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A Land-Based *Thalassia testudinum* Nursery Near Tampa Bay, Florida

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An experimental, land-based seagrass nursery, built near Tampa Bay, FL, produced cultivars of *Thalassia testudinum* Banks and Solander *ex* König (turtle grass). The nursery was a rectangular basin measuring 6.1 × 12.2 m that graded from 1.5 to 2.0 m in depth constructed inside a fiberglass-covered pole building. The basin had a vinyl liner covered with 10–20 cm of sand and 1.0–1.3 m of water. The nursery ran for 26 mo and focused on producing cultivars of *T. testudinum* using differing planting techniques. Survival rates were 84% after 3–12 mo in the first planting and 91% after 4 mo in the second planting because early harvesting was required as a result of leaks in the vinyl liner. The planting method that resulted in the highest survival rate was bare rhizomes with two or more short shoots. The cultivars from the two nursery experiments were used in two mitigation projects in Tampa Bay. The nonrecurring cost of the nursery was $12,081.45 over a 3-yr period, and recurring costs are estimated at $22,280.00, with a potential production of 2,500 turf-like 20-cm^2 units of *T. testudinum* that could be sold at $20.00 per planting unit.

Introduction

Seagrasses form one of the world's most productive marine plant communities (Dawes, 1998), with extensive beds occurring in Florida's estuaries and near-shore coastal waters (>2.5 million acres; Sargent et al., 1995). In Florida, seagrass communities stabilize the sediments, serve as a direct food source (e.g., for manatees and sea turtles) and an indirect food source (e.g., for urchins and snails), provide habitats for commercial and sport fish (spotted sea trout, tarpon, pink shrimp, and spiny lobster), and support fauna preyed on by wading and swimming birds (Thayer et al., 1984; Zieman and Zieman, 1989; Dawes et al., 2004).

Unfortunately, seagrass meadows have been declining worldwide, often as a result of human-induced disturbances (Short and Wyllie-Echeverria, 1996). For example, about 35% of seagrass beds have been lost in Florida, with the most severe impact experienced in estuaries, where *Thalassia testudinum* is the dominant seagrass (Livingston, 1984; Hadad and Harris, 1985; Lewis et al., 1985; Robblee et al., 1991; Durako, 1994). Tampa Bay, FL, with 1,036 km^2 of surface water, may have supported almost 31,000 ha of seagrass meadows in 1870; however, by 1982 only 8,763 ha of seagrass beds remained (Lewis et al., 1985; Johansson, 1991). Although pollution is the major cause underlying loss of seagrass beds in Florida, propeller scarring of the shallow (0.5–2.0 m) *T. testudinum* beds has damaged more than 70,000 ha of the 1.1 million ha surveyed in Florida (Sargent et al., 1995). Recovery is slow in damaged beds, and it requires an average of 7.6 years to fill in propeller scars in Tampa Bay (Dawes et al., 1997). Recovery is slow because vegetative expansion of *T. testudinum* is limited to rhizome meristems (Tomlinson, 1974), and new meristems only form on erect short shoots (Kelly et al., 1971; Andorfer and Dawes, 2002; Dawes and Andorfer, 2002).

The extensive propeller scarring or other mechanical damage (i.e., erosion from boat wakes, shifts in sand berms due to seawall construction) to *T. testudinum* beds can be ameliorated by transplanting (Dawes et al., 1997). Procedures for transplanting seagrass taxa taken from donor beds in the field are described in general reviews (Fonseca, 1994; Wyllie-Echeverria and Thom, 1994; Fonseca et al., 1998) and in studies of specific taxa, including *Zostera marina* L. (Phillips, 1974; Davis and Short, 1997; Orth et al., 1999; Short et al., 2002), *Posidonia oceanica* (L.) Delile (Meinesz et al., 1992; Molenaar and Meinesz, 1995), *Halodule wrightii* Ascherson (Fonseca, 1994; Fonseca et al., 1994, 1996; Sheridan et al., 1998), *Syringodium filiforme* Kützing (Fonseca et al., 1994, 1996), and a number of Australian species (Paling et al., 2003; van Keulen et al., 2003). A land-based nursery as a source of transplants apparently has not been tested.

In Florida, improved restoration techniques using *T. testudinum* are especially important because it is the dominant seagrass (Zieman and Zieman, 1989; Dawes et al., 2004), it forms climax communities yielding greater habitat and faunal complexity (Zieman and Zieman, 1989), and it is the most heavily affected seagrass (Sargent et al., 1995; Kenworthy et al., 2000). Damaged *T. testudinum* habitats can revert to *H. wrightii* beds because the latter species spreads more rapidly and is more easily transplanted (Fonseca, 1994). However, *H. wrightii* does not produce as complex a community nor does it support as diverse a fauna (Fonseca et al., 1987; Zieman and Zieman, 1989) as *T. testudinum.* The slow recovery of turtle grass after natural or anthropogenic impacts (Dawes et al., 1997), the continued growth of Florida's human population, and the increased number of state-registered, shallow-draft boats indicate that seagrass beds will continue to be seriously affected (Sargent et al., 1995).

Transplantation of *T. testudinum* is not used extensively in Florida because of the cost of obtaining and transplanting the plants and the resulting damage to donor beds (Fonseca, 1989; Tomasko et al., 1991; Fonseca et al., 1994). However, if nursery plants were available, transplantation costs should be lower and should allow rapid mitigation of damaged beds or the creation of new beds. Harvesting *T. testudinum* from natural beds usually results in rhizome breakage, with most donor plants having one short shoot on a rhizome fragment. Unfortunately, survival in the field after 1–2 yr is low (0–40%) for single short shoots of turtle grass taken from donor beds (Kelly et al., 1971; Phillips and Lewis, 1983; Tomasko et al., 1991).

The goals of this study were to determine (1) if seagrasses could be grown in a land-based nursery without connection to a natural marine basin and (2) the cost of developing and running a seagrass nursery. This article describes a land-based nursery in Ruskin, FL, where *T. testudinum* was grown for use in establishing beds in Tampa Bay; it also describes the problems and costs associated with building and running this nursery for 26 mo.

Methods

Nursery site and construction.—The nursery was built between Feb. and April 2005 on the grounds of the Cockroach Bay Aquatic Preserve Headquarters (27°41.36′N, 82°30.93′W) on the west side of Tampa Bay in Ruskin, FL. The Hillsborough County Parks and Recreation Department offered a protected (fenced) site, free electricity and water, and monitoring of the nursery. The site was not connected to any marine community; thus, permits were obtained more easily. The basin measured 6.1 × 12.2 m in size (74.42 m^2), was graded from 1.5 to 2.0 m in depth, and was covered by a pole building (Structures Unlimited, Florida) that had a transparent plastic roof and roll-up fiberglass sides (Fig. 1A). Light levels were reduced by about 20% when the sides of the pole building were rolled down. The basin had a 20-mm Permalon™ vinyl liner (Reef Industries Inc., Texas) covered with 10–20 cm of coarse (cement) sand, with 78% of the particles measuring 0.25–1.00 mm in diameter (Fig. 1B). A polyvinyl chloride (PVC) pipe was run from a well to the nursery and connected to a float switch in the basin. The water level was maintained at 1.0–1.3 m. Because natural seawater was not available at the site, 81 boxes (20 kg each) of sea salt (Marine Enterprises, Ohio) were added to produce a salinity of 30 ppt. A Hammer Head saltwater pump and priming filter/pot (Coral Reef, Inc., Texas) with a 12.6-cm (5-inch)–diameter PVC pipe were used to recycle the nursery water and to create a current in the basin.

Seagrass cultivars.—The two donor sites selected in Tampa Bay had different environmental features, allowed collections with minimum damage to the donor beds (as a result of ongoing erosion at the sites), and provided a comparison of survival between estuarine and oceanic donor plants. Bare rhizomes with short shoots of *T. testudinum* were collected by hand at the south end of Tampa Bay (SKY; 27°32′N, 82°29′W) and in Cockroach Bay (CRB: 27°43′N, 82°29′W) on the east side of Tampa Bay. The SKY site has stable oceanic salinities (30–34 ppt), coarse sand, and a northern exposure to wave action that caused the bed to erode so that removal of rhizomes resulted in little additional damage to the bed. The CRB estuary has variable salinities (20–34 ppt), fine sediments, and limited exposure to wave action (Dawes, 1974). Donors were collected along an eroding edge of a tidal channel where rhizomes were exposed. All plants were placed in coolers, transported to the nursery without seawater, and planted on the same day.

In the first year, *T. testudinum* donors were planted in the nursery beginning in May 2005, with a total of seven plantings over the course of 11 mo. The study examined percent survival of short shoots (final number/initial number) and planting methods that would simplify returning cultivars to the field. Planting methods were as follows: (1) 35 × 80–cm rectangles of PVC pipe measuring 1.26 cm (0.5 inches) in diameter covered by a net of a 1-cm plastic mesh (PVC racks), (2) two types of pots (Pots) made of pressed paper (7.6-cm diameter; Jiffy Pots, Illinois) and biodegradable cloth (20-cm diameter; B & T Grower Supply, Louisiana), and (3) bare rhizomes (Bare). Eight rhizomes with two or more short shoots were tied to each PVC rack with plastic ties, and the racks were buried in the

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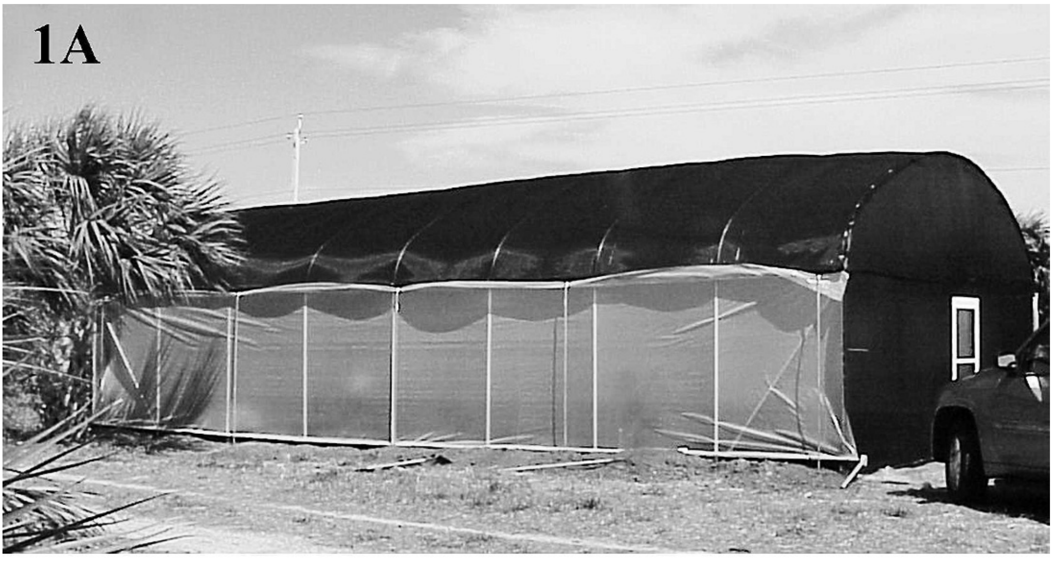

Fig. 1. Photographs of the land-based seagrass nursery at the Cockroach Bay Aquatic Preserve in Ruskin, FL. (A) Pole building with the fiberglass side screens rolled down. (B) View from outside the building with a side screen rolled up, showing the 10–20-cm layer of coarse sand covering the Permalon^{TM} vinyl liner in the 74.4-m^2 basin.

sand. Two rhizomes with two short shoots each were planted in the two pot types with sand, and the pots were buried. Bare rhizomes with two short shoots also were planted in the nursery sand. A total of 1,002 short shoots (initial number) were planted between May 2005 and April 2006. Each set of field transplants was clustered based on method of planting (PVC racks, Pots, Bare), separated from other plantings, and identified by tagged stakes. Short shoot counts were made only at harvesting to avoid damage to growing rhizomes.

A second planting was initiated in Feb. 2007. Only bare rhizomes of *T. testudinum* with one to nine short shoots were used with five sets of field transplants placed in the nursery between Feb. and May, for a total of 1,617 short shoots (initial number). Each planting was clustered based on the initial number of short shoots per rhizome, separated from other plantings, and identified by tagged stakes. Percent survival of short shoots (final number/initial number × 100) was determined at harvest.

In both the 2005–06 and 2007 studies, all rhizomes arising from a short shoot (side branches) were removed before planting. Thus, new rhizome meristems were easily identified at harvesting because they were side branches of short shoots, the only source of new meristems in *T. testudinum* (Andorfer and Dawes, 2002; Dawes and Andorfer, 2002).

In Nov. 2005, during the 2005–06 study, a yellow–brown color formed in the water from a bloom of a species of the unicellular alga *Chrysochromulina*. The color remained except when the salinity dropped to 10 ppt in the summer of 2006, after removal of the cultivars. Two temporary filters (consisting of 3,700-liter plastic barrels with overflow pipes and containing three to seven layers of polyester fiber mats) that were cleaned every other week did not remove the bloom. Also, a swimming pool pressure filter was installed in Jan. 2006 to replace the temporary filters, but it did not remove the bloom either. However, the bloom did not appear to affect the cultivars and did not reappear in 2007.

Results

Nursery costs.—The nonrecurring cost of the nursery was \$12,081.45, of which a major portion involved the purchase and erecting (\$8,704.66) of the pole building (Table 1). Another major expense was sea salt (\$1,782.00). A cost estimate for running the nursery for 3 yr includes part-time labor at a cost of \$15.00 hr^{-1}. The first-year labor cost is estimated to be \$7,800 for a 10-hr wk^{-1} labor force (6 hr wk^{-1} for collection and planting, 4 hr wk^{-1} for maintenance). Cost for the first year also includes initial field collections of seagrasses (including use of a boat and motor), planting, and nursery maintenance (planting costs, \$1,500.00). Labor costs for years 2 and 3 are estimated to total \$12,480 (ca. 8 hr wk^{-1}), with few field collections needed; instead a portion of the cultivars could be used to repopulate the nursery (Table 1).

Table 1. Cost of a land-based *Thalassia testudinum* nursery at Tampa Bay, FL. See ''Discussion'' for details on nonrecurring and recurring costs.

A. Nonrecurring costs	Value (\$)
Basin (6.1 × 12.2 × 1.3 m)	500.00
Pole building	4,954.66
Pole building erection	3,750.00
Permalon™ vinyl liner	450.00
Coarse sand (11.5 m^3)	260.90
PVC pipe, connections, and valves[a]	50.00
Sea salt (\$22.00 box^{-1} × 81 boxes)	1,782.00
Saltwater pump	293.94
Sequence priming filter and pot	39.95
Total nonrecurring costs	12,081.45
B. Recurring costs (3 yr)	
Electrical[b]	500.00
Labor costs (year 1)[b]	7,800.00
Labor costs (years 2, 3)[c]	12,480.00
Planting materials	1,500.00
Total recurring costs	22,280.00
C. Total cost (3 yr)	34,361.45

[a] Polyvinyl chloride (PVC) pipe 12.6 cm in diameter and 1 m long, joints, slip connections, and two PVC valves.
[b] Estimated labor costs at \$15.00 hr^{-1} × 10 hr wk^{-1} × 52 wk.
[c] Estimated labor costs at \$15.00 hr^{-1} × 8 hr wk^{-1} × 104 wk.

Seagrass production.—The first set of *T. testudinum* transplants in 2005–06 (Table 2) showed new rhizome and short shoot growth within 4 wk. Although no nutrients were used, the total number of short shoots harvested for the 2005–06 cultivars (1,002 short shoots) was 84% of those placed in the nursery. Use of PVC racks and Pots resulted in short shoot survivals ranging from 30% (Table 2; No. 4, PVC racks) to 111% (Table 2; No. 5, Pots). Growth data using pressed paper and biodegradable cloth pots were combined in Table 2 as a result of their low numbers and similar survivorship. Bare rhizomes planted in the coarse sand had short shoot survivals of 75% (Table 2; No. 6) and 219% (Table 2; No. 7). The large response in short shoot number for the April 21 planting (No. 7) may have been due to a number of incipient rhizome meristems on short shoots that were not visible when collected. Bare rhizomes were easily removed from the

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Table 2. 2005–06 transplants of *Thalassia testudinum* in a land-based nursery at Tampa Bay, FL, using various planting techniques. The table gives the initial number of short shoots collected (#SS coll) from Cockroach Bay (CRB) and the south end of Tampa bay (SKY) and planted in the nursery, the final number that were harvested and transplanted into the field (#SS transp), and the percent survival (% Sur) of short shoots for each planting method and date (see ''Methods'' for details).

Planting date	Method	#SS coll	Source	#SS transp	% Sur
1. (05/22/05)	PVC racks[a]	100	SKY	102	102
2. (06/19/05)	PVC racks[a]	92	CRB	85	92
3. (01/16/06)	PVC racks[a]	240	SKY	133	55
4. (01/27/06)	PVC racks[a]	200	CRB	61	30
5. (02/27/06)	Pots[b]	70	CRB	78	111
6. (04/10/06)	Bare[c]	100	SKY	75	75
	Bare[c]	100	SKY	84	84
7. (04/21/06)	Bare[c]	100	CRB	219	219
Total		1,002		837	84
SKY plant totals		540		394	73
CRB plant totals		462		443	96

[a] Polyvinyl chloride (PVC) racks were 35 × 80–cm rectangles using 1.26-cm–diameter piping and covered with a 1-cm plastic mesh, on which plants were tied.
[b] Pots were pressed paper (7.6-cm diameter) or biodegradable cloth (20-cm diameter), each of which has two rhizomes with two short shoots per rhizome.
[c] Bare rhizomes had one, two, three, or more than four short shoots per unit and were planted in sand.

coarse sand and separated without breakage, which facilitated transplantation into the field.

It was intended that the first planting (2005–06) would remain in the nursery for a period of 16 mo. However, all 1,002 short shoots were removed from the nursery in late June and early July 2006 as a result of leaks in the vinyl liner. Only short shoots were counted to avoid prolonged handling and to facilitate transport to a field site. When survival of plants from the two donor sites is compared, overall percent survival of plants in the nursery from CRB was 96%, and the percent survival was 73% for SKY plants (Table 2). All 837 cultivars (1,002 short shoots) were planted in a mitigation project in July 2006 that dealt with long-shore berm stabilization in upper Tampa Bay, near MacDill Air Force Base. The project was carried out under the supervision of Walt Avery (City of Tampa, Bay Study Group) and the Tampa Bay Estuary Program. One year later (July 2007), the transplants from the nursery were coalescing on the bare sediment, with survival estimated to be 60% (M. Meads, pers. obs.).

The second set of cultivars of *T. testudinum* planted in 2007 comprised one to nine short shoots per rhizome, with survival after 5 mo ranging from 67% (Table 3; No. 1) to 110% (Table 3; No. 4) and an overall survival of 91%. Percent survival and production of short shoots was highest for rhizomes with three or more short shoots in four out of the five plantings (Table 3; No. 1, three short shoots: 104%; No. 2, four or more short shoots: 143%; No. 3, three short shoots: 124%; No. 4, four or more short shoots: 176%). Overall, the highest production of short shoots occurred on rhizomes with four or more short shoots (111%). In contrast to the above finding, the highest short shoot production in the last planting (Table 3; No. 5) was recorded for single short shoot units (148%). However, the number of initial single short shoot plants was the lowest (31 units) of all plantings, so the high survival rate may be an anomaly. After some initial dieback 2–3 wk after planting, over one third of the 2007 plants were producing new rhizome meristems and short shoots. In Aug. 2007, after 6 mo, all cultivars (1,526 short shoots) had to be removed as a result of new leaks in the liner. When survival is compared between the two source sites, percent survival for nursery plants from CRB was 83%, and percent survival was 103% for plants from SKY. The cultivars were transplanted in a seagrass-free, bare sediment basin created by Hillsborough County (adjacent to Little Cockroach Bay) in 2003. After 1 yr (July 2008), survival was estimated to be 50%, and the nursery transplants were coalescing in the new basin (C. Dawes, pers. obs.).

Discussion

To our knowledge, this is the first report of a land-based nursery in which *T. testudinum* was planted, cultivated, and used in field mitigation projects, as proposed in the first and second goals of this article. The nursery was effective in terms of growing *T. testudinum*, which is the dominant seagrass in Florida, produces the most complex communities (Zieman and Zieman, 1989; Dawes et al., 2004), and is the most difficult seagrass to transplant (Dawes et al.,

TABLE 3. 2007 transplants of *Thalassia testudinum* into the land-based nursery at Tampa Bay, FL, with differing numbers of short shoots per rhizome. The planting date (Date), source (Source), initial (at planting), and final (at harvesting) number of *Thalassia testudinum* short shoots (Initial/final totals), and percent survival (% Survival) of short shoots are given. Bare rhizomes with one to more than seven short shoots on each one (1SS, 2SS, 3SS, 4+SS) were used. Plants were taken from Cockroach Bay (CRB) and the south end of Tampa Bay (SKY) and were removed from the nursery on 9 Aug. 2007.

Date	Source	1SS	2SS	3SS	4+SS	Initial/final totals
1. (02/13)	CRB	50/29	108/82	87/91	95/25	340/227
	% Survival	58	76	104	26	67
2. (02/27)	CRB	60/60	88/53	87/33	80/114	315/260
	% Survival	100	60	38	143	83
3. (03/19)	CRB	66/48	112/88	105/130	111/128	394/394
	% Survival	73	79	124	115	100
4. (04/03)	SKY	50/33	56/30	75/50	131/230	312/343
	% Survival	66	54	67	176	110
5. (05/02)	SKY	31/46	64/57	54/49	167/150	316/302
	% Survival	148	89	91	90	96
Totals	Initial	257	428	408	584	1,667
	Final	216	310	353	647	1,526
	% Survival	84	72	87	111	91

1997). Although the nursery cultivars were producing new rhizomes and short shoots within 3 wk of transplantation, overall survival in the two nursery plantings was 84% and 91%. This is because neither planting had a sufficient growth period as a result of leaks in the vinyl liner. Survival of estuarine plants from CRB and oceanic plants from SKY showed no obvious patterns, indicating that that plants from the two populations acclimated to the nursery equally well. The most successful transplanting and harvesting method in the nursery included the use of bare rhizomes with three or more short shoots, which then formed turf-like areas. However, rhizomes with three or more short shoots are more difficult to obtain in the field, except where erosion due to wave action (SKY) or tidal current (CRB) exposes them. Regardless, even rhizomes with a single short shoot showed percent survivals of 58–148% (Table 3), which is much higher than that obtained in the field (van Breedveld, 1974; Tomasko et al., 1991; Dawes and Andorfer, 2002). Furthermore, a need for donors from the field should be minimal once the nursery is operational. Bare rhizomes of *Z. marina* Linnaeus are commonly collected in the field and transplanted in Chesapeake Bay, VA (Orth et al., 1999), and in Great Bay, NH (Davis and Short, 1997), whereas plugs are more commonly used for smaller plants, such as *H. wrightii* (Fonseca, 1994). In contrast, bare rhizomes of *T. testudinum* are difficult to collect and transplant in the field as a result of rhizome breakage; this process also results in damage to the donor bed (Tomasko et al., 1991; Dawes and Andorfer, 2002). As a result of the coarse nursery sand, cultivars were easily removed and separated for transport to the field, with little rhizome breakage or root loss.

Transplanting a turf of *T. testudinum* obtained from a land-based nursery would enhance survival and speed recovery in affected beds while at the same time restricting damage to donor beds (Fonseca et al., 1994). In this regard, after 1 yr the cultivars had begun to grow in a remediation project in Upper Tampa Bay and in a newly created basin near CRB. The nursery could be a reliable source of transplants and could also allow the control of photoperiod and temperature to enhance rhizome growth and initiate flowering in the winter (Witz and Dawes, 1995). Also, leaf growth continues during the winter months because of the warmer water in the nursery, in contrast to the field, where slower leaf growth and dieback occurs in Tampa Bay (Dawes et al., 1997). Seeds of *T. testudinum*, gathered from drift, as was done with *Z. marina* (Harwell and Orth, 1999; Pickerell et al., 2005), also could be used.

We estimate that over a 36-mo period, 2,500 turf-like units 20 cm^2 in size could be harvested and sold at $20.00 each, for a total of $50,000. The production is based on using 70 m^2 of the basin's 74.4 m^2, in which 1,750 20-cm^2 units could be established. The 20-cm^2 turf unit would contain up to four rhizomes, each with two or more short shoots and at least one growing apical meristem per rhizome. A minimum of 6 mo would be needed to allow establishment and production of rhizome meristems, based on previous studies in the laboratory and field

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(Dawes and Andorfer, 2002) and based on the findings in the present nursery. After 9 mo, the new cultivars would have become established, and the first 500 turf units could be harvested. Subsequent removal of 500 units could probably occur every 6 mo, with some of the remaining cultivars redistributed in the nursery. The nonrecurring costs and recurring costs per planting unit should be lower and cultivar production higher with an increase in nursery area. Cost also would be lowered if natural seawater could be used instead of commercial sea salt (Table 1; $1,782), which also would help prevent plant removal if leaks occurred. For example, small tanks (ca. 1,850 liters, 500 gallons) on trailers are used in the Ruskin, FL, area to transport seawater to tropical fish ponds and could be rented for about $100 a day. The basin contains about 75 m^3 (7,500 liters) of seawater; thus, four tanks would fill the basin.

Leaks in the vinyl liner that were not in the side of the basin could not easily be sealed because of the 12–20-cm layer of sand. However, leaks in the liner could be avoided by having a 2-m–high retaining wall (e.g., three concrete blocks high) and a fiberglass floor to prevent slumping and root penetration. We estimate that this would cost about $1,000.00 more if built during the initial construction.

Thalassia testudinum was successfully grown in an experimental, land-based nursery near Ruskin, FL, and the cultivars were used in two remediation projects in Tampa Bay. It is estimated that building and running the nursery would cost $34,361.45 over 36 mo and that 2,500 turf-like units (20 cm^2) could be harvested and sold at $20.00 each, for a total of $50,000 over that same period. Leakage problems in the nursery due to punctures in the vinyl liner could be solved with the construction of concrete side walls and a fiberglass floor.

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Literature Cited

Andorfer, J., and C. Dawes. 2002. Production of rhizome meristems by the tropical seagrass *Thalassia testudinum*. The basis for slow recovery into propeller cuts. J. Coast. Res. 37:130–142.

Davis, R. C., and F. T. Short. 1997. Restoring eelgrass, *Zostera marina* L., habitat using a new transplanting technique: the horizontal rhizome method. Aquat. Bot. 59:1–15.

Dawes, C. J. 1974. Marine algae of the west coast of Florida Univ. Miami Press, Coral Gables, FL.

———. 1998. Marine botany. 2d ed. John Wiley and Sons, New York.

———, and J. Andorfer. 2002. Production of rhizome meristems by *Thalassia testudinum*, p. 185–198. *In:* Seagrass management: it's not just nutrients. 2000 August 22–24. H. S. Greening (ed.). Tampa Bay Estuarine Program, St. Petersburg, FL.

———, ———, C. Rose, C. Uranowski, and N. Ehringer. 1997. Regrowth of *Thalassia testudinum* into propeller scars. Aquat. Bot. 59:139–155.

———, R. C. Phillips, and G. Morrison. 2004. Seagrass communities of the Gulf Coast of Florida: status and ecology Florida Fish and Wildlife Conservation Commission, Fish and Wildlife Research Institute, and the Tampa Bay Estuary Program, St. Petersburg, FL.

Durako, M. J. 1994. Seagrass die-off in Florida Bay (USA): changes in shoot demographic characteristics and population dynamics in *Thalassia testudinum*. Mar. Ecol. Prog. Ser. 110:59–66.

Fonseca, M. S. 1989. Regional analysis of the creation and restoration of seagrass systems, p. 175–198. *In:* Wetland creation and restoration: the status of the science, Vol. 1. Regional reviews. J. A. Kusler and M. E. Kentula (eds.). EPA/600/3-89/038a. Environmental Research Laboratory, Corvallis, OR.

———. 1994. A guide to planting seagrasses in the Gulf of Mexico Texas A&M Univ. Sea Grant College Program, College Station, TX.

———, W. J. Kenworthy, and F. X. Courtney. 1996. Development of planted seagrass beds in Tampa Bay, Florida, USA. I. Plant components. Mar. Ecol. Prog. Ser. 132:127–139.

———, ———, ———, and M. O. Hall. 1994. Seagrass planting in the southeastern United States: methods for accelerating habitat development. Restor. Ecol. 2:198–212.

———, ———, and G. W. Thayer. 1998. Guidelines for the conservation and restoration of seagrasses in the United States and adjacent waters National Oceanic and Atmospheric Administration (NOAA) Coastal Ocean Program Decision Analysis Series No. 12, NOAA Coastal Ocean Office, Silver Springs, MD.

———, G. W. Thayer, and W. J. Kenworthy. 1987. The use of ecological data in the implementation and management of seagrass restorations, p. 175–187. *In:* Proceedings of a symposium on subtropical-tropical seagrasses of the southeastern United States. M. J. Durako, R. C. Phillips, and R. R. Lewis, III (eds.). Florida Marine Research Publication No. 42, Florida Department of Natural Resources, Bureau of Marine Research, St. Petersburg, FL.

HADAD, K. D., AND B. A. HARRIS. 1985. Assessment and trends of Florida's marine fisheries habitat: an integration of aerial photography and thematic map imagery, p. 130–138. *In:* Proceedings of machine processing of remotely sensed data with special emphasis on quantifying global process: models, sensor systems, and analytical methods Laboratory of Applied Remote Sensing, Purdue Univ., West Lafayette, IN.

HARWELL, M. C., AND R. J. ORTH. 1999. Eelgrass (*Zostera marina* L.) seed protection for field experiments and implications for large-scale restoration. Aquat. Bot. 64:51–61.

JOHANSSON, J. O. R. 1991. Long-term trends of nitrogen loading, water quality and biological indicators in Hillsborough Bay, Florida, p. 157–176. *In:* Proceedings, Bay Area Scientific Information Symposium 2. S. F. Treat and P. A. Clark (eds.). Lewis Environmental Systems, Tampa, FL.

KELLY, J. A., JR., C. M. FUSS JR., AND J. R. HALL. 1971. The transplanting and survival of turtle grass, *Thalassia testudinum* in Boca Ciega Bay, Florida. Fish. Bull. 69:273–280.

KENWORTHY, W. J., M. S. FONSECA, P. E. WHITEFIELD, K. HAMMERSTROM, AND A. C. SCHWARZCHILD. 2000. A comparison of two methods for enhancing the recovery of seagrasses into propeller scars: mechanical injection of a nutrient and growth hormone solution vs. defecation by roosting seabirds. Final Report to National Oceanic and Atmospheric Administration, Center for Coastal Fisheries and Habitat Research, Beaufort, NC.

LEWIS, R. R., M. J. DURAKO, M. D. MOFFLER, AND R. C. PHILLIPS. 1985. Seagrass meadows of Tampa Bay: a review, p. 216–246. *In:* Proceedings of the Tampa Bay Area Scientific Information Symposium. S. F. Treat, J. L. Simon, R. R. Lewis, and R. L. Whitman, Jr. (eds.). Burgess Publ. Co., Minneapolis.

LIVINGSTON, R. L. 1984. The relationship of physical factors and biological response in coastal seagrass meadows. Estuaries 7:377–390.

MEINESZ, A. M., H. MOLENAAR, E. BELLONE, AND F. LOQUES. 1992. Vegetative reproduction in *Posidonia oceanica* 1. Effects of rhizome length and transplantation season in orthotropic shoots. P.S.Z.N.I: Mar. Ecol. 13:163–174.

MOLENAAR, H., AND A. MEINESZ. 1995. Vegetative reproduction in *Posidonia oceanica*: survival and development of transplanted cuttings according to different spacings', arrangements and substrates. Bot. Mar. 38:313–322.

ORTH, R. J., M. C. HARWELL, AND J. R. FISHMAN. 1999. A rapid and simple method for transplanting eelgrass using single, unanchored shoots. Aquat. Bot. 64:77–85.

PALING, E. I., M. VAN KEULEN, K. D. WHEELER, J. PHILLIPS, AND R. DYHRBERG. 2003. Influence of spacing on mechanically transplanted seagrass survival in a high wave energy regime. Restor. Ecol. 11:56–61.

PHILLIPS, R. C. 1974. Transplantation of seagrasses with special emphasis on eelgrass, *Zostera marina* L. Aquaculture 4:161–176.

———, AND R. L. LEWIS III. 1983. Influence of environmental gradients on variations in leaf widths and transplant success in North American seagrasses. Mar. Tech. Soc. 17:59–68.

PICKERELL, C. H., S. SCHOTT, AND S. WYLLIE-ECHEVERRIA. 2005. Buoy-deployed seeding: demonstration of a new eelgrass (*Zostera marina* L.) planting method. Ecol. Eng. 25:127–136.

ROBBLEE, M. B., T. R. BARBERE, P. R. CARLSON, M. J. DURAKO, J. W. FOURQUREAN, L. K. MUEHLSTEIN, D. PORTER, L. A. YARBRO, R. T. ZIEMAN, AND J. C. ZIEMAN. 1991. Mass mortality of the tropical seagrass *Thalassia testudinum* in Florida Bay (USA). Mar. Ecol. Prog. Ser. 71:297–299.

SARGENT, F. J., T. J. LEARY, D. W. CREWZ, AND C. R. KRUER. 1995. Scarring of Florida's seagrasses: assessment and management options Florida Marine Research Institute Technical Report 1, Florida Department of Environmental Protection, St. Petersburg, FL.

SHERIDAN, P., G. MCMAHAN, K. HAMMERSTROM, AND W. PULICH JR. 1998. Factors affecting restoration of *Halodule wrightii* to Galveston Bay, Texas. Restor. Ecol. 6:144–158.

SHORT, F. T., R. C. DAVIS, B. S. KOPP, C. A. SHORT, AND D. M. BURDICK. 2002. Site-selection model for optimal transplantation of eelgrass *Zostera marina* in the northeastern US. Mar. Ecol. Prog. Ser. 227:253–267.

———, AND S. WYLLIE-ECHEVERRIA. 1996. Natural and human-induced disturbance of seagrasses. Environ. Conserv. 23:17–27.

THAYER, G. W., D. A. WOLFE, AND R. B. WILLIAMS. 1984. The impact of man on seagrass systems. Am. Sci. 63:288–296.

TOMASKO, D. A., C. J. DAWES, AND M. O. HALL. 1991. Effects of the number of short shoots and presence of the rhizome apical meristems on the survival and growth of transplanted seagrass *Thalassia testudinum*. Contrib. Mar. Sci. 52:41–48.

TOMLINSON, P. B. 1974. Vegetative morphology and meristem dependence. The foundation of productivity in seagrasses. Aquaculture 4:107–130.

VAN BREEDVELD, J. F. 1974. Transplanting of seagrasses with emphasis on the importance of substrate Florida Department of Natural Resources, Marine Research Laboratory, St. Petersburg, FL.

VAN KEULEN, M., E. I. PALING, AND C. J. WALKER. 2003. Effect of planting unit size and sediment stabilization on seagrass transplants in Western Australia. Restor. Ecol. 11:50–55.

WITZ, M. J. A., AND C. J. DAWES. 1995. Flowering and short shoot age in three *Thalassia testudinum* meadows off west-central Florida. Bot. Mar. 38:431–436.

WYLLIE-ECHEVERRIA, S., AND R. M. THOM. 1994. Managing seagrass systems in western North America. Research gaps and needs Alaska Sea Grant College Program, Univ. of Alaska, Fairbanks, AK.

ZIEMAN, J. C., AND R. C. ZIEMAN. 1989. The ecology of the seagrass meadows of the west coast of Florida: a community profile. U.S. Fish and Wildlife Service Biological Report 85(7.25), U.S. Fish and Wildlife Service, Washington, DC.

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