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Effect of Propagule Type and Holding Method on Survival of Transplanted Water Willow (*Justicia americana*)

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INTRODUCTION

Macrophytes are important to the aquatic ecosystem as they provide substrate for a large number of aquatic organisms (Edwards and Owens 1965), help reduce erosion, and enhance recruitment of many fish species (Savino and Stein 1982, Gotceitas and Colgan 1987). In many bodies of fresh water, aquatic vegetation becomes so extensive that it interferes with irrigation, boating, or the maintenance of a desirable sport fishery. Overabundant vegetation is often most acute in shallow, highly fertile lakes, or when an exotic plant species becomes established. In a large number of reservoirs, however, aquatic vegetation is almost completely absent. In most cases biologists prefer an intermediate level of macrophytes (Crowder and Cooper 1982).

Factors that contribute to sparse aquatic macrophytes in reservoirs include unnatural changes in water levels, high turbidity, lack of plant propagules, and unsuitable bottom types such as hard-packed clay (Smart et al. 1996). Attempts have been made to plant various rooted aquatic macrophytes in lakes and reservoirs that are lacking vegetation (Smart et al. 1996, Dick et al. 2004). Most of the plant species failed to survive. Water willow *Justicia americana* is an emergent species that tends to tolerate these harsh conditions and can be established by planting founder colonies (Strakosh et al. 2005, Dick et al. 2004).

When conducting a reservoir habitat enhancement project, biologists are often faced with numerous logistical restraints. One such restraint is that donor plant sites are often located considerable distances away from the target reservoir, making collection and replanting of propagules in one day impossible. Additionally, the number of propagules needed to be collected and planted, even to attempt to establish relatively few small founder colonies, is quite large (Smart et al. 1996). As a result, in order to effectively conduct a reservoir habitat enhancement project, biologists may need to enlist the aid of local interest groups (e.g., fishing clubs, boys and girls scout groups, elementary, and high school biology classes) to help with collecting and transplanting the aquatic vegetation.

A second consideration biologists face is the type of propagule that will provide the best chance for transplanting success. The purpose of this study was to investigate the effects of holding method and holding time on the survival of transplanted whole plants and stem fragments of water willow.

MATERIALS AND METHODS

Sixty planter boxes (0.9 m × 0.3 m × 0.3 m) were placed in one (0.04 hectare) pond located at Southern Illinois University Touch of Nature (SIUC-TON) aquaculture facility. Planter boxes were suspended in the pond by wooden braces that ran the entire length of the pond (Figure 1). Each box was filled with approximately 0.3 m of pond bottom sediment. After filling the boxes, the water level of the pond was raised to just below the wooden braces and maintained at this level throughout the experiment. Planter boxes were allowed one week to stabilize prior to planting.

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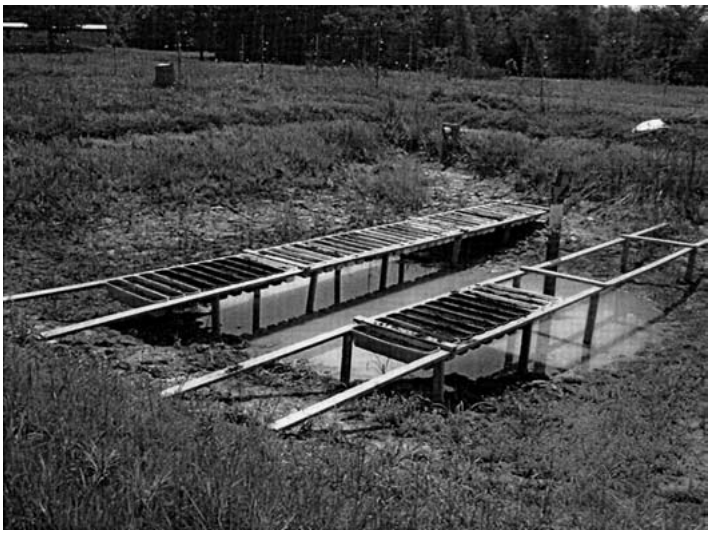

Figure 1. Planter box set up in a pond located at Southern Illinois University Touch of Nature (SIUC-TON) aquaculture facility.

Whole plants (whole plants with root systems intact) and stem fragments were obtained from native colonies located at Kinkaid Lake (Jackson County, IL) on 31 July 2000. Prior to planting harvested whole plants and stem fragments, they were held either in a cooler with water and no lid, exposed to ambient temperature and light, or in a cooler with a damp towel placed over them and the lid closed. All coolers were stored outside in the shade. Plants were held in coolers from 31 July to 27 August and air temperature ranged from 16-33°C during this period. Whole plants and stem fragments with two nodes were held for 1 d, 7 d, 14 d, 21 d, and 28 d prior to replanting.

One-day post harvest, 15 plant whole plants and 15 stem fragments were removed from each of the two coolers and transplanted into the planter boxes. Each planter box was randomly assigned to a propagule type, holding method, and holding time. This procedure was repeated at 7 d, 14 d, 21 d, and 28 d post harvest. Plantings were replicated in triplicate. Survival was measured from each planter box approximately one month after the last transplanting (28 d). Percent survival data was arcsine transformed for ANOVA (Hinkel et al. 1998). Data was analyzed as a $2 \times 2 \times 5$ factorial ANOVA (using the appropriate error terms for each test) with propagule type, holding method, and holding time as the main effects. When significant differences were found, Tukey's HSD test was used to show where differences occurred. SAS software (SAS Institute, Inc. 1995) was used for all statistical tests at a significance level of 0.05.

RESULTS

Over the 28-d holding period, both whole plants and stem fragments had a higher survival rate after planting when held in water than when held under a moist towel ($P < 0.0001$; $F = 14.05$; $df = 4$). There was no significant difference in survival rate between whole plants and stem fragments ($P = 0.37$; $F = 0.81$; $df = 1$), nor was there any significant difference in the survival rate of whole plants or stem fragments held in water for 1 to 28 d prior to planting (Table 1). Both whole plants and stem fragments held under a moist towel up to 14 d had post-planting survival rates that ranged from 96 to 100% (Table 1). A significant reduction in survival rate occurred by day 21 (Table 1). After 28 d, whole plants held under a moist towel had only a 2% survival rate while stem fragments had an 18% survival rate.

DISCUSSION

Results indicate survival of harvested water willow was most significantly related to how propagules were held (holding method), as well as the length of time propagules were held (holding time) prior to replanting. Either whole plants or stem fragments can be held in water or under a damp towel as long as 14 d before being transplanted and still attain >90% survival. If water willow must be held for longer than 14 d, we suggest it be held in the shade in coolers with water and no lid. We attained 92% survival of harvested water willow held this way for 21 d prior to transplantation.

Both whole plants and stem fragments are viable propagule types for an aquatic vegetation transplantion project. The choice of which propagule type is best suited for transplanting should be considered prior to collection, taking into account various aspects such as availability, genetics, and origin (Smart et al. 1996). Space, physical characteristics at target sites (sediment composition, vulnerability to waves, and water level fluctuation), abundance of the donor source, time, money, and personnel are also important considerations.

Collection of whole plants is more labor intensive compared to collection of stem fragments. Extreme care must be given when removing whole plants, so as to minimize damage to root systems, alleviate stress, and ease of redistribution of the root system at target sites. In addition, large donor sites must also be located so that removal of whole plants does not negatively impact the overall health and abundance of these critical habitats.

Stem fragments provide a non-lethal alternative to removing whole plants from donor sites. Multiple stem fragments may be cut from one donor plant to provide multiple transplants at target sites. Additionally, stem fragments can be collected much faster than whole plants. Despite these beneficial characteristics, stem fragments require approximately 1 month before their root systems begin to develop

Table 1. Survival (%) of water willow whole plants and stem fragment held in water or under a moist towel for 1 to 28 d prior to planting.

Holding time (d)	Whole plants		Stem fragment	
	Water	Moist towel	Water	Moist towel
1	89[a]	98[a]	98[a]	96[a]
7	100[a]	98[a]	93[a]	100[a]
14	93[a]	100[a]	98[a]	96[a]
21	91[a]	44[b]	93[a]	69[b]
28	82[a]	2[c]	87[a]	18[c]

[a]Means with different superscripts are significantly different.

(P. Collingsworth, unpublished data). Since their root system aid in anchoring these propagules to the substrate, planting of stem fragments may need to be restricted to areas protected from strong wave action. Unfortunately, these are often the areas most in need of shoreline stabilization.

Beginning at day 11, stem fragments held in water and under a moist towel began to show signs of significant root development occurring from the nodes. By day 16, most stem fragments exhibited growth of rooting systems. Failure of stem fragments to possess anchoring root systems is a prime reason for their low survival at sites exposed to moderate wave action (Doyle and Smart 1995, Smart et al. 1996). Survival of stem fragments may be increased by allowing them to develop their initial root systems before planting. The development of the root system would allow for more rapid stability and attachment of the propagule to the sediment and possibly enhance survival. Future research should compare survival of stem fragments with no root systems to stem fragments with developing root systems.

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LITERATURE CITED

Crowder, L. B. and W. E. Cooper. 1982. Habitat structural complexity and the interaction between bluegills and their prey. Ecology 63(6):1802-1813.

Dick, G. O., R. M. Smart and J. K. Smith. 2004. Aquatic vegetation restoration in Cooper Lake, Texas: a case study. U.S. Army Corps of Engineers, Research and Development Center, Report ERDC/EL. TR-04-05, Vicksburg, MS.

Doyle, R. D. and R. M. Smart. 1995. Potential use of native aquatic plants for long-term control of problem aquatic plants in Guntersville Reservoir, Alabama: report 1, establishing native plants. U.S. Army Corps of Engineers Waterways Experiment Station. Technical Report A-93-6, Vicksburg, MS.

Edwards, R. W. and M. Owens. 1965. The oxygen balance in streams, pp. 149-172. *In:* G. T. Goodman, R. W. Edwards and J. M. Lambert (eds.). Ecology and the industrial society, a symposium of the British Ecological Society Symposium 5. Blackwell Scientific Publications Oxford, England.

Gotceitas, V. and P. Colgan. 1987. Selection between densities of artificial vegetation by young bluegills avoiding predation. Trans. Am. Fisheries Soc. 116: 40-49.

Hinkle, D. E., W. Wiersma and S. G. Jurs. 1998. Applied statistics for the behavioral sciences, 4th edition. Houghton Mifflin Company, Boston, MA.

SAS Institute. 1995. SAS Proprietary Software Release 6.11. SAS Institute, Inc., Cary, NC.

Savino, J. F. and R. A. Stein. 1982. Predatory-prey interactions between largemouth bass and bluegills as influenced by simulated submersed vegetation. Trans. Am. Fisheries Soc. 111:255-266.

Smart, R. M., R. D. Doyle, J. D. Madsen and G. O. Dick. 1996. Establishing native submersed aquatic plant communities for fish habitat. Am. Fisheries Soc. Symp. 16:347-356.

Strakosh, T. R., J. L. Eitzmann, K. B. Gido and G. S. Guy. 2005. The response of water willow *Justicia americana* to different water inundation and desiccation regimes. N. Am. J. Fisheries Manage. 25:1476-1485.