Proc. Fla. State Hort. Soc. 125:386–389. 2012.

Greenhouse Culture of Submersed Aquatic Vegetation "Sod"

Lyn A. Gettys*[1] and William T. Haller[2]

[1]*University of Florida, IFAS, Fort Lauderdale Research and Education Center, 3205 College Avenue, Davie, FL 33314*

[2]*University of Florida, IFAS, Center for Aquatic and Invasive Plants, Department of Agronomy, 7922 NW 71st Street, Gainesville, FL 32653*

Additional index words. *Vallisneria americana*, eelgrass, lake restoration, native aquatic plants

Lake restoration projects can be challenging due to the limited availability of submersed native plant material, the difficulty of installing plants in an underwater environment, and the instability of many submersed sediments. Significant resources are expended to execute these types of projects, but success is often hindered because newly planted vegetation fails to anchor, establish, and expand from the transplant site. These roadblocks can be addressed by producing "sod" of submersed vegetation in the greenhouse. This technique starts with a small number of plants that are plugged into a biodegradable matrix and cultured in tanks for several months. The process culminates with well-rooted, densely vegetated mats that can be rolled up and transported to the restoration site. "Sod" produced in this manner is easily installed in the field and results in an instant population of submersed native vegetation that quickly establishes and expands from the transplant site.

Water has always played an important role in Florida's ecology and economy. The construction of channels, locks, and other structures has allowed us to maintain some semblance of control over this powerful resource, e.g., we can reduce the likelihood of flooding, while providing water for anthropogenic activities such as agriculture, recreational fishing, and boating. A notable drawback to these alterations in the state's hydrologic system is the negative impact these modifications have had on many of Florida's lakes, which have experienced marked changes in parameters critical to the maintenance of a healthy habitat for fish and wildlife. One of the most important changes in Florida lakes is stabilization of the water level, which encourages dense overgrowth of emergent plants and ultimately renders littoral areas inhospitable for fish due to greatly reduced dissolved oxygen concentration (Moyer et al., 1995). Excess sediment accumulations due to these same factors can also cause declines in submersed aquatic vegetation (SAV). Muck and sediment accumulation can create a variety of problems for aquatic species by burying established vegetation. Leaves buried by sediment have reduced photosynthetic potential and foliar gas exchange and buried plants may produce elongated shoots in an attempt to increase access to light and oxygen (Adamus et al., 2001). Water depths are also reduced due to sediment accumulation that can result in shifts in species composition (Adamus et al., 2001).

The Florida Fish and Wildlife Conservation Commission (FWC) has conducted extensive lake habitat enhancement projects to reverse systemic changes caused by altered hydrological patterns. The first steps in the restoration process have been elimination of excessive vegetative material through drawdowns and subsequent removal of detritus-laden muck. Fish populations are healthiest when vegetative cover is between 15% and 85% (Canfield and Hoyer, 1992), so SAV is often planted after muck removal to improve habitat quality for fish and wildlife (Allen and Tugend, 2002).

Revegetation projects rely on the use of native plants to foster ecological integrity. Eelgrass (*Vallisneria americana* Michx.) is a highly desired candidate for inclusion in these programs for a variety of reasons (Jaggers, 1994). Eelgrass is a member of the monocotyledonous Hydrocharitaceae family and it is native to eastern North America. This species, also commonly called tapegrass or American watercelery, is a perennial submersed aquatic herb with ribbon-like leaves emanating from a central rosette (Godfrey and Wooten, 1979). Sexual reproduction takes place between plants with pistillate or staminate flowers in this dioecious species, but most colonization is the result of vegetative reproduction (i.e., runners and winter buds). Winter buds enable eelgrass to overwinter in northern latitudes (Smart et al., 2005, 2006). However, these vegetative propagules are not produced in Florida populations of eelgrass. Godfrey and Wooten (1979) stated that two species of *Vallisneria* (*V. americana* and *V. neotropicalis*) are found in North America, with *V. neotropicalis* occurring mainly in Florida and other areas where water temperature remains nearly constant throughout the year. These workers also state that the only apparent difference between these types is quantitative (i.e., *V. neotropicalis* is larger than *V. americana*) and suggest that the greater biomass accumulated by specimens classified as *V. neotropicalis* may actually be due to plant age and favorable year-round growing conditions as opposed to speciation (Godfrey and Wooten, 1979). This hypothesis is supported by ITIS (2012), which states that the genus *Vallisneria* has the species *V. americana* and *V. gigantea*, with *V. asiatica*, *V. neotropicalis,* and *V. spiralis* listed as synonyms for *V. americana*.

Eelgrass is widely adapted and tolerant of diverse environmental parameters, including high turbidity (Davis and Brinson, 1980), low light levels (Titus and Adams, 1979), and various

*Corresponding author; phone: (954) 577-6331; email: lgettys@ufl.edu

water chemistry regimes (Korschgen and Green, 1988, and references within). Hunt (1963) found that eelgrass was able to establish in virtually any substrate as long as the substrate allowed root penetration and was not overly soft, although best growth occurred in silty clay. The species tolerates a wide range of fertility conditions, but Anderson and Kalff (1986) noted that eelgrass attained the greatest biomass when cultured with low concentrations of N, P, and K.

Smart et al. (2006) emphasized the importance of using locally grown (or collected) native species in restoration and revegetation projects, since these regional ecotypes are often adapted to the geographic region. Two distinct biotypes of eelgrass have been identified that differ in their response to winter conditions. Both function as perennials, but southern biotypes are evergreen while northern biotypes produce overwintering buds (Smart et al., 2005, 2006). It seems likely that most or all populations of eelgrass present in Florida are actually southern biotypes, but it is quite possible that multiple biotypes or ecotypes have developed within the species as a result of regional adaptation.

Field transplantation of eelgrass is reportedly most successful when seedlings in peat pots are planted into lakes at a fairly high density (25 plants/m^2) (Doyle and Smart, 1993). This technique improves the likelihood of successful population establishment, but it is very tedious and labor-intensive. As a result, most restoration projects rely on transplantation of individual bare-root plants. Plant material is field-collected from nearby sites with similar environmental conditions when possible, but suitable donor populations of sufficient size are not always available. In these cases, nursery-grown material may be employed, but there are a number of drawbacks associated with this method. For example, the costs associated with purchasing tens (or hundreds) of thousands of plants may be prohibitive; nurseries may not have adequate numbers of stock plants on hand; and nursery-grown material may be of unknown provenance and not well-adapted to conditions at the transplantation site.

The FWC has implemented lake restoration projects utilizing eelgrass at a number of sites. Revegetation efforts at some sites have been effective and newly planted eelgrass thrives, but in other cases establishment of self-sustaining populations of SAV has been unsuccessful. The reasons for failure are unclear, but may be due to a number of factors. For example, field collection of plants from donor sites often causes damage to root systems, which increases transplant shock and reduces the amount of root material available to anchor new transplants into the sediments at restoration sites. Also, sediments at lakes targeted for restoration are often mucky or flocculent, which provides a poor substrate for anchoring new transplants that may already have compromised root systems, damaged during collection from donor sites. As a result, new transplants often wash away within a day or two after planting as a result of wave or current action. Finally, insufficient numbers of plants may be utilized due to limited availability of locally adapted populations that can serve as suitable donor sites or limited funding to purchase nursery-grown material.

These challenges can be addressed by developing a system that begins with relatively small numbers of locally-adapted plant material and culminates in dense, well-rooted populations of plants that can be quickly anchored to soft sediments in such a way that new transplants can withstand wave and current action until they become established at the transplant site. Therefore, the goal of these experiments was to assess the feasibility of greenhouse production of eelgrass "sod." This technology could provide lake restoration managers with a useful tool to increase establishment success and reduce labor costs associated with collecting and transplanting individual plants.

Materials and Methods

Experiment 1: Greenhouse production of eelgrass sod. Rooted plants of eelgrass were cultured in a biodegradable matrix to determine the feasibility of using this method to produce rooted mats ("sod") of SAV under greenhouse conditions. Two potential matrix materials [100% cotton burlap (Joanne Fabrics, Gainesville, FL) and 1.25-cm-thick coir (coconut fiber; RoLanka International, Inc., Stockbridge, GA] and two commercially available ecotypes of eelgrass (hereafter referred to as "Narrow" and "Wide" based on phenotype; Suwannee Labs, Lake City, FL) were used in these experiments. Four replicates were prepared for each matrix–ecotype combination. Each experimental unit consisted of a single sheet of matrix cut to 45 × 60 cm. Eight rooted plants were inserted on 15-cm centers through the matrix. Each unit was placed on an 8-cm-deep layer of sand amended with 2 g/L of Osmocote Plus 15–9–12 (The Scotts Co., Marysville, OH) in tanks filled with well water maintained at a depth of 50 cm; water was circulated through a biofilter using a 600 gal/h pond pump. Newly planted units were buoyant, so they were weighted with small metal pipes or bags of sand to prevent floating. Plants were grown for 16 weeks; then the number of plants per experimental unit was recorded. Treatment effects were determined by LSD separation of means.

Experiment 2: Field transplantation of eelgrass sod. Coir-based sod of the Narrow and Wide ecotypes of eelgrass was produced in the greenhouse using the methods described above. Well-rooted eelgrass sod of each ecotype was transplanted in the field during July 2010, with both ecotypes planted at single locations in Lakes George, Jesup, and Josephine. Water depth at planting sites was about 50, 50, and 70 cm (Lakes George, Jesup, and Josephine, respectively). Fertility was supplied to some plots in the form of two 7.5-g tablets of 16–8–12 Osmocote Plus (The Scotts Co.), whereas other plots were left unfertilized. Both ecotypes were transplanted at all sites with and without fertilizer, with four replicates of each ecotype–fertilizer combination. Eelgrass sod was placed on the bottom of the lake and was secured with 8-inch-long metal spikes; fertilizer tablets were pushed into the lake sediment under the sod in plots calling for nutritional supplementation. Planting sites were protected by exclosures at all three locations to reduce the likelihood of herbivory by turtles and other aquatic fauna.

Results and Discussion

Experiment 1. Ecotype did not have a significant effect on total number of plants per unit at the end of the experimental period (treatment means were 95.0 and 113.1 plants per unit for Narrow and Wide, respectively). However, the location of plants—in the matrix or in the sediment—differed significantly based on ecotype (Table 1). The vast majority of Narrow plants were produced from runners along the top of or within the matrix, with roots forming a cohesive mat in and through the matrix. In contrast, most Wide plants were produced from runners underneath the matrix and were rooted primarily in the sediment layer beneath the matrix. As a result, mats planted with the Narrow ecotype were much more structurally sound because the roots of this ecotype were incorporated into the matrix. In addition, mats of the Narrow ecotype may establish more quickly in the field

Table 1. Average number of eelgrass plants in or under the matrix in each mat of SAV sod.

Ecotype	Avg no. of plants incorporated in the matrix	Avg no.of plants under the matrix or in the substrate
Narrow	83.9	12.1
Wide	47.0	66.1

because the majority of the plants are above the surface of the matrix. This result contrasted with mats planted with the Wide ecotype, where most plants were trapped underneath the matrix.

Matrix selection did not have a significant effect on total number of plants at the end of the experimental period (98.3 and 110.9 plants per unit for coir and burlap, respectively). However, mats using the burlap matrix were extremely unstable and fell apart upon removal from culture tanks. Mats with a coir matrix had much more structural integrity and held together well upon removal from tanks.

Experiment 1 revealed that ecotype selection plays an important role in successful production of eelgrass sod. The Narrow ecotype produced mats that were more structurally sound than mats planted with the Wide ecotype. While matrix selection did not have a significant effect on the number of plants produced per mat, the burlap matrix failed to produce mats that would be likely to remain intact during transport from a greenhouse production facility to the transplant site in the field. Based on these results, the most stable and well-rooted eelgrass sod was produced using the Narrow ecotype in a coir matrix. The results of this experiment suggest that it is indeed possible to produce SAV sod in a greenhouse setting for field transplantation. This new technology may increase the success rate of revegetation projects and may subsequently reduce labor and material costs associated with repeated plantings of areas where revegetation efforts have previously been unsuccessful. This method may also be especially useful in situations where limited amounts of locally-adapted plant material are available. Initial plant density was eight plants per mat, but density increased to an average of more than 100 plants per mat by the end of the 16-week culture period.

Experiment 2. Within 48 h of planting, sod planted at Lakes George and Jesup had been torn or pulled up by wave action. This problem was ameliorated by top-dressing sod at these locations with pea gravel to provide more stability. The problem was not observed at Lake Josephine, where deeper water at the planting site resulted in reduced wave action. It therefore seems likely that planting site instability is a function of water depth.

Eelgrass sod was planted at Lake George on 19 July 2010 and top-dressed with pea gravel on 22 July. Sod appeared secure and all plants looked healthy on 29 July. Subsequent visits to Lake George suggested that plants had failed to establish, but a visit on 3 Nov. revealed that some small plants (<5 cm tall, leaves <1 cm wide) were still present in the treatment area, although there was no evidence to suggest that growth extended beyond the SAV sod. Visual observations suggested that there was no difference between fertilized and non-fertilized plots and that all plants remaining at the Lake George planting site were the Narrow ecotype.

Eelgrass sod was planted at Lake Jesup on 19 July 2010 and top-dressed with pea gravel on 22 July. Site visits on 22 Sept. and 8 Oct. revealed good growth and early establishment by the Narrow ecotype, whereas the Wide ecotype quickly became scarce and failed to thrive. Subsequent visits to Lake Jesup on 14 Oct. and 6 Nov. confirmed observations noted during earlier site visits and provided more evidence that the Narrow ecotype was growing vigorously and spreading beyond the area initially planted with eelgrass sod. However, a number of plants of the Wide ecotype were also found to be present and growing well at the treatment site. Although a few Wide plants were identified in final site evaluations, the majority of plants at the Lake Jesup planting site were the Narrow ecotype. Also, there was no apparent difference between fertilized and non-fertilized plots.

Eelgrass sod was planted at Lake Josephine on 20 July 2010. Top-dressing with pea gravel was deemed unnecessary as SAV sod appeared to be stable, secure, and in good contact with the lake sediment. Good growth of both ecotypes was evident on 14 Oct. A subsequent visit to Lake Josephine on 19 Oct. revealed that the Narrow ecotype was growing vigorously and was predominant at the site, but a number of plants of the Wide ecotype were also found to be present and growing well. Similar to observations of the Lakes George and Jesup sites, there was no apparent difference between fertilized and non-fertilized plots.

These experiments revealed that the use of SAV sod for restoration and revegetation projects may be an effective strategy to increase transplant success and improve population establishment. The Wide ecotype was still present at the Lakes Jesup and Josephine sites 4 months after planting, but the Narrow ecotype performed well at all three field sites. These results are consistent with earlier findings (e.g., Gettys, 2011; Gettys and Haller, 2008, 2010) that the Narrow ecotype is more tolerant of a wide range of environmental conditions and thus more likely to successfully establish at less-than-ideal sites such as those examined in these studies. Although little growth was evident at Lake George, the fact that Narrow plants were still present at the site 4 months after planting is encouraging, as previous revegetation attempts at this particular site ("The Desert") within Lake George have failed. These results suggest that the use of eelgrass sod planted with the Narrow ecotype may provide a new tool to restoration managers and could culminate in more successful, cost-effective lake restoration programs.

These findings have allowed us to transfer new technology to the field that will increase the success rate of revegetation projects and may subsequently reduce labor and material costs associated with repeated plantings of areas where revegetation efforts have previously been unsuccessful. Other experiments utilizing larger pieces of coir-based eelgrass sod are underway. Resource and restoration managers at FWC and other agencies are excited about this new method and they are looking forward to including eelgrass sod in their lake restoration projects

Literature Cited

Adamus, P., T.J. Danielson, and A. Gonyaw. 2001. Indicators for monitoring biological integrity of inland, freshwater wetlands: A survey of North American technical literature (1990-2000). EPA843-R-01-Fall 2001. U.S. Environ. Protection Agency, Office of Water, Wetlands Div. (4502F), Washington, DC.

Allen, M.S. and K.I. Tugend. 2002. Effects of a large-scale habitat enhancement project on habitat quality for age-0 largemouth bass at Lake Kissimmee, Florida. Intl. Black Bass Symp. 2000, Amer. Fisheries Soc., Bethesda, MD.

Anderson, M.R. and J. Kalff. 1986. Regulation of submerged aquatic plant distribution in a uniform area of a weedbed. J. Ecol. 74(4):953–961.

Canfield, D.E., Jr. and M.V. Hoyer. 1992. Aquatic macrophytes and their relation to the limnology of Florida lakes. Final report. Bur. of Aquatic Plant Mgt., Florida Dept. of Natural Resources, Tallahassee, FL.

Davis, G.J. and M.M. Brinson. 1980. Responses of submersed vascular plant communities to environmental change. U.S. Fish and Wildlife Serv. FWS/OBS-79/33.

Doyle, R.D. and R.M. Smart. 1993. Potential use of native aquatic plants for long-term control of problem aquatic plants in Guntersville Reservoir, Alabama. Report 1, establishing native plants. Tech. Rpt. A-93-6, U.S. Army Corps of Eng. Environ. Lab., Vicksburg, MS.

Gettys, L. 2011. Adding to the restoration toolbox: Identifying widely adapted biotypes of eelgrass. Aquaphyte 30(1):5.

Gettys, L.A. and W.T. Haller. 2008. Effect of nutrient levels on biometric characters of *Vallisneria americana* Michx. 48th Annu. Mtg. of the Aquatic Plant Mgt. Soc., Charleston, SC. (Abstr.)

Gettys, L.A. and W.T. Haller. 2010. Growth requirements of *Vallisneria americana* and other native submersed aquatic plants for lake restoration projects. Final Rpt. to the Florida Fish and Wildlife Conservation Commission – FWC Contract No. 07161.

Godfrey, R.K. and J.W. Wooten. 1979. Aquatic and wetland plants of the southeastern United States. Univ. of Georgia Press, Athens.

Hunt, G.S. 1963. Wildcelery in the lower Detroit River. Ecology 44:360–370.

ITIS. 2012. Retrieved 15 June 2012 from the Integrated Taxonomic Information System on-line database, <http://www.itis.gov>.

Jaggers, B.V. 1994. *Vallisneria americana*: Considerations for restoration in Florida. Florida Game and Fresh Water Fish Commission, Eustis, FL.

Korschgen, C.E. and W.L. Green. 1988. American wildcelery (*Vallisneria americana*): Ecological considerations for restoration. U.S. Fish and Wildlife Serv., Fish and Wildlife Tech. Rpt. 19. Jamestown N.D.: Northern Prairie Wildlife Research Center Online. <http://www.npwrc.usgs.gov/resource/plants/wildcel/index.htm> (Version 16JUL97).

Moyer, E.J., M.W. Hulon, J.J. Sweatman, R.S. Butler, and V.P. Williams. 1995. Fishery responses to habitat restoration in Lake Tohopekaliga, Florida. North Amer. J. Fisheries Mgt. 15:591–595.

Smart, R.M., G.O. Dick, and J.R. Snow. 2005. Update to the propagation and establishment of aquatic plants handbook. ERDC/EL TR-05-4. U.S. Army Eng. Res. and Dev. Ctr., Lewisville, TX.

Smart, M., G. Dick, J. Snow, L. Williams, M. Webb, and R. Ott. 2006. Aquatic plant establishment workshop. Propagation and Establishment of Native Aquatic Plants Wkshp., Southern Div. of the Amer. Fisheries Soc. 2006 Mtg.

Titus, J.E. and M.S. Adams. 1979. Coexistence and the comparative light relations of the submersed macrophytes *Myriophyllum spicatum* L. and *Vallisneria americana* Michx. Oecologia (Berl.) 40:273–286.