha. Average stem densities were much higher (228 to 244 stems m^2) in the two plots that were treated with lower rates of imazapyr.

DISCUSSION

Torpedograss was controlled in 10 of 26 experimental plots following one or two treatments with the herbicide imazapyr or a combination of imazapyr and fluridone. Although the level of control varied spatially, control did not appear to be a stochastic process. Instead, there were consistent regional patterns that suggest environmental conditions may affect treatment efficacy. At the Pierce Canal location, torpedograss always was controlled effectively in plots north

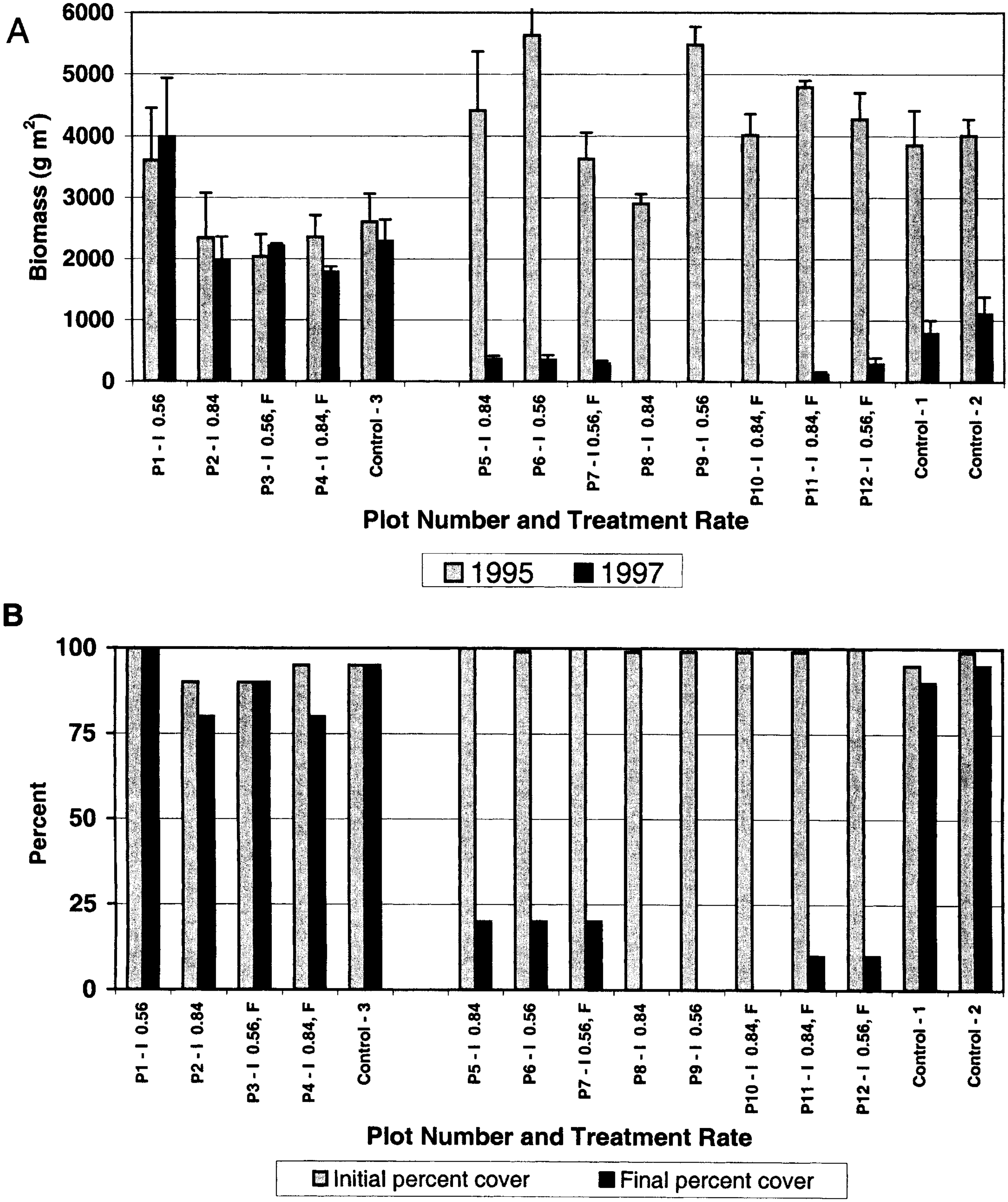

Figure 2. (A) Initial and final biomass (m^2)in the Pierce Canal plots during a 24 month period. The treatment rate is indicated for each plot where P = plot number, I = imazapyr (kg ae/ha) and F = fluridone (0.43 kg/ha). Treatment plots 1 to 4 and control plot 3 (C3) were located south of Pierce Canal and plots 5 to 12 and control plots 1 and 2 (C1 and C2) were located north of the canal. (B) Initial and final percent cover of torpedograss in the Pierce Canal plots during a 24 month period.

TABLE 2. PERCENT CONTROL OF TORPEDOGRASS IN THE MOORE HAVEN PLOTS DURING A 86 WEEK PERIOD. EVALUATION DATES ARE SHOWN AS WEEKS AFTER THE JUNE 1996 TREATMENT DATE.

		Weeks After Treatment				
Treatment Rate	Plot	11	16	24	63	86
0.84 kg ae imazapyr/ha	3	80	90	80	30	15
	4	85	85	65	40	10
	5	85	95	80	45	10
0.84 kg ae imazapyr/ha	1	80	95	85	30	10
and 0.43 kg fluridone/ha	2	80	90	80	20	15
	6	85	95	80	45	10

of the canal but never in plots south of the canal. Similarly, torpedograss was controlled only in the Indian Prairie plots that first were burned and then treated with the two highest rates of imazapyr. Therefore, herbicides can be used effectively to control torpedograss under certain conditions. The key is to isolate and identify those environmental factors that may influence treatment efficacy.

At this point, it is not clear why the level of control in the replicated treatments at the Pierce Canal location varied spatially. There were, however, several differences between the northern and southern plots that may have influenced treatment efficacy. First, the coverage of torpedograss was more dense in the plots north of the canal; plant biomass averaged 4.4 kg m^2 versus an average of 2.6 kg m^2 in the plots south of the canal. Second, large periphyton mats were observed floating at or near the surface only in the five plots south of the canal.

Grimshaw et al. (1997) determined that the periphyton community in the Everglades south of Lake Okeechobee was greatly reduced or absent when the amount of photosynthetically active radiation was reduced by emergent macrophyte shading. Thus, the higher density of plants in the plots north of Pierce Canal may have created shaded conditions that inhibited the development of periphyton mats. In contrast, the lower density of torpedograss in the plots south of Pierce Canal may have created conditions that were more favorable for the development of periphyton mats. Because periphyton mats have been shown to assimilate herbicide (Gurney and Robinson 1989, Hoagland et al. 1996), it is likely that some of the herbicide applied to the plots south of Pierce Canal was bound by the algal mats, causing torpedograss to be exposed to sub-lethal concentrations of imazapyr and fluridone. Additional studies should be conducted to determine whether floating periphyton mats can affect treatment efficacy by reducing the amount of herbicide reaching target plants.

The reductions in torpedograss biomass that occurred in the control plots north of Pierce Canal also might be related to differences in hydroperiod when compared to the control plot south of the canal. Water depth fluctuated considerably throughout the study. Initially, water depth averaged about 0.8 m in the treatment and control plots. Three months post-treatment, water depth increased to 1.7 m. By the end of the study, the plots north of Pierce Canal had been dry for nearly four months while the plots south of the canal remained slightly inundated.

Environmental conditions including soil moisture can affect plant growth and biomass (Padget et al. 1997, Runharr 1997, Pezeshki et al. 1998). The drier soil conditions that were

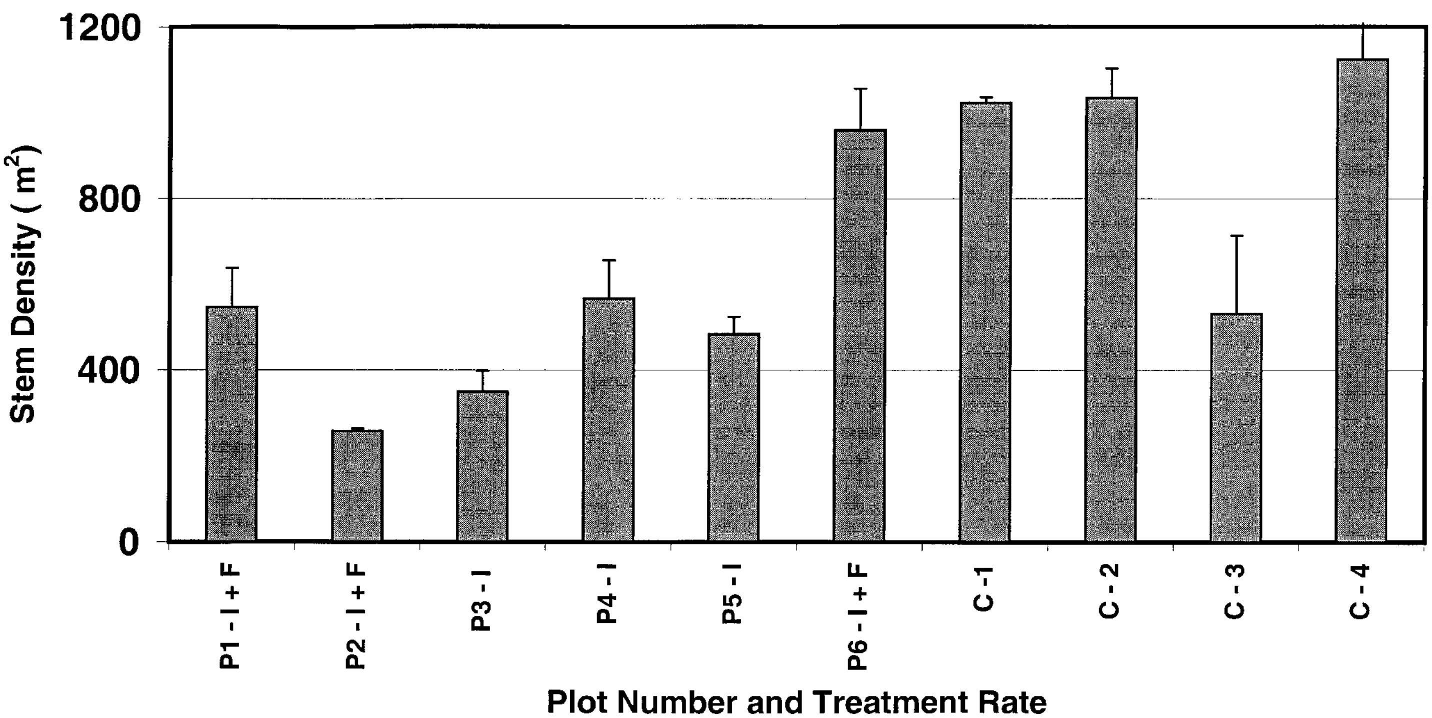

Figure 3. Average torpedograss stem densities (m^2) and standard error bars for the Moore Haven plots 125 weeks after treatment. The treatment rate is indicated for each plot where P = plot number, I = 0.84 kg ae imazapyr/ha and F = 0.43 kg fluridone/ha. Control plots (C1 to C4) were located between the treated plots.

Table 3. Percent control of torpedograss in the Indian Prairie plots. Evaluation dates are shown as weeks after the April 1997 treatment date. Plots 1 -4 ('pre-burn') were burned six weeks prior to the herbicide treatment and plots 5-8 ('post-burn') were burned about three weeks after the treatment.

		Weeks After Treatment					
Treatment Rate (imazapyr)	Plot	12	26	42	59	68	118
0.28 kg ae /ha	Pre-burn -1	70	80	65	10	0	0
0.56 kg ae /ha	Pre-burn -2	95	95	75	20	10	0
0.84 kg ae /ha	Pre-burn -3	90	95	70	80	90	90
1.12 kg ae /ha	Pre-burn 4	90	95	85	90	95	90
0.28 kg ae /ha	Post-burn -5	30	5	0	0	0	0
0.56 kg ae /ha	Post-burn -6	50	15	0	0	0	0
0.84 kg ae /ha	Post-burn -7	25	15	0	0	0	0
1.12 kg ae/ha	Post-burn -8	70	30	20	0	0	0

observed north of Pierce Canal may have been less favorable for torpedograss when compared to the slightly inundated area south of the canal. Even though the areal coverage of torpedograss remained high (> 90%) in the dry control plots, plant biomass may have been reduced because of low soil moisture conditions. Additional studies are needed to determine the effect of hydroperiod and water depth on torpedograss growth, and how these variables influence treatment efficacy.

Treatment efficacy at the Moore Haven location may have been affected by a canopy of emergent thatch that covered some of the actively growing torpedograss shoots. Smith et al. (1999) found that when the portion of torpedograss tissue exposed to herbicide was reduced, regrowth was enhanced. Therefore, if the thatch reduced the portion of actively growing torpedograss tissue that was exposed to herbicide, either by shielding plants or competing for herbicide, treatment efficacy could be reduced. Six months after treatment, control declined as new torpedograss shoots became abundant in all treated plots. Although the initial torpedograss biomass and stem density were not determined and long-term control was not achieved, treatment effects were apparent in the Moore Haven plots 125 weeks post-treatment. In addition to having 43 percent fewer torpedograss stems inside the treated areas when compared to the untreated plots, there was a 8 to 15 cm thick surface mat of dead plant material (thatch) present only in the control plots. Based on these observations, the

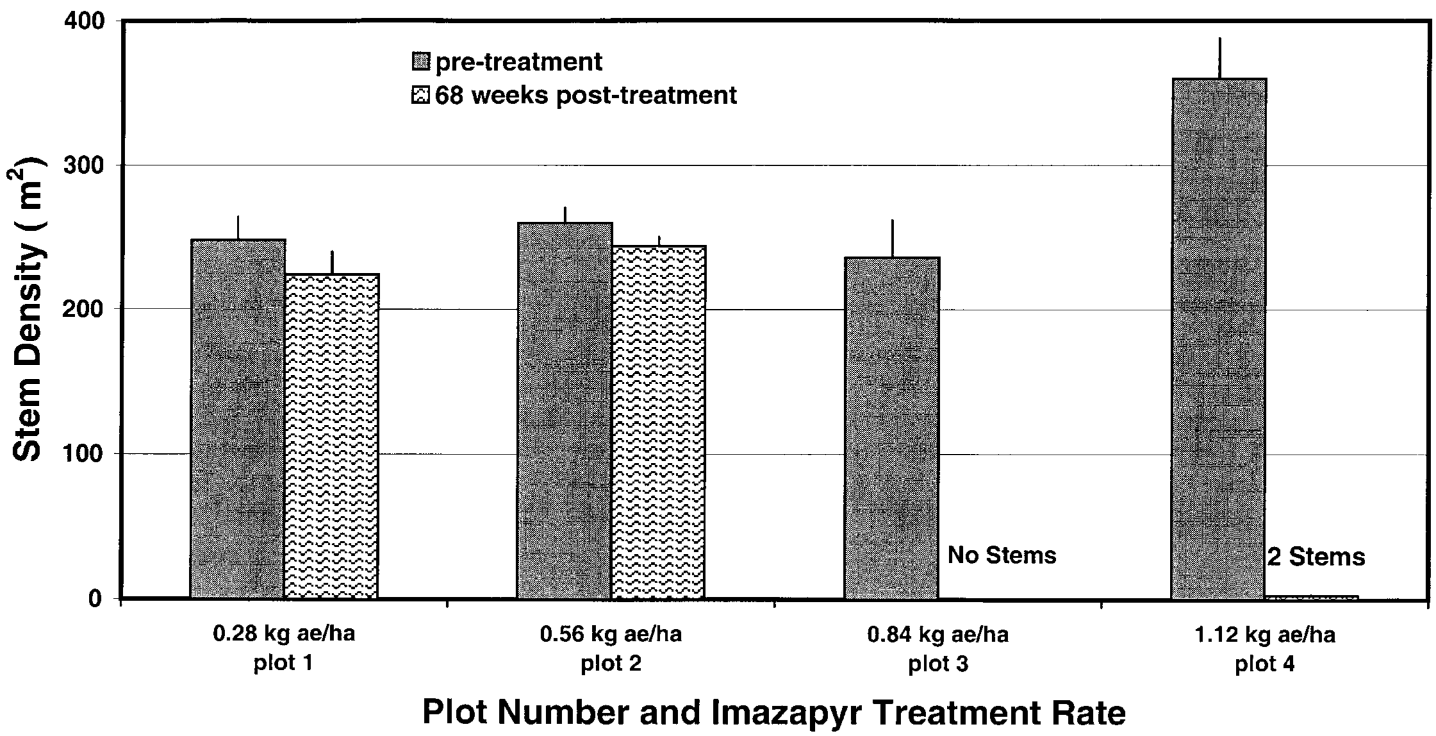

Figure 4. Average torpedograss stem densities (m^2) and standard error bars for the Indian Prairie Canal plots that were burned prior to treatment. Solid bars represent pre-treatment stem densities and hatched bars represent stem densities 68 weeks after treatment. No stems were found in the plot treated with 0.84 kg ae imazapyr/ha 68 weeks post-treatment.

single herbicide treatment was not sufficient to control torpedograss at this location, but it did have a long-term impact on the growth and the production of shoots and thatch material.

At the Indian Prairie site, treatment efficacy was increased by removing the torpedograss thatch with fire prior to treating the 20 cm regrowth with herbicide. When higher rates of imazapyr were used following the burn, torpedograss control exceeded 90 percent. No control was observed in the areas that were not burned prior to the herbicide treatment. This supports the hypothesis that a dense layer of thatch may act as a barrier and reduce the amount of herbicide that reaches the actively growing vegetation below the thatch.

Smith et al. (1998) were able to control torpedograss in small experimental plots by treating plants with glyphosate four times during a two year period, at an estimated cost of $1,000/ha. During the present study, torpedograss was controlled for more than two years in some areas following a single treatment with the herbicide imazapyr. Because it was not necessary to combine imazapyr and fluridone to control torpedograss, treatment costs were reduced. Depending on the rate at which imazapyr was applied, treatment costs ranged from $277/ha (plot 9 - Pierce Canal) to $420/ha (plot 4 - Indian Prairie Canal pre-treatment burn site), or 60 to 70 percent less than the cost of controlling torpedograss with glyphosate.

Although imazapyr is a non-selective systemic herbicide, a number of native plant species either survived the treatments or recolonized treatment sites, perhaps from germination of buried seeds (Williges and Harris 1995). Nine months post-treatment, native plants including duck potato (*Sagittaria lancifolia* L.), pickerelweed (*Pontederia cordata* L.), fragrant water-lily (*Nymphaea odorata* Ait.), spikerush (*Eleocharis cellulosa* Torr.), and cattail (*Typha* spp.), had become the dominant plants in the two Indian Prairie plots where torpedograss was controlled. Thirity months post-treatment, native plants were still dominant in both plots.

These results indicate that imazapyr may be an effective herbicide for control of torpedograss, as long as environmental conditions are suitable. It remains to be determined just what those precise conditions may be (e.g., lack of periphyton mats, shallow water depth). Additional research also is needed to determine the value of burning dense stands of torpedograss to remove plant thatch prior to a herbicide treatment.

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LITERATURE CITED

Aumen, N. G. 1995. The history of human impacts, lake management, and limnological research on Lake Okeechobee, Florida (USA) Arch. Hydrobiol., Advances in Limnology. 45: 1-16.

Bell, F. W. 1987. The economic impact and valuation of the recreational and commercial fishing industries of Lake Okeechobee, Florida. Final Report submitted to the Florida Game and Fresh Water Fish Commission and Florida Department of Environmental Regulation. Tallahassee, FL, USA. 102 pp.

Bull, L. A., G. L. Warren, L. J. Davis, J. B. Furse, and M. J. Vogel. 1991. Lake Okeechobee-Kissimmee River-Everglades Resource Evaluation. Wallop-Breaux Completion Report to U.S. Dept. of Interior, Florida Game and Fresh Water Fish Commission, Tallahassee, FL. 328 pp.

Chandrasena, J. N. N. R. 1990. Torpedograss (*Panicum repens* L.) control with lower rates of glyphosate. Trop. Pest. Man. 36: 336-342.

Grimshaw, H. J., R. G. Wetzel, M. Brandenburn, K. Segerblom, L. J. Wenkert, G. A. Marsh, W. Charnetzky, J. E. Haky, and C. Carraher. 1997. Shading of periphyton communities by wetland emergent macrophytes: Decoupling of algal phyto-synthesis from microbial nutrient retention. Arch. Hydrobiol. 139: 17-27.

Gurney, S. E. and G. G. C. Robinson. 1989. The influence of two triazine herbicides on the productivity, biomass, and community composition of freshwater marsh periphyton. Aquat. Bot. 36: 1-22.

Havens, K. E., L. A. Bull, G. L. Warren, T. L. Crisman, E. J. Phlips, and J. P. Smith. 1996. Food web structure in a subtropical lake ecosystem. Oikos 75: 20-32.

Hoagland, K D., J. P. Carder, and R. L. Spawn. 1996. Effects of organic toxic substances. In R. J. Stevenson, M. L. Bothwell, and R. L. Lowe (eds.) Algal Ecology. Academic Press, San Diego. pp. 469-496.

Hodges, E. M. and D. W. Jones. 1950. Torpedo grass. Circular S-14. Univ of Fla. Ag. Experimental Stations, Gainesville. 4 pp.

Holm, L. G., D. L. Plucknett, J. V. Pancho, and J. P. Herberger. 1977. The Worlds Worst Weeds. Distribution and Biology. Univ. Press of Hawaii, Honolulu. 609 pp.

Padget D. E., C. B. Rogerson, and C. T. Hackney. 1998. Effects of soil drainage on vertical distribution of subsurface tissues in the salt marsh macrophyte *Spartina alterniflora* Lois. Wetlands 18: 35-41.

Pezeshki S. R., P. H. Anderson, and F. D. Shields Jr. 1998. Effects of soil moisture regimes on growth and survival of black willow (*Salix nigra*) posts (cuttings). Wetlands 18: 460-470.

Runhaar H. J. 1997. Ground-water level, moisture supply, and vegetation in the Netherlands. Wetlands 17: 528-538.

SAS. 1989. SAS/STAT Users Guide, Version 6. SAS Institute, Cary, NC. 1,686 pp.

Schardt, J. D. 1994. 1992 Florida Aquatic Plant Survey. Tech. Report No. 942-CGA. Florida Department of Environmental Protection. Tallahassee. 89 pp.

Smith, B. E., D. G. Shilling, W. T. Haller, and G. E. MacDonald. 1993. Factors influencing the efficacy of glyphosate on torpedograss (*Panicum repens* L.). J. Aquat. Plant Manage. 31: 199-202.

Smith, B., K. Langeland, and C. Hanlon. 1998. Comparison of various glyphosate application schedules to control torpedograss. Aquatics 20(1): 4-9.

Smith, B. E., K. A. Langeland, and C. G. Hanlon. 1999. Influence of foliar exposure, adjuvants, and rain-free period on the efficacy of glyphosate for torpedograss control. J. Aquat. Plant Manage. 37: 13-16.

Sutton D. L. 1996. Growth of torpedograss from rhizomes planted under flooded conditions. J. Aquat. Plant Manage. 34: 50-53.

Wilcut, J. W., R. R. Truelove, and D. E. Davis. 1988. Factors limiting the distribution of cogongrass, *Imperata cylindrica*, and torpedograss, *Panicum repens*. Weed Sci. 36: 577-582.

Williges, K. A. and T. T. Harris. 1995. Seed bank dynamics in the Lake Okeechobee marsh ecosystem. Arch. Hydrobiol., Advances in Limnol. 45: 79-94.