J. Aquat. Plant Manage. 43: 24-29

Mapping the Distribution of Torpedograss and Evaluating the Effectiveness of Torpedograss Management Activities in Lake Okeechobee, Florida

CHARLES G. HANLON AND MARK BRADY[1]

ABSTRACT

Thousands of hectares of native plants and shallow open water habitat have been displaced in Lake Okeechobee's marsh by the invasive exotic species torpedograss (*Panicum repens* L.). The rate of torpedograss expansion, it's areal distribution and the efficacy of herbicide treatments used to control torpedograss in the lake's marsh were quantified using aerial color infra red (IR) photography. During a 5-year period, torpedograss coverage increased by 21%, from 89 to 107 ha, inside three 1-km^2 study sites. In 1996, torpedograss covered more than 6,700 ha of the lake's 40,000 ha marsh. A torpedograss management program was implemented in 2000 to control the spread of torpedograss and allow reestablishment of native vegetation. Between 2000 and 2002 nearly 4,300 ha of torpedograss were treated with the herbicide imazapyr (2-[4,5-dihydro-4-methyl-4-(1-methylethyl)-5-oxo-1H-imidazol-2-yl]-3-pyridinecarboxylic acid) or a combination of the herbicides imazapyr and glyphosate (isopropylamine salt of N-(phosphonomethyl) glycine). In some areas, torpedograss control exceeded 95% for greater than one year. Overall, torpedograss control averaged 83% and 60% in the central and northwest marsh, respectively. We estimate that the herbicide treatments resulted in the control of more than 3,000 ha of mostly monoculture torpedograss. Following a reduction in torpedograss coverage, native plants including spikerush (*Eleocharis cellulosa* Torr.) and fragrant water lily (*Nymphaea odorata* Sol.) became established in many of the previously impacted areas.

Key words: invasive species, wetlands, spikerush, herbicide, imazapyr, glyphosate.

INTRODUCTION

Torpedograss is an invasive perennial grass species that is native to Europe, Asia and Africa (Hossian et al. 1999). It is a prominent grass weed of many agricultural crops (Holm et al. 1977, Peng 1984, Chandrasena 1990) and is one of the most invasive perennial grass species of terrestrial, wetland and aquatic natural areas in tropical and subtropical regions of the world (Sutton 1996). In Florida, torpedograss is found throughout much of the state and was present in 72% of surveyed public lakes and rivers (Schardt 1994).

In Lake Okeechobee, Florida, torpedograss has severely impacted the lake's 40,000 ha marsh landscape by displacing more than 6,700 ha of native plants and shallow areas of open water. Two of the most impacted native species include spikerush and beakrush (*Rhynchospora* spp.) (Richardson et al.

[1]South Florida Water Management District, Lake Okeechobee Division, 3301 Gun Club Road, West Palm Beach, FL; e-mail: chanlon@sfwmd.gov.
Received for publication March 29, 2004 and in revised form March 30, 2005.

1995). Like most wetland plants, the distribution of torpedograss appears to be strongly influenced by hydrologic conditions (Smith et al. 2004). Richardson et al. (1995) reported that in Lake Okeechobee, torpedograss was restricted to the higher elevation regions of the marsh that had an average hydroperiod of 81%.

Although torpedograss flowers and produces seed, most seeds are believed to be sterile (Peng 1984, Haroun 1995). Reproduction of torpedograss primarily occurs vegetatively from rhizomes and small fragments (Chandrasena and Dhammika 1988, Smith et al. 2004). Rhizomes can grow rapidly throughout the year in the subtropics (Sutton 1996), reaching lengths of 3 m within six months (Hossain et al. 1999). Axillary buds or nodes are present along the entire length of the rhizome (Wilcut et al. 1988). Because each active node has the potential to produce a large number of stems and plant biomass in a short period of time (Sutton 1996, Smith et al. 2004) the entire rhizome must be killed to effectively control torpedograss (Chandrasena 1990).

In 2000, the South Florida Water Management District (SFWMD) initiated a torpedograss management program to reduce the distribution and the rate of expansion of torpedograss in Lake Okeechobee's marsh. This study was designed to support torpedograss management efforts by 1) mapping the baseline distribution of torpedograss and quantifying its areal coverage, 2) evaluating the rate of spread of torpedograss under different hydrologic conditions, 3) determining the efficacy of herbicide treatments used to control torpedograss and 4) documenting the succession of plant communities within the treated areas. Results from this study can be used to predict how rapidly torpedograss may invade wetland areas, how torpedograss and other plants respond to changing hydrologic conditions and to determine the effectiveness and selectivity of currently used torpedograss management methods. The results should be applicable to other subtropical wetland systems.

MATERIALS AND METHODS

Aerial color infra red (IR) photographs were collected in 1994, 1996, 1999 and 2002 and used to create vegetation distribution maps for regions of Lake Okeechobee's marsh. The maps were used to monitor and quantify temporal changes in the marsh landscape that occurred during the 8-year period of time. The color IR photographs were evaluated in stereo using a Bausch and Lomb® zoom 95 transfer stereoscope. The boundary lines of each plant community and open water area were traced onto transparent sheets of acetate. Each traced polygon defined the location and areal coverage of a monotypic plant community, a mixed plant community or open water. The polygons were scanned, converted into a geographic information system (GIS) coverage using ArcInfo® (ESRI, Redland, CA), and labeled according to the type of habitat they represented.

A baseline coverage map that quantified the distribution of torpedograss in Lake Okeechobee's central and northwest marsh was generated using color IR images that were collected in 1994 and 1996, respectively. Data from 1999 photography were used to quantify the rate of torpedograss expansion that occurred inside three 1-km^2 study sites between 1994 and 1999. The three study sites were located in the central marsh and are referred to as the east, middle and west sites. The photography collected in 2002 was used to evaluate and quantify changes in the marsh landscape that occurred inside the 1-km^2 study sites following a series of herbicide treatments. Treatment efficacy was rated as excellent when greater than 90% of the torpedograss was controlled and moderate when 50% to 90% of the torpedograss was controlled.

In treated areas outside of the 1-km^2 study sites, treatment efficacy was evaluated visually every 1 to 6 months using the criteria stated above. Three evaluators estimated the percent of torpedograss that was controlled in treatment sites as large as 406 ha. The evaluations were made from a helicopter while slowly flying over a treated area at an altitude 5 to 15 m. The evaluator's treatment efficacy scores were averaged and reported as percent control.

During a regional drought in 2000, the SFWMD began to systematically burn sections of the marsh according to a permitted fire management plan that targeted torpedograss and cattail (*Typha* spp.). In August 2000, nearly 2,000 ha of marsh vegetation were ignited using a drip torch that was suspended from a helicopter and fueled with a jelled petroleum accelerant. In January, February and March 2001, additional prescribed fires were set by helicopter. In total, 28,000 ha of the western marsh burned in 2001 due to prescribed fires and wild fires.

The first series of imazapyr (Arsenal®) treatments targeting torpedograss occurred during September 2000 following the August fires. In the northwest marsh one burned 202 ha site and one unburned 405 ha site were treated. In the central marsh one burned 202 ha site was treated. The treatment consisted of 1.12 kg acid equivalent (ae) imazapyr/ha. In addition, the surfactant SunWet® and the fastener NuFilm® were used at a rate of 2.5% and 0.15%, respectively. At the time of treatment the average plant height in the burned areas was 10 to 20 cm while shoot length commonly exceeded 70 cm in the unburned area.

In April and May 2001, 1,619 ha and 81 ha of recently burned torpedograss were treated with imazapyr as previously described. The sites were located in the central and northwest marsh, respectively, and were dry at the time of treatment.

A second series of aerial treatments were applied to torpedograss in the central marsh during spring 2002. The treatment areas included 1,777 ha of torpedograss that had been burned during spring 2001. Although shallow pools of standing water were present in some areas of the marsh, none of the treatment sites were inundated. The 2002 treatments were modified to include a combination of the systemic herbicides imazapyr and glyphosate (Rodeo®). Imazapyr and glyphosate were applied at rates of 0.56 kg ae/ha and 4.2 kg/ha, respectively. The surfactant SunWet® and the fastener NuFilm® also were used at rates of 2.5% and 0.15%, respectively.

RESULTS AND DISCUSSION

Torpedograss Coverage and Expansion

In 1996 there were approximately 6,710 ha of torpedograss in Lake Okeechobee's marsh. The torpedograss was generally located within 6 km of shore and rarely occurred at elevations below 4.0 m MLS (Figure 1).

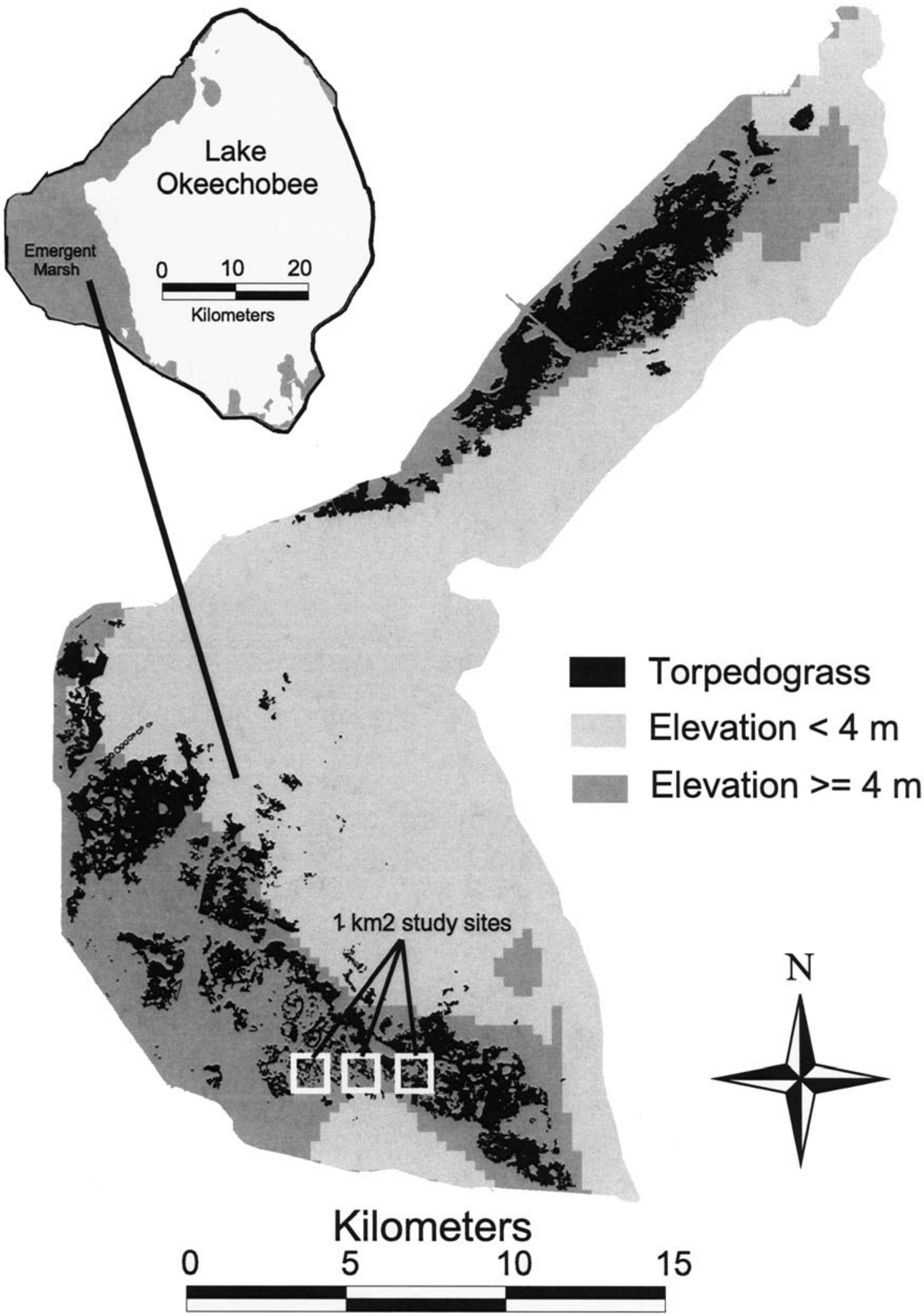

Figure 1. Distribution of 6,710 ha of torpedograss (black) by elevation in Lake Okeechobee's marsh (1994 to 1996). The dark gray area represents the drier regions of the marsh where the elevation is greater than 4 m above MSL. Regions of the marsh where the elevation is less than 4 m above MSL are shown as light gray. The location of each 1 km^2 study site is indicated by a white outlined box. Inset—Lake Okeechobee and the location of its 40,000 ha emergent littoral zone (marsh) shown in gray.

During the 5 year period 1994 to 1999, torpedograss coverage inside the three 1-km² study sites increased by 21%, from 89 ha to 107 ha. The rate of torpedograss expansion varied by location. In the middle site, 8 ha of spikerush and open water were displaced as torpedograss coverage increased by 32%, from 25 ha to 33 ha (Figure 2). In the west and east sites, torpedograss coverage increased by 26% and 13%, respectively (Figure 2).

Torpedograss has an extensive system of rhizomes that can aid in its dispersal and survival under a variety of environmental conditions (Chandrasena 1990, Hossian et al. 1999). In addition, torpedograss is well adapted for dispersal by buoyant vegetative propagules that can become rooted in exposed sediments or areas that are slightly inundated (Smith et al. 2004). Although we did not determine the primary mechanism responsible for the spread of torpedograss, the increase oc-

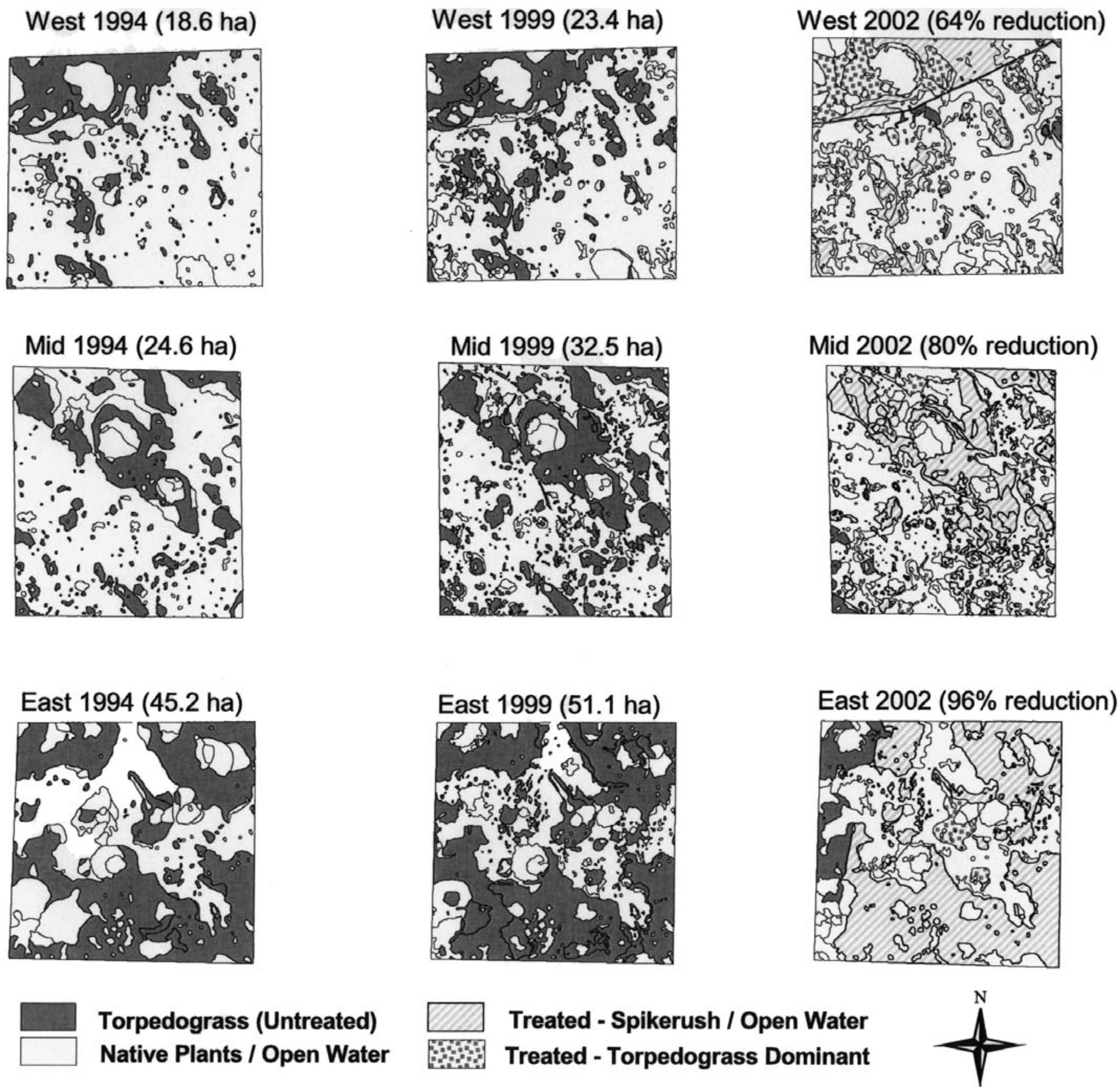

Figure 2. Distribution of torpedograss and native plants inside three 1 km² study sites in 1994, 1999 and 2002. The areal coverage (hectares) of untreated torpedograss is indicated for each location in 1994 and 1999. The percent reduction in torpedograss coverage following a series of herbicide treatments is indicated for each location on the 2002 maps.

curred in areas where the flooding depth was less than 0.5 m for 18 months, less than 1 m for 48 months and exceeded 1.0 m for 10 months (Figure 3). Thus, torpedograss was able to invade sites that were inundated for extended periods of time and tolerate prolonged exposure to relatively deep flooding.

Treatment Results

Spatial differences in treatment efficacy were apparent eight months after the September 2000 treatments. In the burned areas, 95% and 60% of the torpedograss was controlled in the 202 ha central and northwest marsh sites, respectively. In comparison, only 40% of the torpedograss was controlled in the unburned 405 ha site. Similar regional differences in treatment efficacy were observed among burned sites following spring 2001 treatments. Nineteen months post treatment, 65% of the treated torpedograss was controlled in an 81 ha site located in the northwest marsh. In comparison, treatment efficacy in the central marsh commonly exceeded 85% in areas that ranged in size from less than 5 ha to greater than 50 ha. Although treatment efficacy varied spatially, visual evidence indicated that the herbicide remained on target and never moved horizontally outside of the treated areas.

Torpedograss can form an extremely dense vegetative canopy reaching lengths of 1 m and exceeding a density of 900 stems m^2 (Hanlon and Langeland 2000). Treatment efficacy tended to be greatest in areas where torpedograss was burned prior to being treated with herbicide. Burning torpedograss likely enhanced treatment efficacy by reducing plant biomass and exposing the sediments and most of the newly emergent vegetation to the herbicide.

In addition to the role dense vegetative canopies may play in intercepting herbicide, the uptake of imazapyr by plant roots may also be inhibited without adequate soil moisture (American Cyanamid Company 1994). Therefore, spatial differences in soil moisture and drought stress may have influenced treatment efficacy in the northwest and central regions of the marsh.

In 2002, torpedograss coverage inside the three 1 km^2 study sites had increased to 116 ha. During spring 2002, 107 of the 116 ha were treated. Six months post-treatment, torpedograss coverage had been reduced by 89 ha. Treatment efficacy was rated as excellent in the east site where 96% (44 ha) of treated torpedograss was controlled (Figure 2). Moderate control was observed at the west and middle sites where 64% (17 ha) and 80% (28 ha) of the torpedograss was controlled, respectively. Thirteen months post treatment, torpedograss was still absent in most of the areas where it had been classified as controlled. Following the reduction of torpedograss coverage, spikerush became the dominant plant species in many treated areas (Figure 2). The native plant fragrant water lily (*Nymphaea odorata* Sol.) also was commonly observed throughout the central marsh following the reduction in torpedograss; but its occurrence was not quantified.

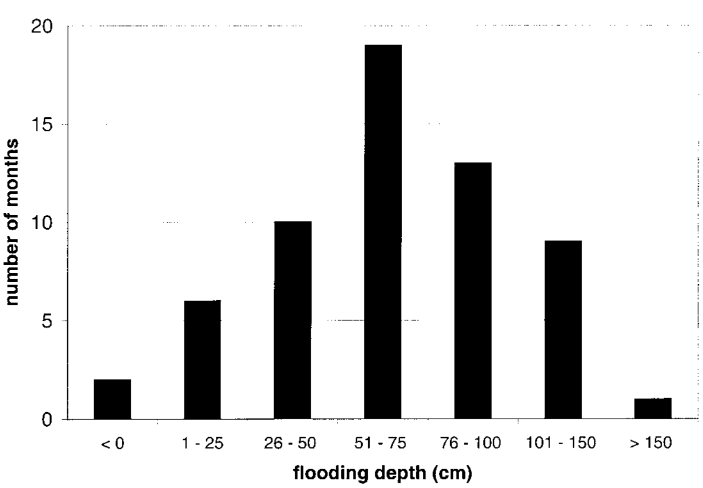

Figure 3. Monthly average flooding depth (cm) that occurred inside three 1 km^2 study sites between 1994 and 1999.

Some non-target plants were impacted by the spring 2002 treatments. The greatest non-target effects were observed in the east site where 7 ha of phragmities (*Phragmities australis* Cav.) and 5 ha of sawgrass (*Cladium jamaicense* Crantz) were injured or killed. In the middle and west plots, greater effort was made to avoid treating torpedograss in areas that were mixed with non-target plants. As a result, less than 1 ha of phragmities and sawgrass were affected by the treatments.

In summary, torpedograss is one of the most invasive exotic species of terrestrial and wetland areas in tropical and sub tropical regions of the world. In Lake Okeechobee, torpedograss has expanded throughout much of the upper marsh due to the lake's low elevation gradient and hydrology. An additional concern is that torpedograss recently demonstrated its ability to impact lower elevation regions of the marsh by expanding into an area known as Moonshine Bay during the 2001 drought.

Without intervention, torpedograss will continue to spread throughout the marsh and further alter the landscape by displacing important fish and wildlife habitat. To date, the targeted treatment areas generally have included large fronts of monotypic torpedograss that were invading native spikerush and shallow areas of open water. Although we observed spatial variances in treatment efficacy our ability to control torpedograss far exceeded its measured rate of expansion. In addition, spikerush and other native plants became dominant in many of the areas where torpedograss was controlled.

The torpedograss management methods applied in Lake Okeechobee should be applicable in other aquatic ecosystems that are threatened by torpedograss. Both treatment methods, imazapyr or imazapyr and glyphosate, provided similar levels of control. However, because imazapyr and glyphosate are relatively non-selective herbicides, treatments may not be appropriate in areas where torpedograss is heavily mixed with non-target plants. As a result, there are areas in Lake Okeechobee where torpedograss management will not be initiated until more selective treatment methods are developed or until torpedograss completely displaces the native plant communities.

ACKNOWLEDGMENTS

The authors are grateful to the Florida Department of Environmental Protection for their support, to Mike Page (Aerial Applicators) for his skilled and professional work, to Steve Smith, Mike Bodle and Dan Thayer for their assistance in coordinating field treatments and to Karl Havens and Bruce Sharfstein for technical reviews.

REFERENCES

American Cyanamid Company. 1994. Arsenal Herbicide. Technical report PE-11283.

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

Chandrasena, J. P. N. R. and W. H. Y. Dhammika. 1988. Studies on the biology of *Panicum repens* L. 1 Comparative morphological development of three selections from different geographical localities in Sri Lanka. Tropical Pest Management 34(3):291-297.

Hanlon C. G. and K. Langeland. 2000. Comparison of experimental strategies to control torpedograss. J. Aquatic Plant Manage. 38:40-47.

Haroun, S. A. 1995. Cytological abnormality control seed set in *Panicum repens* L. in Egypt. Cytologia 60:347-351.

Holm, L. G., D. L. Plucknett, J. V. Pancho and J. P. Herberger. 1977. The world's worst weeds: distribution and biology. University Press of Hawaii, Honolulu.

Hossian, M. A., Y. Ishimine, S. Murayama and S. M. Uddin. 1999. Effect of burial depth on emergence of *Panicum repens*. Weed Science 47:651-656.

Peng, S. Y. 1984. Weeds in cane fields and biology, pp. 25-79. *In:* S. Y. Pend (ed.). Development of Crop Science (4): The biology and control of weeds in sugarcane. Elsevier, Amsterdam.

Richardson J. R., T. T. Harris and K. A. Williges. 1995. Vegetation correlations with various environmental parameters in the Lake Okeechobee marsh ecosystem. Arch. Hydrobiol. Beih. Ergebn. Limnol. 45:41-61.

Schardt, J. D. 1994. Florida Aquatic Plant Survey 1992. Technical report 942-CGA. Florida Dept. of Environmental Protection, Tallahassee. 83 pp.

Smith, D. H., R. M. Smart and C. G. Hanlon. 2004. Influence of water levels on torpedograss establishment in Lake Okeechobee, Florida. Lake and Reservoir Management 20:1-13.

Sutton, D. 1996. Growth of Torpedograss from rhizomes planted under flooded conditions. J. Aquatic Plant Manage. 34:50-53.

Wilcut, J. W., R. R. Dute, B. Truelove and D. E. Davis. 1988. Factors limiting the distribution of Cogongrass, *Imperata cylindrical*, and torpedograss, *Panicum repens*. Weed Science 36:577-582.