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Planting Strategies to Establish Giant Bulrush

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ABSTRACT

Giant bulrush (*Schoenoplectus californicus* (C.A. Mey.) Palla = *Scirpus californicus* (C.A. Mey) Steud.) is frequently planted to reestablish desirable native vegetation in aquatic-habitat restoration and enhancement projects. Planting specifications have been defined but have not been scientifically evaluated. The objectives of this study were to compare retention rates (proportion of live plants plus dead plants remaining), survival rates (proportion of live plants remaining), post-planting condition (number of live stems per surviving plant), and mean stem production per unit stock (number of live stems per planted stock) of planted giant bulrush by using varying stem and rhizome length experimental treatments. Six weeks after planting in Lake Tohopekaliga, Florida, mean retention rates were not significantly different between experimental treatments. Four months after planting, mean survival rates were significantly different between stem treatments but not between rhizome treatments; survival rates of submersed-cut stems were lower than that of emergent-cut or uncut stems. Four months after planting, the condition of uncut stems was significantly better than the condition of submersed-cut stems but not different than that of emergent-cut stems. The condition of 10 to 15 cm rhizomes was significantly better than the condition of 2 to 4 cm and 6 to 8 cm rhizomes, but mean stem production per unit stock was not significantly different between rhizome treatments. Results showed that giant bulrush plants should be planted emergent. Cutting stems above the water surface did not affect the retention rate, survival rate, or condition of giant bulrush in Lake Tohopekaliga. Dividing rhizomes into smaller units to increase the number of plants in harvested stock did not significantly affect the retention rate, survival rate, or mean stem production per unit stock of giant bulrush. For the objective of establishing robust individual plants, planting 10 to 15 cm rhizomes with multiple live stems was more effective than was planting smaller size classes of rhizomes with single stems. For the objective of establishing the maximum number of plants from a given stock, planting 2 to 4 cm rhizomes with one live stem was more effective than was planting larger size classes of rhizomes with multiple live stems.

Key words: habitat enhancement, revegetation, *Schoenoplectus californicus, Scirpus,* wetland restoration.

INTRODUCTION

A goal of most aquatic-habitat restoration and enhancement projects conducted by the Florida Fish and Wildlife Conservation Commission (FWC) is to reestablish desirable native aquatic plant communities. Native aquatic plants provide beneficial habitat for fish and wildlife (Dibble et al. 1996, Dick et al. 2004, Tugend and Allen 2004) and may suppress invasion of nuisance vegetation (Smart et al. 1998). Additionally, aquatic vegetation is important to nutrient cycling, water quality, productivity, and sediment stabilization in aquatic ecosystems (Wetzel 1983, Hinkle 1986). Revegetation projects can establish desirable plants in areas lacking vegetation, including newly flooded wetlands (Marburger et al.

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1998), reservoirs (Smart et al. 1996), and sites where nuisance plants have been controlled or removed (Bonvechio et al. 2006, Pouder et al. 2006).

Giant bulrush (*Schoenoplectus californicus* (C.A. Mey.) Palla = *Scirpus californicus* (C.A. Mey) Steud.) is an emergent aquatic plant native to much of the southern United States and Florida that has been planted in numerous water bodies (Denson and Langford 1982, Marburger et al. 1998). The species provides desirable habitat for fish (Holcomb and Wegener 1971) and wildlife (Marburger et al. 1998). Donor stock (source plant material) for most revegetation projects conducted by the FWC has been harvested from wild collection sites within the same lake or in nearby lakes (Mallison et al. 2006). Planting nursery-grown stock has also been effective (Marburger et al. 1998). For large-scale projects ≥10,000 plants), the FWC usually hires contractors to supply and plant the vegetation.

To maximize effectiveness of revegetation efforts, especially when dealing with contractors, planting specifications must be defined. The planting unit for giant bulrush is usually an individual plant consisting of a rhizome (subsurface stem) with at least one live culm (flowering stem, herein referred to as stem) attached. Harvested plants often include a rhizome portion (>10 cm) with several live stems attached, which can be planted as one large clump or divided into multiple smaller planting units thereby increasing the number of plants in harvested stock. A minimum rhizome length must be specified, and the effectiveness of planting clumps versus multiple smaller plants using the same stock should be considered.

Because mature giant bulrush stems can grow to be 3 m tall (Godfrey and Wooten 1979) and large-scale revegetation projects may include thousands of planting units, plants can be cumbersome to handle and transport, and the volume and biomass of plant material can become a problem. During some previous revegetation projects, contractors cut the tops off the stems to reduce biomass and asserted that doing this does not affect planting success. They also suggested that cutting stems may improve retention of plantings (i.e., fewer "pop-ups" where plantings become dislodged from the sediments and wash away) by reducing the top weight and the surface area subjected to wind and wave action. On occasion, cut stems were planted so that tips were at or below the water's surface. Considering the lack of guidance for planting giant bulrush propagules of this type, various planting strategies being employed by contractors need to be evaluated so that effective methods can be specified and justified in revegetation contracts. The objectives of this study were to compare retention rates (proportion of live plants plus dead plants remaining), survival rates (proportion of live plants remaining), post-planting condition (number of live stems per surviving plant), and mean stem production per unit stock (number of live stems per planted stock) of giant bulrush plants that were planted using different stem and rhizome treatments.

METHODS

Giant bulrush was planted in Lake Tohopekaliga, Florida (7615 ha), during 29 July to 5 August 2005. The planting location (south of Lanier Point: 28°13'50.9"N, 81°24'43.9"W) was selected based on suitable water depth (60 to 65 cm), substrate (primarily hard sand with some clay), lack of aquatic vegetation, and proximity to existing giant bulrush stands (to confirm that giant bulrush could grow in that region of the lake). At this location, dense emergent vegetation and accumulated organic sediments were mechanically removed during the 2004 Lake Tohopekaliga drawdown and habitat-enhancement project (Bonvechio et al. 2006, Pouder et al. 2006).

A permit authorizing collection of giant bulrush for revegetation was obtained from the Florida Department of Environmental Protection. Donor stock was collected by digging with a shovel from mature giant bulrush stands within Lake Tohopekaliga. Plants were transported by boat to the planting location, which was within 5 km of collection sites. Plants were kept hydrated by laying them in lake water or pouring water over them as needed (e.g., hourly) prior to transplanting. For cut-stem treatments, stems were cut 1.0 to 1.5 m from the roots with a machete. Prior to planting, rhizomes were rinsed of sediments, measured, and trimmed with pruning shears to appropriate lengths as defined below. Within 7 h of collection, vegetation was planted bare-root by using a shovel to separate sediments to a depth of 10 to 20 cm. After planting, sediments were compacted by stepping several times around the plantings to anchor them in place, and pruning shears were used to trim stems for cut-stem treatments as defined below. All planting activities were completed by FWC personnel.

At the planting location, 15 adjacent plots (3 by 3 m) were demarcated with wooden stakes and numbered. Plots were systematically planted, with sequence selected at random, for three replications of each treatment. Treatments included: (1) emergent-cut stem: 6 to 8 cm rhizome with a single live stem cut 10 cm above the water surface; (2) submersed-cut stem: 6 to 8 cm rhizome with a single live stem cut 10 cm below the water surface; (3) uncut stem: 6 to 8 cm rhizome with a single live stem; (4) uncut stem: 2 to 4 cm rhizome with a single live stem; and (5) uncut stem: 10 to 15 cm rhizome with 2 to 7 live stems. For 10 to 15 cm rhizomes, damaged (brown, cut, and/or bent) stems were cut at the base of the plants prior to planting. Eight plants per plot were planted, and the number of live stems per plant was recorded. For all other methods, damaged or extra live stems were cut at the base of the plant so that only one live stem per plant remained attached to the rhizome at the time of planting. Twenty-five plants per plot were planted in five rows of five plants to facilitate sampling for these treatments.

Researchers carefully waded through each plot during sampling periods to ascertain presence/absence and survival of individual plants, and visually counted all live stems. Plants (including live and dead plants) remaining in each plot (R) were counted 6 weeks after planting. Retention rate in each plot was defined as the proportion of live plants (measured by presence of live stems) plus dead plants (measured by absence of live stems) remaining, or, R/N where N = the number of plants initially planted in each plot. Live plants remaining in each plot (S) were counted four months after planting. Survival rate in each plot was defined as the proportion of live plants remaining (S/N). Live stems (including emergent and submersed new sprouts) present in each plot (L) were counted 1.5, 2, 3, 4, 7, and 8 months after planting. The condition of surviving plants in each plot was defined as the mean number of live stems per surviving plant (L/S) four months after planting.

The amount of donor stock required to supply each rhizome treatment varied. Mean stem production per unit stock was estimated to compare rhizome treatments. One unit of stock was defined as a 12 cm rhizome with four live stems. A mean relative stock value per plant (V) was calculated for each treatment, based half on the proportion of rhizome length per unit stock (median rhizome length in cm/12 cm) and half on the proportion of live stems per unit stock (mean number of live stems per plant/4 live stems). For 2 to 4 cm rhizomes, $V = \frac{3/12 + 1/4}{2} = 0.25$. For 6 to 8 cm rhizomes, $V = \frac{7/12 + 1/4}{2} = 0.42$. For 10 to 15 cm rhizomes, $V = \frac{12.5/12 + 4.8/4}{2}$, where the mean number of live stems per plant (4.8) was the total number of stems planted (115) divided by the total number of plants planted (24) in three plots. The total amount of stock planted in each plot (T) was the relative stock value per plant times the number of plants planted ($V \times N$). Mean stem production per unit stock in each plot was defined as the total number of live stems 4 months after planting divided by the total amount of stock planted (L/T). Thus, mean stem production per unit stock estimated the mean number of live stems generated from one unit of planted stock.

Statistical analyses were performed by FWC researchers at the Center for Biostatistics and Modeling using SAS v 9.2 (SAS Institute, Inc., Cary, NC). Nonparametric statistics were appropriate for analyses of proportions (comparisons of retention rates and survival rates within treatment groups; Zar 1999). Generalized linear mixed models (PROC GLIMMIX) were used to model the effects of stem treatments (emergent-cut, submersed-cut, and uncut) and rhizome treatments (uncut stem: 2 to 4 cm, 6 to 8 cm, and 10 to 15 cm rhizomes). Akaike's corrected information criterion was used to compare model fits, and beta distributions without random plot-specific effects were selected to analyze retention and survival rates. Both condition and mean stem production per unit stock met the assumption of normality, and heterogeneous variances were addressed by employing variance groupings. Linear mixed modeling (PROC MIXED) was used for analyses. Multiple means comparisons (Tukey) using CONTRAST statements were used to determine treatment differences. All analyses were conducted at the $P = 0.10$ level of significance.

RESULTS AND DISCUSSION

The water level in Lake Tohopekaliga remained stable for 3 weeks after planting giant bulrush (site S-61, South Florida Water Management District, www.sfwmd.gov). During the fourth week after planting, the water level increased by 12 to 25 cm and emergent-cut stems may have been inundated for up to 7 d. By then, <10% of the planted stems in all treatment plots were still alive and several plants had sprouted new stems (i.e., surviving plants of all treatments grew new stems but most original stems died). Subsequently, the water level receded and fluctuated between 22 cm below to 13 cm above the stage present during planting. On 24 October, outer bands of Hurricane Wilma produced winds up to 80 km/h and rainfall up to 10 cm on Lake Tohopekaliga (Abtew and Iricanin 2008), and the water level increased by 55 to 95 cm for 3 weeks. The total number of live plants remaining (sum of all plots) was 194 before (29 Sep) and 194 after (14 Nov) the hurricane. No adverse effects of wind or water level were observed in treatment plots after the 6-week (retention) period following planting, indicating that giant bulrush was well-established prior to the hurricane. However, stem damage occurred during early November in one plot planted with 10 to 15 cm rhizomes. More than half of the stems within the plot were bent or cut, presumably caused by a boat. Survival of individual plants was not affected, but this plot was omitted from analyses of condition and mean stem production per unit stock.

Mean retention rates of giant bulrush plants 6 weeks after planting were not significantly different between stem treatments ($F_{2,10} = 1.0$, $P = 0.41$; Table 1-A) or rhizome treatments

TABLE 1. (A) RETENTION (NUMBER OF PLANTS REMAINING), (B) SURVIVAL (NUMBER OF LIVE PLANTS REMAINING), AND (C) CONDITION (MEAN NUMBER OF LIVE STEMS PER SURVIVING PLANT) FOR STEM TREATMENTS OF GIANT BULRUSH PLANTED IN LAKE TOHOPEKALIGA, FL, JUL TO NOV 2005. DIFFERENT LETTERS (A, B) DENOTE SIGNIFICANT DIFFERENCES IN MEAN VALUES BETWEEN PLANTING TREATMENTS ($P < 0.10$).

Stem treatment	Submersed-cut	Emergent-cut	Uncut
Number of plants planted per plot	25	25	25
(A) Retention, 6 weeks after planting			
Plot 1	16	19	24
Plot 2	15	18	18
Plot 3	21	20	17
Mean (%) ± SE	69.3 ± 6.6	74.4 ± 6.2	81.4 ± 5.5
(B) Survival, 4 months after planting			
Plot 1	13	15	22
Plot 2	4	16	17
Plot 3	17	20	15
Mean (%) ± SE	43.8 ± 8.5^{a}	67.0 ± 7.9^{b}	71.9 ± 7.5^{b}
(C) Condition, 4 months after planting			
Plot 1	2.1	2.2	3.1
Plot 2	1.0	2.3	3.4
Plot 3	2.4	3.0	4.1
Mean ± SE	1.8 ± 0.3^{a}	$2.5 \pm 0.3^{a,b}$	3.5 ± 0.3^{b}

($F_{2,10}$ = 1.9, P = 0.20; Table 2-A). Retention rates (or, conversely, post-planting loss of plants) were not influenced by cutting stems or by rhizome length. For all methods combined, the mean retention rate was 72%. Loss of plants was attributed to dislodging due to wind and wave action.

Mean survival rates of giant bulrush plants 4 months after planting were significantly different between stem treatments ($F_{2,10}$ = 3.2, P = 0.09; Table 1-B). Submersed-cut stems had a lower mean survival rate (44%) than did emergent-cut or uncut stems, but the mean survival rate of uncut stems (72%) was not significantly different than that of emergent-cut stems (67%). Response to harvesting or cutting beneath the water surface varies among plant species. Cattails (*Typha* sp.) were mechanically harvested 0.5 m below the water surface on Lake Marion, Florida, and minimal regrowth occurred during the subsequent 6 months (Hulon et al. 2000). Egyptian paspalidium (*Paspalidium geminatum* [Forssk.] Stapf) was mechanically harvested 0.5 m below the water surface on Lake Kissimmee, Florida, and complete recovery was documented within 3 weeks (Mallison et al. 2006). For planted giant bulrush, cutting stems beneath the water surface significantly reduced survival.

Condition of surviving plants 4 months after planting was significantly different between stem treatments ($F_{2,6}$ = 8.2, P = 0.01; Table 1-C). Submersed-cut stems had fewer live stems per surviving plant than did uncut stems, but the mean number of live stems per surviving plant of emergent-cut stems was not significantly different than that of other stem treatments. Approximately the same amount of donor stock was required to supply 75 plants (sum of three plots) for each stem treatment. Eight months after planting, the total number of live giant bulrush stems in plots planted with uncut stems was 511, of emergent-cut stems was 433, and of submersed-cut stems was 201 (Figure 1).

Survival rates of 2 to 4 cm rhizomes were low (40 and 44%) in two of the three plots, compared to ≥60% survival in all other plots for all treatments (excluding submersed-cut stems), despite seemingly identical site conditions; however, mean survival rates were not significantly different between rhizome treatments ($F_{2,10}$ = 2.1, P = 0.18; Table 2-B). Survival rates of all rhizome treatments and stem treatments (excluding submersed-cut stems) averaged 64% and ranged from 40

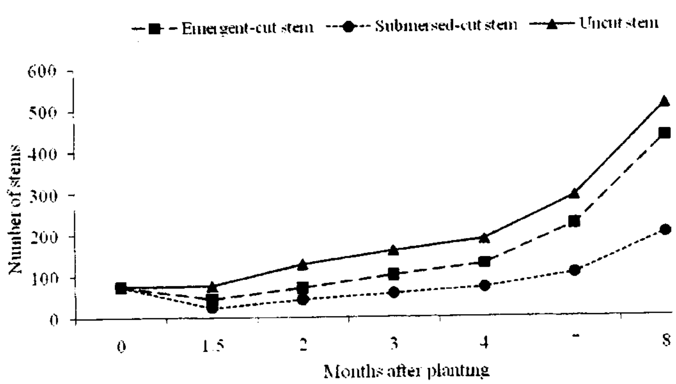

Figure 1. Total number of live giant bulrush stems remaining for stem treatments planted in Lake Tohopekaliga, FL, Jul 2005 to Apr 2006.

to 88%. No data on retention rates or survival rates from previous transplanting projects (i.e., revegetation with stock harvested from wild collection sites) were available for comparison. Survival rates of nursery-grown giant bulrush, planted in sandy substrate of Emeralda Marsh, Florida, averaged 54% and ranged from 25 to 85% (Marburger et al. 1998). Nursery stock consisted of small plants (stem height averaged 35 cm) that were anchored with fencing staples to improve retention. Survival rates of giant bulrush transplanted in Lake Tohopekaliga were slightly higher than those of nursery stock planted in Emeralda Marsh, but potential differences (e.g., site conditions, environmental conditions, and season) prevented reliable comparison.

Condition of surviving plants 4 months after planting was significantly different between rhizome treatments ($F_{2,9}$ = 229.6, P < 0.01; Table 2-C). The 10 to 15 cm rhizome treatment had far more live stems per surviving plant than any other treatment group. However, rhizome treatments did not differ in mean stem production per unit stock 4 months after planting ($F_{2,9}$ = 0.94, P = 0.43; Table 2-D). The growth potential of donor stock was not significantly affected by dividing plants into multiple planting units. The condition of 10 to 15 cm rhizomes was better than that of smaller size-classes of rhizomes simply because the amount of planted stock per plant was greater.

Observed results may be projected to predict success of alternative rhizome treatments. For example, *x* units of donor stock may be planted as N 12 cm rhizomes with 4 live stems, 2N 6 cm rhizomes with two live stems, or 4N 3 cm rhizomes with one live stem. For this comparison, survival rate (S/N)and mean stem production per unit stock (L/T) may be assumed equal for all treatments because these variables were not significantly different. The expected number of live stems 4 months after planting would be equal ($x \times L/T$) for each treatment because the amount of stock and mean stem production per stock would be constant. However, because the number of planting units would be larger for smaller size-classes of rhizomes, the expected number of surviving plants would be $4N \times S/N$ for 3 cm rhizomes, $2N \times S/N$ for 6 cm rhizomes, and $N \times S/N$ for 12 cm rhizomes. From a given amount of donor stock, planting 3 cm rhizomes with one live stem would yield the largest number of surviving plants with the fewest live stems per plant, and planting 12 cm rhizomes with four live stems would yield the smallest number of surviving plants with the largest number of live stems per plant.

The results of this study show that giant bulrush plants should be planted emergent. Cutting stems above the water surface did not affect the retention rate, survival rate, or condition of giant bulrush in Lake Tohopekaliga. Cutting the stems would reduce the volume and biomass of the plants, thus making them easier to transport. For donor stock containing stems 2.5 to 3 m in height, stems may be cut in half (assuming that planting depth is ≤1 m) to reduce the volume by nearly 50%. This would be particularly helpful in large-scale revegetation projects because it would improve efficiency of transplanting activities. Rhizome length did not influence the retention rate, survival rate, or mean stem production per unit stock of giant bulrush. However, condition of plants grown from 10 to 15 cm rhizomes with multiple live stems was better than that of plants grown from

TABLE 2. (A) RETENTION (NUMBER OF PLANTS REMAINING), (B) SURVIVAL (NUMBER OF LIVE PLANTS REMAINING), (C) CONDITION (MEAN NUMBER OF LIVE STEMS PER SURVIVING PLANT), AND (D) MEAN STEM PRODUCTION PER UNIT STOCK (NUMBER OF LIVE STEMS PER PLANTED STOCK) FOR RHIZOME TREATMENTS OF GIANT BULRUSH PLANTED IN LAKE TOHOPEKALIGA, FL, JUL TO NOV 2005. DIFFERENT LETTERS (A, B) DENOTE SIGNIFICANT DIFFERENCES IN MEAN VALUES BETWEEN PLANTING TREATMENTS ($P < 0.10$).

Rhizome treatment	2 to 4 cm	6 to 8 cm	10 to 15 cm
Number of plants planted per plot	25	25	8
(A) Retention, 6 weeks after planting			
Plot 1	18	24	5
Plot 2	18	18	5
Plot 3	12	17	7
Mean (%) ± SE	63.7 ± 7.0	81.4 ± 5.5	71.4 ± 6.5
(B) Survival, 4 months after planting			
Plot 1	17	22	5
Plot 2	11	17	5
Plot 3	10	15	7
Mean (%) ± SE	50.8 ± 8.5	71.9 ± 7.5	70.8 ± 7.6
(C) Condition, 4 months after planting			
Plot 1	3.6	3.1	—
Plot 2	2.7	3.4	12.2
Plot 3	2.8	4.1	12.6
Mean ± SE	3.1 ± 0.3[a]	3.5 ± 0.3[a]	12.4 ± 0.4[b]
(D) Mean stem production per unit stock, 4 months after planting			
Plot 1	9.9	6.6	—
Plot 2	4.8	5.5	6.8
Plot 3	4.5	5.9	9.8
Mean ± SE	6.4 ± 1.1	6.0 ± 1.1	8.3 ± 1.4

smaller size classes of rhizomes with single stems. To establish more-robust individual plants, planting large rhizomes with multiple live stems was most effective. To establish the maximum number of plants from a given stock of donor plants, planting small rhizomes with one live stem was most effective. Note that all plants were planted within 7 h of collection, and results may vary if transplants are held out of water for longer periods, such as overnight.

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