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Resistance of Vallisneria to Invasion from Hydrilla Fragments

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ABSTRACT

Weighted hydrilla fragments were introduced to containers of wild celery (*Vallisneria americana* Michx.) grown at four water depths (18, 46, 91, 122 cm) in a research pond at the Lewisville Aquatic Ecosystem Research Facility, Lewisville, Texas. Established wild celery effectively reduced invasion by hydrilla fragments, while hydrilla fragments readily established in control containers filled with sediment alone. Hydrilla biomass harvested from controls, representing the "empty niche," was significantly greater (40 times) than hydrilla biomass harvested from containers planted with wild celery for all water depth treatments. This study addresses the concept that preemptive establishment of wild celery can slow or prevent invasion from hydrilla fragments at different water treatment depths.

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INTRODUCTION

Wild celery (*Vallisneria americana* Michx.) is a native submersed aquatic plant found in eastern United States westward to South Dakota and south throughout the Gulf Coast states (Korschgen and Green 1988, USDA 2005). The plant is dioecious, with northern populations dying back to dormant winter buds (herbaceous perennial) and southern populations that can actively grow throughout the year (Titus and Hoover 1991, Dawes and Lawrence 1989). Wild celery is an important food source for waterfowl and aquatic mammals (Fassett 1957). The canvasback duck (*Aythya valisneria* [Wils.]) depends heavily on wild celery, especially during migration (Korschgen et al. 1987). Wild celery as well as other native aquatic plants also provide habitat for fisheries, sediment stabilization, improved water quality and clarity, and can slow or prevent the invasion of nonindigenous aquatic plant species, including hydrilla (*Hydrilla verticillata* [L.f.] Royle; Smart 1993, 1995, Smart et al. 1994, Smart and Dick 1999).

Hydrilla is an invasive, nonindigenous submersed aquatic plant distributed worldwide on all continents except Antarctica (Pieterse 1981, Cook and Luond 1982). First discovered in Florida (Pieterse 1981), hydrilla exhibits aggressive growth strategies, rapidly expanding to the surface and forming a dense canopy. Once hydrilla invades an aquatic ecosystem, several factors contribute to its spread. Stolons and tubers promote localized spread, while turions and allofragments contribute to long-distance spread (Madsen and Owens 1998, Madsen and Smith 1999). Unlike Eurasian watermilfoil (*Myriophyllum spicatum* L.), which produces autofragments for deliberate long-distance dispersal, hydrilla fragments are produced via outside influences such as recreational activities (Owens et al. 2001), boating (Owens unpubl. data), mechanical harvesting (WAPMS 2007), wildlife, winds, and flood events (Sculthorpe 1985). Almost any fragment that has a node or bud can generate new growth (Sculthorpe 1985). According to Langeland (1990), 50% of all hydrilla fragments possessing a single whorl of leaves can produce new growth.

In poorly vegetated systems, establishment of native aquatic plants that preempt available resources, including location, light, and nutrients, may provide a buffer against invasion by weedy species such as hydrilla (McCreary et al. 1991, Smart 1993, Smart et al. 1994, Smart and Dick 1999, Ott 2005). Ott (2005) found that 13 months of preemption before introduction of hydrilla fragments resulted in no adverse impacts on wild celery colonies in research ponds after two growing seasons. However, Smart (1993, 1995) found that if weedy species such as hydrilla or Eurasian watermilfoil arrive in an aquatic system before strong establishment of native plants, the weedy species usually consumes available resources, establishing a monoculture.

This study further addresses the concept that preemptive establishment of wild celery can slow or prevent invasion from hydrilla fragments at different depths. Success of well established native aquatic plants in resisting invasion from hydrilla fragments would demonstrate the importance of protecting existing native plant communities as a means of preventative control of nuisance aquatic plants. Additionally, this information will support the need for persistent introductions and establishment of native plants into manmade or disturbed lakes and reservoirs, and especially inclusion of native aquatic plant establishment as a component of noxious aquatic weed management strategies.

MATERIALS AND METHODS

Six wild celery plants (average 5 leaves per plant, southern ecotype) were planted into each of 64 6.7-L containers (diameter 35.6 cm, depth 10.2 cm) of sterilized pond sediment amended with 1.4 g ammonium sulfate in December 2003; sediments were collected from a pond at the Lewisville Aquatic Ecosystem Research Facility, Lewisville, Texas (LAERF). Water samples were collected twice monthly from the pond and analyzed for pH, conductivity, alkalinity, and turbidity (APHA 1995). Containers were equally and randomly distributed in the pond among water depths of 18, 46, 91, and 122 cm. An additional eight bare sediment containers were placed at each water depth to serve as the "empty niche." Treatments included: (1) eight containers per water depth of wild celery without hydrilla fragment introduction, (2) eight containers per water depth of wild celery with hydrilla fragment introduction, and (3) eight bare sediments per water depth with hydrilla fragment introduction. Continuous flow and a standpipe were used to maintain water levels in the pond throughout the experiment.

In June 2005, 18 months after planting wild celery, hydrilla was introduced to appropriate treatment containers (8 wild celery and 8 bare sediments) per water depth. Two 20-cm apical tips of hydrilla were threaded through each of three 3.1-g metal nuts and were released at the surface above the 18-cm deep containers and approximately halfway down the water column for other water depths. The metal nuts were used to reduce buoyancy; thus, the fragments sank rather than floated away. After fragments were given approximately four weeks to root and begin establishment, all containers were harvested. Samples were processed into aboveground and belowground biomass, and maximum leaf/stem length of wild celery and hydrilla was measured. Samples were dried at 55 C in a Blue M forced air oven (General Signal, Atlanta, GA) to a constant weight. Statistical analyses were conducted using a Two-Way ANOVA (analysis of variance) and Tukey's test at 0.05 level of significance (Statistica, Statsoft 2002, Tulsa, OK).

RESULTS AND DISCUSSION

Water chemistry and sediment nutrients at the LAERF were conducive for aquatic plant growth and well within published ranges for both wild celery (Nichols 1999) and hydrilla (Smart et al. 1995, Madsen and Owens 2000; Figure 1). Smart et al. (1995) reported that LAERF pond sediment was predominately fine textured (28% sand, 33% silt, 38% clay), and with additions of N were sufficiently fertile to grow rooted aquatic plants.

Wild celery growth responded to water depth by significantly increasing maximum leaf length with increasing depth, with leaves at all water depths reaching at or near the surface by the final harvest (Table 1). By harvest time the wild celery plants were well established with well-developed aboveground and belowground biomass (Owens, pers. observ.). For wild celery aboveground biomass, significant differences were found between water depths, but treatment differences were not significant and no interactions between depth and treatment was found (Figure 2A and 2B). Aboveground biomass of all wild celery plants grown at the 122 cm water depth was nearly four times that of plants grown at 18, 46, and 91 cm (Figure 2A). Smart et al. (1994) found that wild celery was capable of adjusting biomass allocation and morphology to maximize photosynthesis, and that under lower light conditions fewer daughter plants were produced. In a recent study evaluating wild celery response to water depth distribution, plants growing at shallower depths allocated more resources to increasing daughter plant production (Owens et al., unpublished data). Our study indicated that wild celery grown under increased water depth allocated more resources to elongation (length) and biomass. For wild

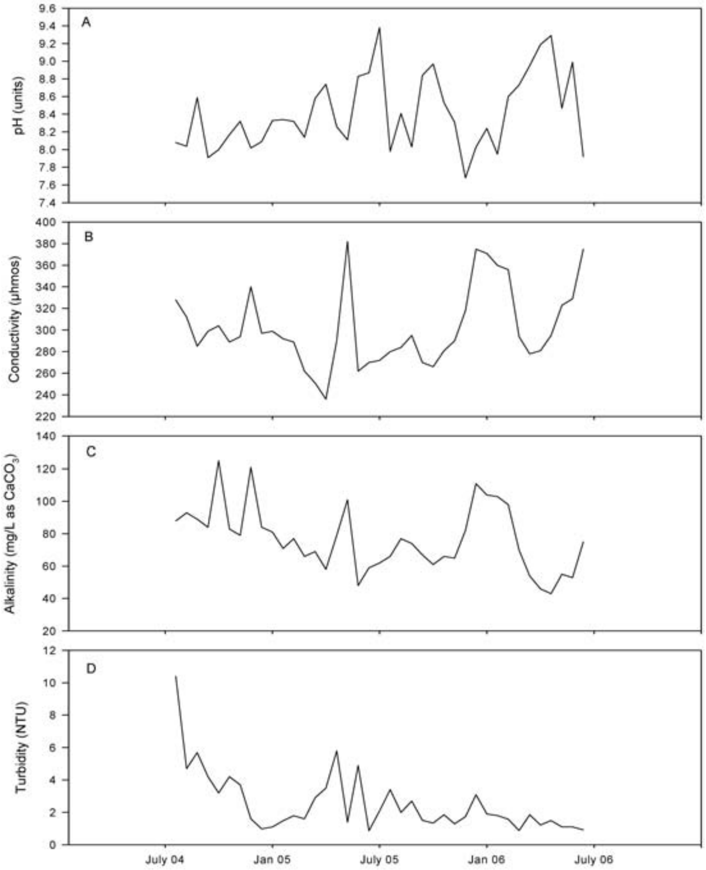

Figure 1. Water chemistry for wild celery and hydrilla grown in LAERF pond from July 2004 through July 2006. Parameters include pH (units), conductivity (µhmos), alkalinity (mg/L), and turbidity (NTU).

celery belowground biomass, there were significant differences between water depths, but treatment differences were not significant and no interaction between depth and treatment was found (Figure 3A, B). All wild celery containers were filled with well-developed belowground material (Owens, pers. observ.), thus providing little-to-no empty sediments available for hydrilla fragment invasion (Figures 2D and 3B). Wild celery was not significantly impacted by hydrilla invasion (Figures 2B and 3B).

After approximately four weeks, hydrilla fragments had settled and rooted in all bare sediment containers, and plants had grown to or near the water surface for all depths (Table 1). For hydrilla aboveground and belowground biomass, there were no significant differences between water depths, but treatment differences were significant and no interaction between depth and treatments was found (Figures 2C, D, and 3C, D). In only 30 days, hydrilla invaded the bare sediment containers, representing the "empty niche," produced roots, and elongated, producing approximately 40 g of aboveground biomass and 4.5 g of belowground material (Figures 2D and 3D). The presence of wild celery had significant impacts on hydrilla invasion (Figures 2D and 3D). Few hydrilla fragments were found in the wild celery containers. In addition to wild celery serving as a physical barrier between hydrilla fragments and sediments, light and nutrient

Table 1. Average length (cm) for all wild celery and hydrilla (empty niche) ± standard error. Letters indicate significant differences.

Depth (cm)	Wild celery (± S.E.)	Hydrilla (± S.E.)
18	37.38 ± 1.94 (a)	45.38 ± 2.59 (a)
46	51.25 ± 2.61 (b)	47.16 ± 10.06 (a)
91	72.63 ± 3.45 (c)	79.00 ± 6.41 (ab)
122	88.62 ± 3.17 (d)	106.50 ± 11.89 (b)

availability were likely limited in the water column immediately associated with wild celery, further inhibiting the ability of successful establishment by the fragments.

Resistance to hydrilla invasion supports the hypothesis that healthy native aquatic plants, particularly wild celery, can serve as pre-emptive controls for spread of nuisance species through competitive exclusion. Smart (1995) found that when wild celery was given sufficient lead-time to pre-empt resources, it was able to maintain long-term biomass dominance over hydrilla planted from fragments. While small-scale container studies may not completely reflect reservoir conditions, they are a first-step in understanding the mechanics of pre-emption ecology. Ott (2005) gave several native aquatic plant species, including wild celery, a full

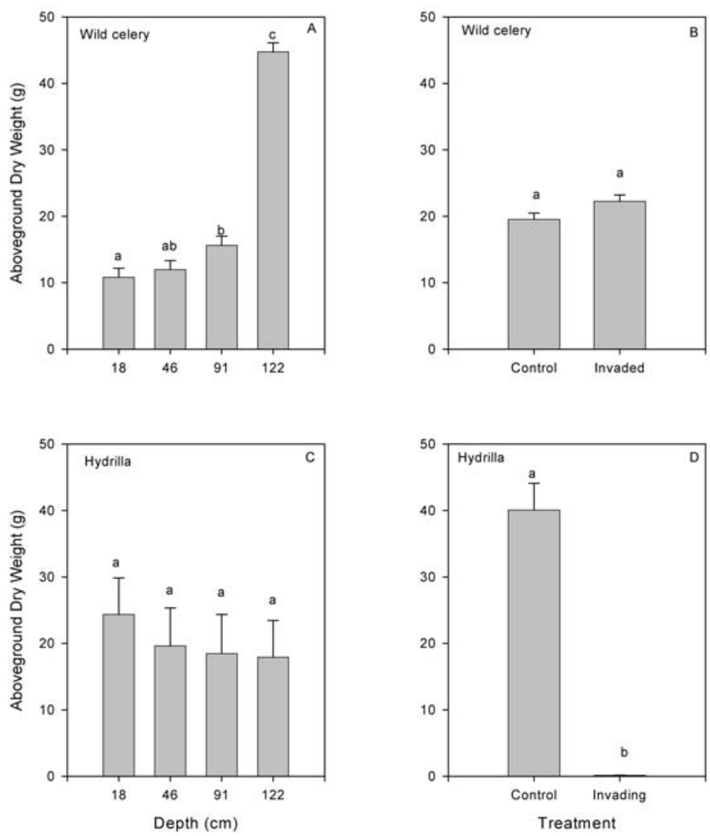

Figure 2. (A) Aboveground dry weight (g) for wild celery at four different depths (p = 0.0000, F = 141.59; (B) aboveground dry weight (g) for wild celery with and without invasion (p = 0.0678, F = 3.46; (C) aboveground dry weight (g) for hydrilla at four different depths (p = 0.9410, F = 0.28; and (D) aboveground dry weight (g) for hydrilla with and without invading (p = 0.0000, F = 0.09). Bars represent standard error.

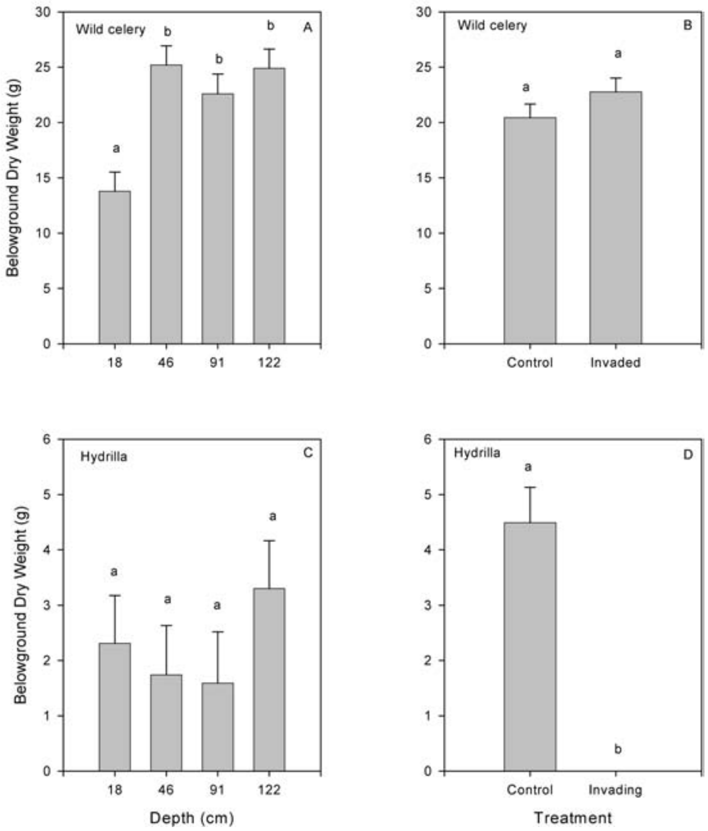

Figure 3. (A) Belowground dry weight (g) for wild celery at four different depths ($p = 0.0000$, $F = 9.42$; (B) belowground dry weight (g) for wild celery with and without invasion ($p = 1.899$, $F = 1.76$; (C) belowground dry weight (g) for hydrilla at four different depths ($p = 0.5028$, $F = 0.79$; and (D) belowground dry weight (g) for hydrilla with and without invading ($p = 0.0000$, $F = 25.53$). Bars represent standard error.

growing season in four LAERF ponds before introducing hydrilla fragments. He monitored the ponds for two additional growing seasons and found wild celery was able to resist invasion from hydrilla fragments. Because fragments (along with turions) are the primary long-distance dispersal mechanism for hydrilla, empty niches are especially vulnerable to invasion. Filling these niches with species such as wild celery before invasion by exotics occurs is a sensible, ecosystem-based approach to managing aquatic plants.

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LITERATURE CITED

APHA (American Public Health Association. American Water Works Association and Water Pollution Control Federation). 1995. Standard Methods for Examination of Water and Wastewater. 19th ed. Washington, D.C. 1108 pp.

Cook, C. D. K. and R. Luond. 1982. A revision of the genus *Hydrilla* (Hydrocharitaceae). Aquat. Bot. 13:485-504.

Dawes, C. J. and J. M. Lawrence. 1989. Allocation of energy resources in the freshwater angiosperms *Vallisneria americana* Michx. and *Potamogeton pectinatus* L. in Florida. Fla. Sci. 52:59-63.

Fassett, N. C. 1957. A manual of aquatic plants. University of Wisconsin Press, Madison. 405 pp.

Korschgen, C. E., L. S. George and W. L. Green. 1987. Feeding ecology of canvasback staging on Pool 7 of the Upper Mississippi River, pp. 237-249. *In*: M. E. Weller (ed.). Waterfowl in winter, University of Minnesota Press.

Korschgen, C. E. and W. L. Green. 1988. American wild celery (*Vallisneria americana*): Ecological considerations for restoration. U.S. Fish and Wildlife Service, Tech. Rep 19, 24 pp.

Langeland, K. A. 1990. Hydrilla: A continuing problem in Florida waters. Circular No. 884, Cooperative Extension Service, University of Florida, Gainesville.

Madsen, J. D. and C. S. Owens. 1998. Seasonal biomass and carbohydrate allocation in dioecious hydrilla. J. Aquat. Plant Manage. 36:138-145.

Madsen, J. D. and D. H. Smith. 1999. Vegetative spread of dioecious hydrilla colonies in experimental ponds. J. Aquat. Plant Manage. 37:25-29.

Madsen, J. D. and C. S. Owens. 2000. Factors contributing to the spread of hydrilla in lakes and reservoirs. Technical Note-APCRP-EA-01, U.S. Army Environmental Research and Development Center, Vicksburg, MS. 14 pp.

McCreary, N. J., D. W. McFarland and J. W. Barko. 1991. Effects of sediment nitrogen availability and plant density on interactions between the growth of *Hydrilla verticillata* and *Potamogeton americana*. Technical Report A-91-7, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 35 pp.

Nichols, S. A. 1999. Distribution and habitat descriptions of Wisconsin lake plants. Wisconsin Geological and Natural History Survey, Bull. 96:228-229.

Ott, R. A. 2005. Influence of native macrophytes and herbivory on establishment and growth of *Hydrilla verticillata* in pond-scale mesocosms. PhD dissertation, Stephen F. Austin University, Nagadoches, TX. 138 pp.

Owens, C. S., J. D. Madsen, R. M. Smart and R. M. Stewart. 2001. Dispersal of native and nonnative aquatic plant species in the San Marcos River, Texas. J. Aquat. Plant Manage. 39:75-79.

Owens, C. S., R. M. Smart and G. O. Dick. 2007. Effects of depth and water level fluctuations on *Vallisneria americana* Michx. growth. (In press).

Pieterse, A. H. 1981. *Hydrilla verticillata*—a review. Abstr. Trop. Agric. 7:9-34.

Sculthorpe, C. D. 1985. The biology of aquatic vascular plants. Edward Arnold (Publ.) Ltd., London, England. 334 pp.

Smart, R. M. 1993. Competition among introduced and native species. Proceedings, 27th Annual Meeting, Aquatic Plant Control Research Program. Miscellaneous paper A-93-2, U.S. Army Environmental Research and Development Laboratory, Vicksburg, MS. pp. 235-241.

Smart, R. M., J. W. Barko and D. G. McFarland. 1994. Competition between *Hydrilla verticillata* and *Vallisneria americana* under different environmental conditions. Technical Report A-94-1, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 34 pp.

Smart, R. M. 1995. Preemption: An important determinant of competitive success. Miscellaneous paper A-95-3, U.S. Army Enginner Waterways Experiment Station, Vicksburg, MS. pp. 231-236.

Smart, R. M, J. D. Madsen, G. O. Dick and D. R. Honnell. 1995. Physical and environmental characteristics of experimental ponds at the Lewisville Aquatic Ecosystem Research Facility. Misc. paper A-95-2, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS.

Smart, R. M. and G. O. Dick. 1999. Propagation and establishment of aquatic plants: A handbook for ecosystem restoration projects. Technical Report A-99-4, U.S. Army Engineer Waterways Experiment Station, Vicksburg, MS. 34 pp.

Titus, J. E. and T. Hoover. 1991. Toward predicting reproductive success in submersed freshwater angiosperms. Aquat. Bot. 41:111-136.

USDA (United States Department of Agriculture). 2005. http://plants.usda.gov/home.

WAPMS (Western Aquatic Plant Management Society). 2007. http://www.wapms.org/plants/hydrilla.html.